APPENDIX E
COSTS FOR DESALINATION

Cost Estimate for Preliminary
Conceptual Desalination Project

This appendix is an excerpt prepared by Carollo Engineers (subcontractors) and originally presented as Attachment B of the *Development of a Basin Plan Amendment for Salt and Boron in the Lower San Joaquin River (LSJR): Task 5 – Economic Analysis* Report by Larry Walker Associates (LWA) Team (October 5, 2015)

1) PURPOSE

The purpose of this document is to:

1. Describe the preliminary concept for a regional desalination facility designed to control salinity inputs to Reach 83 of the Lower San Joaquin River (LSJR) to a level that would support the achievement of a potential salinity water quality objective (WQO) of 1,010 μmhos/cm EC as measured in the LSJR at Crows Landing.
2. Provide a planning level cost estimate for implementing the project.
3. Provide an estimate of the greenhouse gas emissions resulting from the operation of the facility.

The regional desalination facility is identified as potential Implementation Action 5a in Table 1 of the Report entitled “Task No. 4 – Implementation Planning for Proposed Salinity Objectives,” (LWA, 2015). In addition, through the work conducted by the LSJR Committee (LSJRC) and its consultants, this potential implementation action was identified as a salinity management alternative (“Planned Plus Maximum Treatment Focus Alternative” - Section 3.3.2, LWA 2015) that was modeled to determine if the diversion and treatment of agricultural drainage flows from upstream of Reach 83, followed by the discharge of treated, low total dissolved solids (TDS) water just downstream of the diversion points, could result in the achievement of a potential salinity WQO of 1,010 μmhos/cm EC as measured in the LSJR at Crows Landing (Section 4.1, LWA, 2015).

The Maximum Treatment Alternative is considered a preliminary conceptual project at this planning level stage of analysis. The desalination facility, which is the major component of the Alternative, would pump all drainage water from three sources, Mud Slough, Salt Slough, and the Gustine Area, at two diversion points to a proposed 160 million gallons per day (mgd) reverse osmosis (RO) treatment facility located in the Grassland Drainage Area, outside of the 100-year floodplain (**see Figure 1).** The two diversion points would be located along Mud Slough and Salt Slough just upstream of the confluence with the LSJR. The project would remove salts from the diverted flows using a RO process, and then pump low TDS water back to Mud Slough and Salt Slough immediately downstream of the initial diversion points. Approximately 20 percent of the flows removed from the three drainage sources would be lost in the concentrated brine produced by the RO process. This concentrated brine would then have to be pumped out of the basin for ultimate disposal to the ocean via a proposed Central Valley Brine Line (CDM Smith, 2014) as described in the Strategic Salt Accumulation Land and Transportation Study (SSALTS) Draft Final Phase 2 Report – Development of Potential Salt Management Strategies (CDM Smith, 2014).

2) DESCRIPTION OF DESALINATION FACILITIES

The facilities required to achieve desalination of the Mud and Salt Slough inputs to the LSJR include two pump stations, pipelines, and a RO treatment facility. The following major pipelines would be required:

- Untreated water (feed to the RO treatment facility from the two drainage courses);
- Finished water return (low TDS product water from the RO treatment facility to the two drainage courses); and
- Concentrated brine (high TDS waste from the RO treatment facility).

A preliminary, planning level concept map of pipelines and facilities that would be needed is provided in **Figure 1** and summarized in **Table 1**. The locations of the facilities and pipelines are shown for the purposes of developing the concept-level project to help inform and facilitate development of the treatment alternative, and are not intended to depict a fully developed alternative or recommendation. Development of the concept-level project did not include a comparison of siting options, facility siting or conveyance alternatives, field reconnaissance, considerations of environmental impacts or habitat impacts in affected waterways or lands, communication with land owners, etc.

Table 1 Estimated Capacities of Desalination Facilities
Cost Estimate for Preliminary Conceptual Desalination Project

Infrastructure Identification	Conceptual Capacity/Diameter	Conceptual Quantity
Desalination Facility	160 mgd(1)	100 acres
Untreated Water Pipelines	84-inch	42,000 Linear Feet
Drainage Water Supply Lift Stations	160 mgd (each)	2 Lift Stations
Desalination Finished Water Pipelines	54 to 84-inch	40,000 Linear Feet
Desalination Concentrate Pipeline	42-inch	36,000 Linear Feet

(1) 160 mgd capacity is based on the peak flow to the desalination facility. On average, the desalination facility would treat 22 mgd.

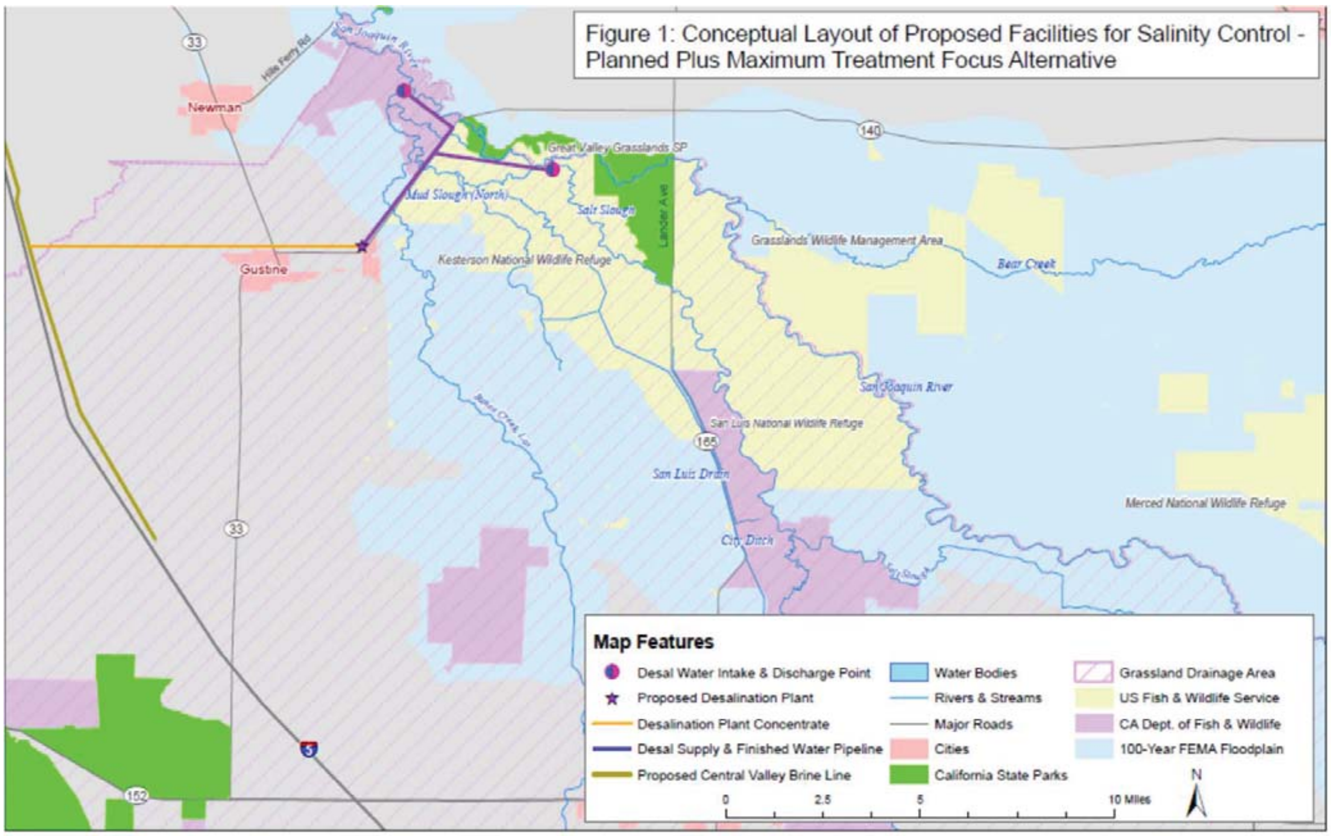

Figure 1: Conceptual Layout of Proposed Facilities for Salinity Control - Planned Plus Maximum Treatment Focus Alternative

Untreated Water Conveyance

As shown in **Figure 1**, untreated water would be pumped from two (2) pump stations: the Salt Slough Pump Station and Mud Slough Pump Station. The volume of untreated water pumped would be determined by the mass of TDS removal needed upstream of Crows Landing in order to meet a potential EC WQO of 1,010 µmhos/cm as measured in LSJR at Crows Landing. The evaluation is based on the Watershed Analysis Risk Management Framework (WARMF) simulated results for Crows Landing generated from the Maximum Treatment Alternative modeling run, using a daily time step, and assumes that untreated water would be pumped from each of the drainage courses with the following priority: Salt Slough then Mud Slough (Section 4.1, LWA,2015). The daily flows and 30-day average TDS concentrations from the WARMF simulation for the drainage courses were used in this evaluation. It is important to note that on worst-case days (when highest TDS load reductions upstream of Crows Landing would be required), 100 percent of flow from both drainage courses would be pumped for treatment.

RO Treatment Facility

The untreated water from the drainage courses would be desalinated in a RO treatment process. To operate an RO process effectively, the untreated water requires pretreatment to remove particulate matter from the RO Feed. The planning level desalination process consists of coarse screening at each of the drainage course pump stations, fine screening at the treatment facility, followed by a coagulation/flocculation process, microfiltration, and RO. Ancillary facilities would include microfiltration backwash treatment, solids handling (from screening and microfiltration processes), and various chemical addition facilities including antiscalant, sulfuric acid, and lime.

Using baseline drainage water quality data for Salt Slough and Mud Slough included in the WARMF model and RO membrane modeling software, estimates for water recovery and salt rejection were made for the preliminary conceptual desalination project. The use of a standard brackish water RO membrane is assumed.

The preliminary estimates indicate that an 80-percent water recovery and 98-percent salt rejection could be achieved in the treatment facility. This indicates that, for every ten (10) gallons of water removed from the drainage courses, eight (8) gallons of low TDS product water would be returned and that for every ten (10) pounds of TDS removed from the drainage course, 9.8 pounds would be removed as brine. These estimated values for water recovery and salt rejection were then applied to the daily flow and TDS values provided in the WARMF simulation to estimate daily finished water flows and TDS returned to the LSJR. While the RO treatment process will remove TDS from the untreated water pumped from Salt and Mud sloughs, constituents similar to boron will pass through the RO membrane (at a pH less than 9, boric acid has a neutral charge and is similar in size to water molecules).

The next step of this conceptual level analysis was to determine the required capacity of the treatment process. This was accomplished by using the Planned Alternative WARMF simulation results of the daily TDS loadings in excess of the potential EC WQO of 1,010 µmhos/cm that would need to be removed upstream of Crows Landing (LWA, 2015), and the estimated feed TDS concentration of the combined drainage courses to determine required daily treatment flows. The daily treatment flows were then used to estimate the maximum treatment flow required. A 30-day running average was calculated from the daily data to dampen the daily variation of flow and TDS in the drainage water to be treated.

Using the WARMF simulated flow and TDS data from October 1995 to September 2013, it was determined that the desalination facility would need to have the capacity to treat 160 mgd of drainage water in order to reliably meet the potential EC WQO of 1,010 µmhos/cm during times when TDS load reductions upstream of Crows Landing are greatest. On average, it was estimated that the RO facility would treat 22 mgd. The conceptual desalination facility would be constructed as a modular system with the ability to bring modules online and offline, as needed, to treat flows necessary to meet the potential 1,010 µmhos/cm EC WQO. It should be noted that the RO facility would not be continuously operated, since, at times, the river meets the proposed EC objective without treatment. However, idling of facilities would be necessary when active treatment is not occurring, as a means to keep treatment processes operating as designed and available for treatment when required. The modular operation would increase the unit cost of the RO product due to the increased maintenance and membrane replacement costs of the 160 mgd facility.

Finished Water/Concentrate Conveyance

At the RO treatment facility, the untreated water would be processed into two effluent streams: low TDS finished water (permeate) and high TDS concentrate. As shown on the concept map (**Figure 1)**, the finished water pipeline would approximately follow the route of the untreated water pipeline and discharge back into the two (2) drainage courses downstream of the intake locations on Salt Slough and Mud Slough. The concentrate pipeline would be routed west to discharge the concentrate waste into a proposed Central Valley Brine Line.

3) GREENHOUSE GAS EMISSION EVALUATION

The greenhouse gas (GHG) emissions estimate for this preliminary conceptual project is based on the estimated annual purchased energy consumption (40,000,000 kWh/year based on the annual average flow of 22 mgd) for the operation of the Salt Slough and Mud Slough pump stations and the RO treatment facility. The GHGs of concern at treatment plants include carbon dioxide (CO_2), and, to a lesser degree, methane (CH_4)

and nitrous oxide (N_2O). Each of these can be emitted indirectly through the use of purchased electricity.

Emissions were converted into carbon dioxide equivalent (CO_2e) emissions. The major GHG in the atmosphere is CO_2. Other GHGs differ in their ability to absorb heat in the atmosphere. For example, CH_4 has 25 times the capacity to absorb heat relative to CO_2 over a hundred-year time horizon, so it is considered to have a global warming potential (GWP) of 25. N_2O has 298 times the capacity over a hundred-year time horizon and is given a GWP of 298. Therefore, a pound of emissions of CO_2 is not the same in terms of climatic impact as a pound of CH_4 or N_2O emitted. CO_2e emissions are calculated by multiplying the amount of emissions of a particular GHG by its GWP. These GWPs are taken from the Intergovernmental Panel on Climate Change Fourth Assessment Report (2007) for a 100-year time horizon. These GWPs are used today by international convention and the U.S. to maintain the value of the carbon dioxide "currency", and are used in this evaluation to maintain consistency with international practice.

The GHG emissions resulting from the purchase of 40,000,000 kWh/year for the operation of the pump stations and the RO treatment facility would total 15,989 metric tons of CO_2e based on emission factors for the state of California. Because these are indirect emissions, they are not a regulated source and would not be reported to the State or EPA.

4) DESALINATION PROJECT COST ESTIMATE

Preliminary capital, operations and maintenance (O&M), and life-cycle costs were developed for the Preliminary Conceptual Desalination Project. The estimated costs are presented in the following sections.

Level of Accuracy

This cost estimate is considered a Class 5 (order-of-magnitude) estimate, as classified by the Association for the Advancement of Cost Engineering International. Class 5 cost estimates are suitable for concept screening. The expected accuracy range of a Class 5 estimate is within +50 percent and -30 percent.

Capital, O&M, and Life-Cycle Cost Assumptions

The assumptions used in the development of the Preliminary Conceptual Desalination Project capital and O&M costs are summarized in **Table 2**. The costs do not include any possible buy-in fees for the purchase of disposal capacity in a proposed Central Valley Brine line. However, due to the significant impact of residual management on annual O&M costs, estimates for concentrate disposal (salt removed from river) and solids hauling and disposal (solids removed from untreated river water) have been included in the O&M estimate. These values were estimated based on typical costs for inland desalination facilities located in Southern California.

Table 2 Capital, O&M, and Life-Cycle Cost Assumptions
Cost Estimate for Preliminary Conceptual Desalination Project

Parameter	Unit	Value
Peak Flow to Treatment(1)	Mgd	160
Average Flow to Treatment(2)	mgd	22
Power	$/kWh	$0.125
Lime (slaked)	$/lb	$0.20
Sulfuric Acid	$/lb	$0.03
Scale Inhibitor	$/lb	$0.95
Membrane Elements - 8 inch diameter	$/element	$500.00
Membrane Elements - MF	$/element	$775.00
Cartridge Filters	$/filter	$12.00
Step 1 Cleaning Chemical Cost	$/lb	$2.82
Step 2 Cleaning Chemical Cost	$/lb	$3.16
Step 3 Cleaning Chemical Cost	$/lb	$2.00
Plant Operating Factor	-	0.98
O&M Inflation	%/year	0
Discount Rate	%/year	5
Term	years	30

(1) The peak flow was used to develop the Capital Costs.
(2) The average flow was used to develop the O&M Costs.

Capital Costs

The capital costs consist of all items that would be constructed/purchased for the Preliminary Conceptual Desalination Project. The direct cost of each process is based on the following:

- Vendor-quoted information.
- Cost curves based on historical costs from other projects.
- Typical planning level values.

The conceptual level capital costs are summarized in **Table 3**. Costs are based on 2015 dollars (20-City Engineering News-Record (ENR) Construction Cost Index, April 2015 - 9,992). Costs to purchase land for the facilities are not included.

Table 3 Capital Costs
Cost Estimate for Preliminary Conceptual Desalination Project

Component Description		Cost
Salt Slough Pump Station and Intake Structure		$22,000,000
Mud Sough Pump Station and Intake Structure		$22,000,000
Untreated Water Pipelines		$30,300,000
MF/RO Desalination Facility[2]		$283,000,000
Desalination Finished Water Pipeline		$26,900,000
Desalination Concentrate Pipeline		$18,800,000
	Total Direct Cost	**$403,000,000**
Project Level Allowance @ 50 percent		$201,500,000
	Subtotal	**$604,500,000**
Sales Tax @ 9 percent[3]		$27,200,000
	Subtotal	$631,700,000
Contractor General Conditions @ 6 percent		$37,900,000
	Subtotal	**$669,600,000**
General Contractor Overhead and Profit @ 12 percent		$80,400,000
	Total Estimated Construction Cost	**$750,000,000**
Engineering and Contract Administration @ 20 percent		**$150,000,000**
	Total Estimated Project Cost	**$900,000,000**

(1) Capital costs are based on a peak capacity of 160 mgd.
(2) Conceptual facility design and cost estimate does not consider boron removal.
(3) Calculated assuming 50 percent of direct costs are taxable.

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers, Inc. have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices, or bidding strategies. Carollo Engineers, Inc. cannot and does not warrant or guarantee that proposals, bids, or actual construction costs will not vary from the costs presented as shown.

Operations and Maintenance Costs

O&M costs include the labor, utilities, chemicals, maintenance, membrane replacement, and brine disposal required to operate a MF/RO system. The conceptual level O&M costs are summarized in **Table 4**.

Table 4 O&M Costs

Cost Estimate for Preliminary Conceptual Desalination Project

Component Description	Cost
Total Power Cost ($/yr)	$4,900,000
Chemical Costs ($/yr)	$2,100,000
MF/RO Membrane Replacement Costs ($/yr)	$931,000
Cartridge Filter Costs ($/yr)	$51,000
Maintenance Costs ($/yr)	$1,300,000
Laboratory Costs ($/yr)	$50,000
Concentrate Disposal Costs ($/yr)	$4,600,000
Solids Hauling and Disposal Costs ($/yr)	$900,000
Labor Costs ($/yr)	$1,310,000
Annual O&M Cost ($/yr):	**$16,100,000**
Annual O&M Cost ($/kgal):	**$2.05**
Annual O&M Cost ($/AF):	**$667**

(1) Due to the variability of EC in the LSJR, the RO treatment facility would not operate continuously. Flows could range from zero to 160 mgd when in operation. O&M costs are based on a yearly average flow of 22 mgd.

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Life Cycle Costs

A life cycle cost analysis was performed for the Preliminary Conceptual Desalination Project. The life-cycle costs are based on a discount rate of 5 percent per year and the life- cycle period of 30 years. The life-cycle costs are summarized in **Table 5**.

Table 5 Life-Cycle Costs Cost Estimate for Preliminary Conceptual Desalination Project

Component Description	Cost
Total Project Cost[1] ($)	$900,000,000
Annual O&M Cost[2] ($/yr) 30-	$16,100,000
year Life-Cycle Cost ($)	$1,148,000,000

(1) Total Project costs are based on peak capacity of 160 mgd.
(2) O&M costs are based on an average flow of 22 mgd.

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5) REFERENCES

CDM Smith. 2014. Strategic Salt Accumulation Land and Transportation Study

(SSALTS) Phase 2 – Development of Potential Salt Management Strategies. Draft Final Report. Prepared for San Joaquin Valley Drainage Authority. Submitted by CDM Smith. September 2014.

Larry Walker Associates (LWA) 2015. Task #4 – Implementation Planning for Proposed Salinity Objectives. Prepared for San Joaquin Valley Drainage Authority. Submitted by Larry Walker Associates, Inc., in association with Systech Water Resources, Carollo Engineers, and PlanTierra. July 2015.