

Water Unavailability Methodology for the Delta Watershed

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Table of Contents

1	Introduction	1
1.1	Background	2
1.2	Current Conditions	3
1.3	Emergency Proclamation and Regulations	3
1.4	Purpose of the Water Unavailability Methodology	3
1.5	Curtailment Orders	7
1.6	Current Updates to the Water Unavailability Methodology Report	7
2	Water Unavailability Methodology	9
2.1	Supply	9
2.1.1	Supply Analysis	10
2.1.2	Types of Water	12
2.1.3	Subwatershed Delineation	13
2.1.4	Supply Data Sources	16
2.1.5	Filling Supply Data Gaps	23
2.1.5.1	Extrapolation	23
2.1.5.2	Augmentation	24
2.1.6	Abandoned Instream Flows	26
2.2	Demand	29
2.2.1	Initial Selection of Water Right Records	35
2.2.2	Initial Quality Control	36
2.2.3	Additional Quality Control	38
2.2.4	Wet Season Demand Adjustments	39
2.2.5	Disaggregation of Statements of Diversion and Use	43
2.2.6	Demand Aggregation by Subwatershed	43
2.2.7	Project Demands	44
2.2.7.1	Trinity River Imports	45
2.2.7.2	Settlement Contractor Demands	45
2.2.8	Interbasin Diversions (Yuba-Bear and Drum-Spaulding)	46
2.2.9	Accretions and Return Flow Estimates	47
2.3	Adjustments to the Supply and Demand Datasets	50

2.3.1	Elimination of Unmet Demand.....	50
2.3.2	Treatment of Riparian Demands and Elimination of Supply and Demand in Disconnected Headwater Subwatersheds	54
2.3.3	Proration of Legal Delta Demands	54
2.4	Water Unavailability Visualizations.....	56
3	Implementation	58
3.1	Issuance of Notices of Water Unavailability and Curtailment Orders	58
3.1.1	Exceedance Forecast Selection and Precipitation Monitoring.....	59
3.2	Water Quality and Public Trust Resources.....	61
3.3	Communication and Public Engagement Strategy	61
4	Areas of Potential Refinement	62
4.1	Near-Term Opportunities.....	62
4.1.1	Supply	62
4.1.2	Demand.....	62
4.2	Longer-Term Opportunities	63
5	References Cited	65
	Technical Appendix A.....	A-1
	Technical Appendix B.....	B-1
	Appendix C.....	C-1
	Technical Appendix D	D-1

1 Introduction

California and the Sacramento-San Joaquin Delta (Delta) watershed have experienced extremely dry conditions over the last two years. Statewide, water years 2020 and 2021 were the driest two-year period on record resulting in very low runoff. These low runoff conditions resulted in very low inflows to reservoirs and associated limited storage supplies for various purposes. Currently, reservoir storage levels in the Delta watershed are significantly below average despite early season precipitation and will remain so until significant additional precipitation returns. To help address these conditions, the State Water Resources Control Board (State Water Board or Board) developed a methodology to assess water unavailability in the Delta watershed. This report describes that methodology identifying when available data indicates that natural and abandoned water supplies are unavailable for diversion by water right holders and claimants in the Delta watershed under their priority of right (Delta Water Unavailability Methodology or Water Unavailability Methodology for short).

This report has been updated regularly since the initial draft was released for public review on May 12, 2021. The July 23, 2021 version of this report was incorporated by reference into the emergency regulations that became effective August 20, 2021 (see section 1.3 below). Since that time three revised versions of the report have been released. Most of the revisions to the report did not reflect changes to the methodology that was described in the July 23, 2021 report, but some relatively minor refinements to the methodology have been made. These minor refinements include:

- Exclusion of the Goose Lake subwatershed due to disconnection from the lower watersheds such that curtailing diversions would not make water available to serve senior downstream water rights or claims.
- Adjustment of subwatershed boundary delineation for certain subwatersheds previously representing headwater and valley floor portions of the larger watershed.
- Use of a weekly timestep instead of a monthly timestep as appropriate during the wet season.

The spatial refinements of the methodology served to improve the accuracy of the methodology in certain portions of the watershed, while the temporal refinement has enabled the temporary suspension of curtailments for a greater number of diverters during a submonthly precipitation event.

Updates to the report introduced in this November 15 version are summarized in section 1.6 below. Previous updates to this report are summarized within the introductory sections of those versions of the report, which are available on the [Delta Drought webpage](#).

1.1 Background

The mission of the State Water Board is: “To preserve, enhance, and restore the quality of California’s water resources and drinking water for the protection of the environment, public health, and all beneficial uses, and to ensure proper water resource allocation and efficient use, for the benefit of present and future generations.” The Board’s critical goals of providing safe drinking water to all Californians and maintaining the quality of our waterways, in keeping with both state and federal requirements, rely on the Board’s successful administration of the water rights system. California’s water rights system is one of the most complex in the nation, incorporating both riparian¹ and appropriative water rights, including appropriative rights issued under the Board’s authority and those in existence prior to the inception of its predecessor-in-interest.²

The water right priority system, based on the “priority date” of each water right, forms the basis for determining which users may divert, and how much, when there is insufficient water in the stream for all users. Older, more senior appropriative water rights have priority over more junior appropriative water rights. Senior water right holders are more likely to receive water at times of shortage than more junior water right holders. However, once water is stored or imported, the entity that stored or imported the water has the only right to it, though others may acquire contingent junior rights to any return flows.

When the amount of water available in a surface water source is not sufficient to support the needs of existing water right holders and in-stream uses, junior appropriators must cease diversion in favor of higher-priority rights. However, it is not always clear to a junior diverter whether there is sufficient natural flow in the system to support their diversion and senior water uses and instream needs downstream. As part of administering water rights, the State Water Board may issue notices of curtailment to water rights holders based on California’s water rights priority system.

¹ Generally, a riparian water right is a right to use the natural flow of water on land contiguous to a natural water course. Riparian water rights are unquantified, allowing the diverter to take water from the natural flow of the water course for any immediate reasonable and beneficial use on the subject land. In times of shortage, all riparian rights share the shortage on a correlative basis; that is, each riparian is required to reduce its use proportionally so that the reduced supply is divided among all riparian rights.

² Use of water on non-riparian land or seasonal storage of water for later beneficial use requires an appropriative water right. An appropriative water right that was initiated before the Water Commission Act went into effect on December 19, 1914, and subsequently perfected is called a pre-1914 appropriative water right. Appropriative rights initiated and acquired after this date are called post-1914 appropriative water rights, and they are administered and regulated by the State Water Board.

1.2 Current Conditions

After two years of low precipitation, the U.S. Drought Monitor reports that the entirety of California is experiencing moderate to exceptional drought, of which 83 percent is experiencing extreme to exceptional drought (USDM 2021). The U.S. Seasonal Drought Outlook, released by the Climate Prediction Center on October 21, 2021 and valid through January 31, 2022, shows drought conditions present throughout California but improving in the northern portion of the state (NOAA 2021). Within the Delta watershed, conditions have been extraordinarily dry, with Water Year (WY) 2021 ranking as the third driest on water year record based on precipitation (DWR 2021a; DWR 2021b). These dry conditions have resulted in reservoir storage levels in the Delta watershed that are significantly below average (DWR 2021c). As of November 8, 2021, storage volumes in major reservoirs, including Lake Shasta and Lake Oroville are lower than 30 percent of capacity and below 60 percent of average storage conditions; recent precipitation has improved conditions in some reservoirs, such as Folsom Lake, which currently holds 33 percent of capacity and 79 percent of its historical average (DWR 2021d).

1.3 Emergency Proclamation and Regulations

On May 10, 2021, as a result of the dry conditions this spring, Governor Newsom issued a drought emergency proclamation covering 41 of California's 58 counties (Exec 2021a). On July 8, 2021, the Governor expanded the emergency declaration to 9 additional counties (Exec 2021b) and called on Californians to reduce their water use by 15 percent compared to 2020 levels (Exec 2021c). On October 19, 2021, the Governor further expanded the emergency declaration to cover the entire state and urged Californians to increase their water conservation efforts as urban water conservation to date has fallen significantly short of the 15 percent goal (Exec 2021d).

The May 10 proclamation orders the State Water Board and other agencies to consider a number of actions to protect water needed for health, safety, and the environment in the Delta watershed (Exec 2021a). The proclamation specifically indicates that the State Water Board shall consider emergency regulations to curtail water diversions when water is not available at water right holders' priority of right or to protect previously stored releases of water (*Ibid*). On August 3, 2021, the Board adopted emergency regulations that authorize the use of this methodology as the technical basis for curtailment orders issued pursuant to the directives in the emergency drought proclamation. On August 19, 2021, the Office of Administrative Law approved the regulations, which became effective upon filing with the Secretary of State on the same day.

1.4 Purpose of the Water Unavailability Methodology

The San Francisco Bay-Delta (Bay-Delta) watershed includes supplies from both the Sacramento and San Joaquin river systems and their tributaries. As shown in Figure 1

below, water from about 40 percent of California's land area drains to the Bay-Delta, supporting a variety of beneficial uses of water. The Bay-Delta is one of the most important ecosystems in California, as well as the hub of California's water supply system. As the largest tidal estuary on the western coast of the Americas, it provides essential habitat to a vast array of aquatic, terrestrial, and avian wildlife in the Delta, San Francisco Bay, and near-shore ocean, as well as a diverse assemblage of species upstream of the Delta. Water from the Delta provides a portion of the supplies to more than two-thirds of Californians, supports industry, and is used to irrigate millions of acres of farmland

Given the importance of the water supplies in the Delta watershed for multiple purposes and the extreme limitations in water supplies this year, action is needed to determine when water supplies are not available under water right holders' or claimants' priorities of right. The Department of Water Resources' (DWR) State Water Project (SWP) and the U.S. Bureau of Reclamation's (Reclamation) Central Valley Project (CVP) (collectively Projects) are responsible for providing salinity control and meeting environmental flows in the Delta, as well as specific requirements for flows and temperature management on Project tributaries. Currently, all Project reservoir storage levels are well below average, creating significant concerns for salinity control, municipal water supplies (particularly from Folsom Reservoir), and temperature management and other environmental needs if dry conditions continue into the next water year. As a result of these concerns, the Projects submitted, and were granted subject to terms and conditions, a temporary urgency change petition (TUCP) in water year 2021 to reduce their obligations to release water from storage to meet flow and water quality requirements in the Delta.³ The Projects are anticipating submitting an additional TUCP in 2022 in the event of continued dry conditions and limited water supplies. Concerns for reservoir storage levels are compounded when diversions occur by users when supplies do not exist at their priority of right, resulting in the need for additional releases of stored water from Project reservoirs in order to repel salinity intrusion from the ocean and meet other minimal needs.

Determining when water supplies are unavailable to users is important to ensuring that supplies are available to meet current water quality and flow requirements and the demands of senior water right holders. However, it may be unclear to water users when supplies are unavailable for their use because supplies are needed by downstream senior water right holders or because streamflows are comprised of releases of previously stored water that is released to serve contractors or to meet water quality or flow requirements.

³ The Board order conditionally approving the petition is available at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/docs/2021/20210601_swb_tuco.pdf

Figure 1. Delta Watershed Location



The State Water Board has developed the Water Unavailability Methodology for identifying when available data indicates that natural and abandoned water supplies are unavailable for direct diversion or diversion to storage for consumptive use by water right holders and claimants in the Delta watershed under their priorities of right. The methodology is not intended to address other supplies of water like rediversion of previously stored water for use by Project contractors. The methodology also does not address water unavailability for non-consumptive uses of water like direct diversion for hydropower production when these supplies are returned back to the source stream. However, since wet season diversions to storage for later production of hydropower may change the timing of flows and affect the availability of water for other users, the methodology does consider these demands when determining water unavailability during the wet season.

The methodology evaluates water supplies and demands at the subwatershed and watershed scale for both the Sacramento River and San Joaquin River watersheds with currently available data, reporting, and tools. The methodology utilizes the best currently available data on supplies and demands, which may include use of past and projected demand data submitted in response to the August 20, 2021 curtailment and reporting orders. The Water Unavailability Methodology improves upon methods used for determining water unavailability in prior droughts, most recently in 2014 and 2015. Major improvements are described below and are focused on ensuring that demands are not overinflated in ways that would overestimate water unavailability, causing more water users to receive notices of water unavailability or curtailment orders or resulting in those notices or orders applying for a longer time period. Other improvements include better supply estimates. With more time, better data, and improved tools, additional improvements will be possible.

This report and associated technical appendices describe the current approach and major assumptions for the Water Unavailability Methodology. Technical Appendix A describes the Water Unavailability Methodology Spreadsheet, including the input data sources, computational steps, and outputs used to develop the water unavailability visualizations. Technical Appendix B describes the process used to collect and quality control the demand datasets. Appendix C summarizes the substantive technical, factual, or legal comments regarding the Water Unavailability Methodology that were received prior to the release of the July 23, 2021 version of the report that was incorporated by reference into the emergency regulation, as well as any relevant sections of the report where those comments have been addressed. Technical Appendix D was included to respond to comments received regarding the hydrologic complexities of the Legal Delta and to provide additional explanation regarding the assumptions used in the Methodology with regard to freshwater residence time in the Legal Delta and the exclusion of tidal inflows as a source of supply. The technical appendices and spreadsheet are available on the State Water Board's [Delta Water Unavailability Methodology webpage](#).

The Board intends to update the methodology as needed in order to administer the water rights priority system using the best available information. Due to the uncertainties that exist in determining water unavailability in the Delta watershed, conservative assumptions were used within the methodology itself and will also be used in the methodology's implementation. This report will continue to be updated, as appropriate, as the methodology is updated. All revisions will be made available on the Board's Delta Water Unavailability Methodology webpage.

1.5 Curtailment Orders

Pursuant to the emergency regulation and based on the output of the methodology, on August 20, 2021, the Board issued curtailment and reporting orders to water right holders and claimants throughout the Delta watershed. In addition to imposing curtailments, the initial orders imposed reporting requirements on all water right holders and claimants in the Delta watershed, and directed diverters to subscribe to the Board's Delta Drought email distribution list or visit the Delta Drought webpage to view Delta Watershed Curtailment Status List (Curtailment Status List) for updates regarding these and future curtailment orders. On at least a weekly basis since August 20, 2021, updates to the curtailment status of all water right holders and claimants within the Delta watershed have been made available on the Delta Drought webpage and sent to the Board's Delta Drought email subscription list. Weekly or sub-weekly updates of the curtailment status for the month continued until October 13, 2021, when increasingly dynamic water supply conditions in the watershed prompted a change to a weekly curtailment timestep in place of the previous monthly timestep. Beginning October 19, 2021, sufficient water supply was forecast to warrant the temporary suspension of all curtailments within the watershed. The current curtailment status within the watershed will continue to be updated on a weekly basis, and more frequently if warranted due to precipitation and runoff. Additional information related to the Delta curtailment regulation and curtailment and reporting orders can be found on the Board's Delta Drought webpage.

1.6 Current Updates to the Water Unavailability Methodology Report

This November 15, 2021 update to the report considers information and input provided during a public workshop held on October 20, 2021. In particular, this report update describes:

- Inclusion of abandoned instream flows for additional months and corrections to one October value (see section 2.1.6, including Table 3 and Table 4).
- Notation regarding absence of demand data for certain watermaster service areas from demand dataset (see section 2.2 and Appendix B).

- Description of upcoming changes to required reporting periods and deadlines pursuant to Senate Bill 155 (see section 2.2).
- Description of the inclusion of minor water right types (e.g., stockponds, registrations, etc.) in the demand dataset, assumed to represent a negligible amount of demand (see section 2.2 and Appendix B).
- Description of the enhanced reporting data required by the curtailment and reporting orders for larger diverters (see section 2.2.3).
- Explanation of adjustments made to the demand dataset to account for wet season conditions, such as the inclusion of demand associated with diversion to storage for water rights and claims with non-consumptive beneficial uses (see section 2.2.4).
- Inclusion of estimates of return flows for November and additional discussion regarding estimating return flows (see Table 5 and Table 6).
- Adjustment of subwatershed boundary delineation for certain subwatersheds previously representing headwater and valley floor portions of the larger watershed (see section 2.1.3, Figure 5, and section 2.3.1).
- Explanation regarding the use of a weekly timestep to compare supply and demand during the wet season (see section 3.1.1).
- Description of treatment of pending applications within demand dataset (see Appendices A and B).

Additional analyses will be conducted to further address public comments received related to the residence time of natural and abandoned flows in the Legal Delta and associated assumptions related to water unavailability. At this time, however, changes to the one-month residence time assumption that has been used to date in the water unavailability analyses are not anticipated based on existing analyses and information submitted to date. The existence of water molecules in the Legal Delta that entered the Legal Delta greater than a month prior does not support the use of a longer residence time and a finding that water is continually available within the Legal Delta regardless of hydrologic conditions. This report explains the assumptions and their bases used in the methodology, including the assumption regarding Delta residence time, but the focus of this report is factual and technical, not legal. Legal arguments made during the October 20, 2021 workshop will be addressed as appropriate in the Board's response to petitions for reconsideration of the curtailment and reporting orders, rather than this report.

2 Water Unavailability Methodology

The Water Unavailability Methodology incorporates the best available supply data for the Delta watershed with the best available estimates of demand for the same area. The methodology compares this data for multiple areas within the Delta watershed: the Sacramento River watershed, San Joaquin River watershed, and headwater subwatersheds (see definition in section 2.3.1 below), to determine if supply may be insufficient to meet certain priorities of right. These comparisons are presented visually using interactive graphs and in spreadsheet format. The following sections describe the sources of the supply and demand data, adjustments made to the data as needed, and the resultant outputs of the comparisons.

2.1 Supply

The purpose of this analysis is to account for the availability of natural and abandoned flows within the Delta watershed for diversion by water right holders under their priority of right. This analysis is not intended to account for the availability of imported supplies from other watersheds that do not contribute to available supplies for general use in the Delta watershed. Specifically, imported supplies from the Trinity River system are imported for use by Reclamation and their contractors and are not available to other users under their own water rights. The analysis is also not intended to account for releases of previously stored water for downstream delivery, use, or redirection since those supplies are also not available to other users under their own water rights. In the case where previously stored water is released to meet instream flow requirements that apply in an upstream subwatershed, but not downstream watersheds, and the water is not released for delivery to a downstream user, these flows are considered to be abandoned and part of available supplies.

The methodology incorporates the use of past and projected future full natural flow (FNF) (or unimpaired flow) estimates (see section 2.1.4 below). FNF represents the natural water production of a river basin unaltered by upstream water diversion, storage, or import from or export to other watersheds (DWR 2015). FNF is a theoretical water supply estimate rather than a reconstruction of pre-development streamflows (DWR 2016). Though FNF values are not directly measured, the locations where they are estimated are referred to herein as “gages.”

Past FNF estimates are calculated from measured streamflows, adjusted for upstream operations by subtracting imported water and adding upstream diversions, changes in storage, and evaporative losses. The past FNF values serve two purposes in the methodology: (1) to provide historical context to current water supply conditions and (2) to show water supply conditions for the current year, from January 2021 to the present. Water years in the Sacramento and San Joaquin River watersheds are categorized as Wet, Above Normal, Below Normal, Dry, and Critically Dry based on equations defined in State Water Board Decision 1641 that account for the unimpaired runoff of each

water year and its preceding water year (DWR 2021e). For both the Sacramento and San Joaquin River watersheds, 2021 is considered Critically Dry (see next section).

Forecasted FNF values are calculated from snowpack measurements, estimates of water content, expected weather, rates of evaporation, ground absorption, and other factors. Because future water supply cannot be predicted with absolute certainty, a forecast provides a range of expected water supply volumes. These potential volumes are assigned probabilities that they will occur based on current conditions. Probabilities are expressed in exceedances, or the percent chance that the future FNF will exceed a given amount. For example, the 10 percent exceedance indicates wetter than average conditions where there is a 10 percent chance that the FNF volume will exceed the forecast value, and a 90 percent chance that the FNF volume will be less than this forecast value. Similarly, a 90 percent exceedance indicates drier conditions where there is a 90 percent chance that the FNF volume will exceed the forecast value and a 10 percent chance that the FNF volume will be less than this forecast value. A 50 percent exceedance indicates a 50 percent chance that the FNF volume will exceed the forecast value and a 50 percent chance that the FNF volume will be less than this forecast value. Generally, this forecast is the middle of the range of possible FNF volumes that can be produced given current conditions (50 percent exceedance is equivalent to the median). As the dry season approaches, forecasts become progressively more precise as actual conditions become less variable.

2.1.1 Supply Analysis

The range of data available within the supply dataset described below allows for the comparison of historical FNF to current year estimates and forecasts. For reference, both the 90 percent and 99 percent exceedances, provided in the latest supply forecasts, are shown in Figure 3 and Figure 4 below. As indicated below, the current year supply within the Delta watershed is drier than the median critically dry year over the period of 1922 through 2019.

Figure 2. 2021 Supply Conditions Within the Sacramento River Watershed

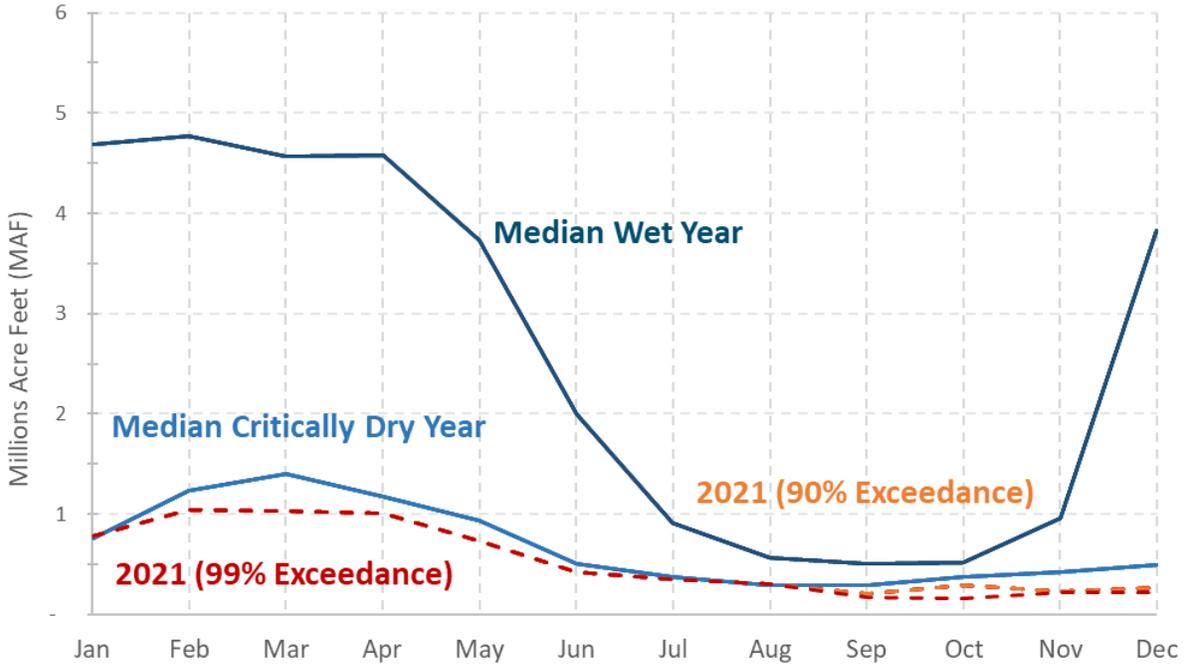
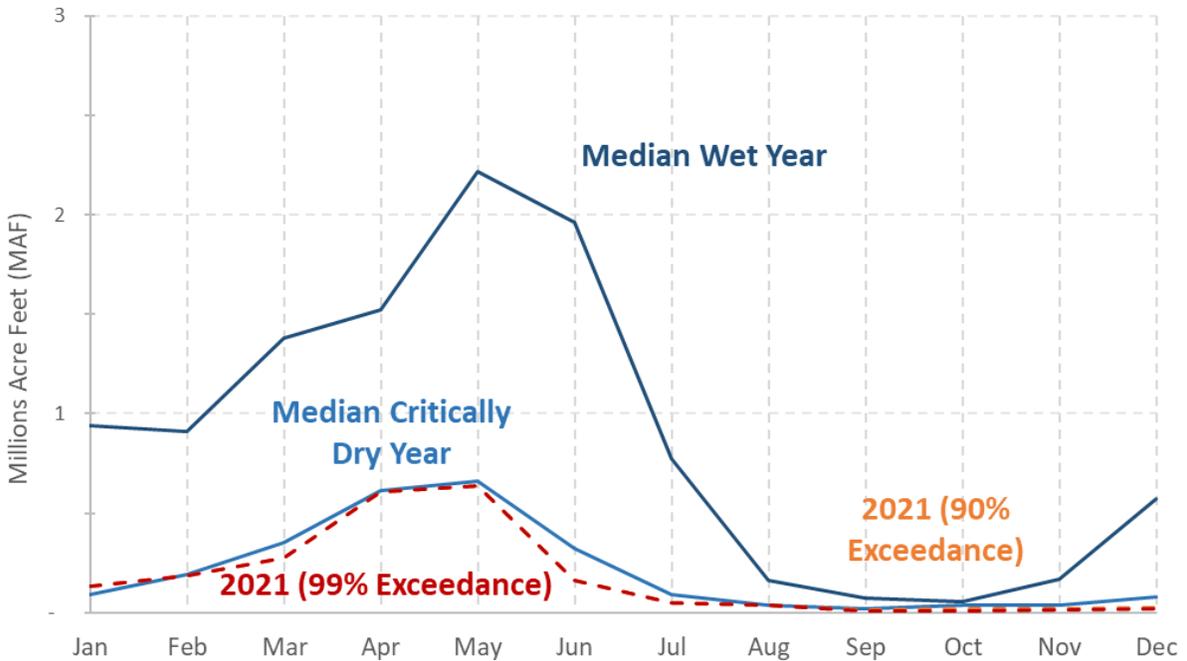


Figure 3. 2021 Supply Conditions Within the San Joaquin River Watershed



2.1.2 Types of Water

The water rights system is complex. In many cases during droughts, the observable water in a stream may not be available for diversion because the water is needed to meet senior downstream demand, has been transferred for use or rediversion downstream, or is previously stored water that has been released to meet downstream demands, water quality and flow requirements, and contractual demands. This section discusses the additional complexities in determining whether water is unavailable for diversion.

Water in a stream system may consist of a combination of “natural flows,” imported supplies, storage releases, abandoned flows, and return flows:

1. **Natural flow** – Natural flows are the natural runoff of a river basin unaltered by upstream water diversion, storage, or import from or export to other watersheds. Natural flows, quantified as FNF, are the basis of this methodology.
2. **Imported Supplies** – Imported supplies include supplies that are brought from one water supply source to another for consumptive uses or non-consumptive uses. In the Delta watershed, imported supplies are brought in from outside of the watershed from the Trinity River. Other projects may import water to one subwatershed from another, entirely within the Delta watershed (e.g., the Yuba-Bear and Drum-Spaulding projects, see section 2.2.8 below). These additional water supplies are not accounted for in this analysis because these supplies do not constitute natural or abandoned flows.
3. **Previously Stored Water** – Seasonally stored water, including releases of previously stored water for downstream use, is not available for diversion or use by diverters other than the entity that stored the water, their contractors, or recipients of a transfer. Accordingly, the methodology does not account for these storage supplies.
4. **Abandoned water** – Abandoned water is water that has been used or dedicated for a specific purpose for which it is no longer needed. If it was previously diverted, the diverter lays no further claim to the water, such as is commonly the case with return flow from agricultural uses. If the water was dedicated for instream use, it becomes abandoned once it flows out of the reach for which it was dedicated. Abandoned flows are available for downstream diversion.
 - a. **Abandoned instream flows** – Water for instream use may be comprised of previously stored water releases that are foreign in time or imported from another watershed or bypassed natural flow that is provided for the purposes of preserving or enhancing wetlands, protecting fish and wildlife, and/or recreation. Some instream flows that only apply to a certain reach of a stream can be considered abandoned past that reach. Instream flows that are required to meet Delta instream flow, outflows, and salinity

requirements are not considered abandoned. Section 2.1.6 below describes adjustments to the supply analysis to account for certain abandoned instream flows.

- b. **Abandoned return flows** – Return flows from other uses such as irrigated agriculture or municipal water treatment plants may be discharged back to the stream system with no residual claim of control, dominion, or right of further use. In such a case, this water would be available to appropriative diverters and may be available to riparian diverters if not foreign in time or source. Section 2.2.9 below describes adjustments made to the demand dataset to account for return flows from use within the Delta watershed.

The Water Unavailability Methodology assumes all FNF is available for diversion. The methodology also includes assumptions for return flows and abandoned instream flows that are available for diversion. Incorporation of return flows reduces demand calculated purely on reported diversions because a component of that diversion is introduced back into the system. As a simplifying assumption, the methodology does not distinguish between the types of water available within a stream system. Additional analysis will be needed to distinguish supplies that are foreign in time or watershed and not available to riparian diverters.

2.1.3 Subwatershed Delineation

The supply-demand analysis begins at a “subwatershed” level. Subwatershed boundaries were defined using the U.S. Geological Survey (USGS) Watershed Boundary Dataset (WBD) and National Hydrography Dataset (NHD), which delineate land areas draining to streams. Subwatersheds in the Delta watershed were primarily delineated based on Hydrologic Unit Code level 8 watersheds (HUC8s), which represent areas of sufficient size to capture as much of the available flow as possible within the watershed given the existing network of FNF gages.

Some subwatershed boundaries were defined as a combination of multiple HUC8s due to the presence of multiple HUC8s upstream of a single FNF gage location. These subwatersheds include the Sacramento River above Bend, the Upper American River, and the Upper Feather River. Some HUC8s containing small tributaries on the valley floor were also combined into a single subwatershed due to the locations of supply estimates produced by DWR,⁴ including the Upper Sacramento River Valley, Sacramento River Valley Floor, and San Joaquin Valley Floor subwatersheds. Due to the presence of demands not met by local supplies within their HUC8 boundaries, the Mokelumne, Chowchilla, and Fresno River subwatersheds were instead delineated as a combination of smaller Hydrologic Unit Code level 10 (HUC10) watersheds (see section 2.3.1). A total of 20 Delta subwatersheds were used in the Water Unavailability

⁴ See DWR’s March 2016 Report on Unimpaired Flows in the Bay-Delta Watershed, described in section 2.1.4 below.

Methodology: 10 each in the Sacramento and San Joaquin River watersheds (see Figure 5). Consistent with the USGS WBD, the methodology assumes that the Cosumnes, Mokelumne, and Calaveras Rivers are part of the San Joaquin River watershed.

An inventory of available FNF gages from multiple sources (see section 2.1.4 below) was compared to the subwatershed boundaries, NHD stream maps, and water right points of diversion (PODs) to identify target FNF gages that are representative of water supplies and demands met by them within each subwatershed. These target FNF gages were considered during the prioritization of available supply data sources discussed in more detail in section 2.1.4 below.

The Water Unavailability Methodology assumes that water supply data at each FNF gage shown in Figure 5 below is representative of the total FNF for the subwatershed as a whole, not only the portion of the subwatershed upstream of the location. This assumption may result in minimal underestimation of supply within certain upstream subwatersheds and minimal overestimation of supply in corresponding downstream subwatersheds. Given the broad spatial coverage of the methodology and the use of generally conservative estimates regarding supply, this assumption is not anticipated to significantly impact watershed-wide determinations of water unavailability.

Supplies and demands from the Goose Lake subwatershed, the Panoche Creek subwatershed, and Tulare Lake watershed (including the Kings, Kern, Kaweah, and Tule Rivers) are not included in the Water Unavailability Methodology. Goose Lake, located on the border of California and Oregon, is expected to only overflow into the North Fork of the Pit River during very wet conditions. Therefore, the methodology excludes supply and demand that occurs within the boundaries of the Goose Lake HUC8. The methodology also excludes supply and demand within the Panoche Creek HUC8, a relatively small tributary in the southwest corner of the San Joaquin River watershed. There is no available FNF supply data for Panoche Creek, and aerial photographs indicate that it terminates in agricultural fields west of Mendota, so it is assumed not to significantly contribute to available water supplies within the Delta watershed.

Natural flows from the Tulare Lake watershed, despite not being a part of the Delta watershed, at times enter the watershed, largely from the Kings River via Fresno Slough. However, surface water contributions of the Tulare Lake region have historically been minimal and may have been significant only in wet years (DWR 2016). Natural flow would not reach the Delta watershed from the Tulare Lake watershed during the dry season of a critically dry year. Similarly, during the upcoming wet season, it is unlikely that natural flow from the Tulare Lake watershed would reach the Delta watershed as long as shortage conditions persist in the Delta watershed. Therefore, supplies and demands from the Tulare Lake watershed have been excluded from the methodology.

2.1.4 Supply Data Sources

Because there is no single data source that provides both past and forecasted FNF estimates for the entire Delta watershed, supply data is derived from multiple sources which vary by location, timescale (i.e., historical data, including prior months of the current water year, and future forecasted data), and temporal resolution (i.e., daily or monthly). These data sources were considered hierarchically; that is, if data for a particular subwatershed was not available from the preferred data source, the next source was checked. If the data was available there, that data was incorporated into the dataset, and so on down the list.

The sources of past supply data, in order of priority of use, are:

1. The [California Data Exchange Center \(CDEC\)](#), which contains published FNF estimates made by water system operators within each watershed. These are primarily available for larger rivers and contain monthly data as far back as WY 1901 in some subwatersheds.
2. [DWR's March 2016 Report on Unimpaired Flows in the Bay-Delta Watershed](#), which contains monthly FNF estimates for water years 1922 through 2014.
3. The National Oceanic and Atmospheric Administration (NOAA) National Weather Service [California Nevada River Forecast Center \(CNRFC\)](#) estimates of daily FNF.⁵ These estimates are available for many streams beginning with WY 2013. This source was used only for streams where no other data was available.

The sources of forecasted supply data, in order of priority of use, are:

1. DWR's California Cooperative Snow Surveys [Bulletin 120](#) Water Supply Forecast (B-120),⁶ which contains monthly FNF forecasts for the current water year for only larger rivers. B-120 Water Supply Index (WSI) products include forecasts with 10, 25, 50, 75, 90, and 99 percent exceedance probabilities.
2. CNRFC daily FNF forecasts⁷ were used only for minor tributaries. Exceedance probabilities were calculated from the available forecast data to match the B-120

⁵ CNRFC data is published on a daily scale, which is summed to generate weekly or monthly values for the purpose of this analysis. Any negative daily FNF values were included as-is in the sums.

⁶ Bulletin 120 (B-120) provides FNF forecasts for the state's major watersheds. It is updated monthly, around the fifth business day of each month, from February to May of each year. The FNF calculation is made using DWR's own database of diversions upstream of unimpaired flow stations. The methodology relies upon DWR's unimpaired flow calculations and did not cross-check DWR's diversion database against the Board's records of reported diversions.

⁷ CNRFC forecasts are presented in the form of 41 different daily FNF "traces." These daily values were summed, and exceedances were calculated from the resulting weekly or monthly forecasts.

format. During the October through January time period when B-120 forecasts are not available, CNRFC daily FNF forecasts will be used for locations that have relied upon B-120 forecasts to date.

If data was available from multiple sources for the same subwatershed (e.g., past data from both CDEC and DWR or forecasted data from both B-120 and CNRFC), both datasets were compared for an overlapping time period to validate that there were no substantial inconsistencies between them. These comparisons did not result in any changes to the assumed hierarchy of data sources described above.

The final water supply dataset used in the Water Unavailability Methodology's supply-demand comparison consists of monthly FNF data. The use of monthly supply forecasts and demand estimates (see section 2.2 below) is assumed to negate the need to consider the water's transit time within the Delta watershed (i.e., it takes less than a month for water to flow from its headwaters to a downstream diverter). Monthly data is also used because there is insufficient real-time data available to evaluate supplies for all streams in the Delta watershed on a daily timestep. Furthermore, daily supply data from sources such as CDEC are less accurate than published monthly values. However, for the purposes of sub-monthly short-term considerations of curtailment suspensions due to precipitation and runoff events, sub-monthly (e.g., weekly) data will be considered to ensure that curtailments are suspended on a time step commensurate with available supplies.

CDEC provides both monthly and daily FNF estimates for many rivers in California. Daily FNF estimates are less accurate than monthly estimates because they are based on less data than is available at the completion of each month (DWR 2015). Therefore, daily CDEC FNF values are not used in the water unavailability graphs described in section 2.4 below. However, daily FNF estimates may be used to determine the most appropriate supply forecast (e.g., 10, 50, 90, or 99 percent exceedance probability) to use when issuing notices of water unavailability or curtailment orders, as described in section 3.1.1 below.

Table 1 and Table 2 below summarize the sources of both past and forecasted supply data for each subwatershed included in the supply dataset for the Sacramento River watershed and the San Joaquin River watershed, respectively. The source information includes the agency from which the data was obtained and the unique identifier for each FNF gage site. Past source data is broken down into the sources of monthly and daily estimates; daily sources with date ranges in Table 1 and Table 2 were summed to generate monthly past data, while those shown without date ranges were used only for periodic forecast monitoring (see section 3.1.1). The monthly past source data also includes the years for which data is available (e.g., WY 1906 to present). For forecasted supply data, information is provided on the resolution, frequency, and format of forecast updates. Subwatersheds where gap-filling procedures were applied (see section 2.1.5 below) are denoted with asterisks, and all gap-filled values are specifically identified as such in the supply dataset.

Table 1. Sacramento River Watershed Supply Data Sources

Subwatershed	Past Supply Data Sources		Forecasted Monthly Supply Data Sources (Agency, Gage, Forecast Resolution)
	Monthly (Agency, Gage, Date Range)	Daily (Agency, Gage, Date Range if applicable)	
Sacramento River at Bend	CDEC SBB: Sacramento River above Bend Bridge, sensor 65 (WY 1906-Present)	CDEC BND: Sacramento River at Bend Bridge, sensor 8	DWR B-120 SRWSI: Sacramento River above Bend Bridge (monthly TAF for current WY in 6 exceedances); when DWR B-120 unavailable, CNRFC BDBC1: Sacramento River-Bend Bridge (daily TCFS for next year in 41 traces)
Stony Creek	DWR UF4: Stony Creek at Black Butte (WY 1922-2014)	CNRFC EPRC1: Little Stony Creek-East Park Reservoir (WY 2015-Present)*	CNRFC EPRC1: Little Stony Creek-East Park Reservoir (daily TCFS for next year in 41 traces)*
Cache Creek	DWR UF3: Cache Creek above Rumsey (WY 1922-2014)	*	*
Upper Feather River	CDEC FTO: Feather River at Oroville, sensor 65 (WY 1906-Present)	CDEC ORO: Oroville Dam, sensor 8	DWR B-120 SRWSI: Feather River at Oroville (monthly TAF for current WY in 6 exceedances); when DWR B-120 unavailable, CNRFC ORDC1: Feather River- Lake Oroville (daily TCFS for next year in 41 traces)

Subwatershed	Past Supply Data Sources		Forecasted Monthly Supply Data Sources (Agency, Gage, Forecast Resolution)
	Monthly (Agency, Gage, Date Range)	Daily (Agency, Gage, Date Range if applicable)	
Yuba River	CDEC YRS: Yuba River near Smartville, sensor 65 (WY 1901-Present)	CDEC YRS: Yuba River near Smartville, sensor 8	DWR B-120 SRSWI: Yuba River near Smartville plus Deer Creek (monthly TAF for current WY in 6 exceedances); when DWR B-120 unavailable, CNRFC HLEC1: Yuba River-Englebright Reservoir (daily TCFS for next year in 41 traces)
Bear River	DWR UF10: Bear River near Wheatland (WY 1922-2014)	*	*
Upper American River	CDEC AMF: American River at Folsom, sensor 65 (WY 1901-Present)	CDEC NAT: Lake Natoma (Nimbus Dam), sensor 8	DWR B-120 SRWSI: American River below Folsom Lake (monthly TAF for current WY in 6 exceedances); when DWR B-120 unavailable, CNRFC FOLC1: American River-Folsom Lake (daily TCFS for next year in 41 traces)
Putah Creek	DWR UF2: Putah Creek near Winters (WY 1922-2014)	*	*

Subwatershed	Past Supply Data Sources		Forecasted Monthly Supply Data Sources (Agency, Gage, Forecast Resolution)
	Monthly (Agency, Gage, Date Range)	Daily (Agency, Gage, Date Range if applicable)	
Upper Sacramento River Valley	DWR UF5: Sacramento Valley West Side Minor Streams (WY 1922-2014)	CNRFC EDCC1: Elder Creek-Paskenta + TCRC1: Thomes Creek-Paskenta (WY 2015-Present)*	CNRFC EDCC1: Elder Creek-Paskenta + TCRC1: Thomes Creek-Paskenta (daily TCFS for next year in 41 traces)*
	DWR UF7: Sacramento Valley East Side Minor Streams (WY 1922-2014)	CNRFC MLMC1: Mill Creek-Los Molinos + DCVC1: Deer Creek-Vina + BKCC1: Butte Creek-Chico (WY 2015-Present)*	CNRFC MLMC1: Mill Creek-Los Molinos + DCVC1: Deer Creek-Vina + BKCC1: Butte Creek-Chico (daily TCFS for next year in 41 traces)*
Sacramento River Valley Floor	DWR UF1: Sacramento Valley Floor (WY 1922-2014)	*	*

*Gap filling procedure used to adjust existing data or fill-in missing data (see section 2.1.5).

Table 2. San Joaquin River Watershed Supply Data Sources

Subwatershed	Past Supply Data Sources		Forecasted Monthly Supply Data Sources (Agency, Gage, Forecast Resolution)
	Monthly (Agency, Gage, Date Range)	Daily (Agency, Gage)	
Chowchilla River	DWR UF20: Chowchilla River at Buchanan Reservoir (WY 1922-2014)	CNRFC BHNC1: Chowchilla River-Buchanan Reservoir (WY 2015-Present)	CNRFC BHNC1: Chowchilla River-Buchanan Reservoir (daily TCFS for next year in 41 traces)

Subwatershed	Past Supply Data Sources		Forecasted Monthly Supply Data Sources (Agency, Gage, Forecast Resolution)
	Monthly (Agency, Gage, Date Range)	Daily (Agency, Gage)	
Upper San Joaquin River	CDEC SJF: San Joaquin River below Friant, sensor 65 (WY 1901-Present)	CDEC SJF: San Joaquin River below Friant, sensor 8	B-120 SJWSI: San Joaquin River inflow to Millerton Lake (monthly TAF for current WY in 6 exceedances); when DWR B-120 unavailable, CNRFC FRAC1: San Joaquin River-Millerton Reservoir (daily TCFS for next year in 41 traces)
Fresno River	DWR UF21: Fresno River near Daulton (WY 1922-2014)	CNRFC HIDC1: Fresno River-Hensley Lake (WY 2015-Present)	CNRFC HIDC1: Fresno River-Hensley Lake (daily TCFS for next year in 41 traces)
Merced River	CDEC MRC: Merced River near Merced Falls, sensor 65 (WY 1901-Present)	CDEC EXC: New Exchequer-Lake McClure, sensor 8	B-120 SJWSI: Merced River below Merced Falls (monthly TAF for current WY in 6 exceedances); when DWR B-120 unavailable, CNRFC EXQC1: Merced River-Exchequer Reservoir (daily TCFS for next year in 41 traces)

Subwatershed	Past Supply Data Sources		Forecasted Monthly Supply Data Sources (Agency, Gage, Forecast Resolution)
	Monthly (Agency, Gage, Date Range)	Daily (Agency, Gage)	
Tuolumne River	CDEC TLG: Tuolumne River-La Grange Dam, sensor 65 (WY 1901-Present)	CDEC TLG: Tuolumne River-La Grange Dam, sensor 8	B-120 SJWSI: Tuolumne River below La Grange Reservoir (monthly TAF for current WY in 6 exceedances); when DWR B-120 unavailable, CNRFC NDPC1: Tuolumne River-New Don Pedro Reservoir (daily TCFS for next year in 41 traces)
Stanislaus River	CDEC SNS: Stanislaus River-Goodwin, sensor 65 (WY 1901-Present)	CDEC GDW: Goodwin Dam, sensor 8	B-120 SJWSI: Stanislaus River below Goodwin Reservoir (monthly TAF for current WY in 6 exceedances); when DWR B-120 unavailable, CNRFC NMSC1: Stanislaus River-New Melones Reservoir (daily TCFS for next year in 41 traces)
Calaveras River	DWR UF15: Calaveras River at Jenny Lind (WY 1922-2014)	CDEC NHG: New Hogan Lake, sensor 8 (WY 2015-Present)	CNRFC NHGC1: Calaveras River-New Hogan Reservoir (daily TCFS for next year in 41 traces)

Subwatershed	Past Supply Data Sources		Forecasted Monthly Supply Data Sources (Agency, Gage, Forecast Resolution)
	Monthly (Agency, Gage, Date Range)	Daily (Agency, Gage)	
Mokelumne River	CDEC MKM: Mokelumne River-Mokelumne Hill, sensor 65 (WY 1901-Present)	CDEC MKM: Mokelumne River-Mokelumne Hill, sensor 8	CNRFC CMPC1: Mokelumne River-Mokelumne Hill (daily TCFS for next year in 41 traces)
Cosumnes River	CDEC CSN: Cosumnes River at Michigan Bar, sensor 65 (WY 1908-Present)	CDEC MHB: Cosumnes River at Michigan Bar, sensor 8	CNRFC MHBC1: Cosumnes River-Michigan Bar (daily TCFS for next year in 41 traces)
San Joaquin River Valley Floor	DWR UF12: San Joaquin Valley East Side Minor Streams + UF17: San Joaquin Valley Floor + UF24: San Joaquin Valley West Side Minor Streams (WY 1922-2014)	CNRFC MPAC1: Mariposa Creek-Mariposa Reservoir + OWCC1: Owens Creek-Owens Reservoir + MEEC1: Bear Creek-McKee Road*	CNRFC MPAC1: Mariposa Creek-Mariposa Reservoir + OWCC1: Owens Creek-Owens Reservoir + MEEC1: Bear Creek-McKee Road (daily TCFS for next year in 41 traces)*

*Gap filling procedure used to adjust existing data or fill-in missing data (see section 2.1.5).

2.1.5 Filling Supply Data Gaps

After the compilation of supply data from the sources listed in section 2.1.4 above, data “gaps” remain for some subwatersheds in the Delta watershed. These gaps include periods of missing past or forecasted data and past or forecasted data that cover only a portion of a subwatershed, as defined for this analysis (see section 2.1.3 above). These gaps were filled using extrapolation and augmentation processes, respectively, to create a complete supply dataset for use in the Water Unavailability Methodology. Technical Appendix A contains descriptions of specific gap-filling processes for each subwatershed where they were applied.

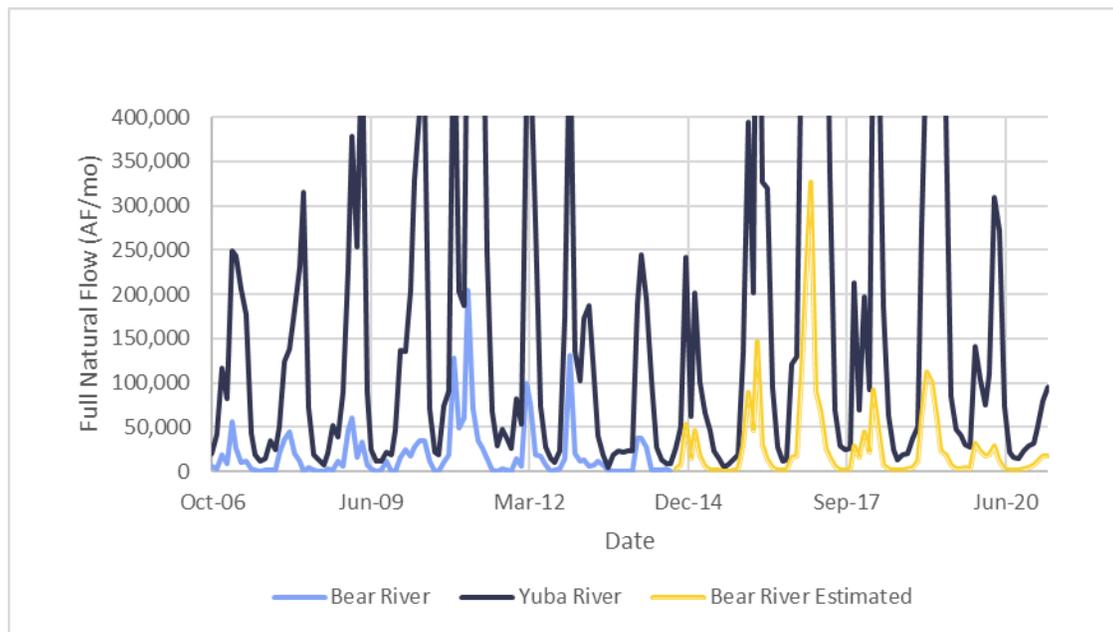
2.1.5.1 *Extrapolation*

To fill missing past or forecasted supply data gaps, overlapping historical data between the subwatershed with missing data (“Stream”) and a nearby watershed with similar

hydrology but more robust data (“River”) were analyzed. The Stream:River ratio was calculated⁸ for each month over this period, and outliers outside three standard deviations from the overall mean were removed. Then, the River FNF estimates were multiplied by the average monthly Stream:River ratio to extrapolate reasonable FNF estimates to fill the gaps in the subwatershed’s dataset.

For example, February 2021 supply data for the Bear River subwatershed was not available from any of the sources listed in section 2.1.4 above. Therefore, prior February FNF estimates for the Bear River subwatershed were compared to the neighboring Yuba River and a ratio of 1:5 was calculated (Bear:Yuba). Missing February data for the Bear River subwatershed was estimated by multiplying the Yuba River subwatershed’s February 2021 FNF estimate by this ratio. Figure 6 below illustrates the Bear:Yuba extrapolation for the period of WY 2014 to present.

Figure 5. Extrapolation Example: Estimation of Bear River FNF (WY 2014–present) Based on Yuba River FNF



2.1.5.2 *Augmentation*

In other areas, past or forecasted data may exist but not represent the entire FNF supply of a watershed that would be expected to be available for diversion. This was the case for watersheds consisting of multiple small tributary streams, in which only some streams have available supply forecasts through CNRFC. DWR’s 2016 Bay-Delta Unimpaired Flow Report includes past FNF estimates that cover all tributaries in these subwatersheds. To increase the “CNRFC” forecasts to approximate a forecast for the entire subwatershed (as the past supply estimates from “DWR” do), overlapping

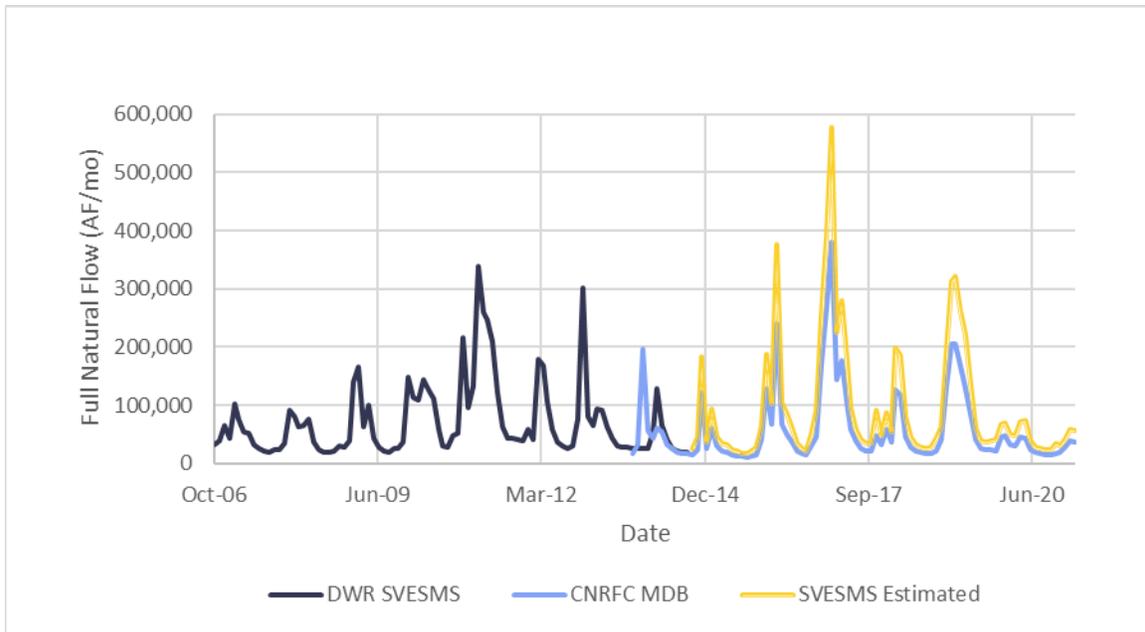
⁸ The Stream:River ratio calculation is analogous to a linear interpolation each month, with the y-intercept always set to zero.

historical data between the two sources were analyzed. The ratio DWR:CNRFC was calculated on a monthly basis over this period, and outliers outside three standard deviations from the overall mean were removed.⁹ Then, the past and forecasted CNRFC values were augmented by multiplying them by the monthly average DWR:CNRFC ratio to produce a reasonable FNF forecast estimate for the subwatershed.

For example, DWR's past (WY 1922–2014) unimpaired flow estimates for the Sacramento Valley East Side Minor Streams (UF7 in DWR's Report), part of the Upper Sacramento Valley subwatershed, include Antelope Creek, Mill Creek, Deer Creek, Big Chico Creek, Butte Creek, and other minor tributaries from Big Chico Creek to the Feather River (DWR 2016). CNRFC only has past (WYs 2013–present) and forecasted FNF data available for Mill, Deer, and Butte Creeks (MDB, in total). By comparing historical FNF values for a period with overlapping data (WYs 2013 and 2014), a monthly relationship ratio can be calculated. In this example, for February, the total Sacramento Valley East Side Minor Streams unimpaired flow was about 1.5 times the MDB supply. Therefore, missing February data in the Upper Sacramento Valley subwatershed would be estimated by multiplying the MDB supply by 1.5. The Upper Sacramento Valley subwatershed also includes supplies from West Side Minor Streams, which were estimated using a similar method with different DWR and CNRFC gages. Figure 7 below illustrates the DWR:CNRFC augmentation to estimate FNF for the Sacramento Valley East Side Minor Streams.

⁹ Because the DWR FNF values include data for all of the CNRFC streams and additional tributaries, the value of the DWR:CNRFC ratio is always greater than one. This ratio calculation is analogous to a linear interpolation each month, with the y-intercept always set to zero.

Figure 6. Augmentation Example: Adjusting CNRFC Data for Mill, Deer, and Butte Creeks (MDB) to Estimate FNF Within Sacramento Valley East Side Minor Streams (SVESMS), a Portion of the Upper Sacramento Valley Subwatershed, Based on DWR’s FNF Estimate for SVESMS



2.1.6 Abandoned Instream Flows

Specific reaches of streams within the Delta watershed may be subject to minimum instream flow requirements due to water right permit/license conditions, Board orders/decisions/regulations, Federal Energy Regulatory Commission (FERC) hydropower license conditions, biological opinion requirements, or private agreements. If these instream flow requirements are met by diverters bypassing flow, these flows are already included in FNF values. If these instream flow requirements are met via releases of stored water, these flows are not captured by FNF calculations. Beyond the reach for which they are intended for instream use, these storage releases are available for diversion, and, therefore, may theoretically be considered alongside FNF values to more accurately represent the amount of water available for downstream diversion unless there are provisions making these flows unavailable for use.

Current data limitations prevent a precise accounting of when instream flow requirements that will be abandoned have been met by stored water. Therefore, to incorporate abandoned instream flows into the supply dataset without artificially inflating estimates of available supply by assuming all abandoned instream flows have been met by releases of stored water, the methodology uses the greater of the FNF value and the abandoned instream flow value to represent the amount of supply contribution of the subwatershed to the respective watershed-wide supply. In other words, it was assumed that if the FNF is greater than the instream flow then instream flow requirement is being met by FNF; conversely, if the instream flow is greater than the FNF then it was

assumed that the instream flow is met at least in part by storage releases which can be considered abandoned below their intended reach. For the purpose of this analysis, all abandoned instream flows whose intended reach ends near the bottom of a subwatershed were considered. If two instream flow requirements exist in series in a watershed, it is possible that the same water could be used to meet both requirements. To avoid double counting of additional supplies, the methodology does not include instream flows that end higher up in the subwatershed. Using data from the State Water Board's Sacramento Valley Water Allocation Model (SacWAM)¹⁰ and Water Supply Effects (WSE) model,¹¹ a total of seven instream flow requirements that would produce abandoned flows were identified. These flow requirements, locations, and amounts are summarized in Table 3 and Table 4 below for the Sacramento and San Joaquin River watersheds, respectively. Water released by the Projects to meet water quality and flow requirements included in State Water Board Decision 1641 is not considered abandoned because those flows are intended to remain instream through the Delta and as outflow from the Delta.

Instream flow requirements are often based on a given water year type and are therefore subject to change. Generally, the requirements listed in Table 3 and Table 4 assume dry or critical conditions, resulting in the lowest possible flow requirements. Higher flow requirements may be used in the methodology if appropriate due to wetter hydrologic conditions during the applicable time period.

¹⁰ SacWAM is a hydrologic and system operations model developed by the Stockholm Environment Institute (SEI) and State Water Board using the Water Evaluation and Planning (WEAP) platform to represent the Sacramento River watershed, Delta, and eastside tributaries to the Delta (the Calaveras, Cosumnes, and Mokelumne Rivers). Information on SacWAM is available at:

https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/sacwam/

¹¹ WSE is a hydrologic and system operations model developed by the State Water Board to represent the lower San Joaquin River and its lower tributaries (the Merced, Tuolumne, and Stanislaus Rivers). Information on WSE is available at:

https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/2018_sed/

Table 3. Sacramento River Watershed Flows Considered to Contribute Abandoned Supplies¹²

Subwatershed		Upper Feather River^a	Yuba River^b	Bear River^c	Upper American River^d	Putah Creek^e	Total
Abandoned Instream Flow (cfs)	Jan.	180	400	10	246	5	841
	Feb.	225	400	10	246	5	886
	Mar.	300	400	10	246	5	961
	Apr.	300	433	25	287	5	1050
	May	300	500	25	350	5	1,180
	Jun.	300	500	25	425	5	1,255
	Jul.	300	250	10	425	5	990
	Aug.	300	250	10	420	5	985
	Sep.	250	250	10	325	5	840
	Oct.	180	400	10	251	5	846
	Nov.	180	400	10	246	5	841
	Dec.	180	400	10	246	12	848

^a Upper Feather River flow requirements are based on FERC project P-2107 license conditions for Upper North Fork Feather River flows below Poe Dam.

^b Yuba River flow requirements are based on State Water Board Decision 1644 requirements at Marysville; this requirement assumes an Extreme Critical water year and does not include the portion of instream flows that are transferred to DWR.

^c Bear River flow requirements are based on FERC P-2997 license conditions for flow below Camp Far West Diversion Dam, not including flows transferred to DWR.

^d Upper American River flow requirements are based on FERC P-2155 license conditions for South Fork American River flows below Chili Bar (assuming a Dry year and including Conditions 1 and 3) and P-2079 requirements for flows on the North Fork American River below the American River Pump Station).

^e Putah Creek flows requirements are based on the 2000 Putah Creek Accord's requirements for outflow to the Toe Drain.

¹² Abandoned flows from Stony Creek were included in the May 12, 2021 version of the methodology but have been excluded from this updated version because, given current hydrology, any abandoned instream flow from Stony Creek is expected to seep into the underlying groundwater basin prior to reaching the Sacramento River and contributing to available downstream supplies.

Table 4. San Joaquin River Watershed Flows Considered to Contribute Abandoned Supplies

Subwatershed		Merced River ^a	Tuolumne River ^b	Total
Abandoned Instream Flow (cfs)	Jan.	60	150	210
	Feb.	60	150	210
	Mar.	60	150	210
	Apr.	60	245	305
	May	60	311	371
	Jun.	15	50	65
	Jul.	15	50	65
	Aug.	15	50	65
	Sep.	15	50	65
	Oct.	38	125	163
	Nov.	75	150	225
	Dec.	75	150	225

^a Merced River flow requirements are based on FERC project P-2179 license conditions for flows below Crocker Huffman Diversion Dam, assuming a dry year type.

^b Tuolumne River flows are based on FERC P-2299 license requirements for flow below La Grange Diversion Dam and assume the San Joaquin River 60-20-20 index is between 1.5 and 2.0 million acre-feet (MAF) from May–September or less than 1.5 MAF October–April.

For simplicity of analysis, the Water Unavailability Methodology does not currently account for whether the abandoned flows included in the supply dataset are foreign in either time or source and not available for use by riparian diverters. On a watershed-wide scale, these additional flows are not significant and would not significantly affect the analysis.

2.2 Demand

The Water Unavailability Methodology evaluates demands for natural and abandoned flows by basis of water right. It is not intended to account for demands for previously stored water, imported supplies, and contractual demands. The analysis to date has relied on reported demand data from the State Water Board’s Electronic Water Rights Information Management System (eWRIMS) computer database.¹³ The State Water Board may also rely upon updated reporting of projected demands for larger users that is provided pursuant to the emergency regulation. Projections of demands during the wet season are expected to be more accurate than historical diversion data for purposes of estimating demands, particularly for storage which historically occurred

¹³ A public version of the eWRIMS database is available at: <https://ciwqs.waterboards.ca.gov/ciwqs/ewrims/EWPublicTerms.jsp>

when flows were present, which does not necessarily reflect demands that would exist this year. The eWRIMS data system contains information regarding water rights, including but not limited to:

- Water right ownership information
- Water right type (e.g., “Appropriative” or “Statement of Diversion and Use”)
- Water right claim type for Statements of Diversion and Use (e.g., “Riparian,” “Pre-1914,” etc.) as reported in the diverter’s Initial Statement of Water Diversion and Use or annual Supplemental Statements of Diversion and Use
- Water right status (e.g., active, inactive, revoked, etc.)
- Authorized diversion seasons and volumes
- Authorized beneficial uses, including both consumptive (e.g., irrigation) and non-consumptive (e.g., hydropower generation) beneficial uses
- Spatial location of PODs,¹⁴ including HUC8 watershed(s)
- Electronically reported water diversion and use information, available on a monthly basis

The eWRIMS database system contains information for various water right types, including both riparian and appropriative water rights. Within the eWRIMS database system, post-1914 appropriative water rights are categorized as “Appropriative,” and other claims of right, which mainly consist of pre-1914 appropriative and riparian claims, are categorized as “Statements of Diversion and Use.” The eWRIMS database system also includes information for other minor water right types, such as water right registrations.

Currently, all diverters whose diversion and use is not reported by a watermaster¹⁵ are required to submit annual reports of water diversion and use (annual reports) to the

¹⁴ The eWRIMS database contains a mapping application to view the spatial location of PODs.

¹⁵ Watermasters are empowered to ensure water is allocated according to established water rights as determined by court adjudications or agreements (DWR 2021f). Watermasters may report the diversion and use of water within their areas of oversight to the Board via various means other than the eWRIMS Report Management System. This data is not currently incorporated into the eWRIMS database except to the extent that individual diverters may have also reported their diversions to the Board via the eWRIMS Report Management System. As a result, diversions in watermaster service areas not also reported individually are not included in the methodology’s demand dataset and did not receive the August 20, 2021 curtailment and reporting orders or prior notices of water unavailability. From the standpoint of diverters included in the

State Water Board electronically through the eWRIMS Report Management System (RMS). The annual reports are mandatory filings that document water diversions and uses made during each month of the previous calendar year, including monthly direct diversion volumes, monthly diversion to storage volumes, and monthly water use volumes. A separate annual report of water diversion and use is required for each water right each year; therefore, a diverter may be required to submit more than one annual report if they hold or claim more than one right. During 2021, reports for the prior calendar year were due by April 1 for appropriative water rights, stockpond certificates,¹⁶ and registrations¹⁷ and by July 1 for groundwater recordations and statements of water diversion and use. Future annual reporting periods and deadlines will change pursuant to Senate Bill 155, signed into law on September 23, 2021.¹⁸ Diversion data contained within annual reports forms the basis for estimates of water demand used in the Water Unavailability Methodology. Water right holders and claimants that divert water under Statements of Diversion and Use also provide information about the water right claim type (e.g., riparian, pre-1914 appropriative, etc.) in annual reports.

For this analysis, water demand is based on the total monthly diversion amount reported for each water right record, including monthly direct diversions and monthly diversions to storage. The demand dataset used in the Water Unavailability Methodology is specifically derived from the reported annual diversion data for calendar years 2018 and 2019, the most current years available. 2020 diversion data was not used for this analysis because the full dataset was not yet available in time to complete

methodology, the omission of diverters within watermaster service areas results in a modest underestimation of demand within the watershed that results in less curtailment to some degree. Data from watermaster reports may be incorporated into the demand dataset in the future after assessment of the extent of duplicative reporting between the reports and the eWRIMS database.

¹⁶ Stockpond certificates are appropriative water rights issued by the State Water Board through 1997 and are limited to diversion of 10 acre-feet (AF) or less per year.

¹⁷ Water right registrations are appropriative water rights issued by the State Water Board through an expedited acquisition process for certain small projects first available in 1989. Water right registrations are available for small domestic use, livestock stockpond use, small irrigation use, and cannabis small irrigation use.

¹⁸ Senate Bill 155 changes the reporting period for all water rights and claims from the calendar year to the water year (October 1 through September 30) and consolidates the reporting deadlines into a single date for all water rights and claims. To transition to this new system, water diversion and use reporting for January 1 through September 30, 2021, will be due for all diverters on April 1, 2022. Thereafter, diversion and use reporting for each water year will be due on February 1 of the subsequent year (e.g., water diversion and use reporting for October 1, 2021, through September 30, 2022, will be due by February 1, 2023).

this analysis, though 2020 data may be used in the future.¹⁹ In some cases demand data are transformed from monthly to weekly values (assuming uniform average demand throughout the month) in order to better reflect the effects of precipitation and runoff events that occur on a shorter time scale in order to inform decision to temporarily suspend curtailments. Appendix A contains additional information about how weekly water demands are estimated using monthly data. As described below, current compliance with new diversion measurement and reporting regulations have not made substantial daily and/or real-time diversion information available for even the largest water users in the Delta watershed.

The methodology primarily relies on 2018 demand data, with additional data from 2019 also available for comparison purposes. 2018 was a below normal water year in both the Sacramento and San Joaquin River watersheds and is assumed to more closely resemble demands during a critically dry year than 2019, which was a wet water year in both watersheds. The reliance on 2018 demand data may underestimate actual demand since demands are likely to be greater during a critically dry year due to drier soil conditions. There are also likely higher losses to evaporation and seepage in a critically dry year. Conservation activities that may be pursued this year may offset higher critical year demands to some degree, but it is assumed that using below normal year demand estimates in a critically dry year is a conservative assumption for the purposes of avoiding issuance of notices of water unavailability or curtailment orders when they may not be warranted.

In addition, 2018 diversion data was used because it is the first drier year for which diversion data is available since updated water right measurement and reporting requirements went into effect with Senate Bill 88 (SB88). Pursuant to regulations implementing SB88, all water right diverters authorized to divert more than 10 AF annually from rivers, creeks, springs, or subterranean streams must comply with measurement requirements. There are three ways to achieve measurement compliance: (1) install, use, and maintain a device capable of measuring the rate of direct diversion; (2) propose an alternative compliance plan; or (3) utilize a measurement method for multiple diverters. SB88 set expectations for both the accuracy of measurement devices as well as the monitoring frequency of the device and included measurement device installation deadlines of January 1, 2018 or earlier.

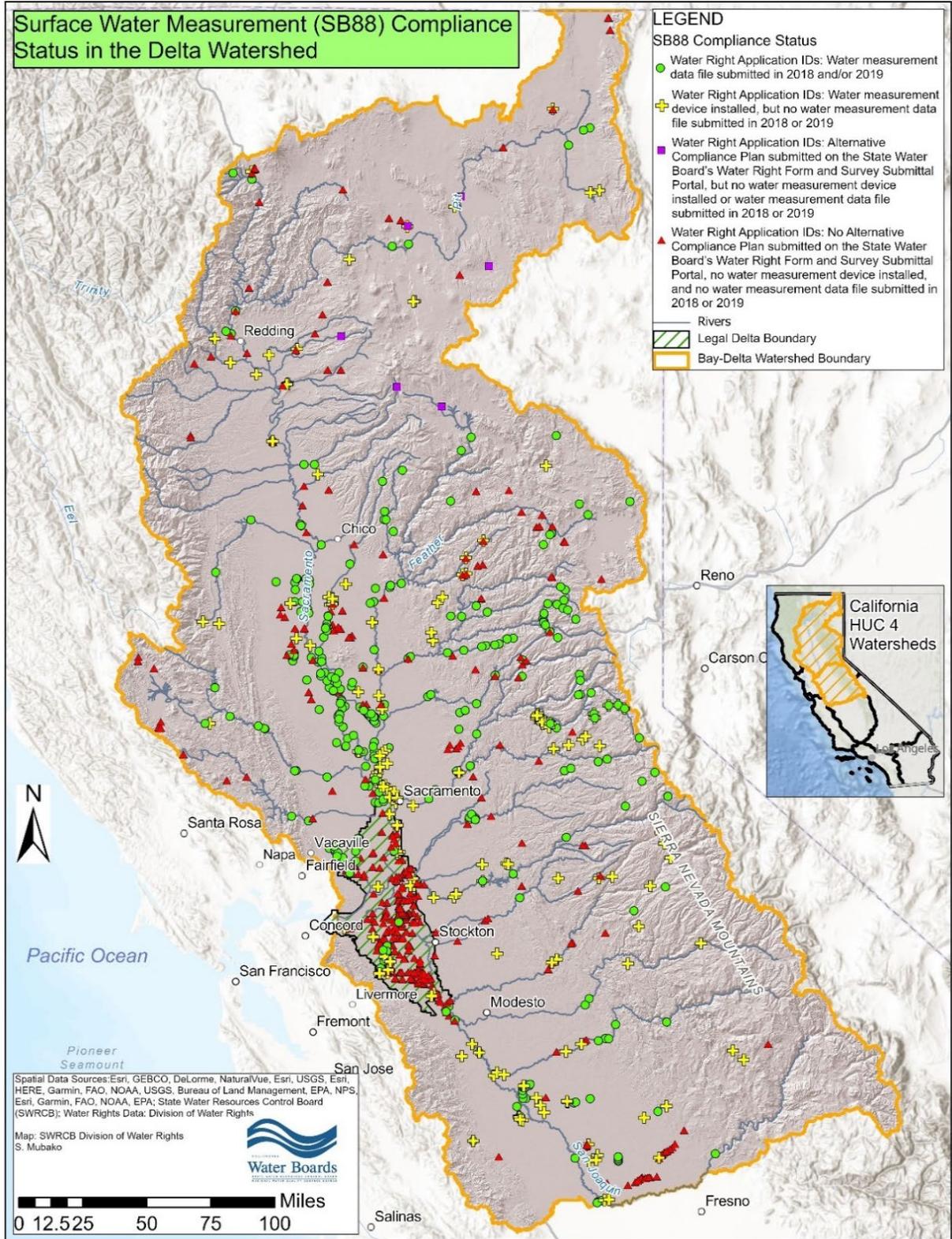
Although the implementation of SB88 has increased the frequency of required reporting for many diverters and may help to improve the quality of reported diversion and use data submitted to the State Water Board, many diverters have not yet achieved full compliance with the water right measurement requirements even though the measuring device installation deadlines have now passed. For example, among the 244 largest consumptive water right records in the Delta watershed located outside of the Legal

¹⁹ Because reporting of 2020 diversion and use information was not due for Statements of Diversion and Use until July 1, 2021, sufficient data were not available in time to complete this analysis but may be used in the future.

Delta, diverters installed a measuring device and submitted a measurement data file for 2018 or 2019 in accordance with SB88 for only 57 percent (140) of the records. Diverters submitted proposed Alternative Compliance Plans pursuant to SB88 for an additional 2 percent (4) of the records. Diverters installed a measuring device but failed to submit a measurement data file for 2018 or 2019 for 27 percent (65) of the records, and did not install a measuring device, submit a measurement data file for 2018 or 2019, or submit a proposed Alternative Compliance Plan for 14 percent (35) of the records. Compliance with the measurement requirements may be even lower for smaller diverters.

Figure 8 below shows the locations of the PODs associated with the largest (those with a 5,000 AF or larger face value or 5,000 AF or larger of reported diversions) consumptive water right records in the Delta watershed and displays their SB88 compliance status as of March 2, 2021.

Figure 7. Surface Water Measurement (SB88) Compliance Status of Large Rights and Claims in the Delta Watershed²⁰



As discussed in more detail below, diversion data contained within annual reports is self-reported and is not systematically verified for accuracy upon submittal. As a result, an internal review and quality control effort was conducted.

2.2.1 Initial Selection of Water Right Records

A subset of the water right records in the eWRIMS database for the Delta watershed were selected for use in the Water Unavailability Methodology based on several criteria:

- Spatial Location: POD(s) located within the Delta watershed²¹
- Water Right Status: Active status types only, thereby excluding inactive-type statuses (e.g., inactive, revoked, cancelled, etc.)
- Water Right Type: “Appropriative” (i.e., post-1914 appropriative, excluding registrations and stockpond certificates) and “Statement of Diversion and Use” (i.e., pre-1914 appropriative and riparian), thereby excluding demands for minor water right types²²
- Beneficial Uses: All beneficial uses except exclusively non-consumptive beneficial uses²³

Water right records with active-type statuses were selected to best approximate current year water demand since it is unlikely that inactive-type statuses (e.g., inactive, revoked, cancelled, etc.) would be reactivated during the current year. Only the demands for water right records with “Appropriative” and “Statement of Diversion and Use” water right types were included because minor water right types, such as

²⁰ Figure 8 currently shows a watershed boundary that includes Goose Lake. The Goose Lake subwatershed will be removed from a future iteration of this report to accurately reflect its exclusion from the Delta watershed for the purposes of this analysis due to disconnection.

²¹ All PODs within the Delta watershed were selected except for those within the Panoche Creek subwatershed. As described in section 2.1.3 above, supply data is not available for this subwatershed; therefore, neither supply nor demand for this area were included in this analysis. PODs within the Goose Lake subwatershed were also excluded due to its assumed disconnection with the Delta watershed.

²² Minor right types, such as stockponds and water right registrations, are included in the current version of the demand dataset but are assumed to constitute a negligible demand. Accordingly, all demand values for these records have been set to zero in the demand dataset.

²³ As discussed in section 2.2.4, demands for storage under non-consumptive water rights and claims have been incorporated into the demand dataset as a wet season adjustment.

registrations and stockponds, were assumed to constitute a negligible amount of the water diversion and use within the Delta watershed.²⁴

Water right records identified as non-consumptive based on their beneficial use type (e.g., hydropower generation, fish and wildlife preservation and enhancement, etc.) were also originally excluded from the analysis. Non-consumptive uses, such as for hydropower generation, may change the timing of flows but do not reduce the amount of supply available unless they result in an interbasin diversion (see section 2.2.8 below). During the dry season, the potential impact of these non-consumptive diversions on the timing of flows is not assumed to be significant given the negligible amount of hydropower-related storage assumed to be occurring during the dry season. As discussed below in section 2.2.4 (Wet Season Demand Adjustments), during the wet season non-consumptive water right records that divert water to storage can make water unavailable for other users for a period of time greater than the temporal resolution of the analysis (e.g., weekly or monthly). Therefore, adjustments were made for the wet season to account for diversions to storage under non-consumptive rights, such as hydropower rights, to accurately reflect where these diversions make water unavailable within a month.

This initial selection of water right records resulted in a demand dataset consisting of approximately 12,000 total post-1914 appropriative water rights (excluding minor appropriative water right types) and statements of diversion and use. Of these, approximately 5,000 were post-1914 appropriative water rights and 7,000 were statements of diversion and use. The demand dataset also includes approximately 4,000 additional minor water rights, such as stockponds and registrations; the demand values for these records is assumed to be negligible and have been set to zero in the demand dataset.

As discussed in section 2.2.4, demands for storage under non-consumptive water rights and claims were later incorporated into the demand dataset as a wet season adjustment. After incorporating these demands, the demand dataset includes approximately 17,000 total water right records, including 6,000 appropriative water rights (excluding minor appropriative water right types), 7,000 statements of diversion and use, and 4,000 additional minor water rights (such as stockponds and registrations).

2.2.2 Initial Quality Control

Water diversion data contained within the eWRIMS database originates from annual reports of water diversion and use electronically submitted by diverters. This self-

²⁴ Exclusion of the demands for these minor right types from the methodology represents a conservative assumption because it underestimates overall demand. These diverters are included in the issuance of notices of water unavailability and curtailment orders in keeping with the principles of the water rights priority system.

reported data is not systematically verified for accuracy upon receipt and contains inaccuracies, inconsistencies, and other errors. Staff conducted a quality control effort following the initial selection of water right records for the demand dataset.

The approximately 12,000 total post-1914 appropriative water rights and statements of diversion and use existing within the demand dataset after initial selection were too numerous to feasibly review in their entirety at this time. Therefore, the scope of the review was narrowed to appropriative water rights with a face value (maximum diversion amount) of 5,000 AF or greater and statements of diversion and use with reported diversions of 5,000 AF or greater in either calendar year 2018 or 2019. This produced a manageable subset of water right records to review within a limited timeframe of approximately 580 records, including approximately 360 post-1914 appropriative rights and approximately 220 Statements of Diversion and Use. These records account for approximately 90 percent of the water diverted in the Delta watershed in 2018 and 2019 but less than 10 percent of the users.

For this narrower set of records, the 2018 and 2019 annual reports of water diversion and use associated with each record were reviewed to identify potential inaccuracies in the diversion data. During the review process, several types of data errors were identified and corrected, if the appropriate correction was discernable.²⁵ These corrections included:

- Correction of diversion data entry and reporting issues, such as incorrect units of measurement and decimal placement errors
- Removal of duplicate diversion values, such as the same diversions reported under multiple water right records
- Removal of non-consumptive diversions improperly appearing as consumptive
- Correction of diversion values as necessary where reported diversion exceeds the water right's face value

During the quality control process, if the appropriate correction was unclear, the affected records were flagged for potential further investigation beyond the information readily available in eWRIMS.

In addition to the records review described above, approximately 100 post-1914 appropriative rights were identified that reported diversions less than 5,000 AF but in excess of the face value of the water right. Most of these diversions are very small. Due to time constraints, these records were not investigated individually. Instead, for

²⁵ Comments provided within the annual reports of water diversion and use often contained critical information to inform these corrections. For example, some diverters stated that their purpose of use is entirely non-consumptive. Others indicated that a particular diversion was fully reported under two or more separate rights (i.e., duplicated).

these rights, the reported diversion amounts within the demand dataset were updated to equal the face value of the right.

Except for the correction to reported diversions in excess of the face value of post-1914 rights, all post-1914 appropriative water rights and statements of diversion and use with a face value or reported use under 5,000 AF were included in the demand analysis without a quality control review. As mentioned above, these records constitute only about 10 percent of the total demand within the Delta watershed.

2.2.3 Additional Quality Control

After conducting the initial quality control review of 2018 and 2019 annual reports for the largest diversions as discussed above, and after applying corrections to rectify errors, some diversion values remained flagged as potentially including incorrect demand information with outstanding issues that could not be resolved without further information. Examples of these issues include:

- Possible duplicate reporting of diversion volumes under multiple water right records where it was not possible to quantify the duplicate reporting amount.
- Possible overreporting of diversion volumes that could not be corrected to reflect a best estimate of the actual diversion volume based on the available information. For example, some annual reports contained information that appeared to indicate that the diversion volume was not measured and, as a result, the maximum diversion amount authorized under the permit or license had been reported.
- Apparent inclusion of both consumptive and non-consumptive uses in the reported diversion amount where it was not possible to quantify the volume of water diverted only for consumptive uses.
- Other potential data reporting issues where an error was detected, but the appropriate correction was unclear.

In these cases, additional information may be needed to determine the appropriate correction or resolve other reporting-related issues. State Water Board staff has contacted numerous water right holders, claimants, or their agents to gather this information. Diversion volumes within the demand dataset were updated according to the responses provided. However, it was not feasible to contact all water right holders, claimants, or agents in all cases where a potential reporting related error was identified or a correction applied to a diversion value. Efforts were prioritized to contact water right holders or agents based on several factors, including reported diversion size and relative level of uncertainty regarding potential reporting-related inaccuracies. In addition, some water right holders, claimants, and agents did not provide responses to inquiries regarding potential reporting related errors. In the absence of additional information provided by the water right holder, claimant, or agent, best estimates of the

actual diversion values were used based on information contained within the annual report of water diversion and use and supplemental information available within the eWRIMS database.

Further refinements to the demand dataset used in the Water Unavailability Methodology may occur. Diverters who are aware of reporting issues, including, but not limited to, the items discussed above, should contact the State Water Board at Bay-Delta@waterboards.ca.gov. In addition, the quality-controlled 2018 and 2019 demand datasets were compared to FNF for each of these years, respectively, at the subwatershed scale (see section 2.1.3 above), and at the Sacramento and San Joaquin River watershed scales to assess the reasonableness of the demand datasets. The demand datasets used in the Water Unavailability Methodology represent the State Water Board's current best estimate of demand for these years based on the available information.

Enhanced reporting information submitted by water users in accordance with the emergency regulation may also inform future refinements to the demand dataset. Pursuant to the emergency regulation, on August 20, 2021, the Board issued curtailment and reporting orders to water right holders and claimants throughout the Delta watershed. The August 20, 2021 curtailment and reporting orders require monthly reporting of water diversion and use for water rights and claims in the Delta watershed that have a face value or recent annual reported diversion volume of 5,000 acre-feet or greater. For these water rights and claims, diverters are required to provide monthly reports of water diversion and use information for prior months and monthly reporting of projected water demand by completing the Delta Watershed Enhanced Reporting of Actual Diversions and Projected Demand Form (Enhanced Reporting Form). The first and second Enhanced Reporting Forms were due September 17 and October 10, respectively, and subsequent Enhanced Reporting Forms will be required monthly through July 2022 unless otherwise specified by the State Water Board. Staff are currently evaluating the water diversion and use information submitted in the Enhanced Reporting Forms, and the demand dataset may be updated accordingly at a later date based on this information.

2.2.4 Wet Season Demand Adjustments

Prior versions of the demand dataset were intended primarily to identify when available data indicated that natural and abandoned water supplies were unavailable for water users in the Delta watershed during the dry season. This section describes adjustments to the demand dataset for application during the wet season.

As noted in section 2.2.1, water right records identified as non-consumptive based on their beneficial use type (e.g., hydropower generation or fish and wildlife preservation and enhancement) were previously excluded from the analysis due to its prior focus on dry season operations. During the dry season, these non-consumptive uses of water do not typically significantly alter the timing of flows or change the amount of water

available downstream. However, during the wet season, water right records with non-consumptive beneficial use types, such as for hydropower generation, can significantly alter the timing of flows when water is diverted to storage. These diversions can make water unavailable for diversion by other users within a month. The demand dataset has now been adjusted to incorporate approximately 500 additional post-1914 appropriative water rights and statements of diversion and use with non-consumptive beneficial use types that were originally excluded from the demand dataset (see Appendix B and the Water Unavailability Methodology Spreadsheet). For these records, the diversion values contained in the demand dataset reflect only diversion to storage volumes. Non-consumptive direct diversions do not alter the timing of flows or change the amount of water available downstream and are not included in the demand dataset.

A wet season adjustment quality control review effort was conducted following selection of the additional water right records with non-consumptive beneficial use types. Similar to the previous quality control review effort, the scope of the review was narrowed to produce a manageable subset of records to review within a limited timeframe. For this quality control review, post-1914 appropriative water rights and statements of diversion and use with a reported diversion to storage volume of 5,000 AF or greater in either 2018 or 2019 were selected. Approximately 75 records were included in this quality control review effort. The 2018 and 2019 annual reports of water diversion and use for these records were reviewed to identify and correct potential inaccuracies in the diversion to storage data.

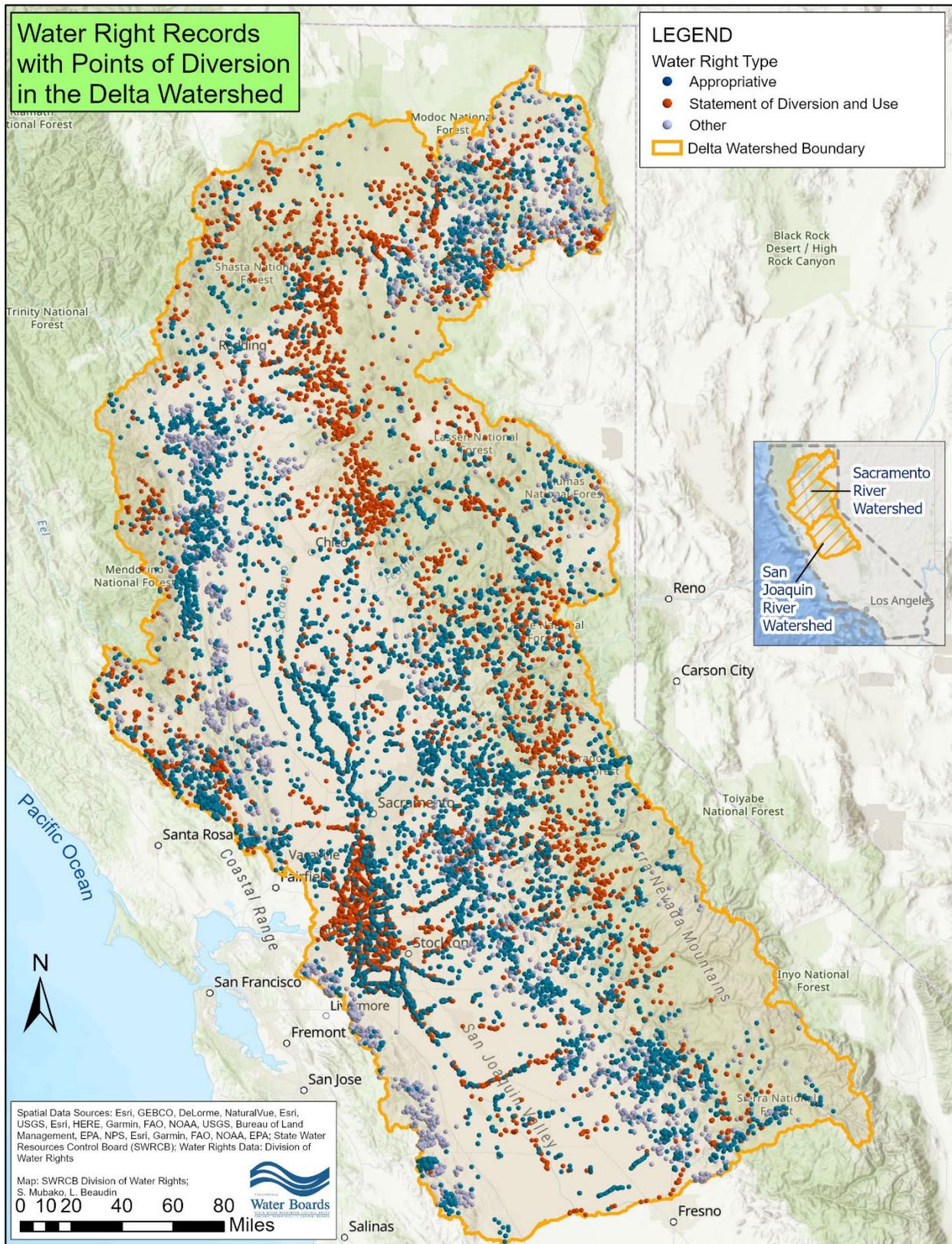
In addition, this quality control review addressed occurrences of duplicative reporting of diversions to storage under overlapping consumptive and non-consumptive use rights. Staff compiled 2018 and 2019 reported diversion to storage volumes for all water right records, including those associated with consumptive uses, held by the same primary owners of the approximately 75 largest water right records with non-consumptive beneficial use types. When identical diversion to storage volumes were reported for consumptive and non-consumptive water right records held by the same primary owner and associated with the same location, the reported diversion to storage volumes were assumed to be duplicative and the demand value for the non-consumptive water right record was changed to zero to avoid overreporting of diversion to storage volumes. Staff also reviewed information regarding overlapping reporting between consumptive and non-consumptive water right records submitted in the September 2021 Enhanced Reporting Forms, which were required pursuant to the emergency regulation. Staff's review of information regarding overlapping water rights and claims contained in the September 2021 Enhanced Reporting Forms identified additional occurrences of overlapping reporting of diversions under consumptive and non-consumptive water right records. In these cases, the demand value for the non-consumptive water right record was changed to zero.

Further refinements to the demand values for non-consumptive use rights included in the demand dataset may occur. Diverters who are aware of reporting issues, including,

but not limited to, overlapping reporting of diversions to storage between consumptive and non-consumptive water right records, should contact the State Water Board at Bay-Delta@waterboards.ca.gov.

Points of diversion for all water right records included in the demand dataset at this time are shown in Figure 9 below. The figure has been updated since the August 20, 2021 version of this report and now includes points of diversion for the approximately 500 non-consumptive water right records described above. Figure 9 displays points of diversion for approximately 17,000 water right records in the Delta watershed, including 6,000 Appropriative water rights, 7,000 Statements of Diversion and Use, and 4,000 additional minor rights (e.g., stockponds and registrations).

Figure 8. Water Right Records with Points of Diversion in the Delta Watershed



2.2.5 Disaggregation of Statements of Diversion and Use

The May 12, 2021 draft and June 15, 2021 version of the methodology were developed to identify when available data indicates that natural and abandoned water supplies are unavailable for post-1914 appropriative water users in the Delta watershed. These prior versions were not intended to identify when water supplies are unavailable for pre-1914 appropriative and riparian claims, and prior versions of the demand dataset did not separate Statements of Diversion and Use into categories. Instead, these earlier versions grouped water demand for all Statements of Diversion and Use under a single demand category with the same assumed senior priority rank.

The Statements of Diversion and Use have now been disaggregated into several assigned categories and have been assigned priority dates. This refinement provides for the forecasting of water unavailability for pre-1914 appropriative and riparian claims. Statements of Diversion and Use were assigned a category based on the water right claim types reported by diverters in Initial Statements of Water Diversion and Use and in 2018 and 2019 annual reports. This user-submitted information was not reviewed for accuracy as part of this analysis but represents the best information currently available. This information may be updated based on additional information, including information submitted by water right claimants through the emergency regulation process.

The following Statement of Diversion and Use categories are currently included in the demand dataset: Riparian, Pre-1914, “Riparian or Pre-1914,” Reserved, Other, and Unclassified. The vast majority (over 95 percent) of the Statements of Diversion and Use included in the demand dataset were categorized as Riparian, Pre-1914, or “Riparian or Pre-1914.” For the purposes of assigning priority within the Methodology, those water right records categorized as “Riparian or Pre-1914” or “Other” were assumed to have the more senior priority of right, i.e., Riparian.²⁶

Technical Appendix B further describes the process used to categorize and assign priority dates to Statements of Diversion and Use.

2.2.6 Demand Aggregation by Subwatershed

The Water Unavailability Methodology requires that both the supply and demand data be aggregated to a common spatial resolution for comparison purposes. The supply

²⁶ For the purpose of curtailment, diverters who claim both a riparian and a pre-1914 appropriative water right to serve the same place of use (or have reported diversion pursuant to a combination of such unadjudicated claims among their Initial Statement of Water Diversion and Use and their 2018 and 2019 annual reports) are treated solely as riparian claimants. Assuming, solely for curtailment determinations, that the diverter has a valid riparian right, they may continue to divert under that right, subject to its restrictions, unless and until the riparian right is curtailed. In nearly all scenarios, this represents a conservative simplifying approach within the Methodology, because riparian rights are assumed to be senior to all appropriative rights, absent specific evidence to the contrary.

data is generally only available at the HUC8 watershed scale or larger, while the demand data includes both the HUC8 watershed and the precise spatial location (latitude and longitude) of each POD. For the purpose of this analysis, demand values within the demand dataset were aggregated at the same subwatershed scale as supply values within the supply dataset (see section 2.1.3 above). The subwatershed assignments of specific PODs, such as those located near Folsom, Oroville, and Friant Dams, were reassigned on a case-by-case basis within the demand dataset to better fit the demand to the subwatershed from which it draws supply.

All of the PODs of most water right records are geographically located within a single subwatershed. In these instances, all of the demand associated with these rights is attributed to that subwatershed. Sixty-five water right records in the Delta watershed have PODs that span multiple subwatersheds. Of these, 11 are Project water rights, which frequently have PODs upstream at the major storage reservoirs, downstream on major tributaries, and within the Legal Delta. As described in section 2.2.7 below, the Water Unavailability Methodology treats these demands differently because of the unique circumstances of the Projects' diversions. For the 54 remaining non-Project rights that have PODs within multiple subwatersheds, the total reported diversion for each water right record was split among the applicable subwatersheds based on the proportion of the total active direct diversion PODs located within each subwatershed. For example, if a water right record had 3 associated PODs, one of which was located within the Sacramento Bend subwatershed and 2 within the Upper Sacramento Valley subwatershed, one-third of the total demand for the water right would be attributed to the Sacramento Bend subwatershed and two-thirds to the Upper Sacramento Valley subwatershed. An apportionment of demand based on the amount diverted at each POD is not possible at this time because water diversion and use information is typically reported by water right and not for individual PODs.

2.2.7 Project Demands

The Projects divert and store water for use by contractors both within and outside of the Delta watershed. These contractors include contractors that do not have their own basis of right and contractors that have their own bases of water right that may also receive supplemental contract supplies (referred to as settlement contractors). Settlement contractors entered into contracts with the Projects to resolve water right disputes related to construction of the Projects. These contracts are not synonymous with the underlying rights but are instead negotiated agreements. Project contractors that do not have their own water rights include CVP service contractors and SWP Table A contractors. CVP service contracts and SWP Table A contracts include contracts for use within the Delta watershed and use outside of the Delta watershed. Diversions by the Projects for uses outside of the Delta watershed are subject to area of origin protection pursuant to the Water Code.²⁷ This protection prohibits the Projects from

²⁷ Wat. Code, §§ 11128, 11460.

diverting for purposes of exporting natural and abandoned flows needed for uses within the Delta watershed.

In recognition of area of origin protection, Project demands were assumed to have the lowest priority date among Delta watershed rights. While some of the Projects' diversions serve inbasin purposes that are not subject to area of origin protection, this summer all of these uses are expected to be met with previously stored water due to the lack of significant inflow and other Project obligations. Adjustments will be considered for the wet season to account for the priority of inbasin uses. However, any changes to the priority dates are not expected to have a significant effect on the analysis given the Projects' relatively junior water right priority and the likelihood that curtailment will not be in place when Project direct diversions are occurring for inbasin uses. In addition to recognizing area of origin protection, identifying Project demands as junior to all others ensures that any duplicate reporting between the Projects and their various settlement contractors that have their own underlying water rights or claims of right does not inflate demands in a manner that materially affects the analysis. The exception to this approach is for New Melones Project water rights (A014858A and A014858B). Since New Melones water is not authorized for export out of the Delta watershed, these demands are assumed to be met in accordance with the original priority date of the rights.

Generally, the Projects will not be diverting natural and abandoned flow and will be releasing previously stored water under conditions when notices of water unavailability or curtailment orders would be issued. The responsibility to meet water quality and flow requirements effectively results in curtailment of Project water rights without any further action. Accordingly, while notices of water unavailability or curtailment orders may still be issued to the Projects, such notices or orders are unlikely to have a material effect.

2.2.7.1 Trinity River Imports

Several consumptive water rights associated with the CVP Trinity River Division (A005628, A015374, A015375, A016767, and A017374) have PODs within the Delta watershed, but the water they divert originates from the Trinity River watershed. These water rights and correlating diversion data were removed from the Delta watershed demand dataset for analysis because the water associated with these diversions is imported to the Delta watershed and does not impact supply forecasting for the watershed.

2.2.7.2 Settlement Contractor Demands

As discussed above, there are various water users in the Delta watershed that have settlement contracts with DWR and Reclamation that provide a contractual entitlement of a certain supply to these users. These contracts are intended to satisfy these users' underlying rights and to provide supplemental supplies. Because these users have both their own water rights or claims of right for which they likely report use and contractual

supplies for which DWR and Reclamation report use, there may be overlapping reporting of demands.

For the purpose of this analysis, it is assumed that most settlement contractors, with the exception of the Exchange Contractors on the San Joaquin River (see below discussion), have demands for natural and abandoned flows in accordance with their water use reports and that these users will take water pursuant to their senior water rights first if it is available. The fact that the supply may not be available at the senior priority of right or claim of right is not assumed to diminish the demand. Accordingly, settlement contractors may receive notices of water unavailability or curtailment orders under their own water rights and would then need to rely upon contractual supplies to the extent those supplies are available.

Sacramento River and Feather River Settlement Contractor Demands

As a result of the very dry hydrologic conditions this year, allocations to Sacramento River and Feather River settlement contractors under their contracts during the contract period have been reduced to approximately 75 and 50 percent, respectively. However, these reductions are not assumed under this analysis because the contracts are not synonymous with the underlying right or claim. For example, Sacramento River settlement contract amounts total 2.1 million acre-feet (MAF) but reported use under these contractors' underlying water right claims is closer to 1.4 to 1.6 MAF (which is close to 75 percent of the contract amount). Also, these groups of users have different priorities of rights and include a combination of pre-1914 and post-1914 rights (e.g., over 600 thousand acre-feet of Sacramento River settlement contractors' reported use in 2018 occurred under post-1914 claims of right). Accordingly, it is not clear which rights' demands should be reduced.

Exchange Contractors

The Exchange Contractors receive replacement supplies exported from the Delta in exchange for use of water from the San Joaquin River under the Exchange Contractors' underlying rights as part of settlement contracts related to the development of the Friant Project by Reclamation. Accordingly, all Exchange Contractor demands are assumed to be met with previously stored CVP supplies since the Exchange Contractors do not use water from the San Joaquin River under their underlying water right claims unless they are shorted supplies under their Exchange Contracts. If shortages occur the assumptions in the methodology will be adjusted to account for those shortages and the resulting demand for San Joaquin River water under the Exchange Contractors' claimed water rights.

2.2.8 Interbasin Diversions (Yuba-Bear and Drum-Spaulding)

Non-consumptive uses are generally not included in demand estimates under the methodology at this time. However, the May 12, 2021 draft methodology identified that adjustments were planned to be made to account for the interbasin diversions that occur from the Yuba River watershed to the Bear and American Rivers as part of highly

complex hydroelectric project operations under Pacific Gas and Electric Company's (PG&E) Upper Drum-Spaulding Hydroelectric Project and Lower Drum Hydroelectric Project and Nevada Irrigation District's (NID) Yuba-Bear Hydroelectric Project. Under Upper Drum-Spaulding and Yuba-Bear hydroelectric project operations, water is exported from the Yuba River watershed to the Bear River via the South Yuba Canal and the Drum Canal.

Since May 12, 2021, adjustments to the demand dataset to account for interbasin diversions between the Yuba River watershed and Bear River watershed were considered. However, a review of information contained within the applicable PG&E and NID water right records indicated that diversions through the South Yuba Canal and Drum Canal are already reported under water right records located in the Yuba River subwatershed. In addition, it appears that previously stored water accounts for a large portion of the water transferred from the Yuba River to the Bear River during the summer months. Therefore, adjustments were not applied to account for the interbasin diversions at this time. Adjustments will be considered for the wet season and based on updated demand data that may be submitted pursuant to an emergency regulation.

2.2.9 Accretions and Return Flow Estimates

Accretions in the valley floor during the dry season are primarily due to return flows. In recognition that only a portion of diversions are actually consumptively used due to return flows from irrigation and, to a lesser extent, municipal uses, a return flow factor was applied to diversion values within the Delta watershed demand dataset. Return flows are water that is diverted and returned to the river as part of agricultural and urban uses. Agricultural return flows include operational spills from canals, flow through and draining of rice paddies, and drainage from other agricultural fields. The volume of return flows from agriculture varies based on type of use, crop type, location, soils, and season. Urban return flows are primarily comprised of treated effluent from wastewater treatment plants. Natural depletions due to stream-groundwater interaction and demand by riparian vegetation are difficult to estimate and not accounted for in the methodology, which represents a conservative assumption that may overestimate water availability and reduce curtailments.

Out of the hundreds of return flow sources in the Delta watershed, the rates and volumes of most are unknown and only a handful have measurement gages. Rates of return flow can be estimated using models developed to simulate surface and groundwater hydrology. Models that have been developed for the Delta watershed include SacWAM, CalSim, C2VSIM, and regional water budgets developed by DWR. Of these models, CalSim 3 is the most complete hydrologic simulation model of the Sacramento and San Joaquin River watersheds. SacWAM provides detailed representations of the hydrologic processes including return flows in the Sacramento River watershed but does not include a representation of the San Joaquin River watershed. CalSim 3 return flow rates show similar trends to SacWAM results for the Sacramento River watershed. DWR's surface-groundwater model, C2VSIM fine grid,

may provide useful information on return flows with future calibration efforts, but at this time the surface hydrology does not correspond well with observed data during dry periods. DWR's regional water budgets may also provide useful estimates of return flows in the future, but at this time they are not available.

CalSim 3 includes simulations for the 1922–2015 period. For the purpose of estimating return flows for the methodology, results for water year 2014 were analyzed because it is a recent year out of the period of simulation that has hydrology that most closely matches current and forecasted conditions for 2021. A review of CDEC data from 2014 and this year at locations dominated by return flows indicates that these return flow estimates are likely much higher than is actually occurring this year. As such, use of the CalSim 3 data is considered a conservative assumption. This assumption is planned to be further evaluated to determine if changes should be made in the future.

The CalSim 3 results, summarized in Table 5 and Table 6 below, show an increasing return flow as a percent of diversion after May continuing throughout the remainder of the irrigation season in the Sacramento River watershed and generally lower and more constant return flows in the San Joaquin River watershed. The increasing proportion of return flow in the Sacramento River watershed is primarily due to decreased diversions in August and September and draining of rice fields in September. Given the extreme dry conditions this year and changes in rice acreage this year, return flow assumptions in September and to some extent August may be high representing a conservative assumption that would reduce curtailments. Urban return flows remain relatively constant throughout the irrigation season. In the San Joaquin River watershed, agricultural and urban return flows remain relatively constant throughout the summer.

Table 5. CalSim 3 Results of Monthly Diversions and Return Flows for Sacramento River Watershed, May–September 2014

Month	Diversions (TAF)	Return (TAF)	Percent Return
May	829	320	39%
June	845	161	19%
July	875	184	21%
August	660	187	28%
September	339	324	96%
October	331	121	37%
November	322	156	49%
December	228	147	65%
Annual Average	4,990	2,093	43%

Table 6. CalSim 3 Results of Monthly Diversions and Return Flows for San Joaquin River Watershed, May–September 2014

Month	Diversions (TAF)	Return (TAF)	Percent Return
May	313	75	24%
June	362	76	21%
July	403	85	21%
August	331	68	21%
September	216	54	25%
October	191	39	20%
November	78	25	32%
December	54	28	51%
Annual Average	2,566	605	24%

Spatially, most diversions and return flows occur in the Sacramento and San Joaquin Valley regions. Accordingly, return flow factors were only applied to demands in the Sacramento Bend, Upper Sacramento Valley, Sacramento River Valley Floor, and San Joaquin River Valley Floor subwatersheds.

During the wet season, diversion to storage may account for a significant proportion of total diversions. Because diversions to storage do not produce return flows until stored water is released and rediverted for consumptive use, demands for diversion to storage should not be scaled by a return flow factor. At the time of publication of this report, the demand data have not been fully disaggregated between diversions to storage and direct diversions. Therefore, at this time, any diversions to storage in the Sacramento Bend, Upper Sacramento Valley, Sacramento River Valley Floor, and San Joaquin River Valley Floor subwatersheds are still scaled by return flow factors during the wet season. Because this assumption results in an overall reduction in demand, it is conservative in that it reduces the overall level of curtailment. Future updates to the demand dataset, including potential use of enhanced reporting data, may allow elimination of return flow factors for all diversions to storage.

Likewise, in September 2021, the Board received comments that suggested that return flow values may be too high. Reclamation conducted field measurements in the Colusa Basin Drain and Sutter Bypass to validate the proposition that return flows from rice fields in the Sacramento River watershed are lower than would be expected in a typical year. Nonetheless, at this time it is not clear how to better account, in advance of reliable final data that can usually only be definitively determined after-the-fact, for differences between actual and assumed return flows adequately to support a change to the methodology without further public discussion. In addition, the State Water Board received comments from Reclamation indicating that Reclamation believes it retains the rights to its return flows. These subjects were discussed in the technical workshop held

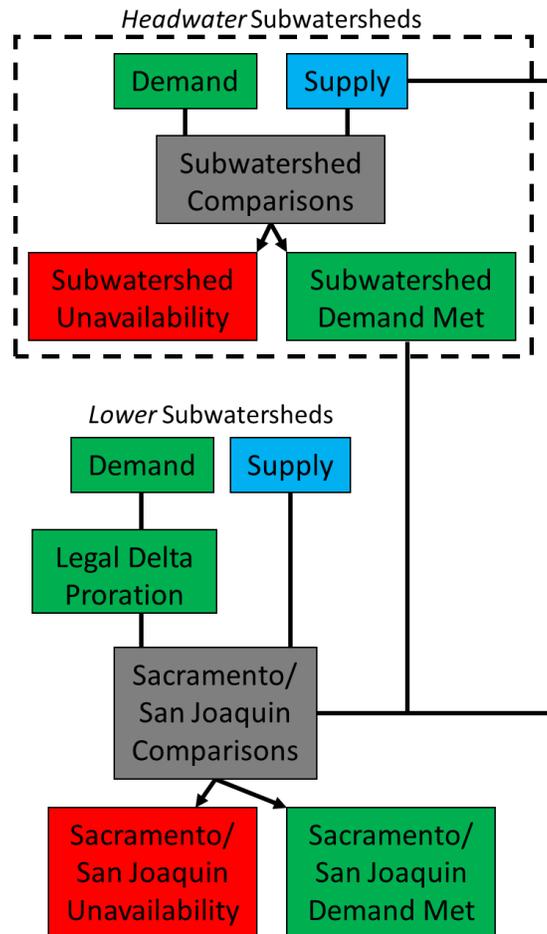
October 20, 2021. At the time of publication of this report, insufficient technical information has been provided to support changes to return flow assumptions or to adequately account for return flows resulting from delivery of water previously stored by Reclamation. Any further information provided prior to the next irrigation season may be used to inform future changes to return flow assumptions.

2.3 Adjustments to the Supply and Demand Datasets

2.3.1 Elimination of Unmet Demand

A significant improvement over the water unavailability methodology used in the previous drought is the implementation of a more granular analysis, evaluating supply and demand on both a subwatershed level (e.g., a single tributary like the Feather River) and watershed-wide level (the Sacramento and San Joaquin River watersheds). The watershed-wide analysis also includes water rights that divert from within the Legal Delta (see section 2.3.3 below). This allows for water unavailability to be determined based on physical supplies within a headwater stream and for the accounting of senior demands that may have priority to divert that supply further downstream. Supply and demand are compared at a subwatershed level for those subwatersheds that are not downstream of any other subwatershed. Demands within these “headwater” subwatersheds can only be met by supply originating within the subwatershed itself. Figure 10 below is a schematic showing how this analysis was performed using the supply and demand data previously described.

Figure 9. Schematic of Supply and Demand Analysis at the Subwatershed and Watershed Levels



As shown in Figure 10, supply and demand are first compared within headwater subwatersheds. While supplies from headwater subwatersheds are considered available to meet downstream demands in the larger Sacramento or San Joaquin River watershed analyses, only headwater subwatershed demand that is able to be met by available supply in the headwater subwatershed is considered in the watershed analysis.

The headwater subwatersheds in the Sacramento River watershed include the Sacramento River and tributaries above Bend, Stony Creek, Cache Creek, Putah Creek, the Upper Feather River above Oroville Dam, Yuba River, Bear River, and the Upper American River above Folsom Dam (see Figure 5). The headwater subwatersheds in the San Joaquin River watershed are the Chowchilla River, Upper San Joaquin River above Friant Dam, Fresno River, Merced River, Tuolumne River, Stanislaus River, Calaveras River, and the Cosumnes River. Figure 11 below shows a schematic of the subwatersheds previously mapped in Figure 5. A small number of rights in the headwater Putah Creek, Stanislaus River, Calaveras River, Mokelumne

River, and Cosumnes River subwatersheds which lie within the Legal Delta were excluded from the headwater subwatershed analysis and included only in the Sacramento and San Joaquin watershed-wide analyses, as they have access to water from both the Sacramento and San Joaquin Rivers (see section 2.3.3 below).

Lower subwatersheds are defined as such because they contain demands that can be met by supplies from outside tributaries (the headwater subwatersheds). The Upper Sacramento River Valley and Sacramento River Valley floor subwatersheds are considered lower watersheds because demands within them may be met from the mainstem of the Sacramento River flowing in from the Sacramento River at Bend. Similarly, the San Joaquin River Valley Floor includes demands on the mainstem of the San Joaquin River that can be met by inflow from the Stanislaus, Tuolumne, Merced, and Upper San Joaquin River subwatersheds.

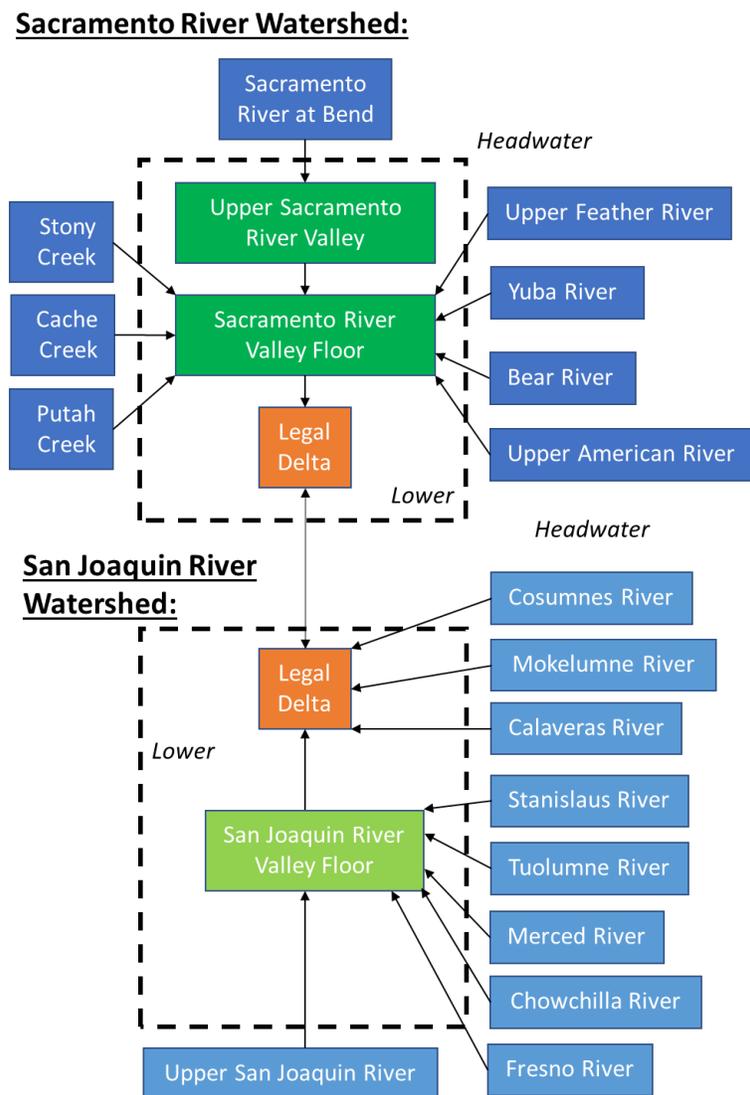
Some headwater subwatersheds in the San Joaquin River watershed were delineated based on a combination of smaller HUC10 watersheds because their HUC8 boundaries (see section 2.1.3 above) contain demands that are not met exclusively by supplies from within the subwatershed. The Chowchilla River HUC8 (Middle San Joaquin-Lower Chowchilla) also includes minor east side tributaries and the mainstem of the San Joaquin River from Friant Dam to the confluence with the Merced River, so the Chowchilla River headwater subwatershed was instead defined as a combination of two HUC10s representing only the Chowchilla River drainage (Upper Chowchilla River and Lower Chowchilla River). Though they fell outside these boundaries, PODs within the Fresno River HUC8 which divert from Ash Slough were also considered to be within the Chowchilla headwater subwatershed. The Fresno River HUC8 includes diversion points on the Eastside Bypass that are supplied by San Joaquin River flood flows, so the Fresno River headwater subwatershed was instead defined as a combination of three HUC10s (Upper Fresno River, Coarse Gold Creek, and Middle Fresno River). PODs diverting from lower Dry Creek, the mainstem of the Fresno River between Road 16 and the Eastside Bypass, and the mainstem of the Fresno River between the Road 9 diversion structure and the confluence with the San Joaquin River were also assumed to be within the Fresno River headwater subwatershed. Finally, the Mokelumne River HUC8 (Upper Mokelumne) includes demands on the mainstem of the San Joaquin River within the Legal Delta, so the Mokelumne River headwater subwatershed was instead defined as a combination of five HUC10s (Upper Mokelumne River, South Fork Mokelumne River, Middle Fork Mokelumne River, Upper North Fork Mokelumne River, and Lower North Fork Mokelumne River). PODs diverting from the mainstem of the Mokelumne River from Camanche Reservoir to the confluence with Dry Creek were also considered as within the Mokelumne River headwater subwatershed.

Previous versions of this report derived the delineation of the Mokelumne River, Chowchilla River, and Fresno River subwatersheds from the HUC8 boundaries, which resulted in their classification as lower subwatersheds. By deriving the delineations from the HUC10 boundaries as described above, these subwatersheds are able to be

treated has headwater subwatersheds within the analysis; thereby enabling a headwater subwatershed-level analysis to be conducted in these areas. As is discussed in more detail below, this enables any unmet demand from these areas to be eliminated from the wider watershed-level analysis of which the former lower reaches are now a part.

The Legal Delta is not a distinct subwatershed; it is a category of rights within several subwatersheds which have access to water from both the Sacramento and San Joaquin Rivers (see section 2.3.3 below).

Figure 10. Subwatersheds Schematic



Diverters within headwater subwatersheds whose demand cannot be physically met by the supply available within those subwatersheds may receive notices of water unavailability or curtailment orders based on the headwater subwatershed-level

analysis. In addition, if demand in a headwater subwatershed exceeds the available supply, the excess demand is eliminated from the larger watershed-wide analysis. As a result, demand that cannot be met by physically available supplies is not “charged against” supplies from elsewhere in the Delta watershed.

The evaluation of water unavailability at the headwater subwatershed scale is only part of the evaluation of water unavailability. Though water may be physically available within a headwater subwatershed, it may be needed to meet the demand of senior users downstream that may have the right to some of the water originating in the headwater subwatershed. This broader unavailability is shown in the watershed-wide analysis for the Sacramento and San Joaquin River watersheds.

2.3.2 Treatment of Riparian Demands and Elimination of Supply and Demand in Disconnected Headwater Subwatersheds

The Water Unavailability Methodology does not currently specifically evaluate water unavailability for individual riparian claimants unless there is no flow available.²⁸ In times of shortage, riparian rights provide for sharing of those shortages. Given the scale and complexity of the Delta watershed, the methodology does not yet fully evaluate how that sharing should occur. However, the methodology can be used to evaluate general quantities of water that may be unavailable for riparian claimants and when riparian claimants should implement measures to address those shortages. In the future, refinements to the methodology may be made to further address water unavailability for riparian claimants.

If the headwater subwatershed analysis indicates that the total demands of riparian claimants exceed the available supply in a particular headwater subwatershed, the headwater subwatershed’s supplies and demands are removed from the watershed-wide analysis for that month. In other words, the methodology assumes that the given stream would not have continuity with the larger Delta watershed and would be considered “disconnected” due to fulfillment of the local senior water right demands.

The Water Unavailability Methodology Spreadsheet, available on the State Water Board’s Delta Water Unavailability Methodology webpage, contains a table in the ‘Supply Final’ tab which summarizes which headwater subwatersheds were assumed to be disconnected from the Delta watershed in specific months as a result of this analysis.

2.3.3 Proration of Legal Delta Demands

Diverters with appropriative water rights with points of diversion within the Legal Delta (as defined in Water Code section 12220) may have access to water supplies entering the Delta from both the Sacramento and San Joaquin River watersheds. To account for

²⁸ These demands are assumed to be senior in priority to all other demands for the purposes of the methodology. As discussed above, there may be instances where a pre-1914 appropriative right is senior to a riparian. In those cases, adjustments can be made.

this, appropriative demands within the Legal Delta were prorated between the two watersheds based on the monthly proportion of connected supply available (see section 2.3.2 above) from each watershed. For example, if the Sacramento River watershed contributes 80 percent of the water supply reaching the Legal Delta in a given month, 80 percent of Legal Delta appropriative demand is charged against Sacramento River watershed supply for that month and 20 percent is charged against San Joaquin River watershed supply. The proration of Legal Delta appropriative demands is only applicable to the assessment of water unavailability at a watershed-wide scale and does not impact the assessment of water unavailability at the headwater subwatershed scale. Water rights and claims with points of diversion within the Legal Delta that claim only appropriative water rights will only receive notices of water unavailability or curtailment orders if both the Sacramento River watershed analysis and the San Joaquin River watershed analysis show that water will be unavailable at their priority of right. The hydrology of the Legal Delta is complex, and this proration method offers a simplified and generous assessment of water unavailability to appropriators in the Legal Delta during this critically dry period.

Consistent with the analysis contained in State Water Board Order WR 89-8, the methodology assumes that riparian claims do not have access to supply outside the watershed where they are located (i.e., a riparian claim along the San Joaquin River in the Legal Delta does not have a right to divert natural or abandoned flow of water originating from the Sacramento River). Therefore, Statements of Diversion and Use with points of diversion within the Legal Delta that claim only riparian rights are excluded from the Legal Delta proration process described in the previous paragraph and are only charged against supply in the watershed where they are located. Statements of Diversion and Use with points of diversion in the Legal Delta claiming both riparian rights and pre-1914 or other non-riparian categories of right were assumed for the purposes of the methodology to be riparian claims and were therefore accorded senior priority over all appropriative water rights (see section 2.2.5 above).²⁹

Monthly supply ratios for the Sacramento and San Joaquin River watersheds were calculated based on data for 2021; for past months of 2021, these months' FNF values were used. For current or future months, the exceedance forecast selected for use in determining water unavailability for each watershed (see section 3.1.1 below) was used for the proration. These supplies include abandoned instream flows in excess of FNF (see section 2.1.6 above) and do not include flows from headwater subwatersheds assumed to be disconnected from the Delta watershed (see section 2.3.2 above).

²⁹ This categorization of colorable riparian claims within the Legal Delta is consistent with the legal principles described in a memorandum dated December 15, 2017, regarding Issues Related to Overlap between Pre-1914 and Riparian Water Right Claims in the Delta and available on the website of the Office of the Delta Watermaster ([Overlap Memo](#)).

The methodology does not assume there is storage (residence time) longer than a month in the Legal Delta that would affect water unavailability given the extremely dry conditions that have persisted for an extended period and the supplementation of flows in the Delta with previously stored water for many months. The methodology also only accounts for freshwater natural flows from the Sacramento and San Joaquin Rivers as part of the available supplies and does not include any water supplies from tidal inflows to the Legal Delta. Saline water entering the Legal Delta from the San Francisco Bay via tidal action is assumed to be of insufficient quality to be usable for agricultural or municipal purposes. Technical Appendix D explains the technical analysis that supports these assumptions.

2.4 Water Unavailability Visualizations

The Water Unavailability Methodology includes two major types of water unavailability visualizations: the headwater subwatershed visualizations (14 in total) and the watershed-wide visualizations,³⁰ consisting of one for the Sacramento River watershed and one for the San Joaquin River watershed. Samples of these graphs are provided below in Figures 12, 13, and 14. Each graph can display demand data from either the 2018 or 2019 demand datasets. The demands are sorted by water right priority, with riparian demand at the bottom of the graphs, followed by pre-1914 appropriative demand and post-1914 appropriative demand, which are grouped by priority decade. Project demands are stacked at the top (see section 2.2.7 above).

The subwatershed visualization displays four water supply scenarios: the 10 percent, 50 percent, 90 percent, and 99 percent FNF exceedance forecasts, representing optimistic, neutral, pessimistic, and extremely pessimistic forecasts, respectively. When conditions in the Delta watershed were extremely dry, the adjustments to the supply and demand datasets described in section 2.3 above were done using the 90 percent FNF exceedance forecast.³¹ During the wet season when precipitation conditions have been dynamically evolving, the 50 percent FNF exceedance forecast was used. As a result, the current watershed-wide visualizations display a single supply scenario, the adjusted 50 percent exceedance forecast.

³⁰ Supply and demand within the watershed-wide analyses is adjusted as described in section 2.3 above.

³¹ Section 3.1.1 below describes how daily FNF may be used to determine which monthly FNF exceedance forecast most closely represents actual conditions. From May through September 2021, the water supply forecasts used in the visualizations were the 90 percent exceedance forecast from DWR's May B-120. Beginning in October 2021, B-120 forecasts are not available; therefore, CNRFC forecasts have been used since October.

Figure 11. Sample Headwater Subwatershed Water Unavailability Visualization (Yuba River)

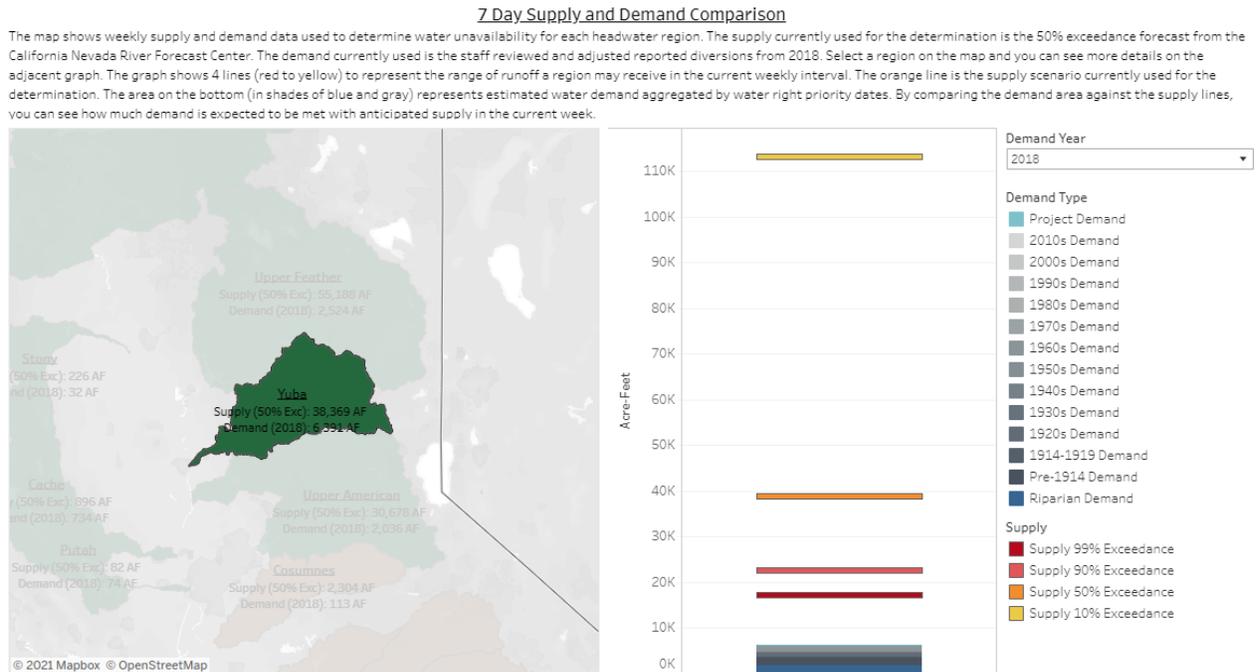


Figure 12. Sample Sacramento River Watershed Water Unavailability Visualization

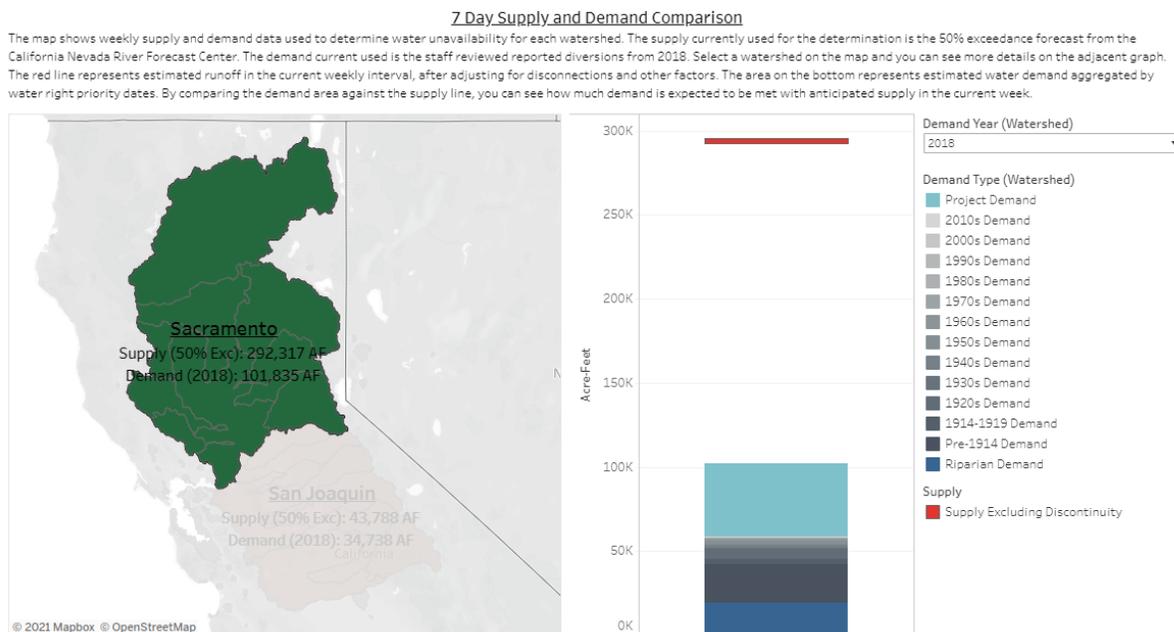
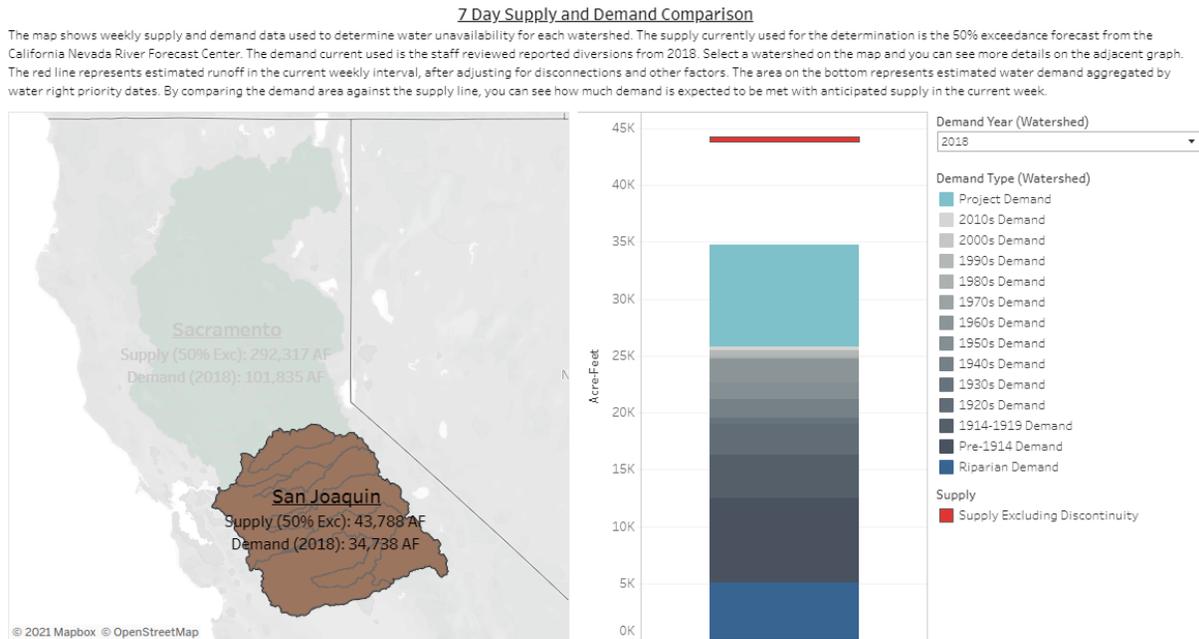


Figure 13. Sample San Joaquin River Watershed Water Unavailability Visualization



The visualizations have been made available on the Board’s Delta Water Unavailability Methodology webpage using the Tableau interactive platform and will be updated to reflect current supply conditions and forecasts. As discussed above, the 2018 demand dataset is planned to be used to assess if insufficient supply is available to meet demands (i.e., the demands positioned above the applicable supply line(s) in the visualizations). In cases where riparian demand exceeds supply (i.e., in disconnected headwater subwatersheds or for riparian demands above the applicable supply line(s) in the visualization) there may be insufficient water available to meet all riparian demands. Section 3.1 below describes the process for issuing notices of water unavailability or curtailment orders to diverters.

3 Implementation

3.1 Issuance of Notices of Water Unavailability and Curtailment Orders

The Water Unavailability Methodology is being used to determine when there is insufficient supply to meet diverters’ priorities of right within the Delta watershed based on the best available information, either at the scale of a headwater subwatershed or the wider Sacramento or San Joaquin River watersheds. Based on prior outputs of the methodology, on June 15 and July 23, 2021, the State Water Board issued notices of water unavailability (also referred to simply as “notices”) to water right holders and/or

claimants in the Delta watershed indicating that water supplies are not available for their use. Notices, unlike curtailment orders, are not directives to stop diverting. Rather, they inform affected diverters that water is expected to be unavailable for their diversion in a future time frame. These notices also play an important policy and public relations role by offering the opportunity for voluntary compliance prior to formal enforcement action by the Board. Diverting unavailable water can result in penalties for injuring more senior water right holders and public trust resources.

Given the dire water supply conditions in the Delta watershed, on August 20, 2021, based on the output of the methodology and the authority granted to the Board under the emergency regulation, the Board issued curtailment orders to all post-1914 appropriative water right holders in the Delta watershed, many pre-1914 appropriative claimants, as well as some riparian claimants. Unlike notices of water unavailability, curtailment orders are directives to stop diverting. The curtailment orders, which will continue to be updated as conditions change, require affected right holders and claimants to cease diversions when water is not available under a water right holder's or claimant's priority of right unless and until (1) they have authorization to continue diverting pursuant to one of the exceptions enumerated in the regulation or (2) they receive notice that the curtailment order has been temporarily suspended or permanently lifted. In addition, the emergency regulation authorizes the State Water Board to require enhanced reporting of some larger water users to provide additional information on past diversion and use, and future projected use. That information is planned to be used to better inform future curtailment decisions.

As discussed above, appropriative diverters in the Legal Delta will only receive notices of water unavailability or curtailment orders if supply is unavailable to them from both the Sacramento and the San Joaquin Rivers, the issuance of which will be coordinated with the Office of the Delta Watermaster. In addition, implementation of this methodology will operate separately from issuance of curtailment notices pursuant to standard water right Term 91, which was in effect from April 29 to October 26, 2021, and will be reimposed if the conditions or triggering Term 91 curtailments occur (the Projects are required to release previously stored water to meet water quality requirements in the Delta).

3.1.1 Exceedance Forecast Selection and Precipitation Monitoring

In order to evaluate water unavailability, water demands are evaluated against an appropriate supply forecast (e.g., 10%, 50%, 90%, or other exceedance forecasts). Due to variable conditions throughout the Delta watershed, different exceedance forecasts may be used for the Sacramento River watershed, the San Joaquin River watershed, and subwatersheds, if appropriate. To help inform the selection of the most

appropriate exceedance forecast within each area, cumulative daily FNF estimates³² for the current month, sourced from CDEC and CNRFC³³ (see Table 1 and Table 2 above), are compared to the most recent monthly supply forecasts. Visualizations of these comparisons for total supplies in the Sacramento and San Joaquin River watersheds have been made available on the Board's Delta Water Unavailability Methodology webpage using the Tableau interactive platform. These plots will be updated periodically to reflect current supply conditions.

The comparison of monthly forecasts to cumulative daily supplies as the month progresses may be used to inform selection of the appropriate forecast. At the beginning of each month, when few or no daily FNF values are available, an evaluation of current conditions will be conducted to determine the appropriate supply forecast. As daily FNF values become available throughout the month, cumulative daily supplies will be compared to monthly forecast volumes. If the daily data is considered to be sufficiently reliable (daily data for some stations may not be consistently reliable), the forecast used to assess water unavailability may be changed to reflect the trend of the daily data. In cases where daily FNF values are not reliable, data from a nearby reliable station may be used to inform the appropriate supply forecast. Assessments of data reliability may be made in consultation with the National Weather Service, DWR, and other agencies or entities that generate daily FNF estimates.

To reflect more dynamic conditions during times of forecasted precipitation, beginning on October 13, 2021, the State Water Board began evaluating water unavailability on a weekly timestep for the watershed, with the exception of the Legal Delta. This analysis helps ensure that curtailments can be suspended if forecasted precipitation events are expected to generate sufficient runoff during a particular week. Furthermore, CNRFC forecasts have the greatest confidence in forecasted precipitation for the next seven days so relying on that data reflects the best available supply data. The shorter-term weekly analysis also allows for the greatest flexibility in suspending curtailment orders based on forecasted or actual precipitation and runoff that is expected to result in a measurable increase to available supplies. Due to issues related to transit and residence times, the issuance of curtailments within the Legal Delta will continue to be

³² As described in section 2.1.4 above, daily FNF data are valuable for the purpose of this check but are not suitable to replace available past or forecasted monthly FNF values because they are based on fewer data points than are available at the end of each month and due to the lag time between upstream operations and their effect on downstream flow measurements. Some daily FNF data are also not consistently reliable.

³³CDEC or CNRFC may report negative daily FNFs. These negative values, which may result from temporary changes in observed reservoir levels due to wind or other factors that would be offset on later days when wind and other patterns change, are retained as-is within the calculations.

considered based on an analysis using a monthly timestep. However, shorter term expected precipitation and runoff data can still be considered as appropriate in determining whether to temporarily suspend curtailments.

Additional available datasets that may be used to monitor and forecast precipitation and runoff include qualitative Area Forecast or Hydrometeorological Discussions from NOAA and CNRFC, Quantitative Precipitation Forecasts (QPF) from CNRFC, Atmospheric River (AR) Activity sub-seasonal outlooks from the Center for Western Weather and Water Extremes, use of the USGS Basin Characterization Model, and other tools.

3.2 Water Quality and Public Trust Resources

The Water Unavailability Methodology does not account for any of the following: (a) water needs for public trust resources; (b) natural instream losses and evaporation; or (c) non-agricultural consumptive uses in the Delta (e.g., open water evaporation, riparian vegetation, etc.).³⁴ Currently, notices of water unavailability or curtailment orders are not proposed to be issued to make water available for the environment, only to make water available for senior water right holders and claimants and to prevent the unlawful diversion of storage releases, which are intended to meet water quality and flow requirements or contract demands. The methodology does not affect other obligations that water users may have for meeting flow and other requirements.

3.3 Communication and Public Engagement Strategy

State Water Board staff has engaged with a number of water users on issues related to the development of the Water Unavailability Methodology. In addition, a public workshop regarding the May 12, 2021 draft version of the methodology was held on May 21, 2021, during which numerous parties provided oral comment. Numerous written comments on the draft methodology were also timely received by the May 25, 2021 deadline. Since that time, modifications have been made to the methodology to support the determination of water unavailability for water right holders and claimants in the Delta watershed. These changes are described throughout this document, as well as its technical appendices. This version of the report also includes report updates that consider topics raised during the October 20, 2021 technical, staff-led workshop.

The State Water Board will continue to regularly update the information used to determine water unavailability in the methodology as new data becomes available and as needed to address wet season information needs as described above. Regular updates regarding issues related to water unavailability will be provided to the public during Board meetings. At least monthly updates will also be provided on the Board's Delta Water Unavailability Methodology webpage, including updated water unavailability visualizations. If the forecast used to estimate water supply is updated mid-month, as

³⁴ For context, the State Water Board's 1977 Drought Report Appendix, Table 14 estimated that non-agricultural consumptive water use in the Delta was as high as 74,560 AF in June 1977.

described in section 3.1.1, the webpage will be updated more frequently to communicate any changed estimates of water unavailability to diverters.

This methodology does not represent a static assessment of how the State Water Board will determine water unavailability within the Delta watershed. The methodology may change as the seasons progress and based on new information and refined analyses, as appropriate. This methodology is a first step toward refining the Board's process for issuing notices of water unavailability or curtailment orders, which includes refinements upon the 2014 and 2015 methodology that were feasible given existing time and data constraints. Additional refinements to the methodology beyond those discussed above may be needed if the methodology is applied during the upcoming wet season.

Public engagement was also an important component in the development of the emergency regulation ultimately adopted by the Board on August 3, 2021. Public comment was solicited and received during a July 27, 2021 workshop and at the Board meeting, which led to refinement of the regulation.

4 Areas of Potential Refinement

4.1 Near-Term Opportunities

4.1.1 Supply

California water supply data is generated by agencies other than the State Water Board and is, therefore, subject to the data quality assurance programs and improvements of those agencies. In the near-term, the State Water Board will continue to focus refinement efforts on improvements to the preparation of supply data for use in water unavailability analyses. These improvements relate to analysis repeatability, automation of the data preparation process, and data documentation. Within the next few years, the Board may further improve the preparation of supply data via the implementation of additional data validation methods, refinement of the process to identify and fill data gaps, and incorporation of new supply data as it becomes available. The Board may also alter the assumptions of the analysis to reflect increased understanding of groundwater interactions, riparian evapotranspiration, and evaporative losses.

4.1.2 Demand

The State Water Board will continue to refine the demand dataset used in the Water Unavailability Methodology as appropriate by streamlining existing processes and improving demand estimates and accounting. This includes the identification of additional data entry errors, estimation of demand values where necessary and feasible, and additional data quality control methods. In addition, as discussed above, the emergency regulation provides that the submittal of demand projections may be required and these projections may be used in the methodology as appropriate.

Refinement of the representation of non-consumptive uses will also be evaluated. The Board will also continue ongoing work with diverters to improve water accounting by minimizing instances of duplicate reporting, identifying incorrectly reported re-diversions, refining estimates of return flows from larger scale diverters such as those diverting more than 100,000 AF per year, and increasing compliance with the regulations that resulted from SB88. The Board may also consider specific demand issues within the Legal Delta for lands below sea level as described in the emergency regulation.

Over the next few years, the State Water Board plans to develop cross-validation methods using other datasets such as aerial imagery, OpenET, and land use datasets to assess the validity of reported demand values. The Board may also refine the subwatershed demand aggregation method (see section 2.2.6 above) by developing more accurate estimates of proportional demand for water rights that have PODs located in more than one subwatershed. In addition, the Board may use the historical demand record to develop statistical and predictive approaches to identify outliers in the demand dataset and, in conjunction with outside datasets, develop higher temporal resolution for demand estimates.

4.2 Longer-Term Opportunities

In the next several years as part of larger efforts, the State Water Board will work toward developing a data management plan for the demand dataset. The plan's primary functions will be to formalize quality assurance measures, improve data intake processes, and publish the dataset in accordance with Assembly Bill 1755 and the State Water Board's Open Data Resolution to the extent feasible. During the plan development, the Board will expand upon existing data validation efforts using land use-based demand estimates and collaborate with other agencies or organizations to identify where the installation of telemetered diversion gages is needed to enable the validation of demand data to an acceptable level of accuracy. The Board may also look to refine internal and external accounting methods for contracted water, water transfers, and other issues.

Ultimately, the demand data is most limited by the number of required or available telemetered diversion measurement gages and the relatively infrequent manual reporting requirements. These spatial and temporal limitations prevent the State Water Board from conducting a finer scale analysis and responding in real time to limited water availability. New requirements for reporting diversions and transitioning to land use-based demand estimates could improve the spatial and temporal coverage of water demand data in California and improve the Board's ability to effectively monitor and manage water supplies.

In the long-term, the Board is also planning to evaluate the use of more sophisticated dynamic evaluation tools capable of addressing the complexities of water unavailability issues in the Delta watershed and other areas of the state with greater spatial and

temporal resolution. To be effective, however, these tools are dependent on data of adequate quality.

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Technical Appendix A

Technical Appendix A: Methodology Spreadsheet Description is available on the Delta Water Unavailability Methodology webpage at

https://www.waterboards.ca.gov/drought/drought_tools_methods/delta_method.html

Technical Appendix B

Technical Appendix B: Demand Dataset Description and Preparation is available on the Delta Water Unavailability Methodology webpage at

https://www.waterboards.ca.gov/drought/drought_tools_methods/delta_method.html

Appendix C

Appendix C: Summary of Public Comments is available on the Delta Water Unavailability Methodology webpage at

https://www.waterboards.ca.gov/drought/drought_tools_methods/delta_method.html

Technical Appendix D

Technical Appendix D: Assessment of Water Unavailability Issues within the Legal Delta is available on the Delta Water Unavailability Methodology webpage at

https://www.waterboards.ca.gov/drought/drought_tools_methods/delta_method.html