CENTRAL VALLEY SALINITY ALTERNATIVES FOR LONG-TERM SUSTAINABILITY (CV–SALTS)

Strategic Salt Accumulation Land and Transportation Study (SSALTS)

Final Phase 2 Report – Development of Potential Salt Management Strategies

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Prepared for
SAN JOAQUIN VALLEY DRAINAGE AUTHORITY

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Acronyms and Abbreviations

µS/cm	micro Siemens per centimeter
ACL	Administrative Civil Liability
ADWF	Average Dry Weather Flow
AF	Acre-feet
bgs	below ground surface
BLM	Bureau of Land Management
BMPs	Best Management Practices
BNSF	Burlington Northern and Santa Fe Railway
BOD	biological oxygen demand
BPA	Basin Plan Amendment
CAO	Cleanup and Abatement Order
CCR	California Code of Regulations
CDFG	California Department of Fish and Game
CDO	Cease and Desist Order
CEQA	California Environmental Quality Act
CIMIS	California Irrigation Management Information System
CVHM	Central Valley Hydrologic Model
CVBL	Central Valley Brine Line
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CWA	Clean Water Act
Delta	Sacramento-San Joaquin River Delta
DIW	deep injection well
DOGGR	California Division of Oil, Gas & Geothermal Resources
DOI	Department of the Interior
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
EC	Electrical Conductivity
EDR	Electrodialysis Reversal
FEIS	Final Environmental Impact Statement
FO	Forward Osmosis
GAF	Grassland Area Farmers
GBP	Grassland Bypass Project
GDA	Grassland Drainage Area

Acronyms and Abbreviations

GEA	Grassland Ecological Area
GEEC	Grassland Environmental Education Center
GHG	Green House Gas
gpm	gallons per minute
GRCD	Grasslands Resource Conservation District
GWD	Grasslands Water District
HCC	Hilmar Cheese Company
HDPE	high-density polyethylene
HERO	High efficiency reverse osmosis
HF	hydraulic fracturing
I&C	Instrumentation and Controls
IAZ	Initial Analysis Zone
ICM	Initial Conceptual Model
IFDM	Integrated On-Farm Drainage Management
IX	Ion exchange
kg	kilogram
kWh	kilo Watt hour
LPRO	Low pressure reverse osmosis
LSJR	Lower San Joaquin River
MD	Membrane Distillation
MGD	million gallons per day
NCDC	National Climatic Data Center
NEPA	National Environmental Policy Act
NM	New Melones
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
PDSI	Palmer Drought Severity Index
POTW	Publicly-Owned Treatment Work
Q&A	questions and answers
Reclamation	US Bureau of Reclamation
RO	Reverse Osmosis
RRR	Red Rock Ranch
RTMP	Real-Time Management Program
RWD	Report of Waste Discharge

Acronyms and Abbreviations

SAA	salt accumulation area
SARI	Santa Ana Regional Interceptor
SAWPA	Santa Ana Watershed Project Authority
SFEI	San Francisco Estuary Institute
SJRECWA	San Joaquin River Exchange Contractors Water Authority
SJRIP	San Joaquin River Water Quality Improvement Project
SJVDIP	San Joaquin Valley Drainage Implementation Project
SNMP	Salt and Nitrate Management Plan
SSALTS	Strategic Salts Accumulation Land and Transportation Study
SWP	State Water Project
SWRCB	State Water Resource Control Board
TAC	Technical Advisory Committee
TDS	total dissolved solids
TLBWSD	Tulare Lake Basin Water Storage District
TLDD	Tulare Lake Drainage District
TMDL	Total Maximum Daly Load
UF	Ultrafiltration
UIC	Underground Injection Control
USDW	underground source of drinking water
USEPA	US Environmental Protect Agency
USGS	US Geological Survey
VAMP	Vernalis Adaptive Management Plan
WARMF	Watershed Area Resource Management Framework
w/v	weight volume
WDR	Waste Discharge Requirements
WQO	Water Quality Objectives
WWTP	Wastewater Treatment Plant
ZDD	Zero Discharge Distillation
ZLD	Zero Liquid Discharge

Section 1
Introduction

1.1 Project Purpose

The purpose of the Strategic Salt Accumulation Land and Transportation Study (SSALTS) is to identify the range of viable Central Valley alternatives for salt disposal to provide input for consideration during development of the Salt and Nitrate Management Plan (SNMP) for the region under the jurisdiction of the Central Valley Regional Water Quality Control Board (CVRWQCB). The findings will be used to guide discussions regarding establishment of regional salt management policies and the need for changes to the existing CVRWQCB Water Quality Control Plans (Basin Plans) to facilitate salt disposal in a manner that is most beneficial to the region and consistent with the State Water Resource Control Board (SWRCB) Recycled Water Policy.

This work is being conducted under the direction of the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) initiative, which is developing the SNMP for the Central Valley. The SSALTS project is being conducted in three phases (Figure 1-1):

- *Phase 1: Identify and Characterize Existing Salt Accumulation Study Areas* – Selection of representative study areas to serve as prototype situational examples to facilitate discussions regarding salt accumulation and disposal in the Central Valley. Each of these study areas was characterized to establish baseline information that will be used to support development of salt disposal alternatives in subsequent project phases.

- *Phase 2: Develop Potential Salt Management Strategies* – SSALTS will develop potential long-term salt disposal alternatives in three parts: (1) in-valley alternatives; (2) out-of-valley alternatives; and (3) hybrid alternatives that combine in-valley and out-of-valley salt disposal options.

- *Phase 3: Evaluate Potential Salt Disposal Alternatives to Identify Acceptable Alternatives for Implementation* – Alternatives developed under Phase 2 will be evaluated using selected feasibility criteria (*e.g.*, regulatory, institutional, economic, technological, *etc.*). The outcome of this evaluation will be the identification and prioritization of acceptable salt disposal alternatives for potential incorporation into Central Valley SNMP as salt management implementation measures.

The Phase 1 report was finalized in December 2013. This report summarizes the findings of Phase 2. Phase 3 work will begin after the stakeholders have reviewed the Phase 2 report and provided comments.

1.2 Phase 1 SSALTs Archetype Study Areas

The Phase 1 work revolved around the concept of an archetype study area, whereby a study area represents a geographic or situational example that can be used as a basis to develop salt management alternatives for the Central Valley. The Phase 1 activities included three key steps: (1) selection of representative study areas consistent with the goals of SSALTS; (2) characterization of the selected study areas; and (3) evaluation of the potential for long-term sustainable salt management given the characteristics of the study area.

For the SSALT evaluation of the archetype study areas, factors were evaluated to facilitate a more objective and meaningful analysis of which disposal methods and projects would be able to be maintained at a certain level into the future.

- ***Implementability** of the salt disposal method*. This factor reviews the technical feasibility and efficacy of a given salt disposal method. In other words, given today's technology, how feasible or implementable is the given method? **Implementability** was rated from a high score of 4 (utilizes proven technologies and is readily implementable) to a low score of 1 (salt disposal method is not working or utilizes unproven technologies).

- *Salt **capacity** of the disposal method*. This factor looks at the mass or concentration of salt that can be disposed by the method in question. For a given salt disposal method, the controlling factor might be a component part of the disposal method. For example, when analyzing a brine line with an ocean outfall, the mass discharged into the ocean can be virtually limitless, because the ocean is the ultimate global salt sink (and source). The salt capacity of an ocean outfall brine line is limited by the wastewater treatment plant (WWTP) capacity, pipe diameter, flow capacity, permitting, and/or receiving water quality limitations. For deep well injection it might be the injection capacity of the well field, the hydrogeology of the aquifer system, receiving water quality, formation pressures, or the governing permit. The capacity of a surface water discharge might be the ability of the project to meet the electrical conductivity (EC, or salt concentration) discharge limits. Salt capacity was reviewed in terms of the proportion of salt load that can be reduced. Capacity was rated from a high score of 4 (the project's salt disposal load was not limited by the disposal method) to a low score of 1 (salt disposal method has a capacity less than the salt disposal load).

- ***Regulatory** challenges*. This factor reviewed pertinent regulatory challenges including Basin Plan water quality objectives, WWTP discharge limits, WWTP Resource Recovery permits, Waste Discharge Requirements (WDRs), Underground Injection Control (UIC) permits, proposed Basin Plan amendments, National Environmental Policy Act (NEPA)/California Environmental Quality Act (CEQA), water rights, *etc*. **Regulatory** was rated from a high score of 4 (the project is readily permitable and is able to meet current regulatory requirements) to a low score of 1 (the project faces considerable regulatory challenges now or in the 50-year planning horizon).

- ***Institutional** requirements.* Institutional requirements speaks to successfully bringing the project on-line, not from a technology standpoint (which is addressed by Implementability), but from a context of governance or management. What agency, group of agencies, coalition, joint powers authority, company or consortium of companies is responsible for the development and operation of the project? **Institutional** was rated from a high score of 4 (bias toward fewer entities involved – unless they are part a group with a strong governance structure; bias was also given toward, in some cases, public sector project proponents with known or secure funding sources) to a low score of 1 (group of small, underfunded individual stakeholders).

- *Capital and operation and maintenance **costs***. An objective evaluation of salt disposal cost is difficult because much of the cost information is not present, not separable from costs associated with the entire project (disposal vs. source control and/or treatment), and not able to be placed on the same cost basis (for example, dollars per ton of salt removed). Some SSALTS study area projects are underway and some are still in the planning stages, so the costs will need to be reconciled to a common starting point in time. These are all issues that will be addressed in developing alternatives in the current phase (Phase 2) of SSALTS. In the meantime, the **cost** factor was rated from a high score of 4 (projects with lower anticipated costs) to a low score of 1 (projects with higher anticipated costs).

- *Potential **environmental issues***. Aside from salinity, there are other constituents of potential concern that are evaluated in this section as well as other possible environmental concerns. For example, selenium accumulation in standing water in evaporation ponds or discharge ponds provides a potential exposure pathway and ecological risk to certain species. Trucking waste as a disposal option – when expanded in scope and scale (*e.g.*, valley-wide) – may have air quality and carbon footprint issues. **Environmental issues** were rated from a high score of 4 (little to no anticipated environmental issues) to a low score of 1 (reasonable potential for significant environmental issues to arise).

- ***Public acceptance***. This factor takes into account public awareness and acceptance of the disposal method utilized by the project. **Public acceptance** was rated from a high score of 4 (little to no public awareness and reasonable public acceptance) to a low score of 1 (high level of public awareness and little to no public acceptance).

The ten archetype study areas were ranked in the following order (highest sustainability to lowest):

- **Tulare Lake Bed**. The Tulare Lake Bed is the salt sink/salt sequestering disposal archetype. This study area scored very well (4) for implementability - the construction, operation, and maintenance of the infrastructure for the evaporation ponds utilizes proven technologies and is implementable for the Tulare Lake Bed. The study area scored well (3) for capacity, regulatory issues, institutional issues, and costs. There are potential environmental concerns about salt disposal at the Tulare Lake Bed including the control of salt at the evaporators (leaching, water and wind erosion). There is also potential concern about the formation of ponds of standing water which may lead to the bioaccumulation of certain trace constituents in the food chain. However, a number of the evaporation ponds have been in operation for over 30 years at the Tulare Lake Bed and several environmental issues have been encountered and addressed previously, ameliorating some of the environmental concerns and leading to a score of 2. The public will be somewhat sensitive to the potential environmental issues associated with this project (2).

- **Hilmar Cheese Company– Trucking to WWTP**. HCC – Trucking to WWTP is the archetype for industrial plants in the Central Valley whose processes require the treatment of saline water and disposal of salt by trucking brine to a WWTP with an ocean disposal. This study area scored very well (4) for institutional issues because it is managed and operated by a single company. Trucking scored well (3) for implementability, capacity, regulatory, environmental issues, and public acceptance. The cost factor score was poor (1) because the 2012 processing fees paid to East Bay Municipal Utilities District (EBMUD) were about $1.9M, with an additional $1 million to $2 million in hauling costs paid by Hilmar to its contracted hauler.

- **Hilmar Cheese Company – Deep Well Injection**. HCC – Deep Well Injection is the archetype for industrial plants in the Central Valley whose processes require the treatment of saline water and disposal of salt by disposal by deep well injection. This study area scored very well (4) for institutional issues because it is managed and operated by a single company. Deep well injection also scored very well (4) for capacity; HCC is permitted to inject at a rate of 23 million gallons per month, which is more than 7 times the volume of brine HCC currently produces. However, every study area would require analyses, including the development of a hydrogeological conceptual model, development of a numerical simulation model, and pilot testing to determine site- and project-specific salt capacities. Deep well injection scored well (3) for regulatory, costs, and environmental issues. Deep well injection scored poorly for implementability and public acceptance. Deep well injection utilizes proven technologies; however, direct experience at HCC demonstrates that there can be technological challenges to be met. The implementability of deep well injection to other areas in the Central Valley is dependent on a deep aquifer of degraded water quality to inject into, capacity of the aquifer to accept the requisite volume of brine, permitting, compatibility of the water chemistries of the brine and the groundwater, and on-going maintenance to keep the injection wells operational. In terms of public acceptance, there may be confusion that wastes are being disposed of by injection into a potable aquifer. There also may be concerns about hydraulic fracturing (fracking) among the general public.

- **City of Dixon**. The City of Dixon is an archetype study area for the disposal of salt in municipal discharge ponds and ultimately to groundwater. This study area scored very well (4) for implementability and institutional issues. The construction, operation, and maintenance of municipal discharge ponds utilize proven technologies and the project is implemented by a single agency. This study area scored poorly (1) to fair (2) in terms of capacity, regulatory issues, and costs. These three factors are all related to the finding that shallow groundwater continues to degrade in terms of total dissolved solids (TDS) and nitrate due mostly to consumptive use by the surrounding irrigated agriculture. Depending on the water quality objectives developed by the CVRWQCB, there may not be assimilative capacity for TDS in groundwater. Permitting a waste discharge to groundwater where the waste's TDS is greater than the objective (there is no assimilative capacity) – even though it is less than the receiving water's TDS concentration – calls to mind the Rancho Caballero decision and does not comply with State Resolution 68-16. However, the basin plan water quality objective can be raised through a Basin Plan amendment process. Developing a new, higher quality source of water will be costly, whether deeper wells or surface water becomes a more dominant component of the supply mix.

- **Grassland Water District – Real Time Management**. The GWD-RTMP is the archetype study area for the disposal of salt to a surface water body through the use of sophisticated modeling and operations to utilize assimilative capacity in the water body. The GWD-RTMP scored well (3) for implementability, capacity, and public acceptance and fair (2) for regulatory issues, institutional issues, costs, and environmental issues. One of the critical challenges of this archetype study area is aligning the goals of the RTMP and the goal of wetlands management by the GWD. The GWD wetlands drawdown in the spring is discharged into tributaries of the Lower San Joaquin River and is timed to meet wetland management objectives. The GWD wetlands drawdown in the spring does not coincide with higher assimilative capacity in the San Joaquin River (between January and April) which is the primary management goal of the RTMP. Another critical challenge includes balancing flows for the whole basin to maximize salt export, not just for the wetlands which only accounts for a small portion of the salt load. Most salt load comes from the surrounding agriculture of which there are numerous entities that will need to be coordinated in order to maximize salt export from the basin.

- **City of Tracy**. The City of Tracy is the municipal discharge to surface water archetype study area. Tracy scored very well (4) for implementability since the construction, operation, and maintenance of a municipal outfall to a surface water discharge point utilizes proven technologies. Tracy scored poorly (1) for salt capacity, regulatory issues and costs. The court entered a judgment and peremptory writ of mandate ruling that the South Delta salinity objectives do not apply to Tracy or other municipal discharges. However, the State Board is in the process of considering new flow and water quality objectives meaning that there is regulatory uncertainty. There is also a mass loading limitation in CVRWQCB Order R5-2012-0115 that may lead to compliance issues in the WWTP expansion (the mass or salt load does not increase with increasing permitted discharge volumes). Tracy is in the process of converting its water supply sources to surface water to improve source water quality, in part to meet the potential Water Quality Objectives (WQOs) at DP001. It should be noted, however, that surface water supplies continue to be limited and uncertain, particularly in drought periods, and may not always be reliable, particularly if a junior water right was used to secure the source of water.

- **Industrial Food Processing**. The Industrial Food Processors are the archetype for industries that produce high salinity waste water in the valley. The two primary disposal methods for salt (in industrial wastewater) are disposal to a WWTP and discharge to the land surface. The construction, operation, and maintenance of a service connection to a municipal WWTP utilize proven technologies and are implementable. Likewise, the construction, operation, and maintenance of land discharge methods (application directly to land, discharge ponds, *etc.*) utilized proven technologies and is implementable, hence this archetype study area scored very well (4) for implementability. Industrial food processing scored well (3) for public acceptance and fair (2) for capacity, institutional issues, and environmental issues. This archetype study area scored poorly (1) for regulatory issues and costs. It is anticipated that the future regulatory paradigm will be more restrictive and that projects under current permits will receive new permits with more stringent requirements. These future regulations may require substantive pre-treatment for industrial processors for both discharges to a WWTP and to the land surface.

- **San Luis Unit Ocean Disposal**. The San Luis Unit Ocean Outfall is the archetype study area for salt disposal through a newly-permitted ocean outfall. The study area scored very well (4) for implementability and capacity. The construction, operation, maintenance, and replacement of a conveyance system for ocean disposal – including pipelines, tunnels, lift, stations – utilizes proven technologies and is implementable. The pipeline capacity is sized to accommodate the anticipated drainage water, taking into account land retirement and regional reuse facilities. The San Luis Unit Ocean Outfall scored poorly (1) for regulatory issues, costs, environmental issues, and public acceptance. This project would be extremely difficult to permit and to demonstrate that it is consistent with the California Coastal Management Program. The Final Environmental Impact Statement (FEIS) determined that there would be water quality degradation in the vicinity of the outfall. The project is expected to significantly impact federal and state listed special-status species through construction and operation of the pipeline. High selenium levels in reuse facilities could impact sensitive habitat for aquatic or wetland-dependent species. The ocean outfall project is also very energy intensive because of the elevation differences between the San Joaquin Valley and the Coastal Ranges.

- **Westside Regional Drainage Plan**. The WRDP is the archetype study area for regional salt disposal. WRDP scored well (3) for institutional issues because the management of the salt should be coordinated under one stakeholder group. Implementability, regulatory issues, and public acceptance all scored fair (2). In terms of implementability, the salt disposal options range for (i) initial and indefinite storage at regional evaporation facilities, (ii) attempt to find or develop a commercial market, and (iii) ultimately remove the salt to a permitted disposal facility. The containment facilities would be regulated under Title 27. Depending on the nature of the containment facilities there may be air quality and erosion issues, as well as percolation to groundwater concerns. Capacity, costs, and environmental issues all scored poor (1) and are all related. One of the pillars of the salt disposal portion of both WRDP and the Red Rock Ranch (RRR) is for the development of a commercially-viable market for the salt produced from their operations. Absent this market, the salt disposal options for both become either on- or off-site storage. The lack of a viable market has a negative impact on capacity, costs, and environmental issues.

- **Red Rock Ranch**. RRR is the archetype study area for Integrated On-Farm Drainage Management (IFDM) systems in the Central Valley, characterized by zero-discharge, attempting to market the salt as a commercially-viable product or sequestering the salt at the site. RRR scored the same as WRDP for all factors save institutional – the assumption being that a regional coordinated program would function better than disconnected, individual IFDMs. There might also be economies of scale in developing future salt markets or pricing ultimate landfill-disposal options.

- **Stevinson Water District**. The salinity issues addressed by the SWD are primarily source control solutions. These solutions either prevent or reduce the volume of saline groundwater from entering the San Joaquin River (through the Lateral Canal Pipelining Project), or release saline agricultural drainage water during times of high assimilative capacity in the river (through the Agricultural Drainage Control Project). However, this project does not remove salt, although it does reduce salt entering into the water district by conserving water supplies. Hence, an evaluation of the sustainability of salt disposal methods could not be performed.

1.3 Phase 2 Scope of Work

Phase 2 of the SSALTS project consists of developing potential long-term salt disposal alternatives or strategies in three parts. The Phase 1 information developed for the representative Study Areas provides a foundation for Phase 2 analyses. For example, if the capacity for continued salt disposal within a particular study area is limited, then under Phase 2 alternatives for addressing that limitation through in-valley or out-of- valley disposal strategies (or some combination of both) will be identified and characterized.

- *Develop In-Valley Salt Management Alternatives*. SSALTS will analyze the Phase 1 Study Areas to determine if these areas can be expanded to increase the opportunity for their continued use for salt disposal, and also identify potential new areas that can serve as additional, intentional salt disposal areas in the Central Valley. The outcome of this effort will be the identification of in-valley salt disposal alternatives for further evaluation under Phase 3.

- *Develop Out of Valley Salt Management Alternatives*. SSALTS will develop alternatives to export or transport salt out of the Central Valley. The viability of the identified alternatives will be evaluated under Phase 3.

- *Develop Hybrid Salt Management Alternatives*. SSALTS will evaluate the in-valley and out-of-valley alternatives to identify potential alternatives that utilize a combined or hybrid approach for managing salt. The viability of any identified alternatives will be evaluated under Phase 3

The deliverables for Phase 2 include fact sheet summaries prepared for management practices that are identified in this report. To the extent that information is available, the format of each fact sheet will be based on the Management Practice Screening Tool Checklist developed by the CV-SALTS Management Practices Subcommittee.

Phase 2 of SSALTS is intended to provide planning-level information on the various combinations of source control BMPs, treatment options, and storage/disposal/use options that would be combined into salinity strategy alternatives. One of the objectives of this phase is to determine the magnitude of salt accumulation and strategies that could mitigate the accumulation. From a planning-level perspective, SSALTS Phase 2 will determine what strategies – or combination of strategies – will have the capacity to treat and dispose of salt that is currently accumulating in the Central Valley and at what cost.

Table 1-1 describes various methods and implementation actions that are being developed as part of the Lower San Joaquin River implementation Plan[1]. The table cross links archetype study areas from the Phase 1 SSALTS report, as well as source control measures and treatment and disposal options or actions. The table further provides a brief description of the implementation actions.

[1] LWA, pers. comm. Email from Karen Ashby on August 13, 2014.

Flysheet for Table 1-1, Page 1

Flysheet for Table 1-1, Page 2

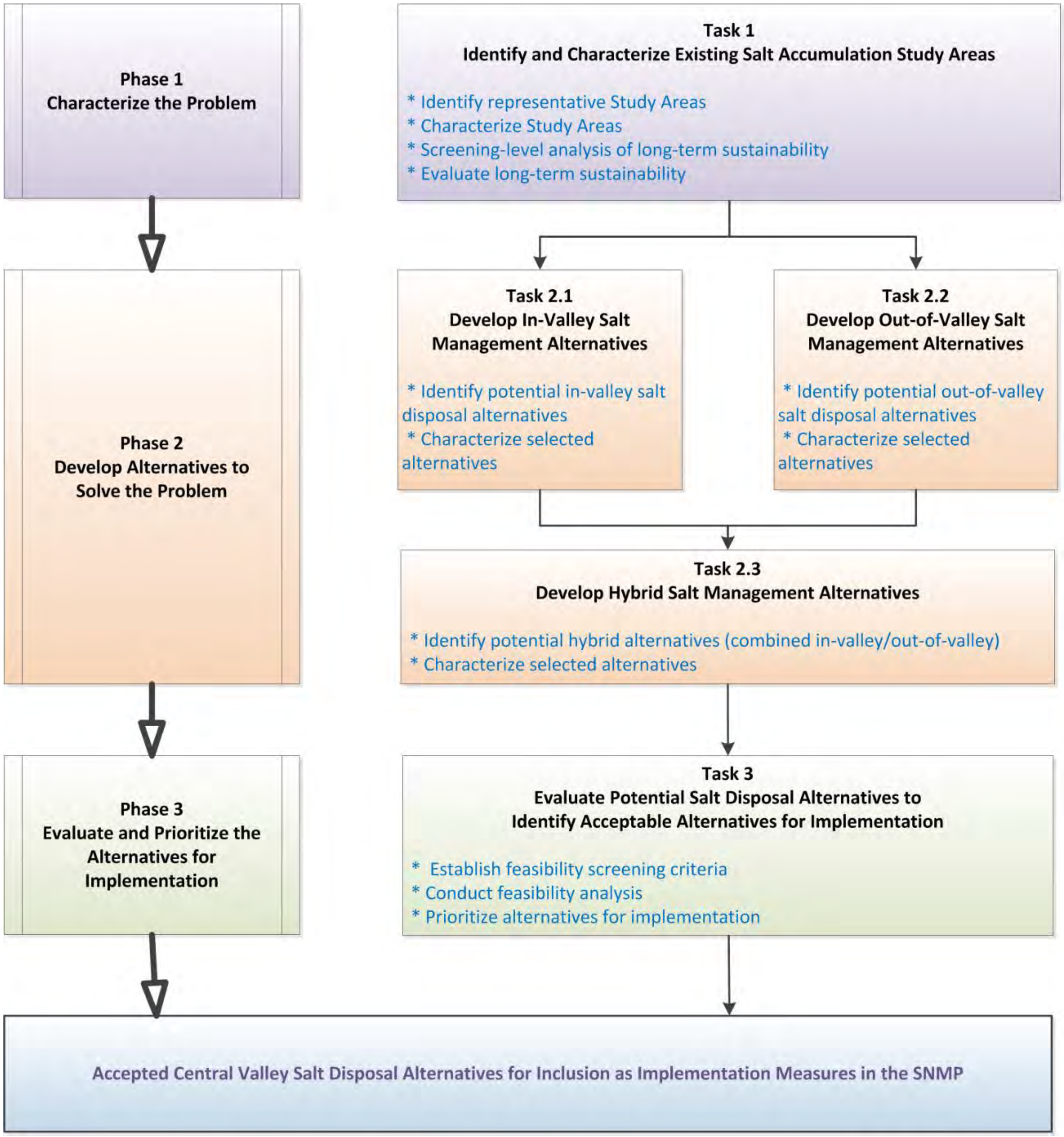

Figure 1-1 SSALTS Phases and Key Tasks

Section 2
Salt Balance

The analysis of various alternative strategies for salinity management in the Central Valley is fundamentally dependent on the magnitude of the salt accumulation and the potential regulatory target. Section 2.1 will list certain regulatory and compliance goals that will serve as potential salinity management strategic objectives.

Figure 2-1 shows the Salt Flux-Salt Management Process Flow Diagram that allows for a conceptual level estimate of the salt accumulation problem in the Central Valley and the source control BMPs, treatment options, and storage/disposal/use options that would be relevant. As shown in Figure 2-1, the Initial Conceptual Model (LWA, 2013) provides information on the net salt flux into the shallow groundwater system in each Initial Analysis Zone (IAZ). This will determine the mass of salt that would need to be removed from the system (or in the case of source control BMPs, prevented from entering the groundwater) to achieve a zero salt balance (net inflows minus net outflows equal zero) or some other target for salt mitigation.

To refine this estimate, it is assumed that the entire IAZ would not be pumped and treated. Desalter wells would be strategically located and designed to extract areas of elevated concentrations of TDS. Therefore, ambient concentrations of TDS in pumped groundwater for areas that have been degraded[2] with respect to TDS are also estimated. These concentrations are then used to determine the volume of brackish groundwater or tile drain water that would need to be pumped and treated or removed by some means. The groundwater chemistry along with the volume of water to be treated will determine the array of treatment technologies and the sizing of facilities or other removal methods. Finally, the brine produced (volume, concentration, trace constituents) will inform the range of disposal/use/storage options.

2.1 Regulatory and Compliance Goals

State Water Board Resolution 68-16, the Statement of Policy with Respect to Maintaining High Quality of Waters in California (State Anti-Degradation Policy) applies to both surface waters and groundwater. The State Anti-Degradation Policy generally prohibits the CVRWQCB from authorizing discharges that will degrade “high-quality waters,” unless the Board first finds that: (1) the degradation is consistent with the maximum benefit to people of the state: (2) the discharge will be controlled through the use of “best practicable treatment or control” methodologies: and (3) the discharge will not unreasonably affect present and potential beneficial uses.

One potential salinity objective of the SNMP could be a return to ambient groundwater quality conditions that existed in the period near the adoption of Resolution 68-16. A precedent for using this period for setting groundwater quality objectives is in the Santa Ana Watershed where the objective setting period was selected to be a 20-year period from 1954 to 1973 by the Santa Ana Regional Board and other stakeholders. A different objective could be to achieve a salt flux balance wherein the net salt inflows are balanced by net salt outflows and therefore there would be no net accumulation of salt. The

[2] For the purposes of this report, the term degraded groundwater refers to ambient concentrations greater than 1000 mg/L.

latter objective scenario was selected for SSALTS; other compliance objectives can be studied in future phases of SSALTS.

Another regulatory/policy consideration is to allow groundwater basins – or portions of groundwater basins – to degrade programmatically. Archetype salt accumulation areas are described in Section 5.4. Part of the SNMP effort undertaken by the CV-SALTS Executive Committee includes evaluating appropriate designation and level of protection for water bodies currently designated with the MUN beneficial use, taking into account the requirements of the Sources of Drinking Water Policy (88-63). In particular, CV-SALTS members were encouraged to provide submissions to identify waters that clearly meet the exemption criteria set forth in the Sources of Drinking Water Policy. Addressing the appropriateness of the MUN designation for one or more of these waterbodies through the completion of technical studies and basin planning documentation would provide an opportunity to establish reference archetypes for making subsequent MUN determinations on other water bodies in the future. An example of an area where MUN beneficial uses are being considered for de-designation is a portion of the Tulare Lake Bed. As discussed in Section 2.2, salt is allowed to accumulate in the Tulare Lake Bed and is not accounted for as part of the overall mass of salt that would be extracted as part of this conceptual plan.

2.2 Estimates of Salt Accumulation and Salt Extraction

The Larry Walker Associates Team has developed the Initial Conceptual Model (ICM) in a collaborative setting with stakeholders, regulatory agencies, and municipal agencies (LWA, 2013). As with Phase 2 of SSALTS, the ICM is a "30,000-foot concept level" analysis – in the case of the ICM – of Central Valley-wide water balance, in order to estimate salt and nitrate fluxes and loads to IAZs. The CV-SALTS Technical Advisory Committee (TAC) recommended that the USGS's Central Valley Hydrologic Model (CVHM) be used as the basis for water balance determinations. The CVHM Delta-Mendota Basin was subdivided into subbasins so that there are 22 IAZs in the ICM. The IAZs are listed in Table 2-1, depicted in Figure 2-2, and are grouped into Northern Central Valley, Middle Central Valley, and Southern Central Valley for discussion purposes (see, for example, Tables 2-2 and 2-3).

The spatial boundaries of the IAZs are from the CVHM model and these boundaries are related to DWR's water balance regions. The ICM model performs water, salt and nitrate balance calculations for each quarter over a 20-year modeling period. Table 10-4 *"Annual Mass Loading of a Per Acre Basis for the Six (6) Nitrate and Three (3) TDS Loading Scenarios"* from LWA (2013) contains the following information for each of the IAZs: area (thousands of acres or square miles) and the net mass loading of salt to shallow groundwater in kilograms (kg) per acre per year. The "Original TDS Loading" is the mass loading using the original input parameters to the model while the "50% of Original and "200% of Original" represents a model sensitivity analysis. Table 10-5 *"Assimilative Capacity Based on Recent (2003-2012) Shallow Data for Nitrate and TDS"* from LWA (2013) summarizes median ambient groundwater TDS for the shallow groundwater zone, based on groundwater well data for the period 2003 to 2012.

The information from Tables 10-4 and 10-5 was used as the basis for Table 2-2 in this report. The TDS loading and area were used to determine the mass loading of salt for each IAZ on an annual basis. The shallow groundwater TDS data were then used in a mass balance analysis to determine the volume of shallow groundwater (or agricultural tail water) that would need to be extracted to achieve a policy compliance goal of balancing net salt inflows and outflows. As shown in Table 2-2, the current net salt accumulation in the entire Central Valley is about 7,000,000 tons annually, according to the ICM model. The salt accumulation in the regional groupings of IAZ is:

- Northern Central Valley – 1,173,300 tons per year
- Middle Central Valley – 2,152,825 tons per year
- Southern Central Valley – 3,758,301 tons per year

If one were to pump each IAZ uniformly this would result in about 4,620 million gallons per day (MGD) of extraction. At a treatment efficiency of 90 percent, this would create a brine concentrate discharge of 462 MGD and an average concentration of 11,415 mg/L. These totals could be slightly reduced to the extent that any source control measures could be feasibly implemented.

There are IAZs where – although salt is accumulating – the ambient groundwater quality is still excellent and responsible entities would not likely pump and treat that water. For example, in IAZ 2, Red Bluff to Chico Landing, 68,000 tons of salt are accumulating annually. However, the ambient groundwater TDS concentration is only 201 mg/L. In order to analyze a more realistic scenario, only areas with significant TDS degradation were considered for extraction and salt removal through desalters or other options. A series of figures (Figures 2-3 through 2-17) were prepared that show the areal distribution of TDS concentrations in shallow groundwater for each regional grouping of IAZs for the following periods:

- 1902 – 1949
- 1950 – 1969
- 1970 – 1989
- 1990 – 1999
- 2000 – 2014

The definition of shallow groundwater in this report is explicitly identical to the definition of shallow groundwater developed for the ICM (LWA, 2013) in that the TDS concentrations in groundwater in Tables 2-2 and 2-3 represents the ambient TDS based on the ICM's definition of shallow groundwater[3].

In some cases, the current data set did not show degradation, because wells were not sampled during that period; in those cases historical data were used to delineate the degraded areas. Areas of degraded groundwater are depicted in Figures 2-18 through 2-20 – these are areas where there are (or historically were) significant clusters of wells with TDS concentrations over 1000 mg/L. Average TDS concentrations were then estimated for the degraded areas. Table 2-3 summarizes the results of this analysis. In this scenario, pumping and desalting would be focused in the following IAZs:

- 6 – Cache-Putah area
- 9 – Delta
- 10 – Delta-Mendota Basin - Northwest Side
- 22 – Delta-Mendota Basin - Grassland
- 14 – Westside and Northern Pleasant Valley Basins

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[3] "The vertical distance represents the distance that the water, at the water table, would travel downward or upward over a 20-year period." (LWA, 2013).

- 15 – Tulare Lake and Western Kings Basin
- 19 – Western Kern County and Southern Pleasant Valley Basin
- 21 – Southeastern Kern County Basin

In this scenario, there would need to be about 916 MGD of extraction to achieve the objective. At a treatment efficiency of 90 percent, this would create a brine concentrate discharge of 92 MGD and an average concentration of 25,429 mg/L. Pumping shallow groundwater or agricultural drainage water from these eight out of 22 IAZs would extract almost 5,000,000 tons of salt annually (about 70 percent of the total net salt influx in the Central Valley). As noted above, this objective could potentially be reduced to the extent that any source control measures reduce the net influx to these IAZs.

Although the analyses in this report focusses on the eight most degraded IAZs, the SNMP basin plan amendment will include source control, treatment, and disposal options for the entire Central Valley. These eight IAZs were selected in order to maximize salt export in a cost effective and manageable manner. Areas outside of the eight IAZs will addressed in future phases and are not being forgotten. Salt accumulation in the degraded areas within each of these eight IAZs is being addressed through a combination of source control measures and treatment/disposal options as outlined in Section 7. In salt accumulation areas, *e.g.*, the Tulare Lake bed, salt is being stored indefinitely.

Table 2-1 IAZ Designations

	IAZ	Initial Analysis Zone Description
Northern Central Valley	1	Sacramento River above Red Bluff
	2	Red Bluff to Chico Landing
	3	Colusa Trough
	4	Chico Landing to Knights Landing proximal to the Sacramento River
	5	Eastern Sacramento Valley foothills near Sutter Buttes
	6	Cache-Putah area
	7	East of Feather and South of Yuba Rivers
Middle Central Valley	8	Valley floor east of the Delta
	9	Delta
	10	Delta-Mendota Basin - Northwest Side
	11	Modesto and southern Eastern San Joaquin Basin
	12	Turlock Basin
	13	Merced, Chowchilla, and Madera Basins
	22	Delta-Mendota Basin - Grassland
Southern Central Valley	14	Westside and Northern Pleasant Valley Basins
	15	Tulare Lake and Western Kings Basin
	16	Northern Kings Basin
	17	Southern Kings Basin
	18	Kaweah and Tule Basins
	19	Western Kern County and Southern Pleasant Valley Basin
	20	Northeastern Kern County Basin
	21	Southeastern Kern County Basin

Table 2-2 Salt Loading and Salt Extraction by IAZ

Central Valley Zone	IAZ	Acres (x1000)	Square Miles	TDS Loading for IAZ (tons)			GW [TDS]	Pumped GW [TDS]	TDS Removed from each IAZ (tons)			Volume Needed to be Removed (MGD)			Volume Concentrate - 90% Efficiency (MGD)			Brine [TDS]
				50%	Original	200%	mg/L	mg/L	50%	Original	200%	50%	Original	200%	50%	Original	200%	mg/L
Northern Central	1	391	611	26,722	53,444	107,320	370	370	26,722	53,444	107,318	47	95	190	5	9	19	3,700
	2	744	1,163	33,625	68,070	135,320	201	201	33,624	68,069	135,317	110	222	442	11	22	44	2,010
	3	712	1,112	138,133	275,481	550,961	583	583	138,131	275,476	550,952	155	310	620	16	31	62	5,830
	4	358	560	27,624	55,248	110,496	761	761	27,623	55,247	110,494	24	48	95	2	5	10	7,610
	5	612	957	26,310	53,295	106,589	329	329	26,310	53,294	106,587	52	106	213	5	11	21	3,290
	6	668	1,044	320,310	640,619	1,280,502	1,060	1,060	320,304	640,608	1,280,481	198	397	793	20	40	79	10,600
	7	342	534	13,572	27,143	54,287	398	398	13,571	27,143	54,286	22	45	89	2	4	9	3,980
Middle Central	8	872	1,362	41,332	82,665	165,329	438	438	41,332	82,663	165,326	62	124	248	6	12	25	4,380
	9	756	1,181	56,668	113,335	226,670	961	961	56,667	113,333	226,667	39	77	155	4	8	15	9,610
	10	180	282	110,518	220,837	441,674	842	842	110,516	220,833	441,667	86	172	344	9	17	34	8,420
	11	425	664	151,320	302,639	605,279	565	565	151,317	302,634	605,269	176	351	703	18	35	70	5,650
	12	346	540	165,527	331,055	662,110	825	825	165,525	331,049	662,099	132	263	527	13	26	53	8,250
	13	1,055	1,648	105,827	211,655	422,147	648	648	105,826	211,651	422,140	107	214	427	11	21	43	6,480
	22	513	801	445,603	890,640	1,781,845	1,160	1,160	445,595	890,625	1,781,815	252	504	1,008	25	50	101	11,600
Southern Central	14	685	1,071	565,557	1,131,114	2,262,984	3,375	3,375	565,548	1,131,096	2,262,946	110	220	440	11	22	44	33,750
	15	911	1,423	119,500	239,001	478,002	1,000	1,000	119,498	238,997	477,994	78	157	314	8	16	31	10,000
	16	306	478	59,029	69,485	90,736	575	575	59,028	69,484	90,734	67	79	104	7	8	10	5,750
	17	364	569	77,841	155,682	310,962	520	520	77,840	155,679	310,957	98	196	392	10	20	39	5,200
	18	869	1,358	119,739	228,940	447,343	598	598	119,737	228,936	447,336	131	251	491	13	25	49	5,980
	19	874	1,365	744,724	1,489,447	2,979,857	11,300	11,300	744,711	1,489,422	2,979,808	43	86	173	4	9	17	113,000
	20	451	705	72,086	140,691	278,400	870	870	72,084	140,689	278,395	54	106	210	5	11	21	8,700
	21	707	1,105	162,101	303,940	588,397	335	335	162,099	303,935	588,387	317	595	1,152	32	60	115	3,350
Total/Average		**13,141**	**20,533**		**7,084,426**					**7,084,309**			**4,620**		**236**	**462**	**913**	**11,415**
				Northern CV	1,173,300				Northern CV	1,173,280					Northern CV	122		
				Middle CV	2,152,825				Middle CV	2,152,790					Middle CV	171		
				Southern CV	3,758,301				Southern CV	3,758,239					Southern CV	169		

Table 2-3 Salt Loading and Salt Extraction by IAZ – TDS Degraded Areas Only

Central Valley Zone	IAZ	Acres (x1000)	Square Miles	TDS Loading for IAZ (tons)			GW [TDS]	Pumped GW [TDS]	TDS Removal from each IAZ (tons)			Volume Needed to be Removed (MGD)			Volume Concentrate - 90% Efficiency (MGD)			Brine [TDS]
				50%	Original	200%	mg/L	mg/L	50%	Original	200%	50%	Original	200%	50%	Original	200%	mg/L
Northern Central	1	391	611	26,722	53,444	107,320	370											
	2	744	1,163	33,625	68,070	135,320	201											
	3	712	1,112	138,133	275,481	550,961	583											
	4	358	560	27,624	55,248	110,496	761											
	5	612	957	26,310	53,295	106,589	329											
	6	668	1,044	320,310	640,619	1,280,502	1,060	2,509	320,304	640,608	1,280,481	84	168	335	8	17	33	10,600
	7	342	534	13,572	27,143	54,287	398											
Middle Central	8	872	1,362	41,332	82,665	165,329	438											
	9	756	1,181	56,668	113,335	226,670	961	1,001	56,667	113,333	226,667	37	74.3	149	4	7	15	9,610
	10	180	282	110,518	220,837	441,674	842	1,359	110,516	220,833	441,667	53	106.6	213	5	11	21	8,420
	11	425	664	151,320	302,639	605,279	565											
	12	346	540	165,527	331,055	662,110												
	13	1,055	1,648	105,827	211,655	422,147	648											
	22	513	801	445,603	890,640	1,781,845	1,160	5,845	445,595	890,625	1,781,815	50	100.0	200	5	10	20	11,600
Southern Central	14	685	1,071	565,557	1,131,114	2,262,984	3,375	4,987	565,548	1,131,096	2,262,946	74	148.8	298	7	15	30	33,750
	15	605	1,423	79,360	158,720	317,441	1,000	1,000	79,359	158,718	317,436	52	104.1	208	5	10	21	10,000
	16	306	478	59,029	69,485	90,736	575											
	17	364	569	77,841	155,682	310,962	520											
	18	869	1,358	119,739	228,940	447,343	598											
	19	874	1,365	744,724	1,489,447	2,979,857	11,300	11,300	744,711	1,489,422	2,979,808	43	86.5	173	4	9	17	113,000
	20	451	705	72,086	140,691	278,400	870											
	21	707	1,105	162,101	303,940	588,397	335	1,554	162,099	303,935	588,387	68	128.3	248	7	13	25	3,350
Total/Average		**12,835**	**20,533**		**7,004,146**					**4,948,571**			**916**		**46**	**92**	**182**	**25,429**
				Northern CV	1,173,300				Northern CV	640,608					Northern CV	17		
				Middle CV	2,152,825				Middle CV	1,224,792					Middle CV	28		
				Southern CV	3,678,020				Southern CV	3,083,171					Southern CV	47		

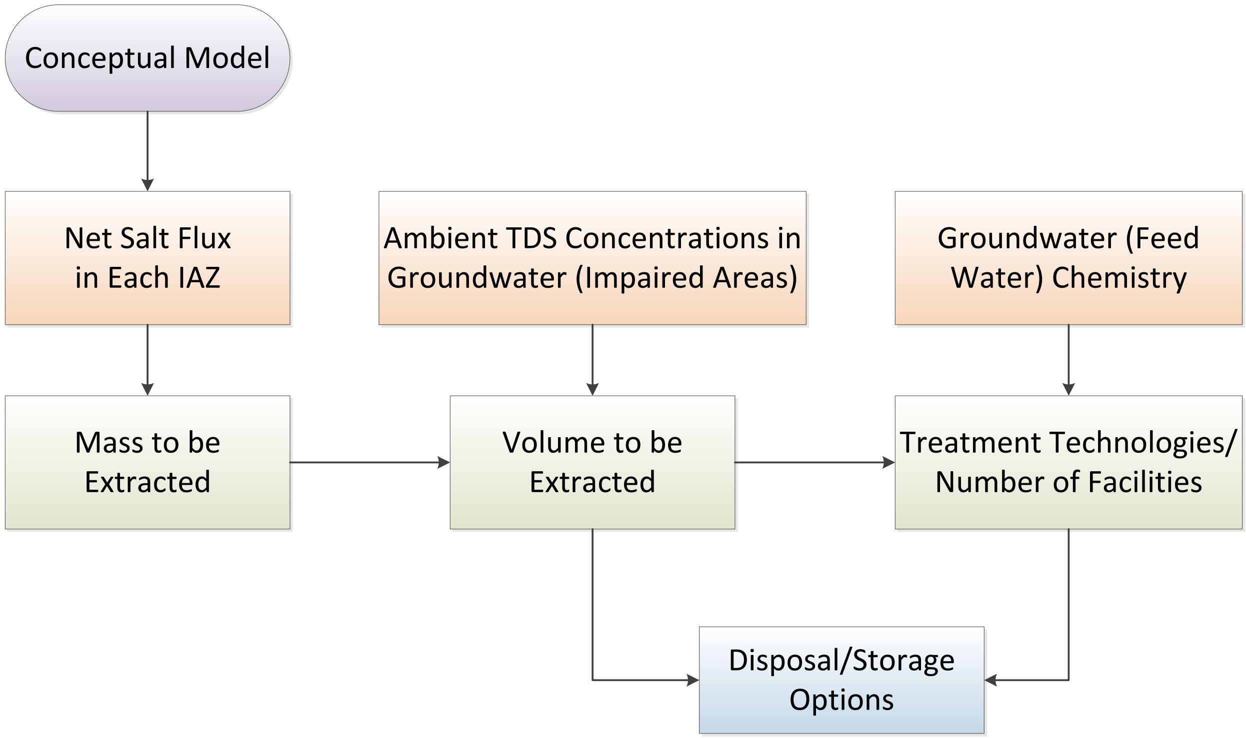


Figure 2-1 Salt Flux-Salt Management Process Flow Diagram

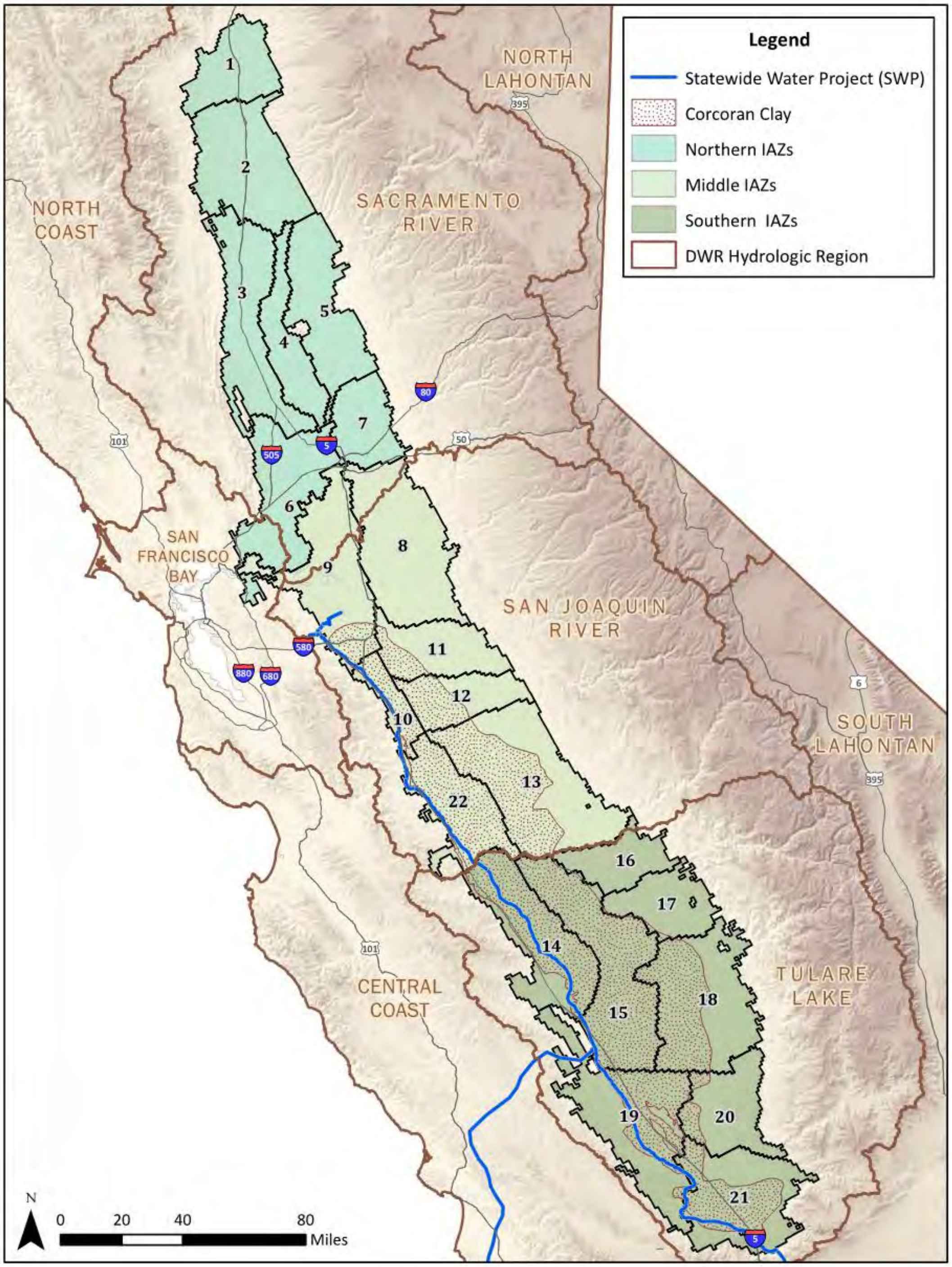


Figure 2-2 Map Depicting the Initial Analysis Areas (IAZs) in the Central Valley

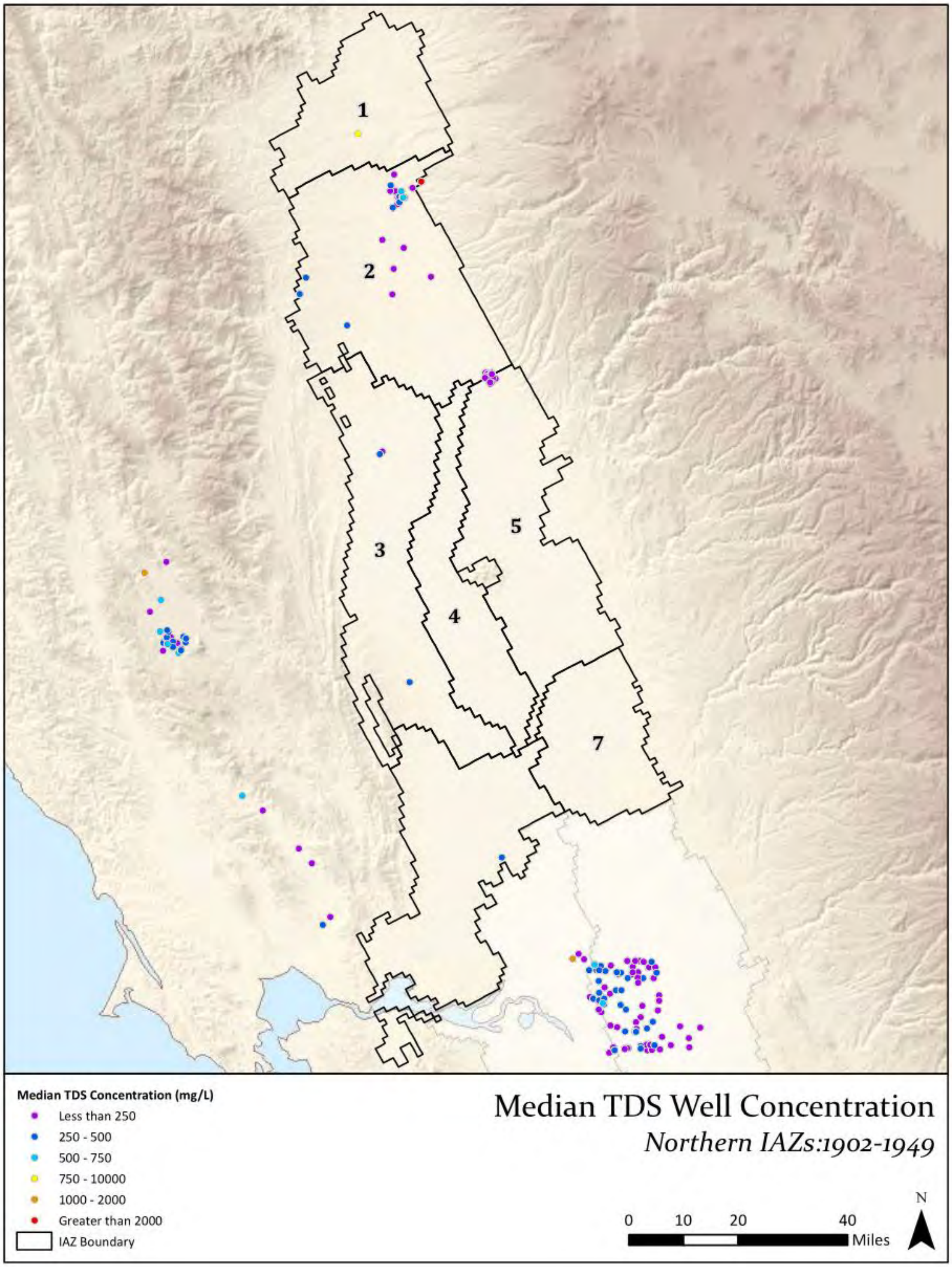


Figure 2-3 Distribution of Median TDS Concentrations in the Northern Central Valley IAZs: 1902 – 1949

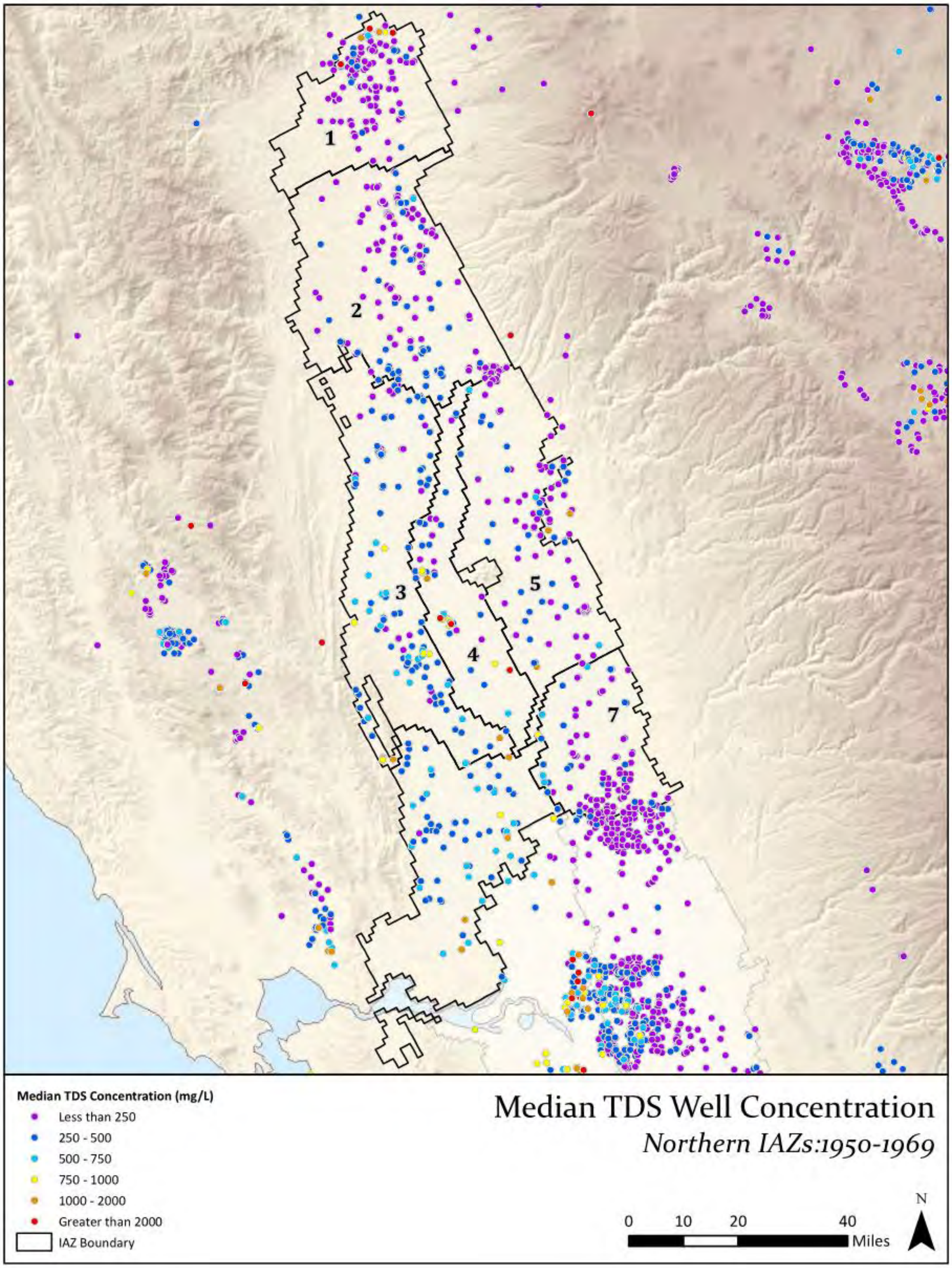


Figure 2-4 Distribution of Median TDS Concentrations in the Northern Central Valley IAZs: 1950 – 1969

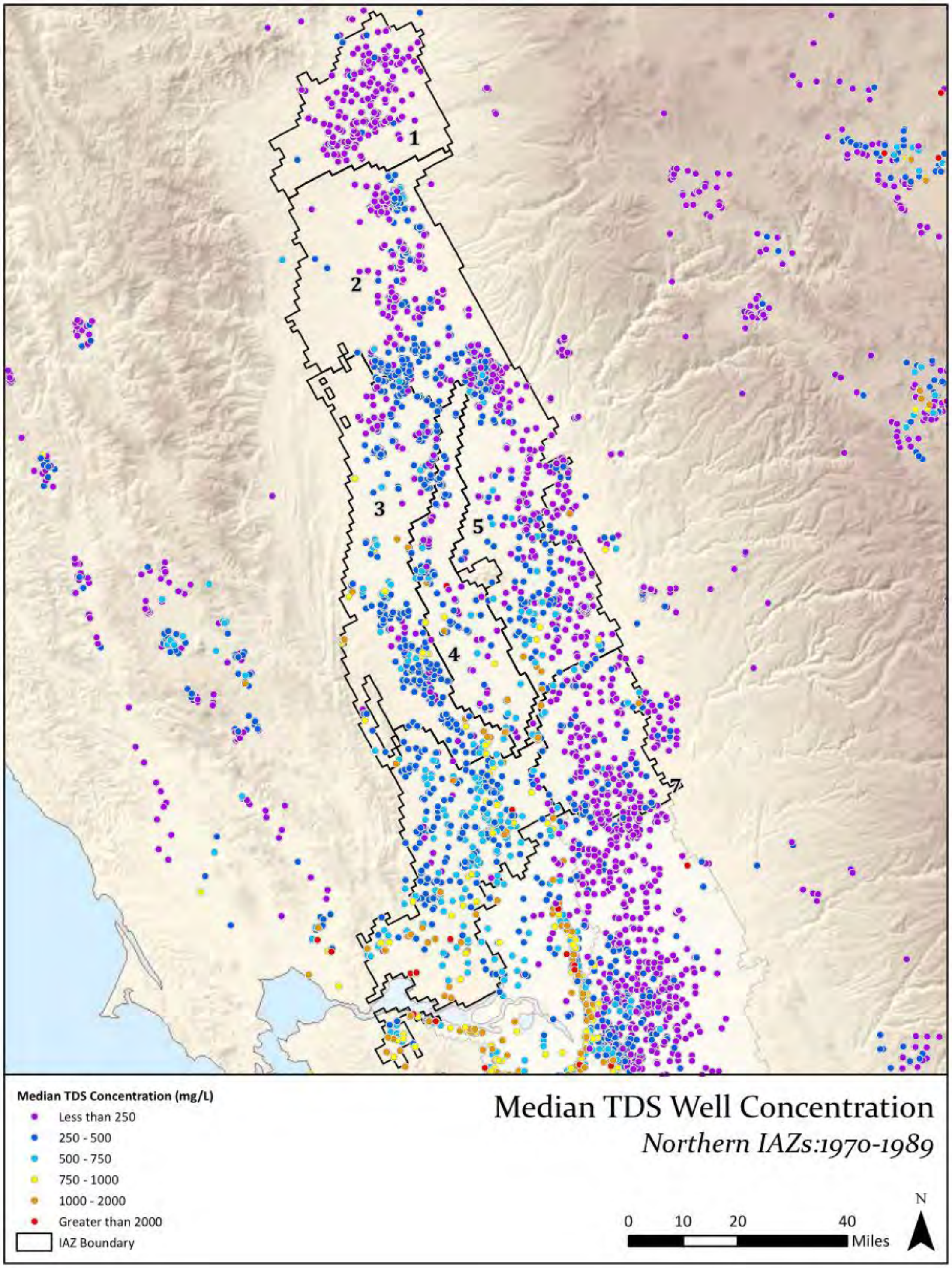


Figure 2-5 Distribution of Median TDS Concentrations in the Northern Central Valley IAZs: 1970 – 1989

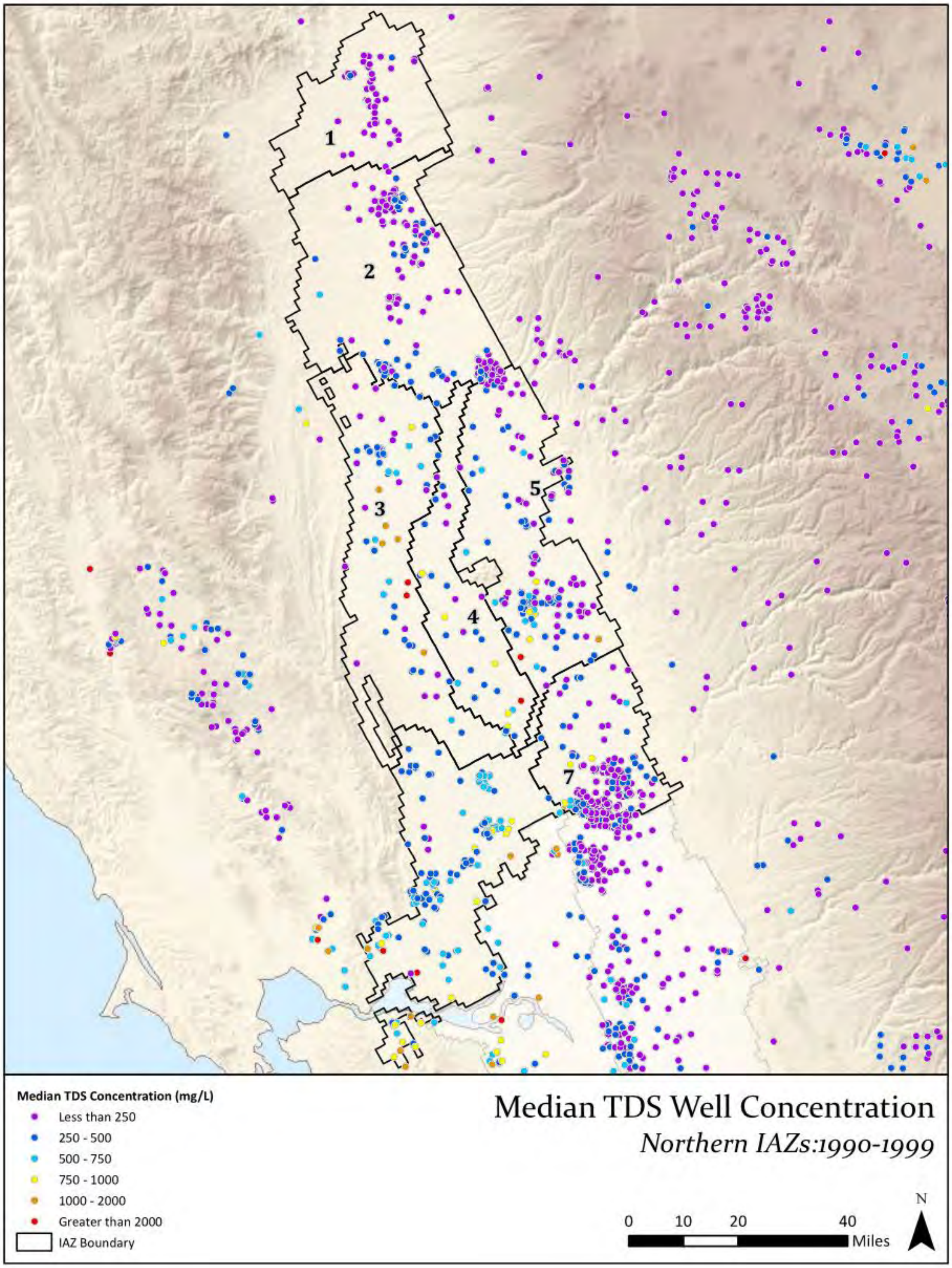


Figure 2-6 Distribution of Median TDS Concentrations in the Northern Central Valley IAZs: 1990 – 1999

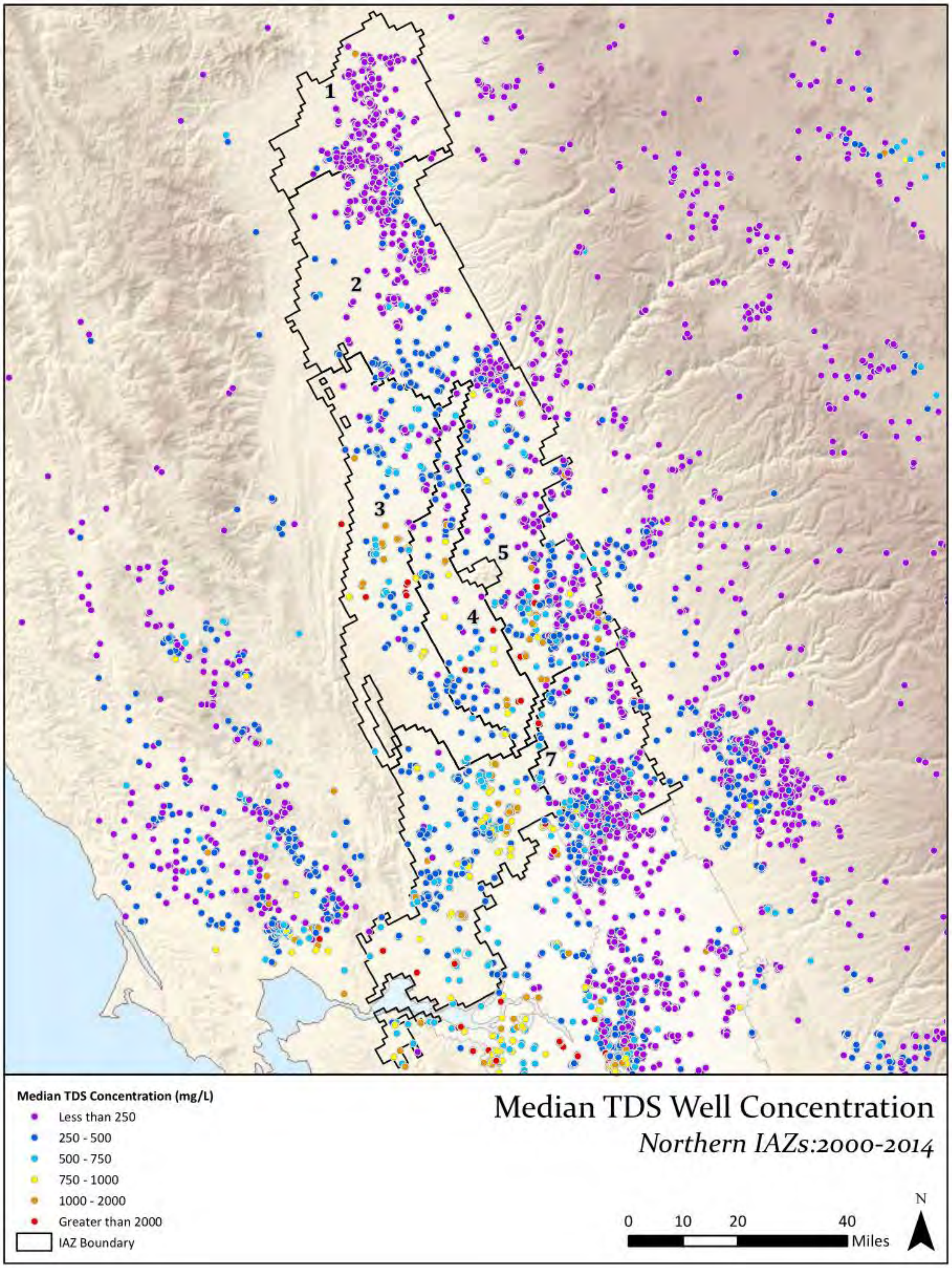


Figure 2-7 Distribution of Median TDS Concentrations in the Northern Central Valley IAZs: 2000 – 2014

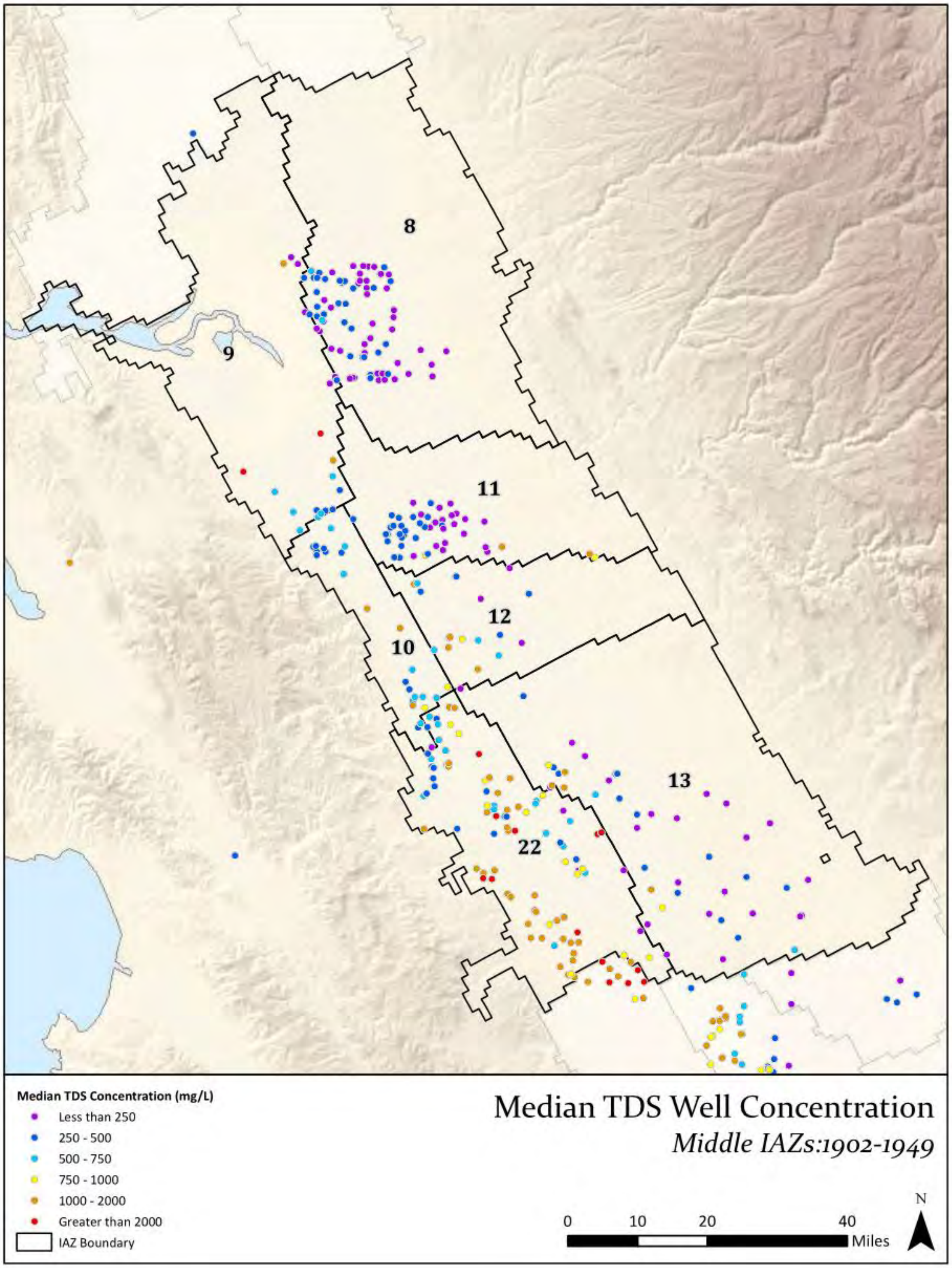


Figure 2-8 Distribution of Median TDS Concentrations in the Middle Central Valley IAZs: 1902 – 1949

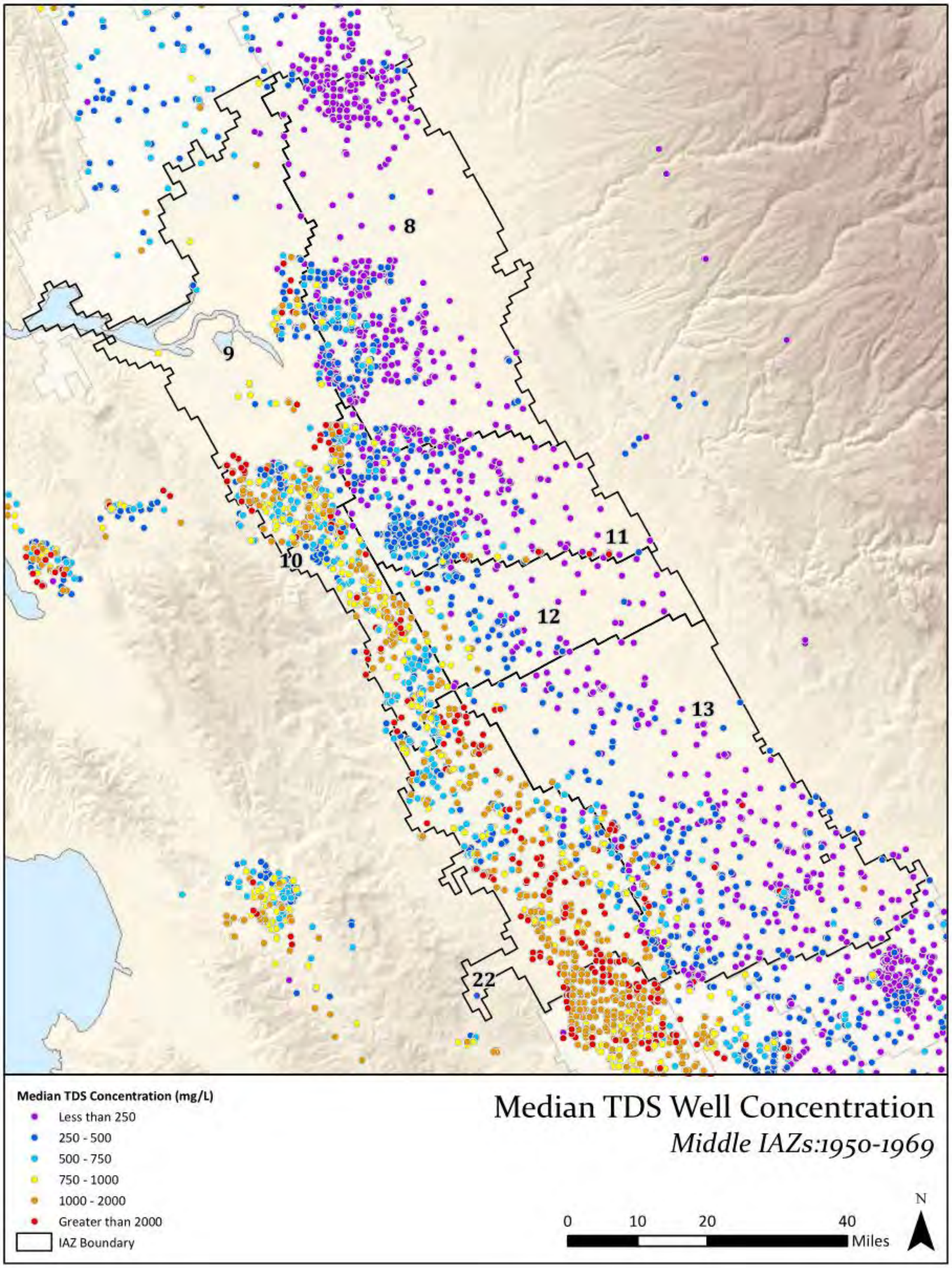


Figure 2-9 Distribution of Median TDS Concentrations in the Middle Central Valley IAZs: 1950 – 1969

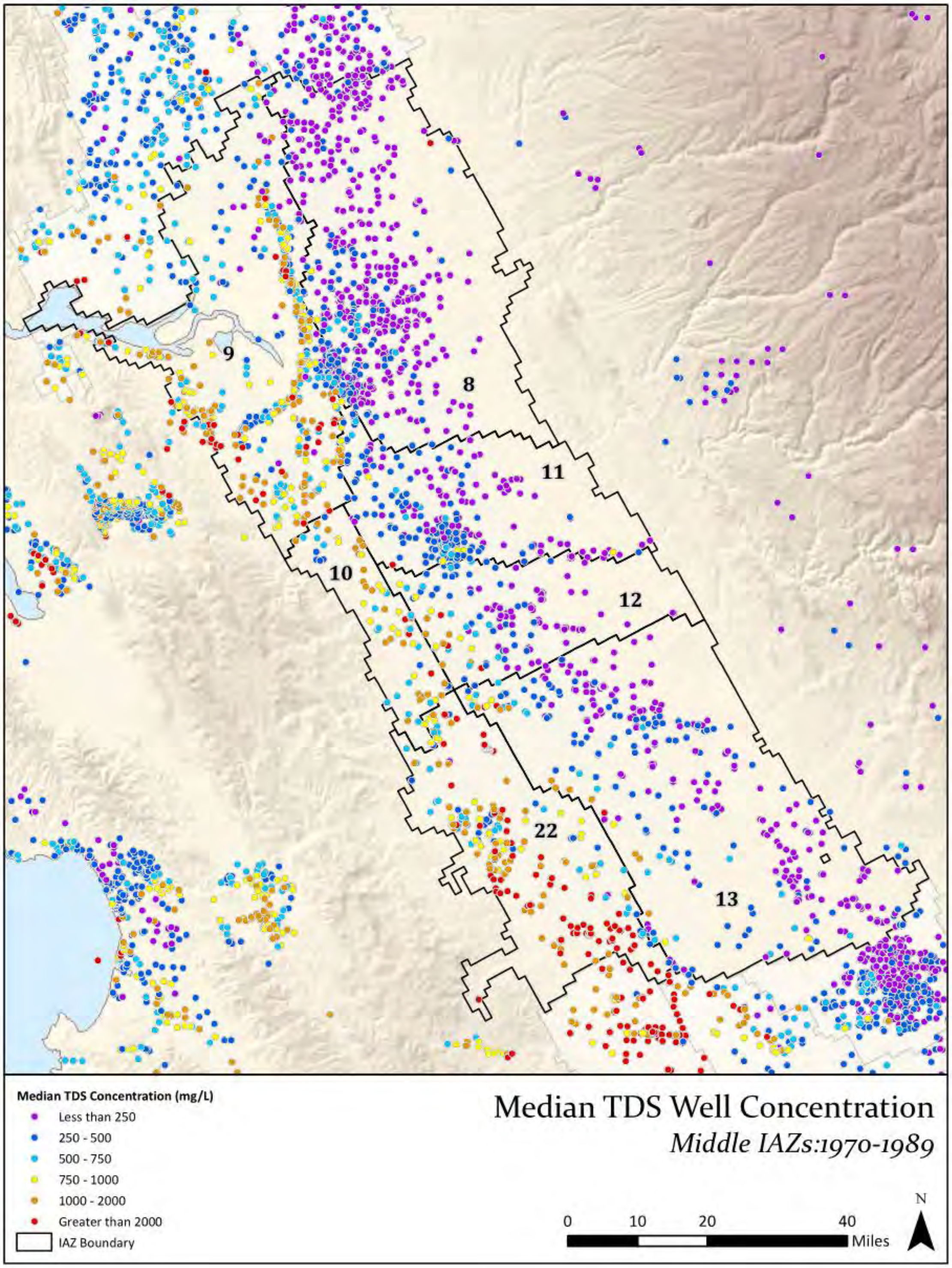


Figure 2-10 Distribution of Median TDS Concentrations in the Middle Central Valley IAZs: 1970 – 1989

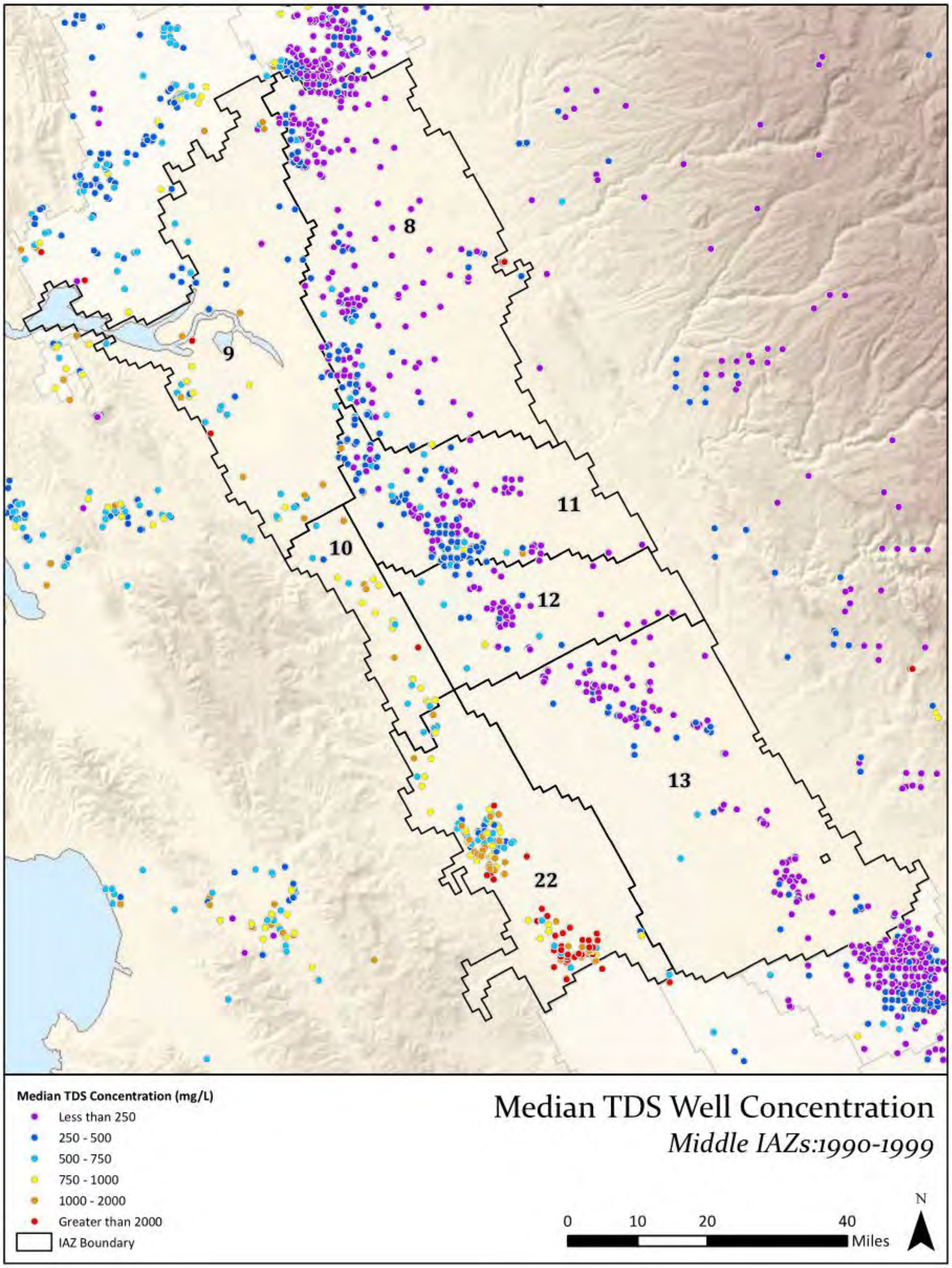


Figure 2-11 Distribution of Median TDS Concentrations in the Middle Central Valley IAZs: 1990 – 1999

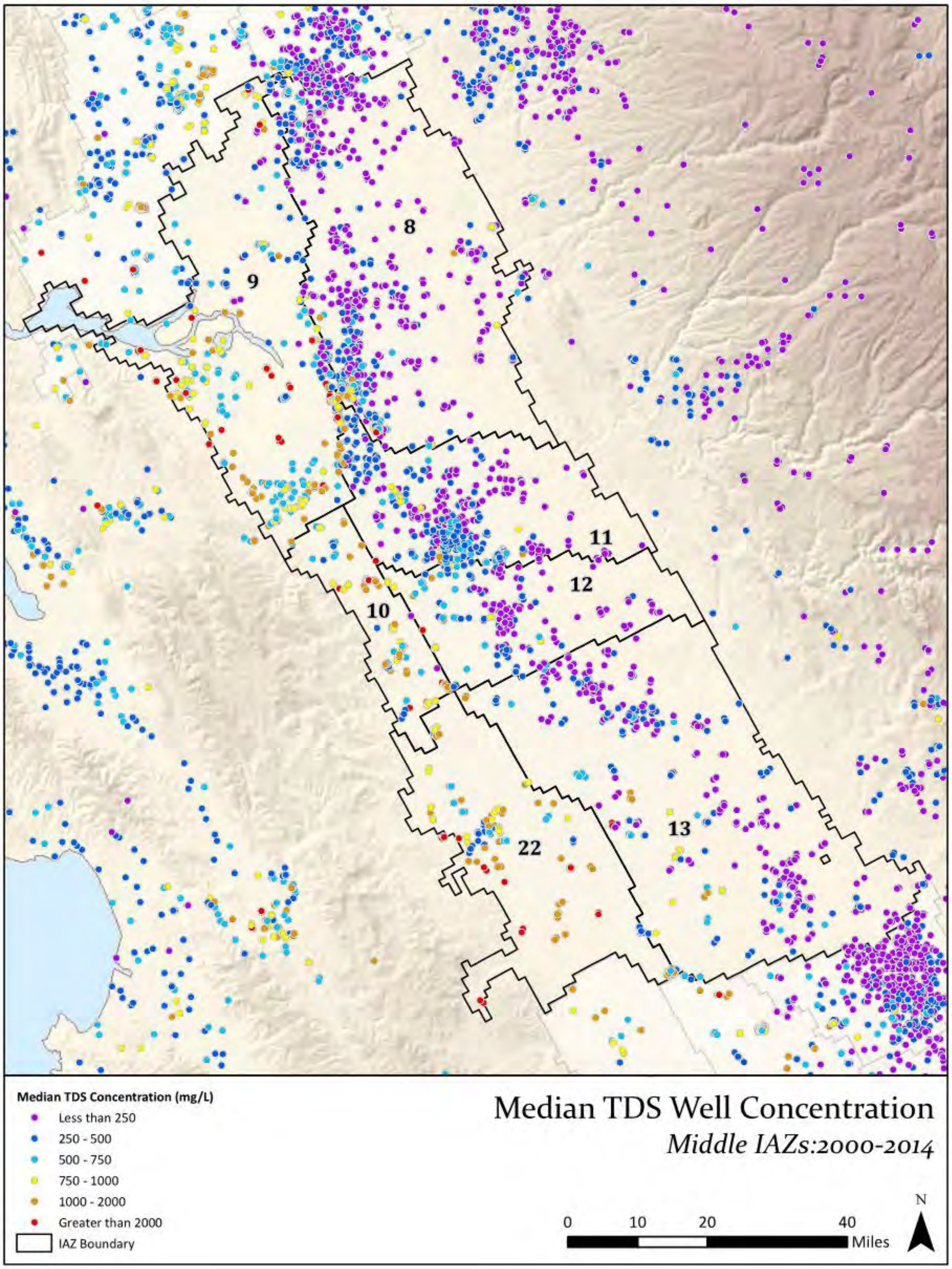


Figure 2-12 Distribution of Median TDS Concentrations in the Middle Central Valley IAZs: 2000 – 2014

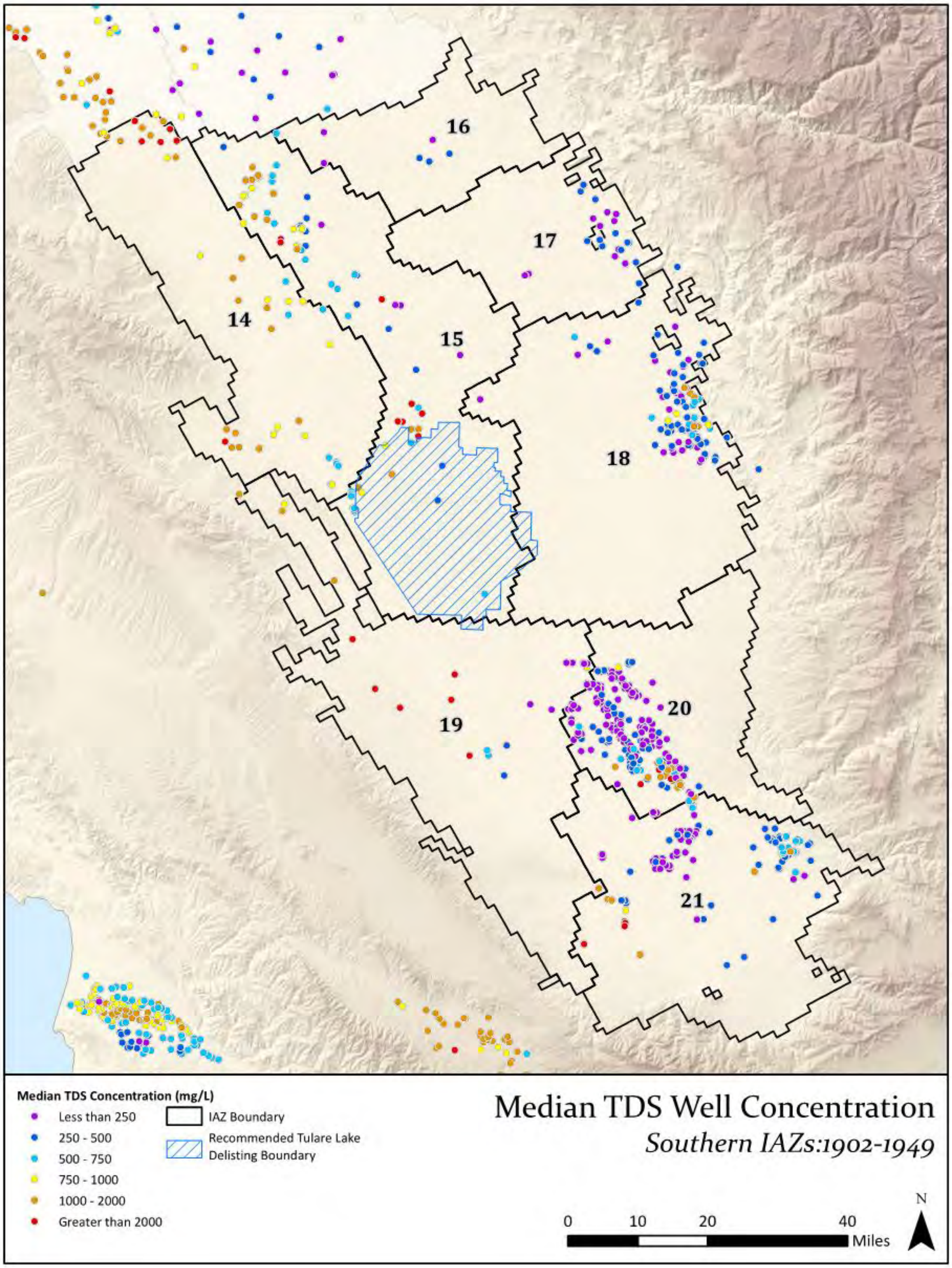


Figure 2-13 Distribution of Median TDS Concentrations in the Southern Central Valley IAZs: 1902 – 1949

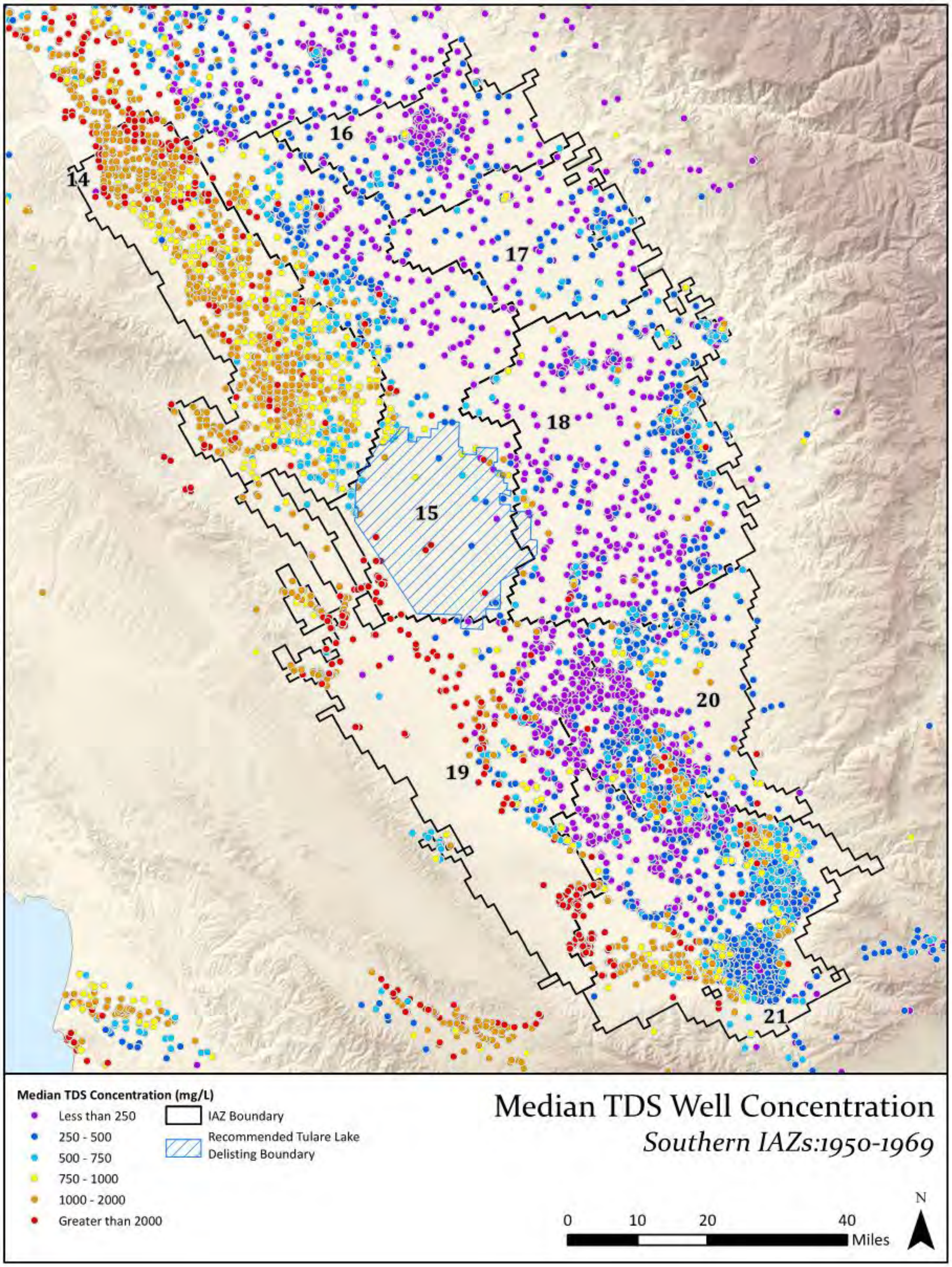


Figure 2-14 Distribution of Median TDS Concentrations in the Southern Central Valley IAZs: 1950 – 1969

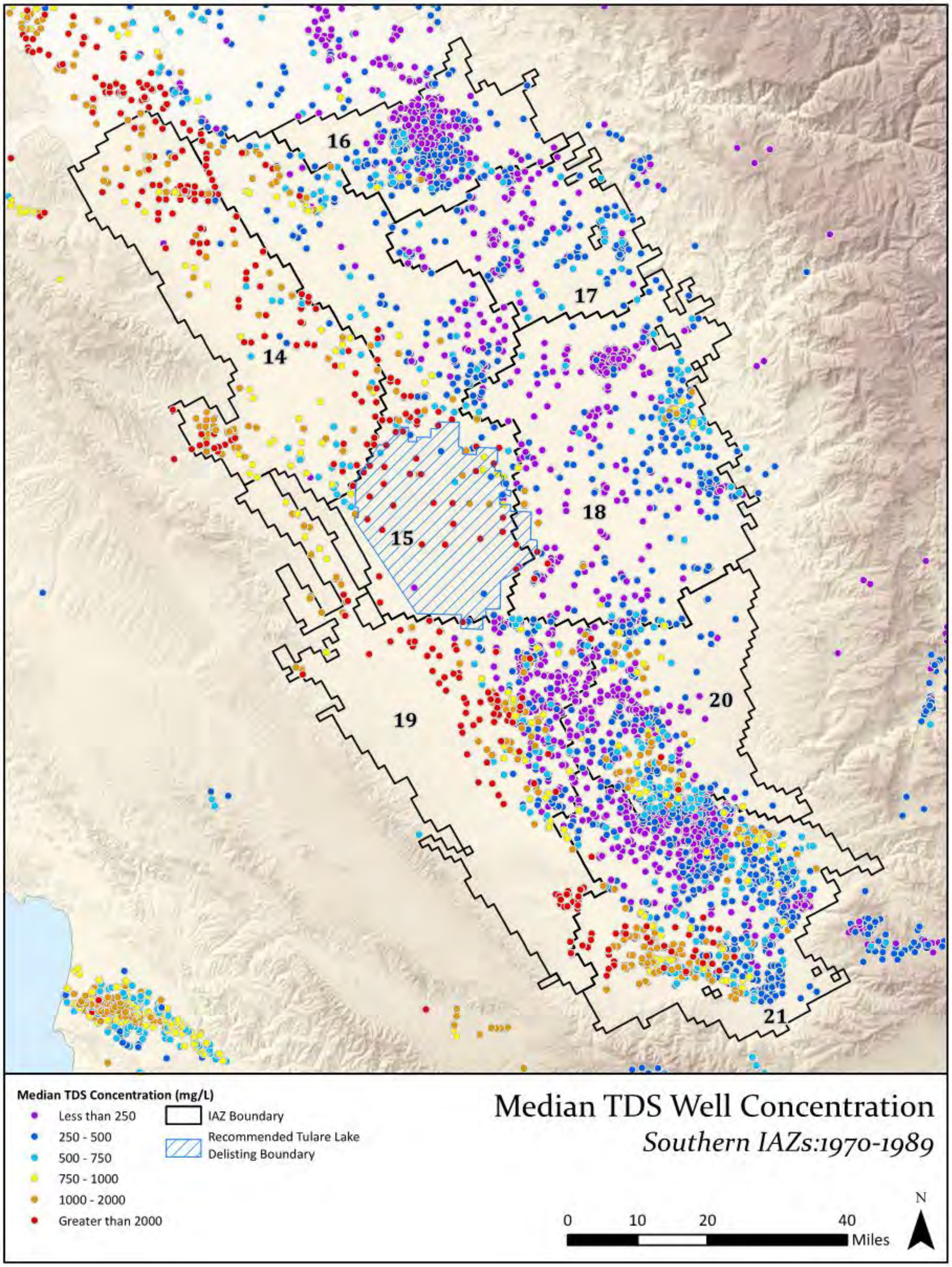


Figure 2-15 Distribution of Median TDS Concentrations in the Southern Central Valley IAZs: 1970 – 1989

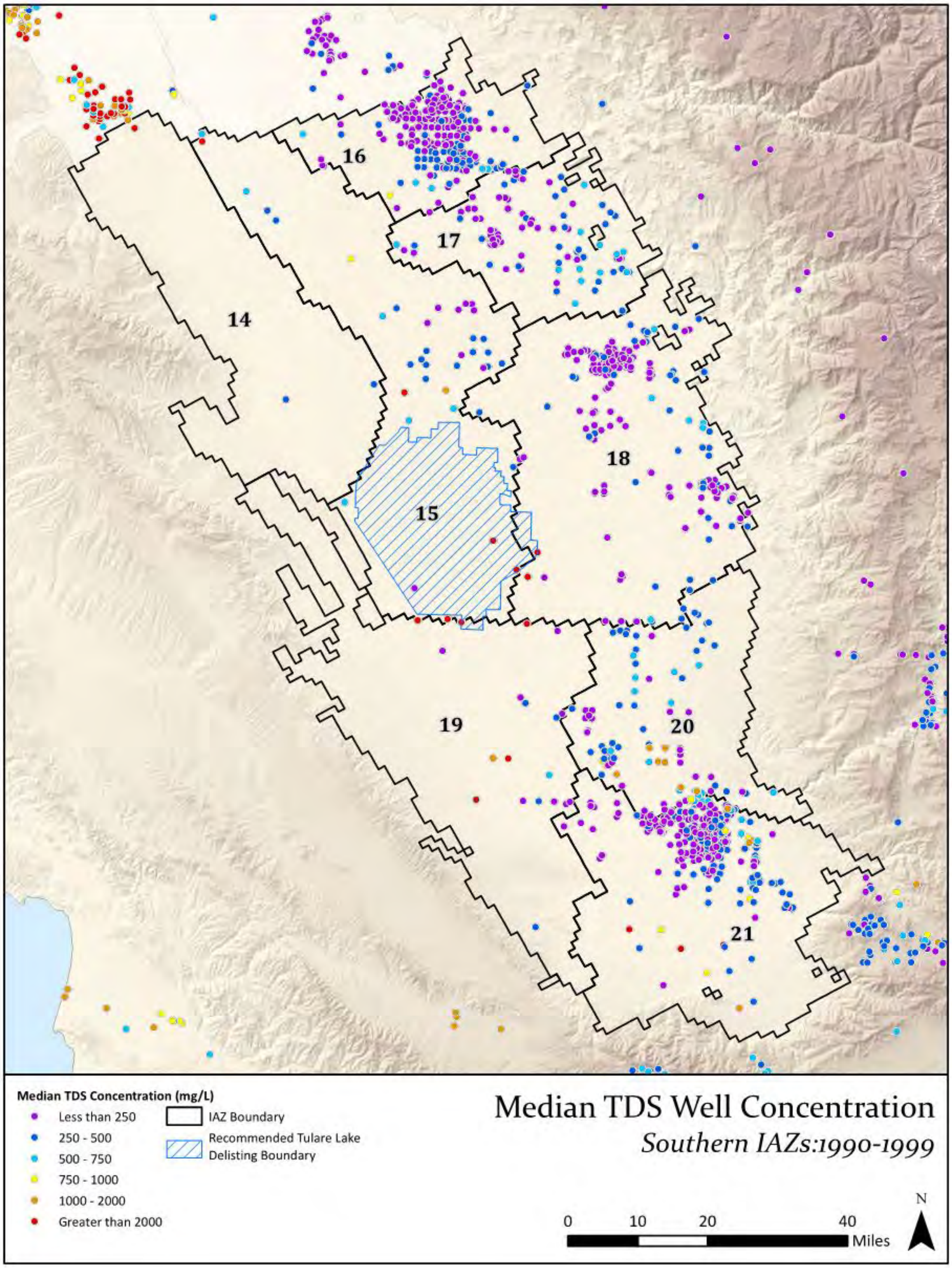


Figure 2-16 Distribution of Median TDS Concentrations in the Southern Central Valley IAZs: 1990 – 1999

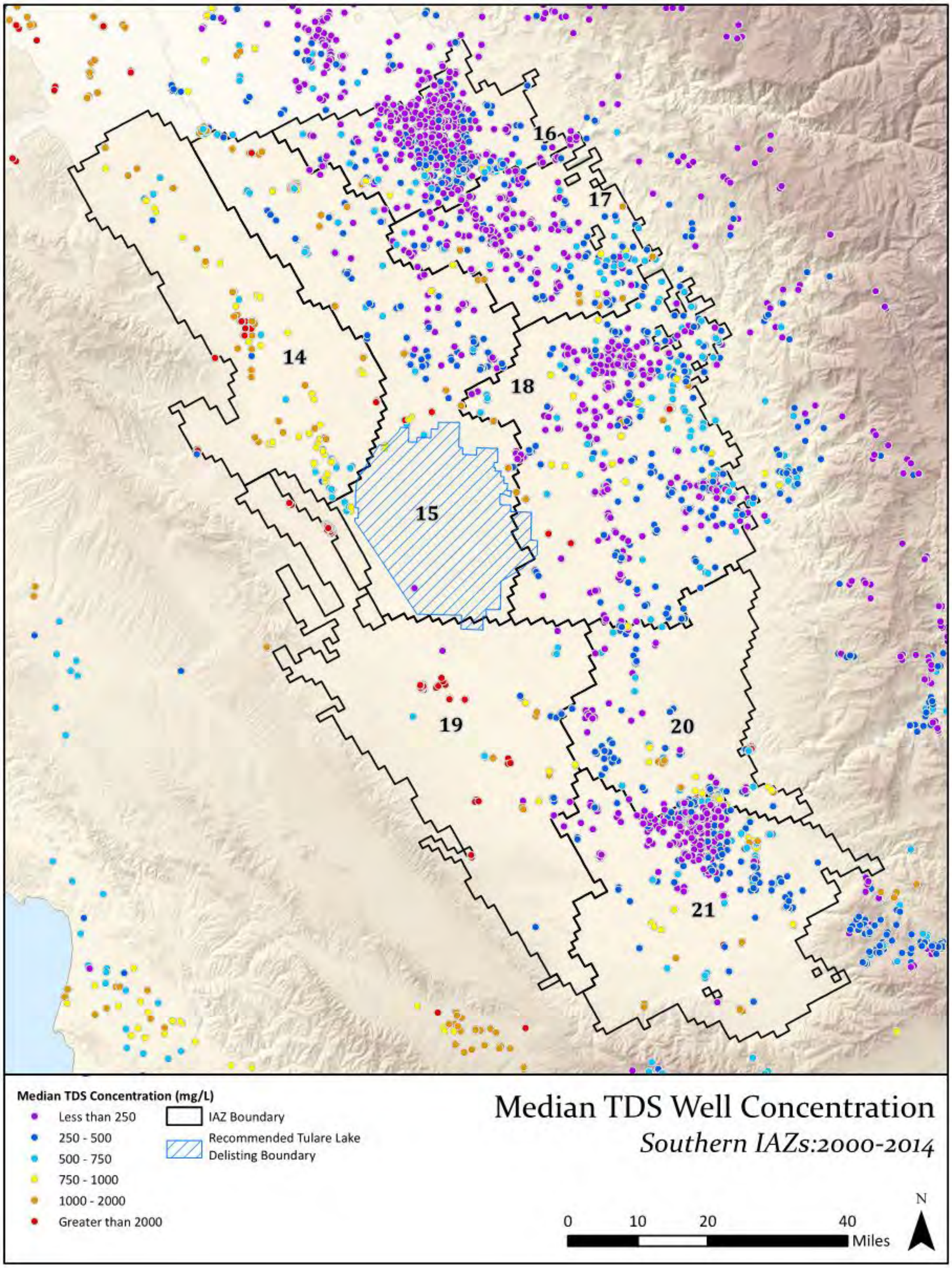


Figure 2-17 Distribution of Median TDS Concentrations in the Southern Central Valley IAZs: 2000 – 2014

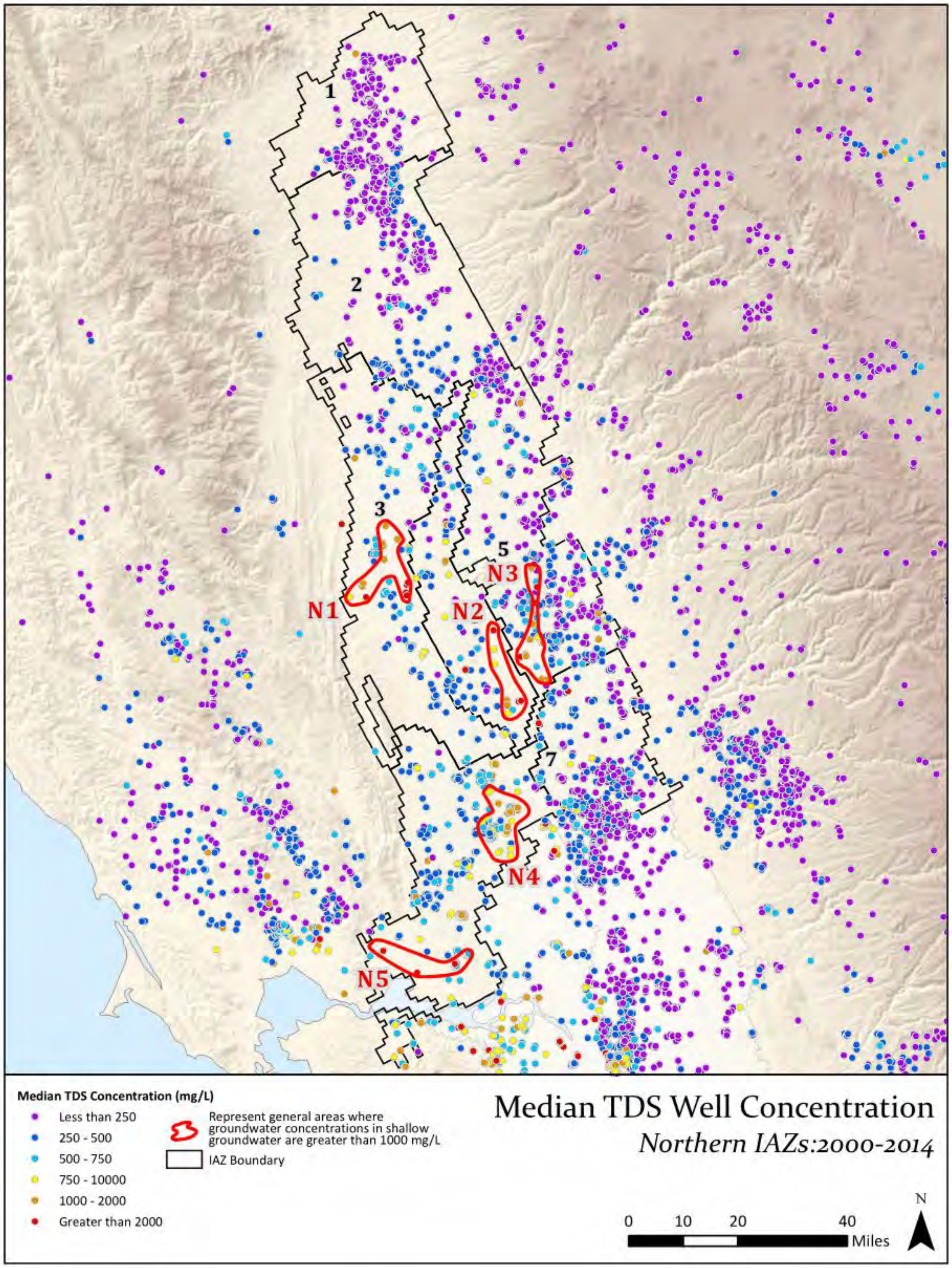


Figure 2-18 Degraded Areas for TDS in the Northern Central Valley IAZs

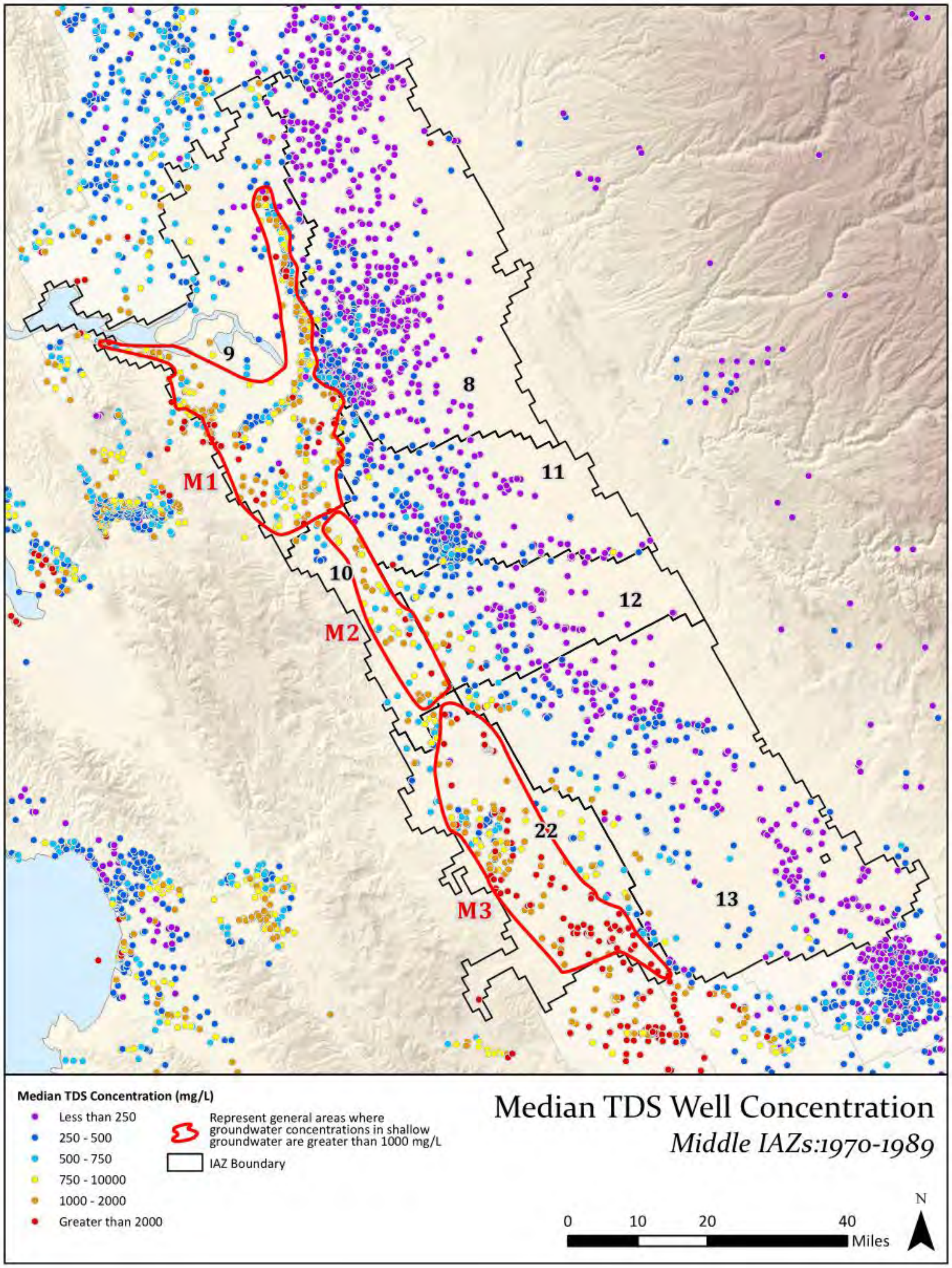


Figure 2-19 Degraded Areas for TDS in the Middle Central Valley IAZs

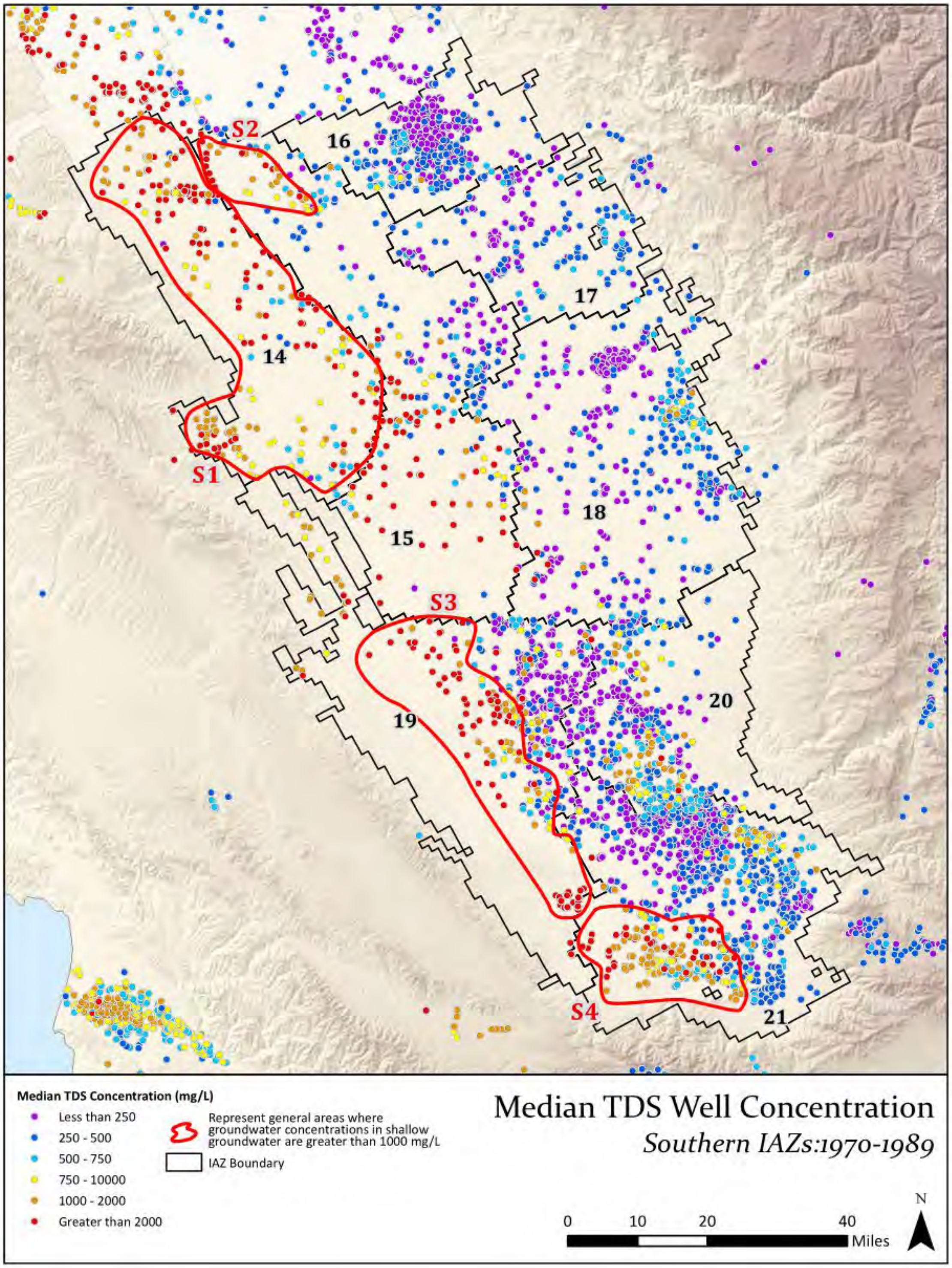


Figure 2-20 Degraded Areas for TDS in the Southern Central Valley IAZs

Section 3
Source Control Measures

Source control measures fall into three broad categories: (i) source control BMPs; (ii) land management; and (iii) de-designation of management zones or IAZs. Potential improvements to the Bay-Delta system, possibly through new conveyance facilities, have the potential of significantly reducing salt imported into the Central Valley via the CVP.

3.1 Source Control BMPs

A number of source control best management practices (BMPs) have been developed to provide management and engineering guidance to limit salt and other constituents from entering the soil/groundwater system. BMPs that reduce salt at the source are a more efficient means of salt reduction than treating salt in the perched zone or groundwater. BMPs provide the scientific and engineering basis and methods for controlling salt at the point of introduction into the natural system. BMPs may help achieve regulatory compliance and may be economical and sustainable solutions to salinity issues.

BMPs for salinity control have been developed for various sectors in California's economy, including: food processing, industrial (other than food processing), municipal, and irrigated agriculture. Source control measures range from water softener incentive program – such as the program recently developed by the City of Dixon – to peeling tomatoes using steam instead of caustics. Salt by categories of source control BMPs will be quantified – to the extent possible – in this section. The types of costs that may be encountered when implementing source control BMPs are discussed in the fact sheets at the end of this section.

3.2 Land Management

Land management is a critical component of the overall salt management in the Central Valley. The soils on the west side of the valley are composed of marine sediments and are naturally saline. Irrigated agriculture leaches these salts (and trace elements like selenium) into the perched zone above the Corcoran clay and into groundwater. The Corcoran Clay unit is a laterally continuous, low-permeability, lacustrine clay layer within the Tulare Formation that extends across middle and southern portion of the San Joaquin Valley (Figure 2-2). The Corcoran clay acts as an aquitard within the San Joaquin and Tulare basins dividing the overlying unconfined aquifer and the underlying confined aquifer. Both the thickness and depth of this unit vary greatly with thickness ranging from 20 to 120 feet and depths to the top of the clay shoaling from approximately 850 feet deep along the Coast Range to 500 feet in the valley trough (DWR, 1981; DWR, 2006; and Faunt *et al.*, 2009). Strategic land retirement can reduce the overall salt loading to groundwater in the Central Valley. According to Reclamation (2008), land retirement:

> *"Would consist of real estate interests that would be acquired through the purchase of non-irrigation covenants that restrict using irrigation water but permit the land to be used for grazing, fallowing, and dryland farming. Land retirement is considered a feature of drainage service because it reduces contributions of water to the shallow groundwater table."*

Land retirement or management will be a critical component of the SNMP in terms of limiting salt leached into groundwater.

3.3 De-Designation of Management Zones

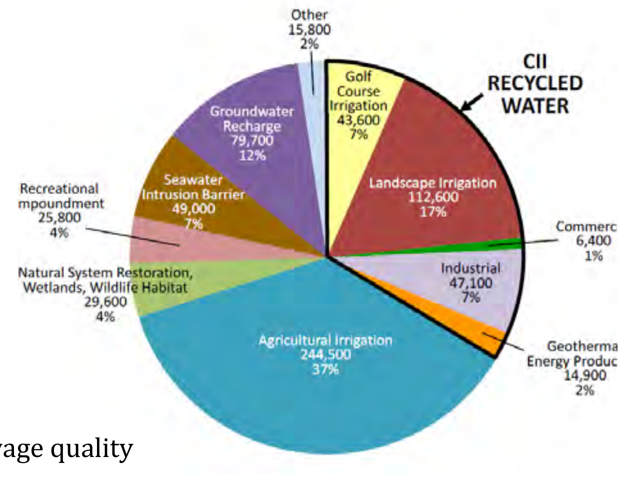
Another regulatory/policy consideration is to allow groundwater basins – or portions of groundwater basins – to degrade programmatically. CV-SALTS, in collaboration with the TLDD and TLBWSD, is currently supporting a project intended to de-designate MUN and AGR from a portion of the Tulare Lakebed because it can serve as an appropriate archetype or template for studies in which the purpose is to evaluate the appropriateness of the MUN and other beneficial uses on a designated groundwater body. Moreover, the outcome of the de-designation effort can help advance the purpose and requirements associated with the development of the SNMP for the Central Valley region in that it may provide a template that can be utilized to identify areas that may serve as salt sinks until alternate treatment, disposal and/or export alternatives are developed.

CV-SALTS is evaluating appropriate designation and level of protection for water bodies currently designated with the MUN beneficial use, taking into account the requirements of the Sources of Drinking Water Policy (88-63). An example of an area where MUN (and AGR) beneficial uses are being considered for de-designation is a portion of the Tulare Lake Bed. As discussed in Section 2.2, salt is allowed to accumulate in the Tulare Lake Bed and groundwater in the area considered for de-designation would not be extracted and treated. (See Figure 2-20). However, salt accumulated in the Tulare Lake Bed would be accounted for as part of the overall mass of salt that would be managed as part of the SSALTS conceptual plan.

Source Control Measures: Municipal

Description

Municipal recycled water is beneficial for numerous industries, however the quality of the recycled water is greatly affected by the quality of the source of potable water supply and the pollutants added to the water during use before wastewater is discharged to wastewater collection systems. Source control issues include:



- Inflow and infiltration - Sewage quality can be deteriorated through infiltration into the sewer system.
- Source Water - High salinity water supply sources can contribute to higher salinity. This is particularly true for the use of high TDS groundwater.
- Water Softeners - Home-based water softeners may introduce additional salts.

Constituent Salts or Nutrients Managed

Salts and other chemical not removed by conventional secondary and tertiary treatment processes.

Applicability

Proper construction and maintenance of sewers can reduce the impacts of infiltration. Good quality surface water instead of high TDS groundwater sources may be seasonal or unavailable during drought conditions. AB 1366 (2009,

CWC §13148) allows local jurisdictions to regulate home self-regenerating water softeners.

Practice Benefits and Impacts

Effectiveness

Significant salinity reduction from the regulation of water softeners has not been

Documentation	documented.
Supporting Documentation	Salinity in the Central Valley (May 2006) Commercial, Industrial, and Institutional Task Forces Water Use Best Management Practices Report to the Legislature Volume II (Sep. 2013)
Implementation: Planning Level Costs	
Implementation: Status and Potential	
Implementation: Monitoring Documentation	
Implementation: Other Regulatory Approvals or Requirements	
Website:	http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/centralvalley_salinity_alternatives_archives/initial_development/swrcb_02may06_ovrvw_rpt.pdf

Source Control Measures: Agriculture	
Description	Reducing the amount of water used in agricultural activities that mobilizes salts in soils and imports salt from supply water will prevent its transport and accumulation. This involves water audits, land retirement, integrated on-farm drainage management (IFDM), and evaporation ponds.
Constituent Salts or Nutrients Managed	Water reuse would manage salts, but other constituents may be managed, including selenium and boron.
Applicability	Drainage management relies on the availability of salt-tolerant plants for salt-laden water to be reused. Land area is also needed for ponds as well as continued monitoring.
Practice Benefits and Impacts	Water audits do not require additional equipment and is a low cost, low maintenance practice that encourages awareness. The increased awareness tends to translate into reduction in water usage. IFDM and land retirement will result in less water used by respectively reusing drainage water and eliminating areas that require irrigation. Land retirement has been less implemented, thus Reclamation may still be conducting studies of the cost of land retirement with habitat restoration. IFDM typically ends with the use of a solar evaporator for salt disposal, which is expensive and not particularly suitable for larger scale sites. The organization has reported that without restoration, other problems arise after retirement and then requires significant maintenance. In methods such as evaporation, the brine cake still requires disposal, which is difficult and expensive. Additionally, land is required for shallow ponds used in evaporation.
Effectiveness Documentation	
Supporting Documentation	Salinity in the Central Valley (May 2006)
Implementation: Planning Level Costs	
Implementation: Status and Potential	While IFDM and land retirement have been implemented in the California Central Valley, it has been done so in less frequency than other options, such as evaporation ponds. These ponds are a more typical BMP utilized to address salinity problems. However, with further studies and regulations for IFDM and land requirement, they may become more widespread management practices for agricultural activities.
Implementation: Monitoring Documentation	
Implementation: Other Regulatory Approvals or	Disposal of salt brine and cakes will require permitting. Drainage water reuse per IFDM may require additional regulatory requirements to protect against degradation.

Requirements	
Website:	http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/centralvalley_salinity_alternatives_archives/initial_development/swrcb_02may06_ovrvw_rpt.pdf

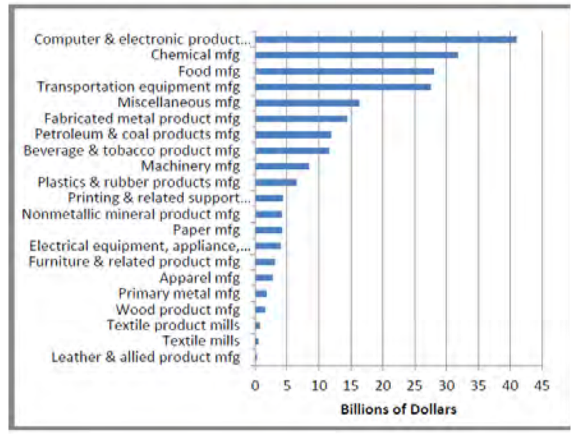
Source Control Measures: Food Processing Industry

Description	According to CLFP, approximately 70% of process/rinse water from the food processing industry is used for land treatment and reuse most of which contain solids, salts, and other minerals. Source control attempts to reduce the amount of salt prior to disposal or treatment with methods including:  • Product substitution for cleaning and pealing processes and soft water alternatives • Steam cleaning • Good housekeeping practices • Water conservation
Constituent Salts or Nutrients Managed	Source control and pretreatment would manage predominantly salts but other constituents may be affected by product substitution.
Applicability	Product substitution of sodium-based cleaners for potassium based cleaners may be slightly more expensive. Steam cleaning as opposed to wet washing foods uses greater amount of electricity but if used for short periods of time it could offset the costs of pumping and treating process water, however the quality of the food end product must be considered. Housekeeping practices such as dry sweeping rather than wet rinses can be inexpensive means of reducing waste products.
Practice Benefits and Impacts	Cleaners • Replace salt-containing cleaners or oxidizers with ones that contain less salt. • Change the type of salt used in cleaners as waste water from sodium-based cleaners can lead to high concentrations of salt in groundwater and is unfavorable for most crops however potassium based cleaners can be beneficial to crops by adding nutrients that can be taken up by plants and bacteria. • Substitution of chlorinated cleaning solutions for peracetic acid or ozone. Peracetic acid not only reduces the amount of salt but its use also impedes the formation of trihalomethanes (THMs), a potentially carcinogenic byproduct of chlorination in the presence of organic substances. Ozone oxidizes and disassociates without leaving any salt contribution. • Hot water cleaning and steam cleaning eliminates the byproduct of salt however, safety precautions must be considered. Peeling • Steam peeling tomatoes is a preferred method over caustic peeling to reduce sodium concentrations. • Product replacement for peeling can also reduce sodium effluent. Replacing sodium hydroxide with potassium hydroxide for peeling operations can improve crop

Source Control Measures: Food Processing Industry	
	production as potassium is a nutrient for both bacteria and plants. Water conservation • Dry sweeping, flow-reducing devices, timers, and automatic shut off valves decreases the amount of waste water but creates a more concentrated waste brine. However, recovery and/or treatment processes may be more efficient when using more highly concentrated water and in turn may reduce treatment costs. Water Softening • Water softening is a common practice and the replacement of sodium chloride with potassium chloride can reduce the amount of salts.
Effectiveness Documentation	Product substitution for cleaners and peeling operations (potassium vs. sodium, steaming vs. caustic peeling) not only reduces salt at the source but can also be beneficial to crop production. Dry sweeping, as opposed to wet rinse, during housekeeping can limit the amount of sodium introduced unnecessarily. Modifying processes through maintenance or optimization can minimize waste produced, which in turn can minimize the amount of process water as well as salt in the process water.
Supporting Documentation	Manual of Good Practice for Land Application of Food Processing/Rinse Water prepared for California League of Food Processors (2007) Comprehensive Guide to Sustainable Management of Winery Water and Associated Energy, Kennedy/Jenks Consultants (2008)
Implementation: Planning Level Costs	Product substitution of potassium over sodium is a primary material cost. Potassium hydroxide can be up to 3 times the price of sodium hydroxide.
Implementation: Status and Potential	The Wine Institute has documented the preferred methods of cleaning in the Manual of Good Practice for Land Application of Food Processing.
Implementation: Monitoring Documentation	Not available at this point.
Implementation: Other Regulatory Approvals or Requirements	Not available at this point.
Website:	http://clfp.com/documents/Manualofgoodpractice/CLFP%20Manual_COMPLETE_FINAL_3-14-07%20(2).pdf

Source Control Measures: Food Processing Industry	
	http://www.wineinstitute.org/initiatives/sustainablewinegrowing

<table>
<tr><th colspan="2">Source Control Measures: Other Industries</th></tr>
<tr><td>Description</td><td>
California industries add significant economic benefits to the state however most produce some amount of wastewater that add salt and other constituents into the environment. The amount and type of wastewater produced from industries varies greatly by sector but one of the most efficient source controls is minimizing the amount of water produced. Five best management practices described in CII Task Force Volume II include:



Value Added by Sector in California - 2009

- Adjustment of equipment and repair of leaks
- Equipment modification or installation of water saving devices and controls
- Replacement with more efficient equipment
- Alternative water supplies and internal recycling
- Change to waterless process
</td></tr>
<tr><td>Constituent Salts or Nutrients Managed</td><td>Reducing water production may help manage salts and other depending on the industrial sector.</td></tr>
<tr><td>Applicability</td><td>The applicability of these practices can range from simple and inexpensive repairs and replacements (less than $100 to replace more efficient pre-rinse spray valves) to major infrastructure changes (greater than $ 1million for tunnel washing machines). Using alternative water sources include using treated municipal wastewater, harvesting rain or storm water and air conditioning condensate recovery however practices like harvesting rain water may be inconsistent or may not produce sufficient amounts in times of droughts. Waterless processes such as thermodynamic for air cooling and dry vacuum pumps in laboratories and medical facilities may be industry specific and costly to implement.</td></tr>
<tr><td>Practice Benefits and Impacts</td><td>Repairs and adjustments to equipment are generally inexpensive and will immediately reduce the amount of water being wasted. Equipment modifications and replacements can have upfront capital cost but generally result in long term water, energy, and cost savings.</td></tr>
<tr><td>Effectiveness Documentation</td><td>CII Task Force Volume II identifies BMP per sector and also breaks down costs and benefits of implementing BMP.</td></tr>
<tr><td>Supporting Documentation</td><td>Commercial, Industrial, and Institutional Task Forces Water Use Best Management Practices Report to the Legislature Volume II (Sep. 2013)</td></tr>
<tr><td>Implementation: Planning Level</td><td>The following should be taken into consideration when determining the implementations of BMP:</td></tr>
</table>

Costs	• Capital costs of installation is equipment is required • Changes in operation and maintenance cost including changes in water, wastewater, energy, waste disposal, pre-treatment, chemical, and labor costs • Expected lifetime of measure • Reducing Risk Factors
Implementation: Status and Potential	Repairs, modifications, and replacements can be done in any size industry and have been well documented in its potential.
Implementation: Monitoring Documentation	
Implementation: Other Regulatory Approvals or Requirements	
Website:	

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Section 4
Desalination and Brine Minimization Technologies

4.1 Mature Treatment Technologies

Desalination technologies commonly used these days can be largely divided into two categories: membrane based technologies and thermal technologies. The membrane based technologies includes Reverse Osmosis (RO) and Electrodialysis Reversal (EDR). RO is generally the most widely used process to reduce dissolved solids from many different sources of water. In the RO process, water from a pressurized saline solution is separated from the dissolved salts by a semi-permeable membrane. The water is forced to flow through the semi-permeable membrane by the pressure differential created between the pressurized feed water and the product water. RO is well verified in the field with numerous applications installed and operating for many years throughout the world and it would be largely applicable to reduce TDS from the degraded source waters in the Central Valley. RO treatment capacity is easily scalable with modular system design from less than 1 mgd to more than 100 mgd. RO can achieve more than 95 percent salt reduction. However, RO has limited recovery of 85 to 90 percent in typical brackish water applications and handling of the RO brine generated with 10 to 15 percent of feed volume is the critical issue to deal with for the implementation of RO. Capital and operational costs of RO vary largely by the locations and feed water characteristics but as a rule of thumb RO costs approximately $2 to 4 per gal per day for the capital facilities. Electrical power is the major portion of the operational cost with total operational cost estimated at approximately $0.5 per acre-ft treated based on $0.12 per kilowatt hour (kWh) power cost. RO facility costs for low and high recovery and for low and high TDS in feed water are shown in Figure 4-1. Two stage RO is more expensive, but produces a higher concentration of brine (say up to 90 to 92 percent) by adding second pass RO.

In this section as well as Sections 5 and 6, general cost information is presented that provides order–of-magnitude level estimates of both capital and operation and maintenance costs to the extent available. The order-of-magnitude unit capital cost factors are intended to be inclusive of all project implementation costs including planning, engineering and contingencies. They also are meant to represent current (2014) conditions. This information is then used later in Section 7 to help provide high-level comparisons among various alternatives as discussed in that section.

Thermal desalination technologies include thermal evaporation and crystallization among other technologies. The thermal processes can typically achieve much higher recovery than reverse osmosis and generate highly purified water. However the thermal processes are energy intensive and have very high operational costs. The operational cost of thermal evaporation processes is more than 4 to 5 times higher per acre-foot than the cost of membrane based processes. The thermal processes also require high capital cost mainly due to the exotic materials they need to utilize to handle highly saturated salt solutions. Hence the thermal processes are not feasible for high volume, low cost application to reduce TDS. They are more suitable for reducing the volume of the brine generated from RO or other desalination process used to reduce the volume of the brine coming out of the pre-treatment processes such as RO. A thermal evaporator is very effective at reducing brine solutions to highly concentrated levels. Typically brine TDS levels as high as 250,000 mg/L are achievable with a recovery of 90 to 98 percent. The thermal evaporator combined with the crystallizer has been used in a few projects to achieve a Zero Liquid Discharge (ZLD) system. The crystallizer is particularly applicable where solar evaporation pond construction is not feasible due to a high construction cost, a low evaporation rate or a limited space and where deep-well injection is geologically not feasible and there are no other viable options for brine disposal.

4.2 Emerging Treatment Technologies

Mature desalination technologies such as RO and EDR have worked well in various applications. However the technologies produce significant volumes of brine waste with normal operation recoveries for single pass systems of 85 to 90 percent. Other new desalination technologies which claims that they can be operated at much higher recovery and reduce the volume of the brine with the cost less than or comparable to the matured technologies.

Forward Osmosis (FO) technology relies on the osmosis phenomena of a semi-permeable membrane, similar to reverse osmosis, to effectively separate water and dissolved solutes. The driving force for this separation is an osmotic pressure gradient. In contrast, the reverse osmosis process uses hydraulic pressure as the driving force for separation. The FO process is less susceptible to the membrane fouling which is the main factor that limits the RO process efficiency. It is also reported that the FO can be operated with feed water whose TDS is more than 10 times of the RO feed water and this can significantly reduce the volume of the brine coming out of the process. The brine from the FO can be directly sent to the crystallizer to realize the ZLD system.

Membrane Distillation (MD) is a low-temperature separation technology that takes place through the pores of a hydrophobic microporous membrane. The driving force for separation is a vapor pressure gradient, which is generated by facilitating a temperature differential across the membrane. MD could theoretically be used to reduce TDS from the degraded water sources. However considering the high cost in general for the system construction and operation compared to the RO process, MD may be more suitable for minimization of the brine from the front end process (such as RO and EDR). Using RO brine as a feed to MD has a great potential for MD utilization. This directly addresses the upper feedwater concentration limit of RO at around 70,000 mg/L, as MD is far less influenced by the salt concentration. MD can be competing technology for the brine reduction such as the thermal evaporator. Even though MD technology has been around for 40 years, both MD and RO are relatively new for the brine reduction applications and the costs of the technologies cannot be verified due to the limited numbers of full scale implementations.

There are other proprietary technologies which can be potentially utilized for desalination or brine reduction in the Central Valley. These are mostly combinations of the existing processes targeting a higher recovery or savings in operational and/or capital costs. The Zero Discharge Distillation (ZDD) from Veolia Water utilizes electrodialysis metathesis to exchange scale forming ions in a brine solution for sodium and chloride. This process is used in conjunction with nanofiltration and reverses osmosis to increase total recovery and has the potential, under certain circumstances, to achieve up to 97 percent water recovery. The Aqua4 System from Water FX is a distillation process incorporating solar thermal power generation to remove all non-volatile materials from water. The process requires a large area of solar collectors to treat the water. It can also be combined with a crystallization and drying process to achieve a ZLD system. Sulfate-based electrolysis processing with flexible feed control is a process developed by New Sky Energy that uses electrochemical technology to treat the brine waste and produce valuable chemical products for sale. However, a mixed salt stream from a water treatment facility or from agricultural drainage containing varied dissolved salts would require many purification steps to produce usable salts or chemical products that would likely increase the cost of the process significantly.

Most of these proprietary technologies are relatively new. Even if they were tested in a pilot scale or small scale projects, they have limited references in the large scale plants which make it difficult to validate the technology and estimate associated costs.

4.3 Concept Level Capital Cost Estimate for Salinity Treatment

A concept-level cost estimate was developed for SSALTS Phase 2 based on estimated flow requirements (Table 4-1) and the following parameters:

Middle and Southern Central Valley IAZs

- The feed water volume is taken from Table 2-3. Accumulation of salt on the Tulare Lake Bed from IAZ was assumed to continue to occur and no wells were assumed for this loading.
- Extraction would occur from shallow groundwater, perched water, and agricultural drain water. An assumed average extraction rate of 750 gpm was used to estimate the number of extraction facilities (extraction wells, drain water sump pumps, etc.). About 693 facilities would be required.
- A unit cost of $1.4 per extraction facility was used – this accounts for the installation of the extraction facility, as well as the appurtenant engineering and conveyance facilities (pumps, pipelines, etc.) to take the extracted water from the facility to the desalter facilities.
- Thirty-three 25-MGD desalter facilities (total capacity – 825 MGD) would be required to treat the requisite extracted groundwater, perched water, and agricultural drain water.
- Each modular 25-MGD desalter facilities is estimated to cost $150M based on high TDS and high recovery. The basis for design and the unit cost estimate for the treatment facility of $6/gpd include an assumption of 90% recovery, and the brine and product water TDS would vary depending upon the source water TDS in each subarea. The cost estimates also include an allowance for up to five miles of 12-inch diameter brine pipeline from each desalter to tie into a regional brine line.
- The treatment facilities would be located near the CVBL, so there would be minimal conveyance facilities to transport the brine from the desalter to the CVBL.
- The estimated concept-level capital cost for extraction facilities at full build-out would be $970M and the concept-level cost estimate for the desalters would be $4950M. Operation and maintenance costs are discussed in Section 7. Potential revenue from beneficial uses of product water is also discussed in Section 7.

IAZ 6

- The feed water volume is taken from Table 2-3.
- Extraction would occur from shallow groundwater, perched water, and agricultural drain water. An assumed average extraction rate of 750 gpm was used to estimate the number of extraction facilities (extraction wells, drain water sump pumps, etc.). About 155 facilities would be required.
- A unit cost of $1.4 per extraction facility was used – this accounts for the installation of the extraction facility, as well as the appurtenant engineering and conveyance facilities (pumps, pipelines, etc.) to take the extracted water from the facility to the desalter facilities.
- Seven 25-MGD desalter facilities would be required to treat the requisite extracted groundwater, perched water, and agricultural drain water.

- Each modular 25-MGD desalter facilities is estimated to cost $150M based on high TDS and high recovery. The basis for design and the unit cost estimate for the treatment facility of $6/gpd include an assumption of 90% recovery, and the brine and product water TDS would vary depending upon the source water TDS in each subarea. The cost estimates also include an allowance for up to five miles of 12 inch diameter brine pipeline from each desalter to transport brine to deep injection well sites.
- Eighteen deep well injection facilities at $7.6M would be required to dispose of the 17.5 MGD of brine concentrate produced for a total of $137M.

The estimated concept-level capital cost for extraction facilities at full build-out would be $217M and the concept-level cost estimate for the desalters would be $1050M. Operation and maintenance costs are discussed in Section 7. Potential revenue from beneficial uses of product water is also discussed in Section 7.

Table 4-1 Concept Level Capital Cost Estimate for RO Treatment Facilities and Extraction Facilities – Southern and Middle Central Valley IAZs

IAZ	Volume of Water to be Pumped and Treated		No of 25 MGD Modules	No. of Wells/Drain Water Sump Pump Facilities	Cost of RO Treament Facilities	Cost of Wells/Drain Water Sump Pump Facilities
	(MGD)	(gpm)			($ x Million)	($ x Million)
21	128.3	89,118	6	119	$900	166
19	86.5	60,059	4	80	$600	112
15	104.1	72,321	5	96	$750	135
14	148.8	103,347	6	138	$900	193
22	100.0	69,430	4	93	$600	130
10	106.6	74,043	5	99	$750	138
9	74.3	51,589	3	69	$450	96
Totals	**748.7**	**519,907**	**33**	**693**	**$4,950**	**$970**

Table 4-2 Concept Level Capital Cost Estimate for RO Treatment Facilities and Extraction Facilities – IAZ 6

IAZ	Volume of Water to be Pumped and Treated		No of 25 MGD Modules	No. of Wells/Drain Water Sump Pump Facilities	Cost of RO Treament Facilities	Cost of Wells/Drain Water Sump Pump Facilities
	(MGD)	(gpm)			($ x Million)	($ x Million)
6	167.5	116,340	7	155	$1,050	217
Totals	**167.5**	**116,340**	**7**	**155**	**$1,050**	**$217**

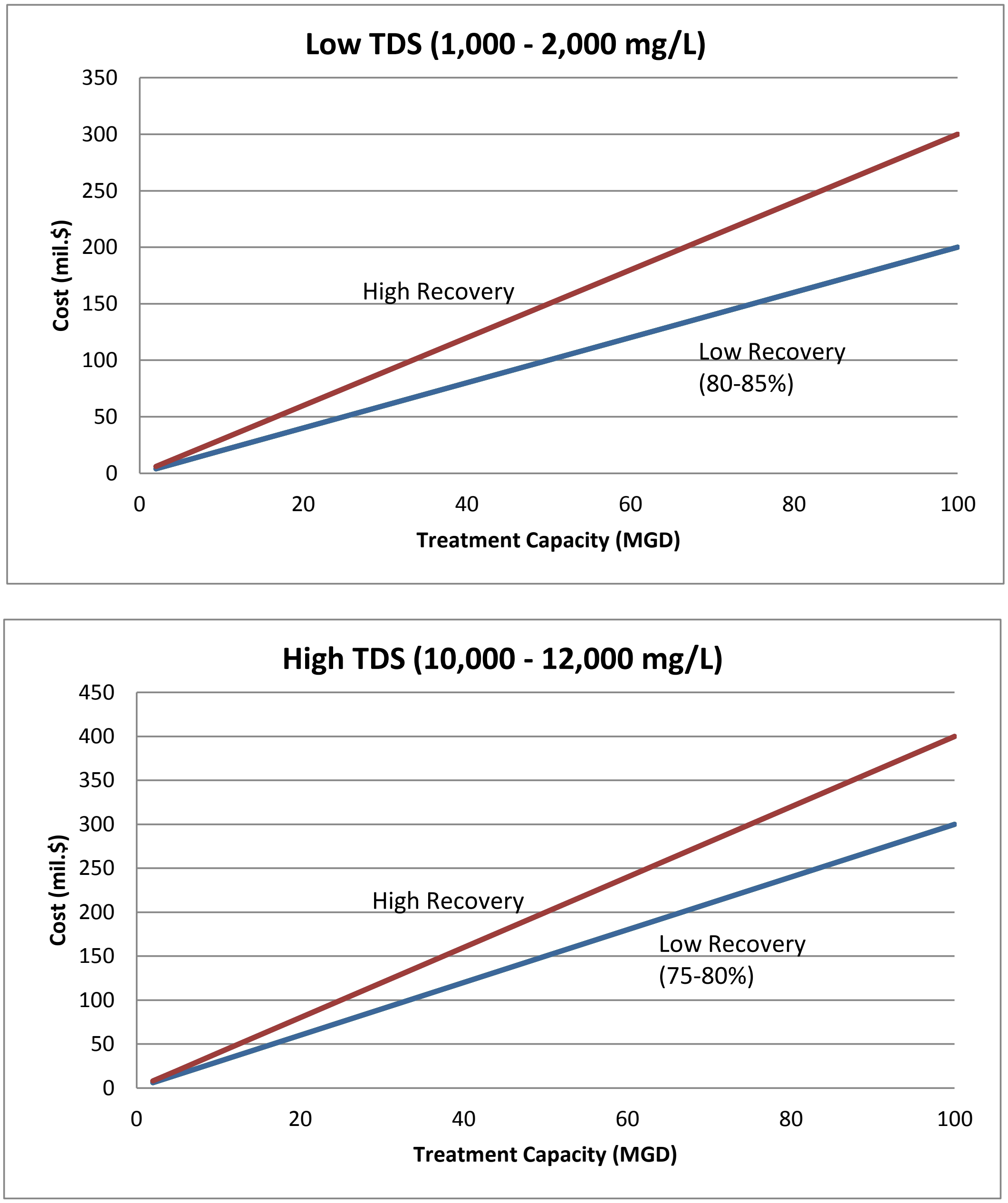
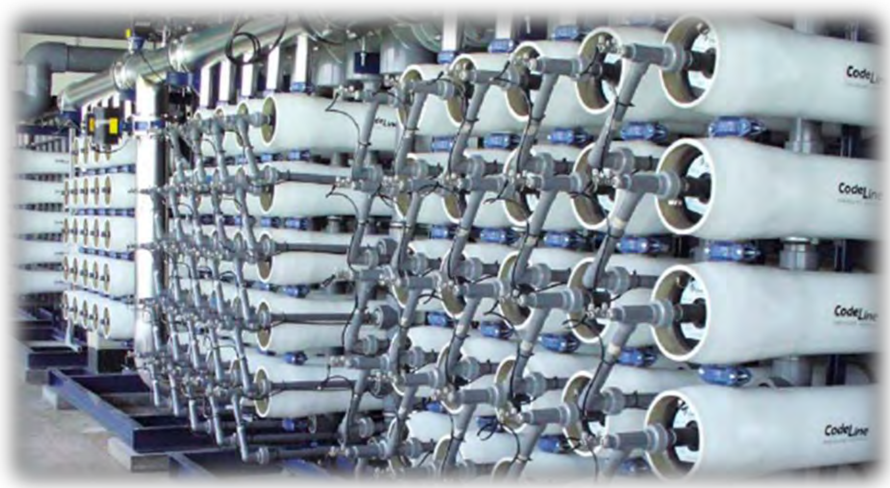
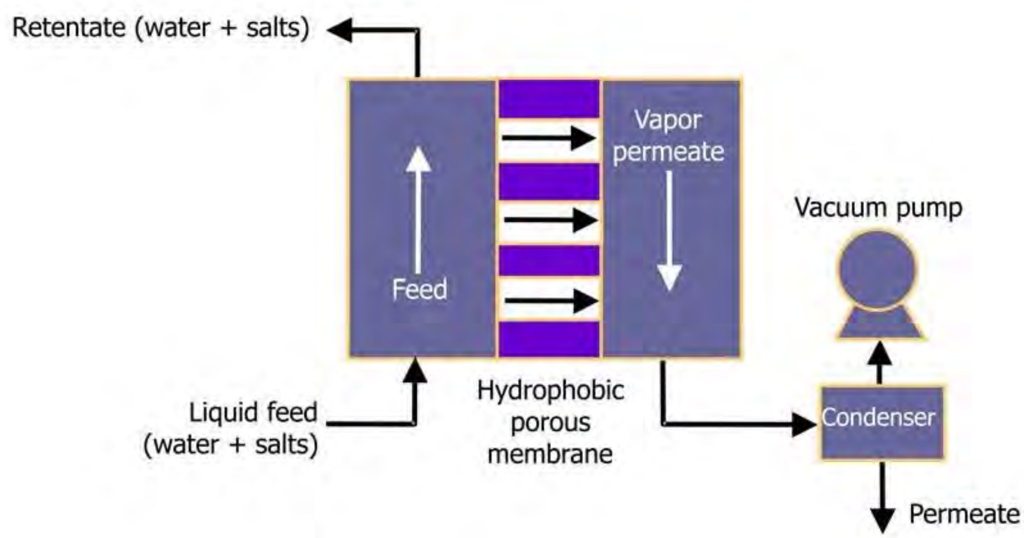


Figure 4-1 RO Facility Costs for Low and High Recovery and for Low and High TDS in Feed Water

Reverse Osmosis Membrane (RO) Technology	
Description	Reverse Osmosis (RO) is one of the most popular and widely adopted technologies to reduce dissolved solids. It is also well proven in the field. Since the first prototype test of the technology in 1950's, numerous plants utilizing the RO technology have been built throughout the world. The technology has been mostly used for brackish water desalination, sea water desalination and wastewater reuse.  In the RO process, water from a pressurized saline solution is separated from the dissolved salts by a semi-permeable membrane. The water is forced to flow through the semi-permeable membrane by the pressure differential created between the pressurized feed water and the product water, which is at near-atmospheric pressure. The remaining feed water concentrated at the pressurized side of the membrane forms brine. The major energy requirement in the RO process is for the initial pressurization of the feed water. Typical operation pressures for brackish water desalination ranges from 250 to 400 psi, and for seawater desalination from 800 to 1 000 psi.
Constituent Salts or Nutrients Managed	The RO technology can effectively remove salts, hardness, synthetic organic compounds, and disinfection-byproduct precursors. However, dissolved gases such as hydrogen sulfide (H_2S) and carbon dioxide, and some low molecular weight organics can pass through RO membranes.
Applicability	The RO technology is largely applicable to reduce TDS from the degraded source waters in the Central Valley. The technology is easily scalable with the modular system design from less than 1 mgd to more than 100 mgd treatment capacity.
Practice Benefits and Impacts	Many engineering companies and utilities have good understanding and experiences of the RO technology. It can be widely applied to the Central Valley and provide a great help to reduce the TDS from the degraded source waters. Minimization and management of the brine is key issue of the implementation of the RO technology. The typical RO system recovery is ranged at 85 to 90 percent. However, depending on the feed water quality, more than 95 percent of the recovery can be achieved with the proper pretreatment

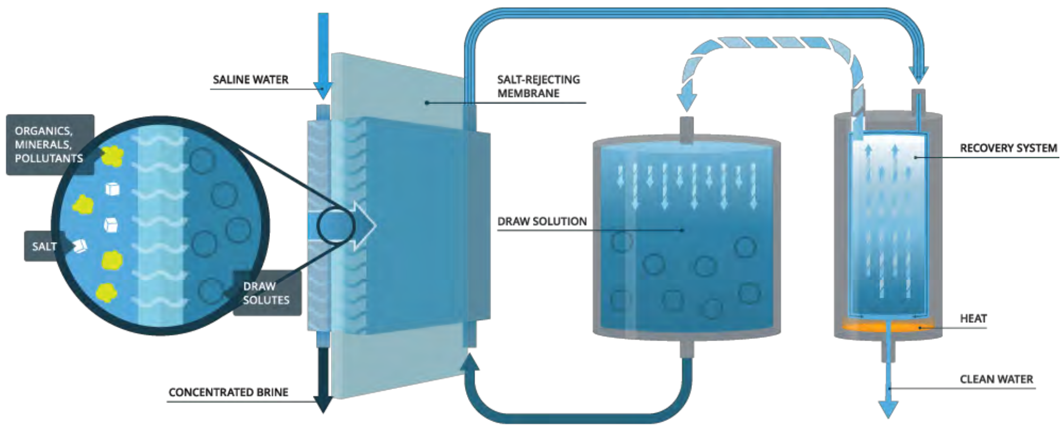
Reverse Osmosis Membrane (RO) Technology	
	processes. Hence handling of the RO brine generated with 5 to 15 percent of feed volume is the critical issue of implementation of the RO technology. For the purposes of developing planning level costs a recovery of 90% is assumed.
Effectiveness Documentation	The effectiveness and limitations of the RO technology are well documented.
Supporting Documentation	Filmtec Reverse Osmosis Membrane Technical Manual, Dow Chemical, 2013 http://www.gewater.com/handbook/ext_treatment/ch_9_membrane.jsp Reverse Osmosis and Nanofiltration, AWWA, 2007
Implementation: Planning Level Costs	As most of the treatment processes, the project cost largely varies location by location. With a large number of implementation, however, the cost of the RO system is relatively well understood. In California it is estimated that the construction cost would be in a range of $2-4 per gal per day of capacity depending on the site location and feed water quality. The high end of the range is used for the cost estimates developed. . Since the typical RO system has a modular design, it can be considered that the construction cost proportionally increases as the size of the RO plant increases. The cost estimates also include an allowance for up to five miles of 12 inch dia. brine pipeline from each desalter to tie into a regional brine line. The power cost is the biggest portion of the total operation cost. Based on $0.12/kWh power cost, the operation cost for the RO system is estimated to be approximately $0.5/acre-ft.
Implementation: Status and Potential	It is widely implemented throughout the world and also here in California. It is reported that currently Desalination provides California with 50,000 acre-feet (AF) annually, or ten percent of California's water needs and 85 percent of California's desalination facilities are reverse osmosis plants. With the urbanization and the scarcity of the clean source water along with the global climate change, the potential use of the RO technology will greatly increase.
Implementation: Monitoring Documentation	
Implementation: Other Regulatory Approvals or Requirements	With typical recovery of 85 to 90 percent in the brackish water desalination, 10 to 15 percent of the feed volume is generated as the high TDS brine waste. Management of the RO brine is a critical permitting issue in addition to the permits related to environmental impacts and construction and operation permits which are typically required for the site development and construction.
Website:	http://www.dowwaterandprocess.com/en/products/reverse_osmosis_and_nanofiltration http://www.toraywater.com/ http://www.gewater.com/products/spiral-wound-membranes.html

Membrane Distillation (MD)	
Description	MD is a low-temperature separation technology that takes place through the pores of a hydrophobic microporous membrane. The driving force for separation is a vapor pressure gradient, which is generated by facilitating a temperature differential across the membrane. The volatile components of a heated-feed solution evaporate and pass through the pores to condense in a cold distillate stream on the permeate side. 
Constituent Salts or Nutrients Managed	Typically, the process is used to separate volatile solutes such as volatile organic compounds (VOCs) from aqueous solutions. However, for aqueous feeds with nonvolatile solutes, only the volatile solvent (water) passes through the membranes; and the distillate is comprised of demineralized water. Fundamental criteria for MD are that the membrane must not be wetted and only vapor and non-condensable gases can be present within its pores. MD has demonstrated excellent ability to retain nonvolatile solutes and generate a nearly pure demineralized stream.
Applicability	MD might be used to reduce TDS from the degraded water sources in the Central Valley. However considering the high cost in general for the system construction and operation compared to the RO process, MD might be more suitable for minimization of the brine from the front end process (such as RO and EDR) or ZLD.
Practice Benefits and Impacts	Since the cost of MD is largely affected by the thermal energy cost, MD can be cost effective technology when the low cost waste heat such as dairy waste is available. MD can handle TDS much higher than what RO can handle.
Effectiveness Documentation	Using RO brine as a feed to MD has a great potential for MD utilization. This directly addresses the upper concentration limit of RO at around 70,000 mg/L, as MD is far less influenced by salt concentration. Typically, the need for an RO-MD process to increase water recovery is for inland applications where disposal of the brine is an issue as the Central Valley. Testing of MD on RO groundwater concentrates revealed that the concept

Membrane Distillation (MD)	
	is indeed viable, but suffers from practical issues such as scaling on MD membranes. A similar result was found for an RO-MD trial on a solar powered direct contact MD system in rural Victoria, Australia. Membrane scaling led to flux declines, but flux was easily restored using an acid clean. Scaling was found to be effectively managed by cleaning or the addition of anti-scalant. For the RO-MD process, the individual RO recovery was 89 percent, and MD recovery was 80 percent, giving a total water recover of 98 percent for the combined system
Supporting Documentation	Walton, J.; Lu, H.; Turner, C.; Solis, S.; Hein, H. Solar and Waste Heat Desalination by Membrane Distillation; Desalination and Water Purification Research and Development Program Report No. 81; Bureau of Reclamation: Denver, CO, USA, 2004. Martinetti, C.R.; Childress, A.E.; Cath, T.Y. High recovery of concentrated RO brines using forward osmosis and membrane distillation. J. Membr. Sci. 2009, 331, 31–39.
Implementation: Planning Level Costs	Since MD is heavily relying on the thermal energy, availability of thermal energy source is the main factor which affects the operation cost of MD. A study developed a cost estimate for MD as a function of thermal energy. Assuming that the cost of thermal energy was $0.01/kWh, the researcher calculated the total cost for MD to be $0.815/m3, which is equivalent to RO. And the study concluded that MD is competitive to RO when low cost heat energy is available and when the water chemistry of the source water is too difficult for treatment with RO. The production cost of small desalination plants with a production capacity of <20 m3/d powered by renewable energy sources such as solar, photovoltaic collectors or wind turbines, are reported in the range of $1.5–$18/m3.
Implementation: Status and Potential	MD technology has been around for 40 years, has been the subject of numerous academic studies, but has yet to see commercial use. Primary limitations to commercial application are lower flux compared to more conventional membrane separation technologies and the lack of membranes optimized for MD processes. In addition, while it is capable of treating many kinds of water, its ability to compete with established technologies such as RO, ED, MED and MSF is currently limited due to its high energy use. Consequently it is likely to find application where current established technologies are unable to operate or in applications that substantially favor its use. For instance, the treatment of brine streams that reverse osmosis finds difficult to treat may be a possible application, and integration of MD with RO to treat RO brine may be a suitable application where brine disposal is problematic. The recent resurgence of interest in MD may be attributed largely to the opportunity it presents to achieve ZLD.
Implementation: Monitoring Documentation	Not available at this point.
Implementation: Other Regulatory Approvals or Requirements	Assuming MD's application for ZLD, permitting related to the environmental impact of the waste discharge can be minimal since no waste discharge is expected.

Membrane Distillation (MD)	
Website:	http://www.memsys.eu/

Forward Osmosis (FO)

Description	Forward osmosis (FO) is a process to reduce TDS. Since the FO can handle much higher feed TDS than the conventional RO system the FO process further can be used to minimize the brine. The FO relies on the osmosis phenomena of a semi-permeable membrane, similar to reverse osmosis, to effectively separate water and dissolved solutes. The driving force for this separation is an osmotic pressure gradient. A high concentration draw solution relative to that of the feed solution is used to induce a net flow of water through the membrane from the feed water to the draw solution, thus effectively separating the feed water from the solutes in the feed water. In contrast, the reverse osmosis process uses hydraulic pressure as the driving force for separation, which serves to counteract the osmotic pressure gradient that would otherwise favor water flux from the permeate to the feed. 
Constituent Salts or Nutrients Managed	The biggest difference between the RO and the FO is driving forces for the water and dissolved solids separation. However, since the FO process uses the mostly same membranes with the RO process, similar level of the dissolved solid removal is expected. FO can effectively remove salts, hardness, synthetic organic compounds, and disinfection-byproduct precursors. However, dissolved gases such as hydrogen sulfide (H_2S) and carbon dioxide, and some low molecular weight organics can pass through the membranes.
Applicability	The FO technology is applicable to reduce TDS from the degraded source waters in the Central Valley. With an effective scaling control, it can be also used to further minimize the RO brine. However, in contrast to the RO the technology it is still in its early stage of the commercialization and the full scale treatment process is not well verified and established in the field.
Practice Benefits and Impacts	Compared to the conventional RO, the FO can be operated with lower electrical power. Since the power cost takes the biggest portion of the operation cost for the RO process, it might be able to reduce the operation cost for the TDS reduction. The FO process is less susceptible to the membrane fouling which is the main factor to drop the RO process

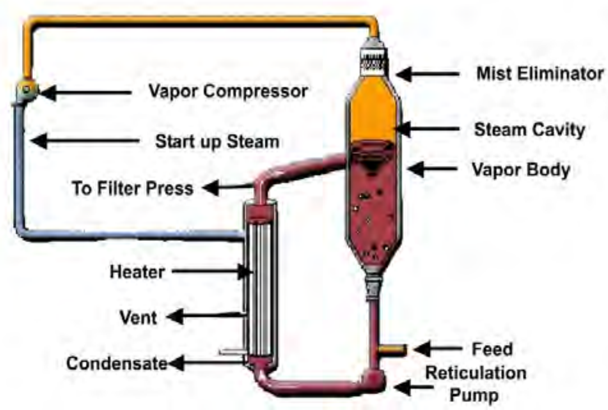
Forward Osmosis (FO)	
	efficiency. It is also reported that the FO can be operated with the feed water whose TDS is more than 10 times of the RO feed water and this can significantly reduce the volume of the brine coming out of the process.
Effectiveness Documentation	Its effectiveness in the laboratory scale research is well documented by Dr. Menachem Elimelech in Yale University and Dr. Amy Childress in University of Nevada Reno among others. However, information on the effectiveness of the technology in the full scale plant is limited. Boston based Oasys Water recently completed a successful pilot test for shale gas produced water treatment to handle raw water with the average salinity of 73,000 ppm TDS which is roughly 10 percent higher than RO brine and the system could produce water that meets EPA drinking water standards, below 500 ppm TDS. The company reports that they will dispatch the first full scale unit for the brine concentration for the oil and gas industry. San Francisco based Porifera reports that they have successfully performed several pilot tests for water and wastewater treatments. Another FO technology provider, Modern Water in United Kingdom, has demonstrated successful performance of the FO system for seawater desalination in Oman since 2008. It is reported that the system could continuously produce water with less than 200 mg/L TDS.
Supporting Documentation	Cath, T.Y., A.E. Childress, M. Elimelech, Forward osmosis: Principles, applications, and recent developments, Journal of Membrane Science, 281 (2006) 70-87. Zhao, L. Zou, C.Y. Tang, D. Mulcahy, Recent developments in forward osmosis: Opportunities and challenges, Journal of Membrane Science, 396 (2012) 1-21.
Implementation: Planning Level Costs	Not much information available regarding the cost to implement the FO technology to the full scale systems. One of the FO technology provider, Oasys Water claims the FO would cost 35 percent less than the thermal evaporator for the brine concentration. However the claim cannot be verified due to the lack of the full scale implementations. In Modern Water's sea water desalination demonstration plant in Oman it is observed that electric cost is about 60 percent of the RO based sea water desalination plant.
Implementation: Status and Potential	The FO is still under the early stage of the full scale implementation. One of the leading FO technology providers, Oasys Water announced last January that they will deploy the first full scale FO unit, a movable unit that can treat and desalinate up to 4000 barrels of produced water per day (630 m3/day) to provide fresh water for beneficial reuse in early summer 2014. Modern Water in United Kingdom has operated a 100 m^3/d (26,420 GPD) FO system to produce potable water in Al Khaluf, Oman, since late 2008. It was also invited to participate in a competitive tender for a second seawater project at Al Najdah, Oman, and was awarded a 200 m^3/d (52,840 GPD) seawater system that has been operating successfully for almost one year. As gaining more operation experiences it is expected that the FO technology will be able to expand the market further.
Implementation: Monitoring Documentation	Not available at this point.

Forward Osmosis (FO)	
Implementation: Other Regulatory Approvals or Requirements	Even though the FO technology providers claim that the system can achieve a recovery higher than the RO, the FO process will still generate significant volume of high TDS brine. Management of the RO brine is a critical permitting issue in addition to the permits related to environmental impacts and construction and operation permits which are typically required for the site development and construction.
Website:	http://oasyswater.com http://www.htiwater.com/technology/forward_osmosis/ http://porifera.com/ http://www.modernwater.com/

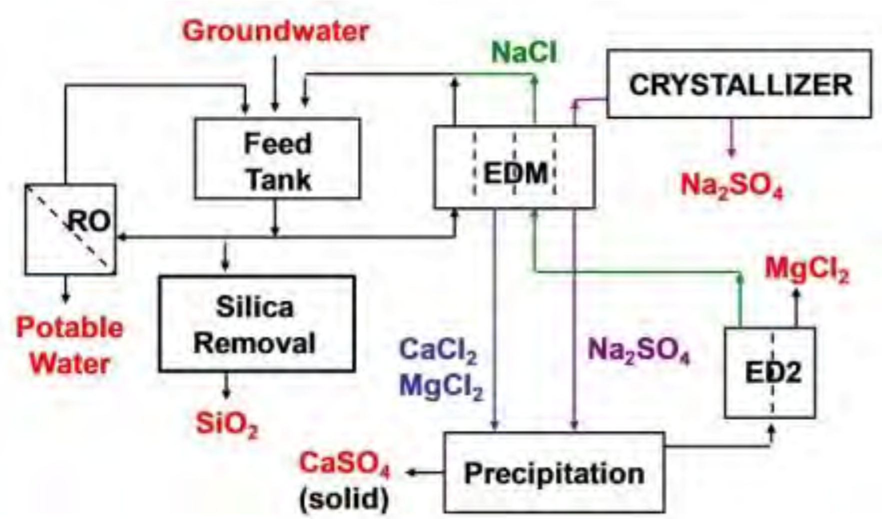
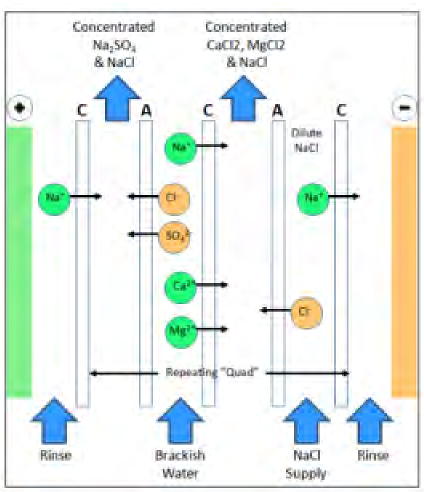
Thermal Evaporator	
Description	Thermal and thermo/mechanical brine concentrators utilize energy to evaporate additional water from the previous TDS reduction process such as RO and EDR. The preferred evaporator design is Mechanical Vapor Recompression (MVR). MVR is a highly efficient process using mechanical energy input to achieve evaporation and condensation. In vapor compression the latent heat of vaporization is fully utilized. The evaporator serves as the condenser. The evaporated vapor flows through a mist eliminator to the suction of the compressor. The compression process produces superheated discharge vapors. The compressed vapors flow to the heating side of the evaporator and as the vapor condenses, it transfers the latent heat of vaporization back to the liquid film on the tube side of the liquid. MVR will reduce the amount of steam required in evaporation and also minimized the need for cooling water. Most thermal evaporators work on single-effect configuration, while they can have multiple stages to increase the overall efficiency and economy of the treatment system.
Constituent Salts or Nutrients Managed	Since the thermal evaporator evaporates water from the concentrated salt solution using the thermal energy, it is possible to obtain high purity distilled water. Most of the solids will be remaining in the brine and the brine solution will be further concentrated. As the result the brine from the thermal evaporator contains higher concentration of the salts.
Applicability	The thermal evaporator combined with the crystallizer has been widely used to provide a ZLD system. Thermal evaporator alone can be also used to reduce the volume of the brine coming out of the pre-treatment processes such as RO, EDR and FO.
Practice Benefits and Impacts	The thermal evaporator is very effective at reducing brine solutions to highly concentrated levels. Typically brine TDS levels as high as 250,000 mg/L are achievable with a recovery of 90 to 98 percent. The process can be effectively used to reduce the volume of the RO concentrate. It also has an advantage of producing additional water from the RO, EDR concentrate stream and reducing the volume of the brine waste. The resultant concentrated brine stream can be sent to a crystallizer for further volume reduction or ZLD.
Effectiveness Documentation	The thermal evaporator has been widely used in various industries; pulp and paper, salt, chemical processing, oil and gas, biofuels, and power generation, and limited municipalities. Its effectiveness is well documented.
Supporting Documentation	
Implementation: Planning Level Costs	The costs for the thermal evaporator are largely determined by the flow rate rather than the feed water quality. The reject brine from the evaporator tends to be very corrosive and requires the evaporators be constructed of very durable and high- quality materials such as high-grade stainless steel and titanium. These costly materials drive up the capital cost of concentrators. A large industrial facility with a traditional wastewater treatment system costing approximately $20 million can recover and reuse up to 80 percent of its liquid waste streams. The 1,000 GPM evaporator and crystallizer system to

Thermal Evaporator	
	capture the last 20 percent can, however, double that cost. The thermal evaporator also has a high operational cost. A desalination plant might use 2-4 kWh/m3, but the thermal evaporator system uses more than 10 timed of the energy (20-40 kWh/m3). As a result, very few municipalities, which generally have high wastewater flows with low TDS concentrations, use ZLD unless forced to by unusual circumstances.
Implementation: Status and Potential	Thermal evaporation technology such as evaporator and crystallizer is relatively well established with a long history of industrial application. However it is not until recently they have been started to be considered as a candidate process for the inland desalination. There are thousands of thermal evaporator thermal systems in use around the world, serving a wide variety of sectors. Chemical plants use them to make chloride for feedstock in the plastics industry. The food and beverage industry produces powdered coffee and milk. But relatively few of these systems are used purely as ZLD systems, in which the purpose is to recover and reuse as much water as possible. Although dozens of regional companies supply various components for evaporation and crystallization, the market is dominated by three major players: Aquatech, GE Power and Water, and HPD, a subsidiary of Veolia. Among them HPD is the largest evaporation and crystallization company in the world and they have close to 700 systems in many different sectors: pulp and paper, salt, chemical processing, oil and gas, biofuels, and power generation. In the Central Valley where groundwater has TDS concentrations of 2,500-15,000 mg/L, a desalting plant can produce a waste brine stream with an approximate TDS concentration of 80,000 mg/L. With the high level of the salt in the brine, environmentally acceptable brine disposal can be a critical issue. Despite the high capital and operation costs, the thermal evaporator can be a good alternative to reduce the amount of the brine in the Central Valley which has the limited options for the brine disposal.
Implementation: Monitoring Documentation	
Implementation: Other Regulatory Approvals or Requirements	Even if it would be a smaller amount than RO, the thermal evaporator process will generate a brine waste. Management of the brine is a critical permitting issue in addition to the permits related to environmental impacts in addition to construction and operation permits which are typically required for the site development and construction. However, if the thermal evaporator is used in conjunction with a crystallizer for ZLD, permits related to the environmental impact of the waste discharge can be minimal since no waste discharge is expected.
Website:	

Crystallizer

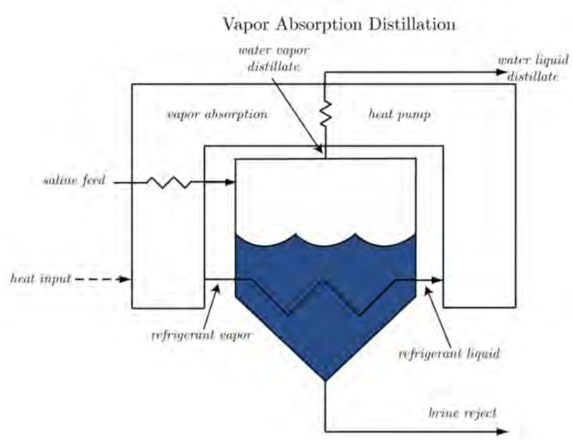
Description	The Crystallizer is mostly used for Zero Liquid Discharge (ZLD) in conjunction with the thermal evaporator. The concentrated brine from the previous process salt reduction process such as RO, EDR enters the crystallizer through a heat exchanger. Heat would be transferred from the distillate leaving the crystallizer to the concentrated brine which raises brine temperature to near boiling. The hot concentrated brine enters the crystallizer chamber. Heat transfers from the superheated steam in the crystallizer to the concentrated brine and vaporize a portion of the concentrate brine. The remaining liquid falls back into the crystallizer sump to be recirculated back to the top. The vapor is drawn off and sent to a compressor where it would be compressed beyond its vapor pressure, creating super-heated steam. This steam would then be sent through the tubes inside the crystallizer chamber. The process would generate a small condensate stream that could be recycled back to the primary RO feed. Solids and crystals would be periodically removed from the crystallizer for offsite disposal. 
Constituent Salts or Nutrients Managed	Since the crystallizer evaporates water from the concentrated salt solution using the thermal energy, it is possible to obtain high purity distilled water separated from the bulk brine. Most of the solids will be remaining in the brine and the brine solution will be further concentrated to be crystallized.
Applicability	For RO concentrate disposal, crystallizers are normally operated in conjunction with a thermal evaporator to reduce the brine concentrator blowdown and achieve a ZLD system. Crystallizers can be used to concentrate RO reject directly, but their capital cost and energy usage is much higher than for a brine concentrator of equivalent capacity. Crystallizers used for brine disposal range in capacity from about 2 to 50 gpm. These units have vertical cylindrical vessels with heat input from vapor compressors or an available steam supply. For small systems in the range of 2 to 6 gpm, steam-driven crystallizers are more economical. For larger systems, electrically driven vapor compressors are normally used to supply heat for evaporation.
Practice Benefits and Impacts	Crystallizer technology is especially applicable in areas where solar evaporation pond construction cost is high; solar evaporation rates are low; and where deep-well injection is costly, geologically not feasible, or not permitted. The crystallizer converts the

Crystallizer	
	remaining waste to water that is clean enough for reuse in the plant and solids that are suitable for landfill disposal.
Effectiveness Documentation	The effectiveness and limitations of the crystallizer technology is well documented.
Supporting Documentation	
Implementation: Planning Level Costs	Due to the extremely high salt concentration of the solution in the crystallizer, the crystallizer requires special alloys which significantly increases the capital cost. The choice of materials will depend on the concentration of constituents in the solution, their scaling and corrosive properties as well as heat transfer characteristics. The materials of construction of crystallizers include 254SMO, AL6XN, CD4MCu, Hastelloy C, and titanium.
Implementation: Status and Potential	Crystallizer technology has been used for many years to concentrate feed streams in industrial processes. More recently, as the need to concentrate wastewater has increased, this technology has been applied to reject from desalination processes, such as brine concentrate evaporators, to reduce wastewater to a transportable solid.
Implementation: Monitoring Documentation	
Implementation: Other Regulatory Approvals or Requirements	Since crystallizer will be mostly used for ZLD, permitting related to the environmental impact of the waste discharge can be minimal since no waste discharge is expected.
Website:	

<table>
<tr><th colspan="2">Zero Discharge Distillation (ZDD)</th></tr>
<tr><td>Description</td><td>The ZDD process utilizes electrodialysis metathesis to exchange scale forming ions in a brine solution for sodium and chloride. This process is used in conjunction with nanofiltration and reverses osmosis to increase total recovery and has the potential, under certain circumstances, to achieve up to 97 percent water recovery.

</td></tr>
<tr><td>Constituent Salts or Nutrients Managed</td><td>This process will remove all ions from the source water and replace them with sodium and chloride. The main difference between this process and conventional electrodialysis is that this process uses an additional type of ion exchange membrane which facilitates the recovery of mixed cation and chloride and mixed anions with sodium, both of which are highly soluble. The treated brine is mainly sodium and chloride, which can be treated by RO to produce additional freshwater. Brine from the secondary RO process can be used as the sodium chloride feed to EDM system.

</td></tr>
</table>

<table>
<tr><th colspan="2">Zero Discharge Distillation (ZDD)</th></tr>
<tr><td>Applicability</td><td>This process is mainly applicable to brines containing sparingly soluble salts that will decrease the recovery potential of nanofiltration or reverse osmosis and projects where ocean disposal is not possible or practical.</td></tr>
<tr><td>Practice Benefits and Impacts</td><td>Water Recoveries of up to 97percent
May be combined with salt recovery technologies to generate reusable salts
Can also include additional membrane for silica removal
Applicable to inland groundwater treatment
Can be retrofitted to RO easily</td></tr>
<tr><td>Effectiveness Documentation</td><td>Some performance data is available in the Veolia ZDD brochure.
Performance Data
<table>
<tr><th></th><th>Source Water</th><th>NF Permeate</th><th>EDM Feed</th><th>EDM Diluate</th><th>Mixed Chloride Salts</th><th>Mixed Sodium Salts</th></tr>
<tr><td>Ca, mg/l</td><td>250</td><td>19</td><td>380</td><td>160</td><td>17,000</td><td>690</td></tr>
<tr><td>Mg, mg/l</td><td>94</td><td>7.5</td><td>190</td><td>86</td><td>7,400</td><td>220</td></tr>
<tr><td>Na, mg/l</td><td>370</td><td>150</td><td>580</td><td>350</td><td>21,000</td><td>27,000</td></tr>
<tr><td>SO_4, mg/l</td><td>1,300</td><td>9.5</td><td>2,600</td><td>1,300</td><td>1,600</td><td>25,000</td></tr>
<tr><td>Cl, mg/l</td><td>290</td><td>260</td><td>140</td><td>100</td><td>89,000</td><td>14,000</td></tr>
<tr><td>F, mg/l</td><td>1.7</td><td>0.86</td><td>1.8</td><td>0.82</td><td>ND</td><td>72</td></tr>
<tr><td>SiO_2, mg/l</td><td>24</td><td>23</td><td>33</td><td>33</td><td>5.7</td><td>37</td></tr>
<tr><td>TDS, mg/l</td><td>2,300</td><td>471</td><td>3,840</td><td>1,940</td><td>133,000</td><td>100,000</td></tr>
</table></td></tr>
<tr><td>Supporting Documentation</td><td>US Patent #: 7,083,730

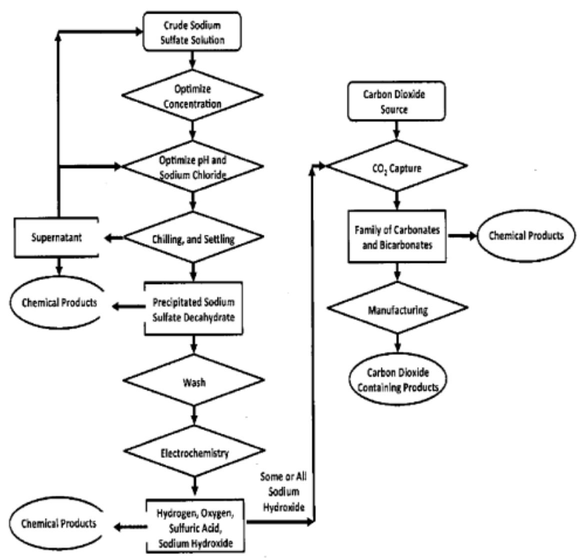
US Patent # 7,459,088</td></tr>
<tr><td>Implementation: Planning Level Costs</td><td>None yet.</td></tr>
<tr><td>Implementation: Status and Potential</td><td>No major implementation to date. Several small pilots have been conducted including a USBR funded product at the Brackish Groundwater National Desalination Research Facility.</td></tr>
<tr><td>Implementation: Monitoring Documentation</td><td>None yet.</td></tr>
<tr><td>Implementation: Other Regulatory Approvals or Requirements</td><td>None yet.</td></tr>
<tr><td>Website:</td><td>http://www.veoliawaterst.com/zero_discharge_desalination/en/</td></tr>
</table>

WaterFX – Aqua4 System	
Description	The Aqua4 system consists of a concentrated solar still incorporating solar thermal power generation and energy storage. It works by recirculating a solar heated refrigerant through the still inside a closed loop. 
Constituent Salts or Nutrients Managed	Distillation processes remove all non-volatile materials from water. This includes all the constituents of interest in the Central Valley.
Applicability	This technology is applicable to brines generated by drinking water treatment processes. Requires 1 acre of solar collector units per 200 AF of water production per year. It can also be combined with a proprietary integrated crystallization and drying process to reach ZLD.

WaterFX – Aqua4 System	
Practice Benefits and Impacts	▪ If not combined with crystallization process, some amount of concentrated brine will be produced. ▪ Claims to use half the energy of other thermal methods and be 30 times faster. ▪ Claims to have 75 percent lower costs compared to reverse osmosis. ▪ Stripping is required to remove volatile constituents, if present. ▪ Uses solar energy  
Effectiveness Documentation	None at this time. Current form of technology is 200kW pilot system which can produce 6 gpm. Claims that a commercial unit of same size would produce 24 gpm. Currently building a 1400 gpm system.
Supporting Documentation	None at this time. Expect to produce a peer reviewed article in three months.
Implementation: Planning Level Costs	The company is structured as an owner-operator to provide services to customers needing water treatment. Operating costs are projected to be around $450/AF ($0.36/m3) in CA at scale.
Implementation: Status and Potential	Technology is currently at pilot scale and will be conducting pilot in the Panoche Water District.
Implementation: Monitoring Documentation	None at this time.
Implementation: Other Regulatory Approvals or Requirements	None at this time

WaterFX – Aqua4 System	
Website:	http://waterfx.co/

<table>
<tr><th colspan="2">Sulfate-Based Electrolysis Processing with Flexible Feed Control</th></tr>
<tr><td>Description</td><td>New Sky Energy uses electrochemical technologies and temperature control to separate dissolved salts, precipitate sodium sulfate, generate usable chemical products, and sequester atmospheric carbon dioxide.</td></tr>
<tr><td>Constituent Salts or Nutrients Managed</td><td>This technology is mainly focused on precipitating sodium sulfate and using it to produce acids, bases, and carbonates. The input water must contain 5 percent (w/v) sodium sulfate. It is chilled to induce spontaneous precipitation of (99.5 percent pure) sodium sulfate. The crystallized sodium sulfate is then dissolved and treated by electrodialysis to produce hydrogen and oxygen gas, sulfuric acid, and sodium hydroxide. Some or all of the sodium hydroxide can be reacted with atmospheric carbon dioxide to produce sodium carbonate. No treatment process is described for the supernatant.


</td></tr>
<tr><td>Applicability</td><td>This technology has good potential for onsite treatment of waste streams from industries that also have waste heat that can be used in the treatment process to reduce energy inputs. Industries may also be able to utilize the acid and base products generated by the process. A mixed salt stream from a water treatment facility or from agricultural drainage containing varied dissolved salts would require many purification steps to produce usable salts or chemical products that would likely increase the cost of the process significantly. Ion exchange has been suggested as a means for purifying the brine prior to processing, but there was not mention of the effect of reduced affinities due to increased ionic strength or brine disposal.</td></tr>
<tr><td>Practice Benefits and Impacts</td><td>No cost estimates have been provided by New Sky Energy.</td></tr>
<tr><td>Effectiveness Documentation</td><td>New Sky Energy has not provided any third party reports of pilot projects or installations to support their claims. They do a patent entitled US 2014/0010743 A1 – Sulfate-based Electrolysis Processing with Flexible Feed Control, and Use to Capture Carbon Dioxide.</td></tr>
</table>

Sulfate-Based Electrolysis Processing with Flexible Feed Control	
Supporting Documentation	Patent: US 2014/0010743
Implementation: Planning Level Costs	No costs have been provided but the technologies cited in the patent include electrolysis, electrodialysis, and temperature control which all require energy. However, these inputs have not been quantified.
Implementation: Status and Potential	No full scale implementations to date. Major development needed.
Implementation: Monitoring Documentation	None
Implementation: Other Regulatory Approvals or Requirements	None
Website:	http://www.newskyenergy.com/

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Section 5
Brine Storage, Disposal, and Use Options

For any of the options that produce a brine stream the concentrated brine or salt residue must either be disposed of, stored, or possibly reused. This section provides a summary of the potential options with a brief introduction for each and a Fact Sheet that summarizes the key information needed to begin evaluating the options.

5.1 Deep Well Injection

Under this approach, brine from reverse osmosis treatment (or other concentration processes) of groundwater would be injected into and stored in deeper aquifers isolated from the primary drinking water aquifers for disposal or storage and future recovery. Details of this approach are provided in the Fact Sheet at the end of this subsection. As discussed in the Fact Sheet, for preliminary planning purposes it is assumed that a single deep injection well could inject a minimum of 0.2 mgd, and if constructed in favorable locations and depths of formations, up to 0.5 mgd.

As shown in Table 5-1, the mass of salt that could be removed through storage in deep aquifers under this approach would range from about 4-10 tons/yr per well assuming a brine concentration of 13,333 mg/L. It is difficult to project the maximum potential capacity of brine volume and therefore salt mass that could be stored in deep formations throughout the Central Valley, although it could theoretically be large and is not limited to areas where oil and gas exploration is occurring as is the case for the following option. However, assuming well capacity is limited to the range noted above, it would require from 2-5 wells to inject and store 1 mgd of brine. A set of hypothetical assumptions was used to develop order-of-magnitude unit costs. Assuming a desalter was constructed to treat 10 mgd of brackish groundwater that would result in approximately 1.5 mgd of brine produced. Using an estimate of 0.5 mgd/well, this would require three injection wells, assumed to be 4,000 feet deep. It is also assumed that the wells could be constructed within two miles of the desalter. The facilities that would be required would include a pump station, approximately two miles of delivery pipelines and three wells plus well head facilities. Estimated capital costs for a cluster of three wells plus piping and appurtenances would be approximately $7.6M including engineering and contingencies to serve a 10 mgd desalter. Of this cost, approximately 60% represents the cost of drilling the wells and the remainder is for well head facilities, piping and a pump station. Operating costs would include the delivery pump station power and maintenance and replacement costs, injection pumping power and well operation and maintenance costs. Assuming that annual operating costs would be approximately 10 percent of the capital cost, this would result in annual operating costs for the same facilities of approximately $600,000.

Injection wells can have useful lives of 40 years or longer if properly maintained. That said, there needs to be an on-going and regular program of maintenance and periodic rehabilitation, and careful thought must be given to the materials of construction, design issues, and brine quality to minimize fouling or mechanical plugging."

5.2 Supply for Hydraulic Fracturing

Under this approach, brine from reverse osmosis (or other concentration processes) treatment of groundwater would be delivered to users in the oil and gas industry for use in hydraulic fracturing. This is a type of "completion" technique where high pressure water, sand, and chemicals are injected usually thousands of feet below the surface into low permeability rock to create microscopic fractures that allow oil and natural gas trapped in small pores to migrate to the wellbore and be produced. Details of this approach are provided in the following fact sheet. Although there has been extensive drilling and well development throughout the Central Valley over many years, as shown in Figure 5-1, this option would only be feasible in the foreseeable future for brine produced from desalting systems in the southern central valley as the Monterrey Shale formation shown in Figure 5-2 is the predominant area where current industry exploration and development efforts are focused. Figure 5-3 illustrates the location of the Oil and Gas Wells that have been hydraulically fractured in the Central Valley.

As discussed in the Fact Sheet at the end of this subsection, for preliminary planning purposes it is assumed that each well developed by the oil and gas industry would require a one-time use of between 80,000 and 300,000 gal over a period of 1 to 2 days. Assuming an industry-projected drilling rate of about 700 wells per year, and assuming drilling goes on essentially at a consistent rate over the year, this would effectively result in annual for demand for brine of between 172 and 644 AFY, or average flow rate of between 0.15 and 0.58 mgd.

As shown in Table 5-2, the mass of salt that could be removed through storage in deep aquifers under this approach would range from about 14,000 to 52,000 tons/yr assuming a brine concentration of 59,000 mg/L which reflects the higher brine concentrations estimated from desalting in the southern IAZs that coincide with the industry needs. As noted in the table, this represents a small fraction of the total salt inflow to these zones. Potential revenue from the sale of brine for hydraulic fracturing is presented in Table 5-3.

5.3 San Joaquin River Real-Time Management

The RTMP is an umbrella program to optimize/maximize the export of salt from groundwater, perched zones, and agricultural drain water from the Lower San Joaquin River (LSJR) Basin while ensuring that salinity and boron water quality objectives are met at Vernalis, and that that future salinity and boron objectives are achieved in the Lower San Joaquin River upstream of Vernalis to the mouth of the Merced River (Reach 83). The CVRWQCB has approved RTMP in the Basin Plan as an alternative salt management strategy in lieu of monthly salt load allocations enforced by the CVRWQCB.

The Vernalis objectives for EC are 30-day moving averages: 700 micro Siemens per centimeter (μS/cm) during the irrigation season (April to August) and 1000 μS/cm during the non-irrigation season (September to March). According to the RTMP Draft Framework (Reclamation *et al.*, 2014), *"The goal under a real-time management program is to continue to meet the irrigation and nonirrigation season salinity water quality objectives by managing salt loads so they are discharged when there is assimilative capacity in the river, rather than be constrained by mandated monthly load allocations in WDR's. Managing the use of assimilative capacity is also anticipated to reduce reliance on fresh water releases from New Melones Reservoir to meet the salinity objectives at Vernalis and to provide a mechanism to maximize salt exports from the SJR Basin."* The RTMP components include:

- Stakeholder participation
- Real time monitoring network
- Data Management
- Predictive modeling/forecasting of flows and salinity in the river in order to predict assimilative capacity
- Physical infrastructure (gates, inlets, rubber dams, *etc.*)

- Program and project management practices
- Funding

In 1995, prior to the implementation of the Grasslands By-Pass (GBP) project, the salt load to the LSJR was 237,530 tons. Through the San Joaquin River Water Quality Improvement Project (SJRIP), discussed in Section 5.4.1, there has been a steady reduction in the salt load to the LSJR (Figure 5-4). In 2013, the salt load was approximately 54,574 tons, a 77 percent reduction (Grassland Area Farmers, 2013). Salt load is a function of discharges to the river and there is a general correlation of increased salt load in wetter years.[4] Overall, there is still a trend of decreasing salt load. The objective is to reach near zero discharge of salt and selenium by 2019.

In Phase 2 of SSALTS, a calculation was performed to determine what the salt export capacity of the LSJR could be if the RTMP could optimize salt loads based on assimilative capacity. Tables 5-4 and 5-5 show the monthly discharge and EC of the San Joaquin River near Vernalis, CA (USGS Gaging Station 11303500) for an approximately 50 year period from1963 to 2014. The monthly average values of discharge and EC are summarized in Table 5-6 and Figure 5-6. In the draft Phase 2 SSALTS report, a calculation of average hydrologic year assimilative capacity and additional salt loads was developed. This estimate includes discharges of high quality (low TDS) water from the New Melones Reservoir. The Lower San Joaquin River Committee is currently developing estimates of assimilative capacity[5]. As part of the Development of a Basin Plan Amendment for Salt and Boron in the Lower San Joaquin River, the LWA team is collaborating with the San Joaquin Tributaries Authority to determine the effects of Stanislaus and Vernalis operations on water quality at Vernalis under various upstream management alternatives. The operation effects will be determined by updating and utilizing the New Melones Operation Model which uses river conditions upstream of Vernalis and a depiction of Stanislaus and Vernalis operations to provide flow and water quality conditions in the lower San Joaquin River at Vernalis. Based on flow and water quality conditions in the lower San Joaquin River at Vernalis, the NM model can be used to assess assimilative capacity. This information will be analyzed as part of Phase 3 SSALTS, and in anticipation of this new information the assimilative capacity analysis that included New Melones discharges has been removed from Table 5-6.

5.4 Salt Accumulation Areas/Landfilling

The San Joaquin River Water Quality Improvement Project (SJRIP) and the Tulare Lake Bed are two of the larger salt accumulation areas in the Central Valley and serve as archetypes for that disposal/storage option. Salt is formed from solar evaporators at the Tulare Lake Bed and accumulates on the land surface. The SJRIP sequesters salt in the perched zone underlying the approximate 6000-acre project area.

5.4.1 SJRIP

The SJRIP is a three phased project (see the fact sheet at the end of this section):

- Phase 1: Purchase land/grow salt-tolerant crops
- Phase 2: Install tile drains and collection system/begin initial treatment

[4] Compare Tables 5-4 and 5-5. The latter table presents the Palmer Drought Severity Index (PDSI) for the middle Central Valley area over the same period as Table 5-4.
[5] LWA. 2014. Meeting notes from an August 25, 2014 conference call for the Development of a BPA For Salt and Boron in LSJR

- Phase 3: Develop the full project treatment system and a salt disposal system

The SJRIP regional reuse facility will – at full project build out – utilize about at least 25 percent of the total drain water produced in the Grasslands Drainage Area (GDA) – about 15,000 acre-feet per year (AFY) of drain water at an approximate TDS concentration of 5000 mg/L. Salt-tolerant crops, like Jose Tall Wheatgrass, are grown in the SJRIP area, which ultimately will consist of up to 6200 acres of fields, irrigation channels, drainage ditches, conveyance facilities and farm structure. The eastern project area is comprised of 3873 acres (out of about 4000) planted with salt-tolerant crop species. The western project area consists of 1901 acres that have been purchased, but have not yet been planted with salt-tolerant crops. The Panoche Drainage District has been the lead CEQA agency for the SJRIP. Approximately 2000 acres of the SJRIP is tiled, some of which has operated since 2002.

The principal benefit of this approach is that it is a viable means of accumulation of salt in a relatively small lowland area. SJRIP at a minimum would receive 25 percent of all drain water from the GDA, or about 15,000 AFY. Based on recent years' experience, however, the SJRIP has SJRIP has displaced more than 20,000 acre feet since 2011 (26,170 acre feet of drain water was displaced in 2013), or about one-third of the drainage production. At full build-out, the average reuse capacity of the SJRIP is likely to be between 25,000 and 30,000 AFY or possibly more. The GDA drain water, which has a current average TDS of about 3,500 to 4,000 mg/L is retained on-site and is not allowed to discharge to the San Luis Drain and Mud Slough through the Grassland Bypass and ultimately to the San Joaquin River, thus helping to meet the compliance objective at Vernalis. The average TDS of drain water at the discharge from the San Luis Drain at Site B is 3300 mg/L (2005-2013)

Water is managed in the SJRIP by the planting and harvesting of salt-tolerant crops. While the plants take up some salt from the root zone, they consume water which allows the project to function. Since the crops consume water – but not much salt – an estimate was made of the increase in salinity in the perched zone over time in order to ascertain the sustainability of the SJRIP. The annual additional salt load to the SJRIP perched zone would be about 102,000 tons, based on an assumed 15,000 AF of GDA drain water[6] at an estimated TDS of 5000 mg/L[7] (Table 5-7). The volume of perched water was also estimated, based on an assumed area of 6000 acres and a perched water depth of 40 feet[2].

Until Phases 2 and 3 are implemented salt is projected to accumulate in the shallow perched zone underlying the SJRIP area. It should be noted that although the readings vary significantly, none of the existing sumps show a clear upward trend in drain water EC measurements over that last six years. While this short term trend is of interest, it is not realistic to assume this trend can continue indefinitely as continued addition of salts must eventually result in increased storage in the groundwater and/or an increase in the salt exported via the drain water. Table 5-8 shows the salinity increases over a 25-year period in which 102,000 tons of salt are added to the SJRIP area, the water is managed by growing and harvesting salt-tolerant crops, and salt is successfully sequestered at the project site and not allowed to leave the system via the San Luis Drain, Mud Slough, and the San Joaquin River. Calculations of salt applied through the drain water in the last 2 years are around 118,000 tons per year, although this is based on a higher application volume than the report assumes. After 25 years, the TDS concentration in the perched zone is estimated to be greater than 60,000 mg/L, and may have deleterious effects on soil structure and plant growth. This assumes the following:

- 15,000 AF of GDA drain water added to SJRIP area annually

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[6] H. T. Harvey & Associates. 2012

[7] Personal Communication, Joe McGahan, June 27, 2014

- assumed area of 6000 acres
- estimated TDS of 5000 mg/L
- perched water depth of 40 feet
- no salt is leached below the perched zone
- significant mass of salt are not harvested by the crops

However, as noted in the previous paragraph, although the EC measurements vary significantly, none of the existing sumps show a clear upward trend in drain water EC measurements over that last six years.

Phases 2 and 3 include treatment of the drain water to remove salt, selenium, and boron and to "dispose of the removed elements to prevent discharge into the San Joaquin River. The remaining salt will be deposited into approved waste units that will result in additional reductions in salt and selenium discharges into the San Joaquin River and will maximize improvement in water-quality and meet reductions needed for future water-quality objectives." (Harvey & Associates, 2012). Pilot tests are being conducted to determine the efficacy of certain treatment technologies. These pilot tests include those led by Reclamation (US Bureau of Reclamation, 2011), UC Los Angeles[8], and WaterFX[9]. The objectives of these pilot plants is to demonstrate and operate the treatment systems (RO and selenium biotreatment for the Reclamation pilot project) in order to develop cost and performance data for the final design.

If the treatment process(es) produce a dried salt product, the volume would be between 88,000 and 180,000 cubic yards each year (Table 5-9). Since it is difficult to estimate the detailed composition of the salt a range of the bulk densities was used.[10] This volume of salt would need to be trucked to "approved waste units." The landfill costs at Kettlemen Hills are $30/ton for the disposal fee, $1.40/ton for California recycling fees, and a 13 percent charge for environmental and permitting for a total of $35.30/ton. This would result in an annual disposal cost of $3.6M. Waste Management also provided an estimate of costs for landfilling including transportation (Appendix A). The combined landfill and transportation costs are $75.25 per ton, with $1.40/ton for California recycling fees, and a 13 percent charge for environmental and permitting for a total of $86.43/ton. This would result in an annual disposal cost of $8.8M.

Costs for the continued operation and expansion of SJRIP, including engineering, building and maintaining irrigation facilities, building and maintaining drains, treatment system costs (capital and operations and maintenance [O&M]), NEPA/CEQA, and compliance monitoring have not yet been determined by Reclamation.

5.4.2 Tulare Lake Bed

The Tulare Lake Bed is located within the Tulare Lake Basin within the southern portion of the San Joaquin Valley. The Tulare Lake Basin, comprising approximately 10.5 million acres, is a mixture of federally owned National Parks, agricultural land, and municipalities. The Basin is essentially a closed system, draining only into the San Joaquin River in extreme wet years.

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[8] http://newsroom.ucla.edu/stories/ucla-engineering-s-mobile-plant-hits-the-road-to-treat-polluted-water
[9] http://waterfx.co/news/press-releases/
[10] http://www.hapman.com/resources/bulk-material-density-guide

Underlying the majority of western and southern Tulare Lake Basin is the impermeable Corcoran Clay, the primary of several clay layers, which separates the groundwater into a perched groundwater table and a deeper groundwater table. The perched groundwater table can be encountered as soon as 5 feet below ground surface. It is estimated that the EC of this shallow groundwater is in the range of 5,000 to more than 35,000 µS/cm (TLBWSD, 2012).

The high salinity in the groundwater is a result of several factors. Since this a closed basin with negligible surface or groundwater discharges, salts accumulate in the perched groundwater beneath the lake basin. In the past 40+ years, application of state project water for irrigation has added salts to the basin, but the historic salt levels in the soils prior to agricultural development are the primary problem. This is why the Westside soils of the Central Valley have higher saline levels than the soils on the East side. This situation was created over thousands of years and without a drainage outlet salts continued to build up within the Tulare Lake Bed. With no drainage out of the Tulare Lake Basin, agricultural operations in the lakebed have constructed a drainage collection system with evaporation basins for the accumulation of salts rather than allowing the salts to continue to increase in the groundwater.

With no drain outlet readily available for the lakebed, stakeholders (through the Tulare Lake Drainage District [TLDD]) have constructed and operated a drainage system with three evaporation basins (North Evaporation Basin, Hacienda Evaporation Basin, and the South Evaporation Basin) to accumulate salts and maintain agricultural productivity. Agricultural drainage water is conveyed to the evaporation basins through a series of sub-surface pipelines and open ditches. The water storage capacity of these three interconnected basins is approximately 17,000 acre-feet (AF). As a result of increased demand for sub-surface drainage water disposal, in recent years, the water stored in the evaporation ponds reaches the maximum storage capacity in the late spring as the demand for surface disposal of drainage water rises prior to the maximum evaporation rates occurring from the ponds. . It is estimated that the annual average evaporation capacity of the three basins is approximately 17,000 AF (TLDD 2012).

Ambient TDS concentrations of groundwater beneath the land where additional basins are proposed ranges from 6,600 to 12,000 mg/L (Summers Engineering, Inc., 2014). For the purpose of estimating the salt accumulation at these evaporation ponds, a TDS concentration of 6400 was used. This is the measured TDS concentration in the main outlet structure in May 2013.

The primary costs for implementation are:

- Administrative/contract costs
- Purchase land
- Provide engineering for evaporation ponds and associated infrastructure
- Provide capital costs for new evaporation ponds
- Provide O&M costs for existing and new evaporation ponds
- NEPA/CEQA compliance
- WDRs (see Implementation: Other Regulatory Approvals or Requirements)

5.5 Ocean Disposal

Another option for salt disposal is an out-of-valley solution: discharge to the ocean or bay. This could be done through an existing permitted WWTP with capacity to accept the brine and combine it with treated wastewater in the outfall pipeline, with or without additional treatment at the plant if necessary. Other options include discharge through a new outfall at some alternative location, with pre-treatment to the extent necessary at a new location.

The SWRCB has proposed new regulations concerning salinity limits on brine lines. This needs to be considered because it could potentially reduce the capacity of a project and/or add to the cost or change the project significantly. If the discharge was to be added to an existing POTW discharge, the salinity increase is not likely to be a significant concern. If a dedicated outfall were to be considered, as discussed in Section 5.5.2, this may or may not be a concern depending upon the relative volumes of brine received from different IAZs, as shown in Tables 2-2 or 2-3. The brine from many areas would be well below natural receiving water background TDS, but could be significantly higher in other IAZs. The flow-weighted average TDS of brine in the initial phase is estimated to be about 25,000 mg/L, which is close to the ambient TDS concentrations in the portions of San Francisco Bay that would be considered for an outfall project, and less than sea water TDS concentrations for an ocean outfall option.

5.5.1 Discharge through EBMUD

A significant opportunity for discharge to an existing WWTP with an outfall to San Francisco Bay is EBMUD in Oakland which is a publicly-owned utility formed under the State of California's Municipal Utility District Act (1921). EBMUD provides water service to more than 1.3 million customers and wastewater service to about 650,000 customers in the East Bay area (Oakland and surrounding areas). The WWTP was designed to meet the wastewater needs of residents, commercial enterprises, and the food processing industry at the time. The reduction in the food processing industry in Oakland has resulted in available capacity in EBMUD's WWTP. For the purposes of this preliminary analysis, it is estimated that of about 80 to 100 MGD of brine could be discharged through EBMUD's outfall, provided that it meets EBMUD's permit requirements. Actual capacity and water quality requirements will be determined in future phases. Table 5-10 shows a range in WWTP capacity and a range of brine concentration that yields, on a conceptual basis, a range of salt mass removed of 3.1 to 7.6 million tons annually (44 to 108 percent of the annual salt accumulation in the entire Central Valley)." The WWTP disposal option has challenges and ancillary opportunities.

Challenges

- Transportation of the brine to EBMUD's WWTP is the major engineering and economic challenge. As discussed in Section 6, the transportation could be by truck, rail or a regional brine line. This would occur in phases (trucking until rail is commissioned, rail until the brine line is constructed).
- Brine would either need to meet EBMUD's permit requirements, or pretreatment systems would need to be designed.
- EBMUD must ensure that agricultural chemicals, nutrients, metals, and naturally-occurring trace elements, such as selenium and boron in brine streams do not interfere with its ability to meet permit requirements for discharge to San Francisco Bay. The existence of inorganic trace constituents in the brine concentrate has the potential to be problematic in terms of permit compliance for discharges from a WWTP. Some areas with subsurface agricultural drainage have elevated concentrations of one or more trace elements, *e.g.*, selenium, molybdenum, arsenic, uranium, and vanadium. These elements may not be adequately removed by reverse osmosis alone. The specific treatment technology to remove trace constituents at any given location will depend on the specific elements found, the concentrations, competing ions, soluble ligands, e*tc*. While there are significant amounts of groundwater data currently available, these data will need be incorporated into a synoptic of groundwater trace element chemistry study for different IAZs and local basins as future phases of

SSALTS are implemented. In addition, a study of additional treatment to reduce trace constituents that may be necessary to allow an existing WWTP such as EBMUD to meet its discharge requirements, or to meet anticipated requirements for any new outfall will need to be conducted.

In general, several processes can be considered for the trace constituent removal, such as ion exchange, lime softening, and coagulation/co-precipitation. The processes can be applied either as a pre- or post-treatment to RO in the desalting process. Applying the process as post-treatment might be economically more feasible since only the brine concentrate would undergo this treatment process, not the entire feed water stream. Treating only the brine concentrate would greatly reduce the equipment size and footprint, as well as O&M costs. A possible downside of applying the process as a post-treatment is that other major and minor constituents are also concentrated in the brine and they can compete with the trace constituents, reducing the removal efficiency of the target trace constituents.

The post-treatment process to remove the inorganic tracer constituents can be constructed at the local desalination facilities and operated and maintained by local plant staff or at a centralized downstream treatment facility. These treatment facilities are relatively complex, requiring well trained staff and frequent maintenance, perhaps making a central treatment facility more cost efficient. However, trace element chemistry of the pumped groundwater/feed water will be different at each desalination facility. There may be desalination facilities that do not need additional treatment for trace elements based on groundwater chemistry. Therefore, for the purposes of this concept-level alternatives analysis, it was assumed that the additional treatment for trace elements would be a post-RO process co-located at regional desalination facilities and would be required at 50 percent of those facilities. The cost to add treatment for trace constituents (ion exchange) at each desalination facility of a capacity equal to the expected brine flow rate ranges from $3/gpd to $4/gpd.

Opportunities

- Transportation of biosolids for use as soil amendments to the Central Valley (perhaps on the return run from delivering brine to EBMUD, either by truck or by rail). Currently, EBMUD is paying about $32 per ton to transport and apply biosolids to agricultural land outside of Alameda County. At 6 truckloads per day and 20 tons per truck (120 tons per day) – were Central Valley generators able to arrange for back-hauling of this end product – conceptually it could result in a cost offset to the Central Valley entities of about $1.4M per year.

- Highly treated, recycled water could be purchased by Central Valley entities for recharge into groundwater basins. As discussed in Section 8, a concept-level evaluation can be in Phase 3 of the efficacy and economics of purchasing recycled water from EBMUD (or another WWTP) and transporting that recycled water in parallel pipelines in the same trench/alignment as the CVBL. Salinity can be reduced by dilution (addition of water of higher quality), as well as by salt removal. The use of recycled water for recharge would have the additional benefit of stabilizing water supply reliability.

5.5.2 Other Ocean Disposal Options

While EMBUD offers a viable possibility, it is prudent to evaluate other possible options that could be considered in the event that EBMUD is unable to accept all or some of the brine at some point in the future. This could potentially include constructing a new outfall somewhere off the shore of San Francisco Bay, San Pablo Bay or Suisun Bay, extending the brine line to the outfall, and, to the extent necessary constructing pre-treatment facilities somewhere along the pipeline route which could be near the outfall or further upstream within the Central Valley, The other option that was discussed and evaluated in the Phase 1 Draft Final Report was the concept of the San Luis Ocean Disposal Outfall and was one of the major alternatives analyzed in Reclamation's San Luis Feature Re-Evaluation Environmental Impact Statement (EIS). This project has many challenges and has not moved forward, and was ranked low in the sustainability analysis among all of the various salt management options. Nonetheless, it is still an alternative that could be re-considered if conditions changed. See also a brief discussion under Section 6.1.

5.6 Salt Marketability

It is technically feasible to segregate RO concentrate brine into different types of salts as either a liquid or a dried product. Previous studies have shown that a range of salts could be obtained from RO concentrate brine (Ahuja and Howe, 2007) depending on the composition of the brackish water supply. Use of these salts would depend largely on the presence of a local or regional market for salt products and meeting the purity requirements for the potential end users.

Ahuja and Howe (2007) identified four candidate salts for removal and recovery for beneficial use based on their solubility. Two additional salts from that study, calcium chloride and sodium carbonate have been added herein as potentially marketable salts. These salts and their solubility, and factors affecting their recovery are presented in Table 5-11.

Ahuja and Howe (2007) suggest that by focusing on these calcium and sodium salts, 85 to 95 percent of the mass of dissolved solids in the concentrate could potentially be separated and marketed. Table 5-12 list the potential uses for each salt product.

There are many technical and logistical, and market-based factors that should be taken into consideration in salt recovery, reuse, and sale. Although recovered salts have various uses, as shown in Table 5-12, there is also a regional component to the way salts are used across the United States. Table 5-13 lists the common uses of salts for different US regions.

Different uses require salt products of different purities, and, in general, creating higher purity salts is more expensive. For example, sodium sulfate for use in laundry detergent must be more than 99 percent pure, by weight. Highly soluble salts require greater energy for separation from water, making them more expensive to produce. The value of salts on the market depends on demand. Some salts, such as calcium sulfate, have vast natural stores that would drive down the price of recovered salts.

A 10 MGD plant with a raw water TDS concentration of 5000 mg/L generates approximately 80,000 tons of solids per year (Table 5-14). Assuming a landfill disposal cost of $50.00 per ton, the annual cost of disposing these solids in a landfill would be $4,000,000. Thus, if the utility was able to give the RO concentrate to an industrial partner at no cost, the avoided cost of landfill disposal would result in significant savings. Note that that these figures do not take into account the cost of salt production.

There is a synergy between brackish water treatment and salt recovery similar to that between wastewater and methane production, although methane is often of direct beneficial use to a wastewater treatment plant. Concentrate management is an ever increasing issue, and ZLD technologies are becoming more cost effective, which will drive down the cost of processing concentrate, thus making selective salt recovery more viable. Selective salt recovery and maximizing water recovery is also a sustainable solution for concentrate disposal which is an issue facing every RO treatment plant.

The emerging technologies discussed in Section 4.2 have the potential to create products that can be marketed at a profit. However, these technologies are not mature enough to evaluate the long-term economics. CV-SALTS will track closely emerging salt removal technologies, not just from the standpoint of technical feasibility, but also from a market perspective.

Table 5-1 Mass of Salt Removed by Deep Injection Wells

Capacity (mgd)	Volume of Water for DWI (gal/yr)	Concentration of TDS in Brine (mg/L)	Mass TDS Removed (tons/yr)	Net TDS Inflow in CV (tons/yr)	Percentage TDS Potentially Removed in CV by DWI (%)
0.2	73,050,000	13,333	4,064	7,084,426	0.06%
0.5	182,625,000	13,333	10,161	7,084,426	0.14%

Table 5-2 Mass of Salt Removed by Supplying Water for Hydraulic Fracturing

Number of Wells Annually	Volume of Water (gal/yr/well)	Volume of Water for HF (gal/yr)	Volume of Water for HF (mgd)	Concentration of TDS in Brine (mg/L)	Mass TDS Removed (tons/yr)	Net TDS Inflow in Southern CV (tons/yr)	Percentage TDS Potentially Removed in Southern CV by HF (%)
700	80,000	56,000,000	0.15	58,900	13,763	3,758,301	0.4%
700	300,000	210,000,000	0.58	58,900	51,612	3,758,301	1.4%

Table 5-3 Potential Revenue Stream from Supplying Water for Hydraulic Fracturing

Number of Wells Annually	Volume of Water for HF (gal/yr/well)	Volume of Water for HF (gal/yr)	Volume of Water for HF (AFY)	Unit Price ($/AF)	Price ($)
700	80,000	56,000,000	172	$1,164	$199,999
700	300,000	210,000,000	644	$1,164	$749,995

Table 5-4 Monthly Discharge at the San Joaquin River near Vernalis, CA Gaging Station (11303500) from 1963 to 2014

	Discharge (AF)											
Year	October	November	December	January	February	March	April	May	June	July	August	September
1963-64	90,149	164,602	179,762	217,236	176,592	97,613	57,116	45,473	43,244	38,684	23,550	27,055
1964-65	53,530	86,759	140,132	371,201	884,192	440,243	327,483	586,651	325,638	336,198	121,315	75,076
1965-66	99,848	181,020	216,833	383,252	323,917	227,203	117,749	58,409	53,070	33,905	27,036	30,738
1966-67	43,158	67,698	79,140	269,008	197,252	353,383	401,883	862,215	1,251,888	1,190,083	642,545	124,266
1967-68	120,734	167,554	206,658	223,507	180,774	150,532	190,181	85,388	54,792	35,197	30,922	47,241
1968-69	55,821	85,099	95,445	155,748	849,144	1,807,736	1,898,122	1,316,231	1,513,210	1,659,570	356,813	142,959
1969-70	193,686	274,358	275,385	246,688	683,742	510,442	441,481	99,550	147,140	160,899	81,779	64,193
1970-71	78,486	90,141	98,479	310,143	319,981	243,864	159,191	116,688	112,707	138,169	65,546	54,828
1971-72	65,276	138,532	97,944	147,447	191,657	155,363	84,853	61,706	45,771	34,929	29,588	33,388
1972-73	93,005	122,483	131,861	153,842	249,578	443,631	467,982	250,096	180,589	153,283	66,530	65,607
1973-74	87,531	156,547	135,729	220,495	478,435	282,906	296,186	348,099	252,468	229,686	100,594	99,302
1974-75	169,349	215,022	231,531	255,911	231,562	344,997	349,557	235,458	244,229	339,650	105,636	103,299
1975-76	157,805	279,338	232,423	230,271	204,508	121,656	112,092	76,939	57,761	47,455	41,270	64,869
1976-77	63,491	78,335	67,597	59,323	67,083	43,791	32,201	12,621	24,583	7,021	5,706	7,637
1977-78	10,633	15,138	25,569	31,094	139,946	406,477	705,263	1,191,868	1,175,643	420,635	117,318	87,189
1978-79	162,446	204,569	208,145	172,903	321,765	396,424	531,991	208,621	155,195	134,122	82,024	89,219
1979-80	109,547	171,550	137,514	152,920	803,643	1,080,238	1,555,636	609,917	609,465	315,669	208,074	121,069
1980-81	226,235	250,378	195,055	181,327	199,896	159,892	191,964	150,664	120,946	89,197	77,782	78,028
1981-82	70,274	85,222	93,064	113,875	239,125	369,045	618,565	1,366,215	1,146,744	451,279	378,948	246,996
1982-83	364,701	502,907	414,982	1,013,931	1,172,569	1,754,975	2,461,964	2,168,926	1,953,461	1,551,868	1,182,407	555,540
1983-84	672,992	819,015	635,504	1,176,258	1,575,927	622,949	461,280	254,975	199,220	136,681	117,072	133,981
1984-85	173,574	234,514	167,921	293,357	249,947	179,996	168,230	146,737	131,092	104,013	157,224	159,929
1985-86	114,545	127,402	114,783	135,580	126,664	485,617	1,539,650	1,165,686	538,877	370,889	177,945	195,715
1986-87	248,787	230,025	167,088	227,873	141,729	118,627	209,980	170,598	133,920	118,413	100,348	100,040
1987-88	95,028	84,238	92,112	78,581	91,186	79,896	137,794	127,696	109,509	101,812	83,439	95,736
1988-89	86,400	69,297	75,808	84,361	77,167	68,533	124,389	113,950	119,839	94,195	78,950	71,879
1989-90	80,509	86,144	83,544	84,914	76,368	75,808	108,218	77,891	78,643	66,407	62,041	63,517
1990-91	52,120	61,069	66,347	56,470	50,192	42,092	109,386	69,501	64,500	33,810	36,524	33,043
1991-92	34,161	48,483	64,502	55,019	58,985	120,276	90,387	84,377	54,816	28,598	27,467	29,692
1992-93	37,761	52,185	56,868	60,350	253,329	168,555	166,140	203,564	221,970	139,299	92,846	122,852
1993-94	164,886	186,984	104,668	100,102	109,018	110,352	135,642	110,856	121,315	65,990	69,788	53,316
1994-95	51,709	84,238	76,641	79,626	282,781	364,268	898,334	1,185,917	1,364,410	833,653	607,559	241,339
1995-96	281,693	349,987	144,476	138,347	149,476	659,762	926,618	446,281	517,849	222,486	135,826	125,066
1996-97	128,767	165,463	161,554	749,534	1,867,993	1,947,134	801,183	281,336	294,218	157,507	107,972	115,289
1997-98	123,114	166,385	117,878	130,108	370,463	1,561,706	1,189,785	1,305,521	1,103,702	1,056,793	811,021	334,616
1998-99	342,625	378,333	195,769	266,303	290,836	649,785	512,315	383,028	341,318	179,464	128,755	121,069
1999-00	121,210	155,687	128,410	103,791	131,338	434,799	744,000	298,294	296,001	164,945	116,703	133,490
2000-01	138,645	173,764	150,307	137,609	150,153	171,721	210,902	178,988	216,867	92,172	86,083	81,779
2001-02	81,878	123,160	124,721	126,910	163,680	105,410	131,215	154,592	168,415	83,722	75,445	68,620
2002-03	69,917	104,836	102,050	122,237	117,626	104,354	134,842	158,757	161,405	121,031	81,225	78,766
2003-04	77,831	122,914	98,003	92,416	110,186	126,603	206,660	163,696	162,758	83,544	70,526	69,174
2004-05	66,704	107,788	97,111	97,027	302,396	294,514	495,898	598,612	640,086	593,792	255,481	160,790
2005-06	143,524	161,036	121,269	216,498	809,792	358,659	719,405	1,662,545	1,601,752	933,620	341,072	227,320
2006-07	197,316	236,789	151,021	144,742	159,068	140,731	157,101	132,397	178,191	103,835	69,973	61,980
2007-08	60,337	96,536	101,812	92,416	142,590	136,266	130,046	143,345	169,398	61,468	53,113	53,414
2008-09	53,643	75,937	67,835	69,358	67,944	79,252	87,435	90,208	130,969	65,395	37,261	37,428
2009-10	56,392	113,445	82,949	81,102	120,208	134,733	180,405	254,499	311,435	238,017	118,856	79,196
2010-11	109,607	146,955	113,177	426,847	724,939	483,118	838,691	1,569,719	777,818	634,314	527,933	331,480
2011-12	254,202	309,098	163,934	111,661	111,969	91,113	99,302	148,701	183,971	94,731	58,530	47,813
2012-13	56,898	110,001	77,058	120,577	113,076	123,848	92,846	128,648	142,528	43,878	35,417	32,299
2013-14	50,525											
Min	10,633	15,138	25,569	31,094	50,192	42,092	32,201	12,621	24,583	7,021	5,706	7,637
Mean	128,294	170,379	143,367	211,402	338,248	388,618	456,191	433,253	400,107	287,839	169,356	111,583
Max	672,992	819,015	635,504	1,176,258	1,867,993	1,947,134	2,461,964	2,168,926	1,953,461	1,659,570	1,182,407	555,540

Source: http://waterdata.usgs.gov/nwis/nwisman/?site_no=11303500&agency_cd=USGS

Table 5-5 Monthly Electrical Conductivity at the San Joaquin River near Vernalis, CA Gaging Station (11303500) from 1963 to 2014

	Electrical Conductivity (μS/cm))											
Year	October	November	December	January	February	March	April	May	June	July	August	September
1963-64	573	445	358	435	643	1,170	1,190	1,010	896	1,250	1,390	1,030
1964-65	739	697	596	213	273	326	309	240	156	543	853	736
1965-66	383	406	200	320	530	693	842	837	1,040	--	1,200	1,220
1966-67	1,010	691	475	733	253	495	300	168	124	555	704	668
1967-68	529	378	368	464	752	522	471	1,010	--	1,190	1,070	1,040
1968-69	946	574	--	218	248	--	290	163	92	255	673	544
1969-70	312	253	336	495	645	498	846	513	484	876	859	818
1970-71	713	863	413	453	409	627	697	645	515	832	806	915
1971-72	500	641	531	450	700	760	1,000	--	1,240	1,250	1,080	280
1972-73	662	550	440	420	725	631	698	466	612	901	820	700
1973-74	449	458	356	317	418	429	440	455	358	826	680	422
1974-75	450	370	266	230	603	560	359	666	187	721	824	666
1975-76	365	284	405	380	999	--	798	--	1,030	1,150	--	1,030
1976-77	739	1,020	1,090	1,040	1,160	1,070	850	1,250	1,620	1,970	1,920	1,700
1977-78	--	1,480	1,030	570	356	686	289	189	150	551	999	424
1978-79	224	206	463	300	376	298	775	243	494	630	760	653
1979-80	240	529	558	368	185	191	274	131	248	344	806	254
1980-81	309	370	501	339	1,180	710	792	723	727	781	842	778
1981-82	--	729	--	698	--	265	--	129	--	466	--	193
1982-83	--	181	--	--	--	278	--	158	--	304	--	137
1983-84	--	--	220	240	--	400	--	--	626	700	--	380
1984-85	--	490	--	614	645	--	--	658	652	518	508	585
1985-86	518	684	781	893	255	211	180	290	266	603	500	365
1986-87	324	496	455	680	801	573	604	644	679	796	881	752
1987-88	829	901	906	1,097	1,275	781	779	737	712	806	849	792
1988-89	878	880	829	1,080	1,230	692	670	832	802	1,020	877	776
1989-90	820	861	1,110	1,180	903	776	773	--	848	--	870	--
1990-91	750	--	980	--	1,310	--	870	--	815	--	872	--
1991-92	525	--	--	1,298	584	657	1,028	906	813	752	848	758
1992-93	889	548	774	1,277	651	506	596	801	595	423	583	804
1993-94	834	783	718	812	341	760	890	728	812	921	713	854
1994-95	919	866	541	429	310	300	127	136	147	--	379	--
1995-96	--	--	--	--	--	--	--	--	586	--	--	--
1996-97	--	--	136	168	162	769	284	594	677	573	643	427
1997-98	651	912	853	209	337	272	819	183	171	137	345	245
1998-99	301	520	341	620	166	315	503	232	549	611	568	546
1999-00	499	517	788	668	511	200	306	505	434	575	523	500
2000-01	500	649	748	764	752	513	895	458	700	645	698	703
2001-02	671	239	558	--	1,020	1,000	866	363	399	631	614	777
2002-03	762	687	735	771	1,060	1,006	1,065	656	470	431	604	623
2003-04	642	542	--	980	1,070	--	736	408	463	439	--	498
2004-05	571	--	896	--	512	--	276	--	305	--	687	--
2005-06	475	--	807	--	293	--	125	--	118	--	374	--
2006-07	288	670	613	586	705	742	514	378	456	684	660	727
2007-08	366	753	807	532	810	807	413	321	724	657	622	771
2008-09	639	747	852	974	909	906	488	327	439	489	528	551
2009-10	--	737	793	867	837	682	412	259	241	445	598	571
2010-11	369	628	264	249	270	258	139	142	139	175	269	277
2011-12	543	738	717	793	935	721	282	440	516	597	481	706
2012-13	785	811	585	474	276	394	340	547	520	394	500	715
2013-14	835	1,000	865	621	271	194	391	399				
Min	224	181	136	168	162	191	125	129	92	137	269	137
Mean	589	631	615	607	631	573	578	487	546	684	747	657
Max	1,010	1,480	1,110	1,298	1,310	1,170	1,190	1,250	1,620	1,970	1,920	1,700

Source: http://waterdata.usgs.gov/nwis/nwisman/?site_no=11303500&agency_cd=USGS

Table 5-6 Real Time Management and Additional Salt Loading to the San Joaquin River

Month	Discharge[1]	EC[1]	TDS	Water Quality Objective at Vernalis		AC	Discharge	Additional Load	
	(AF)	(µS/cm)	(mg/L)	(µS/cm)	(mg/L)	(mg/L)	(L)	(mg)	(tons)
October	128,294	589	377	1,000	640				
November	170,379	631	404	1,000	640				
December	143,367	615	394	1,000	640				
January	211,402	607	389	1,000	640				
February	338,248	631	404	1,000	640				
March	388,618	573	367	1,000	640				
April	456,191	578	370	700	448				
May	433,253	487	312	700	448				
June	400,107	546	349	700	448				
July	287,839	684	438	700	448				
August	169,356	747	478	700	448				
September	111,583	657	420	1,000	640				
								Total Tons	

[1]http://waterdata.usgs.gov/nwis/nwisman/?site_no=11303500&agency_cd=USGS
This includes discharges of high quality (low TDS) water from the New Melones Reservoir.
The Lower San Joaquin River Committee is currently developing estimates of assimilative capacity.
This information will be analyzed as part of Phase 3 SSALTS, and in anticipation of this new information the assimilative capacity analysis that included New Melones discharges has been removed from Table 5-6.

Table 5-7 Estimated Annual Salt Mass Loading at the SJRIP Area

Volume Water		TDS Concentration	Mass of Salt		Area		Depth	Volume of Soil	Volume of Perched Water	
(AF)	(L)	(mg/L)	(mg)	(tons)	(acres)	(ft^2)	(ft)	(ft^3)	(ft^3)	(L)
15,000	18,502,227,828	5,000	**92,511,139,142,250**	101,976	6,000	261,360,000	40	10,454,400,000	1,568,160,000	**44,405,273,088**

Table 5-8 Estimated TDS Concentrations at the SJRIP Area

Year	Calendar Year	TDS Concentration Start of Timestep (mg/L)	Mass of Salt Start of Timestep (tons)	Added Mass of Salt (tons)	Mass of Salt End of Timestep (tons)	TDS Concentration End of Timestep (mg/L)
1	2014	11,400	558,012	101,976	659,988	13,483
2	2015	13,483	659,988	101,976	761,964	15,567
3	2016	15,567	761,964	101,976	863,940	17,650
4	2017	17,650	863,940	101,976	965,916	19,733
5	2018	19,733	965,916	101,976	1,067,892	21,817
6	2019	21,817	1,067,892	101,976	1,169,868	23,900
7	2020	23,900	1,169,868	101,976	1,271,844	25,983
8	2021	25,983	1,271,844	101,976	1,373,820	28,067
9	2022	28,067	1,373,820	101,976	1,475,796	30,150
10	2023	30,150	1,475,796	101,976	1,577,772	32,233
11	2024	32,233	1,577,772	101,976	1,679,749	34,317
12	2025	34,317	1,679,749	101,976	1,781,725	36,400
13	2026	36,400	1,781,725	101,976	1,883,701	38,483
14	2027	38,483	1,883,701	101,976	1,985,677	40,567
15	2028	40,567	1,985,677	101,976	2,087,653	42,650
16	2029	42,650	2,087,653	101,976	2,189,629	44,733
17	2030	44,733	2,189,629	101,976	2,291,605	46,817
18	2031	46,817	2,291,605	101,976	2,393,581	48,900
19	2032	48,900	2,393,581	101,976	2,495,557	50,983
20	2033	50,983	2,495,557	101,976	2,597,533	53,067
21	2034	53,067	2,597,533	101,976	2,699,509	55,150
22	2035	55,150	2,699,509	101,976	2,801,485	57,233
23	2036	57,233	2,801,485	101,976	2,903,461	59,317
24	2037	59,317	2,903,461	101,976	3,005,437	61,400
25	2038	61,400	3,005,437	101,976	3,107,413	63,483

Table 5-9 Estimated Mass and Volume Salt Accumulation at the SJRIP Area

Volume Water		TDS Concentration	Mass of Salt		Salt Density	Volume of Salt	
(AF)	(L)	(mg/L)	(kg)	(tons)	(lbs/ft^3)	(ft^3)	(yd^3)
15,000	18,502,227,828	5,000	92,511,139	101,976	86	2,371,536	87,835
15,000	18,502,227,828	5,000	92,511,139	101,976	42	4,856,002	179,852

Table 5-10 Range of Salt Mass Removed by Disposal at EBMUD

Capacity (mgd)	Concentration of TDS in Brine (mg/L)	Mass TDS Removed (tons/yr)	Net TDS Inflow in CV (tons/yr)	Percentage TDS Potentially Removed in CV by WWTP (%)
80	25,429	3,100,468	7,084,426	44%
100	25,429	3,875,585	7,084,426	55%
80	50,000	6,096,323	7,084,426	86%
100	50,000	7,620,404	7,084,426	108%

Table 5-11 Solubility of Candidate Salts for Removal and Recovery

Salt	Solubility (mg/L)	Factors Affecting Recovery
Calcium Carbonate	6.6	Sparingly soluble. Removal could be controlled by raising the pH, targets carbonate in RO concentrate.
Calcium Sulfate	2050	Sparingly insoluble. Solubility not dependent on pH. May be possible to control separation of calcium sulfate from other carbonate and hydroxide compounds if separation occurred at low pH.
Sodium Sulfate	281,000 (28 percent solution)	Moderately soluble. In some waters the amount of calcium is insufficient to remove the sulfate. Sodium sulfate would need to be removed in these waters to adequately remove sulfate present in the concentrate.
Sodium Carbonate	307,000 (30 percent solution)	Moderately soluble. May be difficult to precipitate sodium carbonate as a dry salt.
Sodium Chloride	360,000 (36 percent solution)	Very soluble. May be difficult to concentrate RO concentrate to precipitate sodium chloride as a dry salt. If substantial amounts of sulfate and carbonate are removed with calcium then chloride would remain for pairing with sodium.
Calcium Chloride	813,000 (81 percent solution)	Extremely soluble. May be difficult to concentrate RO concentrate to precipitate calcium chloride as a dry salt.

Table 5-12 Potential Uses for Salt Products Recovered from RO Concentrate

Salt Product	Uses
Calcium Carbonate	▪ Pulp and paper ▪ Building construction (marble floors, roof materials, and roads) ▪ Glass (improves chemical durability) ▪ Rubber (mainly PCC) ▪ Paint (extend resin and polymers and control texture) ▪ Plastic (PVC pipe, mainly GCC) ▪ Dietary supplement (antacids) ▪ Water treatment (pH control, softening)
Calcium Sulfate	▪ wallboard plaster products ▪ glass making and smelting ▪ athletic field marking ▪ cement production as a stucco additive ▪ grease adsorption ▪ sludge drying
Sodium Sulfate	▪ Glass ▪ Pulp and paper ▪ Textiles ▪ Carpet freshener ▪ Miscellaneous
Sodium Chloride	▪ Roadway deicing ▪ Chemical industry ▪ Distributors ▪ Agriculture and Food ▪ Water Treatment
Calcium Chloride	▪ Deicing/road stabilization ▪ Dust control ▪ Oil extraction and completion fluids ▪ Accelerator in concrete ▪ Industrial processing ▪ Plastics manufacturing

Table 5-13 Regional Brine Market Matrix

	Hot Arid Region	Cold Arid Region	Warm Humid Region	Other US Regions
Calcium carbonate	Paper Glass Building materials	Paper Glass Building materials	Paper Glass Building materials	Paper Glass Building materials
Calcium sulfate (gypsum)	Wallboard Building materials Cement production	Wallboard Building materials Cement production	Wallboard Building materials Cement production	Wallboard Building materials Cement production
Sodium sulfate	Glass Detergents	Glass Detergents	Glass Detergents Textiles	Glass Detergents
Sodium carbonate (soda ash)	Glass Chemicals	Glass Chemicals	Glass Chemicals	Glass Chemicals
Sodium chloride	Chlor-alkali industry	Road salt Chlor-alkali industry	Chlor-alkali industry	Chlor-alkali industry
Calcium chloride	Dust control	Road salt Dust control	Dust control	Dust control

Table 5-14 Potential Annual Revenue from the Sale of Recoverable Salts[1]

Salt[2]	Annual Revenue[3]
Calcium Carbonate	$494,650
Calcium Sulfate	$129,370
Sodium Sulfate	$1,932,940
Sodium Carbonate	$2,073,725
Sodium Chloride	$799,050
Calcium Chloride	$1,522,000

[1]Assumptions: 10 MGD Plant, 100 percent recovery (ZLD process), 5000 mg/L TDS feed water.
[2]Dry form
[3]Based on costs from 2007 (Ahuja and Howe, 2007)

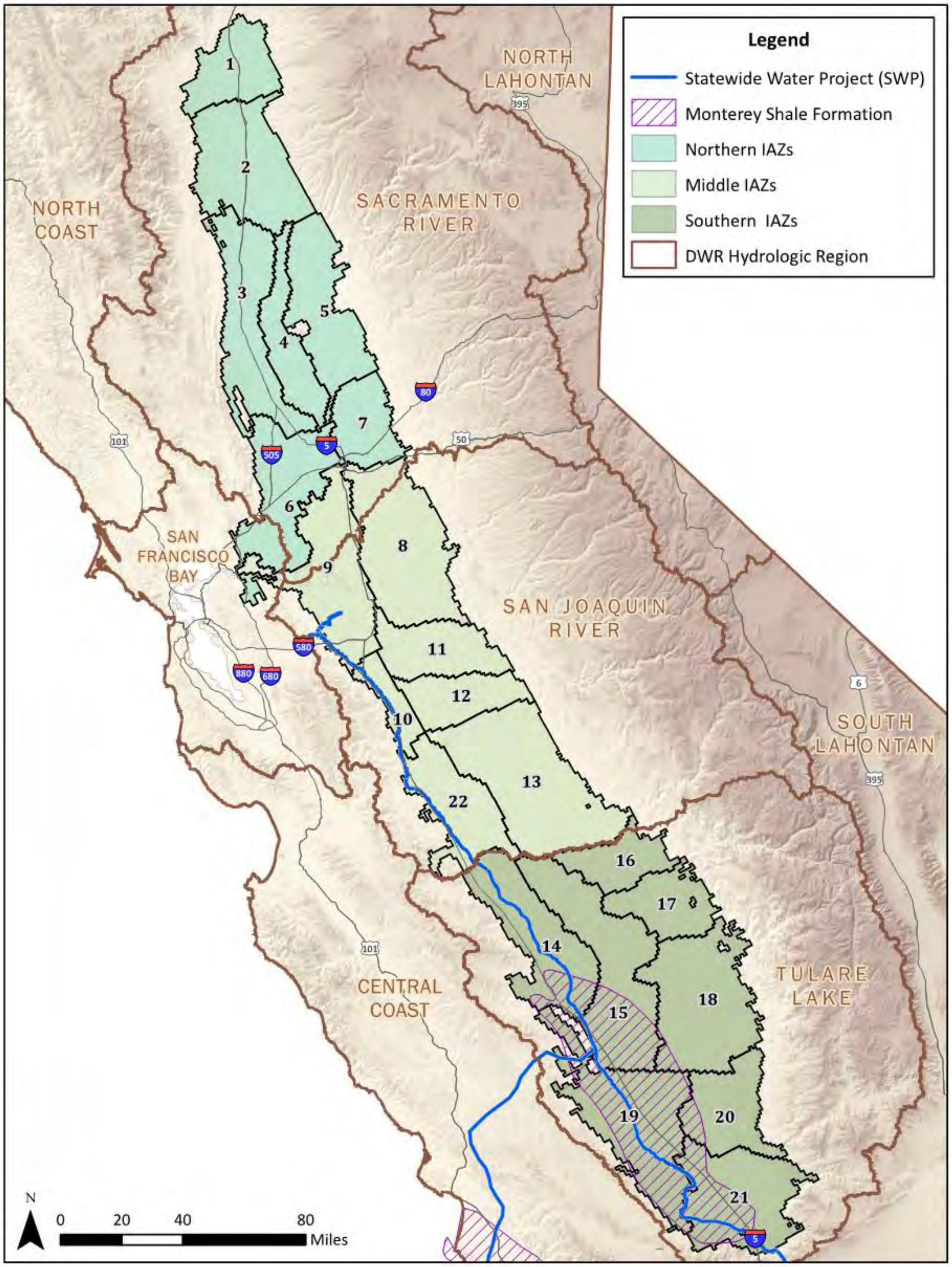


Figure 5-1 Location of the Monterey Shale Formation in the Central Valley

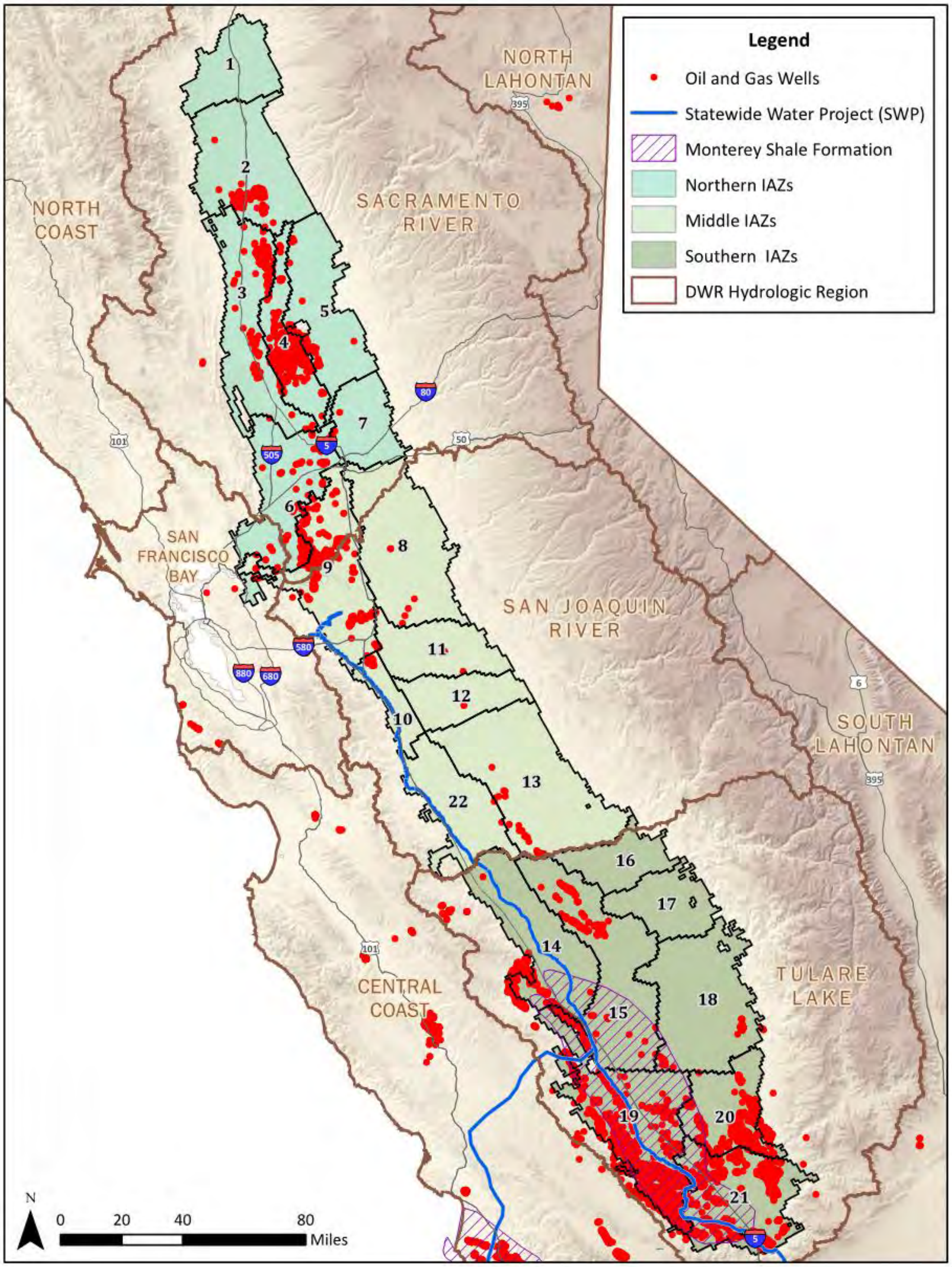


Figure 5-2 Location of Oil and Gas Wells in the Central Valley

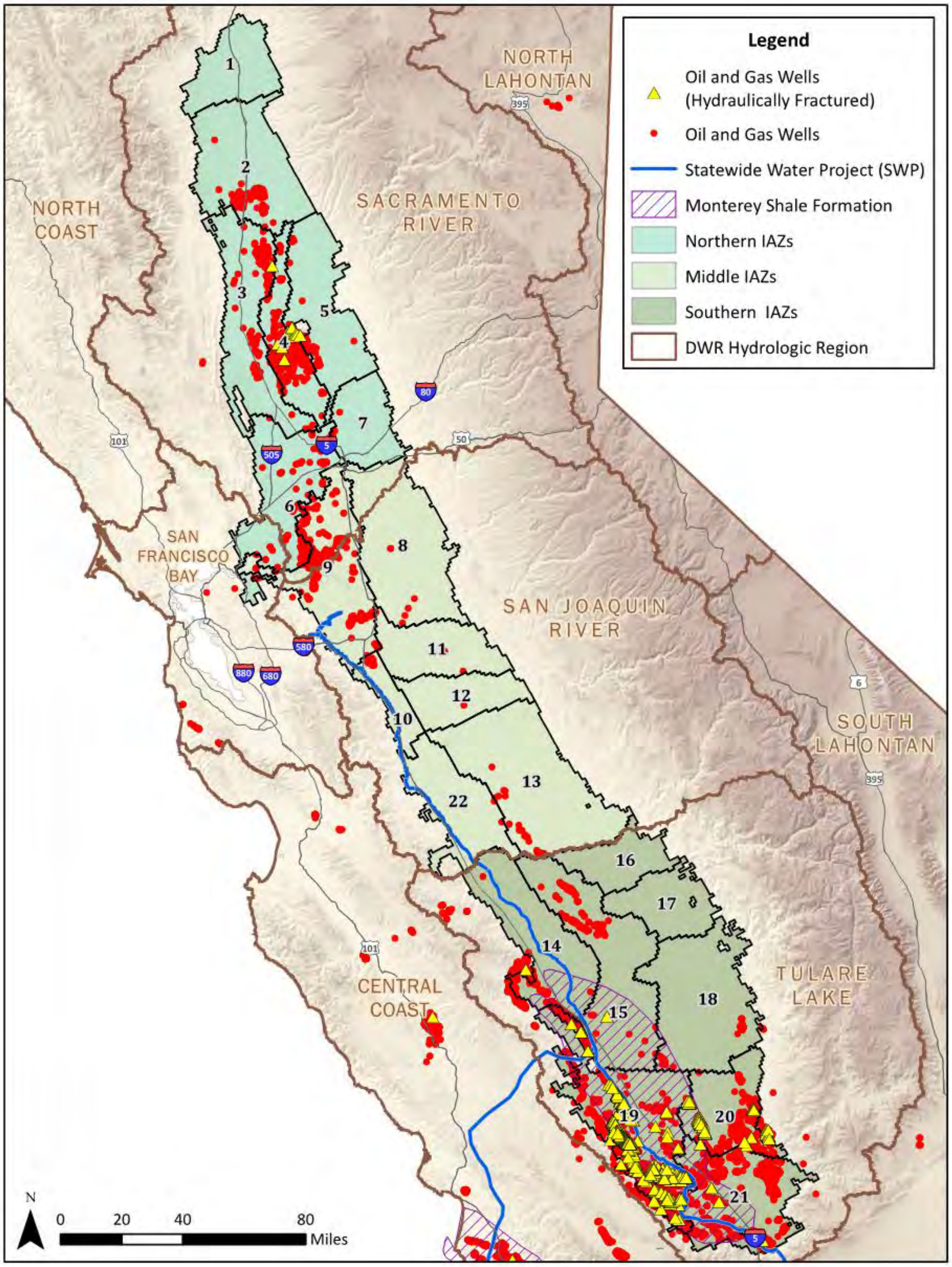


Figure 5-3 Location of the Oil and Gas Wells that have been Hydraulically Fractured in the Central Valley

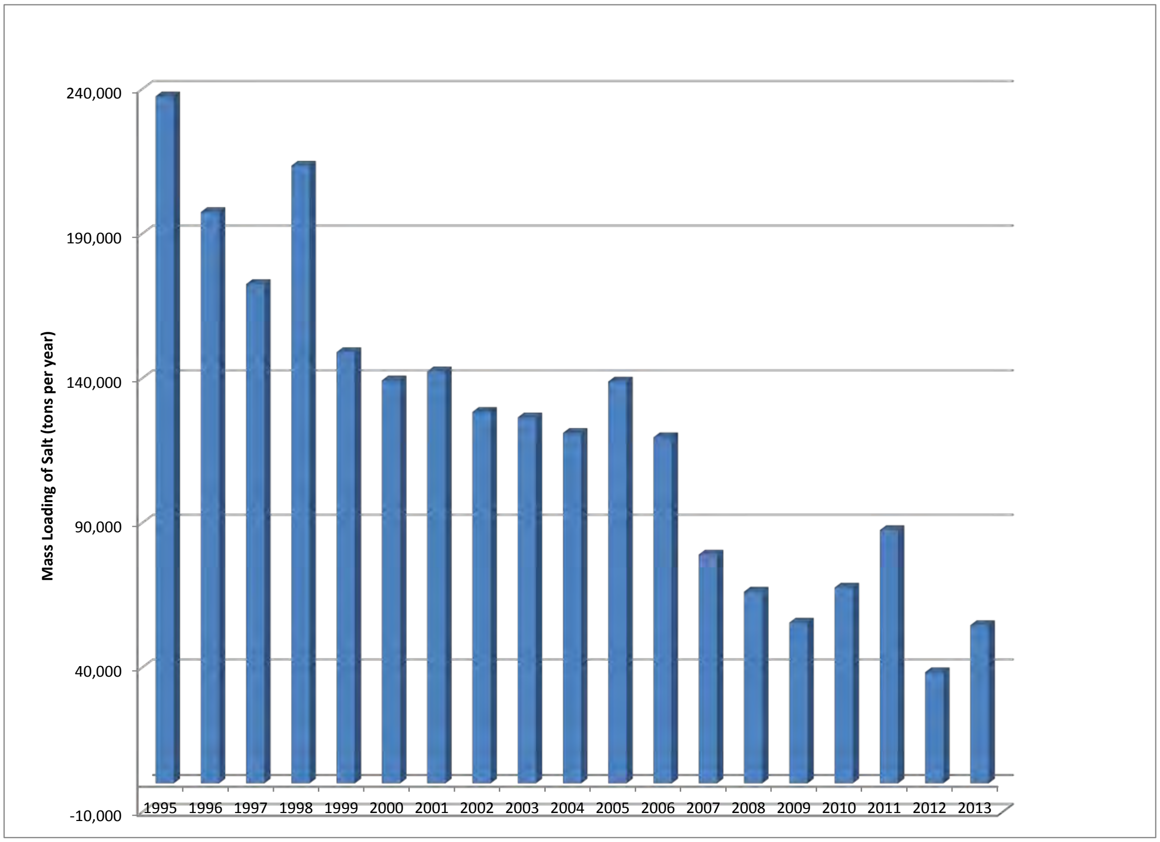


Figure 5-4 Tons of Salt Discharged by the Grassland Drainage Area to the San Joaquin River

Grassland Area Farmers (2013)

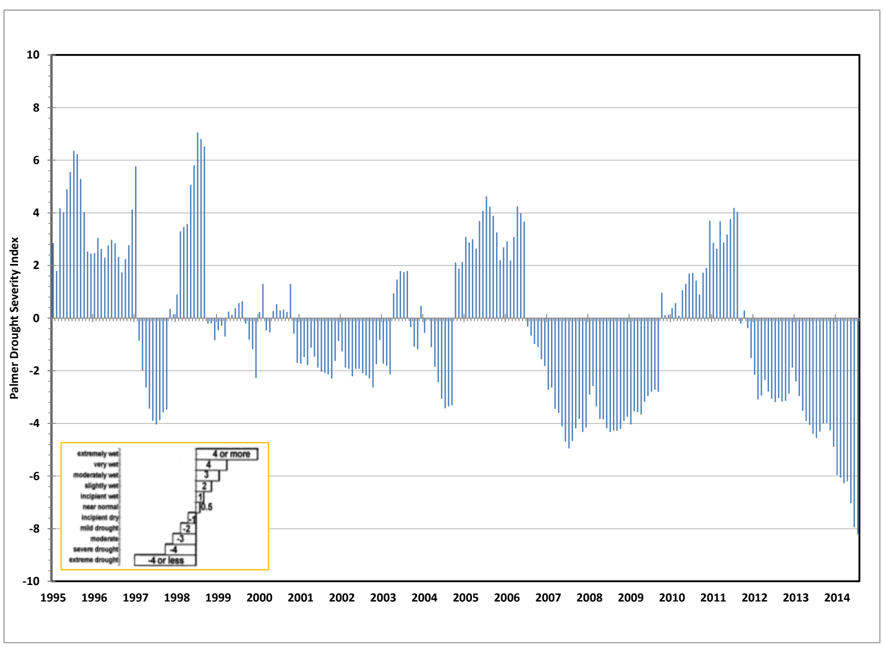
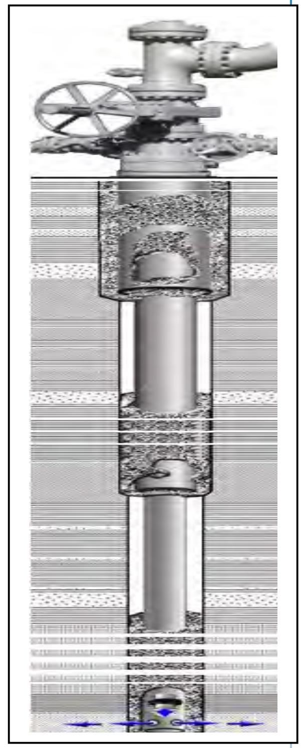


Figure 5-5 Palmer Drought Severity Index for the Middle Central Valley

NOAA (2014)

http://www1.ncdc.noaa.gov/pub/data/cirs/climdiv/

Figure 5-6 Discharge and EC for the San Joaquin River at Vernalis (Station 11303500)

<table>
<tr><th colspan="2">Deep Well Injection with Dedicated Wells</th></tr>
<tr><td>Description</td><td>Under this approach, brine from reverse osmosis treatment (or other concentration processes) of groundwater would be injected into deeper aquifers isolated from the primary drinking water aquifers for disposal or storage and future recovery.
</td></tr>
<tr><td>Constituent Salts or Nutrients Managed</td><td>Deep well injection would effectively manage all salts, nutrients and other constituents retained in the treatment process brine by storing them in deep aquifers that are unusable for most beneficial uses. Depending upon the deep aquifer properties where injection would take place, it might theoretically be possible at some point in the future to install extraction wells if an economical way was developed to extract and recover the saline water for commercial purposes. This option is distinct from Deep Well Injection for Oil and Gas Recovery in which the brine would be used by the oil and gas industry to assist with hydraulic fracturing to release oil and gas trapped in formations. See Deep Well Injection – Oil and Gas Recovery.</td></tr>
<tr><td>Applicability</td><td>To the extent that there is storage capacity in an underlying deep aquifer that is of poor quality and is geologically isolated from any overlying aquifer that has existing or potential beneficial use for municipal, industrial or agricultural purposes, it is possible to consider this approach. This method would inject concentrated brine into deep formations. The USGS has developed a Hydrologic Model of the Central Valley (http://ca.water.usgs.gov/projects/central-valley/central-valley-hydrologic-model.html) that assumes that the deepest layer of the "usable" groundwater aquifer where water is relatively fresh is approximately 2,700 feet below the surface at the center of the valley. Water that may be in formations deeper than this is considered to be saline. Therefore, injection wells may need to be in excess of 3,000 feet deep. Three injection wells that were installed by the Hilmar Cheese Company near Hilmar, CA in 2009 to 2010 were completed to approximately 4,000 feet below ground surface (bgs). The areal extent and depths of the deeper formations are not mapped from a water resources point of view, but there has been extensive drilling, exploration and mapping</td></tr>
</table>

Deep Well Injection with Dedicated Wells	
	of these formations by the oil and gas industry. See Deep Well Injection – Oil and Gas Recovery. While the areal extent of deep wells currently used by the oil and gas industry for both extraction and injection are somewhat concentrated in portions of the Central Valley, particularly in the southern portion, there is not necessarily any limitation as to where dedicated injection wells can be sited geographically other than by the nature of the deeper stratigraphy below the valley.
Practice Benefits and Impacts	If the underlying formation in the vicinity of the brine source(s) is capable of accepting injection, the practice could be accomplished at a number of distributed locations near the source of brine (*e.g.*, local or regional desalters). This would result in relatively limited piping infrastructure to deliver the brine to the wells compared to other options (*e.g.*, brineline to an ocean outfall wastewater treatment plant [WWTP]). Also, if there is significant storage capacity in the formation, this approach could provide substantial long-term storage capacity. Finally, if a market were to be developed for products created from the saline water in storage in the future, the saline water could potentially be recovered with recovery wells. Conversely, there are several issues and impacts that could potentially limit the usefulness of this option. In some areas, geophysical information may be available – particularly from oil and gas operations – to give some guidance as to the localized feasibility of installing injection wells, while in other areas there may be little to no information and significant new exploratory drilling and/or other geophysical testing may be necessary to determine the potential. For this to be a feasible option there would need to be sufficient storage available to sustain a number of years of injected water. Another major issue would be compatibility between the injected brine and the deep groundwater, and the geochemical interactions that may take place. Understanding these issues and planning to avoid such problems is essential to designing and operating a system that will have an extended useful life without excessive maintenance. Finally, approximately 15 percent of the pumped groundwater would not be able to be used and would effectively be lost “yield”, similar to most other disposal options (ocean disposal, evaporation, *etc*.).
Effectiveness Documentation	There are thousands of deep injection wells in use throughout California by the oil and gas industry that have operated successfully for many years. These are used both as re-injection wells to replace the water separated from the oil and gas brought to the surface, and for injection to fracture formations to open up the flow of oil and gas, as described under “Deep Well Injection for Oil and Gas recovery. Therefore, the use of injection wells in the deep formations in California has been well established for over 30 years. However, there no known examples of deep injection of brine from a groundwater treatment plant in California. The project at Hilmar Cheese is intended to use injection for brine from treatment of industrial wastewater which has very different characteristics, and a project at Terminal Island treatment plant in Los Angeles has been injecting biosludge slurry into depleted oil and gas wells screened at approximately 5,300 feet bgs for over four years in a demonstration project. Another example is a very deep injection well at the US Bureau of Reclamation’s Paradox Valley Unit in western Colorado. This project intercepts very high TDS groundwater (brine) in excess of

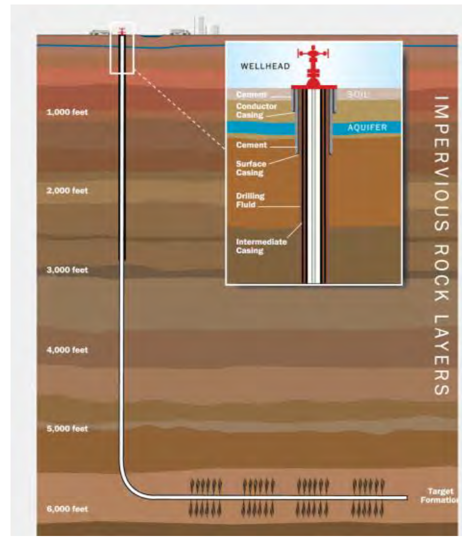
Deep Well Injection with Dedicated Wells	
	250,000 mg/L to prevent the groundwater from rising into the Dolores River which is tributary the to the Upper Colorado River. The well injects the groundwater in a formation that is 16,000 feet bgs. Approximately 100,000 tons/yr of saline groundwater is currently injected into the formation. To date, the formation still has storage potential, although the USGS expects the storage may eventually become limiting and a new well would have to be drilled into a different portion of the formation. While deep well injection is a widely proven technology, the key concerns will be the chemical compatibility of the injected water and the formation to avoid plugging or fouling, and the long-term storage capacity of the formation into which the brine would be injected. Sources of power in remote areas is another potential concern that will need to be evaluated.
Supporting Documentation	
Implementation: Planning Level Costs	The primary costs for implementation is constructing delivery brine pipelines and pumping stations from regional or local desalters to injection well fields and drilling and operating the injection wells. It is not possible to develop any site-specific concepts at this point. A set of hypothetical assumptions was used to develop order-of-magnitude unit costs. Assuming a desalter was constructed to treat 10 mgd of brackish groundwater that would result in approximately 1.5 mgd of brine produced. Using an estimate of 0.5 mgd/well, this would require three injection wells, assumed to be 4,000 feet deep. It is also assumed that the wells could be constructed within two miles of the desalter. The facilities that would be required would include a pump station, approximately two miles of delivery pipelines and three wells plus well head facilities. Estimated capital costs for a cluster of three wells plus piping and appurtenances would be approximately $7.6M including engineering and contingencies to serve a 10 mgd desalter. Of this cost, approximately 60% represents the cost of drilling the wells and the remainder is for well head facilities, piping and a pump station. Operating costs would include the delivery pump station power and maintenance and replacement costs, injection pumping power and well operation and maintenance costs. Assuming that annual operating costs would be approximately 10% of the capital cost, this would result in annual operating costs for the same facilities of approximately $600,000.
Implementation: Status and Potential	Only know similar project in California for deep well brine injection not associated with the oil and gas industry is the previously noted Hilmar Cheese project which is not currently operational. There could be significant potential, limited primarily by storage capacity of the deep formations.
Implementation: Monitoring Documentation	
Implementation: Other Regulatory Approvals or	Construction and operation of injection wells for brine will require permitting under the Underground Injection Control (UIC) Program. These would likely be permitted as Class 1 Injection Wells as defined by the US Environmental Protection Agency (USEPA). These

Deep Well Injection with Dedicated Wells	
Requirements	are defined as wells that inject hazardous and non-hazardous wastes below the lowermost underground source of drinking water (USDW). Injection must occur into deep, isolated rock formations that are separated from the lowermost USDW by layers of impermeable clay and rock.
Website:	

Supply Brine to Oil and Gas Industry for Use in Hydraulic Fracturing

Description

Under this approach, brine from reverse osmosis (or other concentration processes) treatment of groundwater would be delivered to users in the oil and gas industry for use in hydraulic fracturing. This is a type of "completion" technique where high pressure water, sand, and chemicals are injected usually thousands of feet below the surface into low permeability rock to create microscopic fractures that allow oil and natural gas trapped in small pores to migrate to the wellbore and be produced. The vast majority of wells in California are not hydraulically fractured because the geologic zones that have historically been targeted and explored are highly permeable and capable of yielding oil and gas without hydraulic fracture stimulation. The practice is reserved for reservoirs where the geologic conditions are such that the oil and natural gas cannot be commercially produced without the benefit of some form of stimulation. For this process, the brine would be used in lieu of other sources of water.



Before hydraulic fracturing can begin, the drilling rig is removed from the well pad and replaced with highly specialized equipment designed to complete the well. While it may take a drilling rig 2-3 weeks to drill a well, the hydraulic fracturing process usually takes just 1-2 days. Therefore, this is a one-time use for each fracturing well site, but typically multiple sites will be under completion more or less in sequence and therefore the overall need for brine could be close to continuous.

Constituent Salts or Nutrients Managed

Deep well injection would effectively manage all salts, nutrients and other constituents retained in the treatment process brine by injecting them in deep aquifers that do not have assigned beneficial uses. This option is distinct from Dedicated Deep Well Injection in which the brine would be stored in deep aquifers over long time periods. See **Dedicated Deep Well Injection**.

Applicability

Assuming oil and gas exploration and development in California continues for the foreseeable future, the industry has estimated that there could up to 700 wells/year drilled that would require water for hydraulic fracturing. The typical single well one-time water requirement estimated by the industry ranges from 80,000 to 300,000 gal. Using a drilling rate of 700 wells per year, and assuming drilling goes on essentially at a consistent rate over the year, this would effectively result in annual for demand for brine of approximately between 172 and 644 AFY, or average flow rate of between 0.15 and 0.58 mgd. The USGS has developed a Hydrologic Model of the Central Valley Far (http://ca.water.usgs.gov/projects/central-valley/central-valley-hydrologic-model.html) that assumes that the deepest layer of the "usable" groundwater aquifer where water is relatively fresh is approximately 2,700 feet below the surface at the center of the valley. Water that may be in formations deeper that this is considered to be saline. In most cases, more than a mile of impermeable rock and earth separate the

Supply Brine to Oil and Gas Industry for Use in Hydraulic Fracturing	
	hydraulically fractured zones and the overlying groundwater so that even large fractures are very unlikely to result in upward migrate anywhere close to the groundwater zone. There has been extensively drilling, exploration and mapping of the formations in which hydraulic fracturing is used to release oil and gas deposits by the oil and gas industry. The primary area where hydraulic fracturing has been and will continue to be used is in the Monterrey formation in the southern central valley. Therefore this approach for managing brine will only be considered in the near term for brine that would be produced from desalters in the portions of the southern central valley. This could potentially include use in portions of IAZs 15, 19, 20 and/or 21 where the predominant fracturing activity is occurring.
Practice Benefits and Impacts	The principal benefit for this approach, in addition to a means of disposal/storage of brine is that the brine would substitute for other water sources that would otherwise be needed. These include local groundwater and surface water and other sources that the oil and gas industry must currently obtain through purchase or lease of rights. Furthermore, the brine would have value to the industry, presumably equivalent to or greater than the cost to acquire other water sources. Furthermore, the need for the water at specific locations and depths will have already been determined by the industry as part of its exploration and drilling program and does not require independent investigation of the aquifer to accept the water. The most significant limitation of this approach compared to dedicated injection is the relatively small demand for water compared to other options. As noted previously, even if the practice continues for a number of years, and almost all the use shifted to brine as the primary supply of water, the demand would only be in the range of roughly 200 – 600 AFY, a small fraction of the total brine that might potentially be produced to meet the desalination needs of the southern central valley alone. A second major issue is that the location where the brine would be needed would be continually changing as new fracturing wells are continuously being drilled and developed. This would suggest some form of temporary storage and either temporary piping or truck hauling of the water to new sites as the need occurs.
Effectiveness Documentation	Since hydraulic fracturing is a long established and proven process over many years in California, this can be an effective, if limited, use for brine. Chemical compatibility of the injected water and the formation to avoid plugging or fouling is likely much less of an issue compared to dedicated injection since this a short term use at any given well.
Supporting Documentation	
Implementation: Planning Level Costs	The primary costs for implementation is constructing delivery brine pipelines and, as necessary, pumping stations from regional or local desalters to locations where the water can be made available for use. Unlike dedicated injection, the point of uses will be continuously changing over time, so it is not possible to develop any site-specific concepts at this point. It is possible that there may need to be temporary storage and temporary pipelines. Unlike dedicated injection, there would be no permanent injection wells constructed as theses would be part of the drilling and completion operations

Supply Brine to Oil and Gas Industry for Use in Hydraulic Fracturing	
	constructed by the drilling company. Estimating capital costs for the delivery facilities is difficult since the location of the need for injection water would be changing over time. Operating costs would include the pump station power and maintenance and replacement costs and well operation and maintenance costs. Preliminary discussions suggest that the oil and gas companies would likely pay for these conveyance facilities. The capital costs also assume that there is electrical power relatively close by and that extraordinary cost to extend power distribution are not needed. However, this is a very site-specific issue that would need to be considered for any specific area.
Implementation: Status and Potential	Only known similar project in CA for deep well brine injection is not associated with the oil and gas industry is the previously noted Hilmar Cheese project which is not currently operational but there are thousands of injection wells that have been installed over the years for hydraulic fracturing. The potential for brine use, as noted above is very limited
Implementation: Monitoring Documentation	
Implementation: Other Regulatory Approvals or Requirements	Hydraulic fracturing is considered a “completion technique” that is part of the overall process of drilling a new well. Drilling a well is regulated through and Permitted by DOGGR under CCR 1722.2.
Website:	

San Joaquin River Real Time Management Program

Description

The Real Time Management Program (RTMP) is an umbrella program to optimize/maximize the export of salt from groundwater, perched zones, and agricultural drain water from the Lower San Joaquin River (LSJR) Basin while ensuring that salinity and boron water quality objectives are met at Vernalis. RTMP must also ensure compliance with any future salinity objectives in the Lower San Joaquin River that may be adopted. RTMP involves efforts to control salt loadings. The CVRWQCB has approved RTMP in the Basin Plan as an alternative salt management strategy in lieu of monthly salt load allocations enforced by the CVRWQCB.

The Vernalis objectives for EC are 30-day moving averages: 700 μS/cm during the irrigation season (April to August) and 1000 μS/cm during the non-irrigation season (September to March). According to the RTMP Draft Framework (Reclamation *et al.*, 2014), *"The goal under a real-time management program is to continue to meet the irrigation and nonirrigation season salinity water quality objectives by managing salt loads so they are discharged when there is assimilative capacity in the river, rather than be constrained by mandated monthly load allocations in WDR's. Managing the use of assimilative capacity is also anticipated to reduce reliance on fresh water releases from New Melones Reservoir to meet the salinity objectives at Vernalis and to provide a mechanism to maximize salt exports from the SJR Basin."* The RTMP components include:

- Stakeholder participation
- Real time monitoring network
- Data Management
- Predictive modeling/forecasting of flows and salinity in the river in order to predict assimilative capacity
- Physical infrastructure (gates, inlets, rubber dams, *etc.*)
- Program and project management practices
- Funding

Examples of pilot studies of RTMP include:

- Grassland Resource Conservation District Wetland Areas
- Grassland Bypass Project and Panoche Drainage District

San Joaquin River Real Time Management Program	
Constituent Salts or Nutrients Managed	The RTMP effectively manages all salts, nutrients and other constituents, in that it is not a treatment process but a sophisticated management tool for managing and exporting salt loads to the river at times when there is assimilative capacity. Other WQOs (boron, selenium, *etc.*) must also be met.
Applicability	Federal Clean Water Act (CWA) §305(b) requires that each state assesses the water quality status of each waterbody under CWA jurisdiction and report these findings to EPA. For this assessment, the state reviews available water quality data, compares these data to water quality objectives, and evaluates whether the beneficial uses of each waterbody are supported. Through this process and pursuant to CWA §303(d) the state is required identify waterbodies not meeting water quality standards even after all required effluent limitations have been implemented (*e.g.*, through a WDR). These waters are often referred to as "303(d) listed" or "impaired" waters. Waterbodies placed on the 303(d) list may require development of a Total Maximum Daily Load (TMDL). A TMDL is a calculation of the maximum amount or load of a pollutant that a waterbody can receive and still meet water quality objectives; this load is allocated among the various sources of the pollutant. The CVRWQCB adopted a TMDL for salt and boron in the LSJR as a Basin Plan amendment on September 10, 2004. EPA approval occurred in 2006. The approved TMDL establishes a water quality control program for salt and boron to achieve existing salinity and boron WQOs in the San Joaquin River at the Airport Way Bridge near Vernalis ("Vernalis"). The adopted control program requires a second phase TMDL to address salinity and boron concerns in the LSJR upstream of Vernalis. Through CV-SALTS, a LSJR Committee was established to develop recommendations for updated WQOs that support the beneficial uses on the LSJR and an implementation plan to support those objectives. The outcome of this effort will have direct bearing on how salt is managed in the watershed draining to the San Joaquin River. The LSJR Committee effort is ongoing and salinity objectives are anticipated in 2015/2016 time frame.
Practice Benefits and Impacts	The CVRWQCB provided for participation in the LSJR RTMP in lieu of load allocations: *"The Regional Water Board will adopt a waiver of waste discharge requirements for salinity management, or incorporate into an existing agricultural waiver, the conditions required to participate in a Regional Water Board approved RTMP. Load allocations for nonpoint source dischargers participating in a Regional Water Board approved RTMP are described in Table IV-4.4. Additional waiver conditions will include use of Regional Water Board approved methods to measure and report flow and electrical conductivity. Participation in a Regional Water Board approved RTMP and attainment of salinity and boron water quality objectives will constitute compliance with this control program."* The umbrella RTMP is an effective tool for exporting salt out of the LSJR basin, while being protective of WQO compliance at Vernalis.
Effectiveness Documentation	The effectiveness of the GBP in reducing salt and salinity loading to the San Joaquin River via the San Luis Drain and Mud Slough:

San Joaquin River Real Time Management Program	
	SFEI. 2013. Grassland Bypass Project Annual Report 2010-2011. Prepared for the Grassland Bypass Project Oversight Committee. November 2013. http://www.sfei.org/gbp/reports
Supporting Documentation	U. S. Bureau of Reclamation, Central Valley Regional Water Quality Control Board, San Joaquin Valley Drainage Authority, Grassland Resource Conservation District, San Luis & Delta-Mendota Water Authority/Grassland Bypass Project. 2014. Draft Salinity Real-Time Management Program Framework. May 9, 2014.
Implementation: Planning Level Costs	The Grassland Resource Conservation District Wetland Areas RTMP has been in operation for over a decade and has over 45 monitoring stations that characterize discharge and water quality entering and leaving the Grassland Wetland Complex. Reclamation I (2013) states, *"GRCD can offer guidance to those who are implementing similar programs. Costs associated with this program, including equipment acquisition, installation, quality assurance, and data management are currently in excess of $5 million. Approximate annual programmatic costs are currently in the range of $500,000."* About $140M has been invested to date on the GBP and SJRIP. Estimated costs will be provided pertaining to the overall RTMP for the entire LSJR basin in Phase 3 of SSALTS.
Implementation: Status and Potential	The RTMP consists of four Phases: ▪ Phase 1 – Initiation Phase – to be completed prior to first compliance date of July 28, 2014 ▪ Phase 2 - Development Phase – begin at first compliance date and complete in 12 months ▪ Phase 3 – Early implementation Phase – complete 36 months from first compliance date. ▪ Phase 4 - Implementation Phase – completed 60 months from first compliance date
Implementation: Monitoring Documentation	http://www.sfei.org/projects/grassland-bypass-project http://www.sfei.org/gbp/sjrip
Implementation: Other Regulatory Approvals or Requirements	NEPA/CEQA analysis may be required for the future phases of RTMP.
Website:	http://www.water.ca.gov/waterquality/sjr_realtime/ http://www.sfei.org/projects/grassland-bypass-project https://www.usbr.gov/mp/watershare/wcplans/2010/Refuges/Grasslands%20RCD.

San Joaquin River Real Time Management Program	
	pdf http://www.sfei.org/gbp/sjrip http://gwdwater.org/grcd/who-we-are.php

<table>
<tr><th colspan="2">Salt Accumulation Areas:
San Joaquin River Water Quality Improvement Project (SJRIP)</th></tr>
<tr><td>Description</td><td>The San Joaquin River Water Quality Improvement Project (SJRIP) and the Tulare Lake Bed are two of the larger salt accumulation areas in the Central Valley. The SJRIP is a three phased project:

▪ Phase 1: Purchase land/grow salt-tolerant crops
▪ Phase 2: Install tile drains and collection system/begin initial treatment
▪ Phase 3: Develop the full project treatment system and a salt disposal system

The SJRIP regional reuse facility will – at full project build out – displace between 25,000 AFY (40 percent) and 30,000 AFY 50 percent of the total drain water produced in the Grasslands Drainage Area (GDA) - about 60,000 AFY.

The TDS concentration ranges from 3500 mg/L to 4000 mg/L. The average TDS of drain water at the discharge from the San Luis Drain at Site B is 3300 mg/L (2005-2013). Salt-tolerant crops, like Jose Tall Wheatgrass, are grown in the SJRIP area, which consists of up to 6200 acres of fields, irrigation channels, drainage ditches, conveyance facilities and farm structure; about 2000 acres of the SJRIP are tiled with some of these areas operating since 2002. The eastern project area is comprised of 3873 acres (out of about 4000) planted with salt-tolerant crop species. The western project area consists of 1901 acres that have been purchased, but have not yet been planted with salt-tolerant crops. The Panoche Drainage District has been the lead CEQA agency for the SJRIP.</td></tr>
<tr><td>Constituent Salts or Nutrients Managed</td><td>Salt accumulation areas effectively manage all salts, nutrients and other constituents. However, management techniques such as habitat modification (modifying drains to discourage nesting, as well as the creation of a pilot mitigation site to provide clean-water nesting habitat), diligent water management, and bird hazing need are being and conducted and need to continue in order to limit the exposure of plants and animals (killdeer, black-necked stilts, American avocets, red-winged blackbirds, San Joaquin kit fox, etc.) to trace elements, such as selenium, boron, and mercury. The on-going biological monitoring program needs to be continued to document the impacts on sensitive species.</td></tr>
<tr><td>Applicability</td><td>The westside region is composed primarily of agricultural land, which has poor drainage and relatively high concentration of salts, selenium, boron, and other naturally-occurring</td></tr>
</table>

Salt Accumulation Areas: San Joaquin River Water Quality Improvement Project (SJRIP)	
	constituents. The poor drainage is a result of the presence of impermeable shallow clay layers (including the Corcoran Clay) that prevent irrigation water from infiltrating into the deeper groundwater aquifers, resulting in trapped irrigation water forming a shallow, or perched, water table. Without an outlet, the highly saline waters accumulate in the root zone close to the ground surface and reduce crop productivity. The high selenium levels in the drainage water are toxic to wildlife at certain concentrations and create challenges for safe off-farm drainage and disposal of the water. The stakeholders of the drainage area are implementing activities, such as SJRIP, to maintain crop productivity in the region and to manage subsurface drainage water.
Practice Benefits and Impacts	The principal benefit of this approach is that it is a viable means of accumulation of salt in a relatively small lowland area. SJRIP would receive 25 percent of all drain water from the GDA, or about 15,000 AFY. The GDA drain water, which has a current average TDS of about 5,000 mg/L is retained on-site and is not allowed to discharge to the San Luis Drain and Mud Slough through the Grassland Bypass and ultimately to the San Joaquin River, thus helping to meet the compliance objective at Vernalis. Phases 2 and 3 include treatment of the drain water to remove salt, selenium, and boron and to "dispose of the removed elements to prevent discharge into the San Joaquin River… The remaining salt will be deposited into approved waste units that will result in additional reductions in salt and selenium discharges into the San Joaquin River and will maximize improvement in water-quality and meet reductions needed for future water-quality objectives." (Harvey & Associates, 2012). Until Phases 2 and 3 are implemented salt will continue to accumulate in the shallow perched zone underlying the SJRIP area.
Effectiveness Documentation	The effectiveness of the GBP in reducing salt and salinity loading to the San Joaquin River via the San Luis Drain and Mud Slough: SFEI. 2013. Grassland Bypass Project Annual Report 2010-2011. Prepared for the Grassland Bypass Project Oversight Committee. November 2013. http://www.sfei.org/gbp/reports
Supporting Documentation	Biological Monitoring Program: H. T. Harvey & Associates. 2012. San Joaquin River Water Quality Improvement Project, Phase I: Wildlife Monitoring Report, 2011. Prepared for the San Luis and Delta Mendota Water Authority and the Grassland Basin Drainers. File No. 1960-14. June 2012. http://www.sfei.org/gbp/sjrip Reclamation Pilot Study http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=8298

Salt Accumulation Areas: San Joaquin River Water Quality Improvement Project (SJRIP)	
Implementation: Planning Level Costs	The primary costs for implementation are: ▪ Administrative/contract costs ▪ Purchase land ▪ Provide engineering for irrigation and drainage systems ▪ Install and maintain irrigation channels ▪ Install and maintain drainage (drain lines and ditches) ▪ Plant selected forage crops ▪ Design treatment system ▪ Provide capital costs for treatment system ▪ Provide O&M Costs for treatment system ▪ Pay for salt disposal at approved waste units ▪ NEPA/CEQA compliance ▪ Other permitting
Implementation: Status and Potential	SJRIP is currently in Phases 1 and 2. By the end of 2015 all 6000 acres should be developed, however Panoche Drainage District is considering purchasing additional lands. Less than 2000 acres currently have tile drainage systems; the ultimate goal is to have tile drains beneath about 3000 acres. Phase 3 will be designed based on information developed in the various pilot treatment systems that are currently underway.
Implementation: Monitoring Documentation	See Effectiveness Documentation and Supporting Documentation
Implementation: Other Regulatory Approvals or Requirements	NEPA/CEQA analysis will be required for the future phases of SJRIP.
Website:	http://www.sfei.org/gbp/sjrip http://www.waterboards.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_att_d.pdf

Salt Accumulation Areas:

Tulare Lake Bed

Description

The San Joaquin River Water Quality Improvement Project (SJRIP) and the Tulare Lake Bed are two of the larger salt accumulation areas in the Central Valley. The Tulare Lakebed is located within the Tulare Lake Basin within the southern portion of the San Joaquin Valley. The Tulare Lake Basin, comprising approximately 10.5 million acres, is a mixture of federally owned National Parks, agricultural land, and municipalities. The Basin is essentially a closed system, draining only into the San Joaquin River in extreme wet years (Central Valley Regional Water Quality Control Board [RWQCB] 2004).

The historical Tulare Lakebed is a subarea of the Tulare Lake Basin located just southwest of the town of Corcoran. Prior to the twentieth century, lake levels and boundaries would fluctuate as a result of variations of inflow from the major tributaries, with a maximum area of approximately 800 square miles in 1868. The lakebed became dry in 1898 and 1899. Subsequently, the lakebed was developed for irrigated agriculture and, combined with upstream dam construction, the portion of the lakebed which can experience flooding in wet years has shrunk to less than 200,000 acres (Tulare Lake Basin Water Storage District [TLBWSD] 2012).

Underlying the majority of western and southern Tulare Lake Basin is the impermeable Corcoran Clay, the primary of several clay layers, which separates the groundwater into a perched groundwater table and a deeper groundwater table. In the vicinity of the Tulare Lake Bed, the Corcoran Clay is encountered at a depth of about 600-700 ft and is roughly 100 ft thick. The perched groundwater table above the clay can be encountered as shallow as 5 feet below ground surface. It is estimated that the EC of this shallow groundwater is in the range of 5,000 to more than 35,000 µS/cm (TLBWSD, 2012).

The high salinity in the groundwater is a result of several factors. Since this a closed basin with negligible surface or groundwater discharges, salts accumulate in the perched groundwater beneath the lake basin. In the past 40+ years, application of state project water for irrigation has added salts to the basin, but the historic salt levels in the soils prior to agricultural development are the primary problem. This is why the Westside soils of the Central Valley have higher saline levels than the soils on the East side. This situation was created over thousands of years and without a drainage outlet salts continued to build up within the Tulare Lake Bed. With no drainage out of the Tulare Lake Basin, agricultural operations in the lakebed have constructed a drainage collection system and three evaporation basins for the accumulation of salts rather than allowing

Salt Accumulation Areas: Tulare Lake Bed	
	the salts to continue to increase in the groundwater. Under the existing Water Quality Control Plan for the Tulare Lake Basin (Second Edition) (CVRWQCB 2004), the groundwater basin under the lakebed has MUN, AGR, and IND2 beneficial uses. And as a result of its beneficial use designation as MUN, the groundwater underneath the Tulare Lakebed is currently protected by water quality objectives and criteria established to protect a drinking water supply. More stringent regulations related to selenium levels and potential impacts to waterfowl have caused many evaporation basins to close. With their closure, stakeholders are searching for a solution to their drainage problems.
Constituent Salts or Nutrients Managed	Salt accumulation areas effectively manage all salts, nutrients and other constituents. The Basin Plan (CVRWQCB, 2004) states that: *"the EIRs focused on impacts to wildlife and found all basins pose a risk to birds due to salinity and avian disease. To prevent and mitigate these impacts, waste discharge requirements for evaporation basins, adopted in 1993, include the following:* ▪ *Removal of attractive habitat, such as vegetation.* ▪ *A program for avian and waterfowl disease prevention, surveillance and control.* ▪ *Closure and financial assurance plans.* ▪ *Drainage operation plan to reduce drainage.* *Basins with concentrations of selenium greater than 2.7 µg/l in the drainage water have potential for reduced hatchability and teratogenic impacts on waterfowl. To prevent and mitigate these impacts, waste discharge requirements for these basins, adopted in 1993, include those listed above and the following:* ▪ *Intensive hazing prior to the breeding season.* ▪ *Egg monitoring.* ▪ *Basin reconfiguration, if necessary, to minimize attractiveness to waterbirds.* ▪ *Wildlife enhancement program, alternative habitat and/or compensatory habitat."*
Applicability	The Tulare Lake Basin is a closed system, and there is currently no drain outlet. Salt is imported from surface water supplies, which are primarily used to irrigate the majority of the 3 million acres of agricultural land (Sholes 2006). Water that is not used by crops will eventually percolate into the ground, taking the imported salt from water supplies and leaching additional salt from areas with saline soils into the shallow groundwater. Within the closed Tulare Lakebed, groundwater is not able to drain out, and this increases the concentration of salt in groundwater. These high salt concentrations (ranging from 5,000 to 35,000 µS/cm [TLBWSD 2012]) reduce crop yields throughout

Salt Accumulation Areas:

Tulare Lake Bed

	the lakebed and make the shallow perched groundwater unusable for agriculture or municipal purposes. Currently the groundwater source under the Tulare Lakebed is designated as having MUN and AGR beneficial uses. A Basin Plan Amendment (BPA) to add a WILD beneficial use designation is being discussed due to the location of the evaporation ponds in the Pacific Flyway. According to the current Basin Plan, the water quality objectives for salinity are: ▪ *All ground water shall be maintained as close to natural concentrations of dissolved matter as is reasonable considering careful use and management of water resources.* ▪ *The maximum annual increase in EC for Tulare Lake is 3 μmhos/cm (calculated using monitoring data for a cumulative average annual increase over a 5 year period).*
Practice Benefits and Impacts	With no drain outlet readily available for the lakebed, stakeholders (through the Tulare Lake Drainage District [TLDD]) have constructed and operated a drainage system with three evaporation basins (North Evaporation Basin, Hacienda Evaporation Basin, and the South Evaporation Basin) to accumulate salts and maintain agricultural productivity. Agricultural drainage water is conveyed to the evaporation basins through a series of sub-surface pipelines and open ditches. The water storage capacity of these three interconnected basins is approximately 17,000 AF. In recent years, the TLDD has filled their evaporation ponds to capacity as a result of increased demand of sub-surface drainage water disposal. It is estimated that the annual average evaporation capacity of the three basins is approximately 17,000 AF (TLDD 2012). The TLDD is proposing to construct a new fourth evaporation basin, the Mid Evaporation Basin (MED) to manage and dispose of additional drainage water. The new basin would encompass 1,800 acres, along with inlet, pipeline and control structures.
Effectiveness Documentation	
Supporting Documentation	
Implementation: Planning Level Costs	The primary costs for implementation are: ▪ Administrative/contract costs ▪ Purchase land ▪ Provide engineering for evaporation ponds and associated infrastructure

Salt Accumulation Areas: Tulare Lake Bed	
	▪ Provide capital costs for new evaporation ponds ▪ Provide O&M costs for existing and new evaporation ponds ▪ NEPA/CEQA compliance ▪ WDRs (see Implementation: Other Regulatory Approvals or Requirements)
Implementation: Status and Potential	The evaporation ponds have been operating – in various configurations – for more than 30 years.
Implementation: Monitoring Documentation	See Effectiveness Documentation
Implementation: Other Regulatory Approvals or Requirements	The designation of the MUN beneficial use is allowed by the State Water Resources Control Board (SWRCB) under Resolution No. 88-63. Per this order, all surface or groundwater in the State is designated, by default, to have an MUN beneficial use with a few exceptions. The exceptions for both surface and groundwater include waters where: ▪ *The TDS exceeds 3,000 mg/L (an EC of 5,000 µS/cm) and it is not reasonably expected by Regional Boards to supply a public water system, or* ▪ *There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use by using either Best Management Practices or best economically achievable treatment practices.* CV-SALTS, in collaboration with the TLDD and TLBWSD, is currently supporting a project intended to de-designate MUN and AGR from a portion of the Tulare Lakebed because it can serve as an appropriate archetype or template for studies in which the purpose is to evaluate the appropriateness of the MUN and AGR beneficial uses on a designated groundwater body. Moreover, the outcome of the de-designation effort can help advance the purpose and requirements associated with the development of the SNMP for the Central Valley region in that it may provide a template that can be utilized to identify areas that may serve as salt sinks until alternate treatment, disposal and/or export alternatives are developed. Environmental Compliance with NEPA and CEQA would be required in order to plan and implement any new evaporation ponds. *"Persons proposing new evaporation basins and expansion of evaporation basins shall submit technical reports that assure compliance with, or support exemption from, Title 23, California Code of Regulations, Section 2510,* et seq.*, and that discuss alternatives to the basins and assess potential impacts of and identify appropriate mitigations for the*

Salt Accumulation Areas: Tulare Lake Bed	
	proposed basins." (CVRWQCB, 2004)
Website:	http://www.swc.org/about-us/member-agencies-list/55-tulare-lake-basin-water-storage-district http://www.epa.gov/region9/water/wetlands/tulare-hydrology/tulare-summary.pdf

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Section 6
Brine and Salt Transportation Options

6.1 Trucking and Rail

There are five ways to transport salt out of the valley:

- Surface water (*e.g.*, San Joaquin and Sacramento Rivers)
- Trucking dry salt
- Transporting brine concentrate to a WWTP via trucks
- Transporting brine concentrate to a WWTP via rail
- Conveying brine through a regional brine line to an existing WWTP or to a new outfall pipeline with pre-treatment as needed

In this section, three of these options are reviewed: transporting brine concentrate to a WWTP via truck or rail and a regional brine line (transportation of salt via surface water is discussed in Section 5.3).

The SSALTS team conducted two meetings with EBMUD (April 14, 2014 and July 9, 2014) in order to develop an understanding of the efficacy of transporting Central Valley brine concentrate to their WWTP for ultimate disposal. As part of the first discussion, the SSALTS team developed a series of questions for EBMUD with regard to tucking versus rail transportation. EBMUD's responses to these questions were provided by email on July 7, 2014 and discussed with EBMUD's staff on July 9, 2014.

Transportation of the brine to EBMUD's WWTP is the major engineering and economic challenge. The transportation could be by truck, rail or a regional brine line. This would likely occur in phases (trucking until rail is commissioned, rail until the brine line is constructed). Note that in the answer to Question 6, there is a current capacity limit to received trucked waste at about 1 MGD. While additional bays can be built in a relatively short period of time to receive additional loads via truck, for the purposes of the alternatives analysis, a Central Valley Brine Line (CVBL) is the transportation option that is evaluated.

Q&A with EBMUD[11]

1. Would EBMUD re-equip the rail line to the WWTP as part of its services (*i.e.*, not looking for project partner)?

Two rail spurs are near EBMUD's wastewater treatment plant (WWTP) in Oakland. The spur at the east end of the plant has been dismantled, but could be re-established. The spur along Engineer's Road, on the west side of the plant, is owned by Burlington Northern and Santa Fe Railway (BNSF), with third-party operations. We would need to determine how best to convey material from either spur to EBMUD's plant's operations.

*EBMUD would endeavor to re-equip the rail line to the WWTP, given adequate signals that such an investment would be worthwhile (*i.e.*, adequate return on investment, at low risk). With significant*

[11] Steven Sherman, Stephanie Cheng, Jacqueline Kepke

financial assistance or large, stable sources of supply lined up, EBMUD could move forward with re-equipping the rail line. Ideally, the costs for this effort would be borne in part by EBMUD (and paid off by future revenue from customers) and in part via a grant or partner.

Prior to or in the absence of a re-connected rail spur, a possible alternative could be to rail-haul brine from the Central Valley to a transfer point on Union Pacific Railroad's line in Fremont, and then to truck the material approximately 30 miles to EBMUD's WWTP. Below is an example of transferring liquids from a rail car to a tanker truck (location unknown, no citation). The combined cost of these two handling methods may make the rail/truck transfer option less economically desirable than either long-distance hauling by truck or rail.

2. What is the cost per gallon of brine for rail delivery? Range of volumes that each tanker car transports?

The total cost per gallon of brine delivered by rail to EBMUD awaits analysis. EBMUD assumes that an average tanker car can transport approximately 20,000 gallons of brine, which is the holding capacity of nearly 4 tanker trucks. The total cost would consist of EBMUD's tip fee, which currently is 4 to 8 cents per gallon depending on the TDS concentration, and the cost that the rail company charges the customer for delivery by rail to EBMUD. Whether there would be an additional charge by EBMUD to defray the costs of transportation/materials conveyance upgrades is not determined.

3. What is the cost per gallon of brine for tanker truck delivery? Range of volumes that each tanker truck transports?

The cost for truck delivery of brine consists of two parts: transport costs and tip fee. Truck transportation is arranged by the customer. EBMUD can provide potential customers with a list of haulers that currently have permits to deliver, as well as information on the permitting process for prospective haulers. Generally, EBMUD's permitting process takes 3 days to 2 weeks to complete, and permits cost $300 annually.

Typically, long-haul tanker trucks have a 5,000 or 6,000 gallon capacity (range: 1,000 to 6,000 gallons). Trucking cost is determined through negotiation between customers and their haulers. EBMUD does not provide truck hauling service.

*Tip fees for brine are set and revised periodically by EBMUD's Board of Directors. EBMUD's tip fees depend in part on the concentration of total dissolved solids and on the extent to which brines contain other constituents that require treatment. Generally, tip fees are 4 to 8 cents per gallon, depending on TDS concentration (*e.g.*, 4 cents/gallon, if less than 100,000 mg/L), as of 2014. Lower costs may be negotiated for long-term contracts with large customers. Loads are charged per-gallon tip fees on a truck capacity basis.*

4. **How is mileage/distance factored in? One would presume that it is not linear, *e.g.*, the cost/gal/mile is likely higher for shorter runs because the time/effort to load and off load the brine is averaged over fewer miles.**

*For typical long-haul tanker trucks, it is estimated that the trucking cost within a 250 mile radius (bounded by Tulare in the south and Redding in the north) is approximately 15 to 20 cents per gallon. Within 50 miles, the estimated truck cost is approximately 8 to 10 cents per gallon. Thus, there are economies of cost associated with greater distance (*e.g.*, first 50 miles, 8 to 10 cents/gallon, next 200 miles, 7 to 10 cents/gallon), due to minimum haul charges and initial handling fees.*

5. **For non-organic brine, can the rail tanker cars be staged at regional locations so that a single locomotive can pick up several cars along the way (milk run)? How long can the cars be staged? Or perhaps how many cars can be staged? Is there an optimal number of cars? Can Hilmar Cheese brine be staged, or is the BOD too high?**

This conceptual approach would need to be discussed with the rail line. A "milk run" can work effectively for trucked waste to EBMUD; various existing customers use this approach.

6. **For either option, is there a limit on the brine concentration (just in terms of transportation, not treatment)?**

Not at this time. The main issue would be if the salt can stay in solution. There is a physical limit to how many trucks EBMUD could receive, based on the number of unloading bays at the plant headworks and estimated time to unload. EBMUD initially estimated that up to 200 trucks per day (at 5,000 gal/truck, 1 million gallons per day) could be received at the unloading bays.

7. **Can greenhouse gas effects be estimated on a unit basis for both trucking brine and for rail delivery?**

A US EPA study has estimated that trains are 2 to 4 times more fuel efficient than trucks on a ton-mile basis. Trains emit one-third the GHG emissions of trucks on a ton-mile basis. The US EPA Smartway program encourages shippers to use freight rail: "For shipments over 1,000 miles, using intermodal transport cuts fuel use and greenhouse gas emissions by 65 percent, relative to truck transport, alone." The program holds that a single train trip can remove 280 trucks from highways. (See http://www.epa.gov/midwestcleandiesel/sectors/rail/materials/ls.pdf)."

8. **A potential pilot project was proposed for the rail disposal option to uncover the push points and it was proposed that Hilmar Cheese Company (HCC) might be a good candidate. If HCC is willing, can EBMUD determine if it would be possible to link up rail lines between HCC and EBMUD's WWTP?**

*EBMUD staff recently discussed with HCC a potential pilot program, however HCC did not indicate strong interest, citing anticipated level of effort, complexity, and low economic gain relative to existing methods of off-site handling (*i.e., *trucking).*

6.2 Regional Pipeline

Another option for brine concentrate disposal is a regional brine line (CVBL) to pump brine to EBMUD or another bay/ocean disposal location as discussed in Section 5.5. For the purpose of developing this as a concept-level planning option, only potential alignments to EBMUD were analyzed (Figures 6-2 through 6-4). Two alternative alignments were analyzed for this report: Alternative 1 follows a gas pipeline alignment (roughly paralleling the 5 Freeway) along the western side of the valley, turning west near Tracy and then north near Fremont. Alternative 2 crosses the coastal mountains further to the south near Panoche Junction. This alternative is not preferred, because it would not be able to collect brine concentrate from IAZs 22, 12, and 9. Also, the lift over the coastal range is greater than in Alternative 1 (Figure 6-5). A task for a future phase of SSALTS would be to conduct a search to see if there is an abandoned pipeline that could be repurposed for brine disposal.

Using a highly corrosion-resistant pipe material like high-density polyethylene (HDPE) for the CVBL would be beneficial due to the potentially corrosive brine being carried by the pipeline and the expectation of corrosive soils along significant portions of the alignment. The HDPE pipe material requires no corrosion maintenance. The fusion welded joints for HDPE pipe exhibit zero leakage, greatly reducing the risk of re-introducing high TDS water into the soils and groundwater along the pipeline alignment.

HDPE pipelines are ideal for open country alignments because long lengths of pipe can be fused together aboveground and then rolled into the trench, allowing for high-production rates and associated savings during installation. The flexibility of the HDPE material allows easy accommodation of small changes to line and grade during installation to accommodate unexpected site conditions without the need for special fittings. The interior of the HDPE pipe is very smooth, resulting in low hydraulic friction and associated lower pumping costs. HDPE pipe is available in a variety of pressure classes, allowing the pipeline to be tailored to the hydraulic grade line of the CVBL alignment.

Available diameters for HDPE pressure pipe would accommodate flows for the upper (southerly) reaches of the CVBL with a single pipe. Flows in the lower reaches would exceed the efficient hydraulic capacity of a the maximum diameter (63") for a single HDPE pipeline. In the lower reaches, two HDPE pipelines, placed side-by-side in the same trench could be used. Alternatively, a single large-diameter concrete or steel pipe could be used where the flows exceed the efficient hydraulic capacity of a single HDPE pipe. Adequate provisions for internal and external corrosion, including cathodic protection, and specialty linings and coatings, would need to be considered for these alternate pipe materials.

There will also need to be a series of pump stations required along the CVBL to deliver the brine to EBMUD or other potential discharge locations. For the purposes of developing a cost estimate, the following assumptions were made:

- Seven pump stations would be required at strategic locations, ranging from 20 to 60 miles apart
- Each pump station would function essentially as an in-line booster pump station
- Pumping hydraulics assume that HDPE pipe is used, with dual lines for the last three pumping legs

6.3 Concept Level Cost Estimate for Regional Brine Line

A concept-level cost estimate was developed for SSALTS Phase 2 based on estimated flow requirements (Table 6-1) and the following parameters:

- Alignment Alternative 1 was used as described in the first paragraph of this section.
- The total length of the pipeline alignment is 281 miles.
- The feed water volume and brine concentrate volumes are taken from Table 2-3. Accumulation of salt on the Tulare Lake Bed was allowed to occur.
- The mileage within each IAZ are from a GIS analysis and shown on Figure 6-4.
- The pipeline diameter is based on the estimate brine volumes and velocity in the brineline. Based on the estimates of volumes and flow rates derived from Table 2-3, and a target of maintaining velocities of approximately 6 ft/sect, a 24-inch diameter pipeline would be sufficient for the first 50 miles of the CVBL (through IAZs 21 and 19), a 36-inch pipeline would be sufficient for IAZ 15 (through mile 72) and a48-inch pipeline would be required for miles 72 through 135. Two 48-inch pipelines would be required for the remainder of the pipeline – miles 135 to 281.
- A unit cost of $6/linear foot/diameter-inch was used for rural areas (up to mile 135). A unit cost of $15/linear foot/diameter inch for miles 135 to 281m because the pipeline crosses the coastal range (through a pass) and because of the urbanization in the East Bay.
- Based on assumptions in Section 6.2, the pump station capital costs would be $258M. Annual power costs would be about $58.8M, and maintenance would be $13M, based on an 5 percent of capital costs.

The estimated capital cost of the CVBL to accommodate the potential flows shown in Table 6-1 is $771M. Together with the pump station capital cost of $258M, the total cost for the CVBL is $1029M.

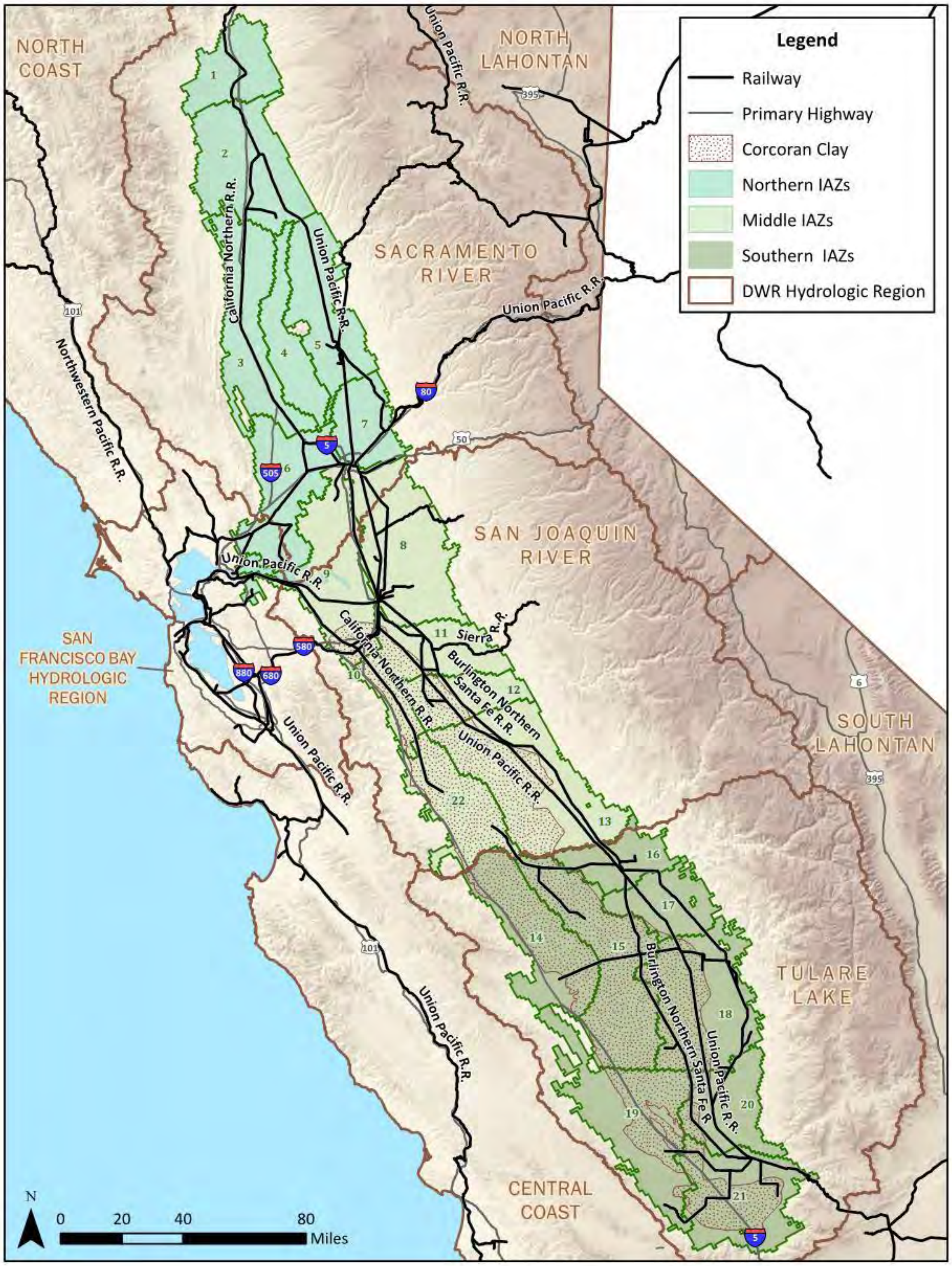
Note that the incremental cost to increase the size(s) of any reach of pipeline is relative lower compared to the incremental increase in capacity. For example, for the upper reach, an increase in pipe diameter from 24-inch to 30-inch would increase the carrying capacity of the pipeline by approximately 50 percent, while the capital cost would increase by only about 25 percent. Detailed sizing and optimization of the pipeline segments and other facilities would be conducted during future planning if a brine line is part of the selected implementation plan.

Also, based on experience with other brine lines, in particular the Santa Ana Regional Interceptor (SARI line) owned and operated by SAWPA, operation and maintenance of a the brine line can be very challenging. Significant planning must be taken to anticipate the potential for chemical reactions, precipitation and scaling and pretreatment of brine at the desalters may need to be considered.

Table 6-1 Potential Cost for the Central Valley Brine Line

IAZ	Volume of Water to be Pumped and Treated		No of 25 MGD Modules	No. of Wells/Drain Water Sump Pump Facilities	Brine Volume		Miles Along CVBL		Miles within Each IAZ	Pipeline Diameter	Pipeline Cost	Brine TDS
					In IAZ	Cumulative	From	To				
	(MGD)	(gpm)			(MGD)	(MGD)	(mile)	(mile)	(mile)	(inches)	($ x Million)	(mg/L)
21	128.3	89,118	6	119	12.8	12.8	0	20	20	24	$15	3,350
19	86.5	60,059	4	80	8.6	21.5	20	50	30	24	$23	113,000
15	104.1	72,321	5	96	10.4	31.9	50	72	22	36	$25	10,000
14	148.8	103,347	6	138	14.9	46.8	72	135	63	48	$96	33,750
22	100.0	69,430	4	93	10.0	56.8	135	180	45	48x2	$120	11,600
10	106.6	74,043	5	99	10.7	67.4	180	212	32	48x2	$85	8,420
9	74.3	51,589	3	69	7.4	74.9	212	225	13	48x2	$35	9,610
Coastal Range to EBMUD							225	281	56	48x2	$373	
Totals	**748.7**	**519,907**	**33**	**693**	**74.9**						**$771**	
Flow-Weighted Average												**25,429**

Figure 6-1 Rail Lines in the Central Valley of California



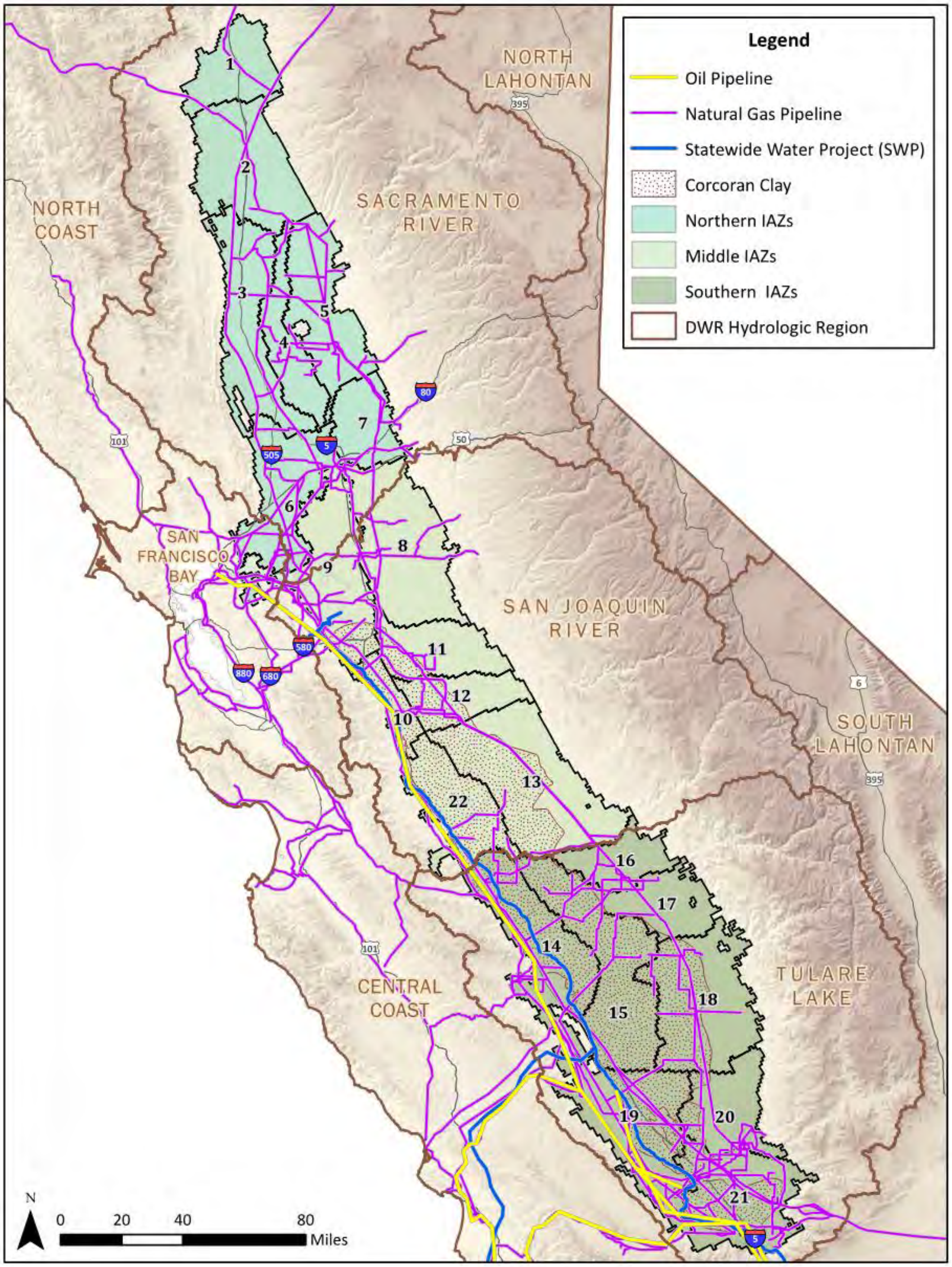


Figure 6-2 Oil & Gas Pipelines in the Central Valley

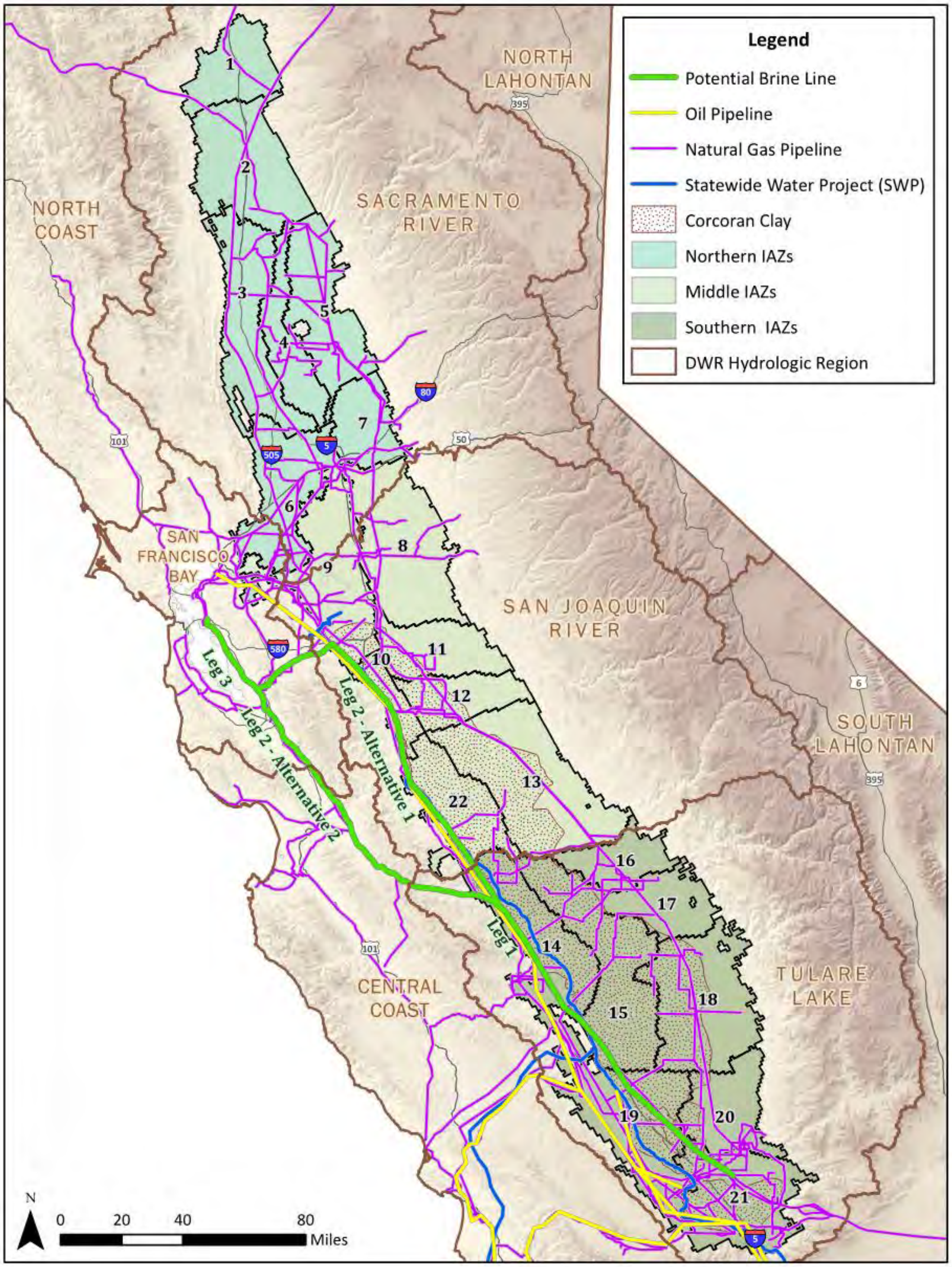


Figure 6-3 Potential Alignments for the Central Valley Brine Line (CVBL)

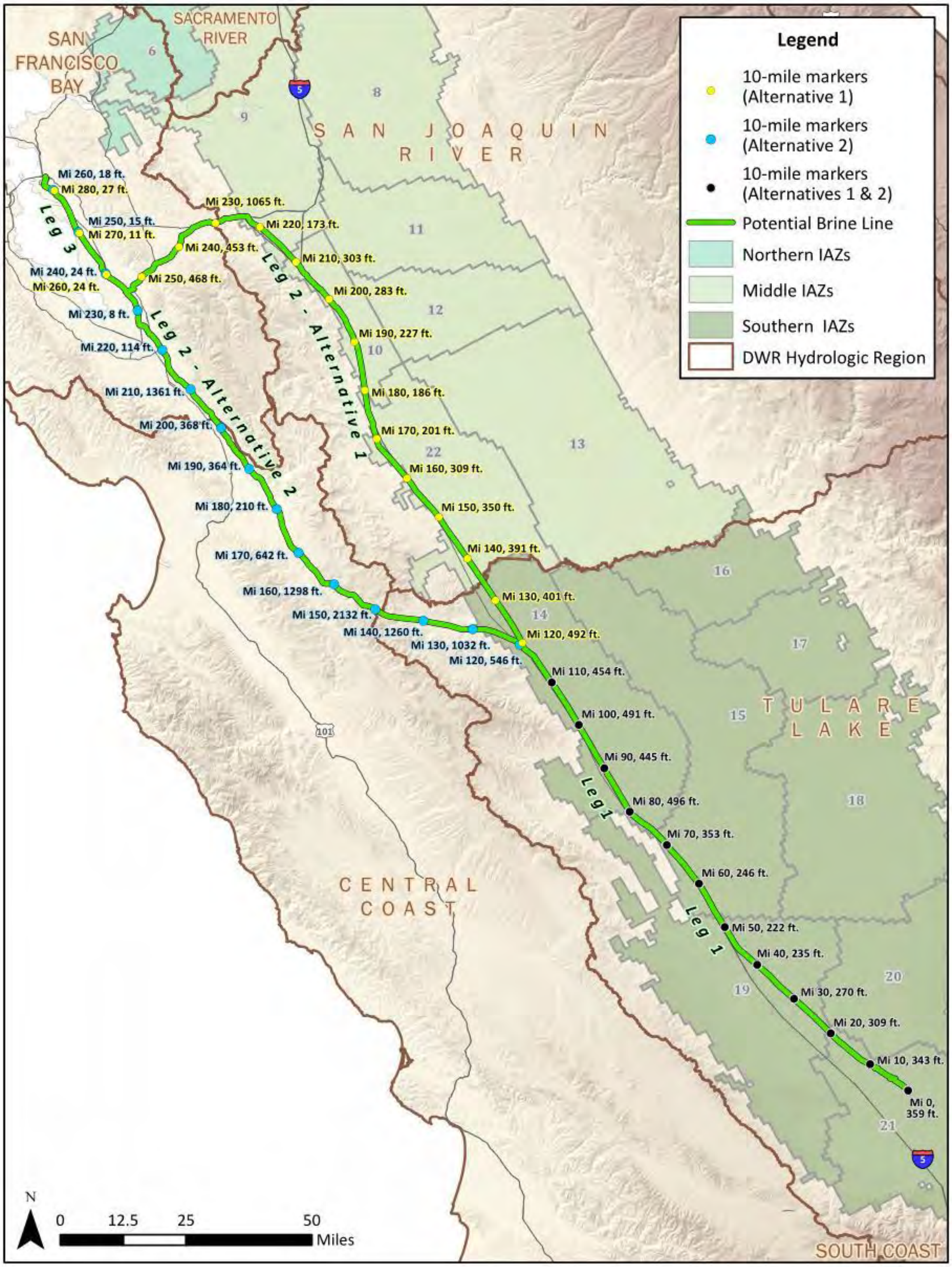


Figure 6-4 Potential Alignments for the Central Valley Brine Line (CVBL): Mileage and Elevation

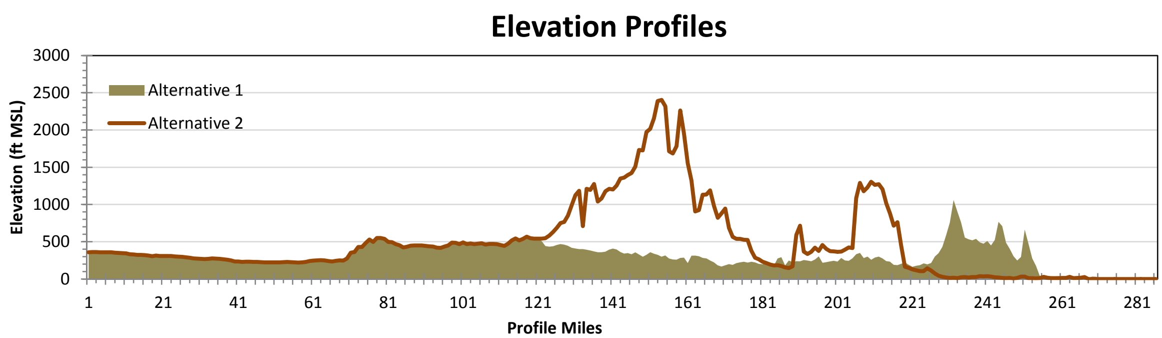


Figure 6-5 Elevation Profiles for Potential Central Valley Brine Line (CVBL) Alignments

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Section 7
Salinity Management Alternatives

This section describes a variety of alternative salt management strategies. The no action alternative is described in Section 7.1 and summarizes the economic impacts of increased salinity in the Central Valley to the state of California (Howitt *et al.*, 2009). All of the other alternatives include transportation of brine to the San Francisco Bay Area – either an existing POTW, such as EBMUD or an alternative location. A brine line (CVBL) was evaluated for transportation because of potential capacity limitations for the other WWTP-transportation options (truck and rail). The Bay Area disposal option potentially has the capacity to manage all of the current salt accumulation in the Central Valley. The other disposal option for managing a significant percentage of the salt mass accumulation is the San Joaquin River RTMP. It is likely that a mixture of all salt disposal storage options will ultimately be implemented, similar to Alternative 4. However, even if all of the other salt management options were to be implemented to their maximum potential (without the Bay Area/ocean discharge), they could not come close to addressing the total salt accumulation to be managed; hence a brine line with Bay Area/ocean discharge would still be needed. RO is evaluated as the treatment technology in this report; emerging technologies will be evaluated and estimates of costs developed as that information becomes available.

Implementation of source control BMPs are included in all of the alternatives and should be considered to the extent appropriate on a case-by-case basis. However, such practices can potentially have a very small cost-benefit ratio under certain circumstances and are not necessarily intended to be applied everywhere or as a first priority. It may be more beneficial to have the affected party participate in a regional project rather than invest in source control.

In Alternative 1, the brine from the middle and southern Central Valley IAZs would be transported to EBMUD for disposal through their WWTP. Brine generated as part of the treatment of groundwater in IAZ 6 is assumed to be disposed of through deep well injection. A northern CVBL to discharge to the Bay area is another option for evaluation in future phases of SSALTS. Alternative 2 is similar to Alternative 1, except that an alternative outfall in San Francisco Bay is proposed for discharge rather than through EBMUD's outfall. Another ocean disposal option that was discussed and evaluated in the Phase 1 Draft Final Report was the concept of the San Luis Ocean Disposal Outfall and was one of the major alternatives analyzed in Reclamation's San Luis Feature Re-Evaluation EIS. This project has many challenges and has not moved forward, and was ranked low in the sustainability analysis among all of the various salt management options. Nonetheless, it is still an alternative that could be re-considered if conditions changed. In Alternatives 3 through 4, the volume of brine transported to EBMUD would be reduced through the introduction of other treatment, conveyance and disposal options.

7.1 No Action

In the no action alternative, the status quo prevails – salinity programs that are currently in place would continue, but no new programs or projects would be started. State and Federal policies and regulations that drive salinity management behavior would also remain unchanged in the future. The SWRCB commissioned an economic study by UC Davis (Howitt *et al.*, 2009). The study team was tasked with determining the economic impact of increasing salinity to the state of California. The study concluded:

> *The study results showed that if salinity increases at the current rate until 2030, the direct annual costs will range from $1 billion to $1.5 billion. Total annual income impacts to California will range between $1.7 billion to $3 billion by 2030. The income impacts to the Central Valley will range between $1.2 billion and $2.2 billion.*
>
> *The production of goods and services in California could be reduced from $5 billion to $8.7 billion a year. The Central Valley output reduction would range between $2.8 billion to $5.3 billion. Furthermore, there is $145 million per year of non-market costs. In terms of job losses the increase in salinity by 2030 could cost the Central Valley economy 27,000 to 53,000 jobs. California could lose 34,000 to 64,000 jobs. In short, the problem is substantial and growing steadily. The magnitude of the economic and employment losses justifies a more detailed study of remedial action and correction policies.*

Hence, the other alternatives can be compared with the no action alternative in assessing benefits and costs. Costs presented in the alternatives tables below are conceptual estimates that may change significantly when subject to further analysis.

7.2 Alternative 1 – San Francisco Bay Discharge to EBMUD, Deep Well Injection in IAZ 6; and Disposal of Brine for Hydraulic Fracturing

This alternative combines the components summarized the Alternative 1 section of Table 7-1 into potential salt management strategies. Some of the costs cannot be quantified at this time; other costs will be quantified – to the extent available – as part of Phase 3 of SSALTS (Evaluate Potential Salt Disposal Alternatives to Identify Acceptable Alternatives for Implementation). Additional information about O&M costs will be included in Phase 3, to the extent available. The description and cost for each of the components for Alternative 1 in Table 7-1 are provided below; please refer back to subsections or tables for more details.

Middle and Southern Central Valley IAZs

- **Source control BMPS**. Unquantified benefit/cost, but a Delta solution would likely have a very significant positive impact on salt accumulation in the Central Valley[12].
- **Extraction facilities**. Extraction would occur from shallow groundwater, perched water, and agricultural drain water. (Section 4.3)
- **Regional desalters**. (Section 4.3)
- **Post-RO treatment for trace constituents**. (Section 5.5.1)

[12] http://baydeltaconservationplan.com/Home.aspx

- **CVBL**. (Section 6.3)
- **CVBL pump stations**. (Section 6.3)
- **Treatment/disposal at EBMUD**. (Section 6.1. At a tip fee of $0.04/gallon and a brine volume of 75 MGD, the EBMUD fees would be $1,096M.)
- **Biosolids exported from EBMUD to the Central Valley**. (Section 5.5.1. About $32 per ton to transport and apply biosolids to agricultural land outside of Alameda County. At 6 truckloads per day and 20 tons per truck (120 tons per day) could result in revenues of about $1.4M per year.)
- **Value of product water**. The middle and southern treatment systems could produce 909,000 AFY of product water, which would have a value of $909M at $1000/AF. (See Section 8 concerning potential beneficial uses of the product water.)
- **Revenue from hydraulic fracturing**. (Table 5.3)

IAZ 6

- **Source control BMPS**.
- **Extraction facilities**. Extraction would occur from shallow groundwater, perched water, and agricultural drain water. (Section 4.3)
- **Regional desalters**. (Section 4.3)
- **Deep injection wells (DIW)**. (Section 5.1)
- **Value of product water**. The middle and southern treatment systems could produce 909,000 AFY of product water, which would have a value of $909M at $1000/AF. (See Section 8 concerning potential beneficial uses of the product water.)

7.3 Alternative 2 – San Francisco Bay Discharge to an Alternate Outfall; Deep Well Injection in IAZ 6; and Disposal of Brine for Hydraulic Fracturing

This alternative is identical to Alternative 1, with the exception that the brine is discharged to a new outfall in the Bay Area rather than to EBMUD. This alternative was added to address concerns about potential population growth in the EBMUD service area and the long-term sustainability of their WWTP's excess capacity. ABAG (2013) projects the population of Alameda County to increase from 1,510,270 to 1,987,950 – a 32 percent increase from 2010 to 2040. Substantial engineering, land acquisition, CEQA, and permitting would be required for the outfall component of this alternative. A place-holder capital cost of $100M has been assumed. If this alternative is considered viable after the screening with the feasibility criteria in Phase 3, more detailed engineering will be required. Although the initial capital costs are higher, the O&M costs are substantially less, because tip fees would not be paid.

7.4 Alternative 3 – San Francisco Bay Discharge to EBMUD, Deep Well Injection in IAZ 6; and Disposal of Brine for Hydraulic Fracturing; Lower San Joaquin River Real Time Management Program

This alternative combines Alternative 1 and the components pertaining to the SJR RTMP into a salt management strategy. The Lower San Joaquin River Committee is currently developing estimates of assimilative capacity. As part of the development of a BPA for salt and boron in the LSJR, the LWA team is collaborating with the San Joaquin Tributaries Authority to determine the effects of Stanislaus and Vernalis operations on water quality at Vernalis under various upstream management alternatives. The operation effects will be determined by updating and utilizing the New Melones Operation Model which uses river conditions upstream of Vernalis and a depiction of Stanislaus and Vernalis operations to provide flow and water quality conditions in the lower San Joaquin River at Vernalis. Based on flow and water quality conditions in the lower San Joaquin River at Vernalis, the NM model can be used to assess assimilative capacity. The assimilative capacity will allow for the determination of the salt load that can be removed from the Central Valley through the LSJR RTMP and hence the estimated reduction in brine concentrate volume discharged through EBMUD or through an alternative discharge. This could also proportionately reduce the cost of infrastructure in the brine line and pump stations, for example. This information will be analyzed as part of Phase 3 SSALTS, to the extent that this information, including projected estimates of cost for the LSJR RTMP, will be available.

7.5 Alternative 4 – San Francisco Bay Discharge to EBMUD, Deep Well Injection in IAZ 6; and Disposal of Brine for Hydraulic Fracturing; Lower San Joaquin River Real Time Management Program; Salt Accumulation Areas

This alternative combines Alternative 1 and the components in the following tables pertaining to the archetype salt accumulation areas (SAA): SJRIP and the Tulare Lake Bed into a salt management strategy. Costs for the continued operation and expansion of SJRIP, including engineering, building and maintaining irrigation facilities, building and maintaining drains, treatment system costs (capital and operations and maintenance [O&M]), NEPA/CEQA, and compliance monitoring have not yet been determined by Reclamation.

For the Tulare Lake Bed, the future proposed evaporation basin area is approximately 1,850 acres, with construction costs ranging from $3,500 to $4,500 per acre of developed basin. Capital costs for the current construction of a large evaporation basin will also vary depending on topography of the site. If the salt accumulation area is constructed in an area with increased land slope the size of the levees and pump station requirements can dramatically increase causing a need to reduce the area of a given evaporation basin The range of construction costs noted above is an estimate of construction costs only and does not include the cost to purchase the land and meet CEQA and other permitting requirements. The three existing basins – North Evaporation Basin, Hacienda Evaporation Basin, and the South Evaporation Basin – were constructed in previous years and therefore are not included in the cost for this alternative.

On-going operation and administration costs for the large agricultural drainage system operations in the Tulare Lake Bed are typically in the range of approximately $70 to $90 per acre of drained land. For the purposes of Table 7-1, the construction costs for the new basin were estimated to be $8.33M (1850 acres * $4500/acre). O&M costs were estimated to be 10 percent of capital costs, since it is not known how many additional acres of drained land will be handled by this evaporation basin. With an annual evaporation rate of around 5 feet per year, the estimated annual evaporation capacity will be approximately 9250 AFY[13]. At an average TDS concentration, this evaporation capacity was converted to an equivalent flow reduction to the WWTP and is reflected in Table 7-1.

7.6 Summary of Cost for the Salt Management Alternatives

Table 7-1 is a summary of the concept level capital and O&M costs for each of the alternatives. Costs presented in this table are conceptual estimates that may change significantly when subject to further analysis. The components of each of the alternatives are explained in the preceding subsections. The bottom of Table 7-1 provides the summary cost information, including totals, contingency, and totals + contingency. The present value of life cycle costs and revenues over 30 years are estimated at an interest rate of 3 percent. The present value of life cycle costs is the cost that would be required to conduct the salt mitigation (extraction, treatment, and disposal) of each of the alternatives over a 30-year life cycle. The present value of revenues is the value of water sales of the product water over 30 years as well as other miscellaneous revenues such as sale of water for hydraulic fracturing and payment for management of biosolids. The last two rows express these values on the basis of product water produced. For example, for Phase 1, the present value of salt mitigation costs (extraction, treatment, and disposal) is $2181/AF over a 30 year life cycle. Likewise, the present value of future revenues from product water sales, brine water sales for hydraulic fracturing, and payment for management of biosolids from EBMUD is $655/AF over 30 years.

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[13] Roger Reynolds, Pers. Comm. August 29, 2014.

Fly Sheet for Table 7-1

Section 8

Phase 3 SSALTS - Evaluate Potential Salt Disposal Alternatives to Identify Acceptable Alternatives for Implementation

Phase 3 will build upon the work completed under previous phases by evaluating the range of in-valley, out-of-valley and hybrid salt management alternatives developed under Phase 2. Under this phase, SSALTS will develop feasibility criteria (*e.g.*, regulatory, institutional, economic, technological, etc.) to provide a basis for evaluating each alternative and complete the feasibility analysis. The outcome of this evaluation will be the identification and prioritization of acceptable salt disposal alternatives (*i.e.*, implementation measures) for incorporation into the developing SNMP for the Central Valley. Phase 3 includes the following tasks:

- *Task 3.1, Develop Planning Level Feasibility Criteria to Evaluate Alternatives* – Potential feasibility screening criteria for evaluation of salt management alternatives will be developed. Examples of screening criteria for consideration include the following categories or types: engineering, technology, economic, environmental, regulatory, and institutional. Consideration will also be given to the potential for an identified salt management practice to have wide applicability in the Central Valley or only be useful within a narrow range of circumstances. One of the criteria will be the effects of the proposed treatment and disposal alternatives on disadvantaged communities that rely on groundwater that has elevated concentrations of TDS and nitrate. Also, where there are regulatory roadblocks that have the potential to being removed or lessened, these will be identified in the overall project selection criteria. For example, most of these solutions could not work for POTWs under the current regulatory framework without an offset or alternative compliance policy. The project team will prepare a TM that identifies potential feasibility criteria, the method by which each proposed criterion will be used as a screening tool, and the approach that will used to apply the final selected criteria to the various alternatives to be evaluated. A draft TM will be submitted to the TAC for review and comment. Following revision, as needed, the TM will be submitted to the Executive Committee for review, revision (if needed), and approval.

- *Task 3.2, Perform Screening-Level Feasibility Analysis of Salt Management Alternatives* – Under this task, the project team will evaluate individual and/or combinations of in-valley and out-of-valley salt management alternatives using the feasibility criteria developed under Task 3.1.

- *Task 3.3, Prepare Phase 3 SSALTS Report* – The Phase 3 Report will be a cumulative extension of the Phase 1 and 2 Reports. The Report will (a) summarize work completed to date under Phases 1 and 2; (b) incorporate the results of the feasibility analysis completed under this Phase; (c) conclusions and recommendations based on the work completed in Phase 3; and (d) recommendations for salt management alternatives for inclusion in the SNMP as acceptable implementation measures. A Draft Phase 3 Report will be prepared and reviewed by the TAC. Once revised, a Final Draft Phase 3 Report will be submitted to the Executive Committee for review and comment. A Final Phase 3 Report will be prepared based on Executive Committee comments.

There are a number of issues that will be evaluated in Phase 3:

- An evaluation of the efficacy and economics of purchasing recycled water from EBMUD (or another WWTP) and transporting that recycled water in parallel pipelines in the same trench/alignment as the CVBL. Recycled water can be used as a non-potable (irrigation) source of supply and can also be used to recharge groundwater basins to improve water quality and help correct overdraft.

- A refined evaluation of alternative uses of the product water from desalters will be further refined. The product water will be of very high quality and irrigation of crops is not likely the best use of this resource. One option that will be evaluated is to transport the product water to southern California State Water Contractors through the California Aqueduct for a fee. This will serve to stabilize water supply and water quality in the State Water Project (SWP) and will make more irrigation water available for the Central Valley Project (CVP). For the purposes of this Phase 2 SSALTS concept-level cost estimate, a value for the product water of $1000/AF was assumed.

- An update to the market analysis for salt products and secondary products will be conducted.

- An evaluation will be made of potential improvements to the Bay-Delta system. Conveyance facilities have the potential of significantly reducing salt imported into the Central Valley via the CVP.

- Growing salt-tolerant crops at SJRIP serves as a *de facto* salinity treatment system, separating water (used for the beneficial use to grow crops - like Jose Tall Wheatgrass - for revenue) from a “brine concentrate” with concentrations equal to or greater than 20,000 mg/L. The perched water could be pumped directly into the CVBL. It is recommended that this perspective of SJRIP as a treatment system be studied in future Phases of SSALTS.

- A records search for an abandoned oil or gas pipeline will be conducted.

- An evaluation of the tradeoff between energy costs and EBMUD tip fees will be made for the use of second pass RO (reduce the brine volume [reduce tip fees to EBMUD], recover more product water, but at a higher energy and maintenance costs).

- An evaluation of a southern CVBL that would take brine generated in IAZs 21, 19, 15, and 14 to the Tulare Lake Bed proposed de-designation area for salt disposal and storage. Brine generated in IAZs 22, 10, and 9 would be transported to EBMUD for disposal. This would reduce the brine volume transported to EBMUD by about 46 MGD. Such an analysis would first need to be discussed first with the Tulare Lake Drainage District and Tulare Lake Basin Water Storage District representatives. The discussion may need to explore potential incentives for considering such an approach.

- An evaluation of engineering feasibility and cost of constructing a tunnel through the coastal range versus pumping the water over the range will be made.

- EBMUD will work with the SSALTS team to further evaluate issues associated with NPDES permit compliance and potential need for pretreatment. It is recommended that CV-SALTS collect groundwater and tail water samples in representative locations throughout the valley. EBMUD would analyze these samples as part of their in-kind contribution to the project.

- Evaluate – to the extent possible – the quantifiable costs/benefits of source control BMPs.

- Evaluate “multi-media” impacts of the alternatives that address salt management, *i.e.*, impacts to air, land, water supply, etc.

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Appendix A – Estimate of Landfill Costs at Kettlemen Hills

WASTE MANAGEMENT

From everyday collection to environmental protection,
Think Green.® Think Waste Management.

11July14

Mr. Joseph P. LeClaire, PhD
Associate
CDM Smith
111 Academy Way, Suite 150
Irvine, CA 93617

Subject: Transportation & Disposal of 102,000 Tons of Non-Hazardous Waste Salt, Firebaugh, Ca.

Dear Mr. LeClaire:

Waste Management is pleased to quote the following rate for the aforementioned project. It is anticipated that the waste will be delivered into our Kettleman Hills Facility.

Kettleman Hills Facility, Kettleman City, Ca:

Transportation & Disposal:	**$75.25 Per Ton**
California Recycle Tax:	**$1.40 per Ton**

Fuel Surcharge/Environmental Management Fee/RCR Fee add 13% to invoice.

Each truck must make two loads per truck per day to KHF.
Demurrage to begin after one-hour load and unload at the rate of $95.00 per hour.
No loads will be billed at $850.00 per load.
23-ton minimums on cleanup loads.

These rates are contingent on the waste being approved through our **Waste Management's Waste Approval Process**. The transportation and disposal rates are based upon payment within the terms of the service agreement and are valid for thirty (30) days unless extended in writing.

Thank you for the opportunity to provide service to you and **CDM Smith.** If you have any further questions, please feel free to call me at 661.332.3773. Thanks again and have a safe & successful day!

Sincerely,

Michael D. Parrent
Waste Management
Manufacturing and Industrial Sales
Sr. Industrial Account Manager

3620 Starwood Lane, Bakersfield, CA 93309
Office 661.397.5360 * Fax 661.398.9553 * Cell 661.332.3773 * mparrent@wm.com
Please visit our website's: www.wmdisposal.com, www.thinkgreen.com & www.lamptracker.com
Green Fact: Waste Management, combined with its wholly owned subsidiary Recycle America (WMRA), recycled enough paper to save over 41 million trees in 2005.

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Appendix B – Comments to Draft Phase 2 SSALTS Reports and Responses

Appendix B – Comments and Responses on the Draft Phase 2 SSALTS Report

No.	Commenter	Page	Reference	Comment	Response
1	Nigel Quinn, US Bureau of Reclamation			I appreciate Joe's use of my term "umbrella concept" - however there is no detail provided as to what fits under the umbrella. This is critical if people are to understand what real-time salinity management is all about. This is an opportunity to utilize the compilation provided by LWA in their current report and summarize the management strategies that might fall under the real-time umbrella. A listing of practices in a table with a few sentences of explanation might suffice. For completeness it might be useful to reference the LWA draft document. This would provide evidence of report coordination that I and a few others on the TAC have been looking for.	LWA prepared a table, in conjunction with the CDM Smith that describes various methods and implementation actions that are being developed as part of the Lower San Joaquin River implementation plan. The table cross links archetype study areas from the Phase 1 SSALTS report, as well as source control measures and treatment and disposal options or actions. The table further provides a brief description of the implementation actions.
2	Nigel Quinn, US Bureau of Reclamation			With respect to salt load estimation and the SJRIP project - I would like to see more explicitly stated the assumptions that underpin the analysis. These could be listed in bulleted or numbered form. There are some pretty bold assumptions being made - although most seem reasonable given the available information. This helps to provide the reader with assurance that CDM has considered pertinent factors that might affect the analysis and guidance to other analysts performing economic and financial estimates.	Comment noted. Assumptions for the SJRIP salt accumulation calculation are provided in bullet form.
3	Jeanne Chilcott & Glenn Meeks, CVRWQCB			Although the San Luis Unit Ocean Disposal option is mentioned in Section 1, all ocean alternative disposal options focus on EBMUD. Some justification should be provided as to why a “spur” or separate disposal line is not considered.	Both the coastal discharge option and other Bay area options were added to the discussion in Section 5.5 as well as under the pipeline discussion.
4	Jeanne Chilcott & Glenn Meeks, CVRWQCB			It is not clear how thoroughly potential treatment costs for the brine that may enter EBMUD has been evaluated. Many of the areas with subsurface agricultural drainage have elevated concentration of selenium, molybdenum, arsenic, uranium and vanadium. What would need to be removed in order to meet EBMUD’s concerns and allow them to be able	The following text has been added to Section 5.5.1, “The existence of inorganic trace constituents in the brine concentrate has the potential to be problematic in terms of permit compliance for discharges from a WWTP. Some areas with subsurface agricultural drainage have elevated concentrations of one or more trace elements, e.g., selenium, molybdenum, arsenic,

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				to continue to meet their effluent discharge requirements?	uranium, and vanadium. These elements may not be adequately removed by reverse osmosis alone. The specific treatment technology to remove trace constituents at any given location will depend on the specific elements found, the concentrations, competing ions, soluble ligands, etc. While there are significant amounts of groundwater data currently available, these data will need be incorporated into a synoptic of groundwater trace element chemistry study for different IAZs and local basins as future phases of SSALTS are implemented. In addition, a study of additional treatment to reduce trace constituents that may be necessary to allow an existing WWTP such as EBMUD to meet its discharge requirements, or to meet anticipated requirements for any new outfall will need to be conducted. In general, several processes can be considered for the trace constituent removal, such as ion exchange, lime softening, and coagulation/co-precipitation. The processes can be applied either as a pre- or post-treatment to RO in the desalting process. Applying the process as post-treatment might be economically more feasible since only the brine concentrate would undergo this treatment process, not the entire feed water stream. Treating only the brine concentrate would greatly reduce the equipment size and footprint, as well as O&M costs. A possible downside of applying the process as a post-treatment is that other major and minor constituents are also concentrated in the brine and they can compete with the trace constituents, reducing the removal efficiency of the target trace constituents. The post-treatment process to remove the inorganic tracer constituents can be constructed at the local desalination facilities and operated and maintained by

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					local plant staff or at a centralized downstream treatment facility. These treatment facilities are relatively complex, requiring well trained staff and frequent maintenance, perhaps making a central treatment facility more cost efficient. However, trace element chemistry of the pumped groundwater/feed water will be different at each desalination facility. There may be desalination facilities that do not need additional treatment for trace elements based on groundwater chemistry. Therefore, for the purposes of this concept-level alternatives analysis, it was assumed that the additional treatment for trace elements would be a post-RO process co-located at regional desalination facilities and would be required at 50 percent of those facilities. The cost to add treatment for trace constituents at each desalination facility of a capacity equal to the expected brine flow rate ranges from $3/gpd to $4/gpd."
5	Jeanne Chilcott & Glenn Meeks, CVRWQCB			All alternatives are roughly the same overall cost 4.1 to 4.5 Billion capital and 1.1 to 1.4 Billion in O & M. Why? How can the costs stay the same as we keep adding components?	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
6	Jeanne Chilcott & Glenn Meeks, CVRWQCB			There is a difference in the CVBL flow rate versus the EBMUD treatment rate in all alternative cost evaluations. What is that difference? It may be more cost effective to keep the CVBL flow at the maximum capacity size for all options, just so there is some surplus capacity available during those extremely wet years.	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
7	Jeanne Chilcott & Glenn Meeks, CVRWQCB			The CVBL's maximum capacity used in the report is only 90 million gallons per day (mgd), but the forecasted flow from the 8 Initial Analysis Zones (IAZs) is 92 mgd. The evaluation may want to increase the CVBL alternative options capacity	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1. The forecasted flow includes brine from IAZ 6.

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				to a little more than 92 mgd to allow for some extra capacity in flow.	
8	Jeanne Chilcott & Glenn Meeks, CVRWQCB			In all alternatives, was the use of the treated water for ag purposes considered? It could reduce the need for an equal amount of imported water into the regions and thereby reduce the importation of salt. If treated to a high enough quality, is it possible that it could be used for drinking water supply or groundwater recharge?	From Section 8, "An evaluation of alternative uses of the product water from desalters will be performed. The product water will be of very high quality and irrigation of crops is not likely the best use of this resource. One option that will be evaluated is to transport the product water to southern California State Water Contractors through the California Aqueduct for a fee. This will serve to stabilize water supply and water quality in the State Water Project (SWP) and will make more irrigation water available for the Central Valley Project (CVP)." The revenue from this exchange has been included in Table 7-1.
9	Jeanne Chilcott & Glenn Meeks, CVRWQCB		Section 8, Task 3.1	One of the high priority issues for CV-SALTS is salt and nitrate impacts to disadvantaged communities that rely on groundwater for drinking water. It may be beneficial to note in the Section 8, Phase 3, Task 3.1 discussion that the resultant effects of the proposed disposal/treatment alternatives on these communities will be one of the feasibility criteria utilized.	Comment noted. The following sentence has been added, "One of the criteria will be the effects of the proposed treatment and disposal alternatives on disadvantaged communities that rely on groundwater that has elevated concentrations of TDS and nitrate."
10	Jeanne Chilcott & Glenn Meeks, CVRWQCB	1-4	Grassland Water District Real Time	The critical challenges description needs to be expanded to include balancing flows for the whole basin to maximize salt export, not just for the wetlands which only accounts for a small portion of the salt load. Most salt load comes from the surrounding agriculture of which there are numerous entities that will need to be coordinated in order to maximize salt export from the basin.	Comment noted. The summary of the GWD-RTMP is from Phase 1 of SSALTS and only covered that archetype study area. The descriptions contained in other sections of this report are more comprehensive. The following text has been added to the paragraph noted on page 1-4, "Another critical challenge includes balancing flows for the whole basin to maximize salt export, not just for the wetlands which only accounts for a small portion of the salt load. Most salt load comes from the surrounding agriculture of which there are numerous entities that will need to be coordinated in order to maximize salt export from the basin."

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11	Jeanne Chilcott & Glenn Meeks, CVRWQCB	2-1	Regulatory Compliance Goals	Is the no net accumulation of salt scenario for the whole region or only for the 70% based on the 8 IAZ extraction areas? The Salt and Nitrate Management Plan basin plan amendment will be for the entire Central Valley region, not just for the 8 IAZs and will include the recommended disposal/treatment options, as well as source control and remedial options for the whole region. The report may need to indicate that this is the initial evaluation designed to maximize salt export in a cost effective and manageable manner, but that areas outside the 8 IAZs will be addressed in future phases and are not being forgotten. The report should also expand the discussion on how areas within the 8 IAZ that currently exceed objectives will be addressed (e.g. remediation? Potential designation as salt management zones utilized for salt disposal? Etc.). As written, a “no net accumulation” appears to continue to leave these areas impaired.	The no net accumulation of salt scenario is currently for the degraded areas of the eight IAZs with areas of highest TDS concentrations. It is understood that the basin plan amendment that incorporates the SNMP must incorporate a solution for the entire Central Valley. The following text has been added to Section 2.2, “Although the analyses in this report focusses on the eight most degraded IAZs, the SNMP basin plan amendment will include source control, treatment, and disposal options for the entire Central Valley. These eight IAZs were selected in order to maximize salt export in a cost effective and manageable manner. Areas outside of the eight IAZs will addressed in future phases and are not being forgotten. Salt accumulation in the degraded areas within each of these eight IAZs is being addressed through a combination of source control measures and treatment/disposal options as outlined in Section 7. In salt accumulation areas, *e.g.*, the Tulare Lake bed, salt is being stored indefinitely.”
12	Jeanne Chilcott & Glenn Meeks, CVRWQCB	2-2		Typo on third paragraph 100% should be 200%.	Comment noted and the text has been revised accordingly.
13	Jeanne Chilcott & Glenn Meeks, CVRWQCB	2-3		Regarding pumping of shallow groundwater or ag drainage waters from the 8 IAZs – What definition of shallow groundwater are we using? Waters above the Corcoran Clay unit? The upper 200 feet? We need to define shallow groundwater as it relates to the WARMF and CVHM models utilized in the Initial Conceptual Model.	Comment noted. The following text has been added, “Shallow groundwater in this report is explicitly identical to the definition of shallow groundwater developed for the ICM (LWA, 2013) in that the TDS concentrations in groundwater in Tables 2-2 and 2-3 represents the ambient TDS based on the ICM’s definition of shallow groundwater.” With the following footnote stating the ICM definition of shallow groundwater, ““The vertical distance represents the distance that the water, at the water table, would

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					travel downward or upward over a 20-year period." (LWA, 2013).
14	Jeanne Chilcott & Glenn Meeks, CVRWQCB	5-3	SJRIP	What is the timing of Phase 2 and Phase 3? Are the phases concurrent? When will treatment of groundwater be implemented? What is the source of the 40 feet perched water depth? Actual depth? An estimate?	Although these are the phases in the plan, work is typically completed on an "as-needed/highest priority" basis as funds are made available. Tasks are not necessarily organized into phases – for example, acquired land would be planted based on the need to reduce discharged volumes and how easily/quickly drain water can be conveyed to individual fields. Fields that have high perched water would be tiled, but the timing of that work would depend on how urgently that particular field is needed and funds available to tile the ground. Treatment would possibly be the only task that is a separate phase mostly because it's more or less independent from the rest of the SJRIP operation. Pilot studies for treatment are on-going. *Roger Reynolds, Pers. Comm. September 2, 2014.* The 40-foot perched water depth is an estimate based on discussions with Joe McGahan.
15	Jeanne Chilcott & Glenn Meeks, CVRWQCB	5-5	Permitted WWTP	Typo 3.1 to 7.6 tons should read million tons. This occurs throughout the document.	Comment noted and the text has been revised accordingly.
16	Jeanne Chilcott & Glenn Meeks, CVRWQCB	5-37 & 7-5	Tulare Lake Bed Salt Accumulation Area	It is not clear in the discussion how much larger the current evaporation ponds would need to be, how long they could be utilized or if the District responsible for the current ponds would be able to accept brine from areas outside of the control of their system. It is assumed that constructing any additional ponds, and the infrastructure necessary to move brine to a single location, was evaluated or would be evaluated as part of the cost estimate for this alternative.	The document has been revised to discuss the proposed construction of a fourth evaporation pond to expand the capacity of the current system. Currently there are no discussions or plans to consider accepting brine from areas outside of the control of the District. Such an option would need to be thoroughly discussed with stakeholders, including the potential for incentives. This concept is addressed further in Section 8.

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17	Jeanne Chilcott & Glenn Meeks, CVRWQCB	5-37		Where the report discusses the Corcoran Clay, the section may want to include depth to Corcoran Clay in the description sheet and its typical thickness in the area to give the reader a better insight into how the clay unit acts as a barrier between the shallow and the deeper groundwater zones.	The following text has been added to Section 3.2, which contains the first mention of the Corcoran Clay in this report. "The Corcoran Clay unit is a laterally continuous, low-permeability, lacustrine clay layer within the Tulare Formation that extends across middle and southern portion of the San Joaquin Valley (Figure 2-2). The Corcoran clay acts as an aquitard within the San Joaquin and Tulare basins dividing the overlying unconfined aquifer and the underlying confined aquifer. Both the thickness and depth of this unit vary greatly with thickness ranging from 20 to 120 feet and depths to the top of the clay shoaling from approximately 850 feet deep along the Coast Range to 500 feet in the valley trough (DWR, 1981; DWR, 2006; and Faunt *et al.*, 2009).
18	Jeanne Chilcott & Glenn Meeks, CVRWQCB	6-4	Regional Pipeline, First sentence	"or another bay/ocean disposal location" No direct offshore outfall option is evaluated, only EBMUD disposal is indicated in the alternatives evaluated. Do we want to include a backup option in case EBMUD is unable to accept all or part of the projected CVBL flow?	Both the coastal discharge option and other Bay area options were added to the discussion in Section 5.5 as well as under the pipeline discussion.
19	Jeanne Chilcott & Glenn Meeks, CVRWQCB	6-5	Pipe size	Why are we limiting the pipe size and not maximizing the potential flow for future. Additional pipe costs versus installation cost is typically not much in the overall construction costs. Also, is the extra recycled water return pipeline included in the cost estimate?	Detailed sizing of the pipeline would be part of future efforts. The text will acknowledge that for any segment, the percentage increase in capacity is proportionately greater that the percentage increase in cost, but oversizing also has some potential risks. The recycled water return pipeline will be included in Phase 3 of SSALTS (see Section 8).
20	Roger Reynolds, Summers Engineering	2-3	Estimates of Salt Accumulation and Salt Extraction	On page 2-3, in the second paragraph, the third and fourth sentences state, "Average TDS concentrations were estimated for the impaired areas. Table 2-3 summarizes the results of this analysis." The prior paragraph says only areas of "significant impairment were considered for extraction	Degraded areas are defined as contiguous regions of groundwater where average groundwater TDS is greater than 1000 mg/L. although the average TDS concentrations for IAZs 10 and 20 were similar, a contiguous area can be delineated in IAZ 10 with an

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				and salt removal." In the Middle Central area of Table 2-3 the lowest GW TDS is 842 mg/L. IAZ 20 has a higher TDS but is not considered as impaired. Is there a clear definition of "Impaired Areas"?	average TDS concentration of 1359 mg/L.
21	Roger Reynolds, Summers Engineering	4-7	Reverse Osmosis Membrane (RO) Technology *Implementation Status and Potential*	The second sentence of this fact sheet section states, "It is reported that currently desalination provides California with 50,000 acre-feet (AF) annually, or ten percent of California's water needs …" Was this supposed to be 1%? California's potable water needs are much greater than 10 x 50,000 AF or 500,000 AF per year.	Yes, this should be one percent. The text has been modified to: "It is reported that currently desalination provides California with 50,000 acre-feet (AF) annually, equivalent to approximately one percent of California's water needs …"
22	Roger Reynolds, Summers Engineering	5-4, 5-37 & 5-38	Comments Related to Tulare Lake Bed sources of salt	1. Section 5.4.2 Tulare Lake Bed, 3rd paragraph, Page 5-4 with sentence "The sources of salinity in the groundwater are a result of the closed basin and resulting saline soils from application of surface waters for irrigation." 2. Salt Accumulation Areas: Tulare Lake Bed, 4th paragraph, Page 5-37 with sentence "The sources of the salinity in the groundwater are a result of the closed basin and resulting saline soils from application of surface waters for irrigation." Please revise this description. The phrase at the end of each sentence implies that the saline soils are only the result of application of surface waters. This is not a full explanation of the salt loading. Irrigation waters do add salt to the lands, but the primary reason for the high saline soils in the Tulare Lake Basin is the long term geologic formation of soils within a closed basin without a drainage outlet. Drainage historically occurred from both streams and rivers on the East side of the Tulare Lake Bed and from the foothills on the West side. Runoff flow from the Sierra Nevada Rivers was much greater but had lower TDS in the runoff than the lower flows and higher TDS occurring on the West side streams. This is why the Westside soils of the Central Valley have higher saline levels than the soils on the East side. This situation was created over thousands of years and without a	Comment noted and appropriate edits were made to both sections.

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				drainage outlet salts continued to build up within the Tulare Lake Bed. Surface water irrigation has only occurred over the last 100 ± years. The delivery of State Water Project water supplies into the Tulare Lake Basin over the last 40 years continues to add salt to these lands but the historic salt levels in the soils prior to agricultural development are the primary problem. The salt load in the soils has not come just from application of surface waters.	
23	Roger Reynolds, Summers Engineering	5-5	Section 5.4 Salt Accumulation Areas/Landfilling 1st paragraph	The last three sentences of this paragraph imply the TLDD evaporation basins are always full. The drainage inflow and evaporation rate vary throughout the year. There is a critical period each year when the drainage inflows gradually increase filling the ponds prior to the hottest time of the year when the peak evaporation rate occurs. It is at this time when the maximum storage capacity of the basins is reached. An increased demand for disposal of subsurface drainage water is occurring and additional evaporation basins are needed, but it is not correct to say the evaporation basins are always full. The current basins have a maximum storage capacity of approximately 17,000 acre feet. The three evaporation basins have a surface area of 3,453 acres. At an estimated evaporation rate of 5.0 feet per year the annual evaporation is approximately 17,000 acre feet per year.	Comment noted and the appropriate edits were made.
24	Roger Reynolds, Summers Engineering	5-5	Section 5.4 Salt Accumulation Areas/Landfilling 2nd paragraph	Some of the water quality values used are not correct. A recommended revision to this paragraph follows, "Ambient TDS concentrations of groundwater beneath the land where additional basins are proposed ranges from 6,600 to 12,000 mg/L (Summers Engineering, Inc. 2014). For the purpose of estimating the salt accumulation at these evaporation ponds, a TDS concentration of 6,400 was used." (e.g., this was the measured TDS in the Main Pipeline Outlet Structure flowing to the main evaporation basins in May 2013).	Comment noted and text was revised accordingly.

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25	Roger Reynolds, Summers Engineering		Section 7, Salinity Alternatives	A question was raised at the TAC meeting that all of the Alternatives list a capacity and cost for each of the different Components. In Alternative 1 the Treatment/disposal component at EBMUD with a load of 3.1 to 7.6 tons annually and a capacity of 75 MGD and a cost of $1,094M. In Alternative 2 for this same component, a load of 3.1 to 7.6 tons annually is listed with a capacity of 69 MGD and a cost of $1,006M. It may be a simple answer, but it is unclear why the numbers and costs vary.	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
26	Roger Reynolds, Summers Engineering	7-5 & 7-7	Section 7, Salinity Alternatives	Under Alternative 3, the Component Tulare Lake Bed, describes its Capacity as "… 17,000 AFY of saline water are stored and evaporated at three evaporation basins on the Tulare Lake Bed." The three evaporation basins have an estimated surface area of 3,453 acres. The basins have a maximum storage capacity of approximately 17,000 acre feet. The drainage water actually stored in the basins varies between the peak drainage period when irrigation occurs and the peak summer evaporation period when the temperatures are the highest. At an estimated evaporation rate of 5.0 feet per year the annual evaporation is estimated at approximately 17,000 acre feet per year.	Appropriate edits were made.
27	Roger Reynolds, Summers Engineering	8-2	Section 8 phase 3 SSALTS	On page 8-2, the seventh bullet mentions a future evaluation in Phase 3 will be to deliver brine generated in the southern IAZ's to the Tulare Lake Bed for salt disposal and storage. Before proceeding with this analysis in Phase 3 it is recommended it be discussed with Tulare Lake Drainage District and Tulare Lake Basin Water Storage District representatives. It is likely this would not be looked on favorably by the local landowners.	The need to discuss this option with stakeholders, including the potential for incentives has been included in the revised text.
28	Chris Linneman & Joe McGahan,		Section 5.4.1	Section 5.4.1 notes that the SJRIP will "at full project build-out – utilize about 25%" of the total drainage productions of the GDA about 15,000 AFY. Although 60,000 AFY is probably	Text revised to reflect comment.

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	Summers Engineering			close to the annual drainage production, the SJRIP has displaced more than 20,000 acre feet since 2011 (2013 displaced 26,170 acre feet of drain water), about 1/3 of the drainage production. At full build-out, the average reuse capacity of the SJRIP is likely to be between 25,000 and 30,000 AFY (possibly more).	
29	Chris Linneman & Joe McGahan, Summers Engineering			The Report notes that the average TDS of the GDA drain water is 5000 mg/L. This is not correct. The Average TDS of water put on the SJRIP ranges from 3500 to 4000 mg/L and the average TDS of drain water at the discharge from the San Luis Drain at Site B is 3300 mg/L (2005-2013).	Revised/added text.
30	Chris Linneman & Joe McGahan, Summers Engineering			The report should note that approximately 2000 acres of the SJRIP is tiled, some of which has operated since 2002.	Added text.
31	Chris Linneman & Joe McGahan, Summers Engineering			The Report estimates that the salt load on the SJRIP would average 102,000 tons per year. Calculations of salt applied through the drain water in the last 2 years is around 118,000 tons per year, although this is based on a higher application volume than the report assumes.	Added text.
32	Chris Linneman & Joe McGahan, Summers Engineering		Table 5-8	Table 5-8 calculates the subsurface TDS and salt load stored in the soil. The initial TDS (2014) is assumed to be 20,000 mg/L. Measured ECs from existing sumps on the SJRIP average 15,500 µS/cm or about 11,400 mg/L TDS. Furthermore, although the readings vary significantly, none of the existing sumps show a clear upward trend in drain water EC measurements over that last six years, which appears to be contrary to the conclusion of Table 5-8 that subsurface water concentrations will dramatically increase over time.	Revised the estimates of current TDS down to 11,400 mg/L. The following text was added, “It should be noted that although the readings vary significantly, none of the existing sumps show a clear upward trend in drain water EC measurements over that last six years. While this short term trend is of interest, it is not realistic to assume this trend can continue indefinitely as continued addition of salts must eventually result in increased storage in the groundwater and/or an increase in the salt exported via the drain water.”

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33	Chris Linneman & Joe McGahan, Summers Engineering		Figure 5-4	The title of Figure 5-4 (Tons of Salt Removed by the Grassland By-pass Project) is confusing, especially considering there's no discussion of its relation to the SJRIP. The chart title should be renamed "Tons of Salt Discharged by the Grassland Drainage Area to the San Joaquin River."	The title of Figure 5-4 was modified.
34	Chris Linneman & Joe McGahan, Summers Engineering	5-34		Page 5-34 begins a summary of the SJRIP Salt Accumulation Area. Under the heading "Constituent Salts or Nutrients Managed" it states: "An on-going biological monitoring program needs to be conducted…". Not sure of the context here but there is already an ongoing program on the SJRIP.	Comment noted and the text was revised.
35	Chris Linneman & Joe McGahan, Summers Engineering	5-35		Page 5-35 the first partial paragraph under "Applicability", we suggest the following wording "…drainage water are toxic to wildlife at certain levels and create…" (underline added) and last sentence modify to read "….to maintain the crop productivity…".	Comment noted and the changes were incorporated.
36	EBMUD	1-3	Hilmar Cheese Company	Recommend changing the text from: "The cost factor score was poor (1) because the 2012 fees paid to East Bay Municipal Utilities District (EBMUD) were about \$4.26M, with an additional \$1 million to \$2 million in hauling costs." to: "The cost factor score was poor (1) because the 2012 processing fees paid to East Bay Municipal Utilities District (EBMUD) were about \$1.9M, with an additional \$1 million to \$2 million in hauling costs paid by Hilmar to its contracted hauler."	Comment noted and the changes were incorporated.

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37	EBMUD	5-5	5.5 Permitted WWTP	Recommend changing the text from: "EBMUD provides water and/or wastewater service to more than 1.3 million customers in the East Bay area (Oakland and surrounding areas)." to: "EBMUD provides water service to approximately more than 1.3 million customers and wastewater service to about 650,000 customers in the East Bay area (Oakland and surrounding areas)."	Comment noted and the changes were incorporated.
38	EBMUD	5-5	5.5 Permitted WWTP	Recommend changing the text from: "The reduction in the food processing industry in Oakland has resulted in available capacity in EBMUD's WWTP of about 80 to 100 MGD." to: "The reduction in the food processing industry in Oakland has resulted in available capacity in EBMUD's WWTP. For the purposes of this preliminary analysis, it is estimated that of about 80 to 100 MGD of brine could be discharged through EBMUD's outfall, provided that it meets EBMUD's permit requirements. Actual capacity and water quality requirements will be determined in future phases."	Comment noted and the changes were incorporated.
39	EBMUD	5-5	5.5 Permitted	Recommend changing the text from:	Comment noted and the changes were incorporated.

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			WWTP	"Table 5-10 shows a range in WWTP capacity and a range of brine concentration that yields a range of salt mass removed of 3.1 to 7.6 tons annually (44 to 108 percent of the annual salt accumulation in the entire Central Valley)." to: "Table 5-10 shows a range in WWTP capacity and a range of brine concentration that yields, on a conceptual basis, a range of salt mass removed of 3.1 to 7.6 million tons annually (44 to 108 percent of the annual salt accumulation in the entire Central Valley)."	
40	EBMUD	5-6	5.5 Permitted WWTP	Recommend changing the text from: "EBMUD has concerns about agricultural chemicals, nutrients, and naturally-occurring trace elements, such as selenium and boron." to: "EBMUD must ensure that agricultural chemicals, nutrients, metals, and naturally-occurring trace elements, such as selenium and boron in brine streams do not interfere with its ability to meet permit requirements for discharge to San Francisco Bay."	Comment noted and the changes were incorporated.
41	EBMUD	5-6	5.5 Permitted WWTP	Recommend changing the text from: "Currently, EBMUD is paying about $37 per ton to transport	Comment noted and the changes were incorporated.

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				brine out of Alameda County. At 6 truckloads per day and 20 tons per truck (120 tons per day) would result in a revenue stream to the Central Valley entities of about $1.6M per year." to: "Currently, EBMUD is paying about $32 per ton to transport and apply biosolids to agricultural land outside Alameda County. At 6 truckloads per day and 20 tons per truck (120 tons per day), were Central Valley generators able to arrange for back-hauling of this end product, conceptually it could result in a cost offset to the Central Valley entities of about $1.4M per year."	
42	EBMUD	6-1	6.1 Trucking and Rail	Recommend changing the text from: "While additional bays can be built, for the purposes of the alternatives analysis, a Central Valley Brine Line (CVBL) is the transportation option that is evaluated." to: "While additional bays can be built in a relatively short period of time to receive additional loads via truck, for the purposes of the alternatives analysis, a Central Valley Brine Line (CVBL) is the transportation option that is evaluated."	Comment noted and the changes were incorporated.
43	EBMUD	6-3	Q&A with EBMUD	Recommend changing the text from: "A US EPA study has estimated that trains are 2 to 4 times	Comment noted and the changes were incorporated.

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				more fuel efficient than trucks on a ton-mile basis. Trains emit 1/3 the Green House Gas (GHG) emissions of trucks on a ton-mile basis. http://www.epa.gov/midwestcleandiesel/sectors/rail/materials/ls.pdf." to: "A US EPA study has estimated that trains are 2 to 4 times more fuel efficient than trucks on a ton-mile basis. Trains emit one-third the GHG emissions of trucks on a ton-mile basis. The US EPA Smartway program encourages shippers to use freight rail: "For shipments over 1,000 miles, using intermodal transport cuts fuel use and greenhouse gas emissions by 65 percent, relative to truck transport, alone." The program holds that a single train trip can remove 280 trucks from highways. (See http://www.epa.gov/midwestcleandiesel/sectors/rail/materials/ls.pdf)."	
44	EBMUD	7-1	Alternatives Analysis	Recommend added the following sentence to the end of the last paragraph on page 7-1: "Costs presented in the alternatives tables below are conceptual estimates that may change significantly when subject to further analysis."	Comment noted and the changes were incorporated.
45	EBMUD	8-2		Recommend changing the text from: "EBMUD will work with the SSALTS team to further define their WQOs and to keep the SSALTS team informed of potential changes in their WWTP permit, which is up for	Comment noted and the changes were incorporated.

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				renewal later in 2014.” to: “EBMUD will work with the SSALTS team to further evaluate issues associated with NPDES permit compliance and potential need for pretreatment’”	
46	Karen Ashby, LWA		Categorization Section 1.3	Section 1-3 refers to the identification of In-Valley, Out-of-Valley, and Hybrid Alternatives, however it is unclear which of the fact sheets fall into these categories. It may be helpful if a master table was developed to cross reference the categories used within this document and each of the fact sheets with the 3 types of alternatives. It would also be very helpful is a master summary table was developed so that the various BMPs could be compared - this would assist the reader in understanding why certain alternatives were selected.	All of the source control measures would be in-valley. All of the treatment options could be in-valley, out-of-valley, a hybrid or both, depending on the ultimate disposal or storage option of the brine/salt. For the disposal options, salt accumulation areas would be in-valley, as would deep well injection and hydraulic fracturing. The salt load that is managed by RTMP would be considered out-valley. The brine line to an ocean-permitted WWTP would be out-of-valley.
47	Karen Ashby, LWA		Consistency of Terms Section 1.1	In order to be consistent with the document that the LWA Team is developing, we recommend that the SSALTS report refer to the "Salt and Nitrate Management Plan" instead of a "Salt and Nutrient Management Plan".	Comment noted and the text has been modified accordingly.
48	Karen Ashby, LWA		Source Control Fact Sheets	The source control fact sheets do not identify costs or expected load reductions. It is unclear how they will be incorporated into groups of alternatives without this information.	All of the alternatives incorporate source control measures. In terms of both capacity and cost, source control BMPs are expected to be very small in comparison with other options.
49	Karen Ashby, LWA			It may be helpful to refer to the specific Fact Sheets that are included under the Source Control BMP category.	Comment noted and a list of fact sheets has been included in the table of contents.
50	Karen Ashby, LWA		Land Management Measures	Although the document identifies land management as a category of source control measures in Section 3.2, there	Fact sheets were not developed for every component of every option of every alternative.

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			Section 3.2	are no fact sheets associated with this category.	
51	Karen Ashby, LWA		De-designation of Management Zones Section 3.3	Although the document identifies this as a category of source control measures in Section 3.3, there are no fact sheets associated with this category.	See response to Comment 50.
52	Karen Ashby, LWA		Fact Sheets Section 4	It may be helpful to refer to the specific Fact Sheets that are included under this category (which ones are associated with mature technologies, emerging treatment, etc.).	Technologies that fall within mature and emerging categories are described in Section 4.
53	Karen Ashby, LWA		Reverse Osmosis Fact Sheet, Thermal Evaporator Fact Sheet, and Crystallizer Fact Sheet	Under "Effectiveness Documentation" - should this section list the key findings re effectiveness instead of noting that this information exists?	Comment noted.
54	Karen Ashby, LWA		Permitted WWTP	It is unclear why a Fact Sheet was not developed for this BMP.	See response to Comment 50.
55	Karen Ashby, LWA		General	It would be very helpful if a master table could be developed that provides baseline information for each of the BMPs listed in Sections 3-6 so that they could be compared on a similar basis. This type of a table could also assist the reader in understanding which BMPs were selected for which alternative.	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
65	Karen Ashby, LWA		General	The following is recommended for the tables presented in 7.2 - 7.5. 1) It is recommended that the capital and O&M costs be separated within the tables for each of the alternatives. In addition, it was unclear if the O&M were annual costs. 2) It would be helpful if the items listed under "Component" referred directly back to one of the fact sheets in sections 3-6. 3) It would be helpful if the expected	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.

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				salt reductions were also listed (in similar units) so that the alternatives can be compared. 4) The assumptions used for all of the costs included within the tables should be included. 5) If revenue is listed in an alternative then it should be listed in a column separate from "cost".	
66	Mike Trouchon, LWA		Fact Sheet - Agricultural Water Reduction and Reuse Table	Please provide description of "restoration" as it applies to action(s) taken after land retirement.	The source control BMP fact sheets have been modified.
67	Mike Trouchon, LWA		Section 4.3 Table 4-1	Are the costs in Table 4-1 capital costs, capital + O&M costs, annualized lifetime costs over some period, or some other form of cost?	The costs shown in Table 4-1 are total capital costs only and this has been clarified. O&M and annualized costs are discussed in Section 7.
68	Mike Trouchon, LWA		Figure 4-1	Please provide the equations for the cost curves in the graph.	High TDS, high recovery - $4/gal High TDS, low recovery - $3/gal Low TDS, high recovery - $3/gal Low TDS, low recovery - $2/gal
69	Mike Trouchon, LWA		Permitted WWTP Section 5.5	Opportunities: First Bullet - Should "transport brine" be "transport biosolids"?	Comment noted and the text has been revised.
70	Penny Carlo, Carollo		General Basis of Costs	It would be helpful to provide a paragraph with more information on the basis of costs (Class 5, order-of-magnitude, level of accuracy (% +/-) etc .) than what is provided in Sections 4.3 and 6.3. It appears that the capital costs represent 2014 dollars. Is it appropriate to provide net present value costs so that ultimate build-out costs can be presented? Provide a table of "cost analysis assumptions" that list the primary cost factors and assumptions used in the cost analysis (interest rate, inflation rate, NPV lifetime, ENR CCI, etc.). Throughout the report, there is no indication that cost contingencies were included. Considering the	A paragraph has been added in Section 5 that describes the general basis for capital and O&M costs for various technologies and options. Further discussion is presented in Section 5 describing how both capital and O&M and other costs are used to compare alternative approaches.

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				magnitude or the project and the time required for implementation, these planning level costs should include a significant contingency factor, and should address engineering/administrative/legal, environmental mitigations, permitting, construction management, land acquisition, etc. The cost impacts of institutional and environmental mitigations, particularly concerning the brine line, are not captured in the study.	
71	Penny Carlo, Carollo		Fact Sheets	It would be helpful if the Fact Sheets were listed within the Table of Contents.	See response to comment 49.
72	Penny Carlo, Carollo		Units	Overall, it would be useful for the unit costs for the alternatives to also be presented in $/AFY as well as $/MGD. It is anticipated costs per AFY may be more meaningful. Suggest including AF parameters alongside other units as much as possible in the tables. Also, consider changing the units in various tables for consistency and for usability (i.e. mg vs kg), etc. Several of the fact sheets have values presented in metric units.	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
73	Penny Carlo, Carollo		Section 2.2 Figures 2-18 through 2-20	Define the red areas and labels (N1, N2 etc) in the figure legend. The areas identified are not discussed in the text and their relevance is not understood. Provide explanation as to why some areas containing wells with elevated median TDS concentrations are not identified as impaired areas.	The legends in Figures 2-18 through 2-20 have been expanded to indicated that the polygons in red approximate define areas where groundwater concentrations are greater than 1000 mg/L. The text in this section has been changed from: "In some cases, the current data set did not show degradation, because wells were not sampled during that period; in those cases historical data were used to delineate the impaired areas. The impaired areas are depicted in Figures 2-18 through 2-20. Average TDS concentrations were estimated for the impaired areas. Table 2-3 summarizes the results of this analysis. In this scenario, pumping and desalting would be focused in the following IAZs:"

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					to: "In some cases, the current data set did not show degradation, because wells were not sampled during that period; in those cases historical data were used to delineate the degraded areas. Areas degraded groundwater are depicted in Figures 2-18 through 2-20. Areas where there were significant clusters of wells with TDS concentrations over 1000 mg/L were identified and are labeled in Figures 2-18 through 2-20. Average TDS concentrations were then estimated for the degraded areas. Table 2-3 summarizes the results of this analysis. In this scenario, pumping and desalting would be focused in the following IAZs:"
74	Penny Carlo, Carollo		Section 3 Headers	Headers on left-hand pages are incorrect.	Comment noted. Header information has been corrected.
75	Penny Carlo, Carollo		Fact Sheet - Agricultural Water Reduction and Reuse	Paragraphs describing Effectiveness Documentation and Implementation Planning Level Costs appear to be from the Source Control Food Processing Fact Sheet	The source control BMP fact sheets have been modified.
76	Penny Carlo, Carollo	4-1	First paragraph, page 4-1, and RO Fact Sheet	Others have said attempts to treat drainage water by RO have been problematic. This paragraph indicates RO treatment can achieve high recovery, and suggests treatment can be expected to be fairly typical. Is high recovery achievable with drainage water? Please provide more information to substantiate this assumption, here and in the fact sheet. Also, please discuss feed water characteristics that may be found in drainage water that are concern for RO. It would be useful to provide a list of common interferrents and some drainage water data for a discussion of potential issues, and for development of the	More detailed engineering will occur in future Phases of SSALTS. Although our current project experience suggests a range of $2-4/gpd is typical for RO treatment, we used a cost of $6/gpd in the concept level cost estimate in order to be conservative.

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				RO treatment assumptions. Is a "rule of thumb" cost assumption appropriate? The $2-4/gpd appears low, and could be more on the order of $5-7/gpd. Provide reference project costs.	
77	Penny Carlo, Carollo		First paragraph, page 4-1	For long term planning, the $0.12/kwh seems low. Have you considered applying an escalation factor, say an annual increase of 3% or 4%?	For the purpose of relative comparison of various options, current power rates were assumed which can range from depending upon what rate schedules are used. Projecting future power cost increases and/or applying a differential escalation factor to power costs when performing a detailed economic analysis may be more appropriate in Phase 3.
78	Penny Carlo, Carollo	4-3	First and second bullets	The first bullet indicates the feed volume is 916 mgd, based on Table 2-3, while the second bullet indicates the feed volume is 750 mgd, based on Table 4-1. (The second bullet says 750 gpm.)	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
79	Penny Carlo, Carollo	4-3	3rd bullet	Please provide the assumptions used to develop the cost (average well depth, hp, capacity, length of pipeline to deliver water to CVBL, etc.).	A discussion was added that describes the factors included and the unit cost/well was increased to $1.4M.
80	Penny Carlo, Carollo		Table 4-1	Is it possible to show the facilities listed in this table (desalters, extraction, plus CVBL pump stations which are not listed here) on the map (such as Figure 6-4) to display approximate locations, or geographic distribution within the IAZs? It will help understand the distances expected for conveyance facilities to the desalters, etc.	This would be very difficult and potentially misleading given the scale of the map and the fact that the potential location of desalters is highly speculative at this point. The text has been clarified to indicate that the locations would generally be in the areas of more elevated TDS as illustrated in the Figures in Section 2.
81	Penny Carlo, Carollo	4-3	5th bullet	Add assumption for %recovery and % reject used in cost estimate, feed water characteristics (see comment for Report Section 4.1),the finished water TDS concentration, and basic RO facility elements (pretreatment and treatment components, feed pumps, finished water pumps, brine pumps, E&I, building, etc). Based on the nature of drainage water, pretreatment and post-treatment is expected.	Assumptions have been added for percent recovery. The cost is based on TDS of 10,000-12,000 mg/L and the system recovery of 90 percent. The cost includes civil, building, equipment, electrical and instrumentation and controls (I&C) cost for the RO system, pretreatment and post-treatment but does not include conveyance piping. This is a concept-level cost

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					estimate of the RO facility. The detailed equipment components would be determined based on the actual site design conditions and these details are beyond the scope of the Phase 2 report.
82	Penny Carlo, Carollo	4-6	Reverse Osmosis Fact Sheet	Add assumptions used in cost estimate here also.	Cost assumptions are provided in Section 4.
83	Penny Carlo, Carollo	5-4	Section 5.4.1 2nd paragraph	Explain the basis for the salt densities used to calculate the volumes of dried salt product (the salt densities are listed in Table 5-9 but no explanation provided on how they were established)	Since it is difficult to estimate the detailed composition of the salt we used the range of the bulk densities provided in the following reference: Source: http://www.hapman.com/resources/bulk-material-density-guide
84	Penny Carlo, Carollo	5-4	Section 5.4.1 2nd paragraph	The $75.25/ton haul cost includes transportation. Can you provide your assumption for the haul distance?	The assumed haul distance is 75 miles from Firebaugh, CA to Kettlemen Hills Landfill operated by Waste Management, Inc.
85	Penny Carlo, Carollo	5-5	Section 5.4.2	Provide assumptions for converting the salt accumulation into tons and MGD for the cost for use in Section 7 alternatives	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
86	Penny Carlo, Carollo	5-6	6th paragraph	Include basis for RO brine solids produced per year. Why do these landfill costs ($50/ton) differ from landfill costs ($75.25/ton) for SJRIP	In terms of brine generation: 10mgd*5000 mg/L*8.34=417,000 lb/day 417,000 lb/day*365 day/2000 lb/ton=76,000 tons The $50/ton landfill costs are from the Ahuja and Howe (2007) study.
87	Penny Carlo, Carollo		Table 5-14	Identify the reference for the 2009 basis of costs. (footnote 3). Should this section consider the capital and annual costs for ZLD?	The footnote has been amended accordingly.
88	Penny Carlo, Carollo		Deep Well Injection with Dedicated Wells	For the $6 million cost for a cluster of three wells, please provide the assumption for the unit cost per injection well and pipeline diameter. Can you break out the pipeline cost	The cost of the wells has been broken out from the rest of the facilities. Further detail is not warranted at this stage. Note cost has increased slightly based on re-

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			Fact Sheet	from the well construction cost for deep well injection?	evaluation of estimate.
89	Penny Carlo, Carollo		Section 6.3 Pipeline diameters	Include criteria for sizing the pipelines.	Criteria for sizing pipelines have been added.
90	Penny Carlo, Carollo		Pipeline costs	How did you develop the unit costs ($6/LF/inch-diam and $15/LF/inch-diam) and do the costs include a contingency? It would be helpful to provide a table of unit costs for the various ranges of pipelines being considered.	The unit costs are based on experience of design and construction of pipeline under various conditions. The $6/LF/diameter-inch typically represents favorable, cross country or rural conditions with limited interferences and minimal pipeline in pavement. As noted, this was used for all pipelines within the undeveloped or minimally developed areas of most of the central valley. The $15/LF/diameter- inch was used for the downstream potion of the pipeline line to reflect crossing hills and construction in urban settings.
91	Penny Carlo, Carollo	6-5	Figure 6-4 and page 6-5	The discussion about pipeline segments in the bullets on page 6-5 refers to 10-mile markers along the northern Alternate 1 route, that are not shown in the map in Figure 6-4. Suggest renumbering the 10-mile marks in the figure along Alternate 1	Comment noted and the figure has been updated.
92	Penny Carlo, Carollo		General	The approach toward determining the extraction capacity for each alternative (by subtracting the capacities diverted via the other options) is hard to follow and the basis for the math related to the capacities in Alternatives 3 and 4 is unclear	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
93	Penny Carlo, Carollo		General	Costs for CVBL pump stations were not included in the table, and a summary of the need for pump stations could not be found in the report.	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1. The costs for the CVBL pump stations have been included. The following text has been added: "There will also need to be a series of pump stations required along the CVBL to deliver the brine to EBMUD or other potential discharge locations. For the purposes

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					of developing a cost estimate, the following assumptions were made: • Seven pump stations would be required at strategic locations, ranging from 20 to 60 miles apart • Each pump station would function essentially as an in-line booster pump station • Pumping hydraulics assume that HDPE pipe is used, with dual lines for the last three pumping legs”
94	Penny Carlo, Carollo		General	In the upcoming Phase 3 discussion on O&M costs, it will be valuable to provide a good understanding of all the potential significant O&M requirements and costs associated with maintaining the brine line, based on history and experiences of other brine lines	Comment noted, text added in Section 5.
95	Penny Carlo, Carollo		General	Can you provide a summary table that compares the capacities, unit costs, and total costs of the various alternatives? Can you provide an appendix with the cost analysis details for the various alternatives?	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
96	Penny Carlo, Carollo		Section 7.3 Table	Should the CVBL capacity be 69 mgd? What is the basis for the SJRTMP capital and O&M costs in this and subsequent tables? Can you provide the cost basis in Chapter 5?	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
97	Penny Carlo, Carollo		Section 7.4 Table	The cost for disposal at Kettleman Hills landfill assumes the brine will be nonhazardous. Should the classification as a designated waste or possibly a hazardous waste be considered in the cost assumption?	The sub-option of disposal of salt at Kettlemen Hills Landfill assumes that the salt would be in solid form and not a brine. If the salt is deemed hazardous, the alternative analysis can be refined in future phases.
98	Penny Carlo,		Table	Extraction capacity appears incorrect. CVBL capacity	The alternatives analysis has been restructured. Please

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	Carollo			appears incorrect. Explain how the SJRIP tons are converted to capacity to deduct. What capacity are you assuming for the Tulare Lake Bed option, how is it derived, and what is cost? Is land acquisition required? Can you provide the basis for the cost in Chapter 5?	refer to Section 7 and Table 7-1.
99	Penny Carlo, Carollo		Section 7.5 Table	Extraction capacity appears incorrect. CVBL capacity appears incorrect. Explain how the SJRIP tons are converted to capacity to deduct. What capacity are you assuming for the Tulare Lake Bed option, how is it derived, and what is cost? Please clarify the last sentence under "Capacity" for deep well injection. How many deep well injection systems are you assuming for this option?	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
100	Tom Grovhoug, LWA		Section 2.1 Regulatory and Compliance Goals	In the third paragraph, second sentence: Insert reference to the salt accumulation area concept as described in Section 5.	Comment noted and the reference has been added.
101	Tom Grovhoug, LWA		Terminology	The use of the word "impaired" should be re-considered in describing those IAZs where pumping and desalting would be the most beneficial in achieving a valley-wide salt balance. The word "impaired" has a special regulatory meaning that is not intended here.	Comment noted. The term has been changed to "degraded" and a more detailed explanation of that term has been added to the text.
102	Tom Grovhoug, LWA		Figure 2-3, and others	The legend says "750-10,000", whereas "750-1000" is intended.	Comment noted and the figures have been revised accordingly.
103	Tom Grovhoug, LWA		Section 3.1, 1st paragraph, last sentence	Suggested edits: It is suggested that a change be made to state that "BMPs may help" and "may be economical and sustainable solutions."	Comment noted and the text has been modified.
104	Tom Grovhoug, LWA		De-designation of management zones Section 3.3, 1st	Change to say that CVSALTS is supporting a project to de-designate both MUN and AGR uses in the Tulare Lakebed and state that this is an archetype to evaluate the appropriateness of the MUN beneficial uses and other	Comment noted and the text has been modified.

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			paragraph, 2nd sentence	beneficial uses.	
105	Tom Grovhoug, LWA		SJ River Real Time Management Section 5.3, 1st paragraph	Change to state that RTMP must also ensure that future salinity and boron objectives are achieved in the Lower San Joaquin River upstream of Vernalis to the mouth of the Merced River (Reach 83).	Comment noted and the text has been modified
106	Tom Grovhoug, LWA		SJ River Real Time Management Section 5.3, 3rd paragraph	Third paragraph: Note that 1995 was a wet year (salt loads were high due to high flows), while 2013 was a critically dry year. The percentage reduction stated in the paragraph is somewhat misleading. Reference should be made to Figure 5-4, which shows a significant reduction in loading over the period in question.	Data from the Palmer Drought Severity Index have been added to indicate the type of water year (wet or dry etc.). The following text has been added, "Salt load is a function of flows in the river and there is a general correlation of increased salt load in wetter years. Overall, there is still a trend of decreasing salt load."
107	Tom Grovhoug, LWA		Figure 5-4	The source for the salt loading values depicted in the figure should be stated. Also, it is suggested that the water year types be shown as a qualitative means to depict the influence of flow volume.	The following reference has been added, "Grassland Area Farmers (2013)."
108	Tom Grovhoug, LWA		Figure 5-5	As stated for table 5-6, the information depicted in this figure reflects New Melones releases and is not necessarily representative of future conditions or illustrative of conditions in the San Joaquin River above the Stanislaus.	The following text has been added to Section 5.3: "In an average hydrologic year, the San Joaquin River RTMP can transport 687,000 tons to the Bay Delta. Because the any system can never be fully optimized, an assumption is made that 85 percent of this value would be discharge annually or a total of 584,000 tons – representing about 8 percent of the annual salt accumulation in the Central Valley." has been replaced with: "In the draft Phase 2 SSALTS report, a calculation of average hydrologic year assimilative capacity and additional salt loads was developed. This estimate

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					includes discharges of high quality (low TDS) water from the New Melones Reservoir. The Lower San Joaquin River Committee is currently developing estimates of assimilative capacity[1]. As part of the Development of a Basin Plan Amendment for Salt and Boron in the Lower San Joaquin River, the LWA team is collaborating with the San Joaquin Tributaries Authority to determine the effects of Stanislaus and Vernalis operations on water quality at Vernalis under various upstream management alternatives. The operation effects will be determined by updating and utilizing the New Melones Operation Model which uses river conditions upstream of Vernalis and a depiction of Stanislaus and Vernalis operations to provide flow and water quality conditions in the lower San Joaquin River at Vernalis. Based on flow and water quality conditions in the lower San Joaquin River at Vernalis, the NM model can be used to assess assimilative capacity."
109	Tom Grovhoug, LWA		Table 5-6	The table reflects the assimilative capacity that is "created" by releases from New Melones. This is not necessarily representative of future conditions, since efforts are underway to seek to reduce such releases.	See response to Comment 108.
110	Tom Grovhoug, LWA		San Joaquin River Real Time Management Program Fact Sheet	In first paragraph, modify to state that RTMP also involves efforts to control salt loadings. Also, clarify that RTMP must ensure compliance with any future salinity objectives in the Lower San Joaquin River that may be adopted. Under "Applicability" on page 5-31, second paragraph, modify text to note that the LSJR Committee effort is ongoing and salinity objectives are anticipated in 2015/2016 time frame. Under Implementation: Planning Level Costs, estimated costs should be provided pertaining to the overall RTMP for	Comment noted and the text has been modified. To the extent that the cost information is available, it will be summarized in Phase 3 of SSALTS.

[1] LWA. 2014. Meeting notes from an August 25, 2014 conference call for the Development of a BPA For Salt and Boron in LSJR. Pers. comm. Danielle Moss.

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				the entire LSJR basin.	
111	Tom Grovhoug, LWA		SJR Water Quality Improvement Project (SJRIP) Fact Sheet	Under Implementation: Planning Level Costs, estimated costs should be provided for the categories listed. Under Implementation: Status and Potential, a date for the start and completion of Phase 3 should be provided.	To the extent this information is available; it will be summarized in Phase 3 of SSALTS.
112	Tom Grovhoug, LWA		Alternatives Section 7.2	Under the category "Source control BMPs" in numerous tables, a comment is made that a Delta solution would likely have a very significant impact on salt accumulation in the Central Valley. Citations for this statement should be provided.	Citation was provided.
113	Debbie Webster, Central Valley Clean Water Association	1-2	Salt Capacity of the Disposal Method	Recommend adding “and/or” prior to “receiving water quality limitations” in the following sentence: “The salt capacity of an ocean outfall brine line is limited by the wastewater treatment plant (WWTP) capacity, pipe diameter, flow capacity, permitting, receiving water quality limitations.”	Comment noted and the changes were incorporated.
114	Debbie Webster, Central Valley Clean Water Association	1-2	Salt Capacity of the Disposal Method	It seems like, depending on the scenario, this could lead to false impressions, because the capacity might be smaller than the load, yet the reduction is great (environmentally beneficial) and cost effective. It may make more sense as a portion of the load.	The following sentence was added toward the end of the paragraph: “Salt capacity was reviewed in terms of the proportion of salt load that can be reduced.”
115	Debbie Webster, Central Valley Clean Water Association	1-2	Regulatory Challenges	Water rights need to be included as a factor when considering regulatory challenges.	The following sentence was modified to included water rights: “This factor reviewed pertinent regulatory challenges including Basin Plan water quality objectives, WWTP discharge limits, WWTP Resource Recovery permits, Waste Discharge Requirements (WDRs), Underground Injection Control (UIC) permits, proposed Basin Plan amendments, National Environmental Policy Act (NEPA)/California Environmental Quality Act (CEQA), water rights, *etc*.”

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116	Debbie Webster, Central Valley Clean Water Association	1-4	City of Tracy	Surface water sources for POTWs also comes with uncertainty in drought periods where surface water supplies are significantly limited if a junior water right is used to secure the source.	The following text has been added, "It should be noted, however, that surface water supplies continue to be limited and uncertain, particularly in drought periods, and may not always be reliable, particularly if a junior water right was used to secure the source of water."
117	Debbie Webster, Central Valley Clean Water Association	3-1	Source Control BMPs	Add the word "be" prior to the word "quantified" in the following sentence: "Salt reduction and associated costs by categories of source control BMPs will quantified – to the extent possible – in Phase 2 of SSALTS."	Comment noted and the changes were incorporated.
118	Debbie Webster, Central Valley Clean Water Association	3-8	Agricultural Water Reduction and Reuse Fact Sheet	This seems duplicative of the management practice above and doesn't seem to answer this practice.	This fact sheet has been re-written.
119	Debbie Webster, Central Valley Clean Water Association	3-8	Agricultural Water Reduction and Reuse Fact Sheet	Seems like the planning level cost are more reflective of the processing end vs land retirement or other steps. That should be explained.	This fact sheet has been re-written.
120	Debbie Webster, Central Valley Clean Water Association	4-3	Concept Level Cost Estimate for Salinity Treatment	Could there be cost recovery if the treated water (not brine) was resold, or is this water needed to replenish the groundwater?	Yes. This option was discussed in Section 8 of the draft report. A concept level value of water was used for the purposes of the cost estimate for the alternatives in this report. The following text was modified in Section 4, "An evaluation of alternative uses of the product water from desalters will be further refined. The product water will be of very high quality and irrigation of crops is not likely the best use of this resource. One option that will be evaluated is to transport the product water to southern California State Water Contractors through the California Aqueduct for a fee. This will serve to stabilize water supply and water quality in the

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					State Water Project (SWP) and will make more irrigation water available for the Central Valley Project (CVP). For the purposes of this Phase 2 SSALTS concept-level cost estimate, a value for the product water of $1000/AF was assumed." The following text was added to Section 4.3, "Potential revenue from beneficial uses of product water is also discussed in Section 7."
121	Debbie Webster, Central Valley Clean Water Association	5-1	Deep Well Injection	What is the normal useful life of injection wells?	The following text was added to Section 5.1, "Injection wells can have useful lives of 40 years or longer if properly maintained. That said, there needs to be an on-going and regular program of maintenance and periodic rehabilitation, and careful thought must be given to the materials of construction, design issues, and brine quality to minimize fouling or mechanical plugging."
122	Debbie Webster, Central Valley Clean Water Association	5-6	Permitted WWTP	The SWB has proposed some regulations concerning salinity limits on brine lines. This should be considered because it could reduce the capacity and add to the cost or change the project significantly so that its application is different.	The following text has been added to Section 5.5, The SWRCB has proposed new regulations concerning salinity limits on brine lines. This needs to be considered because it could potentially reduce the capacity of a project and/or add to the cost or change the project significantly. If the discharge was to be added to an existing POTW discharge, the salinity increase is not likely to be a significant concern. If a dedicated outfall were to be considered, as discussed in Section 5.5.2, this may or may not be a concern depending upon the relative volumes of brine received from different IAZ's, as shown in Tables 2-2 or 2-3. The brine from many areas would be well below natural receiving water background TDS, but could be significantly higher in other IAZs. The flow-weighted average TDS of brine in the initial phase is estimated to be about 25,000 mg/L, which is close to the ambient

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					TDS concentrations in the portions of San Francisco Bay that would be considered for an outfall project, and less than sea water TDS concentrations for an ocean outfall option.“.
123	Debbie Webster, Central Valley Clean Water Association	5-13	Table 5-10 Range of Salt Mass Removed by Disposal at EBMUD	Really need to watch what is happening at the State Water Board. They are proposing a new salinity limit whereby the salinity levels in the waterbody 100 meters from the discharge cannot be more than 2.0 ppt over natural background TDS as a daily maximum. I am not sure if this would limit the brine concentration at EBMUD.	See response to comment 122.
124	Debbie Webster, Central Valley Clean Water Association	5-24	Deep Well Injection with Dedicated Injection Wells	This is also assuming the power is sufficient at the location - right? Is this normally the case?	The following test has been added, “Sources of power in remote areas is another potential concern that will need to be evaluated.”
125	Debbie Webster, Central Valley Clean Water Association	6-2	Trucking brine to a WWTP	Are there air issues that need to be considered with this mode of transport?	An initial discussion of greenhouse gas effects is included in EBMUD Q&A No. 7. Further engineering evaluations will be included in future phases of SSALTS.
126	Debbie Webster, Central Valley Clean Water Association	6-5	Brineline	It seems as if you would need pump stations, feed locations (brine connections) etc. that are not included. Is it or is there an estimate of how much that could impact the cost?	See response to Comment 93.
127	Debbie Webster, Central Valley Clean Water Association	7-2	Source Control BMPs	The Source Control BMPs are included in all the solutions - however, I think that they are not necessarily a given in that they can have a very small cost-benefit ratio. It may be much more beneficial to have someone participate in a regional project rather than invest in source control.	The following text has been added to Section 7, “Implementation of source control BMPs are included in all of the alternatives and should be considered to the extent appropriate on a case-by-case basis. However, such practices can potentially have a very small cost-benefit ratio under certain circumstances

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					and are not necessarily intended to be applied everywhere or as a first priority. It may be more beneficial to have the affected party participate in a regional project rather than invest in source control.”
128	Debbie Webster, Central Valley Clean Water Association	7-2	Source Control BMPs	Comment doesn't seem to address capacity and doesn't fit the component.	See response to Comment 127. Also, the alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.
129	Debbie Webster, Central Valley Clean Water Association	8-1	Feasibility criteria for Phase 3 of SSALTS	I think it will be important to where there are regulatory roadblocks that have the potential to being removed or lightened, that they be identified in the overall project selection criteria. For example, most of these solutions could not work for POTWs under the current regulatory framework without and offset or alternative compliance policy. If the policy existed, these could become useful solutions. In the next phase, I am really hoping for some of this more thoughtful discussion.	The following text has been added to Section 8, “Also, where there are regulatory roadblocks that have the potential to being removed or lessened, these will be identified in the overall project selection criteria. For example, most of these solutions could not work for POTWs under the current regulatory framework without an offset or alternative compliance policy.”
130	Debbie Webster, Central Valley Clean Water Association	8-1	Importing recycled water for use as a source for irrigation or groundwater replenishment.	What levels of salinity are we talking about in the recycled water that would make its way back into the valley?	EBMUD recycled water had a seasonal average concentration of 870 mg/L in 2013. https://www.ebmud.com/sites/default/files/pdfs/wq-comparison-potable-2013-rw-2013.pdf
131	Debbie Webster, Central Valley Clean Water Association	8-2	Project alternatives	I think with any of the solutions we are looking at we need to be looking at multimedia impacts. This only is looking at cost, but do we have air, land, water supply, etc. impacts as we try to take care of our salts?	Comment note and text has been added to Section 8.
132	Thomas Harter/UC			A comment was made on the TAC call that some of the costs for various Alternatives in Section 7.2 seemed very	The alternatives analysis has been restructured. Please refer to Section 7 and Table 7-1.

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	Davis			similar. Please clarify for each of the alternatives if the values shown are annual costs, or the annualized cost with an explicit statement over how many years the capital costs would be annualized. Please also estimate the fresh water that would generated, by each of these options, in addition to the disposal requirements. I think that would be illustrative for understanding the relative cost of this to other fresh waters supplies in terms of understanding the economics. Other than that I didn't really have any comments on it. Thank you for a terrific report and keeping me in the loop.	
133	Karna Herrigfeld			How is discharge of salt from groundwater in a given IAZ to surface water accounted for?	The interaction of surface water and groundwater – all inflows and outflows – are accounted for in the Initial Conceptual Model. "Accounted for" includes both mass of TDS and volume of water moving between surface water and groundwater.
134	Karna Herrigfeld		Table 5-6	Explain the second column of Table 5-6. Table 5-6 includes flows from the New Melones Reservoir that are there solely for the purposes of dilutions to meet the Vernalis water quality objectives.	The second column represents the 50-year average (1963 to 2014) discharge of water in the San Joaquin River near Vernalis, CA Gaging Station (11303500) by month. These data are extracted from Table 5-4. We recognize that the discharge and EC values at the gaging station includes discharges from New Melones Reservoir. The last four columns of the table in this draft have no values, pending additional modeling work by others to estimate discharge and resultant EC that backs out the contribution from New Melones. See response to Comment 108.