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TECHNICAL MEMORANDUM

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Project No.: 1070-60-23-02
SENT VIA: EMAIL

TO: Bernadette Clueit, Senior Conservation Planner

FROM: Matt Ballie, Senior Hydrogeologist II

REVIEWED BY: Samantha Adams, Business Sector Leader

SUBJECT: HCP Comparison Point Scenarios

INTRODUCTION

This Technical Memorandum (TM) presents the results of numerical modeling studies performed to support the development of the Salinas River Operations Habitat Conservation Plan (HCP). The HCP is a required component of an application for an incidental take permit under the federal Endangered Species Act (ESA) for impacts to listed species from covered activities. Covered activities include operations and maintenance of water infrastructure under the control of the Monterey County Water Resources Agency (MCWRA) in the Salinas River Groundwater Basin (Basin). This work was carried out under agreement number 61151 for ICF Jones & Stokes (ICF) and MCWRA. The HCP is described briefly in this TM.

Purpose and Scope

The purpose of the work presented in this TM is to provide a quantitative estimation of the surface water and groundwater conditions in the Basin that would occur under various approaches to managing the Nacimiento and San Antonio Reservoirs and associated projects and programs (including the Salinas River Diversion Facility; SRDF). MCWRA desires to modify its current reservoir operations approach to better optimize the conjunctive management of its surface water and groundwater resources while also providing for flood control. The HCP ultimately aims to define a modified approach to reservoir operations that will minimize adverse effects on listed species in the Salinas River and its tributaries while allowing MCWRA to meet its water resources management goals and obligations.

This TM describes the design and results of three model scenarios, collectively referred to as the Comparison Point Scenarios, that simulate conditions under various operational approaches. Intercomparison of the model scenarios is used to isolate the effect of individual changes (or sets of changes) to the operational approach. In the future, the results presented in this TM will be used as a basis for understanding the effects of proposed reoperation of the system.

Salinas River Operations Habitat Conservation Plan

The Salinas River and its tributaries provide critical habitat for the migration of south-central California coast (SCCC) steelhead trout (*Oncorhynchus mykiss*), federally listed as a threatened species under the ESA, between Monterey Bay and important spawning grounds in Arroyo Seco (and possibly the Nacimiento River below Nacimiento Dam). To support the development of the Salinas Valley Water Project (SVWP) and construction of the SRDF, MCWRA developed the *Salinas Valley Water Project Flow Prescription for Steelhead Trout in the Salinas River* (Flow Prescription; MCWRA, 2005), which includes a set of operational rules for the reservoirs designed to meet all stated goals of the reservoirs, including support for steelhead trout migration. The National Marine Fisheries Service (NMFS) issued a Biological Opinion (BO) for the Salinas River in 2007 (NMFS, 2007). Although the BO was later rescinded, MCWRA continues to operate the reservoirs according to the rules of the Flow Prescription.

To support development of the HCP, ICF and MCWRA are investigating how the operation of the Nacimiento and San Antonio Reservoirs affects conditions in the groundwater-surface water-reservoir system of the Salinas Valley. The HCP will be used as the basis for MCWRA to secure a Section 10(a)(1)(B) incidental take permit under the ESA for their activities in the study area and must describe the effect those activities potentially have on the health and migratory success of threatened steelhead trout and other listed species in the Salinas River and its tributaries. The goal of the modified operational approach is to balance water resources management supporting fish and wildlife with other operational goals, including water conservation and flood control.

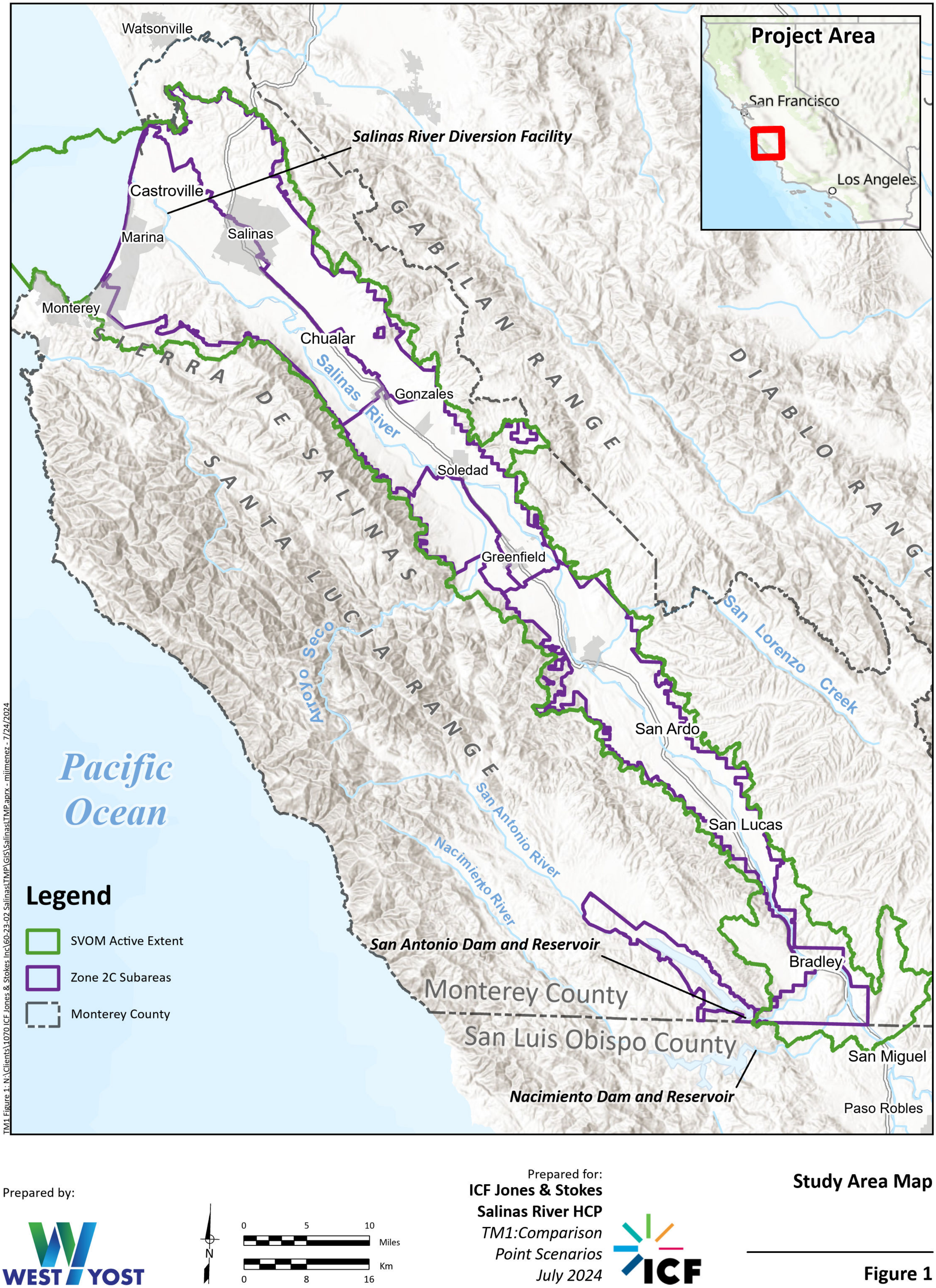
TM Organization

This TM is organized into the following sections:

- Introduction
- Study Setting
- Tools and Methods
- Current Operations Scenario
- No Flow Prescription Scenario
- No Operations Scenario
- Summary and Conclusions

STUDY SETTING

The setting for this study is the Salinas Valley. The study area covers the alluvial Salinas River Groundwater Basin, the Salinas River and its tributaries, and the Nacimiento and San Antonio Reservoirs. Figure 1 is a map of the Study Area, providing the locations of key geographical and hydrologic features described herein.



Prepared by:

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ICF Jones & Stokes
Salinas River HCP
TM1:Comparison
Point Scenarios
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ICF

Study Area Map

Figure 1

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Study Area

A numerical model of the groundwater-surface water-reservoir system of the Salinas Valley was used to assess the impacts of reservoir operations. The study area is defined by the extent of MCWRA's Assessment Zone 2C, excluding the Above Dam subarea, which is not within the model domain. It includes the portions of the Salinas Valley underlain by extensive alluvial aquifers. The study area is bounded by mountainous areas to the east (Gabilan and Diablo Ranges) and west (Sierra de Salinas and Santa Lucia Range). The southern extent of the study area is defined by the boundary between Monterey and San Luis Obispo Counties. The northern extent is defined by Elkhorn Slough and the hills to the east.

The Salinas River is the major hydrological feature within the study area, flowing north into the study area from the Paso Robles Basin and ultimately draining into the Pacific Ocean at Monterey Bay. Major tributaries to the Salinas River within the study area include Arroyo Seco, San Lorenzo Creek, Nacimiento River, and San Antonio River (Figure 1). Along its path, the river interacts with underlying aquifers, either losing streamflow to or gaining streamflow from groundwater. The direction of the groundwater-surface water interaction depends on the water level in the river and in the aquifer; if the river stage is higher than the aquifer head, the river will lose water to the aquifer, and vice versa. In general, the Salinas River loses water to the Basin aquifers along most of its length.

Land use in the study area is heavily agricultural, with about 300,000 irrigated acres in Monterey County producing a total value of over $4 billion as of 2021 (County of Monterey Agricultural Commissioner, 2022), most of it within the Salinas Valley. Agriculture users within the Salinas Valley are almost entirely dependent on groundwater for applied irrigation, and account for about 90 percent of water use in the Basin (Brown and Caldwell, 2015). Groundwater withdrawals have outpaced the rate of replenishment on a local level since at least the 1930s, when seawater intrusion was first recognized in coastal wells (DWR, 1946). Seawater intrusion remains a major issue today, with groundwater heads below sea level in the major production aquifers through much of the Basin north of about Chualar.

Partially to address the issues of groundwater overdraft and seawater intrusion, MCWRA constructed the Nacimiento and San Antonio Reservoirs along tributaries to the Salinas River south of Bradley. These reservoirs began operating in Water Years (WYs) 1958 and 1968, respectively, and together can hold as much as about 713,000 acre-feet (af) in storage. MCWRA operates the two reservoirs in conjunction to provide flood protection, water conservation, fish passage, fish and wildlife habitat support, SVWP operation (including the SRDF), and recreation.

The successful migration of the threatened SCCC steelhead between the Pacific Ocean and these spawning grounds relies directly on there being sufficient flow in the Salinas River at specific times during the steelhead life cycle. Streamflow in the Salinas River and its tributaries is determined by a complex set of interactions between surrounding watersheds, the groundwater system, the stream network, and the reservoirs.

Basin Hydrogeology

The Salinas River Groundwater Basin (Basin) is a deep alluvial basin that supports groundwater users throughout the Salinas Valley. The details of the Basin hydrogeology are described extensively in other sources (e.g., Brown and Caldwell, 2015). Only those details that bear directly on the discussion in this TM are repeated here.

The Basin underlies the Salinas Valley stretching around 100 miles from a constriction in the valley just north of San Miguel to the coast of Monterey Bay and Elkhorn Slough. The Basin contains aquifers and aquitards that control how water moves through the system. From its southern end to about Gonzales, sediments form an undifferentiated aquifer, with no aquitards to restrict the vertical movement of groundwater, including communication between the Salinas River and the surrounding aquifer material. North of about Gonzales, there are extensive aquitards laid down during past marine transgressions that separate the aquitards into distinct units[1]. The presence of these aquitards (particularly the Salinas Valley Aquitard) limits the communication between the Salinas River and the underlying aquifer, which has important consequences for the hydrogeology of the Basin (e.g., Brown and Caldwell, 2015). It also affects the groundwater-surface water exchange occurring in this area, and therefore the amount of streamflow in the Salinas River.

Flow Prescription

The operational approach described in the Flow Prescription was designed to support the migration of steelhead trout along the Salinas River between Monterey Bay and spawning grounds during various stages of their life cycle. The stages covered include:

- **Adult:** mature trout migrating upstream to spawning areas, occurring from approximately January 1st to March 31st
- **Smolt:** young trout migrating downstream to the ocean, occurring from approximately March 15th to June 20th
- **Kelt:** mature trout migrating downstream to the ocean after spawning, occurring from approximately April 1st to June 30th
- **Juvenile:** young trout migrating downstream to the Lagoon, occurring from approximately April 1st to June 30th

MCWRA can take various actions to support migration during each of these stages, depending on reservoir storage, streamflow conditions, and the connection between the Salinas River Lagoon (Lagoon) and Monterey Bay. The Lagoon is only open to Monterey Bay if streamflow entering the Lagoon is sufficient to breach the sand bar that closes the Lagoon or once breached, to maintain the opening (note that MCWRA takes action to mechanically facilitate sand bar breaching when needed to protect nearby lands from flooding). If the Lagoon is closed, fish likely have limited movement potential through the Old Salinas River channel between the Salinas River and Monterey Bay, so Lagoon opening is a prerequisite for certain aspects of steelhead migration described in the Flow Prescription.

TOOLS AND METHODS

This study relies on numerical simulation (i.e., modeling) to understand how different operational approaches would affect conditions in the tightly coupled groundwater, streamflow, and reservoir systems in the study area. The model provides quantitative estimates of groundwater head, streamflow, and

[1] The aquitards become less coherent approaching the foothills of the Gabilan Range, and this area (the East Side Subarea of Zone 2C) is considered to consist of interfingered coarse- and fine-grained sediments containing unconfined to semi-confined groundwater, with the degree of confinement increasing with depth (Brown and Caldwell, 2015).

reservoir storage, stage, and releases in the Salinas Valley that can be used to develop a systematic understanding of the system responses under current operations as well as various alternative operational approaches. Intercomparisons of model scenarios can be used to isolate the effect of individual changes (or sets of changes) to the operational approach. The model results presented in this TM were prepared using the Salinas Valley Operational Model (SVOM), a numerical groundwater-surface water interaction under development by the U.S. Geological Survey (USGS).

This section describes the use of the SVOM, how and why it has been modified to support the study objectives, and the metrics used to assess each model scenario.

Salinas Valley Operational Model

The version of the SVOM (Version 12.1, released September 15th, 2023) available at the time of this work is an interim product made available to select collaborators prior to final publication of the model and distribution to the public. All results from preliminary versions of the SVOM must be considered preliminary and subject to change, and must be accompanied by the following disclaimer:

> *SVOM Model: Unofficial Collaborator Development Version of Preliminary Model. Access to this repository and use of its data is limited to those who are collaborating on the model development. Once the model is published and recieved* [sic] *full USGS approval it will be archived and released to the public. This preliminary data (model and/or model results) are preliminary or provisional and are subject to revision. This model and model results are being provided specifically to collaborate with agencies who are contributing to the model development and meet the need for timely best science. The model has not received final approval by the U.S. Geological Survey (USGS). No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the model and related material nor shall the fact of release constitute any such warranty. The model is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the model.*

The SVOM was built using the three-dimensional groundwater-surface water modeling code MODFLOW-OWHM (Boyce et al., 2020). This version of MODFLOW focuses on the dynamic simulation of crop supply and demand, critical to the heavily agricultural Salinas Valley. The SVOM also relies on a specialized module for simulating reservoir operations, the Surface Water Operations Process (SWO; Ferguson et al., 2016). SWO can simulate the operations of reservoirs that are subject to a number of overlapping uses, determining the appropriate amount of release from each reservoir to react to conditions at the reservoirs while also supplying downstream demands and accounting for carriage losses. For the SVOM, SWO is used to operate the Nacimiento and San Antonio Reservoirs. The reservoirs are not contained within the active MODFLOW model domain; reservoir releases are input to the SVOM along its edge.

The SVOM is built from a calibrated historical model of the study area, the Salinas Valley Integrated Hydrologic Model (SVIHM), using the same model grid and parameters. The SVOM simulates groundwater, streamflow, and reservoir conditions over a 51-year period under a uniform operational approach, uniform land use conditions (representative of 2014 land use), and historical hydrologic conditions (climate and stream inflow) from the period October 1968 to September 2018.

There are several important limitations of the SVOM that affect the model results and must be taken into consideration when comparing them to natural conditions in the system:

- MODFLOW performs all model calculations (of groundwater head, groundwater fluxes, streamflow, reservoir releases, etc.) once per model timestep, and these are assumed to be unchanged during the duration of the timestep. For example, if a model timestep is 10 days long, the streamflow calculated for that timestep would be the same for the entire 10-day period. The SVOM runs on a 5- to 6-day timestep, which means that the model cannot be used to simulate conditions on a finer timescale. The timestep length was chosen by the USGS to balance fine temporal resolution against computational time (which increases as the timestep length decreases), while considering that it typically takes several days for water released from the reservoirs to reach Monterey Bay.
- Certain operational rules in SWO require flow thresholds to be met when determining what action to take. For each rule, SWO flags if the conditional rules have been met. An example is the operational decisions that rely on the Lagoon being open. SWO's determination of whether or not the Lagoon is open is made at the end of each model timestep based on streamflow during that timestep; the determination is then in effect during the following timestep. For decisions depending on flags such as these, the resulting streamflow requirement is set reflecting conditions in the system during the previous timestep.
- The physical opening and closing of the Lagoon (i.e., breaching and reestablishment of the sand bar separating the Lagoon from the ocean) are not simulated in the SVOM. The Lagoon is the terminus of the Salinas River and is represented in the SVOM as a simple stream segment just like all others in the model. For the purposes of making operational decisions, the Lagoon is assumed to be open whenever streamflow in the Salinas River at Spreckels is at least 80 cfs (MCWRA, 2005).
- The SRDF can operate in the SVOM from April 1st to October 31st, and the model operations do not account for the fact that the SRDF cannot operate if streamflow in the Salinas River is too high, as can often occur early in the SRDF season.

Despite these limitations, the SVOM is the best available tool for investigating hydrologic conditions in the Salinas Valley under different operational approaches and for developing the HCP.

Modifications to the SVOM

The SVOM was modified for use in this study. These modifications were made to 1) bring the operations represented in the SVOM in line with MCWRA's current operational approach; 2) improve the temporal resolution of streamflow inputs along the SVOM boundaries; 3) adjust for systematic over-prediction of relatively low streamflows in the Salinas River and its tributaries; and 4) provide customized outputs for use in quantifying fish passage conditions.

Changes to Operational Rules

In the course of testing the SVOM and preparing it for use in this study, several differences were discovered between the operational approach represented in the SVOM rule files and MCWRA's actual operational approach. To address these differences, various changes were made to the model operational rules in consultation with ICF and MCWRA.

Minimum Conservation Release

The SVOM delivered by the USGS allows the SRDF to rely entirely on natural flow if there is a sufficient amount in the system. MCWRA's water rights do not allow them to divert natural flow at SRDF. The SRDF rules were modified to always release at least a certain minimum amount of water when SRDF is operating (minimum conservation release), while allowing the reservoirs to release more than this minimum if conditions in the stream system dictate that higher releases are needed to get the desired amount of water to SRDF. The minimum conservation release modification accounts for typical streamflow losses between the reservoirs and the location of the SRDF diversion.

The minimum releases were calculated by scaling the SRDF demand of 36 cubic feet per second (cfs) by the percentage of inflows to the Salinas River between the reservoirs and the SRDF that are lost to the groundwater system (from upstream to downstream: the Below Dam, Upper Valley, Forebay, and Pressure Subareas). The average monthly inflow[2], seepage, land surface runoff, and tributary inflow were calculated for each Zone 2C Subarea along the Salinas River between the reservoirs and the SRDF for each operational year type (dry, normal, and wet). Only months when SRDF is operating were included in the averages. The seepage was then divided by the sum of the inflow, land surface runoff, and tributary inflow to determine the average percentage of seepage that occurs in each month (from April to October) for each Subarea. Starting with the Pressure Subarea, the target demand at SRDF (36 cfs) was divided by one minus the average monthly seepage for each Subarea to determine the average monthly release needed to overcome the calculated seepage.

This approach was adapted slightly in cases where the calculated minimum conservation release in a given month was lower than the month before. This behavior occurred for the minimum conservation release calculated for dry years, and results from the early cessation of SRDF seasons that occurs in some dry years. The dry years during which SRDF is able to operate later into the season tend to experience lower seepage compared to those years during which SRDF ceases operation earlier. For this reason, the calculated minimum conservation release for dry years was set to always be at least as high as the previous month.

The resulting monthly minimum conservation release amounts that occur in the modified SVOM are shown in Table 1. The reservoirs must release at least these minimum flowrates when SRDF is operating. If the reservoirs cannot maintain the minimum releases, the SRDF season terminates early. As in the delivered model, this rule modification accounts for the need to maintain sufficient water in storage in the reservoirs and sufficient remaining withdrawal under the water right to provide water to San Luis Obispo County and fish and wildlife habitat below the dams.

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[2] For the Below Dam Subarea, the inflow is the amount of reservoir release. For the other subareas, it is the inflow along the Salinas River from the Subarea immediately upstream.

Table 1. Monthly Minimum Conservation Release Target by Water Year Type, cubic feet per second

Month	Wet Years	Normal Years	Dry Years
April	93	145	268
May	121	223	317
June	178	261	317
July	226	291	332
August	261	313	332
September	284	318	332
October	319	327	332

Kelt and Juvenile Rule Update

In the Flow Prescription (MCWRA, 2005), the setting of streamflow requirements to support the outmigration of steelhead trout during the kelt and juvenile stages differs depending on whether or not an engineered block flow to support smolt outmigration is happening. In the event that a block flow is in progress, kelt and juvenile requirements are not set until the block flow is complete. In the absence of a block flow, those requirements may be set whenever conditions allow. Smolt block flows can begin as early as March 15th and end as late as June 20th. Kelt and juvenile flow requirements can be set from April 1st to June 30th if a smolt block flow is not occurring. Smolt block flows only occur in normal years; kelt and juvenile flow requirements can be set in both wet and normal years.

The SVOM delivered by the USGS does not start checking for triggers to set the kelt and juvenile flow requirements until June 1st each year, whether or not a smolt block flow occurs. For this study, the kelt and juvenile rule file was modified to instead start checking for triggers to set flow requirements on April 1st. The SVOM delivered by the USGS also only sets a juvenile flow requirement if the Salinas River Lagoon is open, while the Flow Prescription specifies that the Lagoon does not need to be open for this requirement to be set. The kelt and juvenile rule file was modified to remove this requirement.

Smolt and Kelt Counter Incrementation

The SVOM delivered by the USGS only counted smolt block flow days and kelt flow days toward annual totals if the associated streamflow requirements were met. The relevant rule files were modified to increment these counters if releases are made for those purposes, whether or not the requirements are met.

Changes to Streamflow Inputs

The SVOM utilizes stream inflow inputs along the edges of the model to represent inflow from portions of the Salinas River watershed outside of the model domain, including Salinas River inflow from the Paso Robles Basin and large tributaries like Arroyo Seco. For each inflow location, a time series of inflow is fed into the model. These inflow time series are outputs from a rainfall-runoff model of the entire Salinas River watershed, the Salinas Valley Watershed Model (SVWM), also developed by the USGS.

The SVOM delivered by the USGS uses inflow time series that only include one streamflow value per month; each inflow value is in effect for all timesteps within a given month of the model. This means that streamflow is largely uniform through the course of any given month. Reservoir releases are not subject to this same limitation because they are calculated within the model on a timestep basis. The monthly character of streamflow presents a challenge in situations where reservoir operations are in part determined by whether streamflow drops below or rises above some threshold value. For example, releases can be made to support smolt outmigration beyond the end of the block flow period if Arroyo Seco remains connected to the Salinas River (as indicated by at least 1 cfs passing the Arroyo Seco below Reliz Creek gauge); the use of monthly inflows means that these additional releases may either not be made at all or continue for up to an entire month, depending on the inflow to Arroyo Seco.

MODFLOW-OWHM has the capability of varying stream inflows on a timestep basis, rather than the more typical stress period[3] required by other versions of MODFLOW. The USGS provided simulated mean daily streamflow values from the SVWM for the inflow location of the Salinas River. The inflow location of Arroyo Seco corresponds to the location of the USGS Arroyo Seco near Soledad stream gauge, so mean daily streamflow observed at that gauge over the historical hydrologic period was applied as the model input. The SVOM calculates the timestep-average inflow from the mean daily streamflow time series supplied by the user.

There were also several input files in the delivered SVOM that seemed to be incomplete, stopping at the end of 47.25 years (the end of the SVOM model period for previous versions of the SVOM, corresponding to December 2014 in the historical hydrology). These input files were extended through the end of 51 years using the following information:

- Arroyo Seco near Soledad streamflow: using mean daily streamflow measurements at the USGS Arroyo Seco near Soledad stream gauge
- Nacimiento River near Bryson streamflow: using mean daily streamflow measurements at the USGS Nacimiento River below Sapaque Creek near Bryson stream gauge
- Historical storage in Nacimiento Reservoir: using spreadsheet provided by MCWRA
- Historical storage in San Antonio Reservoir: using spreadsheet provided by MCWRA
- Maximum SRDF diversion: carried forward 36 cfs maximum demand for all months in the Conservation Release Season (April through October)
- Maximum Tembladero Slough diversion: corrected from 1 cfs to 10 cfs, as throughout the rest of the model period
- Recycled water deliveries: copied forward from available period

The historical reservoir storage time series are only used in SVOM to set initial storage in the reservoirs.

Bias Correction

As stated above, the SVOM is built from the SVIHM, and the quality of the SVIHM calibration determines the applicability of the SVOM. Because the SVIHM has not been released publicly, full calibration information is not yet available. As a proxy for determining the quality of the model, SVIHM-simulated

[3] The stress period is the basic unit of time discretization in a MODFLOW model and represents a period of the model during which all stresses on the model (e.g., groundwater pumping) are uniform. Each stress period can be divided into multiple timesteps. For the SVOM, each stress period is exactly one month long; there are 5 or 6 timesteps per stress period, and timestep lengths vary from 5 to 6 days depending on the number of days in the month.

streamflow was compared to the historical record of observed streamflow. This comparison revealed that the SVIHM systematically under-estimates lower streamflows in the system.

Improving the model fit to observed streamflows would require recalibration of the SVIHM, which is beyond the scope of this study. Instead, a bias correction was developed to scale the various streamflow thresholds and requirements in the operational rules to have the model create a more realistic simulation of migration conditions. Bias correction had the effect of mostly increasing the streamflow requirements incorporated into the operational rules of the SVOM.

Appendix A – Bias Correction Approach documents the comparison of simulated and observed streamflow and details the bias correction approach applied for this study.

Customized Outputs

To facilitate efficient post-processing of the model scenarios, customized output files were developed to summarize the range of results from varying reservoir operations. These changes in no way modify the simulated conditions within the model.

Model Metrics

To assess the effects of operational rule changes on steelhead trout migration, various metrics were developed in collaboration with MCWRA and ICF. These metrics quantify how frequently streamflow in the Salinas River and its tributaries meets established streamflow thresholds, as well as the operation of the SRDF. The metrics quantified for this study include:

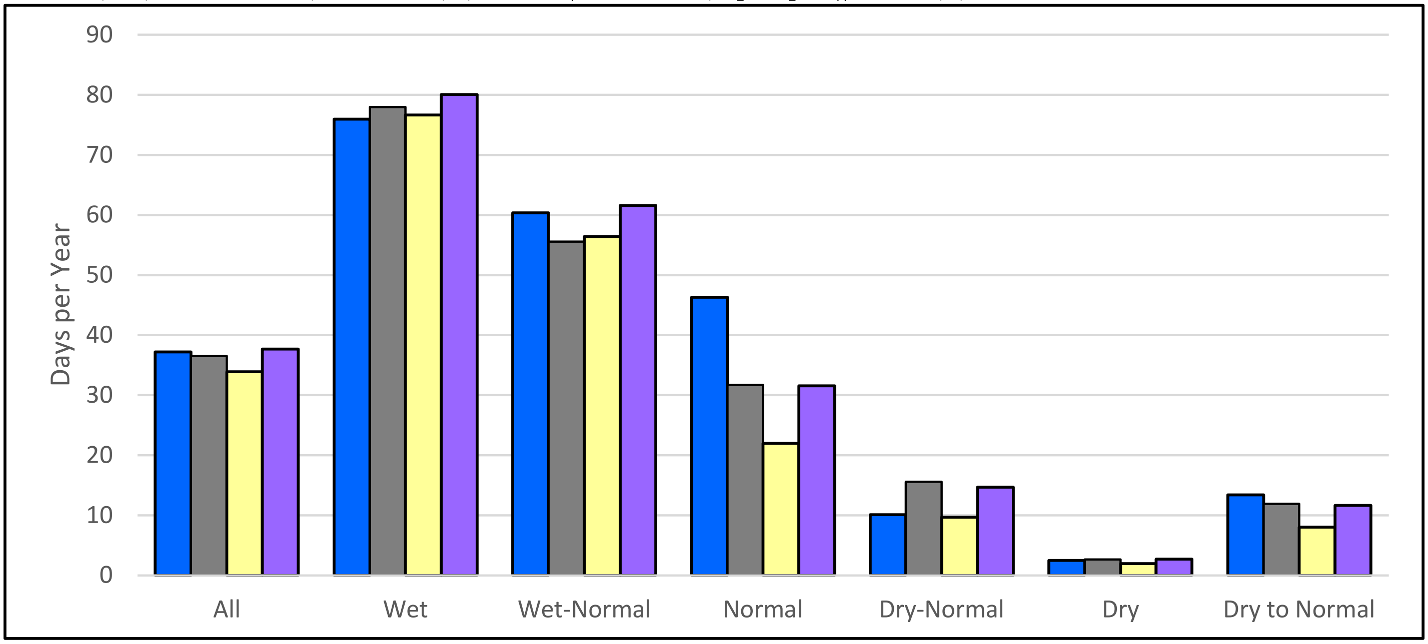
- Adult Passage Days: Number of days between January 1st to March 31st each year with at least 260 cfs of streamflow at the Salinas River near Chualar gauge, and the Lagoon open to the ocean
- Block Flows: Percentage of normal years with a successful (i.e., at least 20 days) smolt block flow
- Additional Smolt Days: Number of days each year of releases to support additional smolt outmigration subsequent to a block flow occurred
- Outmigration Passage Days: Number of days from March 15th to June 30th each year with at least 150 cfs of streamflow at the Salinas River near Spreckels gauge, and the Lagoon open to the ocean
- SRDF Days: Number of days from April 1st to October 31st each year with the SRDF diverting water; the full season is 214 days long
- SRDF Volume: Total volume diverted each year (in acre-feet per year, afy) at the SRDF
- Percentage of Full, Partial, and Failed SRDF Seasons: Percentage of SRDF seasons with 214 days of operation (Full), 1 to 213 days of operation (Partial), and 0 days of operation (Failed)

Additional metrics that quantify various other aspects of the operations (such as the number of days with streamflow meeting the juvenile flow target of 15 cfs to the Salinas River Lagoon) are provided in Appendix A, along with metrics that are based on individual aspects of certain requirements (such as days during the adult upmigration period with the Lagoon open to the ocean), which are used to indicate whether the SVIHM and SVOM are producing realistic results.

The primary metrics listed above generally reflect the quantification approach employed by MCWRA for reporting system conditions in their SVWP annual reports (e.g., MCWRA, 2023). The following summarizes the values of model metrics for the historical period[4]. The historical period metrics are shown in Figures 2 through 3, and Tables 2 through 5, together with the metrics for the three scenarios evaluated for this study (described and interpreted in subsequent sections). The reader should keep in mind that the operational approach for the reservoirs has not targeted the attainment of flow to support steelhead migration throughout the historical period, and the operational approach has changed substantially. The values of these metrics from the historical period should not be expected to correspond exactly to any SVOM scenario and are only presented for comparison.

- On average, there were about 37 Adult Passage Days per year during the historical period, and about 13 days per year during dry to normal years (Figure 2 and Table 2). There were about 76 Adult Passage Days per year during wet years, and about 3 days per year during dry years.
- Smolt block flow triggers were met in 75 percent of normal years during the historical period (Table 3). These triggers are applied retroactively to the historical period; smolt block flows were not made prior to the development of the Flow Prescription. Over the 11-year period from WY 2010 to 2020, there were only 4 years that were classified as dry-normal to wet-normal (i.e., a smolt block flow could occur; MCWRA, 2022 and 2023). Of these, 2 dry-normal years had no block flow, with natural flow triggers not met in WY 2013 and insufficient reservoir storage in WY 2016 (MCWRA, 2022). The remaining dry-normal year and the single wet-normal year during this period had smolt block flows. This 11-year period provides a sample size too small to assess how frequently smolt blow flows are made.
- During the historical period, there were about 27 Outmigration Passage Days per year, with about 4 days per year during dry to normal years (Figure 3 and Table 4). There were about 70 Outmigration Passage Days per wet year, and about 1 per dry year.
- SRDF diversion days and diversion volume are not presented for the historical period because there are substantial differences between the way the SRDF has been operated and the representation of those operations in the SVOM. As noted above, the SVOM allows the SRDF season to last from April 1st to October 31st, and MCWRA has never actually diverted water for this entire period, in part because flow in the Salinas River is often too high early in the SRDF season to divert water. For this study, we define a historical SRDF season as Full or Partial based on its end date. Based on records (MCWRA, 2022 and 2023), it seems that MCWRA typically ceases operation of the SRDF in late September or October in years with conditions that can be expected to result in successful SRDF seasons; therefore, we can consider any historical SRDF season that lasted into at least September to be Full, and any that ended prior to September to be Partial. Based on this definition, of the 11 operational seasons from WY 2010 to 2020, 7 (64 percent) were Full, 1 (9 percent) was Partial, and 3 (27 percent) were Failed (Table 5).

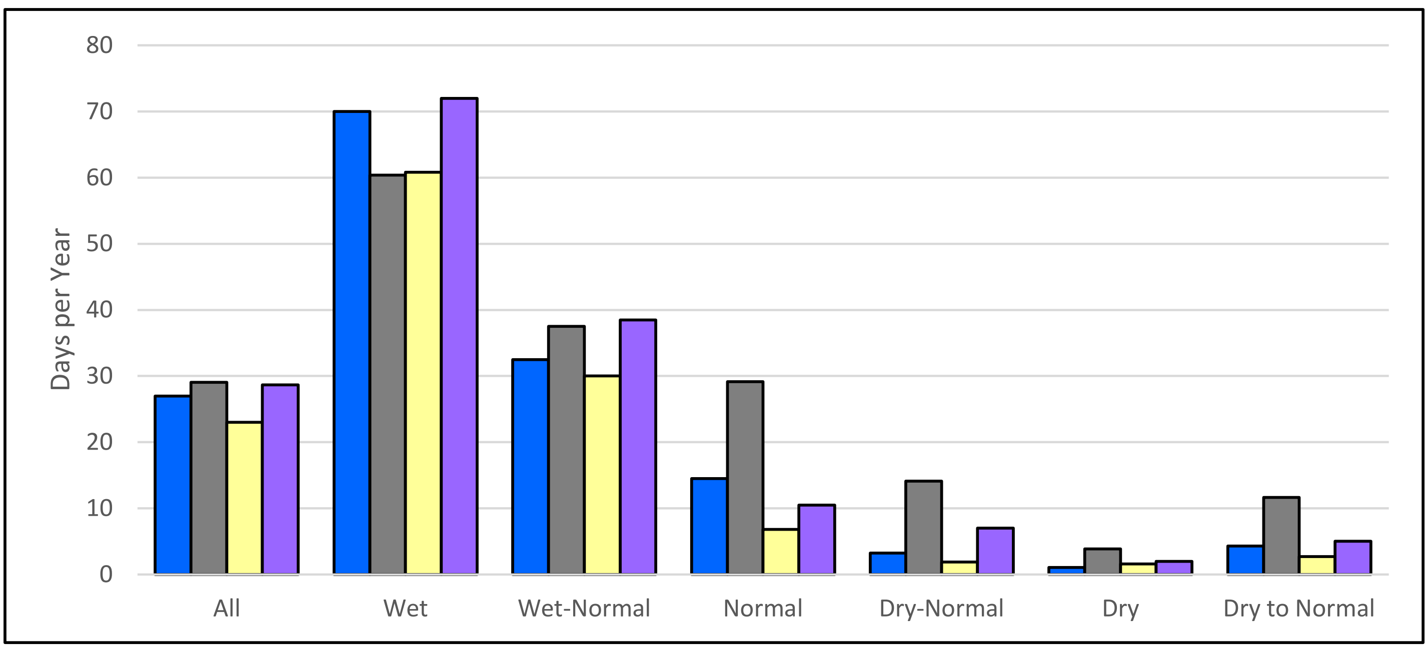
[4] For the purposes of this TM, the historical period is limited to WY 1968 to 2018, the same period as the historical hydrology used to force the SVOM. The tables referenced in this TM only provide metrics for the historical period based on the timestep-averaged observed streamflow to allow direct comparison to the SVOM results. Metrics calculated using observed mean daily streamflow are presented in Appendix A.



Notes:
1. Quantification for observed streamflow based on timestep-averaged streamflow

Figure 2

Adult Passage Days per Year, Comparison Point Scenarios



Notes:
1. Quantification for observed streamflow based on timestep-averaged streamflow

Figure 3

Outmigration Passage Days per Year, Comparison Point Scenarios

Legend
- Observed Streamflow
- Current Operations Scenario
- No Flow Prescription Scenario
- No Operations Scenario

Monterey County Water Resources Agency
TM1: HCP Comparison Point Scenarios
July 2024
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Table 2. Average Adult Passage Days Per Year by Water Year Type

Water Year Type	Observed (Timestep-Average)	Current Operations Scenario	No Flow Prescription Scenario	No Operations Scenario
All	37	37	34	38
Wet	76	77	77	80
Wet-Normal	60	56	56	62
Normal	46	33	22	32
Dry-Normal	10	16	10	15
Dry	3	3	2	3
Dry to Normal	13	12	8	12

Table 3. Smolt Block Flow Triggering

	Observed (Timestep-Average)	Current Operations Scenario	No Flow Prescription Scenario	No Operations Scenario
Total Number of Normal Years	20	25	25	25
Normal Years with Smolt Block Flow Triggers Met	15	19	18	0
Percentage of Normal Years with Triggers Met	75	76	72	0

Table 4. Average Outmigration Passage Days per Year by Water Year Type

Water Year Type	Observed, Timestep-Average	Current Operations Scenario	No Flow Prescription Scenario	No Operations Scenario
All	27	29	23	29
Wet	70	60	61	72
Wet-Normal	33	38	30	39
Normal	15	29	7	11
Dry-Normal	3	14	2	7
Dry	1	4	2	2
Dry to Normal	4	12	3	5

Table 5. SRDF Operation Metrics by Operational Water Year Type					
Water Year Type	Metric	Observed, Timestep-Average	Current Operations Scenario	No Flow Prescription Scenario	No Operations Scenario
All	Div. Days	--	145	175	0
	Diversion Volume[(a)]	--	10,400	12,500	0
	Full|Part|Fail	64%|9%|27%	58%|14%|28%	74%|12%|14%	0%|0%|100%
Wet	Diversion Days	--	214	214	0
	Diversion Volume[(a)]	--	15,300	15,300	0
	Full|Part|Fail	100%|0%|0%	100%|0%|0%	100%|0%|0%	0%|0%|100%
Normal	Diversion Days	--	134	175	0
	Diversion Volume[(a)]	--	9,600	12,500	0
	Full|Part|Fail	50%|25%|25%	57%|9%|35%	74%|13%|13%	0%|0%|100%
Dry	Diversion Days	--	91	131	0
	Diversion Volume[(a)]	--	6,500	9,400	0
	Full|Part|Fail	50%|0%|50%	15%|38%|46%	46%|23%|31%	0%|0%|100%

(a) Diversion Volume is in acre-feet per year

CURRENT OPERATIONS SCENARIO

The Current Operations Scenario was designed to replicate, as closely as possible, the operational approach that MCWRA currently employs for the Nacimiento and San Antonio Reservoirs and SRDF. While there are differences between the actual operations and the operations as represented in the SVOM, these largely stem from:

- Assumptions and approximations inherent to the SVOM (such as the timestep length)
- The fact that all operational decisions must be representable as fairly simple logical operations, precluding ad-hoc decisions.

The purpose of the Current Operations Scenario is to provide a simulation of conditions in the Basin under decades of a uniform operational approach, with other critical factors (such as land use) held steady. Other model scenarios (including the other Comparison Point Scenarios and the Reoperation Scenarios) can be compared against the Current Operations Scenario to show how changes to the operational approach affect conditions in the Basin.

This section presents the results of the Current Operations Scenario, and compares those results against historical observations, with the understanding that the operational approach was not uniform throughout the historical period.

Scenario Design

The Current Operations Scenario utilizes the SVOM, with modifications described in the prior section. As described above, these modifications were made to more closely align the SVOM with the current operational approach, to account for systematic over-prediction of lower streamflows in the model, and to provide customized output files tailored to this study.

Adult Upmigration

Figure 2 and Table 2 provide the average annual number of Passage Days during the 91-day adult upmigration period (January 1st to March 31st). On average, the Current Operations Scenario results in about 37 Adult Passage Days per year across all year types. Wet years tend to see the most Adult Passage Days (about 77 days per year) and dry years the least (about 3 days per year). Dry, dry-normal, and normal years average about 12 Adult Passage Days per year.

The average number of Adult Passage Days under the Current Operations Scenario is similar to the number of days in the observed historical record. The average number of Adult Passage Days simulated under the Current Operations Scenario is within 5 days of that calculated from the historical record for all year types except for normal years (fewer Adult Passage Days per year than the historical record) and dry-normal years (more Adult Passage Days per year than the historical record). However, recall that the Current Operations Scenario is not expected to re-create historical conditions since it utilizes uniform operational criteria throughout the model period, whereas the actual operational criteria have changed over this historical period.

Smolt/Kelt/Juvenile Outmigration

Table 3 summarizes the smolt block flow metrics. Under the Current Operations Scenario, the triggers to initiate a block flow are met in 76 percent of normal years, and block flows complete successfully (i.e., last at least 20 days) in 68 percent of normal years. The average block flow lasts for about 40 days. Additional releases are made subsequent to completion of the block flow to continue to support smolt outmigration in 40 percent of normal years, with an average of 30 additional days of releases in those years where such releases are made.

Figure 3 and Table 4 provide the average annual number of Passage Days during the 112-day smolt, kelt, and juvenile outmigration period[5]. On average, the Current Operations Scenario results in about 29 Outmigration Passage Days per year across all year types, and about 12 days per year for dry, dry-normal, and normal years. Wet years average about 60 Outmigration Passage Days per year, and dry years about 4 days per year.

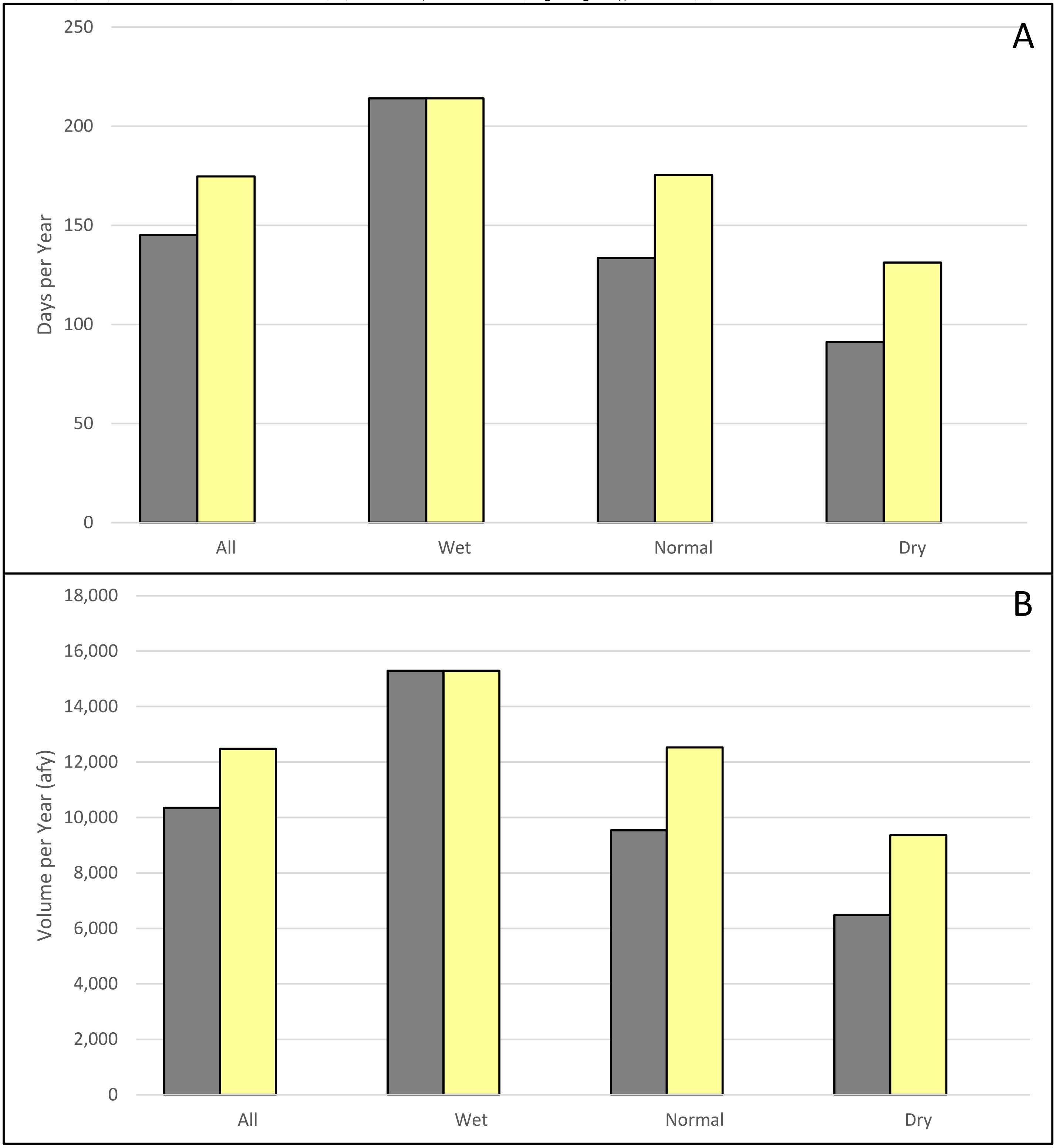
Although the overall average number of Outmigration Passage Days agrees closely with the number calculated from the historical record, individual water year types exhibit substantial differences. The historical record exhibits more Outmigration Passage Days during wet years and fewer for all other year types. As noted above, the Current Operations Scenario is not expected to match historical conditions. Indeed, the differences between the Current Operations Scenario results and the observed record indicate that the operational approach represented in this scenario likely increases the potential success of steelhead trout outmigration compared to the historical period.

[5] According to the Flow Prescription, smolt block flow releases can begin as early as March 15th. In the SVOM, this means that those releases can begin with the model timestep containing March 15th. This timestep actually begins on March 11th, meaning that the smolt/kelt/juvenile outmigration period can last up to 112 days from March 11th to June 30th.

SRDF Operation

Figures 4 and 5, and Table 5, provide information on the simulated operation of the SRDF[6]. On average, SRDF diverted water for about 145 days per year across all year types (Figure 4a), diverting an average of about 10,400 afy (Figure 4b). Full seasons occurred in 58 percent of years, Partial seasons in 14 percent of years, and Failed seasons in 28 percent of years (Figure 5).

[6] Because the SVOM SRDF results cannot be directly compared to the historical period, metrics related to SRDF operation are only presented for the operational year types: wet, normal (including wet-normal, normal, and dry-normal), and dry years.



Notes:
1. Maximum length of SRDF season is 214 days
2. Diversion volume is in acre-feet per year (afy)

Legend
- Current Operations Scenario
- No Flow Prescription Scenario
- No Operations Scenario

Figure 4

SRDF Diversion Days (A) and Diversion Volume (B) Per Year, Comparison Point Scenarios

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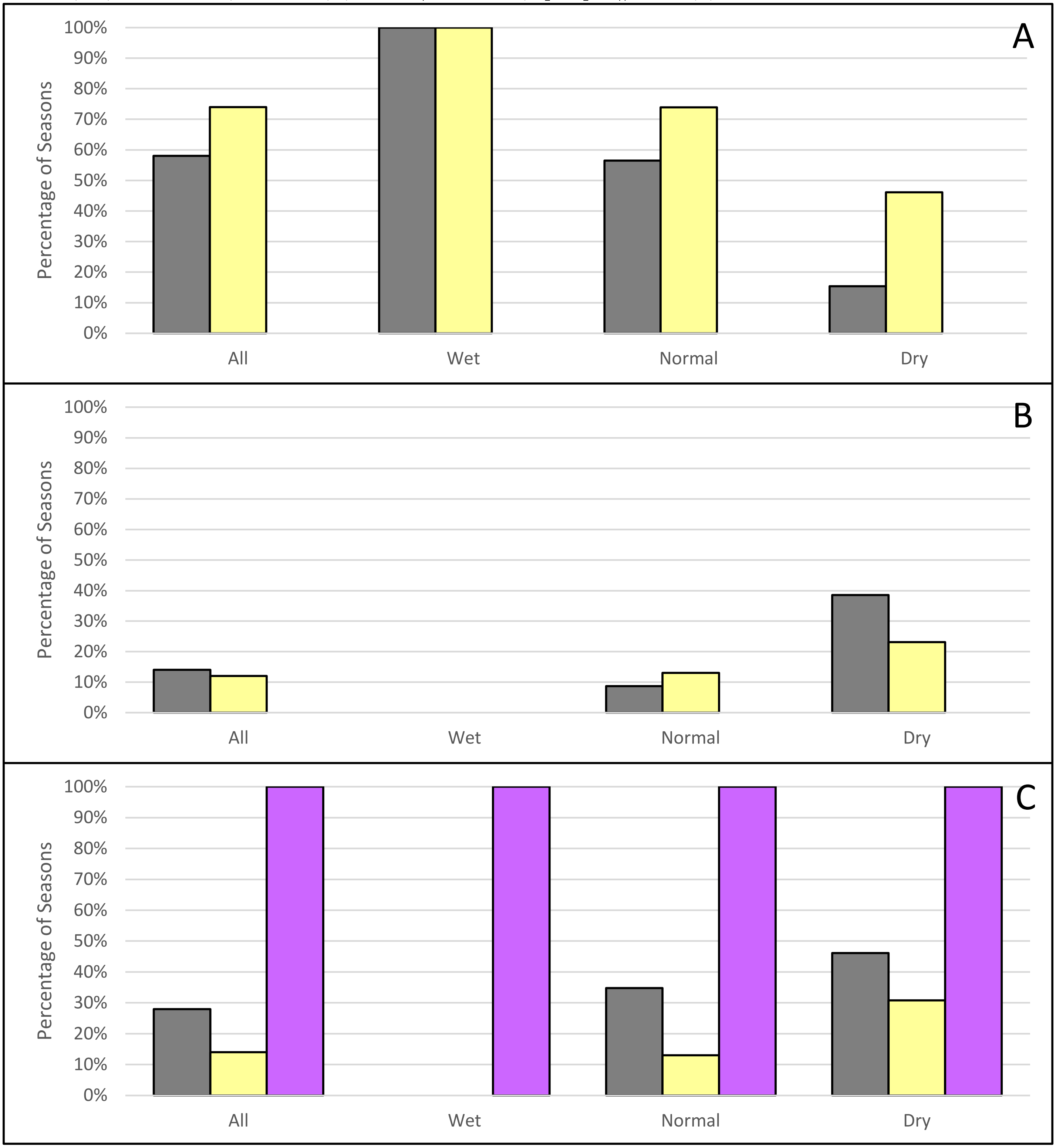

Notes:

1. A Full SRDF season is 214 days, a Failed season is 0 days, and a Partial season is anything in between

Legend

- Current Operations Scenario
- No Flow Prescription Scenario
- No Operations Scenario

Figure 5

Percentage of Full (A), Partial (B), and Failed (C) SRDF Seasons, Comparison Point Scenarios

Monterey County Water Resources Agency

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All wet years experienced Full seasons, with an average diversion of about 15,300 afy. Normal years averaged about 134 diversion days per year, with an average diversion volume of about 9,600 afy. About 57 percent of normal years have Full seasons, with 9 percent having Partial seasons and 35 percent having Failed seasons. Dry years averaged about 91 diversion days per year, with an average diversion volume of about 6,500 afy. About 15 percent of dry years have Full seasons, with 38 percent having Partial seasons and 46 percent having Failed seasons.

It is not straightforward to compare SVOM-simulated SRDF operations to the historical period. First, the SRDF began operating in 2010, meaning that the historical period utilized as hydrologic input to the SVOM (WY 1967 to 2018) only included 9 years of SRDF operation. In addition, MCWRA does not typically start diverting water at SRDF on April 1st each year, or end diversions on October 31st (see Appendix A of MCWRA, 2022). The actual diversion period at SRDF can be affected by various operational considerations that are not reflected in the SVOM operational rules, including the fact that the SRDF cannot divert if flow in the Salinas River is too high. From 2010 to 2020 (an 11-year period), SRDF seasons started between April 1st and May 3rd and ended on dates ranging from August 23rd (2011[7]) to October 19th. Any season with diversions lasting into mid-September was considered Full for this analysis.

For the historical period, 7 out of 11 years (64 percent) were classified as Full, 1 out of 11 years (9 percent) was classified as Partial, and 3 out of 11 years (27 percent) were classified as Failed. Despite the limitations mentioned above, these percentages are quite close to the results of the Current Operations Scenario.

Summary

The Current Operations Scenario simulates conditions in the study area under the operational approach currently employed by MCWRA for the Nacimiento and San Antonio Reservoirs and SRDF. Under this scenario:

- There is an average of 37 Adult Passage Days per year across all year types, or 12 days per year during dry to normal years.
- Engineered smolt block flows are successfully made in 68 percent of normal years.
- On average, there are 29 Outmigration Passage Days per year, or 12 days per year during dry to normal years.
- The SRDF diverts about 10,400 afy with an average season length of 145 days per year.

These results compare well with observations from the historical period (accounting for the fact that the operational approach has changed over time). This provides confidence that the modified SVOM provides realistic estimates of conditions in the system.

NO FLOW PRESCRIPTION SCENARIO

The No Flow Prescription Scenario is designed to represent the system in the absence of any releases made to support steelhead trout migration. Other aspects of the operational approach, including the operation of the SRDF, are retained in this scenario. The results of the No Flow Prescription Scenario can be compared to those of the Current Operations Scenario to show the effect that the Flow Prescription rules have on

[7] Note that the 2011 operational season ended early due to scouring around the SRDF fish ladder, not due to insufficient storage or inability to provide sufficient water to the SRDF.

conditions in the system, including how they affect the potential conditions for steelhead trout migration and the operation of the SRDF.

Scenario Design

The No Flow Prescription Scenario is identical to the Current Operations Scenario, except for the following changes:

- All rules related to fish passage are removed, including the 2 cfs bypass flow to the Salinas River Lagoon when SRDF is operating.
- The minimum target release from Nacimiento Reservoir to support fish and wildlife habitat below the dam is reduced from 60 cfs to 25 cfs, with this change also reflected in the dynamic minimum storage and dynamic water rights withdrawal limits employed at Nacimiento Reservoir to protect fish and wildlife habitat releases and deliveries to San Luis Obispo County for the rest of the year.

Adult Upmigration

There are about 34 Adult Passage Days per year averaged across all year types, an 8 percent decrease compared to the Current Operations Scenario. There is no difference in the average annual number of Adult Passage Days during wet and wet-normal years. Without the Flow Prescription rules there are about 8 Adult Passage Days per year during normal, dry-normal years, and dry years, 33 percent fewer compared to the Current Operations Scenario.

Smolt/Kelt/Juvenile Outmigration

With the Flow Prescription rules removed, there are no smolt block flows or post-block flow releases made to support smolt outmigration.

On average, the No Flow Prescription Scenario results in about 23 Outmigration Passage Days per year across all year types (21 percent less than under the Current Operations Scenario), and about 3 days per year for dry, dry-normal, and normal years (75 percent less than under the Current Operations Scenario). Wet years average about 61 Outmigration Passage Days per year (2 percent more than under the Current Operations Scenario), and dry years about 2 days per year (50 percent less than under the Current Operations Scenario).

These results show that the rules of the Flow Prescription are effective at supporting smolt, kelt, and juvenile outmigration, especially during drier years. According to the SVOM, the Flow Prescription rules approximately quadruple the number of Outmigration Passage Days during dry to normal years, increasing the opportunities for steelhead trout to move out of the Salinas River to the Pacific Ocean.

SRDF Operation

On average, SRDF diverted water for about 175 days per year across all year types, diverting about 12,500 afy. Full, Partial, and Failed seasons occurred in 74 percent, 12 percent, and 14 percent of years, respectively.

The No Flow Prescription Scenario results in about 21 percent more days of SRDF diversion and about 20 percent more diversion volume at SRDF compared to the Current Operations Scenario. More SRDF seasons are Full and fewer are Partial or Failed. The increases in diversions and season length without the Flow

Prescription rules result from higher storage in the reservoirs, resulting in more years with sufficient storage to initiate an SRDF season: about half of the years with insufficient initial storage under the Current Operations Scenario have at least a Partial SRDF season under the No Flow Prescription Scenario. Additionally, fewer years were limited by an inability to meet the minimum conservation release targets: about 80 percent of years that ended early under the Current Operations Scenario because the minimum release target could not be met were Full seasons under the No Flow Prescription Scenario. This scenario demonstrates that the rules of the Flow Prescription limit the operation of the SRDF by releasing additional water during the steelhead trout migration season.

Summary

The No Flow Prescription Scenario simulates conditions in the study area under the current operational approach without the rules of the Flow Prescription. Other rules related to operation of the reservoirs and the SRDF remain in place for this scenario. Under this scenario, there are about 34 Adult Passage Days per year, and about 8 days per year for dry to normal years. Without the Flow Prescription rules, there are no smolt block flow releases made. There are about 23 Outmigration Passage Days per year, with about 3 days per year during dry to normal years. SRDF operates about 175 days per year and diverts about 12,500 afy.

These results indicate that the rules of the Flow Prescription increase opportunities for steelhead trout to migrate during both the adult and smolt/kelt/juvenile migration seasons. Average annual Adult Passage Days without the Flow Prescription rules are about 8 percent lower compared to the Current Operations Scenario, and about 33 percent lower during dry to normal years. Average annual Outmigration Passage Days without the Flow Prescription rules are about 21 percent lower compared to the Current Operations Scenario, and about 75 percent lower during dry to normal years.

The Flow Prescription rules limit the operation of the SRDF by releasing additional water during the steelhead trout migration season. Absent the rules, about 20 percent more diversion occurs than under the Current Operations Scenario.

NO OPERATIONS SCENARIO

The No Operations Scenario is designed to represent the system without any operations. In this scenario, the reservoirs release all water as quickly as possible and do not store water. The results of this scenario can be compared to those of the Current Operations Scenario to quantify the effects of reservoir operations collectively on the system.

Scenario Design

Under the No Operations Scenario, the reservoirs do not release water to support steelhead trout migration, SRDF operation, or fish and wildlife habitat below the dams. Water rights limitations to collection and withdrawal are also removed. No water is delivered to San Luis Obispo County or lakeside users at Nacimiento Reservoir. This scenario is designed to represent the system with the dams physically present but always releasing as much water as possible (i.e., not storing any water).

In the No Operations Scenario, each reservoir releases up to its release capacity at all times, as determined by the reservoir stage. For example, when the stage in Nacimiento Reservoir is below 755 feet above mean sea level (the elevation of the spillway of the High-Level Outlet Works), the dam can only release about

460 cfs; if inflow exceeds this release capacity[8], then stage in the reservoir will rise. Subsequently, the reservoirs continue to release up to their maximum capacity until stage returns to the Deadpool stage (below which water cannot be released through the existing outlet works).

Adult Upmigration

There are about 38 Adult Passage Days per year averaged across all year types, a 3 percent increase compared to the Current Operations Scenario and 12 percent more than under the No Flow Prescription Scenario. There are about 80 Adult Passage Days per year during wet years and 62 per year during wet-normal years, representing increases of 4 percent and 11 percent relative to the Current Operations and No Flow Prescription Scenarios, respectively. There is little difference in the number of Adult Passage Days during dry to normal years between the No Operations and Current Operations Scenarios.

These results show that operation of the reservoirs, as represented in the Current Operations Scenario, do not strongly impact the ability of adult steelhead trout to travel up the Salinas River to spawning grounds. There is approximately no difference during dry to normal years, and only a slight difference in Adult Passage Days during wet-normal and wet years, when conditions are largely supportive of adult upmigration whether or not the reservoirs are operating.

Smolt/Kelt/Juvenile Outmigration

With the Flow Prescription rules removed, there are no smolt block flows or post-block flow releases made to support smolt outmigration under the No Operations Scenario.

On average, the No Operations Scenario results in about 29 Outmigration Passage Days per year across all year types, and about 5 days per year for dry, dry-normal, and normal years. Wet years average about 72 Outmigration Passage Days per year, and dry years about 2 days per year. While the overall average number of Outmigration Passage Days per year is the same under the No Operations and Current Operation Scenarios, 20 percent more Outmigration Passage Days occur in wet years and 58 percent fewer in dry to normal years compared to the Current Operations Scenario.

The occurrence of Outmigration Passage Days under the No Operations Scenario indicates that the operational approach currently employed effectively supports outmigration during the smolt, kelt, and juvenile outmigration season, especially during drier years.

SRDF Operation

Under the No Operations Scenario, the reservoirs do not release water to supply the SRDF, and the SRDF does not divert water.

[8] The maximum reservoir release capacity during any given model timestep is determined at the beginning of the timestep, based on the reservoir stage at that time. This means that the reservoirs cannot react to large reservoir inflows during the course of a timestep, allowing for what may be an unrealistic buildup of storage.

Summary

The No Operations Scenario simulates conditions in the study area as if the reservoirs remain in place, but are not operated, with release only limited by the physical capacity of the various outlet works of the dams. This scenario seeks to represent, as closely as possible, natural flow in the system.

Under this scenario, there is an annual average of 38 Adult Passage Days per year, with 12 days per year in dry to normal years. This represents little difference from the Current Operations Scenario, indicating that the operational approach currently in place does not negatively affect the occurrence of conditions conducive to adult upmigration.

Because the Flow Prescription rules are not present in the No Operations Scenario, there are no smolt block flows. On average, there are 29 Outmigration Passage Days per year, with 5 days per year during dry to normal years. While these results indicate that the overall average number of days per year is not increased by removal of all operations, the current operational approach shifts those days from wet years, when conditions remain very favorable for outmigration, to dry to normal years, greatly increasing the occurrence of conditions supporting outmigration for the endangered steelhead trout.

SUMMARY AND CONCLUSIONS

This TM documents the simulated hydrologic outcomes of various reservoir operation scenarios using a numerical model of the coupled groundwater-surface water-reservoir system in the Salinas Valley. A modified version of the USGS' SVOM, currently under development, was used to perform the modeling. The modifications were implemented to improve its representativeness of MCWRA's operation of the Nacimiento and San Antonio Reservoirs to achieve flood control and water conservation goals and follow the Flow Prescription Rules designed to increase opportunities for the successful migration of the federally listed SCCC steelhead trout.

The three model scenarios analyzed include: 1) the Current Operations Scenario, which simulates the system under MCWRA's current operational approach; 2) the No Flow Prescription Scenario, which removes the rules related to the Flow Prescription; and 3) the No Operations Scenario, which removes all operational rules but keeps in place the physical release limitations of the reservoirs. The difference between the Current Operations and No Flow Prescription Scenarios shows the effect of the Flow Prescription Rules. The difference between the Current Operations and No Operations Scenarios shows the effect of the operational approach as a whole. The difference between the No Flow Prescription and No Operations Scenarios shows the effect of the operational rules in the absence of the Flow Prescription.

Relative to conditions with no reservoir operations (No Operations Scenario), the No Flow Prescription Scenario shows that:

- Adult steelhead trout upmigration opportunities, as measured by the number of annual Adult Passage Days, are reduced by about 10 percent, from 38 to 34 Adult Passage Days per year
- Opportunities for outmigration of steelhead trout in the smolt, kelt, and juvenile stages are reduced by about 21 percent, from 29 to 23 Outmigration Passage Days per year, with reductions across almost all water year types.

The Current Operations Scenario shows that:

- There is no important difference between the number of Adult Passage Days per year relative to the No Operations Scenario for any water year type, including dry to normal years.
- Overall outmigration opportunities are similar relative to the No Operations Scenario, but they are shifted from wet years (reduced by about 17 percent, from 72 to 60 days per year) to drier years (increased by 140 percent for dry to normal years, from 5 to 12 days per year).

These results indicate that the rules of the Flow Prescription offset any effects of SRDF operation on outmigration opportunities (Figure 3). Importantly, the Flow Prescription rules also redistribute outmigration opportunities across variable hydrologic conditions, increasing the occurrence of migration opportunities across dry, dry-normal, and normal years compared to both the No Flow Prescription and No Operations Scenarios.

Although the Flow Prescription rules provide additional opportunities for steelhead trout to migrate between the Pacific Ocean and spawning grounds in the Salinas River and its tributaries, they limit the ability of the SRDF to operate. There are about 21 percent more days of SRDF diversion per year without the Flow Prescription rules.

In conclusion, this study demonstrates that the current operational approach employed by MCWRA does not limit the opportunities for steelhead trout to migrate in the Salinas River and its tributaries compared to a scenario where all reservoir operations are ceased. Indeed, by storing high streamflows during wet years and releasing them during drier periods, the current operational approach provides more opportunities for fish passage during dry, dry-normal, and normal years than would occur without operations. As a tradeoff, the implementation of the Flow Prescription rules reduces the average length of time that the SRDF can divert water each year.

The modeling results presented in this TM provide a basis of comparison for understanding the effects that changes to operations could have on conditions in the Salinas Valley. This understanding will help inform the design of the Reoperation Protocol that will be developed by ICF and MCWRA as the core covered activity of the HCP. Future TMs will document the design and results of the Reoperation Scenarios and will compare those results to those of the Comparison Point Scenarios.

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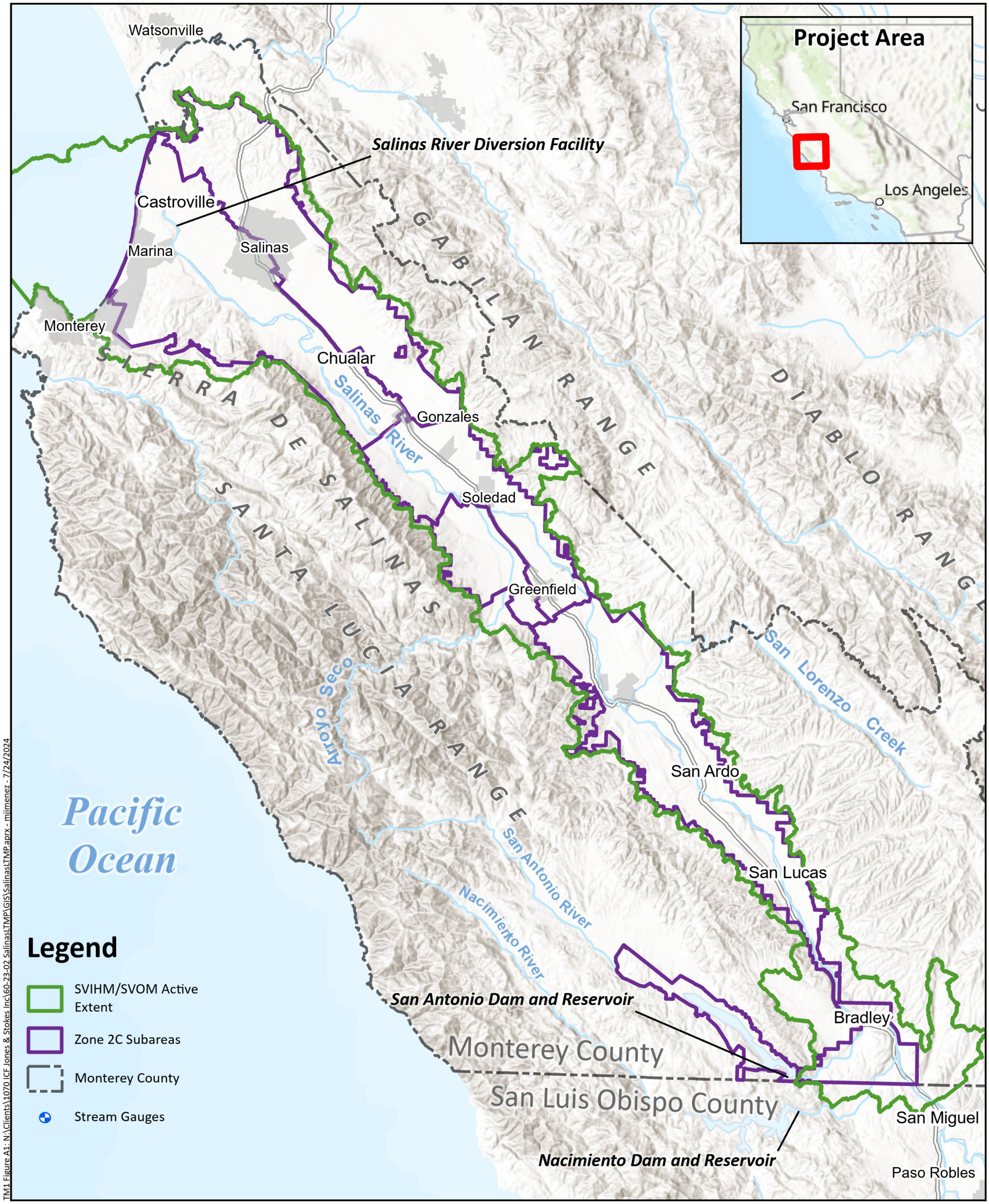
Appendix A

Bias Correction Approach

This appendix presents information on the models used to simulate groundwater and surface water conditions in the Salinas Valley to support the Salinas River Operational Habitat Conservation Plan (HCP). It describes certain critical issues with the models' ability to realistically simulate streamflow in the Salinas River and its tributaries. It details modifications that were made to the models to improve their ability to match observed streamflows and provide useful quantification of conditions conducive to fish passage within the system.

BACKGROUND

The Salinas River flows north through the alluvial Salinas Valley from the Paso Robles Basin to the south to its mouth at Monterey Bay (Figure A1). The river and its tributaries host critical migratory and spawning habitat for endangered Steelhead trout. Successful spawning and migration require that sufficient streamflow be present in river and its tributaries at specific times of the year to allow the Steelhead to move upriver to spawning habitat and downriver to the Pacific Ocean.



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Prepared for:
ICF Jones & Stokes
Salinas River HCP
TM1:Comparison Point Scenarios
July 2024

ICF

Study Area Map

Figure A1
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In addition to being a migratory corridor for Steelhead, the Salinas River is also the dominant surface water feature in the Salinas River Groundwater Basin (the Basin), which provides groundwater to satisfy crop demands from the overlying agricultural lands. The Salinas River and its tributaries are sources of recharge for replenishing the Basin aquifers. The Salinas River also receives inflow from Nacimiento Reservoir (via the Nacimiento River) and San Antonio Reservoir (via the San Antonio River). These two reservoirs are owned and operated by the Monterey County Water Resources Agency (MCWRA) for the combined purposes of fish passage, water conservation, flood control, and recreation.

OPERATIONAL AND PASSAGE REQUIREMENTS

To achieve the goals of water conservation and fish passage, MCWRA operates the reservoirs according to a set of rules that target certain streamflow values at certain times of year. These operational rules provide sufficient streamflow in the Salinas River to allow for the passage of fish to spawning grounds in Arroyo Seco and the lower Nacimiento River at critical times of year. Streamflow requirements are set at specific locations along the Salinas River (the locations of USGS stream gauges in the Salinas River at Soledad, Chualar, and Spreckels) based on year type (wet, normal, or dry), time of year. Flow requirements also consider unimpaired streamflow upstream of the reservoirs and in Arroyo Seco (at the USGS Arroyo Seco near Soledad and Arroyo Seco below Reliz Creek gauges), and whether the Salinas River Lagoon is open to the ocean or closed.

MCWRA published a guide to operation of the reservoirs to support fish migration (the Flow Prescription; MCWRA, 2005) based on historical studies of streamflow and surveys of Steelhead populations in the system. MCWRA also operates the reservoirs to provide sufficient water to the location of the Salinas River Diversion Facility (SRDF) for diversion into the Castroville Seawater Intrusion Project (CSIP) system.

Table A1 lists the streamflow requirements present in the Flow Prescription and those that support operation of the SRDF, along with the range of dates that each requirement may be in place (each requirement may only be in effect for a small portion of the range in any given year; MCWRA, 2005).

Table A1. Streamflow Thresholds and Requirements			
Location	Streamflow Value	Supported Activity	Date Range
Salinas River at Chualar	260 cfs	Adult Upmigration	2/1-3/31[(a)]
Arroyo Seco below Reliz Creek	173 cfs	Adult Upmigration	2/1-3/31
Salinas River at Spreckels	80 cfs	Adult Upmigration	2/1-3/31
Salinas River at Soledad	700 cfs	Smolt Outmigration	3/15-6/5
Salinas River at Spreckels	300 cfs	Smolt Outmigration	3/20-6/20
Arroyo Seco below Reliz Creek	1 cfs	Smolt Outmigration	3/15-6/20
Arroyo Seco below Reliz Creek	70 cfs	Smolt Outmigration	4/1-5/31
Salinas River Lagoon	45 cfs	Kelt Outmigration	4/1-6/30
Salinas River at Spreckels	80 cfs	Kelt Outmigration	4/1-6/30
Salinas River Lagoon	15 cfs	Juvenile Outmigration	4/1-6/30
Salinas River Diversion Facility	36 cfs	SRDF Operation	4/1-10/31
Salinas River Lagoon	2 cfs	SRDF Operation	4/1-10/31

(a) The adult upmigration season is defined to start on January 1, but no reservoir releases are made to target adult upmigration until February

TOOLS

This study relies on a pair of integrated groundwater-surface water models of the Basin built using the MODFLOW-OWHM code (Boyce et al., 2020). The Salinas Valley Integrated Hydrologic Model (SVIHM) simulates historical conditions over the period from October 1967 to September 2018 (i.e., Water Years 1968 to 2018) and is calibrated to groundwater head measurements, streamflow observations, and agricultural pumping estimates. The Salinas Valley Operational Model (SVOM) simulates conditions in the same system for a period of 51 water years under a uniform set of operational rules, land use conditions, and infrastructure build-out, influenced by the historical climate and streamflow conditions from the same period as the SVIHM. The SVOM is built from the SVIHM, and uses the same extent, three-dimensional grid, and model parameters (e.g., streambed conductance or aquifer hydraulic conductivity).

These two models are, as of the writing of this document, still under development by the USGS. As such, no documentation is currently available for either model. All model results presented herein must be considered preliminary and subject to change. The USGS requires that any presentation of model results from the SVIHM and SVOM be accompanied by the following disclaimers:

> *Historical SVIHM Model: Unoffical* [sic] *Collaborator Development Version of Preliminary Model. Access to this repository and use of its data is limited to those who are collaborating on the model development. Once the model is published and recieved* [sic] *full USGS approval it will be archived and released to the public. This preliminary data (model and/or model results) are preliminary or provisional and are subject to revision. This model and model results are being provided specifically to collaborate with agencies who are contributing to the model development and meet the need for timely best science.*

The model has not received final approval by the U.S. Geological Survey (USGS). No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the model and related material nor shall the fact of release constitute any such warranty. The model is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the model.

SVOM Model: Unofficial Collaborator Development Version of Preliminary Model. Access to this repository and use of its data is limited to those who are collaborating on the model development. Once the model is published and recieved [sic] *full USGS approval it will be archived and released to the public. This preliminary data (model and/or model results) are preliminary or provisional and are subject to revision. This model and model results are being provided specifically to collaborate with agencies who are contributing to the model development and meet the need for timely best science. The model has not received final approval by the U.S. Geological Survey (USGS). No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the model and related material nor shall the fact of release constitute any such warranty. The model is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the model.*

To provide a direct comparison between the results of the SVIHM and SVOM, the SVIHM was slightly modified. As delivered by the USGS, the SVIHM utilizes monthly stress periods, each consisting of two timesteps[1]. The SVOM utilizes monthly stress periods, each consisting of either five or six timesteps, depending on the length of the month (five timesteps for each February, six timesteps for all other months). For this study, the SVIHM was modified to follow the same timestep configuration as the SVOM (i.e., five to six timesteps per stress period); this allows for an understanding of how well the model simulates streamflow over the timestep length used in the SVOM for analyzing the effect of operational changes.

During the preparation of this report, the USGS released updated versions of the SVIHM and SVOM (both on September 15th, 2023). Results from model runs using the updated (September 15th, 2023) model versions are indicated as such. The previous versions (July 24th, 2023 for the SVIHM and August 4th, 2023 for the SVOM) were used to develop most of the model results documented in this report.

DATA

Observed mean daily streamflow values from the USGS' stream gauge network were relied upon in preparing this document. The locations of these gauges are shown on Figure A1 and listed in Table A2, along with the period over which each gauge was active during the period simulated by the SVIHM (i.e., October 1967 to September 2018).

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[1] The stress period is the basic unit of time discretization in a MODFLOW model and represents a period of the model during which all stresses on the model (e.g., groundwater pumping) are uniform. Each stress period can be divided into multiple timesteps.

Station Full Name	Station Short Name	Station Number	Start Date	End Date
Nacimiento River below Sapaque Creek near Bryson CA	Sapaque	11148900	9/16/1971	9/30/2018
Salinas River at Soledad CA[a]	Soledad	11151700	10/1/1968 10/1/1983	9/29/1978 9/30/2018
Arroyo Seco near Soledad CA	AS Soledad	11152000	10/1/1967	9/30/2018
Arroyo Seco below Reliz Creek near Soledad CA	AS Reliz	11152050	11/1/1994	9/30/2018
Salinas River near Chualar CA	Chualar	11152300	10/1/1976	9/30/2018
Salinas River near Spreckels CA	Spreckels	11152500	10/1/1967	9/30/2018

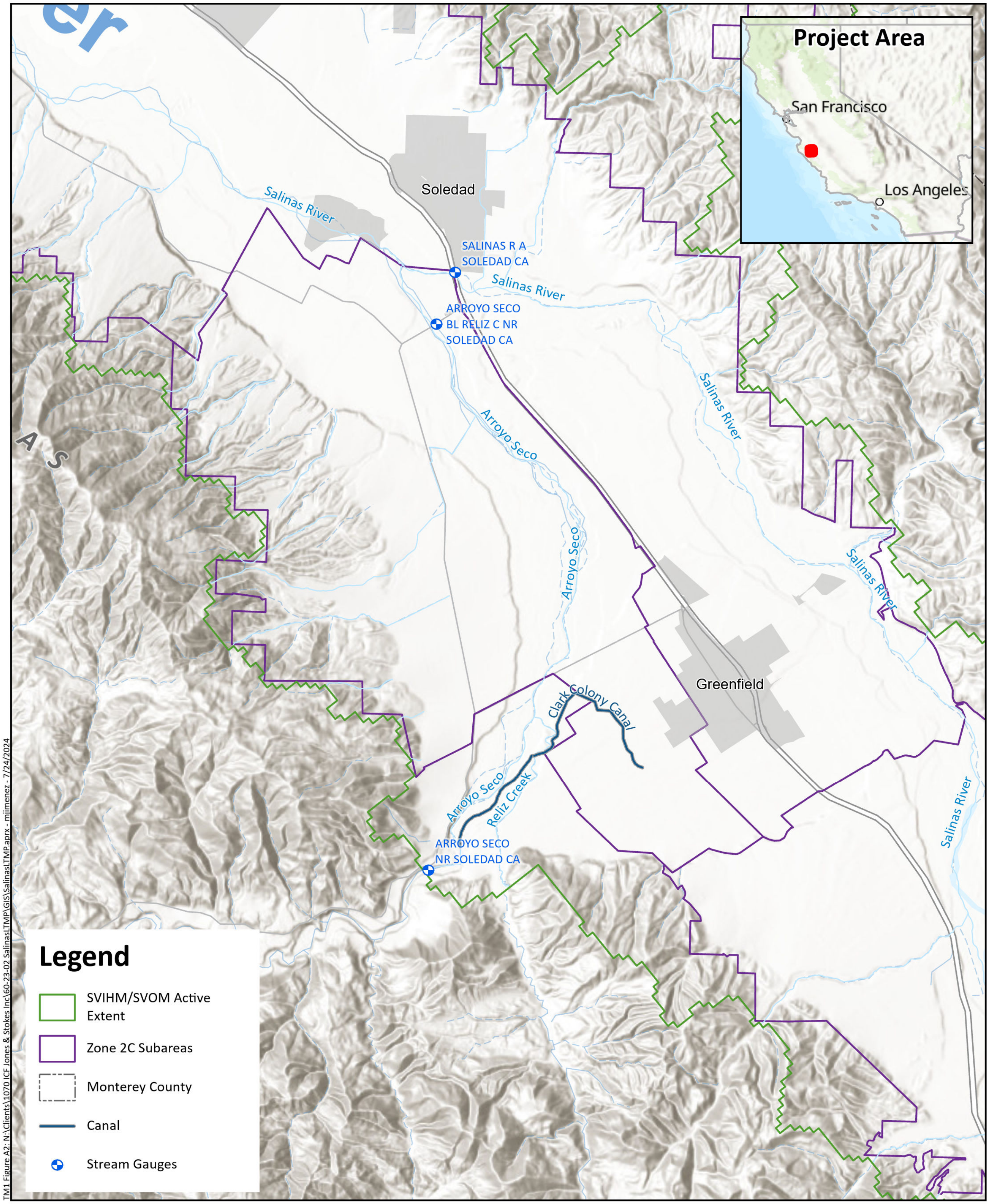
Table A2. Stream Gauges Data for Analysis(a)

(a) Note that the Soledad gauge has a gap in its record from 9/30/1978 to 9/30/1983

Throughout this document, unless otherwise stated, observed streamflow data are presented as timestep-average values using the timestep configuration of the SVOM.

SYNTHETIC TIME SERIES FOR AS RELIZ

As shown in Table A1, the AS Reliz gauge did not start operating until late 1994. To attempt to build a more useful dataset for this analysis, streamflows at the AS Reliz gauge were compared to those at the AS Soledad gauge, further upstream along Arroyo Seco (Figure A2). Figure A3 shows a scatterplot of timestep-average observed streamflow at the AS Soledad (x-axis) and AS Reliz (y-axis) gauges for the period from 11/1/1994 to 9/30/2018, along with a linear regression through the data (equation: $S_{Reliz} = 0.9925S_{Soledad} - 50.073$; regression coefficient: 0.9498). Although the regression coefficient indicates an excellent match between the two datasets, this simple relationship ignores known inflows to and outflows from Arroyo Seco that occur between the two gauges.



TM1 Figure A2: N:\Clients\1070 ICF Jones & Stokes Inc\60-23-02 SalinasLTMP\GIS\SalinasLTMP.aprx - mjimenez - 7/24/2024

Prepared by:

WEST YOST

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0 1 2 Miles

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Prepared for:
ICF Jones & Stokes
Salinas River HCP
TM1:Comparison
Point Scenarios
July 2024

TM1: Comparison Point Scenarios
Map of Arroyo Seco Area

Figure A2
DRAFT

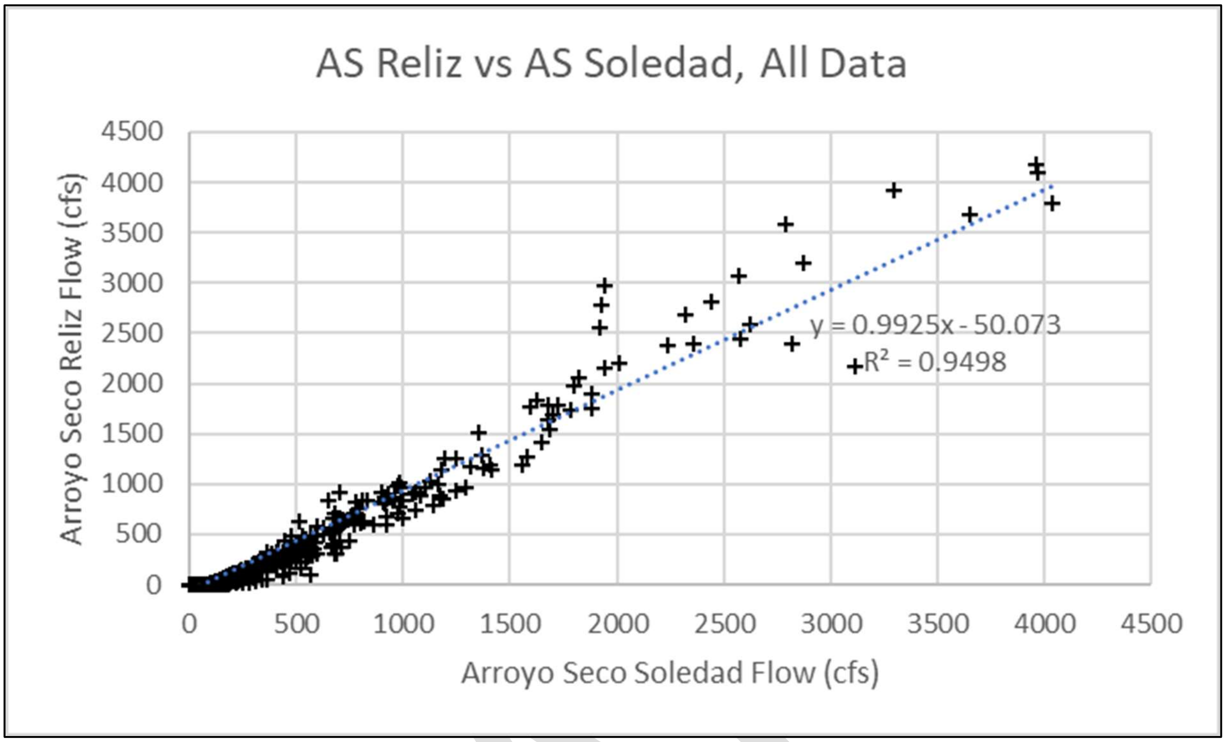

Figure A3: Timestep-average observed streamflow data (in cfs) at the AS Soledad (x-axis) and AS Reliz (y-axis) gauges without any modification

The Clark Colony Canal diverts water from Arroyo Seco just downstream of the AS Soledad gauge location, delivering that water to growers in the Clark Colony area (Figure A2). Reliz Creek provides ephemeral tributary flow to Arroyo Seco above the AS Reliz gauge. Diversions into the Clark Colony Canal and inflows to Reliz Creek are provided as input time series to the SVIHM, with each available as monthly average flows. The timestep-average observed streamflow values at AS Soledad were modified by removing the amount of the Clark Colony diversion and adding the inflow that occurs to Reliz Creek at the edge of the SVIHM (note that this ignores groundwater losses along Reliz Creek for simplicity). Figure A4 shows a scatterplot of the AS Reliz streamflow data plotted against the modified AS Soledad streamflow data. The linear regression through these data produces a slightly improved fit compared to that of Figure A3 (equation: $S_{Reliz} = 0.9792 S_{Soledad} - 42.947$; regression coefficient: 0.9513).

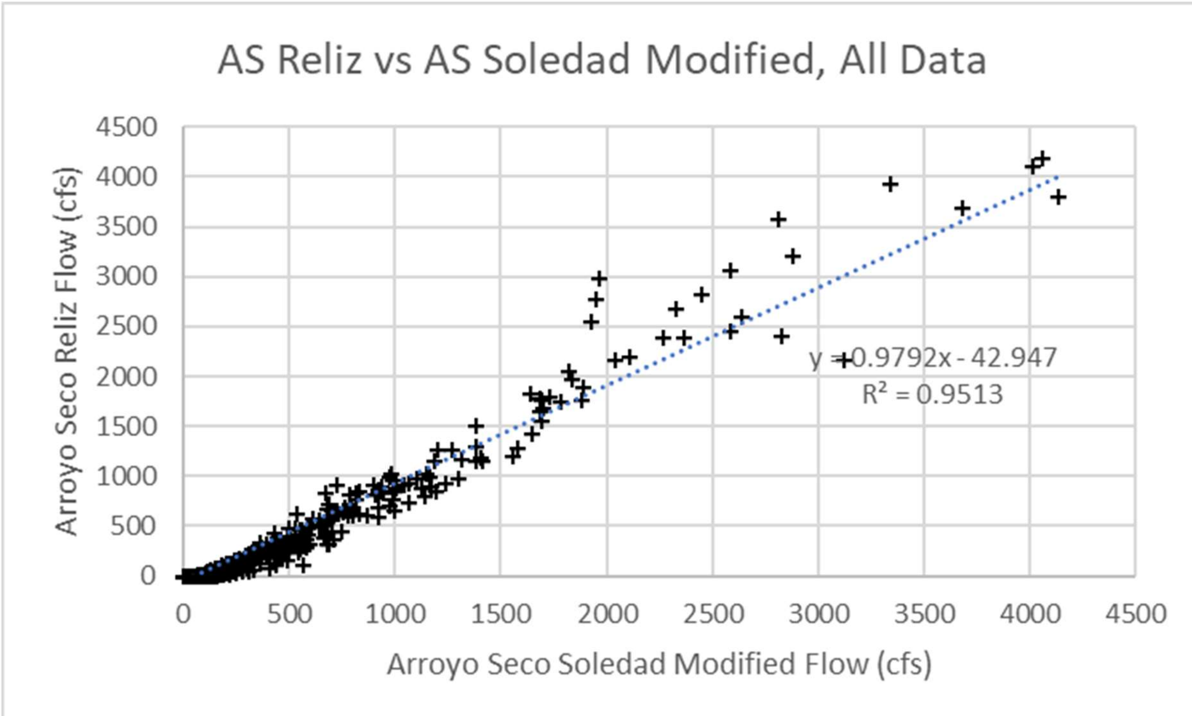

Figure A4: Timestep-average observed streamflow data (in cfs) at the AS Soledad (x-axis) and AS Reliz (y-axis) gauges with AS Soledad data modified to account for Clark Colony diversions and Reliz Creek inflow

Because Arroyo Seco tends to lose water to the groundwater system, there are numerous instances where there is flow at the AS Soledad gauge (accounting for the Clark Colony diversion and Reliz Creek inflow) but no flow at the AS Reliz gauge, which limits the ability for the linear regression shown in Figure A4 to predict flow at the AS Reliz gauge when flow at the AS Soledad gauge is small. A further modification to the data was made to split the streamflow data into two groups: those with $S_{Reliz} = 0$ and those with $S_{Reliz} > 0$.

Figure A5 provides a scatterplot of the timestep-average observed streamflow data from the AS Soledad gauge (x-axis), modified using the Clark Colony Canal diversion and the Reliz Creek inflow, versus the AS Reliz gauge (y-axis), using only the $S_{Reliz} > 0$ data. The linear regression between these datasets has an equation of $S_{Reliz} = 1.0741 S_{Soledad} - 164.71$ and a regression coefficient of 0.9613, a slight improvement compared to Figure A4 and a substantial improvement in fitting lower flows.

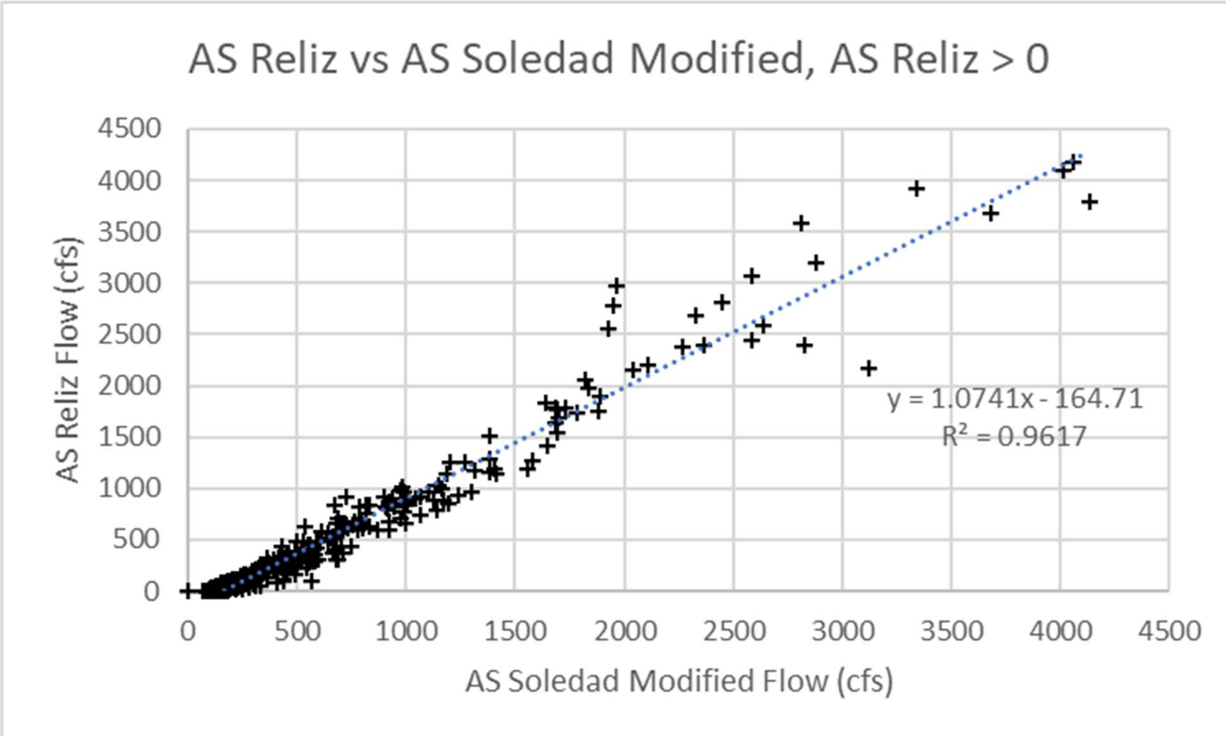

Figure A5: Timestep-average observed streamflow data (in cfs) for the AS Soledad (x-axis) and AS Reliz (y-axis) gauges with AS Soledad data modified to account for Clark Colony diversions and Reliz Creek inflow and all datapoints with no flow at AS Reliz removed

The equation shown in Figure A5 can be used to develop a synthetic dataset for AS Reliz for the period before the AS Reliz gauge began operating (i.e., 10/1/1967 to 10/31/1994). The equation can be expressed as:

$$S_{Reliz} = min\{0\ , 1.0741 S_{Soledad} - 164.71\}$$

The threshold of modified AS Soledad below which streamflow at AS Reliz is predicted to be zero is about 153 cfs. At any AS Soledad modified streamflow below 153 cfs, the synthetic streamflow at AS Reliz is zero.

Figure A6 shows a scatterplot of the timestep-average observed streamflow at AS Reliz (x-axis) against the calculated streamflow at AS Reliz based on the modified streamflow at AS Soledad for the same timestep, including only datapoints with non-zero streamflow at AS Reliz. This figure shows an excellent match between the observed and calculated streamflows for the period when the AS Reliz gauge was operating, validating the equation from Figure A5 as a predictive tool for developing a synthetic time series of streamflow at AS Reliz for the period before November 1994.

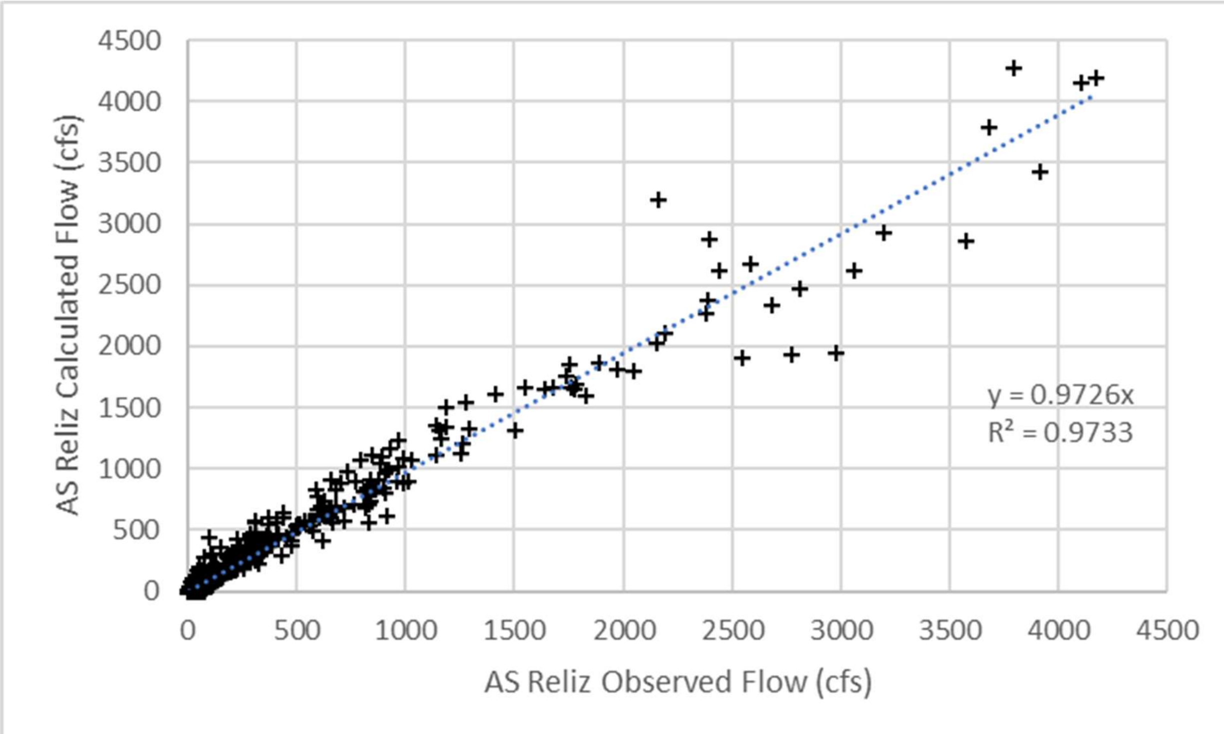

Figure A6. Timestep-average observed streamflow data (in cfs) for the AS Reliz gauge (x-axis) versus the calculated streamflow at AS Reliz based on modified AS Soledad data (y-axis), using only data where observed streamflow at AS Reliz is greater than zero

Throughout the rest of this document, the data at AS Reliz include the calculated streamflows from 10/1/1967 to 10/31/1994, and observed streamflows from 11/1/1994 to 9/30/2018.

SVIHM SIMULATION OF STREAMFLOW

When utilizing the SVOM as a tool for simulating conditions in the Salinas Valley under different operational approaches, it is important to understand how well the SVIHM performs when simulating streamflow (since the SVIHM forms the basis for the SVOM). This is accomplished by comparing observed streamflow at the USGS stream gauges listed in Table A1 against simulated streamflow at the equivalent locations within the SVIHM. For this purpose, the mean daily streamflow values observed at the USGS stream gauges were averaged across the length of each timestep of the SVIHM so that the observed data could be directly compared to simulated streamflows.

Figures A7 through A10 show scatterplots of timestep-average observed (x-axis) versus simulated (y-axis) streamflows at the USGS gauge locations at Soledad (Figure A7), AS Reliz (Figure A8), Chualar (Figure A9), and Spreckels (Figure A10). Each of these figures shows a large degree of scatter with linear regressions that produce regression coefficient between 0.5 and 0.6, indicating a poor fit. This means that the model does not provide a good prediction of timestep-average streamflow at the locations of the USGS gauges. SVIHM-simulated streamflow values are generally too low at the highest observed streamflows and too high at the lowest observed streamflows.

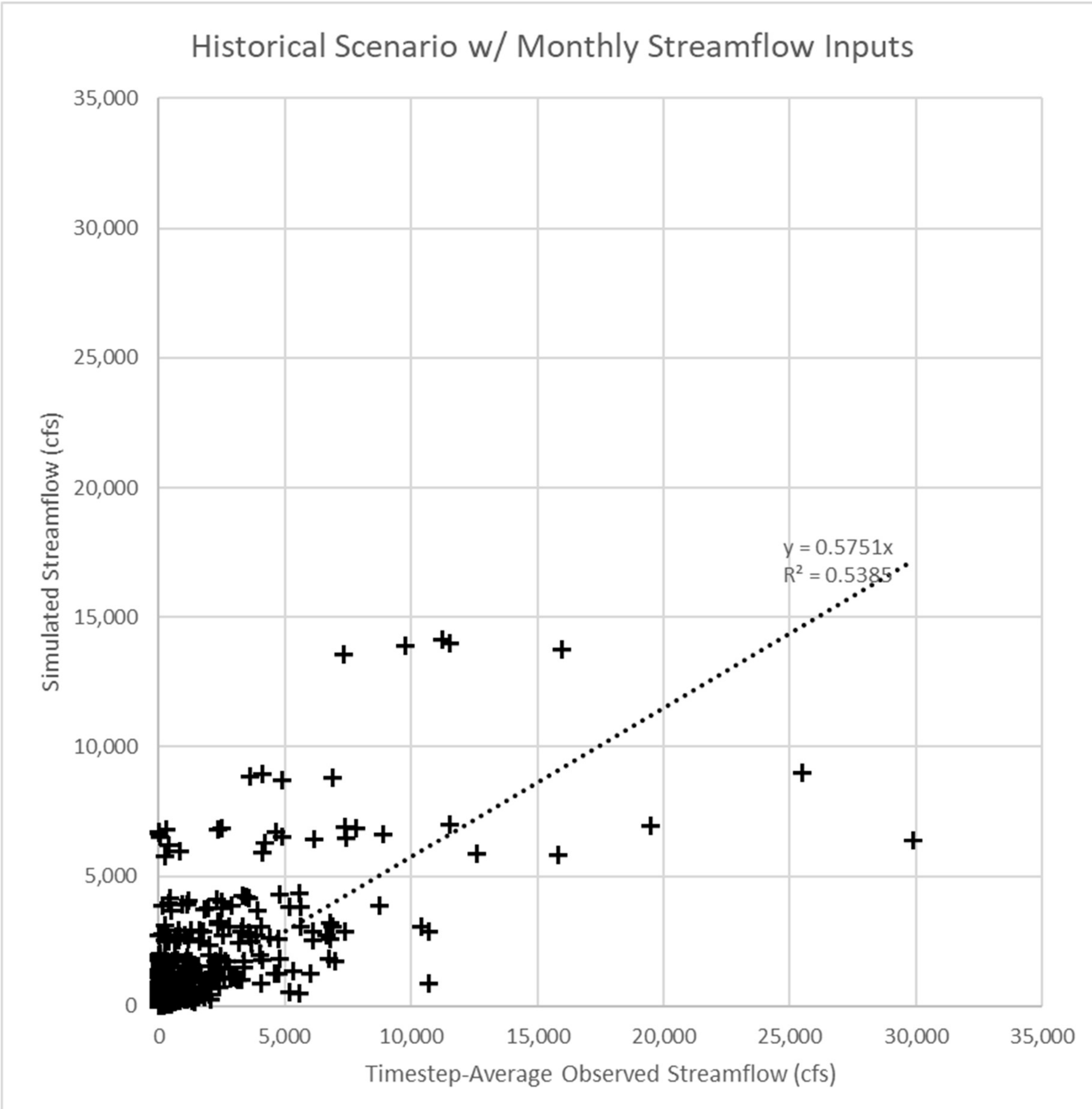

Figure A7. Scatterplot of timestep-average observed streamflow (x-axis) versus simulated streamflow (y-axis) at Soledad

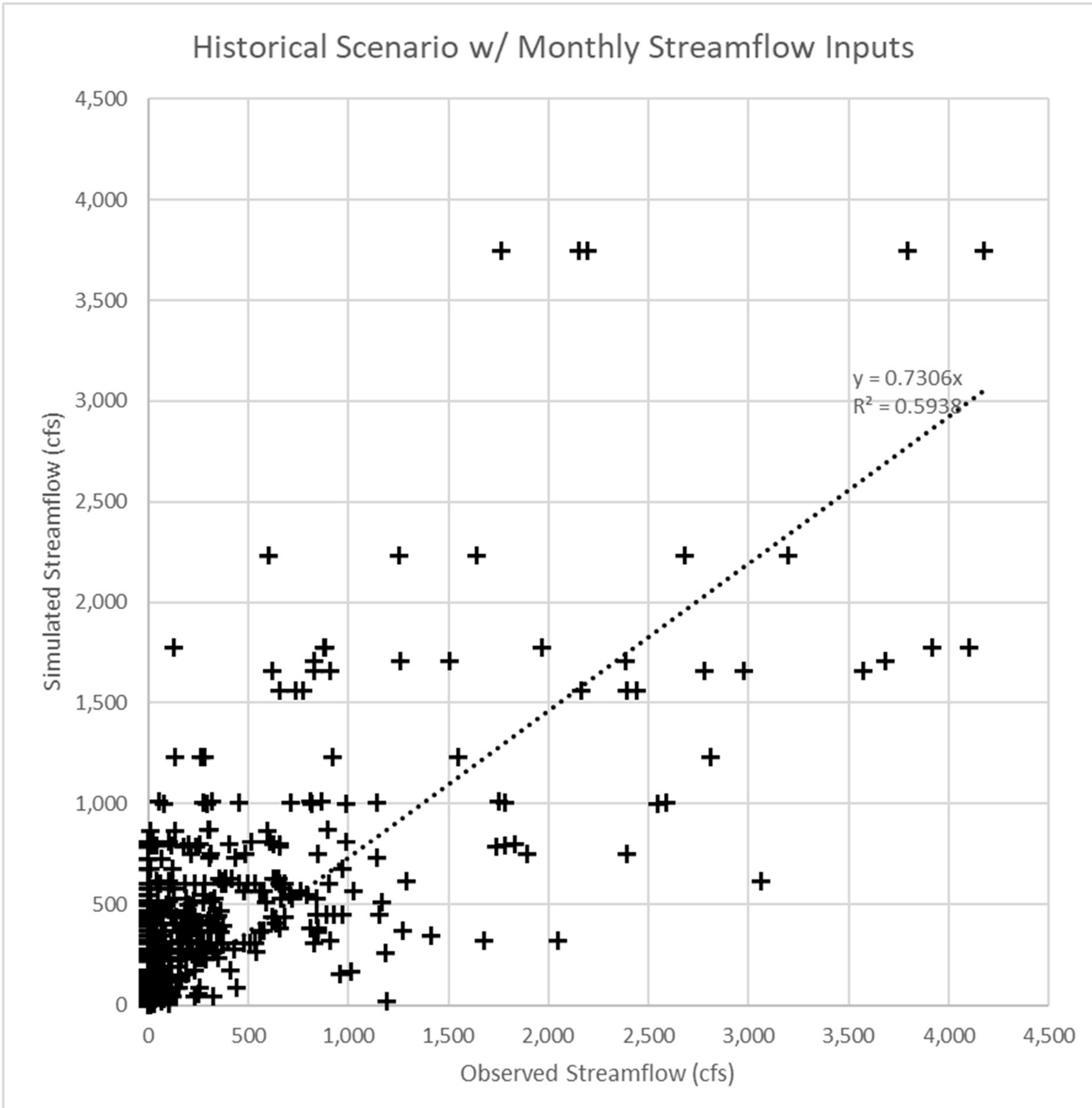

Figure A8. Scatterplot of timestep-average observed streamflow (x-axis) versus simulated streamflow (y-axis) at AS Reliz

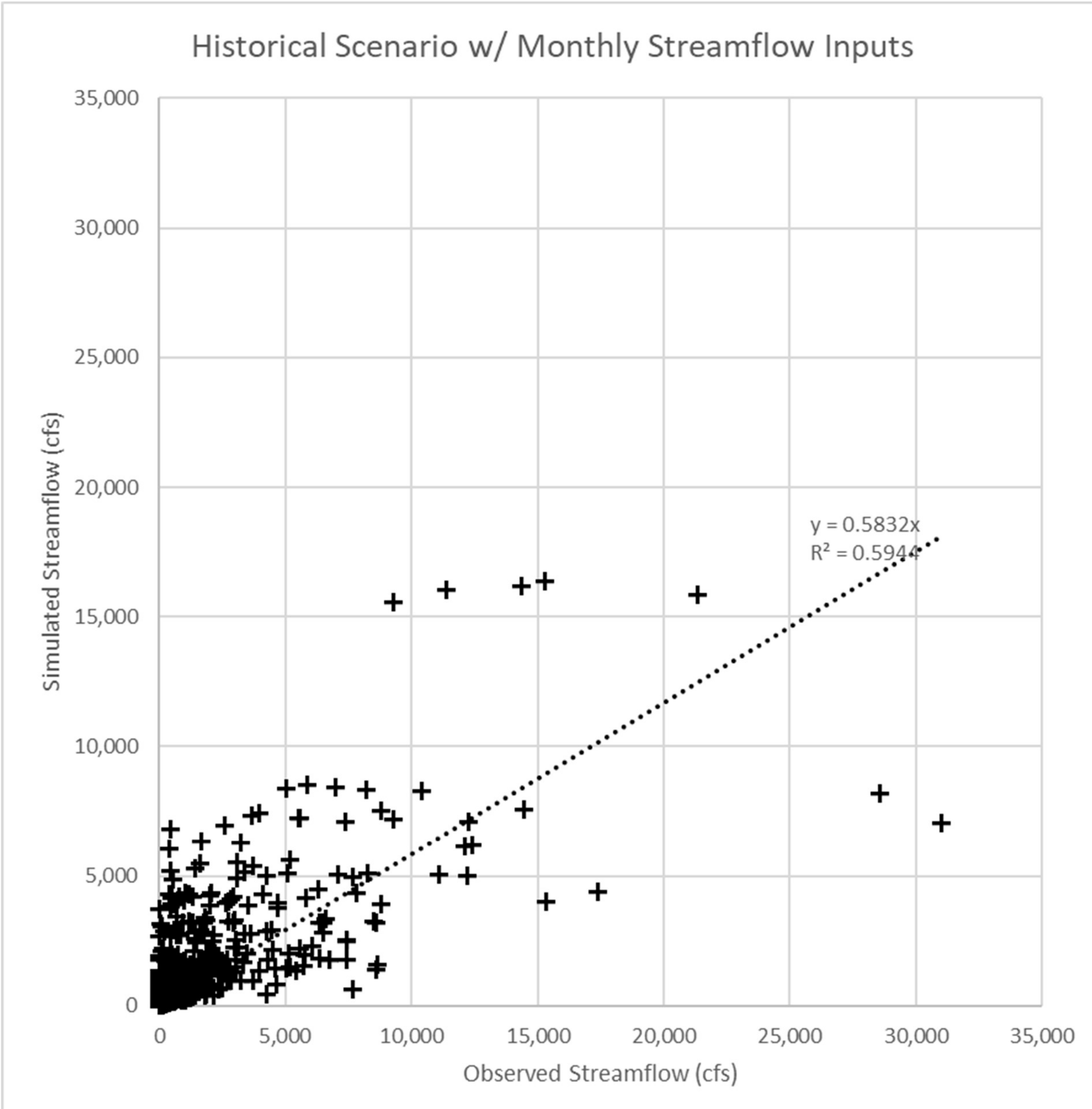

Figure A9. Scatterplot of timestep-average observed streamflow (x-axis) versus simulated streamflow (y-axis) at Chualar

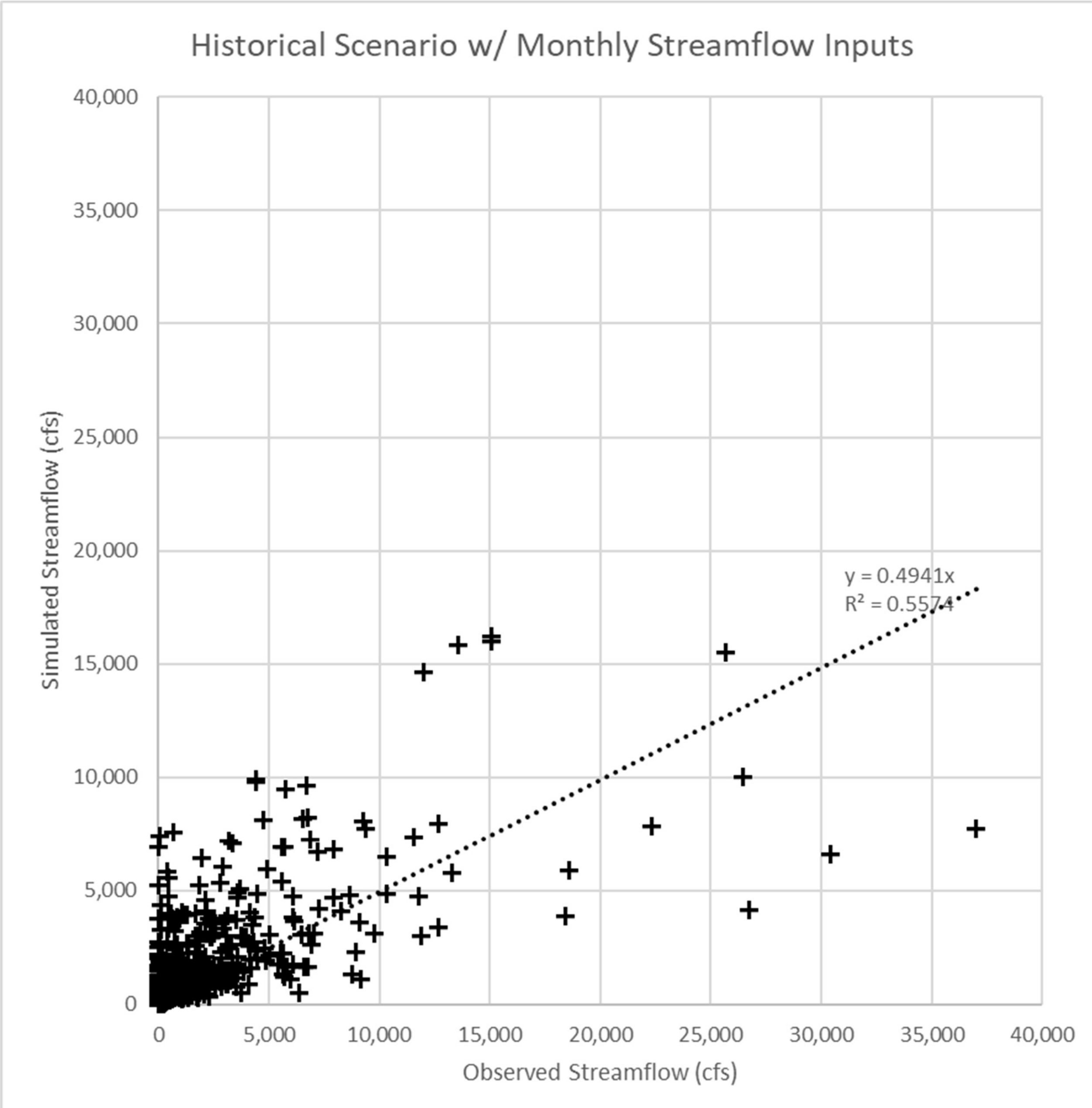

Figure A10. Scatterplot of timestep-average observed streamflow (x-axis) versus simulated streamflow (y-axis) at Spreckels

The HCP focuses on the ability of Steelhead trout to migrate through the Salinas River and its tributaries between spawning grounds and the Pacific Ocean, as indicated by streamflow being above threshold values at specific places and times of year. The thresholds, all below 1,000 cfs, are low compared to the full range of observed streamflow. Therefore, the ability of the SVIHM to accurately re-create streamflow conditions below 1,000 cfs is of greatest importance for this study. For each of the four gauges shown above, the SVIHM generally over-predicts streamflow in this range.

Two of the thresholds most important to assessing fish passage success are the adult upstream migration threshold at Chualar (260 cfs) and the Salinas River Lagoon (Lagoon) opening threshold at Spreckels (80 cfs); the latter is an approximation used by MCWRA for indicating in the SVOM that the Lagoon is open to the ocean, since the opening and closing of the Lagoon are not simulated in the models. The Chualar threshold is used in the determination of the number of Passage Days for adult Steelhead trout, with the conditions for counting Adult Passage Days as follows (MCWRA, 2005):

- at least five consecutive days of mean daily streamflow of at least 260 cfs at Chualar
- during the period from January 1 to March 31
- when the Lagoon is open to the ocean.

The various operational approaches to be simulated using the models for the HCP will be assessed based in part on how well fish passage is supported by each, as measured by metrics such as the number of Adult Passage Days per year. Table A3 provides the annual number of Adult Passage Days and Adult Lagoon Open Days (only counted during the January to March adult migration period) averaged across all years in the model and by water year type (wet, wet-normal, normal, dry-normal, and dry; see MCWRA, 2005, for water year type categorization). Note that the Adult Passage Days based on the observed record are higher compared to the actual number of Adult Passage Days per year because of the timestep averaging; many of the periods during the historical record of fewer than 5 consecutive days of at least 260 cfs at Chualar are counted as Adult Passage Days because the average streamflow over the period equivalent to a model timestep including those days is above 260 cfs. For example, a 5-day timestep during which observed flows were 200, 300, 300, 300, and 200 cfs would not be counted as Adult Passage Days in reality, but the average over that period (260 cfs) would result in these days being included in the count of Adult Passage Days under the timestep averaging used here.

Table A3. Adult Passage Days and Adult Lagoon Open Days

	Adult Passage Days		Adult Lagoon Open Days	
Year Type	Observed (Timestep-Average)	SVIHM	Observed (Timestep-Average)	SVIHM
All	37.2	51.7	43.9	68.1
Wet	75.9	86.9	81.8	90.1
Wet-Normal	60.4	82.3	63.1	90.5
Normal	46.3	73.5	56.8	87.2
Dry-Normal	10.1	38.8	22.6	68.7
Dry	2.5	5.6	6.5	37.2

This table shows that the SVIHM over-estimates the number of Adult Passage Days and Adult Lagoon Open Days for each of the year types, by almost four times in the case of Adult Passage Days in dry-normal years. Overall, the SVIHM estimates about 40 percent more Adult Passage Days and about 55 percent more Adult Lagoon Open Days than were estimated using the timestep-average observed streamflow data.

The remainder of this document describes changes that were made to the model inputs and the post-processing approach to improve the ability of the model to represent observed streamflow conditions in the system, and the effects of those changes.

MODIFIED INFLOW TIME SERIES

The SVIHM and SVOM receive streamflow inputs at the edges of the model representing runoff generated on the watersheds in the uplands outside of the model domain; these inputs are output by the Salinas Valley Watershed Model (SVWM), a rainfall-runoff model of the Salinas River watershed (Hevesi et al., 2019). The streamflow inputs to SVIHM use monthly average streamflows generated by the SVWM. This means that every timestep during a given stress period experiences the same streamflow inputs at the edge of the model (including Salinas River flow entering from the Paso Robles Basin to the south). This means that simulated streamflow within the model domain varies little during a given stress period, however fine the timesteps are.

The SVIHM is capable of accepting streamflow inputs on a timestep basis, as an alternative to monthly average values. The USGS provided the mean daily streamflow output from the SVWM at the Salinas River inflow location (see Figure A1). The Arroyo Seco inflow location is approximately at the location of the AS Soledad gauge, providing a time series of mean daily streamflow input for Arroyo Seco. The existing, monthly-average inflow time series for these two locations were replaced with the mean daily streamflow time series, and the SVIHM was modified to calculate a timestep-average streamflow input from each. This approach does not change the amount of water entering the model, but distributes it in time more realistically.

Figures A11 through A14 show scatterplots of timestep-average observed (x-axis) versus simulated (y-axis) streamflows at the USGS gauge locations at Soledad (Figure A11), AS Reliz (Figure A12), Chualar (Figure A13), and Spreckels (Figure A14). Comparison to Figures A7 through A10 shows the effect of using timestep-average streamflow inputs to the Salinas River and Arroyo Seco rather than monthly average streamflow inputs.

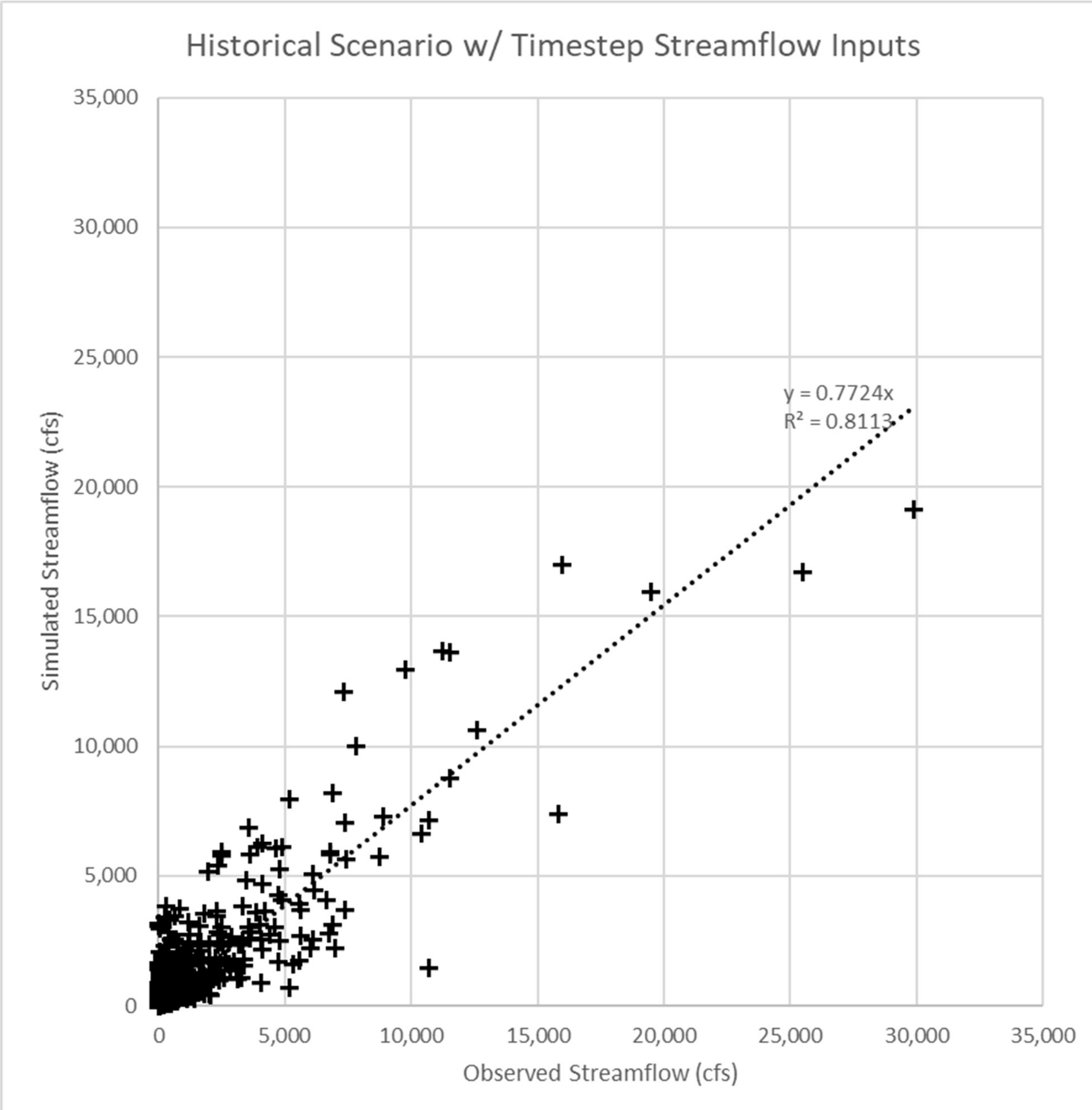

Figure A11. Scatterplot of timestep-average observed streamflow (x-axis) versus simulated streamflow using timestep-average streamflow inputs to the Salinas River and Arroyo Seco (y-axis) at Soledad

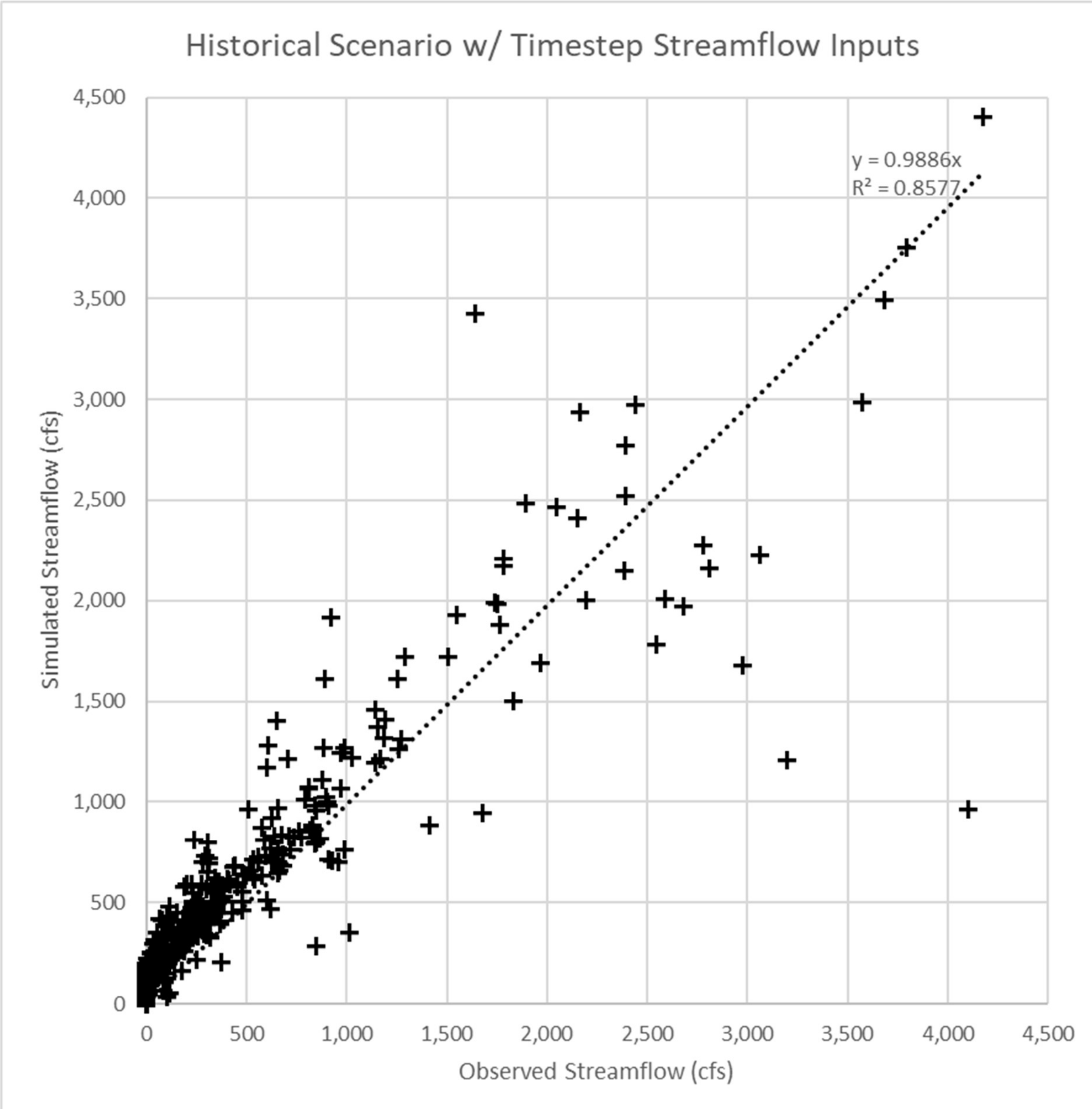

Figure A12. Scatterplot of timestep-average observed streamflow (x-axis) versus simulated streamflow using timestep-average streamflow inputs to the Salinas River and Arroyo Seco (y-axis) at AS Reliz

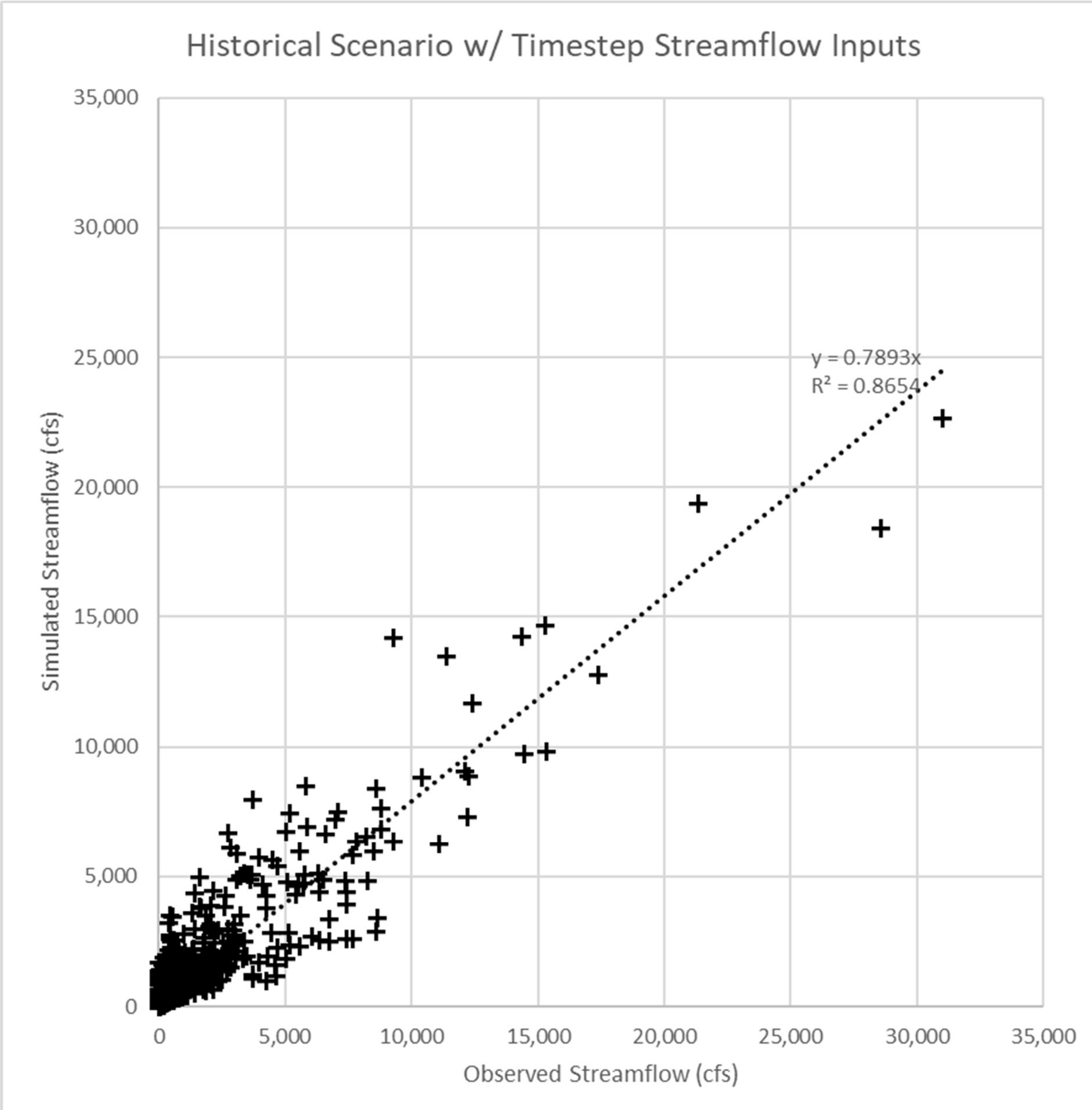

Figure A13. Scatterplot of timestep-average observed streamflow (x-axis) versus simulated streamflow using timestep-average streamflow inputs to the Salinas River and Arroyo Seco (y-axis) at Chualar

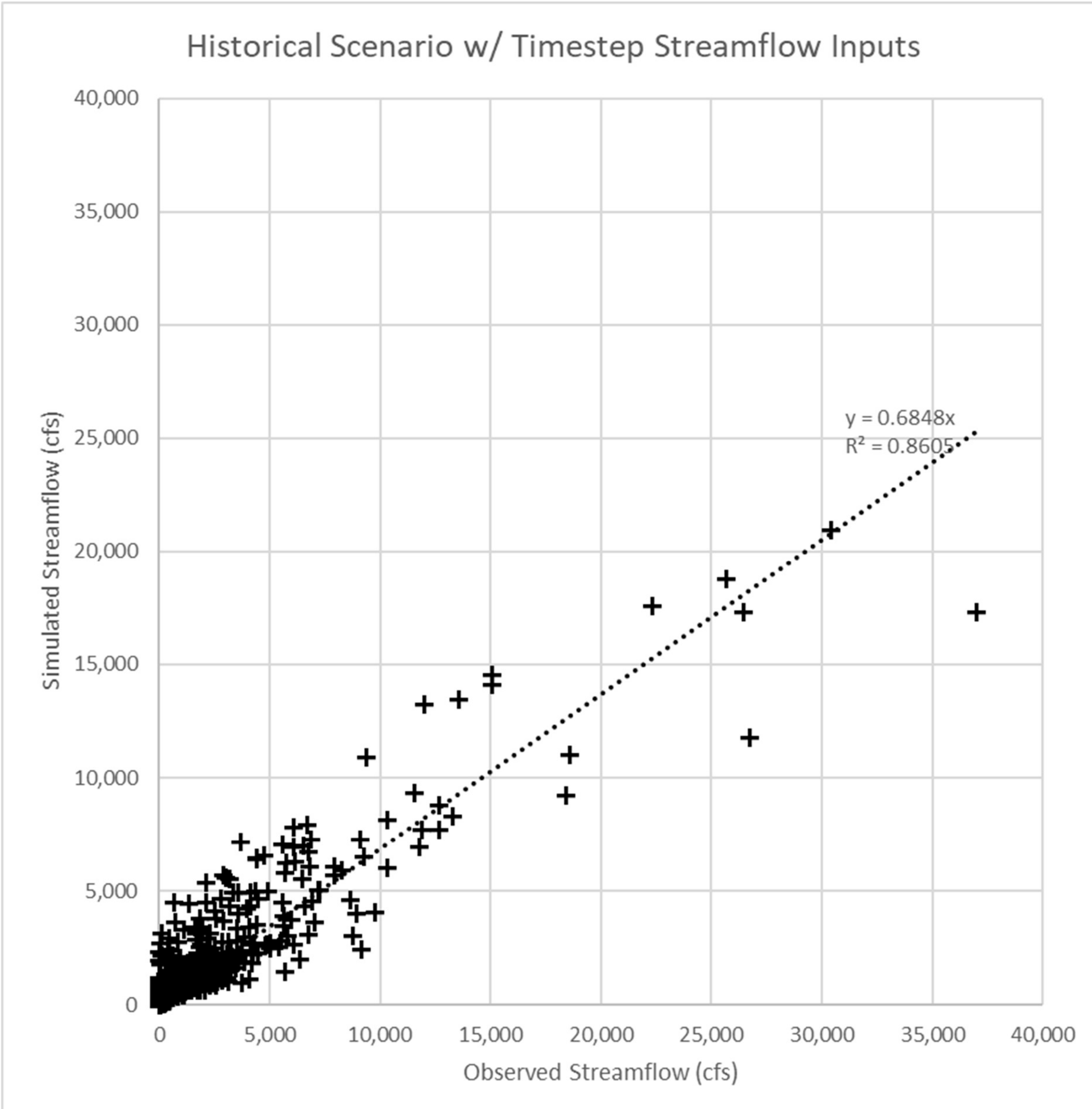

Figure A14. Scatterplot of timestep-average observed streamflow (x-axis) versus simulated streamflow using timestep-average streamflow inputs to the Salinas River and Arroyo Seco (y-axis) at Spreckels

These figures show that utilizing timestep-average inflows to the Salinas River and Arroyo Seco results in a better fit to the timestep-average observed streamflow values at the four USGS gauges discussed above. There remains a large degree of scatter, and the SVIHM still under-estimates relatively high flows while over-estimating relatively low flows, but the regression coefficients for the linear regressions included on the figures are substantially higher (between 0.8 and 0.9).

Table A4 provides the annual number of Adult Passage Days and Adult Lagoon Open Days averaged across all years in the model and by water year type. Compared to the SVIHM with monthly average stream inflows, the SVIHM using timestep-average streamflow inputs to the Salinas River and Arroyo Seco provides an estimate of Adult Passage Days and Adult Lagoon Open Days that is slightly closer to the observed conditions (except for dry year Adult Passage Days). However, Adult Passage Days and Adult Lagoon Open Days remain much higher than is indicated by the observed record.

Table A4. Adult Passage Days and Adult Lagoon Open Days

	Adult Passage Days			Adult Lagoon Open Days		
Year Type	Observed (Timestep-Average)	SVIHM (Monthly Inflow)	SVIHM (Timestep Inflow)	Observed (Timestep-Average)	SVIHM (Monthly Inflow)	SVIHM (Timestep Inflow)
All	37	52	48	44	68	64.5
Wet	76	86	85	82	90	90.1
Wet-Normal	60	91	83	63	91	90.5
Normal	46	70	62	57	87	85.2
Dry-Normal	10	40	29	23	69	56.6
Dry	3	7	8	7	37	34.7

The results presented above indicate that the modifications made to the inflow time series improve the SVIHM simulation of streamflow and fish passage metrics somewhat, but the model still over-estimates streamflow in the range of flows of greatest interest. It is likely that further improvements in model performance in terms of streamflow would require modification of model parameters (e.g., streambed conductance and aquifer parameters) and subsequent recalibration of the model, which is beyond the scope and timeline of the HCP. Instead, the relationship between observed and simulated streamflow was used to scale streamflow thresholds and requirements to result in a realistic frequency of conditions conducive to fish passage in the Salinas River and its tributaries.

STREAMFLOW EXCEEDANCE PROBABILITY

The scatterplots (Figures A11 through A14) showing the relationship between observed and simulated streamflow using the timestep-average streamflow inputs to the SVIHM indicate that the fit between observed and simulated streamflow is not of a high enough quality (as indicated by the large amount of scatter around the linear regression) to allow for a simple scaling of the simulated streamflows to achieve more reliable streamflow estimates. This section presents an alternative approach that was used to develop equivalent simulated streamflow values corresponding to various observed streamflow values using the exceedance probabilities[2] of the observed and simulated streamflow datasets.

Figures A15 through A18 present exceedance probability curves[3] for the same four gauges as were discussed in previous sections. These curves are constructed by ranking all streamflow datapoints in the period of record[4], and calculating the percentage of the data with streamflow above each streamflow value; for example, Figure A15 shows that about 60 percent of both observed and simulated streamflows at Soledad were above 100 cfs. These figures focus on the lower streamflow values most relevant to fish passage, and so do not show the highest observed and simulated streamflows at each gauge. For each figure, the exceedance probability curve for timestep-average observed streamflow reaches the x-axis at a value below 1, while the curves for simulated streamflow all intersect the axis at a value of 1. This occurs because the SVIHM does not typically simulate zero streamflow in the system. These exceedance probability curves were prepared using results from the updated version of the SVIHM (released by the USGS to collaborators on September 15th, 2023) because it is the model version being used to simulate the Comparison Point Scenarios for the HCP.

[2] The exceedance probability for a given datapoint in a dataset is defined as the percentage of values in the dataset larger than the value of the datapoint.

[3] It should be noted that these curves do not show exceedance probability in a statistical sense because they only represent the actual (observed or simulated) datapoints, not a statistical representation of the system.

[4] Note that the exceedance probability curves for simulated streamflow include the entire model duration (i.e., 10/1/1967 to 9/30/2018) even if the stream gauge did not operate throughout the entirety of that period. A visual comparison of the simulated streamflow exceedance probability curves for the entire period and just the period when the observations were collected revealed no substantial difference, so the curves for the entire period were utilized because they provide more resolution.

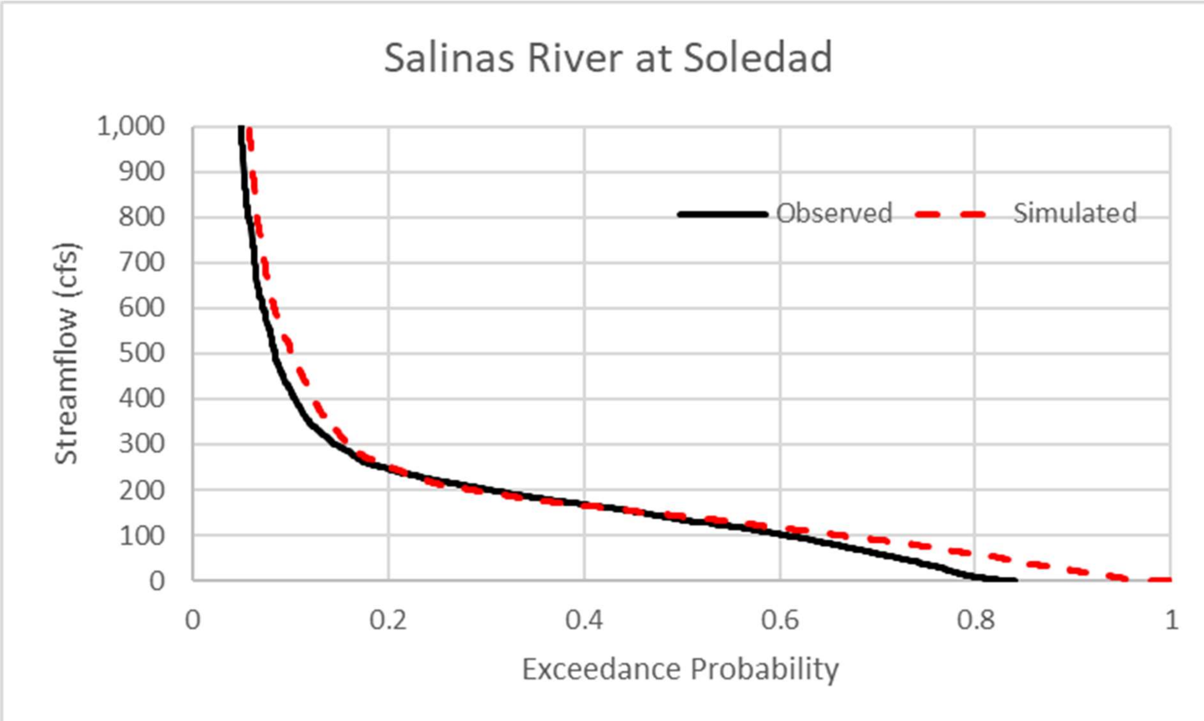

Figure A15. Exceedance probability curve at Soledad for timestep-average observed streamflow and simulated streamflow using timestep inflows

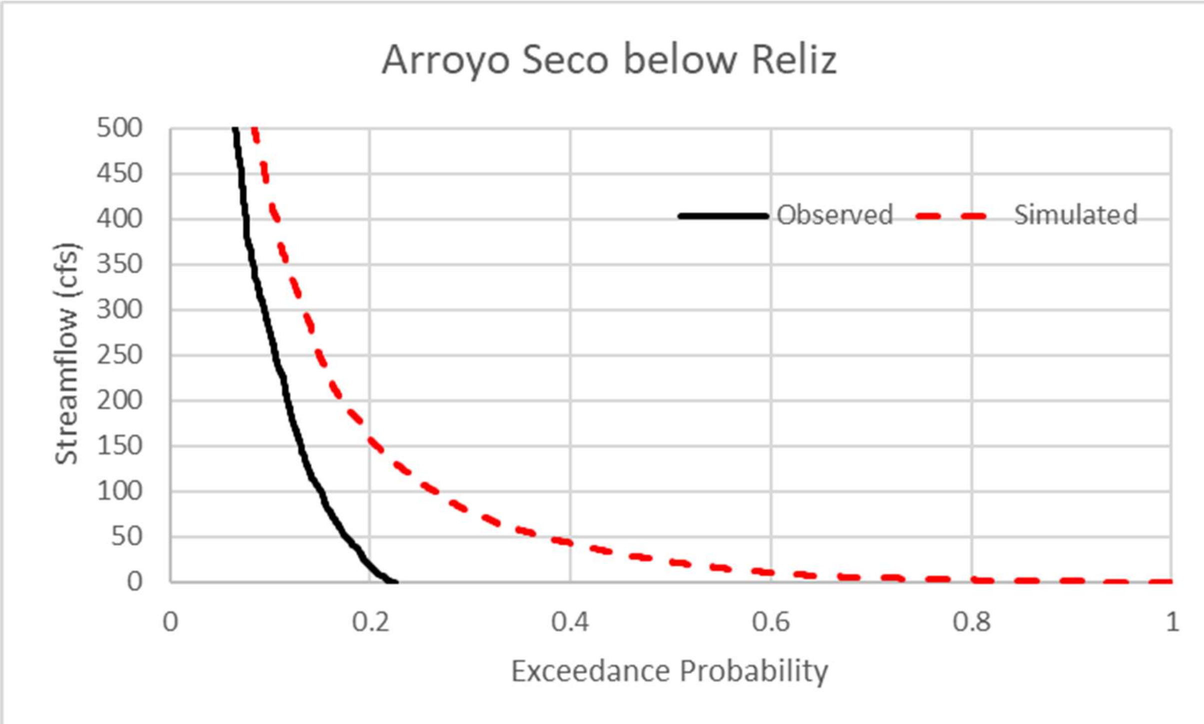

Figure A16. Exceedance probability curve at AS Reliz for timestep-average observed streamflow and simulated streamflow using timestep inflows

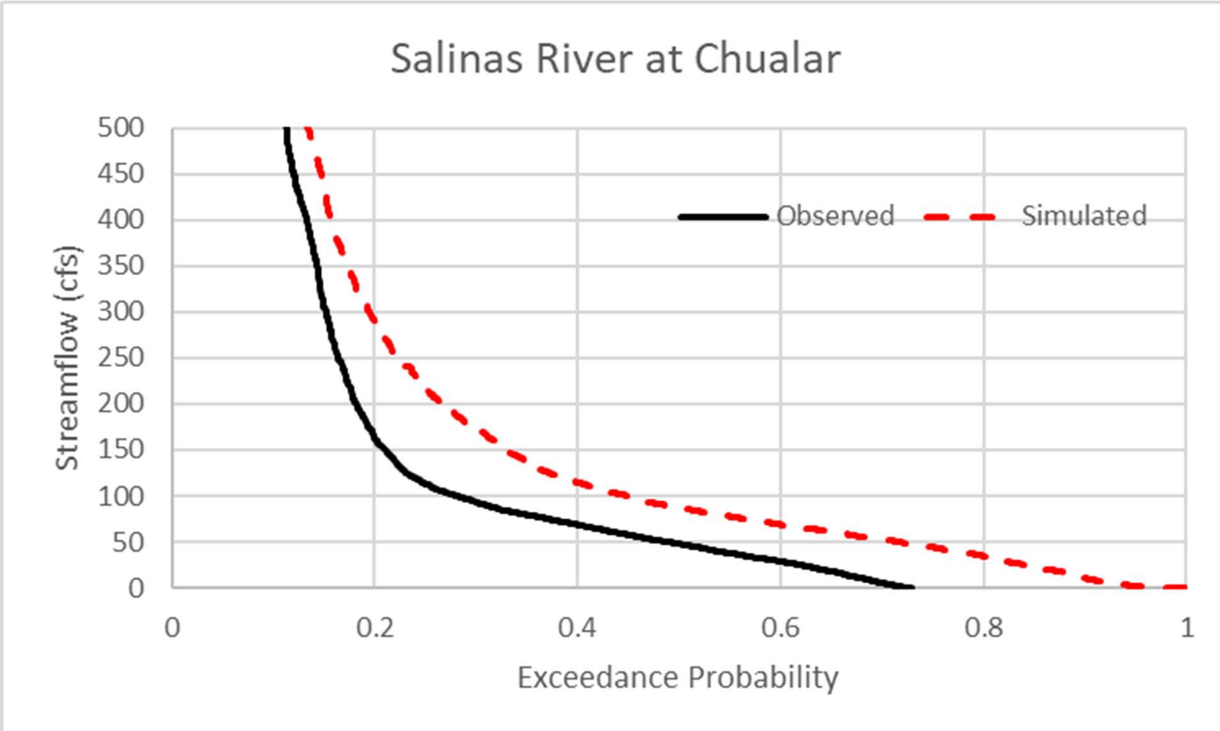

Figure A17. Exceedance probability curve at Chualar for timestep-average observed streamflow and simulated streamflow using timestep inflows

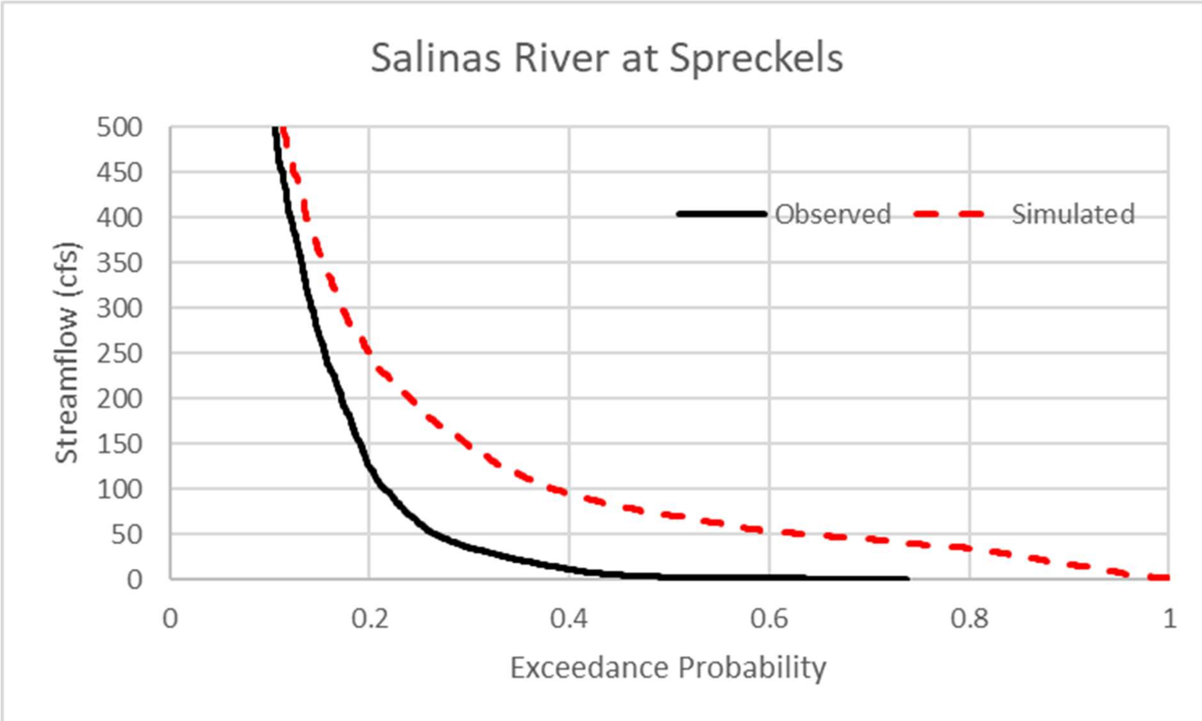

Figure A18. Exceedance probability curve at Spreckels for timestep-average observed streamflow and simulated streamflow using timestep inflows

The exceedance probability curves can be used to identify simulated streamflow values that occur with the same frequency as observed streamflows of interest. As an example, Figure A19 shows that, at Spreckels, the Lagoon opening threshold of 80 cfs is exceeded about 23 percent of the time; the simulated streamflow at Spreckels that is exceeded the same percentage of the time is 208 cfs. If the relationship between observed and simulated streamflow (in terms of the exceedance probability curves) is insensitive to time (i.e., the curves constructed for a given month are identical to those for all data), then a simulated streamflow of 208 cfs could be used in the model and in post-processing to indicate that the Lagoon is open.

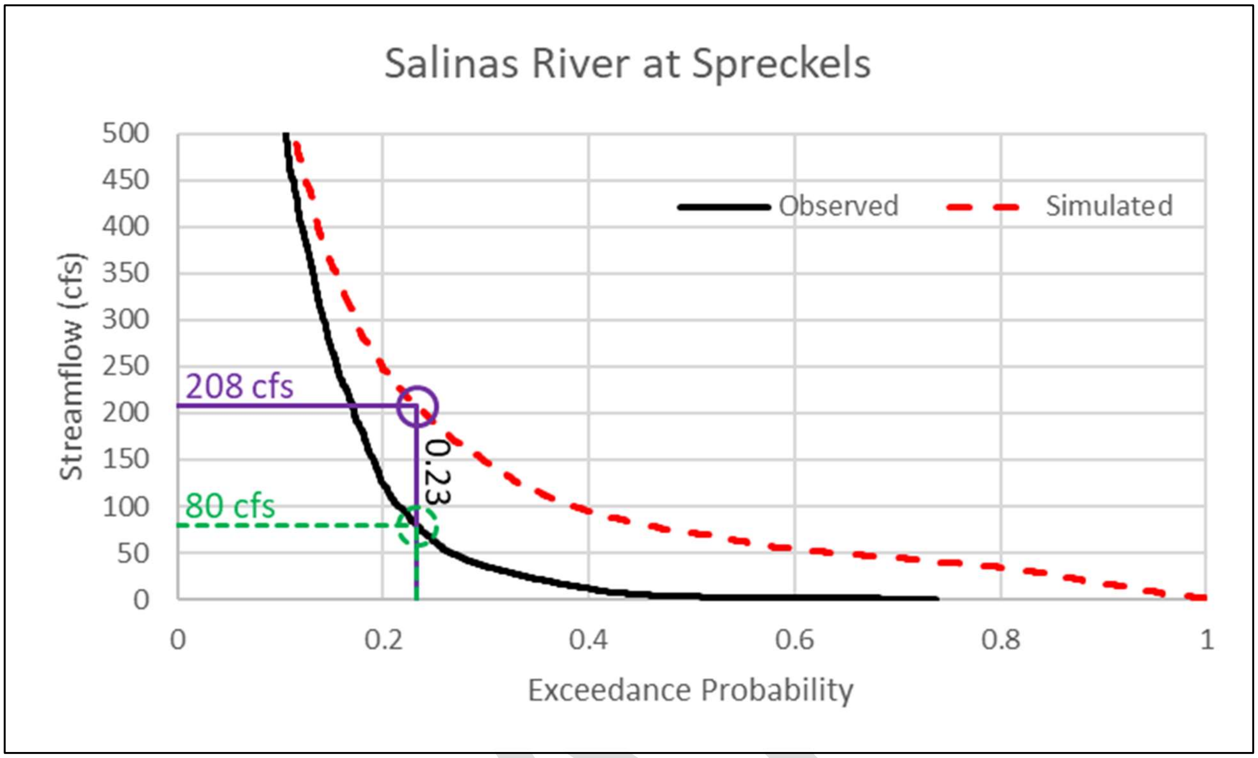

Figure A19. Exceedance probability curves at Spreckels, showing derivation of equivalent simulated streamflow value for the Lagoon opening threshold of 80 cfs

Table A5 provides the simulated streamflow equivalent to each of the requirements and thresholds listed in Table A1. The equivalent streamflows were determined using the exceedance probability curves presented above, as well as monthly exceedance probability curves (not shown herein). For certain requirements (e.g., the 260 cfs adult upmigration threshold at Chualar) the monthly equivalent simulated streamflows change drastically during the period of interest. For others (e.g., the 45 cfs and 15 cfs juvenile outmigration requirements at the Salinas River Lagoon), there is little variation from month to month. Like Figures A15 through A19, Table A5 was prepared using results from an updated version of the SVIHM (released by the USGS to collaborators on September 15th, 2023).

Table A1: Equivalent streamflow values for each streamflow requirement or threshold

Location	Streamflow Value	Supported Activity	Date Range	Equivalent Simulated Streamflow
Salinas River at Chualar	260 cfs	Adult Upmigration (Jan 1 to Mar 31)	All	388 cfs
			Season	438 cfs
			January	634 cfs
			February	432 cfs
			March	334 cfs
Arroyo Seco below Reliz Creek	173 cfs	Adult Upmigration (Jan 1 to Mar 31)	All	331 cfs
			Season	325 cfs
			February	337 cfs
			March	318 cfs
Salinas River at Spreckels	80 cfs	Adult Upmigration (Jan 1 to Mar 31)	All	208 cfs
			Season	272 cfs
			January	313 cfs
			February	272 cfs
			March	223 cfs
Salinas River at Soledad	700 cfs	Smolt Outmigration	All	736 cfs
			Season	465 cfs
			March	470 cfs
			April	411 cfs
			May	506 cfs
			June	N/A[a]
Salinas River at Spreckels	300 cfs	Smolt Outmigration	All	386 cfs
			Season	284 cfs
			March	350 cfs
			April	271 cfs
			May	278 cfs
			June	328 cfs
Arroyo Seco below Reliz Creek	1 cfs	Smolt Outmigration	All	138 cfs
			Season	122 cfs
			March	135 cfs
			April	121 cfs
			May	123 cfs
			June	112 cfs
Arroyo Seco below Reliz Creek	70 cfs	Smolt Outmigration	All	215 cfs

Table A1: Equivalent streamflow values for each streamflow requirement or threshold				
Location	Streamflow Value	Supported Activity	Date Range	Equivalent Simulated Streamflow
			Season	198 cfs
			April	193 cfs
			May	205 cfs
Salinas River Lagoon[(b)]	45 cfs	Juvenile Outmigration	All	166 cfs
			Season	151 cfs
			April	134 cfs
			May	142 cfs
			June	165 cfs
Salinas River Lagoon[(b)]	15 cfs	Juvenile Outmigration	All	101 cfs
			Season	100 cfs
			April	85 cfs
			May	98 cfs
			June	109 cfs
Salinas River at Spreckels	80 cfs	Juvenile Outmigration	All	208 cfs
			Season	174 cfs
			April	172 cfs
			May	176 cfs
			June	173 cfs
Salinas River Diversion Facility[(b)]	36 cfs	SRDF Operation	All	150 cfs
			Season	118 cfs
			April	122 cfs
			May	132 cfs
			June	160 cfs
			July	137 cfs
			August	134 cfs
			September	95 cfs
			October	75 cfs
Salinas River Lagoon[(b)]	2 cfs	SRDF Operation	All	58 cfs
			Season	52 cfs
			April	42 cfs
			May	54 cfs
			June	66 cfs
			July	70 cfs

Table A1: Equivalent streamflow values for each streamflow requirement or threshold

Location	Streamflow Value	Supported Activity	Date Range	Equivalent Simulated Streamflow
			August	61 cfs
			September	47 cfs
			October	37 cfs

(a) A 700 cfs streamflow was not observed in the Salinas River at Soledad during any June from 1968 to 2018

(b) Simulated streamflow at the SRDF and the head of the Salinas River Lagoon is almost identical to streamflow at Spreckels; observed and simulated streamflow at Spreckels are used to develop these equivalent streamflows

These equivalent streamflow values are used as *scaled thresholds* and *scaled requirements* in the model to produce simulated streamflow conditions that are more representative of observed conditions in the system. For example, the use of a scaled value of the Lagoon Opening threshold (80 cfs in the Salinas River at Spreckels) could be expected to result in a simulated number of days per year with the Lagoon open that matches reasonably well with the number of days calculated based on observed data.

METRICS FOR ASSESSING MODEL PERFORMANCE

The goal of the streamflow modification detailed in this document is to improve the ability of the SVOM to provide informative results that indicate the effect that changes to the operational approach have on conditions in the Salinas River and its tributaries. The SVOM is built from the SVIHM, and its reliability as a tool for understanding the effects of operational changes rests on the ability of the SVIHM to simulate the historical conditions in the Basin, particularly related to the ability of Steelhead to move through the system. This section presents a selection of metrics that can be used to assess the SVIHM and SVOM.

Adult Upmigration

The Flow Prescription (MCWRA, 2005) states that adult Steelhead can migrate up the Salinas River from January 1st to March 31st each year. The stream conditions that allow for this upmigration include the Lagoon being open to the Pacific Ocean and sufficient flow in the Salinas River to allow the Steelhead to physically move through the stream network.

- Adult upmigration is assessed by calculating the number of Adult Passage Days each year, where each of the following is true:
- Date is between January 1st and March 31st
- Mean daily streamflow in the Salinas River at Chualar is at least 260 cfs for at least 5 consecutive days
- Salinas River Lagoon is open to the Pacific Ocean

To further assess the ability of the SVIHM to capture the behavior of the system during the adult upmigration period, this report also provides a quantification of the number of days each year when the Lagoon is open during this period (i.e., Adult Lagoon Open Days).

Smolt Outmigration

MCWRA can make releases from the reservoirs to achieve sufficient flow in the Salinas River to support the outmigration of Steelhead in the smolt stage of their life cycle (MCWRA, 2005), termed an engineered block flow. A block flow can be made if the following conditions (i.e., triggers) occur:

- Combined reservoir storage is at least 150,000 acre-feet (af) on March 15th
- The year type is determined to be dry-normal, normal, or wet-normal on either March 15th or April 1st
- Natural (unregulated) flow triggers are met (mean daily streamflow of at least 125 cfs at the Nacimiento River below Sapaque Creek gauge or at least 70 cfs at the Arroyo Seco below Reliz Creek gauge)

Once these triggers are met, the engineered block flow begins with a 700 cfs flow requirement in the Salinas River at Soledad for five days followed by a 300 cfs flow requirement in the Salians River at Spreckels for 15 days or until April 20th, whichever is longer.

Subsequent to the block flow, MCWRA can make additional releases to support smolt outmigration by keeping the Salinas River Lagoon open for as long as Arroyo Seco remains connected to the Salinas River (as indicated by mean daily streamflow at the Arroyo Seco below Reliz Creek gauge of at least 1 cfs) and for 10 days after the connection ceases.

MCWRA considers conditions to support smolt outmigration if the following conditions are met:

- Date is between March 15th and June 20th
- Streamflow in the Salinas River at Spreckels is at least 150 cfs
- The Salinas River Lagoon is open to the Pacific Ocean

For assessment of model performance, this document tracks the percentage of normal years with smolt block flow triggers met and the average number of days each year meeting the smolt outmigration conditions (i.e., Outmigration Passage Days) during the smolt outmigration period (March 15th to June 20th).

Kelt and Juvenile Outmigration

Outmigration of Steelhead in the kelt and juvenile stages can occur in conjunction with and/or following smolt outmigration. How MCWRA supports kelt and juvenile migration depends on whether or not a smolt block flow is occurring (MCWRA, 2005). If a smolt block flow is not ongoing, releases can be made to support kelt outmigration if the following conditions are met:

- Date is between April 1st and June 30th

- Combined reservoir storage is at least 220,000 af
- The Salinas River Lagoon is open to the Pacific Ocean

Releases can be made to support juvenile outmigration if the same criteria are met, except that the Lagoon does not need to be open to the Ocean.

MCWRA considers conditions in the system to support kelt and/or juvenile outmigration if the following conditions are met:

- Date is between April 1st and June 30th
- Streamflow in the Salinas River at Spreckels is at least 150 cfs
- The Salinas River Lagoon is open to the Pacific Ocean

For assessment of model performance, this document tracks the percentage of years with kelt-focused and juvenile-focused release triggers met, the number of days each year these release triggers are met, and the average number of days each year meeting the kelt and juvenile outmigration conditions (i.e., Outmigration Passage Days) during the kelt-juvenile outmigration period (April 1st to June 30th). This document also reports the number of days each year during the kelt-juvenile outmigration period that the Spreckels flow threshold (150 cfs) is met, and the number of days each year that the Lagoon is open.

SRDF Operation

The SRDF diverts water from the Salinas River and delivers it to growers in the CSIP area (Figure A1). For MCWRA to operate the SRDF, combined reservoir storage must be at least 145,000 af, of which at least 55,000 af is held in San Antonio Reservoir, between March 15th and April 30th. SRDF can begin operating on April 1st, and can continue until October 31st. However, the SRDF season can end before October 31st if:

- Streamflow in the Salinas River at Spreckels cannot be maintained at 20 cfs or more after May 1st
- Both reservoirs drop below the minimum allowed storage
- Both reservoirs would exceed water rights restrictions on annual withdrawal if operations continued
- The target minimum conservation release could not be met by the reservoirs

Metrics used to assess the performance of the SRDF in the model include the average annual number of days of SRDF operation, the average annual diversion volume, and the percentage of full (214 days), partial (1 to 213 days), and failed (0 days) SRDF seasons. These metrics are not determined for the SVIHM because the SRDF has been diverting water only since 2010, reservoir storage is not calculated, and reservoir releases are not determined by conditions within the model.

MODEL ASSESSMENT

This section presents the values of the metrics listed above for various datasets, including:

- Observed mean daily streamflow reported by the USGS
- Timestep-average observed mean daily streamflow
- Historical Model results with monthly inflow values for Arroyo Seco and the Salinas River
- Historical Model results with timestep inflow values for Arroyo Seco and the Salinas River
- Historical Model results with timestep inflow values for Arroyo Seco and the Salinas River and scaled streamflow thresholds applied in post-processing
- Updated Historical Model results (15 Sep 2023 version) with timestep inflow values for Arroyo Seco and the Salinas River and scaled streamflow thresholds applied in post-processing
- Operational Model (Current Operations Scenario) results with monthly inflow values for Arroyo Seco and the Salinas River
- Operational Model (Current Operations Scenario) results with timestep inflow values for Arroyo Seco and the Salinas River
- Operational Model (Current Operations Scenario) results with all streamflow thresholds and requirements scaled (Bias Correction Test 1)
- Operational Model (Current Operations Scenario) results with all flow prescription thresholds and requirements scaled (Bias Correction Test 2)
- Updated Operational Model (15 Sep 2023 version; Current Operations Scenario) results with finalized scaling of thresholds and requirements modifications to Juvenile rules

Metrics quantified from these results show how well the models capture the behavior of the integrated groundwater-surface water-reservoir system in the Basin. They are critical for understanding the capability of the operational model to be a predictive tool for simulating potential conditions under alternate operational approaches. As noted previously, values of certain metrics (e.g., days of juvenile flow triggers being met) are presented for the Historical Model but not for the Operational Model, while others (e.g., metrics related to SRDF operation) are presented for the Operational Model but not for the Historical Model.

Further, metrics only available from the Operational Model utilize the April 1st operational year type, which only differentiates between wet, normal, and dry years (i.e., wet-normal and dry-normal years are considered normal). All other metrics use the 5-category year type (wet, wet-normal, normal, dry-normal, and dry) determined at the end of the water year; this is invariant between models because the location where water year type is determined (the Arroyo Seco near Soledad gauge) is at the edge of the model domain, and streamflow there does not change from model to model (and is identical to the historical record).

Tables A6 through A21 provide the values of the metrics described in the previous section, as follows:

- Table A6: Average Annual Adult Passage Days
- Table A7: Average Annual Lagoon Open Days During Adult Migration Period
- Table A8: Percentage of Normal Years with Smolt Block Flow Triggers Met
- Table A9: Average Annual Outmigration Passage Days During Smolt Outmigration Period

- Table A10: Percentage of Non-Dry Years with Kelt Release Triggers Met
- Table A11: Average Annual Days with Kelt Release Triggers Met
- Table A12: Percentage of Non-Dry Years with Juvenile Release Triggers Met
- Table A13: Average Annual Days with Juvenile Triggers Met
- Table A14: Average Annual Outmigration Passage Days During Kelt-Juvenile Outmigration Period
- Table A15: Average Annual Days Above Spreckels Flow Threshold During Kelt-Juvenile Outmigration Period
- Table A16: Average Annual Lagoon Open Days During Kelt-Juvenile Outmigration Period
- Table A17: Average Annual Days of SRDF Operation
- Table A18: Average Annual SRDF Diversion Volume
- Table A19: Percentage of Full SRDF Seasons
- Table A20: Percentage of Partial SRDF Seasons
- Table A21: Percentage of Failed SRDF Seasons

The following subsections present the values of the various metrics for the datasets described above, along with an assessment of model performance for each stage of Steelhead migration or system operation. Ideally, the results of the Historical Model should be very similar to the observed data with timestep averaging. The results of the Current Operations Scenario of the Operational Model are not expected to be very similar to the observed data because the current operational approach (used throughout the Current Operations Scenario) has not been in effect throughout the historical period.

Steelhead migration is expected to be relatively successful during wet years without the aid of releases from the reservoirs, so this assessment focuses more heavily on model performance during dry, dry-normal, and normal years than during wet-normal and wet years.

Adult Upmigration

Tables A6 and A7 provide quantifications of Adult Passage Days and Lagoon Open Days during the adult migration period from January 1st to March 31st. Because these metrics only require the quantification of streamflow, they are presented for the observed data, Historical Model results, and Operational Model results.

Observed mean daily streamflow data from the Salinas River at Spreckels suggest that there have been, on average, about 34 Adult Passage Days per year during the adult migration period (Table A6). For dry to normal years[5], there have been about 11 Adult Passage Days per year. After averaging the observed data

[5] Including dry, dry-normal, and normal years, determined based on the end-of-year average streamflow at the Arroyo Seco near Soledad gauge. For the SVOM, operational decisions may be made based on the preliminary year type determined on March 15th and potentially revised on April 1st.

by model timestep, there have been about 37 Adult Passage Days per year, and about 13 per year for dry to normal years.

The Historical Model, as received from the USGS (i.e., with monthly inflow to Arroyo Seco and the Salinas River), simulates an average of 52 Adult Passage Days per year (41 percent too high compared to the timestep-averaged observed data), and about 28 per year for dry to normal years (115 percent too high), indicating that the Historical Model over-predicts the occurrence of Adult Passage Days. Modifying the model to use timestep-average inflow to Arroyo Seco and the Salinas River slightly improves the prediction of Adult Passage Days, with about 48 per year for all year types (30 percent too high) and about 23 per year for dry to normal years (77 percent too high). Using scaled thresholds to define Adult Passage Days (i.e., 370 cfs instead of 260 cfs at Chualar and 240 cfs instead of 80 cfs at Spreckels) results in an average of 41 Adult Passage Days per year for all years (11 percent too high) and 15 per year for dry to normal years (15 percent too high). The Updated Historical Model, with scaled thresholds, results in an average of 40 Adult Passage Days per year for all years (8 percent too high) and 14 per year for dry to normal years (8 percent too high). This is considered reasonably close to conditions indicated by the observed record.

Operational Model results are not expected to strictly align to the historical data because the operational approach has changed over the historical period, while the Operational Model uses a consistent operational approach over the entire model period. However, Adult Passage Days for the Operational Model results are presented in Table A6.

Table A7 presents the number of days per year that the Lagoon is open during the adult migration period. This is calculated using the threshold used in the model to define Lagoon opening, 80 cfs at Spreckels (or an equivalent scaled value, as specified). The observed mean daily streamflow data indicate that there have been about 43 Lagoon Open Days per year, and about 20 per year for dry to normal years. Using timestep-averaged observed streamflows, that increases to about 44 days per year for all year types and 21 days per year for dry to normal years.

The results of the Historical Model with monthly inflow to the Salinas River and Arroyo Seco indicate that there are about 68 days per year with the Lagoon open (55 percent too high compared to the observed data averaged by model timestep) and about 53 days per year during dry to normal years (152 percent too high). With timestep inflows to the Salinas River and Arroyo Seco, the Historical Model indicates 64 days per year with the Lagoon open (45 percent too high) and about 47 days per year for dry to normal years (124 percent too high). Applying the scaled streamflow requirement to determine whether or not the Lagoon is open (240 cfs instead of 80 cfs at Spreckels) results in about 47 Lagoon Open Days per year (7 percent too high) and about 22 days per year for dry to normal years (5 percent too high). The updated Historical Model, with scaled thresholds, results in about 47 Lagoon Open Days per year (7 percent too high) and about 20 days per year for dry to normal years (5 percent too low).

Table A7 also shows that bias correction brings the number of Lagoon Open Days in the Current Operations Scenario into line with the estimates based on the timestep-averaged observed data.

These results demonstrate that the scaling of thresholds in the Historical Model results in a much-improved match to observed adult Steelhead migration conditions compared to the unscaled Historical Model.

Table A6. Average Annual Adult Passage Days

Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	34	37	52	48	41	40	48	46	41	41	36
Wet	73	76	86	85	80	81	86	84	81	82	78
Wet-Normal	57	60	91	83	73	70	71	70	65	64	56
Normal	40	46	70	62	41	38	60	57	41	46	32
Dry-Normal	8	10	40	29	19	20	38	30	23	22	16
Dry	1	3	7	8	5	5	5	5	3	3	3
Dry to Normal	11	13	28	23	15	14	25	22	16	17	12

Table A7. Average Annual Lagoon Open Days during Adult Migration Period											
Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	43	44	68	64	47	47	66	63	44	45	45
Wet	80	82	90	90	86	86	89	89	82	83	83
Wet-Normal	61	63	91	91	83	83	83	83	68	68	68
Normal	57	57	87	85	61	57	88	86	51	54	54
Dry-Normal	21	23	69	57	26	25	70	63	30	29	29
Dry	5	7	37	35	5	5	27	24	4	4	4
Dry to Normal	20	21	53	47	22	20	50	47	20	21	21

Smolt Outmigration

Table A8 provides a quantification of the percentage of years where smolt block flow triggers are met. Because this only requires the quantification of streamflow, this metric is presented for the observed data, Historical Model results, and Operational Model results. The occurrence of block flow triggers for observed data and Historical Model results both use observed datasets of reservoir storage and streamflow in the Nacimiento River below Sapaque Creek. Smolt block flows only occur during normal type years (as determined on March 15th and April 1st each year).

Based on the observed mean daily streamflow data, the triggers for smolt block flows are met in about 70 percent of normal years. With timestep averaging of the observed streamflows, about 75 percent of normal years saw the smolt block flow triggers met (an increase of one normal year).

The Historical Model with both monthly and timestep-average inflow to the Salinas River and Arroyo Seco results in 90 percent of normal years reaching the triggers for smolt block flows. Scaling the streamflow requirement in Arroyo Seco below Reliz Creek (from 70 cfs to 195 cfs) results in 75 percent of normal years reaching the smolt block flow triggers (for both the previous and updated SVIHM versions), identical to the observed record with timestep averaging. Because Sapaque is outside of the model domain, the requirement there is not scaled.

The Operational Model simulates 78 percent of normal years reaching the smolt block flow triggers for the monthly inflow, timestep inflow, and first bias correction test versions of the model, and 74 percent of normal years for the second bias correction test version. With the updated version of the SVOM, the Operational Model indicates that 76 percent of normal years reach the smolt block flow triggers under the Current Operations Scenario.

Table A9 provides the average annual number of Outmigration Passage Days during the smolt outmigration period (March 15th to June 20th). Based on the observed data, there have been about 25 Outmigration Passage Days during the smolt outmigration period each year, with about 4 days per year during dry to normal years. With timestep averaging, the overall average increases to about 26 Outmigration Passage Days per year during this period, with no change for dry to normal years. With monthly stream inflows, the Historical Model results in about 38 Outmigration Passage Days per year during this period (46 percent too high), with about 12 days per year during dry to normal years (200 percent too high). With timestep average stream inflows, the Historical Model results in about 36 Outmigration Passage Days per year during this period (38 percent too high), with about 9 days per year during dry to normal years (125 percent too high). Scaling the thresholds for determining Outmigration Passage Days (changing the threshold for flow at the Salinas River at Spreckels gauge from 150 to 230 cfs and the threshold for Lagoon opening from 80 to 200 cfs) results in about 27 Outmigration Passage Days per year during this period (4 percent too high) and about 4 days per year during dry to normal years (in line with observations). The Updated Historical Model (which uses a 215 cfs streamflow threshold at the Salinas River at Spreckels gauge and a 180 cfs Lagoon opening threshold) results in about 25 Outmigration Passage Days per year during this period (4 percent too low) and about 4 days per year during dry to normal years.

These results demonstrate that the scaling of thresholds in the Historical Model results in a much-improved match to observed smolt block flow triggering conditions compared to the unscaled Historical Model.

Table A8. Percentage of Normal Years with Smolt Block Flow Triggers Met

	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
Total Number of Normal Years	20	20	20	20	20	20	23	23	23	23	25[6]
Normal Years with Triggers Met	14	15	18	18	15	15	18	19	19	18	19
Percentage of Normal Years with Triggers Met	70	75	90	90	75	75	78	83	83	78	76

[6] The SVOM delivered by the USGS on August 4th, 2023 included some incomplete time series of stream inflow to the model, including the Arroyo Seco. This prevented the correct assignment of operational water year types for the final several model years. These inflow time series were extended for the updated model version, leading to additional water years classified as normal.

Table A9. Average Annual Number of Outmigration Passage Days During Smolt Outmigration Period											
Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	25	26	38	36	27	25	36	37	32	31	29
Wet	64	68	80	80	68	65	67	72	61	61	59
Wet-Normal	28	33	59	57	34	30	48	47	51	51	38
Normal	13	15	34	29	14	10	44	41	29	28	29
Dry-Normal	4	3	17	10	3	3	25	20	24	15	14
Dry	1	1	2	2	2	2	5	6	4	4	4
Dry to Normal	4	4	12	9	4	4	18	17	15	12	12

Kelt and Juvenile Outmigration

Tables A10 through A16 present various metrics related to kelt and juvenile outmigration. The operation of the reservoirs to support kelt and juvenile outmigration is somewhat complicated because of its interaction with the rules related to smolt block flows, so these metrics are only presented for the observed data and Historical Model results. These metrics relate to both the triggering of releases to support kelt and juvenile migration (Tables A10 through A13) and the occurrence of streamflow conditions allowing kelt and juveniles to migrate (Tables A14 through A16). Releases to support kelt and juvenile migration are only made in normal and wet years (as determined on March 15th and April 1st), but it is possible for sufficient streamflow to occur to meet passage conditions in dry years without support from the reservoirs.

Table A10 presents the percentage of non-dry years with the kelt release triggers met. For both the observed (mean daily streamflow) and observed (timestep-average) datasets, 74 percent of non-dry years had the kelt release triggers met. For the Historical Model, both the monthly inflow and timestep inflow versions resulted in 83 percent of non-dry years had the kelt release triggers met. The Historical Model and Updated Historical Model with scaled thresholds had 74 percent of non-dry years see the kelt release triggers met.

Table A11 presents the average annual number of days per year that kelt release triggers are met. Based on observed mean daily streamflow, there have been about 21 days per year during the kelt/juvenile migration period with the kelt release triggers met. With timestep averaging of observed streamflows, this increases to about 23 days per year. The Historical Model with monthly inflows results in about 41 days per year (78 percent too high) with the kelt release triggers met; this increases to about 43 days per year (87 percent too high) with timestep inflows. Applying the scaled threshold for determining whether the Lagoon is open to the ocean, there are about 22 days per year (4 percent too low) with the kelt release triggers met. With the Updated Historical Model, this changes to 23 days per year (same as the observed data).

Table A12 presents the percentage of non-dry years with the juvenile release triggers met. For all of the observed and Historical Model datasets, 94 percent of non-dry years had the juvenile release triggers met. Table A13 presents the average annual number of days per year that juvenile release triggers are met. For all of the observed and Historical Model datasets, there are about 59 days per year with the juvenile release triggers met. The metrics related to juvenile release triggers are identical in the observed and Historical Model datasets because they only depend on conditions (time of year and reservoir storage) that are external to the model.

Table A14 presents the average annual number of Outmigration Passage Days during the kelt and juvenile outmigration period (April 1st to June 30th). Based on the observed data, there have been about 17 Outmigration Passage Days per year during the kelt and juvenile outmigration period, and about 1 per year for dry to normal years. With timestep averaging of streamflow values, this remains about 17 days per year, or about 1 day per year for dry to normal years. The Historical Model with monthly inflows results in about 26 Outmigration Passage Days per year during this period (53 percent too high), with about 5 days per year during dry to normal years (400 percent too high). With timestep inflows, the Historical Model simulates about 25 Outmigration Passage Days per year during this period (47 percent too high), with about 4 days per year during dry to normal years (300 percent too high). Scaling the streamflow thresholds (changing the threshold for flow at the Salinas River at Spreckels gauge from 150 to 230 cfs and the threshold for Lagoon opening from 80 to 200 cfs) results in about 16 Outmigration Passage Days per year during this period (6 percent too low) and less than 1 per year during dry to normal years. The Updated Historical Model (which uses a 215 cfs streamflow threshold at the Salinas River at Spreckels gauge and a 180 cfs Lagoon opening threshold) results in about 15 Outmigration Passage Days per year during this period (12 percent too low) and less than 1 day per year during dry to normal years.

Table A15 presents the average annual number of days with streamflow in the Salinas River at Spreckels above the threshold required to support kelt and juvenile outmigration (i.e., 150 cfs). This table is nearly identical to Table A14 because the Spreckels flow threshold is generally the limiting factor for determining Outmigration Passage Days. Based on the observed data, streamflow is at or above this threshold about 17 days per year during the kelt and juvenile outmigration period, and about 1 day per year during dry to normal years. Timestep averaging of the observed streamflows has no effect on these averages. With monthly inflows, the Historical Model results in about 26 days per year at or above the outmigration flow threshold during this period (53 percent too high) and about 5 days per year during dry to normal years (400 percent too high). With timestep inflows, this reduces to about 25 days per year (47 percent too high), with about 4 days per year during dry to normal years (300 percent too high). Scaling the flow threshold (to 230 cfs) results in about 17 days per year at or above the flow threshold, and about 1 day per year during dry to normal years, both the same as that determined based on the observed data. The Updated Historical Model, with an updated scaled flow threshold of 215 cfs, results in about 15 days per year at or above the flow threshold during this period (about 12 percent too low), and less than 1 day per year during dry to normal years.

Table A16 presents the average annual number of Lagoon Open Days during the kelt and juvenile outmigration period (from April 1st to June 30th). Based on the observed data, there have been about 22 Lagoon Open Days per year during the kelt and juvenile outmigration period, and about 3 days per year during dry to normal years. With timestep averaging of streamflow values, this increases to about 24 Lagoon Open Days per year during this period, and about 5 days per year during dry to normal years. The Historical Model with monthly inflows results in about 45 Lagoon Open Days per year during this period (88 percent too high), and about 18 days per year during dry to normal years (260 percent too high). With timestep inflows, the Historical Model simulates about 45 Lagoon Open Days per year during this period (88 percent too high), and about 16 days per year during dry to normal years (220 percent too high). Scaling the threshold for Lagoon opening (from 80 to 200 cfs at the Salinas River at Spreckels gauge) results in about 22 Lagoon Open Days per year during this period (8 percent too low) and about 3 days per year during dry to normal years (40 percent too low). The Updated Historical Model (with a Lagoon opening threshold of 180 cfs at the Salinas River at Spreckels gauge) results in about 23 Lagoon Open Days per year during this period (4 percent too low) and about 3 days per year during dry to normal years (40 percent too low).

These results demonstrate that the scaling of thresholds in the Historical Model results in a much-improved match to observed kelt and juvenile outmigration conditions compared to the unscaled Historical Model.

Table A10. Percentage of Non-Dry Years with Kelt Release Triggers met

Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
Total Number of Non-Dry Years	35	35	35	35	35	35	35	35	35	35	35
Non-Dry Years with Triggers Met	26	26	29	29	26	26	29	28	27	25	25
Percentage of Non-Dry Years with Triggers Met	74	74	83	83	74	74	83	80	77	71	71

Table A11. Average Annual Number of Days with Kelp Release Triggers Met

Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	21	23	41	43	22	23	42	42	21	20	17
Wet	59	63	87	90	59	61	73	75	44	45	39
Wet-Normal	21	25	75	80	25	30	66	73	35	35	21
Normal	8	12	40	44	10	12	54	57	18	13	13
Dry-Normal	3	4	13	12	1	2	31	20	8	8	6
Dry	0	0	0	0	0	0	6	6	2	2	2
Dry to Normal	2	4	11	12	2	3	22	20	7	5	5

Table A12. Percentage of Non-Dry Years with Juvenile Release Triggers Met											
Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
Total Number of Non-Dry Years	35	35	35	35	35	35	35	35	35	35	35
Non-Dry Years with Triggers Met	33	33	33	33	33	33	29	28	30	28	28
Percentage of Non-Dry Years with Triggers Met	94	94	94	94	94	94	83	80	86	80	80

Table A13. Average Annual Days with Juvenile Triggers met											
Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	59	59	59	59	59	59	50	48	52	48	49
Wet	91	91	91	91	91	91	85	85	85	85	85
Wet-Normal	91	91	91	91	91	91	91	91	91	91	91
Normal	91	91	91	91	91	91	64	61	76	61	61
Dry-Normal	68	68	68	68	68	68	34	23	37	20	25
Dry	0	0	0	0	0	0	6	6	6	6	6
Dry to Normal	36	36	36	36	36	36	25	21	28	21	22

Table A14. Average Annual Outmigration Passage During Kelt-Juvenile Outmigration Period											
Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	17	17	26	25	16	15	22	23	21	20	17
Wet	49	49	61	61	50	46	47	52	42	42	40
Wet-Normal	15	15	39	38	13	11	27	26	32	32	18
Normal	3	3	18	15	1	< 1	23	21	15	13	13
Dry-Normal	3	3	4	3	< 1	< 1	9	8	14	8	6
Dry	< 1	< 1	1	< 1	< 1	< 1	2	3	2	2	2
Dry to Normal	1	1	5	4	< 1	< 1	8	8	8	6	5

Table A15. Average Annual Days Above Spreckels Flow Threshold During Kelt-Juvenile Outmigration Period

Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	17	17	26	25	17	15	22	23	23	21	17
Wet	49	49	61	61	50	46	47	52	45	45	40
Wet-Normal	15	15	39	38	13	11	27	26	37	37	18
Normal	3	3	18	15	1	< 1	23	21	15	14	13
Dry-Normal	3	3	4	3	1	1	9	8	16	8	6
Dry	< 1	< 1	1	< 1	< 1	< 1	2	3	4	3	2
Dry to Normal	1	1	5	4	1	< 1	8	8	9	7	5

Year Type	Observed Data (Mean Daily Streamflow)	Observed Data (Timestep-Average)	Historical Model (Monthly Inflow)	Historical Model (Timestep Inflow)	Historical Model (Scaled Thresholds)	Historical Model (15Sep2023 Version)	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	22	24	45	45	22	23	52	54	24	22	25
Wet	59	63	87	90	59	61	75	78	45	46	54
Wet-Normal	21	25	75	80	25	30	66	73	35	35	33
Normal	8	12	40	44	10	12	75	68	18	17	23
Dry-Normal	3	4	15	13	1	2	38	32	18	9	9
Dry	2	3	11	8	1	1	24	30	5	3	3
Dry to Normal	3	5	18	16	3	3	38	38	11	8	9

Table A16. Average Annual Lagoon Open Days During Kelt-Juvenile Outmigration Period

SRDF Operation

Tables A17 through A21 present various metrics related to SRDF Operation by operational year type (i.e., that determined on March 15th and April 1st each year). Because the SRDF has only been operating since 2010, and because reservoir operations are not simulated in the Historical Model, values for these metrics are only presented for the Operational Model. However, comparison is made to the actual historical operation of the SRDF from 2010 to 2020.

Table A17 shows the number of days each year of SRDF Operation for the five versions of the Operational Model. Using monthly inflows to the Salinas River and Arroyo Seco, the model simulates about 157 days of operation per year on average, with 214 days per wet year, 165 days per normal year (including wet-normal and dry-normal years), and 94 days per dry year. With timestep inflows, the model simulates about 145 days per year on average, with 214 days per wet year, 144 days per normal year, and 89 days per dry year.

The first bias correction test version of the model results in 78 operational days per year, with 101 days per wet year, 92 days per normal year, and 38 days per dry year, representing a substantial reduction in SRDF operation. SRDF operation typically ends early in this model version because streamflow at Spreckels falls below the scaled threshold (90 cfs scaled from 20 cfs) to indicate that the reservoirs are not successfully getting sufficient water through the system. However, because SRDF demand remains at 36 cfs in the first bias correction test version, the fact that streamflow at Spreckels often falls below 90 cfs is not surprising and should not be considered indicative of the system not being capable of supplying water to the SRDF.

The substantially curtailed SRDF operation motivated the development of a second bias correction test version, in which scaling is not applied to the streamflow values included in the SRDF operation rules. In this second bias correction test version, the SRDF operates on average about 145 days per year, with 214 days per year during wet years, 138 days per year during normal years, and 97 days per year during dry years. This is very close to the simulated days of operation without bias correction.

Bias correction was altered slightly for the Updated Operational Model that was used to run the Current Operations Scenario. In this model version, the threshold for initiating channel wetting flows to prime the system prior to the SRDF season is scaled from 20 to 50 cfs at the Salinas River at Soledad gauge. Thresholds for ramping down channel wetting releases (40 cfs at the Salinas River near Spreckels gauge) and early cessation of the SRDF season (20 cfs at the Salinas River near Spreckels gauge) are not scaled. The Updated Operational Model results in about 145 days per year of SRDF operation, with 214 days per wet year, 134 days per normal year, and 91 days per dry year.

Table A18 provides the average annual volume of SRDF diversion for each of the Operational Model versions discussed here. The results shown in Table A18 follow the same pattern as those in Table A17.

Tables A19 through A21 provide the percentage of full, partial, and dry years for the four Operational Model versions. These tables show that the SRDF season is full (i.e., 214 days, or April 1st to October 31st) in the majority of years for all Operational Model versions aside from the first bias correction test version. About a quarter of years have no SRDF season at all, which happens when there is insufficient storage in the reservoirs to initiate releases to supply the SRDF.

As stated above, the SRDF has only been operating since 2010, so metrics related to SRDF operation are not presented for the observed data or Historical Model results. However, MCWRA reports on the operation of the SRDF can be used to gain insight on how frequently and how long each year SRDF is able to divert under the current operational approach. Appendix A to the Salians Valley Water Project Flow Monitoring Report 10-Year Review (MCWRA, 2022) provides a narrative description of the SRDF operational seasons from 2010 to 2019. The SVWP Annual Flow Monitoring Report for 2020 (MCWRA 2023) provides information on the operational season of 2020. These documents indicate that SRDF was able to operate in 8 of the 11 years discussed, with no SRDF seasons from 2014 to 2016 due to low reservoir storage. Of the 8 years of operation, 7 ended in September or October, with the remaining year (2011) ending in late August due to scouring around the SRDF fish ladder. This means that, at least during the period from 2010 to 2020, SRDF typically has been able to operate for the entire period, or close to it. The first bias correction version of the model is therefore not in line with observed conditions in the system regarding SRDF operation. The second bias correction version of the Operational Model and the Updated Operational Model perform well for the metrics related to SRDF operation.

Table A17. Average Annual Days of SRDF Operation					
Year Type	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	157	145	78	145	145
Wet	214	214	101	214	214
Normal	165	144	92	138	134
Dry	94	89	38	97	91

Table A18. Average Annual SRDF Diversion Volume Acre-feet per year					
Year Type	Operational Model (Monthly Inflow)	Operational Model (Timestep Inflow)	Operational Model (Bias Correction Test 1)	Operational Model (Bias Correction Test 2)	Operational Model (15Sep2023 Version)
All	11,100	10,400	5,600	10,400	10,400
Wet	15,300	15,300	7,200	15,300	15,300
Normal	11,600	10,200	6,500	9,800	9,500
Dry	6,700	6,300	2,700	6,900	6,500

Table A19. Percentage of Full SRDF Seasons

Year Type	Operational Model (Monthly Inflow). percent	Operational Model (Timestep Inflow), percent	Operational Model (Bias Correction Test 1), percent	Operational Model (Bias Correction Test 2), percent	Operational Model (15Sep2023 Version), percent
All	60	56	4	56	58
Wet	100	100	8	100	100
Normal	59	59	5	59	57
Dry	27	123	0	13	15

Table A20. Percentage of Partial SRDF Seasons

Year Type	Operational Model (Monthly Inflow), percent	Operational Model (Timestep Inflow), percent	Operational Model (Bias Correction Test 1), percent	Operational Model (Bias Correction Test 2), percent	Operational Model (15Sep2023 Version), percent
All	18	16	78	16	14
Wet	0	0	92	0	0
Normal	27	14	77	9	9
Dry	20	33	67	40	38

Year Type	Operational Model (Monthly Inflow), percent	Operational Model (Timestep Inflow), percent	Operational Model (Bias Correction Test 1), percent	Operational Model (Bias Correction Test 2), percent	Operational Model (15Sep2023 Version), percent
All	22	28	18	28	28
Wet	0	0	0	0	0
Normal	14	27	18	32	35
Dry	53	53	33	47	46

Table A21. Percentage of Failed SRDF Seasons

SUMMARY

This appendix details the process undertaken by West Yost to develop and apply a bias correction to the modeling tools being employed to support development of the Salinas River Operational HCP. This was necessitated by recognized shortcomings in the modeling tools, mainly the systematic over-estimation of relatively low streamflows in the Salinas River. This appendix shows that the bias correction process results in certain critical aspects of model behavior (i.e., the frequency of conditions supporting migration of steelhead trout between the ocean and spawning grounds in the Salinas River and its tributaries) much closer to the observed conditions in the system.

This bias correction process may result in unintended changes to simulated conditions that make the models less representative of certain aspects of the system. For example, scaling (generally increasing) the streamflow requirements in the Salinas River may result in unrealistically high reservoir releases, or important changes to the amount, timing, and direction of exchange between the groundwater and surface water systems. The Historical Model was calibrated using the unscaled streamflow values, and no effort has been made to investigate the effects of the streamflow scaling described in this appendix on model calibration, in part because the SVIHM and SVOM have not yet been released publicly by the USGS, including model documentation that would describe the purpose, approach, and results of model calibration.

It is also important to note that the bias correction approach relies on a comparison between average simulated streamflow conditions against average observed streamflow (as represented by the exceedance probability curves discussed previously). Although the scaling resulting from this comparison may be used to capture the overall behavior of the system, it should not be expected that simulated streamflow at a given time or place is closer to the observed streamflow, and therefore caution should be employed when considering any simulated streamflow information that is not averaged across a substantial time period. The results presented in this appendix show that the bias-corrected model produces a reasonable match to observed conditions when averaged across water year types, but one should not expect individual water years to be as well-represented.

Despite the above caveats, we consider the bias-corrected SVOM to be the best available tool for supporting development of the HCP because of its ability to holistically simulate the coupled groundwater-surface water-reservoir system in the Salinas Valley. Shortcomings in the ability of the SVOM to represent the system can be present in all model scenarios; intercomparisons between scenarios (i.e., the differences between two scenarios) will naturally be less affected by model issues.

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