BUREAU OF RECLAMATION

2022 Management Agency Agreement Annual Report

Interior Region 10 – California-Great Basin

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo: Delta-Mendota Canal/California Aqueduct Intertie Canal with brilliant blue water winding through valley.

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Abbreviations and Acronyms

Action Plan	Actions to Address the Salinity and Boron TMDL Issues for the Lower San Joaquin River November 2008
Basin Plan	Water Quality Control Plan for the Sacramento and San Joaquin River Basins, 5th Edition
BO	Biological Opinion
CALFED	California Bay-Delta Authority
CVO	Central Valley Operations
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CV Water Board	Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley Salinity Alternatives for Long Term Sustainability Stakeholder Group
D-1641	State Water Resources Control Board Decision 1641
DF	Base Design Flow
DMC	Delta-Mendota Canal
DWR	California Department of Water Resources
EC	Electrical Conductivity
GBP	Grassland Bypass Project
GDA	Grassland Drainage Area
GDF	Goodwin Dam Flow
GWD	Grassland Water District
LSJR	Lower San Joaquin River
MAA	Management Agency Agreement

MID	Modesto Irrigation District
MOU	Memorandum of Understanding
NOAA	National Oceanic and Atmospheric Administration
mg/L	milligram(s) per liter (parts per million)
PTMS	Program to Meet Standards
Reclamation	United States Department of the Interior Bureau of Reclamation
RFC	California-Nevada River Forecast Center
RTMP	Real Time Management Program
SJR	San Joaquin River
SJRIP	San Joaquin River Water Quality Improvement Project
SJVDA	San Joaquin Valley Drainage Authority
State Water Board	State Water Resources Control Board
TAF	Thousand Acre-Feet
TDS	Total Dissolved Solids
TID	Turlock Irrigation District
TMDL	Total Maximum Daily Load
VAMP	Vernalis Adaptive Management Plan
WARMF	Watershed Analysis Risk Management Framework
WQO	Water Quality Objective
WRDP	Westside Regional Drainage Plan

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2022 MAA Summary of Reclamation Activities

Purpose

The Central Valley Regional Water Quality Control Board's (CV Water Board) Control Program for Salt and Boron Discharges into the Lower San Joaquin River (LSJR), also known as the Salt and Boron Total Maximum Daily Load (TMDL), was approved, and placed into effect on September 10, 2004. In response to the Salt and Boron TMDL, the U.S. Bureau of Reclamation (Reclamation) developed the salinity management plan titled Actions to Address the Salinity and Boron TMDL Issues for the Lower San Joaquin River (Action Plan) and entered into a Management Agency Agreement (MAA) with the CV Water Board on December 22, 2008. The MAA described Reclamation's actions to meet the obligations allocated to it by the Salt and Boron TMDL for the LSJR. In the MAA, Reclamation agreed to implement the Action Plan. Figure 1 shows seven TMDL subareas for salt load management in the LSJR Basin.

Reclamation and the CV Water Board revised the MAA on December 4, 2015. The revised MAA does not reference the Action Plan. However, Section 2.3d of the revised MAA states that "Reclamation actions will be detailed in an Annual Work Plan and submitted along with a Status of Activities to Date from the previous year."

This report summarizes activities conducted by Reclamation in fiscal year (FY) 2022 in conjunction with the related elements outlined in the revised MAA. The original Action Plan described Reclamation's past practices and procedures to mitigate and manage adverse impacts of salt and boron imported into the San Joaquin Basin via the Delta-Mendota Canal (DMC) to help achieve compliance with the objectives contained in the CV Water Board's *Water Quality Control Plan for the Sacramento River and the San Joaquin River Basins – 5th Edition* (Basin Plan). Reclamation reported the activities in quarterly reports as agreed to in the 2008 MAA. In the 2015 revised MAA (referred to as the MAA from here forward), Reclamation activities are now reported at the end of each calendar year in the Annual Report and activities planned for the next fiscal year are proposed in the Annual Work Plan.

Organization of the Annual Report

The Annual Report provides a synopsis of the various activities performed by Reclamation in accordance with the MAA. Action categories include Providing Flows to the System, Salt Load Reductions, and Phased Program Activities. For each action a brief description and list of activities are provided. The Annual Report includes calculations of salt loads based on DMC deliveries and calculations of assimilative capacity provided through dilution flows. The Compliance Monitoring and Evaluation Plan, dated May 2010 and submitted in 2010, outlines the criteria and methodology for determining DMC loads and credits.

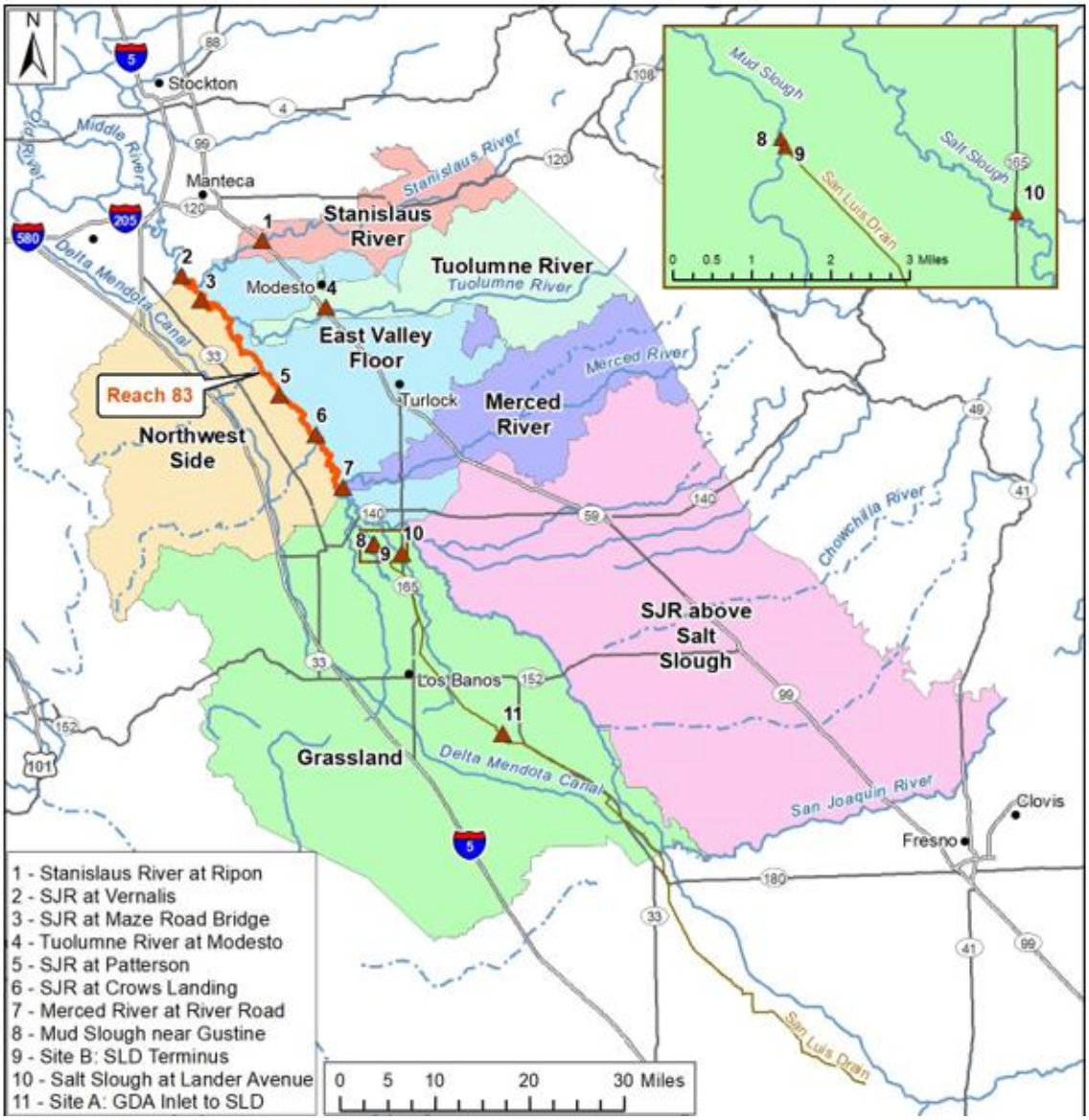

Figure 1. TMDL Subareas for Salt Load Management in the LSJR Basin

Providing Flows to the System

In 2000, Reclamation agreed to the provisions in the State Water Resources Control Board's (State Water Board) revised Decision 1641 (D-1641), which require the release of flows from New Melones Reservoir (Figure 2) to meet the Vernalis salinity objectives. Historically, Reclamation has provided both fishery and water quality dilution flow to the San Joaquin River (SJR) from New Melones Reservoir and through purchases for the Vernalis Adaptive Management Plan (VAMP) or the Central Valley Project Improvement Act (CVPIA). The SJR Agreement, which included provisions to acquire spring and fall pulse flows for the VAMP,

expired on December 31, 2011. Reclamation continued to provide interim spring pulse flows for the SJR through a two-year agreement with Merced Irrigation District, which expired on December 31, 2013. During this timeframe, stakeholders within the watershed, including Reclamation, initiated the San Joaquin Tributary Settlement Process to formulate a collaborative solution to present as an alternative to the State Water Board's new proposed SJR flow standard.

New Melones Reservoir Operations – Provision of Dilution Flow

In the Flood Control Act of October 1962, Congress reauthorized and expanded the function of the Melones Reservoir (P.L. 87-874) to become a multipurpose reservoir constructed by the U.S. Army Corps of Engineers and operated by the Secretary of the Interior as part of the Central Valley Project (CVP), thus creating the New Melones Reservoir. Reclamation signed a Memorandum of Understanding (MOU) with the CV Water Board in 1962 to schedule water releases from New Melones to maintain a dissolved oxygen level of 5 milligrams per liter (mg/L) in the Stanislaus River at the Ripon monitoring station, downstream of the reservoir. The multipurpose objectives of the reservoir now include flood control, irrigation, municipal and industrial water supply, power generation, fishery enhancement, water quality improvement, and recreation. Since June of 2009, New Melones Reservoir has been operated by Reclamation to meet the National Marine Fisheries Service Biological Opinion (BO). The BO addresses the effects of the continued operation of the CVP and the California State Water Project on the various runs of Chinook salmon, Central Valley steelhead, and green sturgeon, and their designated critical habitats.

Figure 2. New Melones Reservoir

The Basin Plan was amended in 2004 to include a control program for salt and boron discharges into the LSJR. The control program dictated that through the MAA between Reclamation and the CV Water Board, Reclamation would either (a) meet DMC salinity load allocations, or (b) provide dilution flows to create additional salt load assimilative capacity in the LSJR equivalent to DMC salt loads in excess of their allocation. Items 12 and 13 in the Salt and Boron Water Quality Control Program include the following statements:

Item 12. Salt loads in water discharged into the LSJR or its tributaries for the express purpose of providing dilution flow are not subject to load limits described in this control program if the discharge:

a. Complies with salinity Water Quality Objectives (WQOs) for the LSJR at the Airport Way Bridge near Vernalis;
b. Is not a discharge from irrigated lands; and
c. Is not provided as a water supply to be consumptively used upstream of the San Joaquin River at the Airport Way Bridge near Vernalis.

Item 13. Entities providing dilution flows, as described in item 12, will obtain an allocation equal to the salt load assimilative capacity provided by this flow. This dilution flow allocation can be used to: 1) Offset salt loads discharged by this entity in excess of any allocation or; 2) trade, as described in item 10. The additional dilution flow allocation provided by dilution flows will be calculated as described in Table IV-8 (CV Water Board 2018).

Activities

Reclamation continues to operate its New Melones facilities to comply with State Water Board D-1641, New Melones Interim Plan of Operations, the applicable BOs, and the Stanislaus River at Ripon monitoring station dissolved-oxygen criteria.

Quantification Methodology: Table IV-4.4 (CV Water Board 2017) states that dilution flow allocations should be calculated as follows:

$$A_{dil} = Q_{dil} \times (C_{dil} - WQO) \times 0.8293$$

Where:

A_{dil} = Monthly assimilative capacity provided by a dilution flow (expressed as salt load) in tons per month

Q_{dil} = Dilution flow rate in thousand acre-feet (TAF) per month [above base flows]

C_{dil} = Electrical conductivity (EC) of the dilution flow in micro-Siemens per centimeter (µS/cm)

WQO = Salinity water quality objective for the LSJR at Airport Way Bridge near Vernalis in µS/cm

Table 1 lists data and monthly calculations for the past year. Data for flow releases from Goodwin Dam, the Stanislaus River, "design flows," and salinity at Orange Blossom Bridge are used to calculate the monthly dilution flow allocations. When Goodwin Dam flows are less than base design flows, the flows are adjusted to equality to set assimilative capacity for the month to zero. The water-year type is estimated based on the 75% probability of exceedance found in California Department of Water Resources (DWR) Water Supply Index Forecasts (https://cdec.water.ca.gov/reportapp/javareports?name=WSI) for the San Joaquin Valley. The 75% exceedance flow forecast for May 1, 2022, is 1.5, which classifies 2022 as a "critically dry" year. In 2022 the SJR Valley floor received 69% of the average seasonal rainfall[1].

Table 1. Salt Load Assimilative Capacity of Goodwin Dam Releases to the San Joaquin River, Water Year 2022

Date	Goodwin Dam Flow (GDF)[a] TAF	Base Design Flow (DF)[b] TAF	Qdil, TAF GDF-DF=Qdil TAF	WQO[c], µS/cm	Monthly Average EC at Orange Blossom Bridge (Cdil)[d], µS/cm	Monthly Assimilative Capacity, A_{dil}, tons
October 2021	34	8	26	1,000	58	20,311
November 2021	15	13	2	1,000	61	1,557
December 2021	19	13	6	1,000	76	4,598
January 2022	14	9	5	1,000	120	3,649
February 2022	60	8	52	1,000	82	39,587
March 2022	28	9	19	1,000	91	14,323
April 2022	27	27	0	700	73	0
May 2022	41	28	13	700	64	6,857
June 2022	49	0	49	700	58	26,088
July 2022	18	0	18	700	57	9,598
August 2022	15	0	15	700	57	7,999
September 2022	14	1	13	1000	60	10,134
Total						144,701

a https://www.usbr.gov/mp/cvo/reports.html

b Reclamation 2010 Compliance Monitoring and Evaluation Plan

c State Water Board Decision 1641

[1] https://www.cnrfc.noaa.gov/monthly_precip_2022.php

d http://cdec.water.ca.gov/dynamicapp/staSearch

Water Resources and Water Quality Regulation

The CVPIA, signed into law on October 30, 1992, modified priorities for managing water resources of the CVP. The CVPIA altered the management of the CVP to elevate fish and wildlife protection, restoration, and enhancement as a co-equal priority with water supply for agriculture and municipal and industrial purposes while recognizing other associated benefits such as power generation. To meet water acquisition needs under CVPIA, the U.S. Department of the Interior developed a Water Acquisition Program as a joint effort between Reclamation and the U.S. Fish and Wildlife Service. The program's purpose is to acquire water supplies to meet the habitat restoration and enhancement goals of the CVPIA and to improve the Department of the Interior's ability to meet regulatory water quality requirements.

Activities

Reclamation did not acquire any additional water for water quality purposes in 2022.

Salt Load Reductions

Reclamation is under a court order to provide drainage to the San Luis Unit on the west side of the San Joaquin Valley. As part of this effort, Reclamation historically supported the Westside Regional Drainage Plan (WRDP) through grants and in-kind services. Incidental salt load reduction actions have included the Grassland Bypass Project (GBP) (ended on December 31, 2020), implementation of the WRDP, and the following conservation programs: Water Conservation Field Services Program, WaterSMART Water and Energy Efficiency Grants (formerly Water 2025 Grants Program), and the California Bay-Delta Authority (CALFED) Bay-Delta Water Use Efficiency Program. Although most of these programs were not initiated as salt load reduction efforts, their successful implementation has resulted in measurable reduced salt loading to the lower SJR.

Grassland Bypass Project (GBP)

The GBP was a multi-agency stakeholder project currently based upon the 2009 Use Agreement[2] between Reclamation and the San Luis and Delta-Mendota Water Authority to manage and reduce the volume of agricultural drainage water produced within the Grassland Drainage Area (GDA). The Project used a 28-mile section of the San Luis Drain to convey this drainage water to Mud Slough, a tributary of the SJR. Annual and monthly reductions in allowable selenium load discharge to Mud Slough were part of the negotiated Use Agreement and were successfully met over the past 20 years of the project. All selenium drainage loading from the GDA to Mud Slough ceased on December 31, 2020 after which all subsurface drainage was diverted to the

[2] U.S. Bureau of Reclamation and the San Luis and Delta-Mendota Water Authority, December 22, 2009. Agreement for Continued Use of the San Luis Drain for the Period January 1, 2010, through December 31, 2019. Agreement No. 10- WC-20-3975.

6,500 acre San Joaquin River Improvement Project (SJRIP) facility. The Interagency Data Collection and Review Team and the San Joaquin Valley Drainage Authority (SJVDA) negotiated a provision to allow flood flows to be conveyed by the San Luis Drain during unusual precipitation events to prevent widespread flooding of the GDA watershed. The GBP has been a highly successful example of agency and stakeholder cooperation to slowly phase out the non-point source environmental pollutant selenium from the water quality impaired SJR.

Activities

- Although the GBP was specifically designed to address selenium non-point source loading to the SJR, the GBP also significantly reduced the drainage discharge loading of salt and boron. The SJRIP now receives all subsurface drainage water from the GDA. The SJRIP has slowly expanded its footprint to accommodate continued inflow as the salinity has increased on some of the acreage and alfalfa crop production has been replaced with Jose tall wheatgrass – a more salt tolerant crop that is in high demand from local livestock producers but has less economic return than alfalfa.

- Prior to Water Year 1996, more than 191,000 tons of salts and 357 tons of boron were discharged annually from the GDA to the LSJR.

- During Water Year 2022, 142 tons of salts and 0.7 tons of boron were discharged from the GDA to the San Luis Drain. and then conveyed to the SJRIP reuse area. The primary purpose of the SJRIP reuse area is disposal of the subsurface drainage from the GDA with forage crops grown and harvested to offset the costs of managing the facility. During Water Year 2022 water allocation to irrigated agriculture south of the Delta was curtailed leading to a significant reduction in salt and boron loading. The subsurface drainage discharge that was conveyed to the SJRIP was the result of irrigation with groundwater and water transfers into the GDA. Fallowing of a large number of forage crop fields was necessary in the SJRIP to provide sufficient irrigation water supply for the fields remaining in production. Reclamation has supported ongoing research in the SJRIP to improve drainage water management and maximize income from forage production activities.

- During Water Year 2022, approximately 84,000 tons of salts and 206 tons of boron were displaced to the SJRIP. Absent the collaboration between Grassland Area Farmers and Reclamation, these loads would have been discharged to the LSJR.

Figure 3 shows the progressive reduction of salts discharged from the GDA[3] due to agricultural flow diversion to the SJRIP.

Figure 4 shows the progressive reduction of boron discharged from the GDA. For Water Year 2022, 0.7 tons of boron was discharged to the LSJR from the GDA and approximately 206 tons were displaced to the SJRIP.

[3] Data Sources: CV Water Board (pre-project), Reclamation, and Summers Engineering.

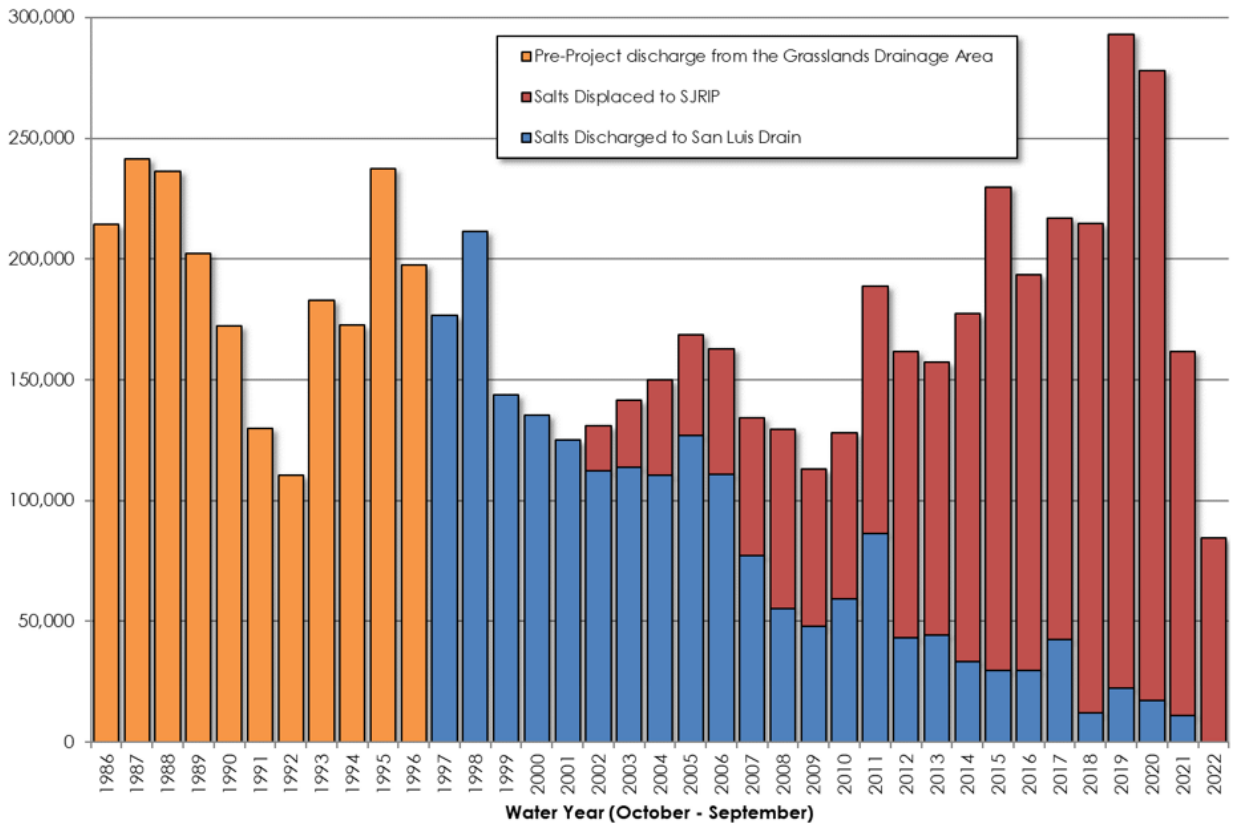

Figure 3. Salts Discharged from the Grassland Drainage Area (tons)

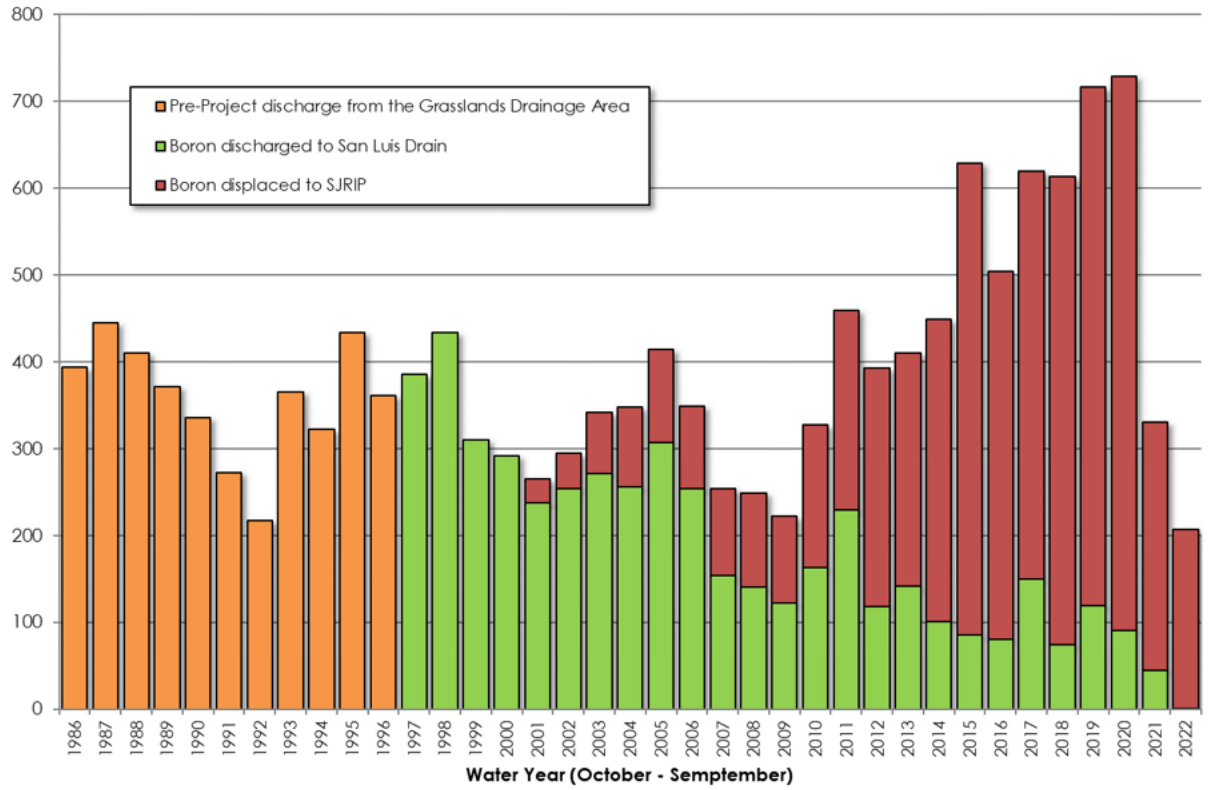

Figure 4. Boron Discharged from the Grassland Drainage Area (tons)

- The ongoing GBP management plan has provision for the facility to provide storm water management benefits under the CV Water Board Order R5-2019-0077. This plan was recently updated. Runoff from winter precipitation in the GDA can be conveyed through the San Luis Drain to Mud Slough and the San Joaquin River during extreme weather events that cause flooding within the Basin. The plan provides details of the circumstances when this discharge is allowable and the reporting requirements.
- Reclamation continues to collect and analyze water samples from nine sites for selenium, boron, salts, nutrients, and molybdenum, and continues to operate auto-samplers in the San Luis Drain and in the river at Crows Landing.

Westside Regional Drainage Plan

The WRDP is a local stakeholder program developed by integrating all consistent elements of drainage management developed by government and local agencies and private partnerships. The original efforts of the WRDP focused on reducing selenium discharges to the SJR. The initial goals of the WRDP have been met although the original plan did not recognize the importance of real-time monitoring and management in the success of this initiative.

Additional Activities Benefiting Salt Management

- The GDA continues to implement activities associated with the WRDP and SJRIP. The SJRIP currently reuses subsurface agricultural drain water from the GDA to irrigate salt-tolerant crops such as Jose tall wheatgrass, alfalfa, and pistachio trees. Income from the sale of forage hay and pistachios has been used to offset costs associated with management of the SJRIP facility.

- The San Luis Demonstration Treatment Facility was shut down for renovations on December 31, 2018. Reclamation posted a solicitation to retrofit the feed pumps and other aspects of the solids waste handling system at the demonstration plant on July 22, 2019. A plan to resume operation of the Treatment Facility during 2022 was shelved due to the lack of drainage return flows from fields with underlying tile drains. The Treatment Facility requires a minimum flow volume to keep the biological treatment and reverse osmosis units for selenium and salt removal operational.

- Reclamation has provided approximately $45 million in past funding to the SJRIP and continues to support research activities at the facility that relate to optimization of the unit processes and improvements in system reliability.

- Reclamation will continue to fund activities in the western San Joaquin Valley through the WaterSMART Program. The competitive grant program has been expanded beyond the drought resiliency and water and energy efficiency themes to include watershed management that is better aligned with the goals and cyberinfrastructure themes of real-time water quality management.

- Del Puerto Water District has completed a $12.075 million grant for reuse of municipal recycled wastewater from the eastside of the San Joaquin Valley as an agricultural water supply. Treatment plants operated by the cities of Turlock and Modesto provided the reclaimed effluent that was piped to Del Puerto Water District. The success of this program could be replicated in other regions of the San Joaquin Valley to the mutual benefit of the cities involved and irrigated agriculture.

- For Water Year 2022 (October 2021 through September 2022), Grassland Basin Drainers report a displacement of 12,514 acre-feet of agricultural drainage water to the SJRIP, containing 84,000 tons of salts and 0.7 tons of boron. Absent the SJRIP, these salt and boron loads would have been discharged into the LSJR.

Water Conservation Efforts Benefiting Salt Management

The water use efficiency program includes several grant programs which fund actions to assure efficient use of existing and new water supplies. Activities to improve water use efficiency can alter the magnitude and scheduling of water diversions from Reclamation canals providing additional benefits. These activities can also result in reduced discharge of agricultural drainage and associated pollutants, improving water quality in receiving waters such as the SJR. Although Reclamation is not always able to quantify the benefits of the various funded projects with respect to salt load reduction, these projects all contribute to the agency's water conservation efforts in the Basin. Funding for approximately 100 projects in the San Joaquin Valley have been

awarded through programs such as WaterSMART, the Reclamation/Natural Resources Conservation Service partnership, and the CALFED Bay-Delta Restoration Program. Most of these programs have required quantifiable benefits and measurable performance measures since 2006.

The funding Reclamation provided in FY 2022 is listed in Table 2.

Table 2. Fiscal Year 2021 2022 Reclamation Funding

Funding Program	FY 2022 Allocation
Program to Meet Standards • Provided financial assistance to GWD for providing support in the real-time management program by collecting and providing data to Reclamation and for providing stakeholder coordination • Systech Water Resources Inc. developed a new auto-data retrieval and process tool with an interface for WARMF model input in FY 2022. • WARMF model was calibrated well using latest five years data from 10/01/2016 – 09/30/2021. The new calibrated WARMF was used for the forecasting in FY 2022. • Systech Water Resources Inc. is developing a self-calibrator to improve the forecasting accuracy using real time data retrieved on the day of forecasting using WARMF model. The self-calibrator will be delivered in FY 2023. • Systech Water Resources Inc. is improving the model routing mechanism to apply diffusive wave equation. The updated WARMF will be available in FY 2023. • University of California at Merced provided technical support and stakeholder coordination via a Cooperative Ecosystem Studies Unit agreement • Reclamation staff provided technical support and project management activities	$750,000

Phased Program Activities

The MAA lists several actions that are intended to improve management of salt and boron loads in the SJR. These actions have been phased in coordination with SJR Basin stakeholders, and each of these phases has been associated with primary goals. These phases and goals were recognized in the most recent Work Plans developed jointly with the San Joaquin Real- Time Management Program (RTMP) Steering Committee (Reclamation 2018, 2019, 2020, 2021,2022). This reorganization of the description of activities has helped to make the annual reporting of program activities and accomplishments easier to follow and understand. The RTMP

Steering Committee meets quarterly and includes both East- and Westside San Joaquin Basin stakeholders, agency personnel, and consultants.

Phases 1 and 2 of the RTMP were focused on initiation (Phase 1) and an early development phase (Phase 2) that tackled monitoring station design, installation, and operation (Goal 1); engaging stakeholder participation (Goal 2); stakeholder cooperation to seek grants and other external funding (Goal 3); and initial development of a watershed-level water quality simulation and water quality forecasting tool that would provide essential decision support for salt load assimilative capacity determination and salt load management (Goal 4). Phase 2 of the San Joaquin RTMP occurred from March 31, 2015, to March 31, 2016. Some goal elements from Phase 2 have been carried forward into Phases 3 and 4.

Phase 3 of the RTMP was the early implementation phase, which concluded in March 2018. Goals under this phase included programmatic weekly forecasting of assimilative capacity in the SJR by one or more cooperating RTMP entities (Goal 1); initiation of data-sharing activities between and among stakeholder entities and information technology innovations to facilitate secure and reliable data flows (Goal 2); periodic analysis of additional infrastructure needs and funding requirements through feedback from the MOU Steering Committee (Goal 3); development and recommendation of specific additional management practices needed to better coordinate the real-time operation of discharges to the SJR (Goal 4); and proactive outreach to current and prospective stakeholder entities in the Basin, specifically those who have not participated in the RTMP to date.

Phase 4 of the RTMP is the implementation phase, in which activities that started in Phases 2 and 3 become fully realized and are formalized as part of an ongoing RTMP. There are technical and institutional components to Phase 4 of the RTMP. Under Phase 4, RTMP participants continue to implement and upgrade monitoring, data networking, and management practices as needed. The WARMF salt load assimilative capacity forecasting model is expected to be utilized by stakeholders to coordinate the timing of drainage discharges to the river with available salt load assimilative capacity (Goal 1); RTMP participants also continue to address long-term funding and project needs (Goal 2); and the RTMP current membership may expand to include all regulated parties that includes both direct and indirect dischargers of salt to the SJR (Goal 3). Ongoing implementation may bring about technical improvements to data processing, quality assurance, and the SJR assimilative capacity forecast modeling (Goal 4).

Ongoing Phase 3 Activity Summary (April 2016 – September 2022)

Goal 1: Model-Based Forecasting of Salt Assimilative Capacity

Reclamation has actively supported the development of SJR salinity forecasting models, including the WARMF model, to estimate daily river salt assimilative capacity and to provide decision support for real-time salinity management at the watershed level. The WARMF model simulates watershed hydrology and irrigation return flow to the River but also allows substitution of real-time, continuous data of flow and salt loads from monitored tributaries and water district diversions. The accuracy of salt load assimilative capacity forecasts is increased with the provision of recent flow and salinity data and advance information on anticipated management

actions that could impact flow and salinity over the two-week forecast period. The accuracy of these forecasts can be enhanced with stakeholder willingness to share information in a timely manner and take interest in the disseminated forecasts.

As previously reported - starting in FY 2018 and continuing through FY 2022, Reclamation has also used a simple, data-driven Regression model for estimating EC at all three compliance monitoring stations (Vernalis, Maze Road Bridge, and Crows Landing) on the SJR. The motivation for developing this alternate approach was to allow greater automation of forecasts and reduce the effort involved, which in the case of the WARMF models involves assembling both hydrological and meteorological data sets. The new compliance monitoring station at Maze Road Bridge specifically recognizes the reach upstream of Vernalis to protect riparian diverters along Reach 83. The data-driven regression approach focuses just on salinity at the three compliance locations along the main stem of the SJR. The inverse gradient Regression model has provided good forecast accuracy, as was described in the journal article in Water that summarized the use of both forecasting models during Water Year 2021 (Quinn, Tansey, and Lu; 2021). Ongoing related activity has compiled past SJR water quality forecasts for Water Year 2022 and the prior analysis will be repeated for this more recent period. Given the unusual hydrology during 2022 which saw a complete curtailment of project deliveries to agricultural and wetland water supply contractors – the more physically based model has been performing more reliably than the regression-based approach and has been used preferentially for daily flow and EC forecasts in the SJR. This analysis will be reported in next year's annual report.

Ongoing activity in CVSALTS related to the roll-out of the Prioritization and Optimization (P&O) Study discussed the potential use of the current WARMF model for application in the San Joaquin Basin. The P&O study is developed around the concept of stakeholder-crafted salinity management zones that would help to corral resources needed to maintain compliance with basin management plan salinity objectives. Although the CV-SWAT model was recommended by the dedicated small technical committee overseeing the P&O modeling approach nonetheless it was recognized that the WARMF model would have great utility in calibrating the CV-SWAT tool. CV-SWAT has been used as a modeling tool within the Regional Water Board's Irrigation Lands Program allowed continuity of this effort although the current model has not been calibrated for salinity in any of its areas of application.

Reclamation continued to support WARMF model developer Systech Water Resources, Inc. during Water Year 2022 to continue to enhance the WARMF model forecasting accuracy. Milestones achieved in this effort are as follows:

1. Completed calibration of WARMF model using the latest five years data from 10/1/2016 to 09/30/2021. The flow and EC calibration results at Vernalis and Crows Landing match the observations very well (Table 3). Figures 5, 6 show the results of final WARMF model calibration for flow and EC at Vernalis, respectively.

Table 3. WARMF Calibration results at Vernalis and Crows Landing

Location	Flow – Relative Error	Flow – R Squad	EC – Relative Error	EC – R Squad
Vernalis	9.4%	0.982	12.6%	0.926
Crows Landing	11.6%	0.982	16.6%	0.829

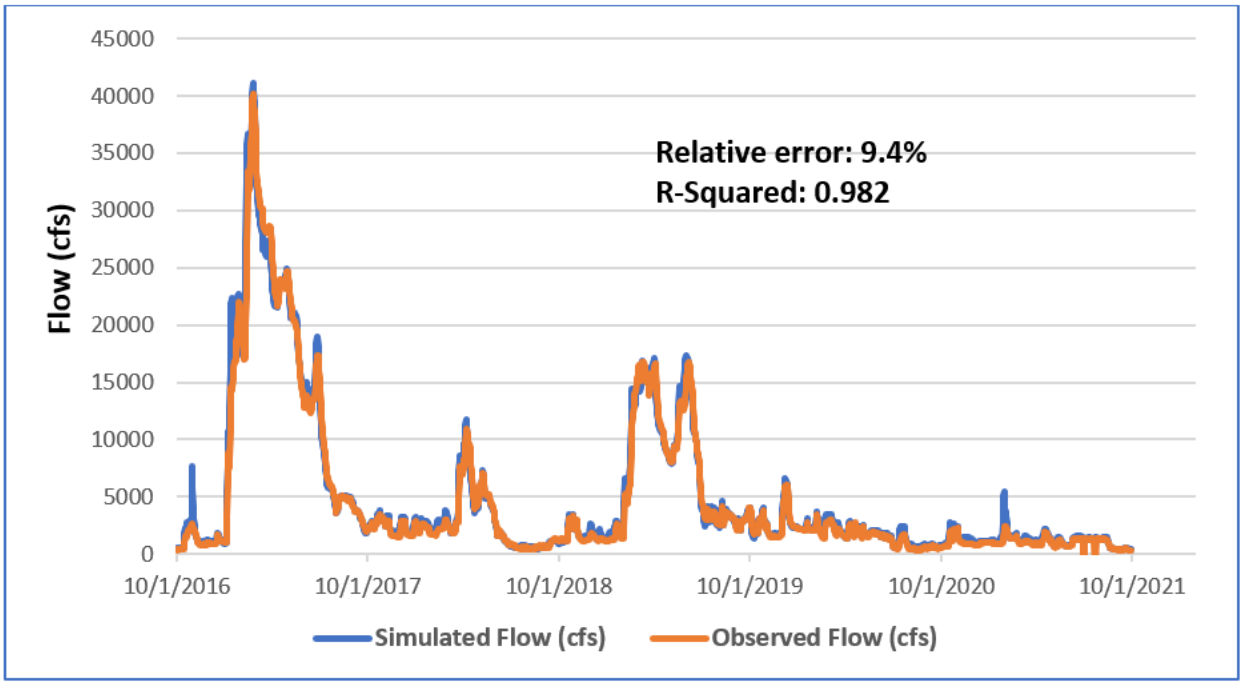

Figure 5. Flow Calibration at Vernalis (10/01/2016-09/30/2021)

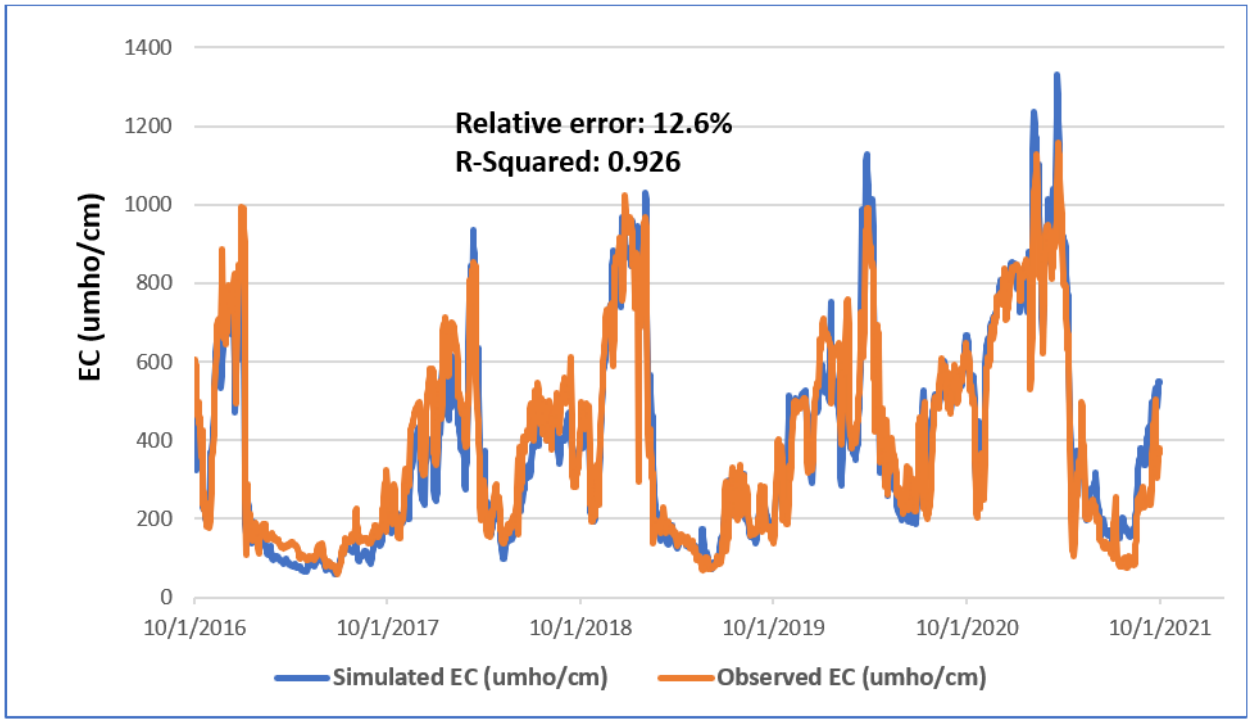

Figure 6. EC Calibration at Vernalis (10/01/2016-09/30/2021)

2. Created a WARMF model self-calibrator feature which is in current use and undergoing continuous testing and development. The WARMF self-calibrator feature will be available for more widespread dissemination at end of December 2022.

   Improvements to WARMF model forecast performance can be achieved by using same day tributary and watershed data for each forecast and updating flow and EC model simulated values with observations at each compliance monitoring station. This is one of the features of the regression approach that relies on this updating to occur in advance of the daily forecast. There are a number of watershed time series inputs to the WARMF model for which observation data is not available but are important parts of the flow and salt balances on the SJR. These include seepage losses from the San Joaquin and Stanislaus Rivers, unknown saline inflow to the SJR, and operational spills from the TID and Modesto Irrigation District (MID). Systech will further develop utility programs that compare the WARMF model simulation with observations and distribute the error between these measurements frequently to improve the match between the model simulated flow and EC and observed data on the day before the forecasts are made. This new feature will better align the WARMF model's more physically-based approach with the Regression model - both models currently rely on SJR daily tributary flow forecasts from the California-Nevada River Forecast Center (RFC)– whose

engineers are in close communication with reservoir operators on all three major tributaries. The ability to adjust initial conditions can help to improve WARMF model flow especially during the dry periods such as was experienced during 2021 and 2022 where the assumption of a negative linear correlation between river EC and flow was shown to be unreliable.

Goal 2: Data Assimilation Automation and Centralization

Continued development work was undertaken in FY 2022 to improve data assimilation from State, Federal, and private water and water quality data web portals. The initiative to update data assimilation software, that began in late 2019, has introduced new subroutines that appear as buttons in the WARMF model graphical user interface that help to streamline and make more reliable the creation of WARMF model input data files. The ongoing work in FY 2022 was undertaken with the view of encouraging greater stakeholder access and involvement in the salt load assimilative capacity forecasting process.

Goal 3: Identification of Necessary Funding for Additional Infrastructure

Reclamation continues to participate in work on two Proposition 84 grants led by GWD and the SJRDA entitled: (a) "Optimizing Real-Time Management of Combined Surface and Subsurface Drainage Return Flows from Seasonally Managed Wetlands in the San Joaquin River Basin" and (b) "Real-Time Management of Surface and Subsurface Drainage Return Flows to Benefit Sustainable San Joaquin River Flow and Water Quality." The main objective of both grants has been to upgrade the monitoring hardware and cyberinfrastructure needed to move the real-time salinity management program into the implementation phase. These upgrades were completed both in the GWD and the SJVDA (San Joaquin Valley Drainage Authority) agricultural service area. Diversion monitoring sensor installations have been operating in both Patterson and West Stanislaus Irrigation Districts that provide both continuous flow and EC data. As previously described - both Districts chose to integrate EC sondes provided by the respective projects with their existing proprietary supervisory control and data acquisition (SCADA) system - designed for flow monitoring and real-time water delivery throughout each District. This arrangement provides a more robust firewall for sensitive District data. Although data is provided only once per week in advance of the forecasts made by Reclamation on Monday each week - these data have been of great value in correcting erroneous diversion assumptions, based on historic data used by the WARMF model and have alerted Reclamation forecasters to unexpected changes in diversion operations. Both PID and WSID have installed Variable Frequency Drive (VFD) pump motors in each pump station that improves power consumption efficiency while also allowing each district to minimize operational spill. This added operational flexibility results in greater hourly and daily fluctuations – these were not as common before this upgrade took place at PID and WSID. Irrigation Districts such as El Solyo Irrigation District practice more traditional practices which involves pumping at a fixed rate and for farmers to return surplus supply through a conveyance that discharges to the SJR.

Reports have been e-mailed to Reclamation from PID and WSID that compute daily salt loading using the flow and EC data at their River pump intake facilities. The District collects other water quality parameters of interest to stakeholders at the same sites that include turbidity, nitrate, and pH/oxidation reduction potential. Drainage monitoring site installations measuring flow and EC

sites in both Patterson and West Stanislaus Irrigation Districts have been reporting for most of 2022 and report 15-minute flow, EC and calculated salt load data to the SJVDA HydroMetCloud web portal. Diversion flow and EC data as well as a weekly data report from the District's supervisory control and data acquisition system is being provided on each District's public access website.

Goal 4: Development and Recommendation of Specific Additional Management Practices to Better Coordinate the Real-Time Operation of Discharges to the SJR

The RTMP is described in the TMDL documentation as a stakeholder-driven effort to use real-time water quality and flow data to support water salinity management decisions to maximize the use of assimilative capacity in the SJR. Reclamation has been working with SJR stakeholders and participants in the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) initiative, as described earlier, to support the development of a stakeholder-driven RTMP. Ongoing work on Goal 4 has been performed in alignment with the CV-SALTS Lower San Joaquin River Committee's development of salinity objectives for Reach 83 of the LSJR (Merced River inflow to Vernalis). Patterson Irrigation District and GWD currently use real-time sensor technology to both reduce drainage export to the SJR and reuse agricultural and wetland return flows, that can help to reduce DMC diversions and make water available for export to adjacent water districts and landowners in unincorporated areas of the Basin. Drainage monitoring sites at Spanish Land Grant Drain and Marshall Road Drain have allowed the district access to flow information and decide whether to incept these flows for conveyance to the Marshall Road reservoir for within-District reuse. These real-time salinity management activities are more advanced than the planning activities currently underway within CVSALTS and provide an exemplar of the real-time salinity management concept.

A multimillion-dollar drainage reuse system in GWD, that was partially funded by Reclamation, has been fully operational since 2021. The real-time monitoring network monitors the EC of the intercepted drainage water and pumps the drainage water upslope to a pond where it is blended with surface water deliveries. The EC concentrations of the diverted wetland drainage is continuously monitored to ensure the blended water doesn't exceed salinity influent guidelines. Elevated salinity in applied water can negatively impact the maintenance and function of wetland moist-soil plant habitat. Reclamation is documenting other examples of stakeholder initiated real-time salinity management activities as we are made aware of them. The GWD wetland drainage recirculation system may be replicated in the State and Federal refuges if sufficient funding is made available and water supply allocations continue to be suboptimal.

Goal 5: Continued Outreach for Additional Stakeholders

Turlock Irrigation District (TID) and MID were required to obtain full compliance with the RTMP in accordance with the Basin Plan's Salt and Boron Control Program in 2018 and are now routinely reporting operational spill and drainage return flow volumes and the EC of these for the eight discharge locations into the SJR and its major tributaries, the Stanislaus and Tuolumne Rivers. These are being provided on a quarterly schedule. These return flows can add significant salt load assimilative capacity to the SJR and are critical for the development of accurate forecasts, especially during certain times of the year when the flow/EC Regression relationship is less reliable. The quarterly flow and EC data from MID and TID are used to update WARMF

model input files. Although daily or weekly data reporting from MID and TID would be ideal, aligned with the diversion data provided by PID and WSID – still these data have been of great utility in updating long-term average flow and EC data used by the WARMF model – much of it based on data assimilated during the 2005-2008 period. Ultimately, the goal would be to move to weekly reporting of this data once data quality assurance practices are further developed in each irrigation district.

Reclamation continues to receive daily flow forecasts at Vernalis, Crows Landing, and Maze Road Bridge from the California-Nevada River Forecast Center (RFC) operated by the National Oceanic and Atmospheric Administration (NOAA). NOAA analysts in the RFC receive daily updates on reservoir release schedules from east-side reservoir operators and maintain a simple flow model for estimating reliable tributary outflow to the SJR. Although the RFC model does not include EC forecasts, the RFC flow forecasts significantly improve the reliability of 14-day projections made with both the Regression and WARMF models. Interaction with the RFC has also informed both Central Valley Operations (CVO) staff and NOAA analysts on the MAA water quality forecasting activities. This coordination led CVO to continue support for several important long-term San Joaquin Basin monitoring stations, including those at Mud Slough, Salt Slough, Crows Landing, and Fremont Ford. Reclamation CVO funds will be used in late 2022/early 2023 to upgrade the monitoring at Mud and Salt Slough stations to include acoustic Doppler flow measurements. These stations are often in backwater conditions during periods of high flow in the lower San Joaquin River and lead to potential loss of data and increased work for the US Geological Survey that has been operating these stations for the past 30 years. Reclamation will oversee these new installations.

Reclamation has attended CV-SALTS Executive Committee meetings more regularly during Water Year 2022 with existing or new staff members or by proxy through Lawrence Berkeley National Laboratory (LBNL). Nigel Quinn (LBNL) still serves as Technical Co-Chair of the Technical Advisory Committee. Reclamation staff members have participated in other CVSALTS technical subcommittees providing guidance on model selection, data availability and model calibration protocols. for the Prioritization and Optimization Study.

The Reclamation RTMP was approached by GWD, which has an interest in developing its own salinity management plan under the conservative salinity permitting approach outlined in the CV-SALTS Prioritization and Optimization Study. Part of the motivation for taking this approach was to align salinity management actions more closely with the Groundwater Sustainability Plan developed for the Grassland Ecological Area and Grassland Subarea and to have a modeling tool capable of simulating surface and groundwater hydrology as well as salt loading to provide the basis for future decision-making. The WARMF model has been suggested as a suitable tool for this initiative. Further progress on this initiative is anticipated in WT 2023.

Phase 4 Activity Summary (April 2018 to Present)

Phase 4 activities include actions initiated during Phase 3 of the program that have been continued, as described above. In Phase 4 additional actions are being encouraged and supported that will lead to more widespread adoption of RTMP practices and better cooperation and coordination among stakeholders. Phase 4 also involves an institutional component to secure

long-term funding and technical expertise to ensure continued success of the RTMP. As previously noted – the RTMP is seen as a potential exemplar by CVSALTS for another salinity management areas in the Central Valley which share some of the characteristics of the San Joaquin River Basin.

Goal 1: Continue to implement/upgrade monitoring and data networks and to support real-time management practices. Use salt load assimilative capacity forecasting to coordinate the timing of discharges to the river.

A successful RTMP requires telemetered networks of flow and salinity sensors along the main stem of the SJR and in watersheds draining to the SJR. The networks allow easy access to data, promote data sharing, and provide knowledge of scheduled releases from the reservoirs that discharge into eastside streams that are tributary to the SJR. Real-time quality assurance is essential to avoid posting erroneous data and to encourage data sharing.

- Reclamation has continued to provide funding and technical support to GWD for the continued development of its RTMP. GWD operates approximately 25 real-time web-based flow and water quality monitoring stations. With the help of additional grant funding through Proposition 84, the District has been able to restore and upgrade monitoring with state-of-the-industry instrumentation. GWD and the SJVDAuse HydroMetCloud Data Services for data telemetry and real-time data access available through Sutron Corporation. Real-time data access has proven useful to both entities for checking sensor readings prior to regular data quality assurance site visit and efficiently scheduling site troubleshooting.
- Real-time data for GWD and the SJVDA projects can be accessed on the HydroMetCloud web portal that lists both project sites:
    - For GWD: http://hydrometcloud.com/ User: RTWQ@gwdwater Password: Grassland
    - For the SJVDA: http://hydrometcloud.com/ User: sjvda-RTM Password: Realtime2020
- Reclamation continues to support its own online web portal where river flow and EC forecasts can be accessed. The site was redesigned to allow easy access from a smartphone by entering “Reclamation PTMS” in a search engine such as Google.com. This web application was demonstrated at stakeholder meetings in 2021 and 2022.

Goal 2: Continue to address long-term funding and project needs.

The project, entitled “Integrated Science and Management of Nutrient, Salt, and Mercury Export from San Joaquin River Wetland Tributaries to the Delta,” which focused on salt and mercury loading from two wetland impoundments in the Los Banos Wildlife Management Area released a final report in August 2022. The project simulated potential management strategies to optimize control of both pollutants discharged to the SJR using the WARMF model. Results of the three-year project are applicable to all wetlands within the Grassland Ecological Area. A number of stations in the GWD monitoring network were used in the project and the sonde at the San Luis

Canal site (SL-1) was supplemented with additional water quality sensors, provided by UC Merced. This type of cooperation between research and water management entities has provided an example of some of the synergies possible through the RTMP.

Goal 3: Expand real-time management program membership to include all regulated parties, including both direct and indirect dischargers of salt to the San Joaquin River.

The RTMP has, to date, focused on those subareas of the SJR Basin that directly discharge salt loads to the SJR. Grant funding over the past decade has supported flow and salinity loading monitoring at a number of agricultural drainage monitoring stations on the westside of the Basin and from seasonally managed wetlands. The California Department of Fish and Wildlife and the Grassland Resource Conservation District operate under Best Management Practices to reduce the salt loads in discharges from managed wetlands into the SJR. Reclamation has provided resources to support the development of the real-time monitoring networks in GWD and we anticipate greater involvement from the State and Federal refuges during FY 2022 through stakeholder outreach efforts.

- Reclamation continues to support the network of real-time flow and water quality monitoring stations that provide flow and EC data at major GWD inlets and outlets as well as along the water distribution network.
- Reclamation funding for the GBP was $760,000 in FY21,[4] including $200,000 to the United States Geological Survey to monitor five stations on the LSJR and tributary sloughs.
- Reclamation has secured funding for flow monitoring upgrades to the Mud and Salt Slough stations with the installation of SONTEK acoustic Doppler sensors. The use of these instruments will help to eliminate flow estimation errors associated with occasional backwater conditions where high river stage impedes tributary inflow and leads to unrealistic elevated flows. Reclamation is working with DWR (Fresno) to enhance flow and water quality monitoring at the maze Road Bridge site. Low flow conditions have created challenges for both flow and water quality monitoring, which have led to instances of erroneous and missing data during both 2021 and 2022. Reclamation has had to improvise with estimation techniques making use of upstream and tributary flows when using the Regression model. The WARMF model, which performs water balances using all available tributary and drainage inflows and diversion data along the SJR is better suited to providing these estimates. During WY 2022 there were no recorded instances of exceedance of the Maze Road Bridge EC objectives. In fact EC concentrations along the mainstem of the SJR were some of the lowest for the past decade given the absence of significant salt loading from westside sources and the in-stream flow requirements and the requirement for fish migration and attraction flows mandated for each major tributary.

[4] The funding allocation is not specifically a part of the MAA RTMP but yields salinity benefits in the LSJR.

Goal 4: Continue technical improvements to data processing, quality assurance, and the SJR assimilative capacity forecast modeling.

Reclamation has continued to investigate further automation of data acquisition to reduce the data processing steps needed for WARMF model forecasts and simplifying the WARMF graphical user interface to reduce the model's learning curve while retaining model performance. The WARMF model relies on a very large array of both publicly accessible and more restricted data to reliably perform weekly forecasts of flow and EC. For the westside drainage stations Reclamation and the SJVDA have worked closely with Patterson and West Stanislaus Irrigation Districts to automate data collection to allow eventual migration of these data to the WARMF model using existing monitoring site telemetry resources and a web portal hosted by HostGator.com. This initiative has the added benefit of demonstrating to stakeholders the direct use of real-time data and helping to build confidence in the performance of the WARMF model.

Data quality assurance has always been a major constraint to implementation of the RTMP. Stakeholders are reluctant to share erroneous data for potential liability reasons. Poor data quality assurance also has potential to diminish stakeholder trust in the data and their willingness to utilize the data and the forecast model results for decision support.

One aspect of the collaboration with UC Merced and the previously mentioned wetland methylmercury and salinity management project has led to the adoption and further development of the HEC-DSSVue platform for real-time data quality assurance. The US Army Corps of Engineer's software is in the public domain and well documented. Customized Python scripts have been developed to work with HEC-DSSVue and the HOSTGATOR web portal (as CRON job scripts) to process raw data to produce daily mean flow and EC data files for direct import to the WARMF model. At present the most recent data from the SJVDA westside drainage stations and two years of data from GWD have been loaded into the HEC-DSSVue database. A user manual is under development to provide essential information to other potential users of this new real-time data quality assurance software.

Central Valley Project Deliveries Load Calculation

Brief Description: The CVP delivers water to both the Grassland and Northwest subareas, as described in the Basin Plan, through the DMC, the San Luis Canal, and the San Joaquin River/Mendota Pool. Most CVP water is pumped from the Delta into the DMC through the Jones Pumping Plant located near Tracy, California. CVP water is conveyed south to DMC Check 13 near Santa Nella, California, where water is either mixed with the State Water Project in O'Neill Forebay and then either pumped into San Luis Reservoir for later delivery through the DMC, or San Luis Canal, or conveyed further south to the DMC terminus at the Mendota Pool. During periods of drought, groundwater and river water are pumped into the DMC at several locations. The calculation methods used in this report are provisional, and some elements in this report do not include estimations of benefits at this time. Reclamation submitted the *Compliance Monitoring and Evaluation Plan* (Reclamation 2010), which outlines the criteria and methodology for determining DMC loads and credits, to the CV Water Board.

Quantification Methodology: The monthly amount of CVP water supply delivered to each district is prorated according to the area of each district within either the Grassland subarea,

Northwest subarea, or outside of these subareas. The monthly mean salinity of CVP water is calculated from average daily measurements taken at three locations along the DMC. The salinity of CVP water delivered to each district is associated with the salinity monitoring site closest to the district's turnout along the DMC.

The Basin Plan allocates a salt load to Reclamation for water delivered to the Grassland and Northwest subareas. This background load allocation is calculated according to Table IV-8 as shown in the following equation:

$$LA_{DMC} = Q_{DMC} \times 52 \text{ mg/L} \times 0.00136$$

Where:

LA_{DMC} = Load Allocation of salts, in tons

Q_{DMC} = monthly amount of CVP water delivered to Grassland and Northwest subareas, in acre-feet

52 mg/L = "background" salinity of water in the San Joaquin River released at Friant Dam (per the Basin Plan) measured as total dissolved solids (TDS)

0.00136 = factor for converting units into tons

Actual DMC salt loads are calculated by the following equation:

$$L_{DMC} = Q_{DMC} \times C_{DMC} \times 0.00136$$

Where:

L_{DMC} = Actual DMC Load, in tons

Q_{DMC} = monthly amount of water delivered to Grassland and Northwest Subareas, in acre-feet

C_{DMC} = monthly average of salinity of the water delivered to Grassland and Northwest subareas, in mg/L TDS

0.00136 = factor for converting units into tons

Each subarea's QDMC is calculated and then paired with the associated monthly average TDS for that reach, so the equation becomes:

$$L_{DMC} = 0.00136 * \Sigma(Q_{DMC} * C_{DMC}) \text{ Subareas}$$

This equation is then broken into calculations for each subarea based on the source of CVP water. Table 4 lists the salt loads of CVP water delivered to the Grassland and Northwest subareas and an estimate of the salts delivered in excess of the monthly load allocation.

Table 4. Calculation of DMC Allocations and Loads

Water Year	Water Year Type	Grasslands Subarea–San Joaquin River and Mendota Pool Salt Load from CVP (thousand tons)	Grasslands Subarea–Delta-Mendota Canal Salt Load from CVP (thousand tons)	Grasslands Subarea– San Luis and Cross Valley Canal Salt Load from CVP (thousand tons)	Grasslands Subarea–Total Flow (thousand acre-feet)	Grasslands Subarea–Load Allocation (thousand tons)	Grasslands Subarea–Actual Load–Load Allocation (thousand tons)	Northwest Subarea–San Joaquin River and Mendota Pool Salt Load from CVP (thousand tons)	Northwest Subarea–Delta-Mendota Canal Salt Load from CVP (thousand tons)	Northwest Subarea–Total Flows (thousand acre-feet)	Northwest Subarea–Load Allocation (thousand tons)	Northwest Subarea–Actual Load– Load Allocation (thousand tons)	Total–Total Excess Load from CVP Deliveries (thousand tons)
2015	Critical	285.7	57.0	46.7	611.8	43.2	346.2	21.9	32.5	84.0	5.9	48.5	394.7
2016	Dry	275.4	89.9	36.2	873.4	61.7	339.8	20.5	15.5	92.8	6.6	29.5	369.2
2017	Wet	147.5	57.8	20.1	1,031.4	72.9	152.6	9.3	11.0	122.8	8.7	11.6	164.1
2018	Below	219.7	117.6	41.6	1,112.1	78.6	300.4	16.9	18.5	114.9	8.1	27.3	327.7
2019	Wet	167.2	75.7	27.7	1,023.0	72.3	198.3	12.1	11.8	109.6	7.7	16.2	214.5
2020	Dry	225.0	99.7	40.0	1,006.3	71.1	293.6	17.9	20.4	110.9	7.8	30.4	324.1
2021	Critical	266.4	104.8	43.7	777.8	55.0	361.4	19.5	29.1	95.6	6.8	41.7	403.1
2022	Critical	269.4	89.7	44.7	892.3	63.1	342.8	21.8	19.6	97.0	6.9	34.4	377.2

Report of Annual Work Plan Activity Performance

Reclamation has met schedule milestones for the MAA and performance of actions for assisting SJR stakeholders in managing salt loads and offsetting the DMC salt load into the SJR. New Melones Reservoir continues to be operated in accordance with D-1641 water quality requirements.

During 2022, Reclamation continued to support the development and use of the WARMF-based 14-day forecasts for EC and discharge. The following three tasks were planned in FY 2022 and FY 2023:

1. **Create a WARMF model self-calibrating feature**. WARMF self-calibration and automation to closely match the model simulation to observations of flow and EC by using the most recent real-time data from the same day. The calibration using the most recent real-time data will significantly improve the model's forecasting accuracy. There are several time series inputs to the WARMF model for which observation data is not available but are important parts of the flow and salt balances on the SJR. These include seepage losses from the San Joaquin and Stanislaus Rivers, unknown saline inflow to the SJR, and operational spills from the TID and MID. Systech has developed utility programs which compare the WARMF model SJR simulations and field observations make required adjustments to bring these values into alignment. Under most conditions, this will result in a better match between the model simulated flow and EC and observed data on the day before forecasts are made.

2. **Upgrade of WARMF Hydrologic Simulation Algorithm**. One of the limitations of the WARMF model is its use of the kinematic wave approximation of the one-dimensional Saint-Venant equation to route flow through the watershed. The kinematic wave approximation assumes that the slope of the water surface is parallel to the river bottom slope and the depth of the river at a given point is independent of the depth further downstream. These assumptions are not accurate during rapidly changing flow in the lower San Joaquin River, however, because of the river's low slope and extensive backwater effects. As a result, simulated flow peaks occur earlier and tend to be higher than is observed and simulated recession from high flow is faster than observed. This error can propagate to simulated EC because the model does not simulate the correct proportions of flow from fresh versus saline. The WARMF simulation engine is being modified to allow hydrologic routing using the diffusive wave approximation. The diffusive wave approximation accounts for backwater effects and is accurate for subcritical flow conditions found on the San Joaquin River. A technical memorandum will be prepared describing the changes to model code and the substitution this adjustment makes to modeling results.

3. **Utilities to Enhance Flow Forecasts**. To simulate flow and salinity during the forecast period, WARMF uses a combination of flow forecasts from the RFC and meteorology forecasts. Other model inputs are assigned based on their most recent measured value or with typical values for the time of year.

    a. **Mud Slough near Gustine**. Other than flow forecasts provided by the RFC, the preprocessing routines which prepare real-time inputs to the WARMF model assume that the most recent measured flow at each of the WARMF boundary inflow points will continue through the forecast period. This is generally as good a strategy as any but there are cases where the model's forecast can be improved. The spring draw down of wetlands in the Mud Slough watershed is a key event since the salinity of the San Joaquin River is often near its water quality criterion at that time of year. The assumption of continued constant flow can be improved upon by referencing historical data as shown in Figure 2 below. Each year flow predictably increases starting about March 10 for 1-2 weeks before decreasing through the end of April. A utility will be developed to estimate flow in Mud Slough during the forecast period based on current flow and historical data.

    b. **Seepage Loss Forecasts**. Seepage loss from different reaches of the San Joaquin River and the Stanislaus River are an important part of the river's flow and salt balance. By default, seepage losses are currently set to typical values for the time of year during the forecast period. Seepage loss depends on river depth (and therefore flow) so losses during the forecast period can be better estimated from forecast flow. A utility will be created which analyzes the current flow, forecast flow, and current seepage loss to estimate seepage loss for the forecast period and modify the corresponding WARMF input files.

    c. **Precipitation Forecast at Stations with Missing Data**. Precipitation is set at each of the meteorology stations used as WARMF inputs from measured CIMIS data or 6-day forecasts issued by the RFC. Any time there isn't data or forecast available, the data must be filled with reasonable values to have complete input for the WARMF simulation engine. Currently, if there is no measured data at a station with a precipitation forecast, the forecast is used as data when it becomes the past. If there is no measured data and no forecast, typical values for the time of year are used. These methods are not very accurate and required making frequent manual adjustments to WARMF meteorology files during the winter of 2021-2022. A better method would be to use measured data from a nearby station with data and scale the precipitation amount based on the average ratio of precipitation between the stations. The import processing procedure will be

modified to automatically use the improved method of filling missing data.

Systech will integrate the utilities developed in this task into the automated preprocessing of input data currently under development. The deliverable of this task will be the updated WARMF graphical user interface and supporting utility programs in an install set.

The WARMF model's capability to perform reliable flow, EC and salt load forecasts has been tested during the unusual 2022 hydrologic year where complete curtailment of Reclamation westside contract water deliveries and threatened curtailment of SJR diversions changed the water quality characteristics of the system. Although conditions, such as those experienced during 2022, were dissimilar from the majority of the historic data in the WARMF model database – still the physical conceptual basis of the model and the past 30+ years of data that have been compiled rewarded Reclamation and other financial supporters of WARMF model development.

During 2022 Reclamation was not able to adhere to the strict language of the salinity TMDL policy document, which requires that excess salt loads delivered to the LSJR via the DMC be offset by dilution flows from eastside Reclamation owned reservoirs. During WY 2022 New Melones Reservoir released tributary flows that added 145,000 tons of salt load assimilative capacity to the SJR (Table 1). When combined with the 84,000 tons of salt load diverted into the SJRIP facility, the salt assimilative capacity was insufficient to offset the total excess salt loads associated with 2022 CVP operations (377,000 tons) (Table 3).

The Salt and Boron Control Program states that "Participation in a Regional Water Board approved real-time management program and attainment of salinity and boron water quality objectives will constitute compliance with this control program." Compliance with the EC WQO suggests compliance with the boron WQO. Figure 7 shows that Reclamation has maintained annual compliance with the salinity WQO at Vernalis during WY 2022.

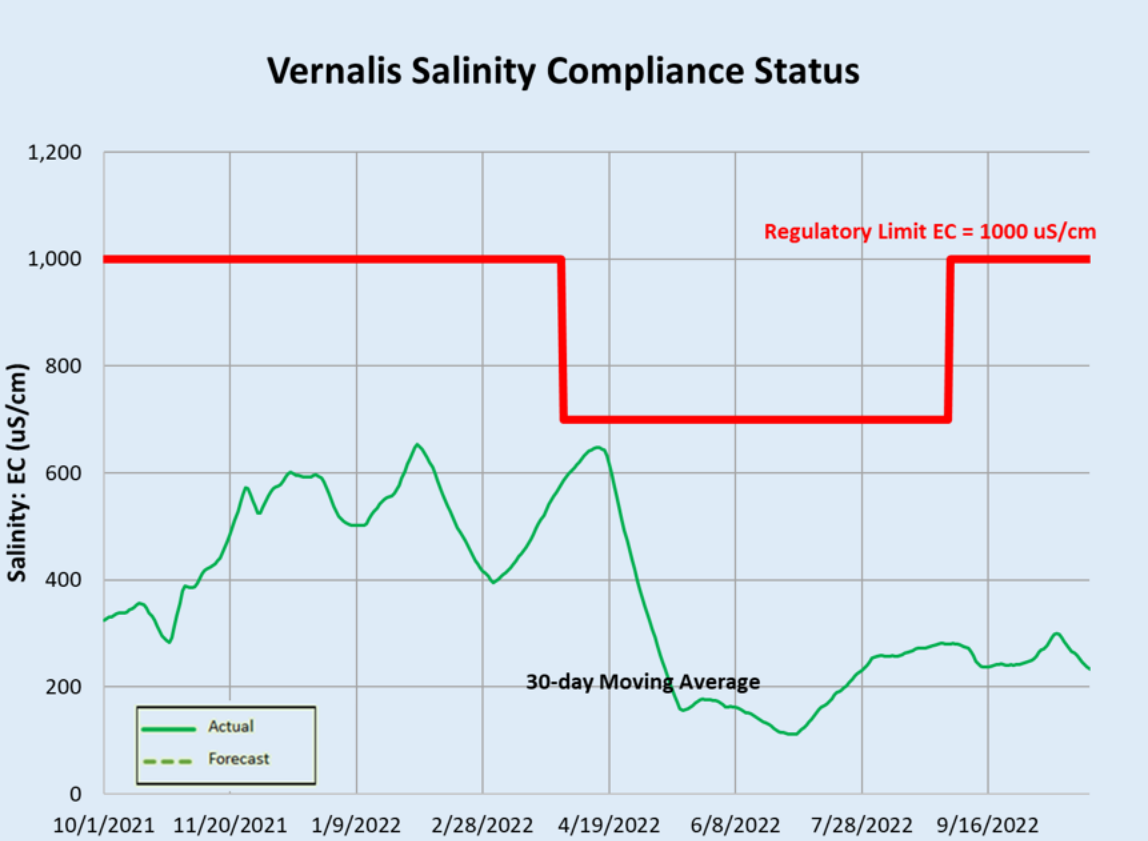

Figure 7. WY 2022 Compliance with the Salinity WQO at Vernalis

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