

**DRAFT** Groundwater Sustainability Plan  
Data Integration Report  
*Integrated Scope of Work - Task 5.3*



*Submitted to:*

**Central Valley Salinity Coalition**

**Central Valley Salinity Alternatives for Long-term Sustainability  
(CV-SALTS)**



*Prepared by:*

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# Acronyms

Acronym	Definition
Ac	Acre
AEM	Airborne Electromagnetic
af	Acre-feet
AFY	Acre-feet per year
ASR	Aquifer Storage and Recovery
CC	Climate Change
CVHM	Central Valley Hydrologic Model
CV-SALTS	Central Valley Salinity Alternatives for Long-term Sustainability
CV-SWAT	Central Valley Soil and Water Assessment Tool
C2VSIM	California Central Valley Groundwater-Surface Water Simulation Model
Co.	County
DEW	Dry Extreme Warming
DWR (add SWRCB?)	California Department of Water Resources
ET	Evapotranspiration
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	Hydrogeologic Conceptual Model
HR	Hydrologic Region
ID	Irrigation District
IWFM	Integrated Water Flow Model
MRI	Magnetic Resonance Imaging
MODFLOW	A USGS model code used for simulating and predicting groundwater conditions
P&O Study	Prioritization and Optimization Study
PMA	Projects and Management Actions
SGMA	Sustainable Groundwater Management Act
SWS	Surface Water System
TAFY	Thousand acre-feet per year
USGS	United States Geological Survey
WA	Water Authority
WD	Water District
WMW	Wet Moderate Warming

# **1. Introduction and Background**

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## **1.1 Study Objective – Use of Findings to Support Prioritization & Optimization Study**

The purpose of Prioritization & Optimization (P&O) Study Task 5.3 (Information Extraction from Groundwater Sustainability Plans [GSP]) is to extract and organize relevant GSP data and information that can be used to:

1. Validate or refine information contained in the P&O Study's Central Valley Soil and Water Assessment Tool (CV-SWAT) watershed model and other models (developed to support ongoing baseline characterization work and future salinity-related analyses);
2. Support the eventual development of salinity management alternatives within specified Central Valley planning areas; and
3. Help ensure that long-term Central Valley salt planning understands and considers ongoing Groundwater Sustainability Agency (GSA) planning efforts, efforts and potential future conditions of the water in the Central Valley region and benefits from the local investment in these plans. It is also expected that this report will be a foundation for enhanced coordination with GSAs as planning occurs in their regions.

## **1.2 Overview of Sustainable Groundwater Management Act and Groundwater Sustainability Plan Regulations**

The Sustainable Groundwater Management Act (SGMA) was signed into law in 2014. Its purpose is to empower local GSAs to manage groundwater sustainably. It is the responsibility of the California Department of Water Resources (DWR) to implement SGMA. In compliance with SGMA regulations, GSAs that were prioritized as high, medium, low or very low by DWR developed GSPs. Each GSP is broadly divided into two main parts: 1) technical information, including quantitative data, and 2) management planning and strategic information, which includes information that may be more qualitative.

The first part of each GSP is more technical in nature. This part is called the Basin Setting, where information about the groundwater basin or portion of the basin referred to as subbasin is compiled and water budgets for historical, current and future conditions are presented along with detailed hydrogeologic, geographic and other information detailing the physical conditions of the groundwater sub-basin. At the highest level, the purpose of the Basin Setting is to define the groundwater basin and how water moves into, within, and out of it. The second part is a planning exercise that includes developing sustainable management criteria and projects and management



actions (PMAs) that will enable the groundwater subbasin/basin to meet those criteria and, in doing so, achieve sustainability.

### **1.3 Coordination with the Executive Committee**

At its November 2023 meeting, the CV-SALTS Executive Committee approved the work plan for the GSP Data Collection Pilot Study (Pilot Study), the first step in the implementation of Task 5.3. The purpose of the Pilot Study was to verify that proposed GSP data collection tools would be successful at extracting information that is relevant to the P&O Study. Accordingly, the Pilot Study completed data extraction from six GSPs representing various examples of geography, size, and GSP format to determine what data can be consistently searched, acquired, and compiled for meaningful results. The P&O Study Consultant Team reported on finding from the Pilot Study in a technical memorandum submitted to the Executive Committee on February 1, 2024. At its February 22, 2024, meeting, the Executive Committee considered results and recommendations from the Pilot Study technical memorandum and approved continued data collection from all 66 GSPs that represent the Central Valley floor in accordance with those recommendations. The draft report will be presented to the Executive Committee and comments incorporated into the final report. The draft report will also be made available to select GSAs, agreed upon by the Executive Committee, to solicit feedback from and engage key GSAs in each hydrologic region.

### **1.4 Report Organization**

This report is organized as follows:

- Introduction and Background – Brief summary of the study objectives, SGMA and coordination with Executive Committee in completion of this study.
- Study Methods – Including development of a work plan, summary of GSPs reviewed, assessment and organization of the following: aquifer information, land use information, recharge information and aggregation of information by hydrologic region.
- Results of GSP Data Collection – Including a summary of water budget scenarios described in the GSPs, changes in groundwater storage, and a summary of projects and management actions provided in the GSPs for demand reduction and groundwater recharge.
- Summary – Presenting the projected increased in managed aquifer recharge, demand reduction from land fallowing and pumping restrictions, a high-level summary of pertinent aquifer information from statewide Airborne Electromagnetic (AEM) survey, and general observations at the Central Valley wide scale.

## 2. Study Methods

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### 2.1 Work Plan Approach – Initial Pilot Project and Refinement of Approach Based on Pilot Results

For the GSP Pilot Study, information was compiled from both single and multi-plan GSPs. Single GSPs were submitted by one or multiple GSAs and were not coordinated with other GSPs in the same subbasin. Multi-plan GSPs represent one or more GSPs were coordinated with other GSPs in the same subbasin and typically shared approaches to modeling and addressing overdraft. The subbasins in the Central Valley that coordinated to submit GSPs include Delta-Mendota, Madera, Kaweah, Kings, Kern County, and Tule. The six GSPs included in the Pilot Study were as follows:

- Sacramento Valley Basin
  - North Yuba (single water budget; shared PMAs with South Yuba)
  - South Yuba (single water budget; shared PMAs with North Yuba)
- San Joaquin River Basin
  - East Contra Costa (single GSP)
  - Gravelly Ford Water District (Delta-Mendota subbasin multi-plan GSP)
- Tulare Lake Basin
  - North Kings (Kings Subbasin multi-plan GSP)
  - Westside (single GSP)

Quantitative data such as groundwater inflows and outflows were compiled from the water budgets in the Basin Setting, and qualitative information such as planned demand reduction or supply expansion activities were compiled from GSP PMAs. The pilot GSPs were reviewed for information that corresponds to the qualitative and quantitative data components presented in the Pilot Study work plan.

GSPs were searched for the data components shown in **Table 2-1**. The degree of success in compiling each of these data components is also noted in **Table 2-1**. Examples of data aggregation are also provided to summarize some of the findings for key GSP elements.

**Table 2-1. GSP Data Collection Pilot Study Data Components**

<b>Data Component</b>	<b>Notes</b>
<b>Compiled from Water Budgets</b>	
Deep percolation of precipitation and applied water	Provided either separately or as combined deep percolation
Streamflow depletions and gains	Surface water recharge to groundwater and discharge from groundwater to surface water
Groundwater pumping	Historic, current and forecast future
Tailwater returns	As provided
Subsurface recharge and discharge	Subsurface recharge to groundwater and discharge from groundwater to subsurface water
Evapotranspiration (ET)	Typically provided according to land use
Precipitation	Provided in water budget components
Applied water	Usually provided in water budgets
<b>Compiled from PMAs</b>	
Demand reduction	Includes following and/or pumping restrictions and/or allocations PMAs
Planned recharge areas	Described in narrative
Planned recycled water use	Described in narrative
<b>Compiled from GSP Narrative</b>	
Water budget model type	Numerical or analytical model types
Existing recharge, recycled water	Typically descriptive/narrative
Principal aquifer information and cross-sections	Provided in Basin Setting
<b>Not Compiled Successfully</b>	
Sustainable yield	For multi-plan GSPs, sustainable yield was sometimes only modeled for the whole basin so there was no sustainable yield for a specific GSP, or it was divided up in an administrative manner, such as according to acreage.
Water quality	Narrative usually referenced work to be performed by CV-SALTS and was quite variable depending on the subbasin/basin. Not recommended as the best source for water quality information for the purposes of the P&O Study.
Spatial representation of existing recharge basins	Described in narrative and/or visual presentation in maps but did not include generally include private recharge projects.

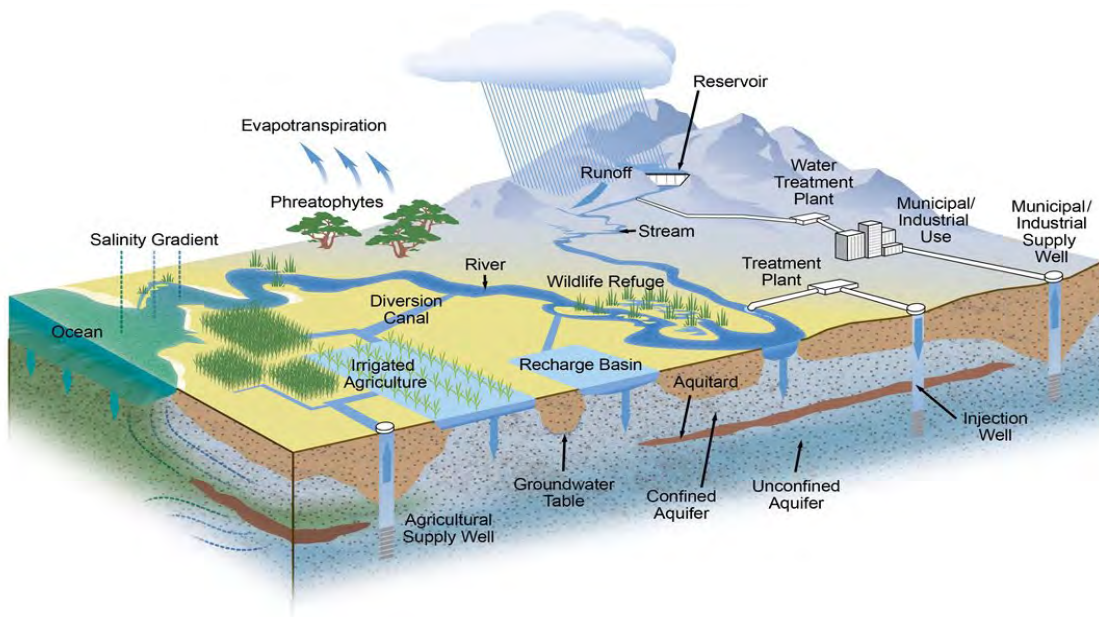
## 2.2 GSPs Reviewed and Review Process

Information was collected from 66 Central Valley GSPs (including the GSPs used in the Pilot Study) in the Sacramento Valley, San Joaquin River, and Tulare Lake Hydrologic Regions (HR). Informed by the results of the Pilot Study summarized in Table 2-1, GSP data collection proceeded with compiling information from water budgets, PMAs and other narrative information found in GSPs. As described in Table 2-1, sustainable yield and water quality information was not collected.

### 2.2.1 Summary of Water Budget Information

GSPs developed water budgets in accordance with DWR requirements using best available data. The water budgets provide an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin or subbasin under historical, current, and projected water budget conditions. GSAs had the choice of using numerical models or analytical approaches (spreadsheet or “checkbook” methods, where water balance is determined using an accounting approach in Excel). DWR provided GSAs with the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and the Integrated Water Flow Model (IWFM) to develop water budgets. Some GSAs chose to use United States Geological Survey (USGS) MODFLOW (a USGS model code used for simulating and predicting groundwater conditions) (e.g., Central Valley Hydrologic Model [CVHM]) platforms for their modeling projections and other GSAs did not use numerical models for their projections.

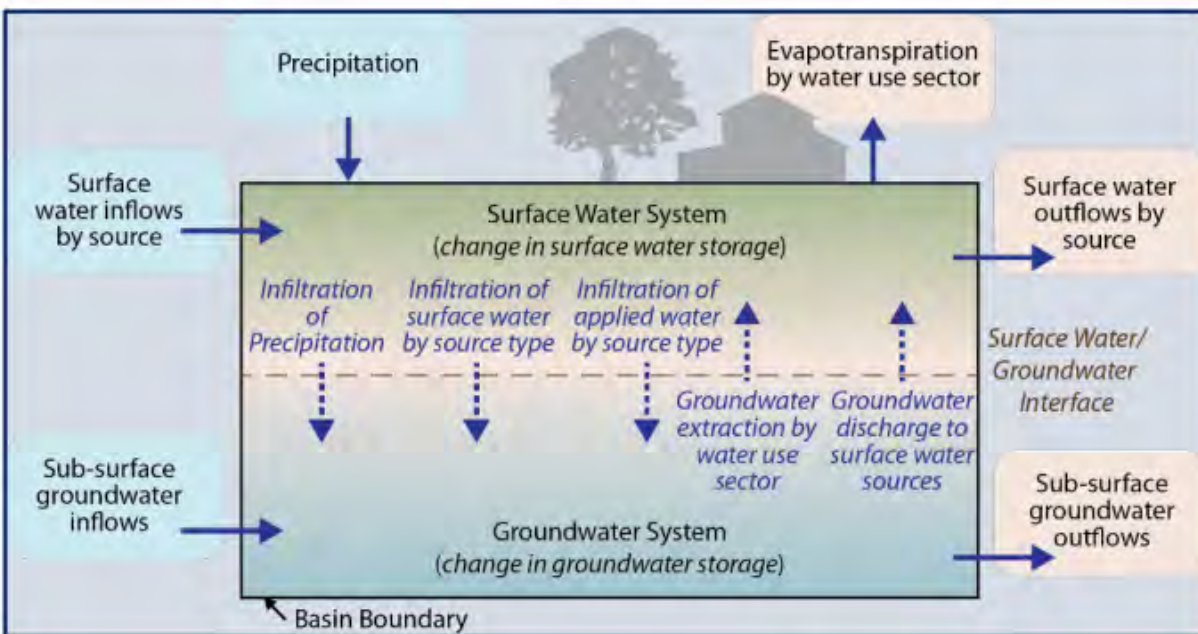
Water budget components such as inflows and outflows from groundwater are typically provided in GSPs either in raw or summarized formats. Other components such as tailwater return or outflows from subsurface drains are not always provided (e.g., if they don’t exist or are not considered to be a significant part of the water budget). A schematic of conceptual water system modeling is shown in **Figure 2-1** and illustrates how water moves through a groundwater basin and the numerous factors that affect that movement.



**Figure 2-1. Schematic of Conceptual Water System Modeling**

Source: <https://water.ca.gov/Library/Modeling-and-Analysis>

The data components collected in the current GSP data collection effort represent the primary inflows and outflows of a water budget (**Figure 2-2**); the level of detail was selected for relevance and consistency of availability in GSPs. For example, deep percolation of applied water and precipitation was sometimes provided as discrete values, and sometimes provided as an aggregated value. Therefore, the aggregated value is shown in the tables of water budget components in **Appendix A**. These data not only provide important information that may be used by the P&O Study technical team to cross-check modeling results within specified areas, but it can support modeling analyses of future salt management scenarios.



**Figure 2-2. Water Budget Concept (DWR 2016)**

The purpose of water budget development in GSPs was to assess groundwater basin/subbasin status and provide a starting point for planning groundwater management. It is understood that there is inherent uncertainty in groundwater budget development, which is estimated and documented in GSPs. Examples of uncertainty estimates for water budget components are shown in **Table 2-2**. Considering these uncertainties, it is important to recognize that water budget components and results should be interpreted as approximations rather than exact values.

**Table 2-2. Example of Uncertainty Evaluation from Chowchilla GSP. P. 2-90**

Flowpath Direction (relative to SWS)	Water Budget Component	Data Source	Estimated Uncertainty (%)	Source
Inflows	Surface Water Inflows	Measurement	5%	Estimated streamflow measurement accuracy
	Deliveries	Measurement	6%	Estimated delivery measurement accuracy (accuracy required for Reclamation contractors)
	Water Rights Deliveries	Measurement	10%	Estimated measurement accuracy.
	Precipitation	Calculation	30%	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Calculation	20%	Typical uncertainty when calculated for Land Surface System water balance closure;
Outflows	Surface Water Outflows	Measurement	15%	Estimated streamflow measurement accuracy with adjustment for infiltration and evaporation.
	Evaporation	Calculation	20%	Estimated accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.
	ET of Applied Water	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, estimated crop coefficients from SEBAL energy balance, and annual land use.
	ET of Precipitation	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, precipitation, estimated crop coefficients from SEBAL energy balance, and annual land use.
	Infiltration of Applied Water	Calculation	20%	Estimated accuracy of daily IDC root zone water budget based on annual land use and NRCS soils characteristics.
	Infiltration of Precipitation	Calculation	20%	Estimated accuracy of daily IDC root zone water budget based on annual land use, NRCS soils characteristics, and CIMIS precipitation.
	Infiltration of Surface Water	Calculation	15%	Estimated accuracy of daily seepage calculation using NRCS soils characteristics and measured streamflow data compared to field measurements.
	Change in SWS Storage	Calculation	50%	Professional Judgment.
Net Recharge from SWS		Calculation	20%	Estimated water budget accuracy; typical value calculated for Subbasin-level net recharge from SWS.

Note – SWS is Surface Water System

## **2.2.2 Summary of Demand Reduction Strategies Information**

The results of the non-water budget components that were sourced from the narrative descriptions and PMAs in GSPs are provided for each HR in Section 3 below. These data are primarily intended to provide context for the P&O Study technical team and to inform decisions about selection of archetype areas and development of scenarios to be analyzed at the archetype and larger scales. This water management information provides insight into water supply, conjunctive use, existing water management strategies and planned water management strategies in each GSP area, all potentially factors affecting management of salt. Water budget type

(analytical or numerical model) information was collected to inform the P&O Study technical team how GSP water budgets were developed to better interpret their results.

This project collected and summarized non-water budget GSP data from all three HRs. Of note:

- In some cases, no estimate of benefit was provided for demand reduction or supply expansion projects. The values for total estimated benefit (at full implementation) that are presented in this report were summed from values that were provided but may underestimate total expected benefit.
- Summarized PMA information does not represent all PMAs documented in GSPs. Only managed recharge, recycled water use, fallowing and pumping restrictions or allocations are included in this report. Other PMAs such as surface water trading, surface storage, and irrigation efficiency improvement projects are not included; implementation of these types of projects may have a substantial impact on the groundwater budgets of some GSPs.
- Managed recharge includes intentional managed recharge in percolation basins, conveyance systems, in-lieu, and aquifer storage and recovery (ASR).
- This data collection effort focused on planned PMAs. Several GSPs have potential PMAs (also called supplemental, alternative, conceptual or Tier 2) that may or may not be implemented. Whether a GSP considers a PMA to be planned or potential may change over time depending on the success of other PMAs, funding opportunities, and other factors that influence PMA prioritization.

#### 2.2.2.1 Other Relevant GSP Information

In addition, general information about GSPs in each HR region, such as approval status, status of DWR groundwater subbasin which they overlie (e.g., critically overdrafted), etc. is provided in aggregated tables in Section 3 and by GSP in **Appendix A**. The purpose of this information is to inform likely future actions within each HR. For example, GSPs with inadequate status may be revised significantly, and those revisions may include or affect estimates of change in groundwater storage. Approved GSPs are not expected to be revised prior to their five-year updates.

GSPs in overdrafted basins or subbasins are expected to implement significant PMAs to address overdraft; supply augmentation and demand reduction strategies will be implemented in these areas and will likely influence water management and movement. In contrast, GSPs overlying basins/subbasins that are not critically overdrafted or not overdrafted at all may not implement PMAs that will significantly affect water management and movement.

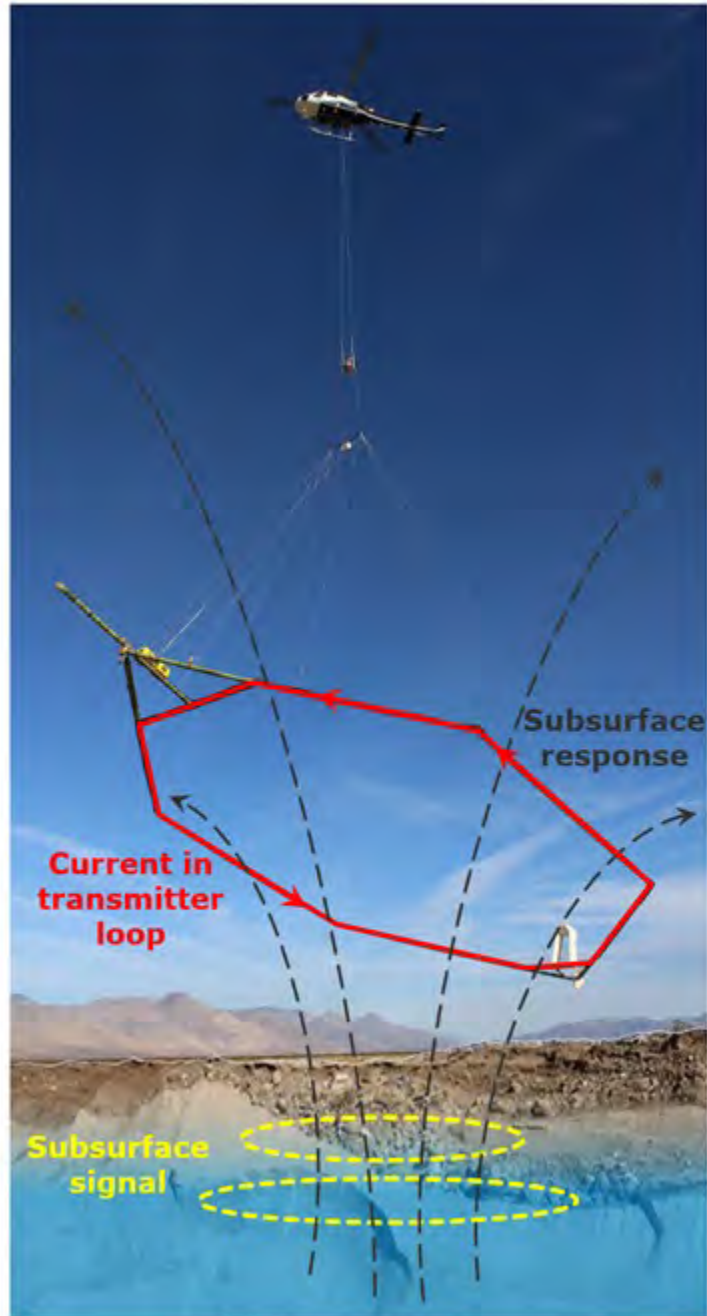
## 2.3 Assessment and Organization of Aquifer Information and Consideration of Statewide AEM Survey Data

As part of the GSP evaluation, the Team extracted information from the Hydrogeologic Conceptual Models (HCM) presented in each GSP including the descriptions of principal aquifers and aquitards in the basin/subbasin, a geologic map (if provided) which designates transect locations of geologic cross-sections, and at least one geologic profile as presented in the GSP.

The Team then accessed Statewide AEM Survey data from the DWR website (<https://water.ca.gov/programs/sgma/aem>). The AEM project provides state and federal agencies, GSAs, stakeholders, and the public with basin/subbasin-specific and cross-basin/subbasin geophysical data, tools, and analyses. The AEM surveys are funded by voter-approved Proposition 68, Senate Bill 5, and from the general fund. More information can be found in the [AEM Proposition 68 Fact Sheet](#).

As illustrated on **Figure 2-3**, during an AEM survey, a helicopter tows electronic equipment that sends signals into the ground which bounce back. The process has been compared to using magnetic resonance imaging (MRI) on the ground's subsurface. The data collected are used to create continuous images that are interpreted for underground geology.



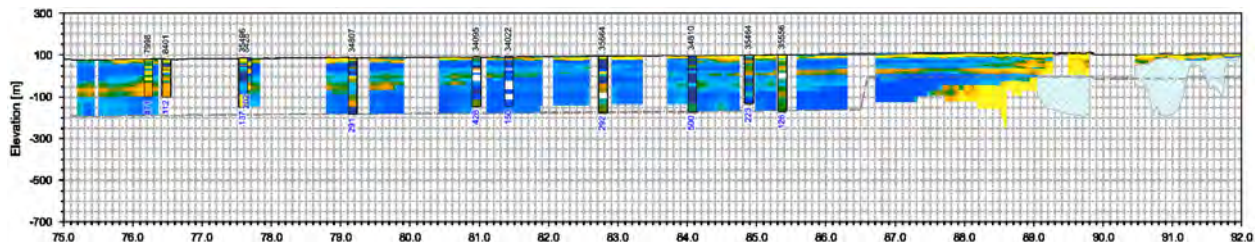


**Figure 2-3. Conceptual Diagram Showing How AEM Data Collection Works (Source?)**

DWR's AEM technical contractors are providing subsurface profiles including both AEM and detailed interpretation of subsurface textures (i.e., gravel, sand, silt and clay) by correlating high quality drillers lithologic logs with the AEM signals. These data are presented as textural profiles available for download at:

<https://dwr.maps.arcgis.com/apps/instant/attachmentviewer/index.html?appid=65f0aa6db8124ae4a54e1f33c5dfe66c>

As part of the GSP Evaluation task, the Team selected AEM textural profiles that most closely aligned with the geologic profiles pulled from the GSP's HCM for ease in direct visual comparison between these two types of subsurface information. **Figure 2-4** is an example textural AEM profile in which warm colors (e.g., yellow) represent coarse grained material and cooler colors (e.g., blue) represent fine grained material.

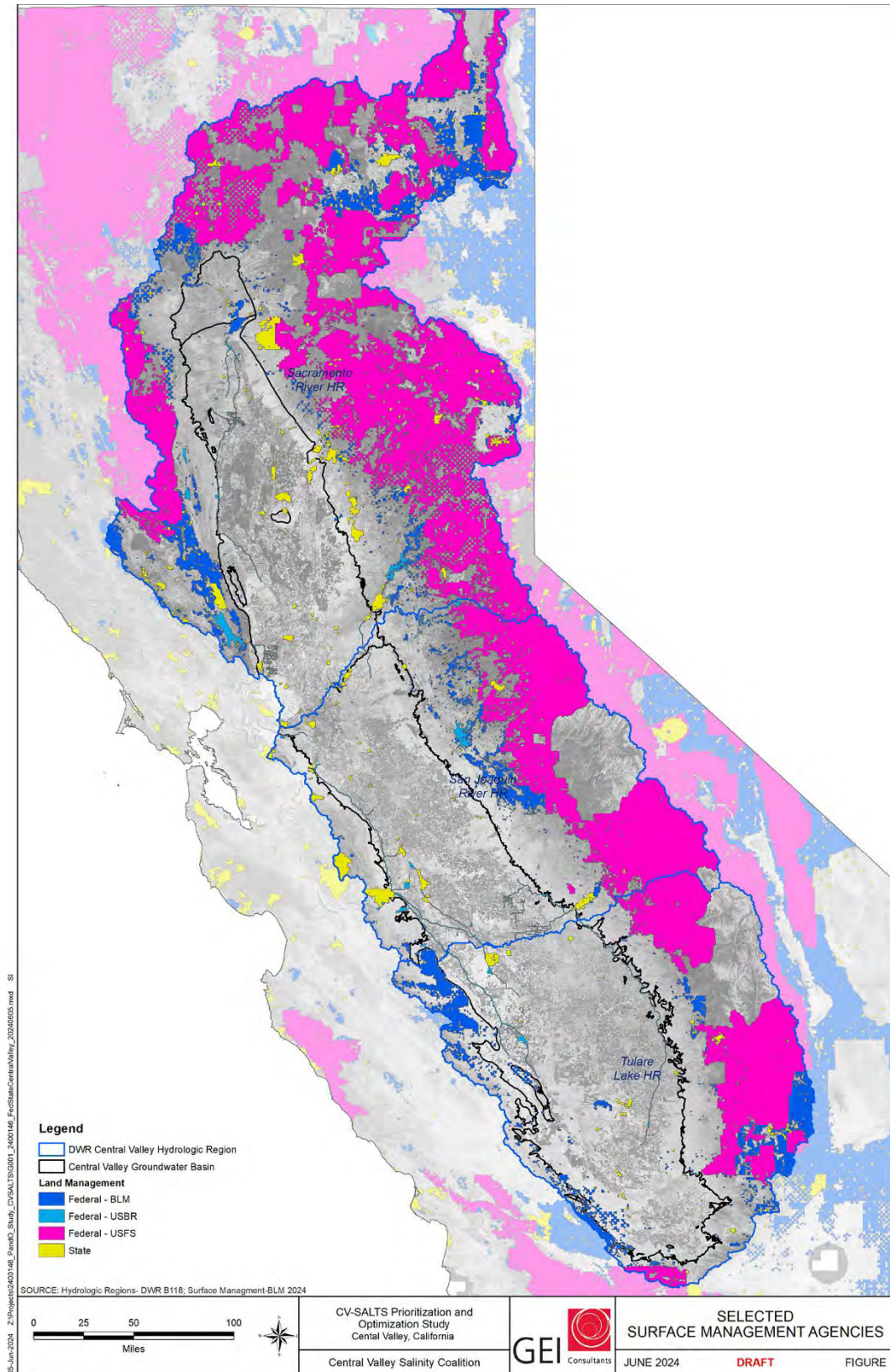


**Figure 2-4. Example AEM Textural Profile**

## 2.4 Assessment and Organization of Land Use Information

The technical team searched the GSPs for planned land conversion and land fallowing as part of the GSA's PMAs to achieve sustainability. The information gleaned from the GSPs is included in the results and summary sections of this report.

In addition to review of GSPs, our work also included an assessment of potential changes in the use of state and federal lands within the Central Valley. To support this assessment, we first prepared a map showing where state and federal lands are present within the Central Valley Region (**Figure 2-5**). Federal lands include those managed by the United States Forest Service (USFS), Bureau of Land Management (BLM) and United States Bureau of Reclamation (USBR). Figure 2-5 shows that most state and federal lands within the Central Valley Region are located outside of the boundary of the Central Valley groundwater basin within the Central Valley Floor. Accordingly, it was determined that any changes in the use of these lands would likely have very little impact on salinity loading in the areas most impacted by salinity, i.e., portions of the Central Valley Floor. Given this finding, we modified the focus of this evaluation to planned changes in water management by state and federal agencies within the Central Valley. A list of projects and management activities was developed based on a review of the 2023 California Water Plan (Water Plan), Public Review Draft (DWR 2023). The relevant 2023 Water Plan actions presented in the results section of this report, if implemented, should be considered further during development of long-term salt management scenarios as the P&O Study progresses.



**Figure 2-5. State and Federal Lands Within or in Watersheds Tributary to the Central Valley**

## 2.5 Assessment and Organization of Recharge Information

Current and planned recharge efforts in each GSP are provided in tables in **Appendix A**. Planned recharge efforts are aggregated by HR and presented in Section 3. If the GSP provided the data, both Section 3 and **Appendix A** include the estimated benefit from recharge projects at full implementation. Estimated benefits, if available, are documented in the GSP. Current recharge projects include those associated with local or regional programs, but, in most cases, do not include private recharge facilities or efforts, which may be important in some GSPs. Section 4 below provides maps showing planned recharge projects and associated estimated benefit at full implementation for the San Joaquin River and the Tulare Lake HRs.

## 2.6 Aggregation of Information by HR

The results section below presents information extracted from the GSPs aggregated and organized by hydrologic region. Basin/subbasin-specific information is provided in **Appendix A**.



### 3. Findings from the Data Collection Effort

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As previously described, water budget data varied among GSPs in water budget components were aggregated and how much raw data were provided. Only groundwater budget components are presented in this section; however, other data used to develop water budgets that are relevant to P&O Study modeling were also collected when they were available, including precipitation, surface water supplies, applied water, and ET. These data, along with the groundwater inflow and outflow data for each GSP are shown in tables organized by HR in **Appendix A**.

It is important to note that groundwater inflows and outflows account for groundwater change in storage; also note that the additional data used to develop water budgets as described above (and shown under the heading Land and Surface Water Budget Components in the **Appendix A** tables) do not represent an accounting of water and should not be used to calculate water budgets. In other words, inflows and outflows can be used to calculate change in groundwater storage, but additional data such as precipitation, applied water, etc. should not be used to calculate change in groundwater storage directly because they are not part of the inflows and outflows; rather, they are used to develop the water budgets. For example, precipitation was documented but it is not part of a groundwater budget. Deep percolation of precipitation is a groundwater budget component.

#### Water Budget Scenarios

Each GSP included multiple water budgets representing different conditions, as required by the SGMA regulations:

- Historical - Historical water budgets were required to represent a prior hydrologic period, typically from 20 to 30 years, that encompassed all types of water years (dry, average, wet, etc.) and approximated average water supply conditions. Historical results might be considered the most representative of each GSP because they are based on actual, rather than predicted or modeled, input data, and represent a relatively long study period with several types of water years. However, in cases where significant changes to surface water delivery contracts or regulations on water use are expected, projected conditions might be more representative of future conditions.
- Current - The current condition was modeled either with hydrology from one recent year or using hydrology from the historical period. It represents a snapshot in time and may not be representative of conditions overall.
- Projected - Projected or future baseline water budgets were required to use 50 years of historical precipitation, ET, and streamflow information as the baseline conditions for estimating future hydrology. The most recent land use, ET and crop coefficients were used to

model projected water demand. Projected surface water supply used the most recent water supply information. Agencies were required to use available data for population growth.

- Climate change (CC) - CC water budgets differed among GSPs; because data availability and applicability differed by region, GSPs varied in their projected CC modeling scenarios. For example, while some GSPs developed water budgets representing CC conditions both in 2030 and in 2070, some only modeled one of those, while others interpolated conditions for years in between (e.g., North Kings used 2040). The CC scenarios were modeled using the central tendency (of an ensemble of general circulation models used to predict future CC conditions) of 2030 climate conditions, the central tendency of 2070 CC conditions, and/or non-central tendency conditions such as dry with extreme warming (DEW) or wet with moderate warming (WMW). The guidelines and data for these conditions in different parts of the state were provided by DWR in a guidance document<sup>1</sup>.
- Other conditions - In addition, some GSPs also developed water budgets for other types of conditions. For example, scenarios with PMAs implemented or anticipated urban development within the planning area. In addition, where applicable, seawater intrusion was included as a modeled condition.

In the subsections that follow, water budget data are summarized by GSP and aggregated by each of the three HRs for the historical, current and projected baseline conditions. Other projected scenarios with conditions such as CC, seawater intrusion, inclusion of large development projects, and inclusion of PMAs were not aggregated by HR because they were not all consistently modeled by each GSP.

### **Change in Groundwater Storage**

The change in groundwater storage can be calculated where groundwater inflow and outflow data are available for the water budget conditions. In the Sacramento River and San Joaquin River HRs, this information was consistently available for the historical, current and projected baseline scenarios, but not consistently available for the climate change scenarios. In the Tulare Lake HR, detailed water budget information was not always available in a format that could be used in this data collection and aggregation effort. Generally, less detailed information about subbasin-wide water budgets was provided in Tulare Lake GSPs; that information was used to aggregate water budget results where possible.

For planning purposes, GSPs selected a “preferred” change in groundwater storage that may or may not equal calculated change in storage, for one or more of the following reasons.

- The preferred change in storage included elements of professional opinion/interpretation.
- It was selected from multiple modeling approaches and results.

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<sup>1</sup> DWR SGMA Best Management Practices and Guidance: <https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents>

- It was selected as an average of a range of values represented by each modeling scenario. For example, the Vina GSP estimated an overdraft of 10,000 AFY, but no modeling scenario produced a water balance with that result; the range of results was approximately 1,000 AFY to 20,000 AFY depending on the modeling period. Rather, the value of 10,000 AFY was selected to represent the range of change in groundwater storage values to use for planning.
- The change in storage value from one scenario was selected as the most representative and accurate change in storage value for planning purposes.

In other words, to understand the preferred estimates of change in groundwater storage provided in each GSP it is necessary to consider the context of the basin setting and modeling approach to wholly understand the conditions under which the estimate was made. In this report, therefore, inflow and outflow water budget components were collected separately to better understand how water is moving within a basin or subbasin, and they are used to calculate change in storage (inflows minus outflows) rather than using the preferred change in groundwater storage as stated by the GSP.

## 3.1 Sacramento River HR

### 3.1.1 Overview of Water Budget Summaries

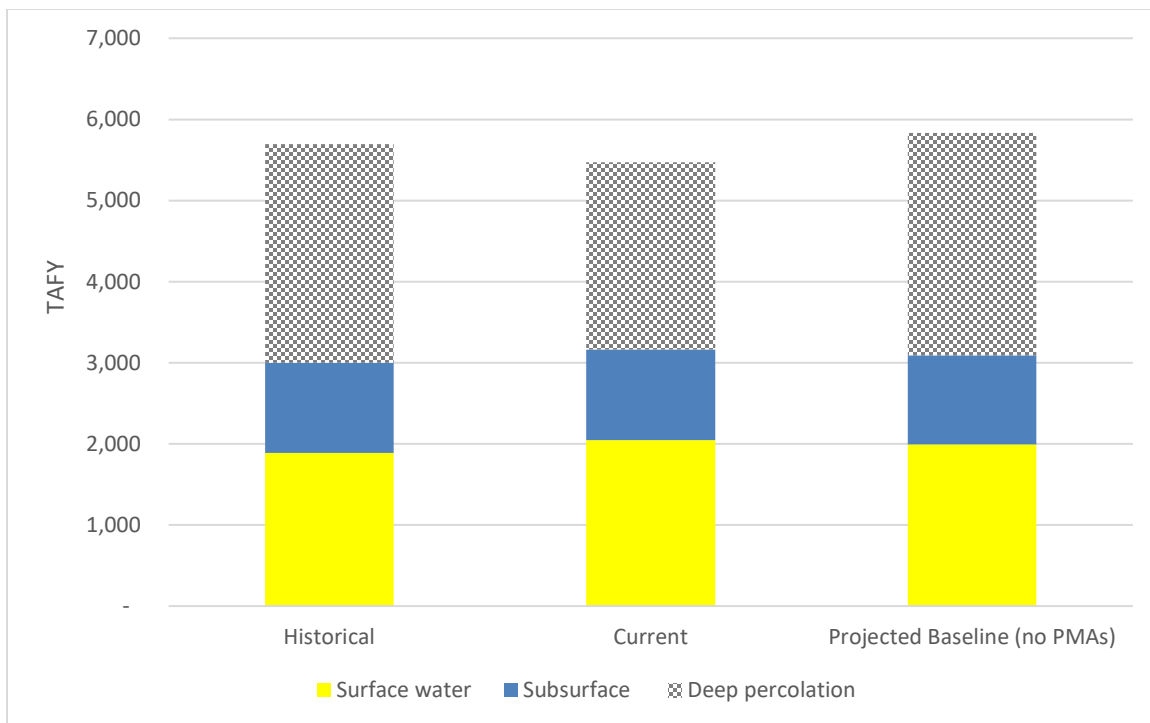
Water budget components aggregated for the Sacramento River HR are shown in **Table 3-1** and **Figure 3-1** and **Figure 3-2**. Water amounts are shown in acre-feet per year (AFY) for GSPs and in thousand AFY (TAFY) for HRs.

**Table 3-1** shows groundwater inflows that contribute to recharge and groundwater outflows that contribute to discharge. Deep percolation is the highest contributor to recharge followed by surface water seepage and subsurface inflow (**Figure 3-1**). Groundwater pumping is the highest outflow from groundwater systems, and while the second highest is discharge to surface water in the historical and current scenarios, subsurface discharge increases in the projected scenario and becomes the second highest outflow (**Figure 3-2**). Discharge to subsurface drains is a negligible outflow overall because it is reported in few GSPs and is not shown here; where available, data for individual GSPs are included in **Appendix A**.

**Table 3-1. Sacramento River HR Aggregated Groundwater Budget Inflows and Outflows**

Water Budget Scenario	Groundwater Recharge/Inflow (TAFY)			Groundwater Discharge/Outflow (TAFY)		
	Deep Percolation	Surface Water	Subsurface	Surface Water	Subsurface	Groundwater Pumping
Historical	2,698	1,888	1,112	1,773	1,233	2,671
Current	2,305	2,047	1,115	1,681	1,361	2,344
Projected Baseline (no PMAs)	2,745	1,993	1,098	1,382	1,559	2,873

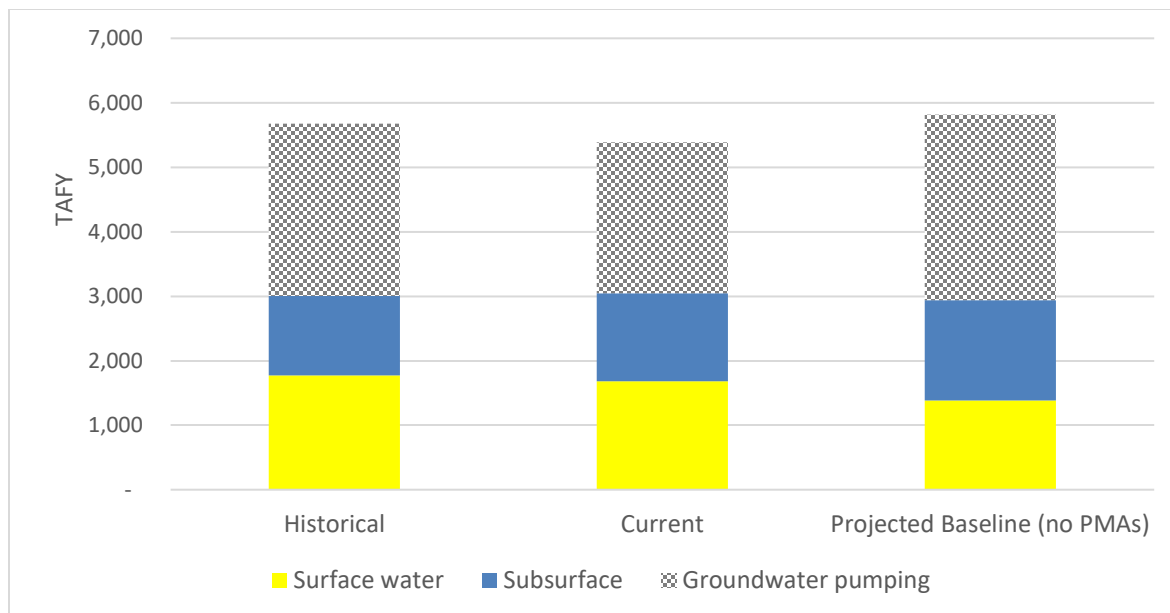
Note: Deep percolation is from precipitation and applied water. Outflow from subsurface drains is considered minor and is not shown.



**Figure 3-1. Aggregated Groundwater Inflows (Recharge) in the Sacramento River HR by Water Budget Scenario**

Note: Deep percolation is from precipitation and applied water. Outflow from subsurface drains not shown.





**Figure 3-2. Aggregated Groundwater Outflows (Discharge) in the Sacramento River HR by Water Budget Scenario**

Note: Outflow from subsurface drains not shown.

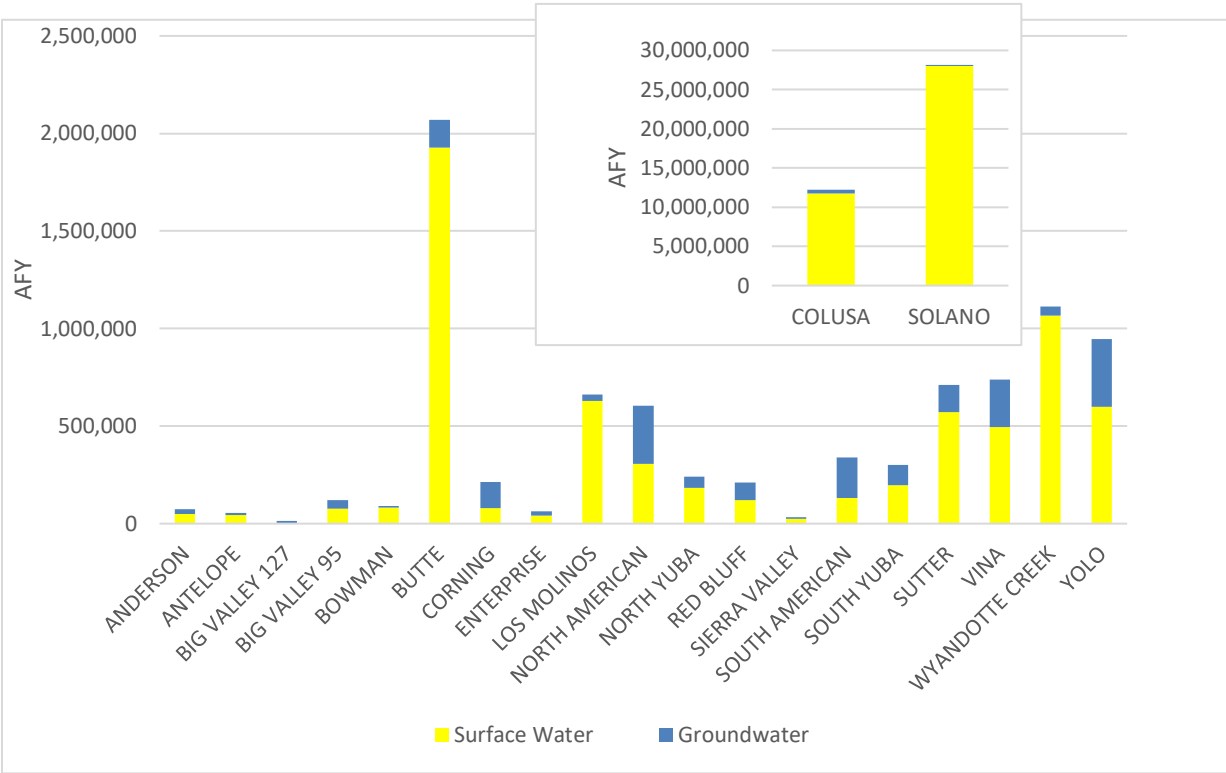
Surface water supplies represented about 95 percent of Sacramento River HR total water supply in the historical, current, and baseline projected water budgets (**Table 3-2**). Water supply data for the CC projected scenarios were not explicitly presented in some cases and therefore cannot be aggregated for the HR.

**Table 3-2. Sacramento River HR Surface And Groundwater Supplies Relative To Total Water Supply For Historical, Current And Projected Baseline Water Budgets**

Scenario	Surface Water (TAFY)	Groundwater (TAFY)	Total Water Supply (TAFY)	Surface Water (%)	Groundwater (%)
Historical	46,373	2,671	49,044	95%	5%
Current	43,712	2,344	46,056	95%	5%
Projected baseline (no PMAs)	59,880	2,873	62,753	95%	5%

Most GSPs in the Sacramento River HR (17 out of 21) documented surface water supplies greater than groundwater supplies, and in six of those GSPs (Bowman, Butte, Colusa, Los Molinos, Solano and Wyandotte Creek), surface water represented over 90% of total supply. These GSPs represent a large portion of the total water supply in the region (44,000 TAFY out of 49,000 TAFY in the historical scenario), which accounts for their influence on the aggregated value. The three GSPs with greater groundwater pumping than surface supply are Big Valley

(GSP ID #127), where groundwater pumping represents 98 percent of supply, Corning (63 percent), and South American (61 percent). The proportion of surface water supplies and groundwater pumping in each GSP for the historical scenario is compared in **Figure 3-3**.



**Figure 3-3. Surface and groundwater supplies by GSP in the Sacramento River HR – Historical Scenario**

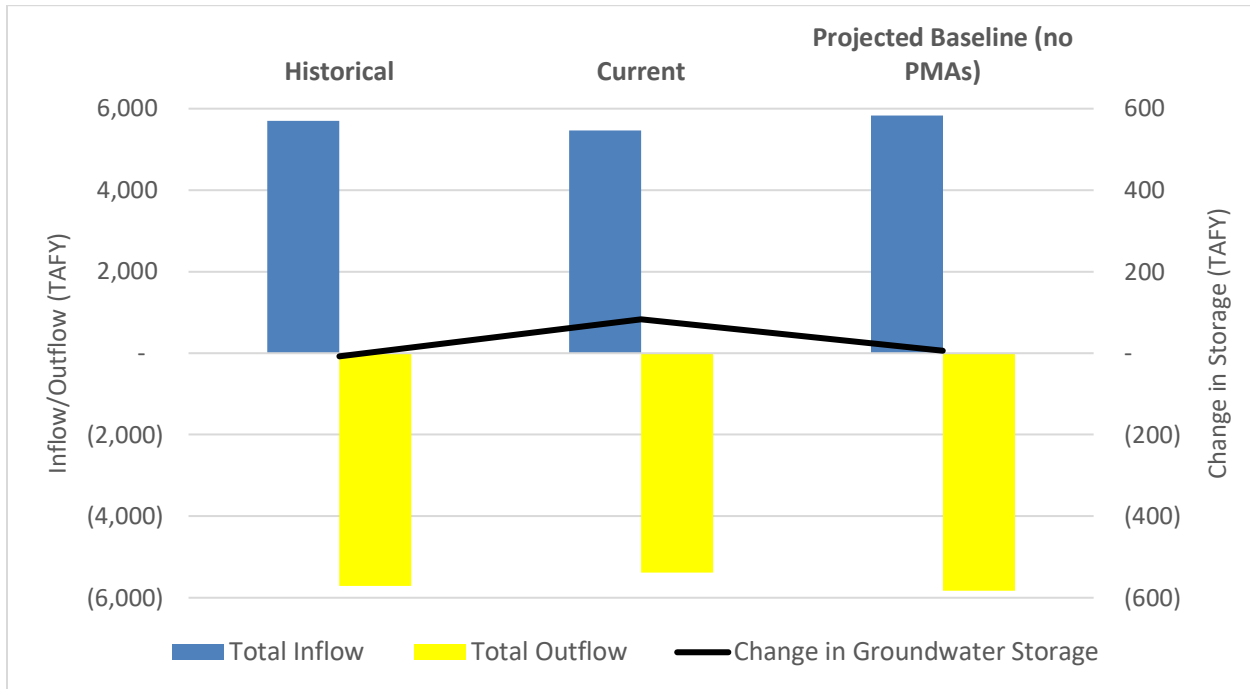
Note: Colusa and Solano subbasins are shown in inset because their water supplies are much larger than those of other subbasins.

3.1.1.1 Change in Groundwater Storage

Aggregated groundwater change in storage (inflows minus outflows) was relatively small compared to the total inflows and outflows for the HR (**Table 3-3 and Figure 3-4**). Change in storage was negative by 8,000 ac-ft in the historical scenario, which is considered little to no change, taking into account the level of uncertainty in water budget modeling. Importantly, the comparison of outflows vs. inflows for each scenario does not necessarily represent the overdraft or surplus used for planning in each GSP, as previously described.

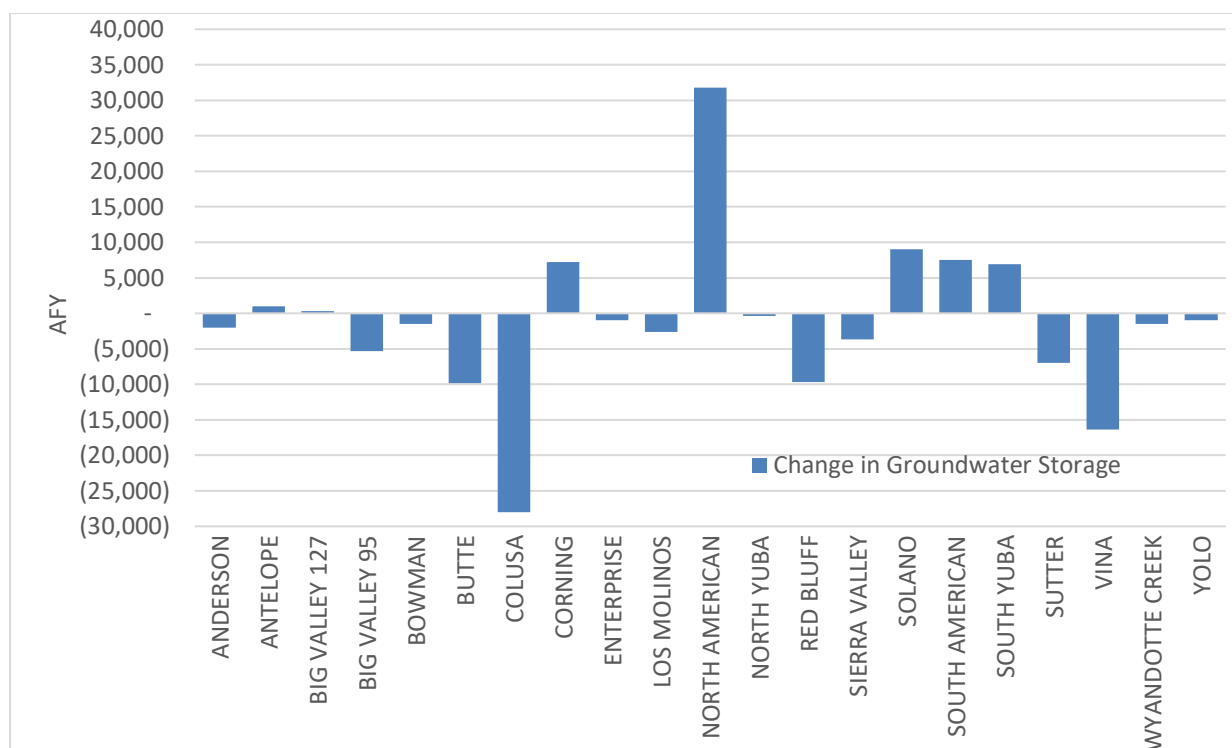
**Table 3-3. Sacramento River HR Change in Storage by Water Budget Modeling Scenario for Aggregated GSPs**

Scenario	Total Groundwater Recharge/Inflow (TAFY)	Total Groundwater Discharge/Outflow (TAFY)	Change in Groundwater Storage (TAFY)
Historical	5,697	(5,705)	(8)
Current	5,466	(5,386)	80
Projected Baseline (no PMAs)	5,836	(5,830)	6



**Figure 3-4. Sacramento River HR Total Groundwater Inflows, Outflows and Balance for Water Budget Modeling Scenarios**

Historical change in groundwater storage for each GSP is shown in **Figure 3-5**.



**Figure 3-5. Change in Groundwater Storage by GSP in the Sacramento River HR – Historical Scenario**

### **3.1.2 Summary of PMAs for demand reduction and supply expansion**

A summary of GSP general information and water management information collected from GSPs in the Sacramento River HR is shown in **Table 3-4**. Most of the GSPs from this HR are approved (14 of 21), six are incomplete, and none have been assigned an inadequate status by DWR (as of June 2024). The Bowman Subbasin GSP is still in review because it is very low priority. No subbasins are critically overdrafted.

Several GSPs reported exploring or planning PMAs related to managed recharge, even though they might not be engaged in recharge activities currently. While only three GSPs reported current recharge projects that have already been implemented, 15 included recharge projects in their planned PMAs. Though there are several planned recharge projects without estimates of benefit, those that do report estimated benefit include Butte (175 AFY); Solano (2,100 AFY); South American (6,000 AFY) and Vina (3,000 AFY).

Recycled water use was reported by three GSPs (North American, South American and Yolo) and those GSPs plus three more included recycled water in their planned PMAs. The largest recycled water accounting for most of the estimated benefit for this region (50,000 AFY of the total 57,830 AFY) is from South American GSP's Harvest Water project, which plans to provide tertiary treated recycled water for agricultural uses, delivering up to 50,000 AFY to irrigate 16,000 ac of agricultural and habitat conservation lands near the Cosumnes River and Stone

Lakes Wildlife Refuge (planned to be operational by 2025). This project is expected to raise groundwater levels by up to 35 feet within 15 years, which will increase groundwater storage volumes by 245,000 AF within 10 years and 450,000 AF within 40 years.

Fallowing is planned in one GSP – Vina – but is being implemented by extending replacement of orchards temporarily, foregoing the water use that would occur if orchards were immediately replanted after removal. The estimated benefit of this project at full implementation is 4,000 to 8,000 AFY.

No GSPs include pumping restrictions or groundwater allocations.

**Table 3-4. Summary of GSP Water Management Information for the Sacramento River HR**

Non-Water Budget Data	Sacramento River HR
Area (ac) of GSPs in HR	4,289,417
Total GSPs in HR	21
High priority GSPs	8
Medium priority GSPs	12
Very low priority GSPs	1
GSPs in critically overdrafted basins/subbasins	0
Approved GSPs	14
Incomplete GSPs	6
Inadequate GSPs	0
GSPs in review	1
Managed Recharge	
GSPs with current managed recharge or ASR	3
GSPs with planned recharge	15
Estimated benefit of planned managed recharge (AFY) <sup>1</sup>	11,275
Recycled Water	
GSPs that use recycled water	3
GSPs that plan to use recycled water as a supply augmentation strategy	6
Estimated benefit of planned recycled water (AFY) <sup>1</sup>	57,830
Fallowing and Land Conversion	
GSPs that plan to use fallowing or land conversion as a demand reduction strategy	1
Estimated benefit of planned fallowing (AFY) <sup>1</sup>	4,000-8,000
Pumping Restrictions and Allocations	
GSPs that plan to use pumping restrictions or allocations as a demand reduction strategy	0

<sup>1</sup> Total estimated benefit at full implementation

## 3.2 San Joaquin River HR

### 3.2.1 Overview of Water Budget Summaries

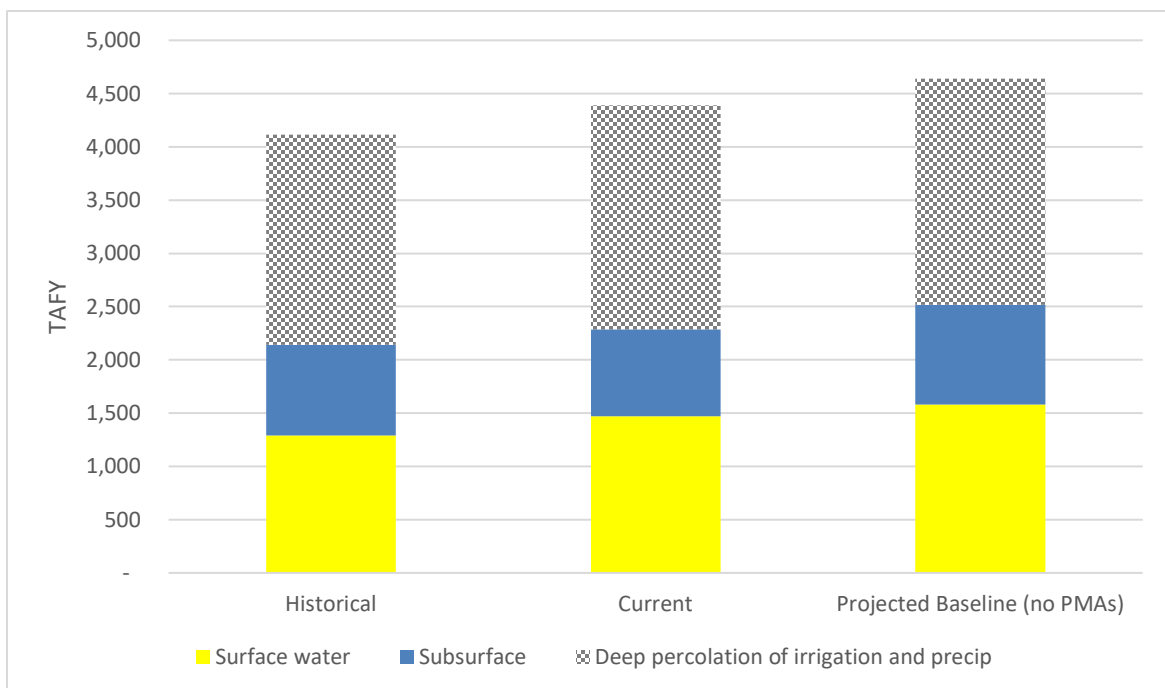
Water amounts are shown in acre-feet per year (AFY) for GSPs and in thousand AFY (TAFY) for HRs.

Water budget components aggregated for the San Joaquin River HR are shown in **Table 3-5**, **Figure 3-6** and **Figure 3-7**. **Table 3-5** shows groundwater inflows that contribute to recharge and groundwater outflows that contribute to discharge. No GSPs in this HR modeled the 2030 central tendency climate change scenario, and there were not enough GSPs that modeled the 2070 climate change central tendency scenario to aggregate results.

**Table 3-5. San Joaquin River HR Aggregated Groundwater Budget Inflows and Outflows**

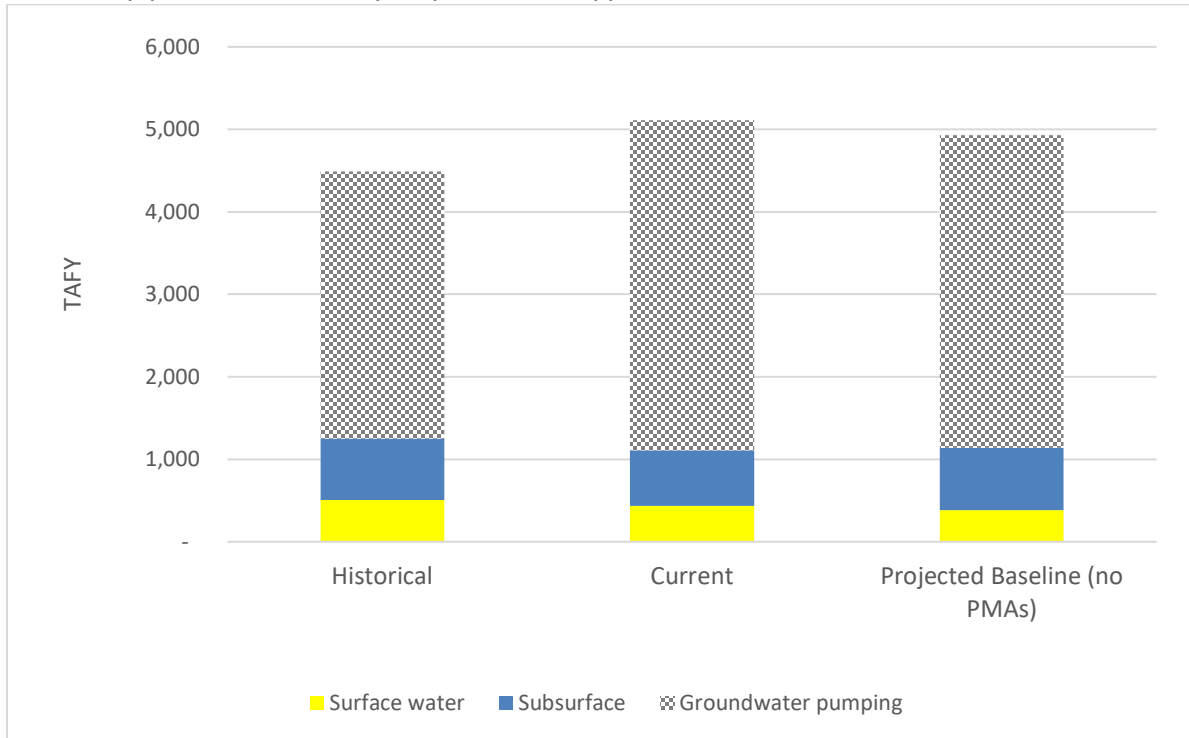
Water Budget Scenario	Groundwater Recharge/Inflow (TAFY)			Groundwater Discharge/Outflow (TAFY)		
	Deep Percolation	Surface Water	Subsurface	Surface Water	Subsurface	Groundwater Pumping
Historical	1,972	1,289	851	509	743	3,235
Current	2,104	1,469	817	435	670	4,007
Projected baseline (no PMAs)	2,124	1,582	934	384	755	3,789

Note: Deep percolation = deep percolation of irrigation and precipitation. Recharge by conveyance systems is included in surface water recharge. Outflow from subsurface drains not shown.



**Figure 3-6. San Joaquin River HR Groundwater Inflows for Water Budget Modeling Scenarios**

Note: Deep percolation is from precipitation and applied water.



**Figure 3-7. San Joaquin River HR Groundwater Outflows for Water Budget Modeling Scenarios.**

### 3.2.1.1 Water Supply

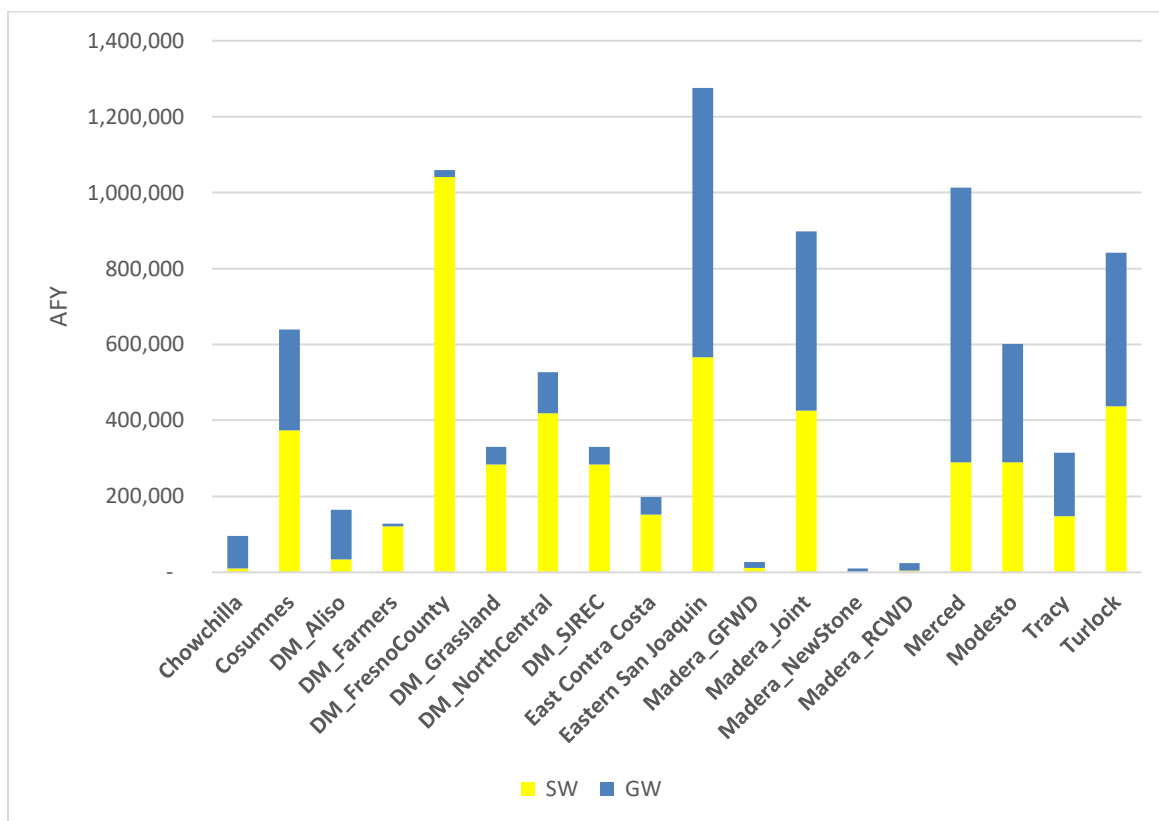
Surface water supplies represented just over half of San Joaquin River total water supply in the historical, current, and baseline projected scenarios (**Table 3-6**).

**Table 3-6. San Joaquin River HR Aggregated Surface And Groundwater Supplies Relative To Total Water Supply For Historical, Current And Projected Water Budget Modeling Scenarios**

Scenario	Surface Water (TAFY)	Groundwater (TAFY)	Total Water Supply (TAFY)	Surface Water (%)	Groundwater (%)
Historical	4,511	3,235	7,746	58%	42%
Current	4,614	4,007	8,620	54%	46%
Projected baseline (no PMAs)	4,542	3,789	8,331	55%	45%

The proportion of use of surface water supplies and groundwater supplies in each GSP for the historical scenario is compared in **Figure 3-8**. Eight GSPs in the San Joaquin River HR reported

surface water supplies greater than groundwater pumping, and two of those (Farmers and Fresno County in the Delta-Mendota Subbasin) rely on surface water for almost all their supplies (95 and 98 percent, respectively). Ten GSPs use more groundwater than surface water, and one of those (Madera – New Stone) relies solely on groundwater for its water supply. Chowchilla also has a high proportion of groundwater use (90 percent) compared to surface water.



**Figure 3-8. Surface and Groundwater Supplies by GSP in the San Joaquin River HR – Historical Scenario**

### 3.2.1.2 Change in Groundwater Storage

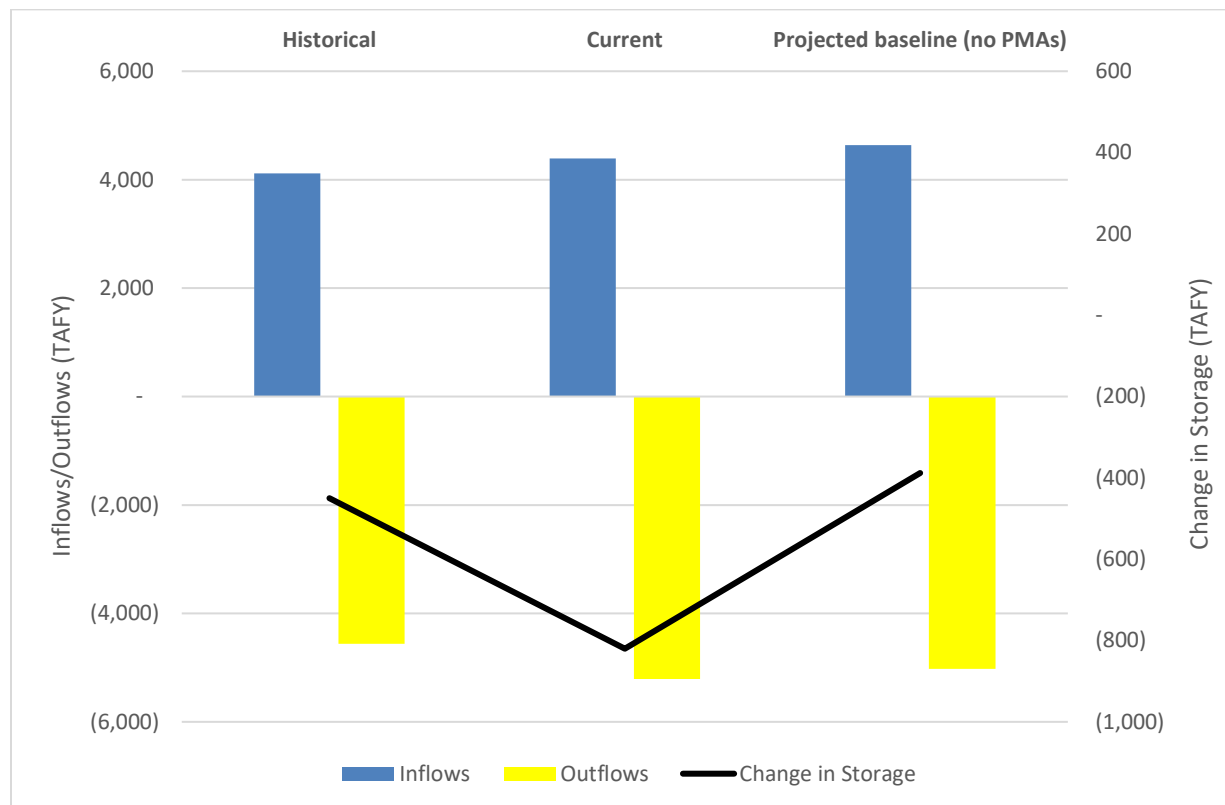
Aggregated groundwater change in storage (inflows minus outflows) was negative for the San Joaquin River HR in the historical, current and baseline projected scenarios (**Table 3-7**).

**Table 3-7. San Joaquin River HR Aggregated Change In Storage For Historical, Current And Projected Water Budget Modeling Scenarios**

Scenario	Total Groundwater Recharge/Inflow (TAFY)	Total Groundwater Discharge/Outflow (TAFY)	Change in Groundwater Storage (TAFY)
Historical	4,112	(4,563)	(451)
Current	4,391	(5,211)	(820)
Projected baseline (no PMAs)	4,639	(5,027)	(388)

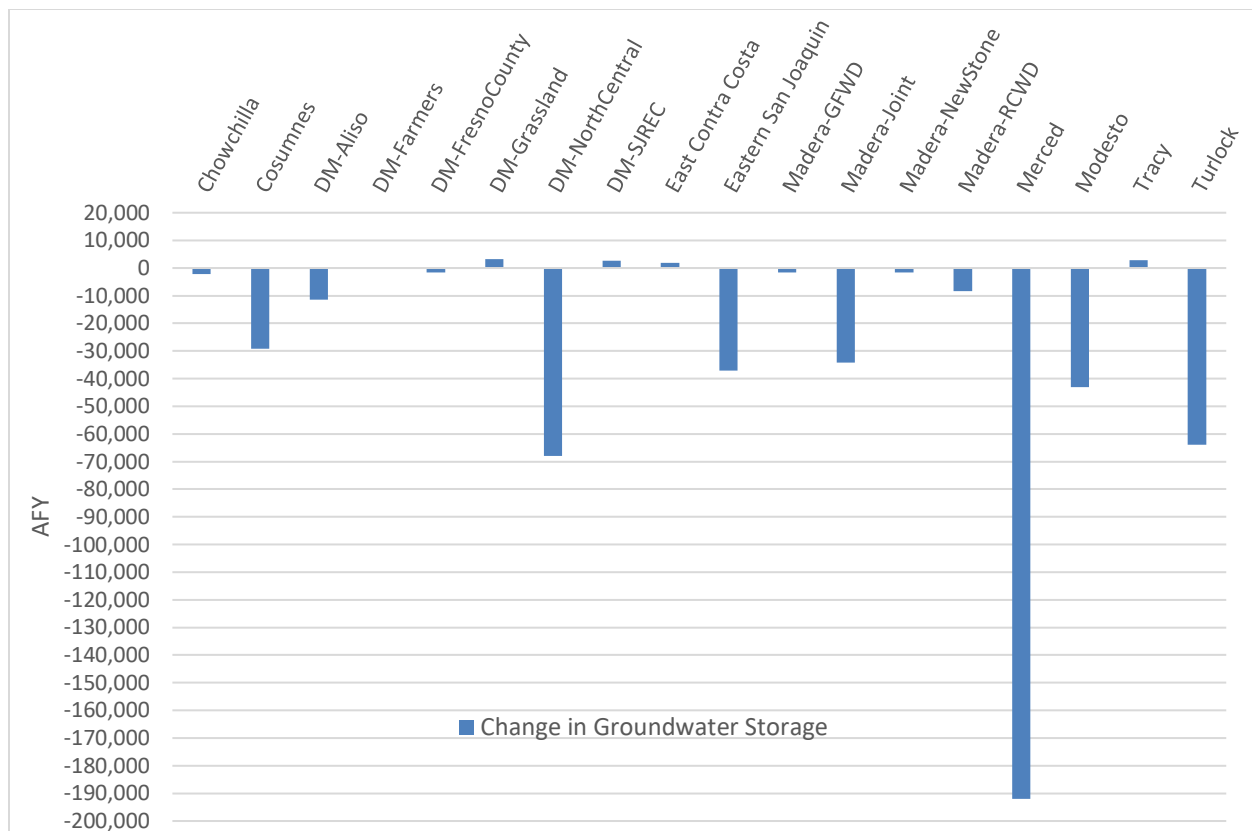


**Figure 3-9** illustrates the relative change compared to total inflows and outflows. As in other regions, the current scenario is a snapshot in time and relies on a small hydrologic period for modeling, which generally included the drought water years 2001-2015. Importantly, the comparison of outflows vs. inflows for each scenario does not necessarily represent the overdraft or surplus used for planning in each GSP, as previously described.



**Figure 3-9. San Joaquin River HR Total Groundwater Inflows, Outflows and Balance by Water Budget Scenario**

Historical change in groundwater storage for each GSP is shown in **Figure 3-10**.



**Figure 3-10. Change in Groundwater Storage of each GSP in the San Joaquin River HR – Historical Scenario**

### 3.2.2 Summary of PMAs for Demand Reduction and Supply Expansion

A summary of water management information collected from GSPs in the San Joaquin River HR is shown in **Table 3-8**. In this HR, half of the 18 GSPs are approved and seven have been assigned an inadequate status. The subbasins in this region were all assigned high priority except three, which were assigned a medium priority. There are two multi-plan subbasins in this HR. The Delta-Mendota subbasin is a large subbasin in this region that comprises six GSPs, and the Madera subbasin includes 4 GSPs.

As a region, GSPs are planning to recharge about 241,000 AFY of water through managed recharge. Pumping restrictions are planned by four GSPs (Delta-Mendota Aliso, Chowchilla, Madera Subbasin Joint, and Merced) to reduce water use by 118,000 AFY (total benefit estimated by all of these except Merced, which did not estimate benefit). The GSPs with the greatest amount of estimated benefit from these two types of strategies are Chowchilla and Madera Subbasin Joint. Chowchilla estimates almost 75,000 AFY of benefit from recharge and over 27,000 AFY of benefit from pumping restrictions. Madera Subbasin Joint GSP includes over 87,000 AFY of benefit from recharge and 90,000 AFY of benefit from pumping restrictions.

Three GSPs – Eastern San Joaquin, Northern & Central Delta-Mendota, and Grasslands (Delta-Mendota Subbasin) - plan to recycle water to augment supplies by an estimated total of 42,000 AFY. Most of the estimated benefit (30,000 AFY) is from projects in the Northern & Central Delta-Mendota GSP.

One GSP plans to use fallowing as a demand reduction strategy with no estimated benefit (Delta-Mendota-Aliso).

**Table 3-8. Summary of GSP Water Management Information for the San Joaquin River HR**

<b>Non-Water Budget Data</b>	<b>San Joaquin River</b>
Area (ac) of GSPs in HR	3,683,830
Total GSPs in HR	18
High priority GSPs	15
Medium priority GSPs	3
Very low priority GSPs	0
GSPs in critically overdrafted basins/subbasins	13
Approved GSPs	9
Incomplete GSPs	2
Inadequate GSPs	7
GSPs in review	0
<b>Managed Recharge</b>	
GSPs with current managed recharge or ASR	8
GSPs with planned recharge	12
Estimated benefit of planned managed recharge (AFY) <sup>1</sup>	241,221
<b>Recycled Water</b>	
GSPs that use recycled water	3
GSPs that plan to use recycled water as a supply augmentation strategy	3
Estimated benefit of planned recycled water (AFY) <sup>1</sup>	41,915
<b>Fallowing and Land Conversion</b>	
GSPs that plan to use fallowing as a demand reduction strategy	1
Estimated benefit of planned fallowing (AFY) <sup>1</sup>	Not provided
<b>Pumping Restrictions and Allocations</b>	
GSPs that plan to use pumping restrictions or allocations as a demand reduction strategy	5
Estimated benefit of planned pumping restrictions or allocations (AFY) <sup>1</sup>	117,550

<sup>1</sup>Total estimated benefit at full implementation.

### 3.3 Tulare Lake HR

#### 3.3.1 Overview of Water Budget Summaries

Water amounts are shown in acre-feet per year (AFY) for GSPs and in thousand AFY (TAFY) for HRs.

The Tulare Lake HR GSPs varied widely in the content and manner of data presentation for water budgets. This HR comprises five single plan GSPs and 22 GSPs that are part of multi-plan subbasins. The multi-plan subbasins also varied in how they coordinated their GSP development. In all cases, a water budget was developed for the entire basin. Some of the GSPs then completed their own water budgets that may have used different approaches (e.g., analytical vs. numerical model), which often resulted in divergent values for water budget components and change in groundwater storage. For example, the Kings subbasin provided two values for change in storage resulting from the historical water budget (-198,200 from Method 1 and -134,000 from Method 2). These two results are not unexpected considering the uncertainty associated with groundwater modeling, however, they make aggregation of results for the whole HR challenging.

In many cases, details were not provided or were not provided in consistent ways to make accurate aggregation possible for this HR. Therefore, aggregated inflows and outflows were not calculated from water budget components for each scenario. However, where data were available and could be verified, inflows and outflows were collected by GSP and/or subbasin for the historical scenario as shown in **Table 3-9**.

**Appendix A** includes additional Tulare Lake HR tables from GSPs that summarize water budgets for the historical, current and projected scenarios in the Kaweah, Kern and Kings subbasins.

**Table 3-9. Tulare Lake HR Aggregated Groundwater Budget Inflows and Outflows for the Historical Water Budget**

GSP Historical Water Budget	Groundwater Recharge/Inflow (AFY)			Groundwater Discharge/Outflow (AFY)		
	Deep Percolation	Surface Water	Subsurface	Surface Water	Sub-Surface	Groundwater Pumping
Castac Lake Valley	2,040	0	1,390	570	2,070	1,530
Kaweah - East Kaweah	67,600	10,900	62,500	0	12,900	153,900
Kaweah - Greater Kaweah	223,600	130,900	272,900	0	207,400	453,400
Kaweah - Mid-Kaweah	119,800	53,000	111,300	0	103,800	192,300
Kern Co. - Buena Vista <sup>1</sup>	-	-	-	-	-	-
Kern Co. - Henry Miller WD	6,908	17	-	0	-	7,220

GSP Historical Water Budget	Groundwater Recharge/Inflow (AFY)			Groundwater Discharge/Outflow (AFY)		
	Deep Percolation	Surface Water	Subsurface	Surface Water	Sub-Surface	Groundwater Pumping
Kern Co. Kern River	71,527	248,355	-	0	-	321,871
Kern Co. Olcese	2,281	730	-	0	2,201	857
Kern Co. Kern Groundwater Authority	669,398	730,964	-	0	87,102	1,590,373
Kern Co. - South of Kern River <sup>2</sup>	-	-	-	-	-	-
Kings - James	4,603	19,191	9,087	0	22,141	15,501
Kings - Kings River East	127,400	71,500	2,600	0	4,700	225,900
Kings - McMullin Area <sup>3</sup>	-	-	-	-	-	-
Kings - North Fork Kings	92,000	71,300	34,500	0	16,200	277,600
Kings - North Kings	213,500	227,800	0	0	122,000	345,400
Kings – South/Central Kings	358,000	79,900	103,900	400	0	35,400
Pleasant Valley	79,900	103,900	400	0	35,400	0
Tulare Lake	7,000	14,700	0	0	1,700	34,400
Tule - Alpaugh	142,093	177,934	118,312	0	136,525	386,272
Tule - Delano-Earlimart ID	6,700	800	46,000	0	26,000	27,200
Tule - Eastern Tule	13,300	26,700	46,000	0	66,000	55,700
Tule - Lower Tule River ID	53,300	59,900	92,000	0	67,000	206,600
Tule - Pixley ID	51,300	108,000	130,000	0	134,000	197,800
Tule - Tri-County WA	36,700	55,000	154,000	0	72,000	146,800
Westside	14,400	1,800	124,000	0	71,000	73,000
White Wolf	317,000	10,000	151,000	0	169,000	324,000

Note: Deep percolation = deep percolation of irrigation and precipitation. Recharge by conveyance systems is included in surface water recharge.

<sup>1</sup> Insufficient data

<sup>2</sup> Some lands overlap with other GSAs

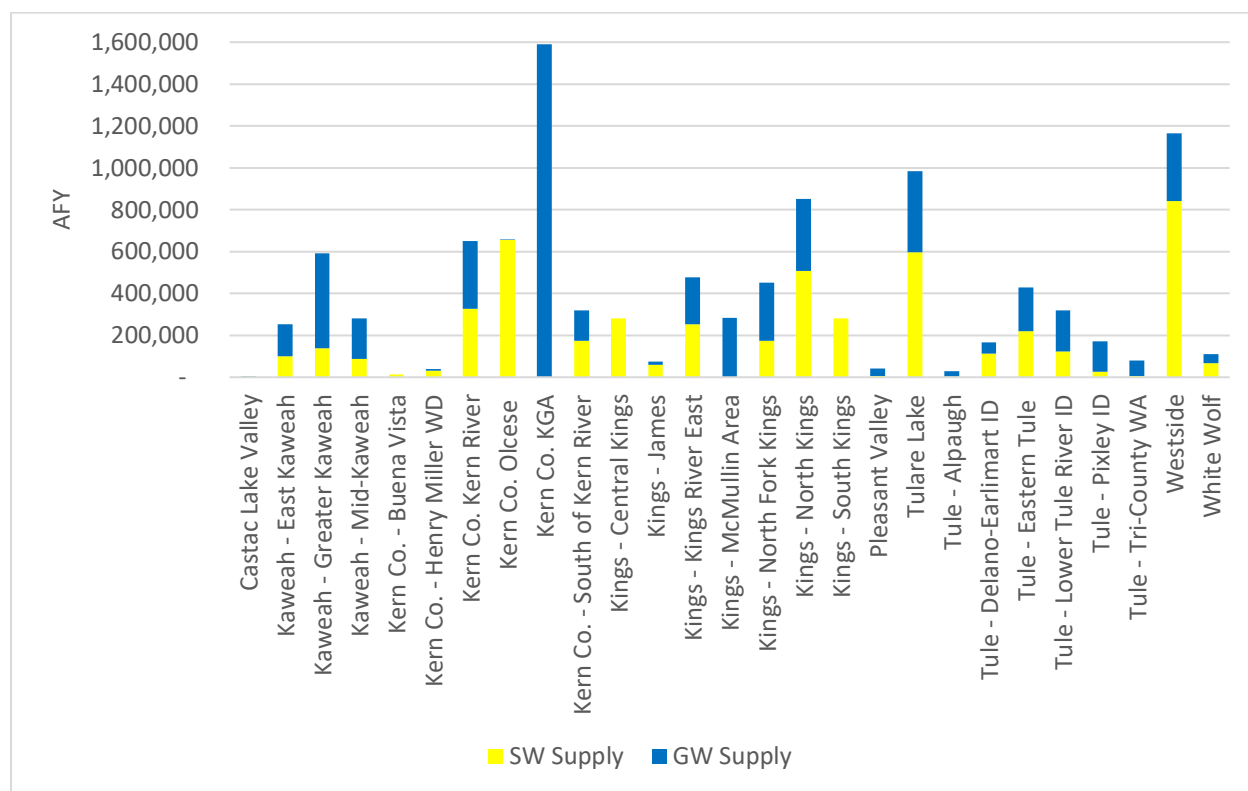
<sup>3</sup> Two water budget methods were used; insufficient data/description to reconcile.

**Table 3-10** shows the aggregated values and proportions of surface water and groundwater used by GSPs. As a region, surface water and groundwater are used fairly equal proportions.

**Table 3-10. Tulare Lake HR Surface And Groundwater Supplies Relative To Total Water Supply For Historical, Current And Projected Baseline Water Budget Modeling Scenarios**

Scenario	Surface Water (TAFY)	Groundwater (TAFY)	Total Water Supply (TAFY)	Surface Water (%)	Groundwater (%)
Historical	5,091	5,508	10,599	48%	52%
Current	3,297	3,600	6,897	48%	52%
Projected baseline (no PMAs)	3,527	3,499	7,026	50%	50%

**Figure 3-11** shows the distribution of surface and groundwater in individual GSPs. Westside, Kern – KGA, Tulare Lake, and North Kings, Kern-Kern River and Kaweah-Greater Kaweah account for just over half of the total water supply reported for the region. Surface water is a larger source of water supply for 14 GSPs, and of those, four GSPs rely solely on surface water (Kern – Buena Vista, Kern – Olcese, Kings – Central Kings, and Kings – South Kings). The remaining 13 GSPs use more groundwater than surface water, and of those, Kern – Kern Groundwater Authority uses groundwater only.



**Figure 3-11. Surface and Groundwater Supplies by GSP in the Tulare Lake HR – Historical Scenario**

Note: Castac Lake Valley GSP has water supplies under 10,000 AFY.

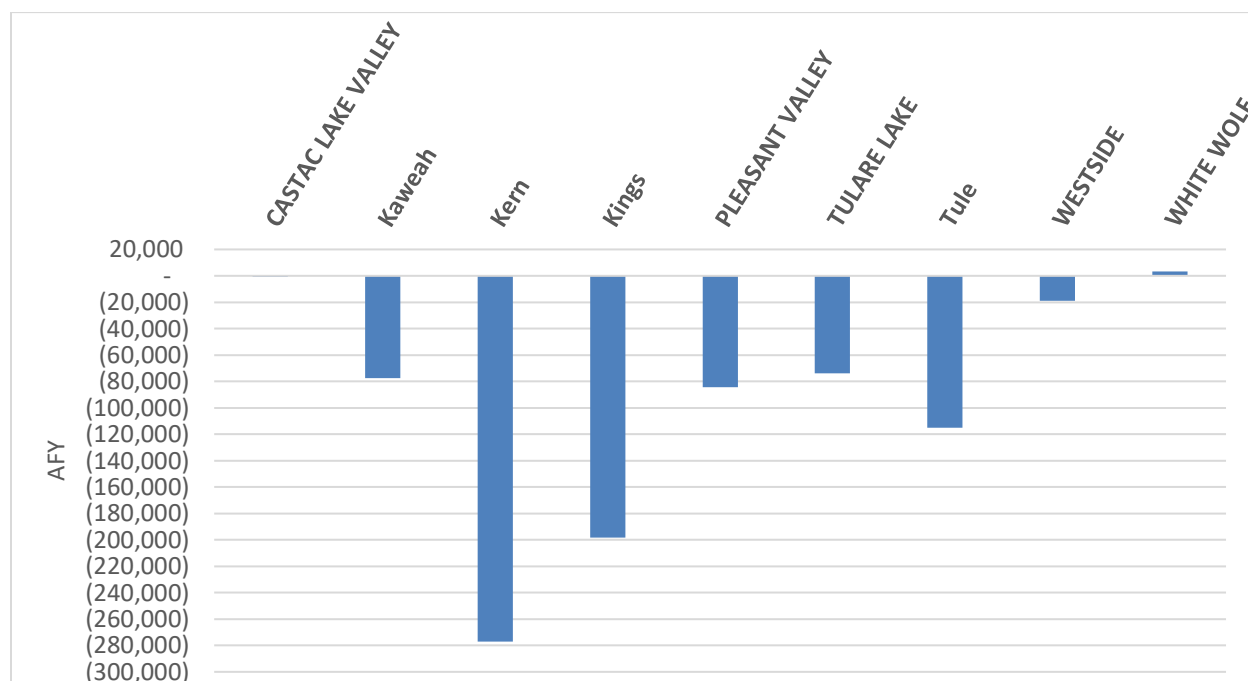
## Change in Groundwater Storage

**Table 3-11** shows the aggregated change in groundwater storage for the historical, current and projected baseline water budget scenarios. Inflows and outflows were not aggregated because of incomplete data for some of the individual GSPs and/or subbasins. **Figure 3-12** shows change in groundwater storage by GSP (for single plan basins) and by whole subbasin (for multi-plan basins).

**Table 3-11. Tulare Lake HR Change in Storage by Water Budget Modeling Scenario for Aggregated GSPs**

Scenario	Change in Groundwater Storage (TAFY)
Historical	(843)
Current	(568)
Projected baseline (no PMAs) <sup>1</sup>	(828)

<sup>1</sup> Does not include Tulare Lake, for which no tabular data were found.



**Figure 3-12. Change In Groundwater Storage By GSP (For Single Plan Subbasins) And By Subbasin (For Multi-Plan Subbasins) In The Tulare Lake HR – Historical Scenario**

### 3.3.2 Summary of PMAs for Demand Reduction and Supply Expansion

A summary of water management information collected from GSPs in the Tulare Lake HR is shown in **Table 3-12**. In this HR, nine GSPs have been approved, one is incomplete, and 16 have been assigned an inadequate status by DWR. The Castac Lake Valley GSP is still in review because it is very low priority. Twenty-four out of 27 GSPs subbasins are in critically overdrafted basins.

Tulare Lake HR GSPs include several types of supply augmentation and demand reduction PMAs to address overdraft such as land fallowing or conversion, groundwater allocations or pumping restrictions, surface water trading, conveyance and distribution improvements, and urban water conservation.

The most common PMA is supply expansion through recharge, which includes percolation or spreading basins, on-farm recharge, in-lieu recharge, and recharge through conveyance systems. The total estimated benefit from recharge for the region, approximately 790,000 AFY, is from projects planned in 20 GSPs. This estimate excludes recharge projects for which no estimates of benefit were provided. The GSPs with the highest estimated benefit from recharge projects are Kern Groundwater Authority, McMullin (Kern Subbasin) and Tulare Lake. These three GSPs account for well over half (almost 445,000 AFY) of estimated benefit from recharge.

The estimated benefit of supply expansion through recycled water planned projects is 48,877 AFY, planned in Kern Groundwater Authority, Kern River, Eastern Tule and North Kings GSPs.

Agricultural land conversion programs are planned in nine Tulare Lake HR GSPs. These PMAs include voluntary and mandatory fallowing programs, incentives, purchasing agricultural land for conversion to other uses, conversion to urban uses, conversion to other crops, and rotational fallowing.

Five GSPs estimated benefit from fallowing/land conversion, totaling about 228,000 AFY, as follows:

- Kaweah - Greater Kaweah 3,750 AFY
- Kern Co. Kern Groundwater Authority 31,700 AFY
- Kern Co. Kern River 27,000 AFY
- Tule - Lower Tule River 43,000 AFY
- Tule - Pixley ID 73,700 AFY
- Tule - Tri-County WA 15,000 AFY
- Tulare Lake 34,250 AFY

Pumping restrictions are planned by 12 GSPs but few noted an estimated benefit, except Eastern Tule (2,600 AFY), Kern Groundwater Authority (33,000 AFY), Tri-County WA (24,000 AFY), and Tulare Lake (1,500 AFY). The total estimated benefit from pumping restrictions for these four GSPs is 59,800 AFY.

The only GSP with details on a specific allocation program is Westside, whose 8-year ramp-down program from 2022 to 2030 will reduce a uniform allocation from 1.3 AF/ac to 0.6 AF/ac by 2030 on potentially 525,000 irrigated acres. (Landowners in Westside can also choose to participate in an alternative aquifer-specific allocation program, and targeted pumping



restrictions are also planned.) Though this project is a significant demand reduction effort, no estimate of benefit is provided in the GSP.

**Table 3-12. Summary of GSP Water Management Information for the Tulare Lake HR**

<b>Non-Water Budget Data</b>	<b>Tulare Lake</b>
Area of GSPs in HR (ac)	5,158,895
Total GSPs	27
High priority GSPs	24
Medium priority GSPs	2
Very low priority GSPs	1
GSPs in critically overdrafted basins/subbasins	24
Approved GSPs	9
Incomplete GSPs	1
Inadequate GSPs	16
GSPs in review	1
<b>Managed Recharge</b>	
GSPs with current managed recharge or ASR	21
GSPs with planned recharge	20
Estimated benefit of planned managed recharge (AFY) <sup>1</sup>	792,168
<b>Recycled Water</b>	
GSPs that use recycled water	6
GSPs that plan to use recycled water as a supply augmentation strategy	4
Estimated benefit of planned recycled water (AFY) <sup>1</sup>	48,887
<b>Fallowing and Land Conversion</b>	
GSPs that plan to use fallowing as a demand reduction strategy	9
Estimated benefit of planned fallowing (AFY) <sup>1</sup>	231,000
<b>Pumping Restrictions and Allocations</b>	
GSPs that plan to use pumping restrictions or allocations as a demand reduction strategy	12
Estimated benefit of planned pumping restrictions or allocations (AFY) <sup>1</sup>	59,800 plus Westside

<sup>1</sup>At full implementation.

### 3.4 Information Relevant to Potential Future Land Use and Water Management Changes

As listed in Tables 10 and 14, 11 of the 66 central valley GSPs include references to land conversion or fallowing. This includes one GSP in the San Joaquin River HR with no estimated benefit, one GSP in the Sacramento River HR with an estimated benefit of 4,000 to 8,000 AFY,

and and 9 GSPs in the Tulare Lake HR with an estimated benefit of 231,000 AFY in overdraft reduction.

As explained in Section 2.4, rather than further evaluating future state and federal land use changes in the Central Valley, we instead evaluated future water management actions as presented in the 2023 Water Plan update.

What follows is a summary of recommended actions as presented in the Public Review Draft of the California Water Plan 2023 (Water Plan) that should be considered in developing salt management strategies as the P&O Study progresses. Items bolded below are believed to have the most relevance for consideration in the P&O Study.

The California Water Plan Update 2023 vision statement reads as follows “All Californians benefit from water resources that are sustainable, resilient to climate change, and managed to achieve shared values and connections to our communities and the environment.” The plan provides a road map for the implementation of future projects and management actions aimed at improving and protecting California’s water future through improvements to both the Natural (watersheds lands, aquifers, and processes that collect, clean, store, and convey water within and among watersheds or hydrologic regions) and Built (human constructed infrastructure that provides water management benefits) backbone infrastructure.

Chapter 8 of the 2023 Water Plan lays out the “Roadmap to Resilience” with the caveat that the pace of implementation depends on the feasibility and availability of staff resources, funding and competing priorities.

The roadmap to resilience is organized around these seven objectives:

1. Support watershed resilience planning and implementation.
2. Improve resilience of State, federal, and regional “backbone” built water infrastructure.
3. Improve resilience of “backbone” natural infrastructure.
4. Advance equitable outcomes in water management.
5. Support and learn from Tribal water and resource management practices.
6. Increase support for regulatory programs and enhance regulatory flexibility to address a changing climate.
7. Provide guidance and support continued resources for implementing actions toward water resilience.

Each objective includes at least one recommendation, and each recommendation includes one or more actions to implement the recommendation. Most of the actions deemed by the technical

team to be most relevant to the P&O Study are associated with Objectives 2 and 3 and are listed below.

- Action 2.1.1. Modernize Backbone Conveyance Systems. The State should prioritize and support investments to modernize State, federal, and regional conveyance systems that provide benefits to multiple regions. This effort also should include **repairing and improving aging or damaged infrastructure to facilitate groundwater recharge**, wildfire protection, system flexibility, and other outcomes intended to improve resiliency.
- Action 2.2.2. Expand SWP Storage and Conveyance Capacity. **The State, SWP, and potential federal and local partners will explore opportunities to expand SWP storage and conveyance capacity (including Delta conveyance) to help regulate supplies under increasingly extreme hydrology** (e.g., climate whiplash) and capture more water during wet periods for use in dry periods.
- Action 2.3.1. Identify Opportunities for System Integration. DWR will identify opportunities where integration of existing or planned systems and programs could expand benefits and more effectively adapt to changed conditions. DWR will work with willing partners to identify and **support interties, operational agreements, and exchanges of water and wheeling capacity that improve quality, flexibility, and resilience**. Evaluation of integration potential will include the Water Storage Investment Program facilities, groundwater banks, regional aqueduct interties, and large-scale regional reuse or desalination programs.
- Action 2.5.1. Expand Understanding and Application of Integrated Water, Energy, and Agricultural Systems. The State should **expand understanding of the linkage between water, energy, and agricultural systems** and the relative impacts of changes in one on the other. The State should improve the application of integrated **water (quality and quantity)**, energy, and agricultural system measures to support **future management of these systems**.
- Action 2.5.2. Support and Integrate California Department of Food and Agriculture Climate-Smart Agriculture Programs. The State should **continue to support and integrate the California Department of Food and Agriculture’s Climate-Smart Agricultural programs** with other resilience efforts, such as SGMA. **Programs that encourage improved manure management practices, healthy soils, and water efficiency can conserve water and protect water quality.**
- Action 3.2.2. Incentivize Land Use Changes on Subsidized Lands in the Sacramento-San Joaquin Delta. The State should continue to **support programs that incentivize land use change on the highly organic and deeply subsidized lands within the Delta** per recommendations in the Delta Plan, the 2023 Scoping Plan, and the forthcoming Climate Adaptation Strategy. **Such land use changes as conversion to rice cultivation or**

**managed wetlands re-saturates the land, thereby reducing subsidence and thus the risk of levee failure that threatens the region and Central Valley Project and SWP facilities.** This also reduces greenhouse gas emissions by slowing the breaking down of peat soils. These practices can improve the long-term resilience and economic viability of the region.

- Action 3.3.1. Increase Opportunities for Managed Aquifer Recharge. **DWR will identify opportunities to enhance managed aquifer recharge by local governments and landowners.** DWR will analyze major rivers and tributaries to establish known conditions of flood stage to enable flood water capture and diversion for managed aquifer recharge and storage and flood risk reduction. **The State should establish a process and conditions for programmatic permitting to accelerate groundwater recharge programs at the local and regional scale, including evaluation of safeguards related to water quality and drinking water.**

### 3.5 Summary of Hydrogeologic Information

Information on principal aquifers and illustrations of geologic cross sections were extracted from each GSP into separate PDF documents which are approximately five to 10 pages in length. These “quick references” to GSP aquifer systems provide an easy way to access this information as an alternative to finding it in GSPs, which can be hundreds or thousands of pages in length. When future salt management planning occurs under the P&O Study, aquifer system information will be especially relevant in determining where and how salt management projects and actions might be successful through water management. An example of an aquifer system quick reference is included in **Appendix B. Table 3-13** [eliminate space here?]lists the specific GSP Area of subbasin, whether AEM data was pulled into the individual basin summaries provided in Appendix B, and if not why this was not possible.

**Table 3-13. X**

<b>GSP Area or Basin Name</b>	<b>AEM Profile (Yes or No)</b>	<b>Comments</b>
<b>B1 - Sacramento River Hydrologic Region</b>		
Anderson_PA	Yes	
Antelope_PA	Yes	
BIG VALLEY_5-004_PA	No	No AEM flight paths
BIG VALLEY_5-015_PA	Yes	
BOWMAN_PA	Yes	
Butte_PA	Yes	
COLUSA_PA	Yes	
CORNING_PA	Yes	
Enterprise_PA	Yes	
LosMolinos_PA	Yes	
North&SouthYuba_PA	Yes	
NorthAmerican_PA	Yes	

GSP Area or Basin Name	AEM Profile (Yes or No)	Comments
Red_Bluff_PA	Yes	See Los Molinos
Sierra_Valley_PA	Yes	
Solano_PA	Yes	
South_American_PA	Yes	
Sutter_PA	Yes	
Vina_PA	Yes	Already has AEM data for cross sections
Wyandotte_PA	Yes	See Butte
Yolo_PA	Yes	
<b>B2 - San Joaquin River Hydrologic Region</b>		
Chowchilla_PA	Yes	
Cosumnes_PA	Yes	
DM_Aliso_PA	No	New common chapter for wide DM subbasin included (Delta Mendota Subbasin Common Chapter_PA_NEW)
DM_Farmers_PA	Yes	
DM_Fresno_PA	Yes	
DM_NorthCentral_PA	Yes	
DM_SJREC_PA	Yes	
EastContraCosta_PA	Yes	
EasternSanJoaquin_PA	Yes	
Madera_GFWD_PA	Yes	
Madera_Joint_PA	Yes	See Chowchilla
Madera_Newstone_PA	Yes	
Madera_RootCreek_PA	Yes	See Madera_Newstone
Merced_PA	Yes	
Modesto_PA	Yes	
<b>B3 - Tulare Lake Hydrologic Region</b>		
Castac_Lake_PA	No	No AEM flight paths
Kaweah_East_Kaweah_PA	Yes	See Greater Kaweah
Kaweah_GreaterKaweah_PA	Yes	
Kaweah_Mid_Kaweah_PA	Yes	See Greater Kaweah
Kern_BVGSA_PA	Yes	
Kern_HenryMiller_PA	Yes	
Kern_KGA_PA	Yes	
Kern_Olcese_PA	Yes	
Kern_SOKR_PA	Yes	
Kern-KRGSA	Yes	
Kings_James_PA	Yes	Part of Kings_Subbasin_PA
Kings_KingsRiverEast_PA	Yes	
Kings_McMullin_PA	Yes	Part of Kings_Subbasin_PA
Kings_NorthFork_PA	Yes	Part of Kings_Subbasin_PA

GSP Area or Basin Name	AEM Profile (Yes or No)	Comments
Kings_NorthKings_PA	Yes	Part of Kings_Subbasin_PA
Kings_SouthKings_PA	Yes	Part of Kings_Subbasin_PA
Pleasant_Valley5-002_PA	Yes	
Tulare_Lake_PA	Yes, but only portions	
Tule_Alpaugh_PA	Yes	
Tule_DEID_PA	Yes	
Tule_ETGSA_PA	Yes	See Tule_DEID
Tule_LTRID_PA	Yes	See Tule_DEID
Tule_Pixley_PA	Yes	See Tule_DEID
Tule_TCWD_PA	Yes	
Westside_PA	Yes	
White_Wolf_PA	Yes	

## 4. Summary

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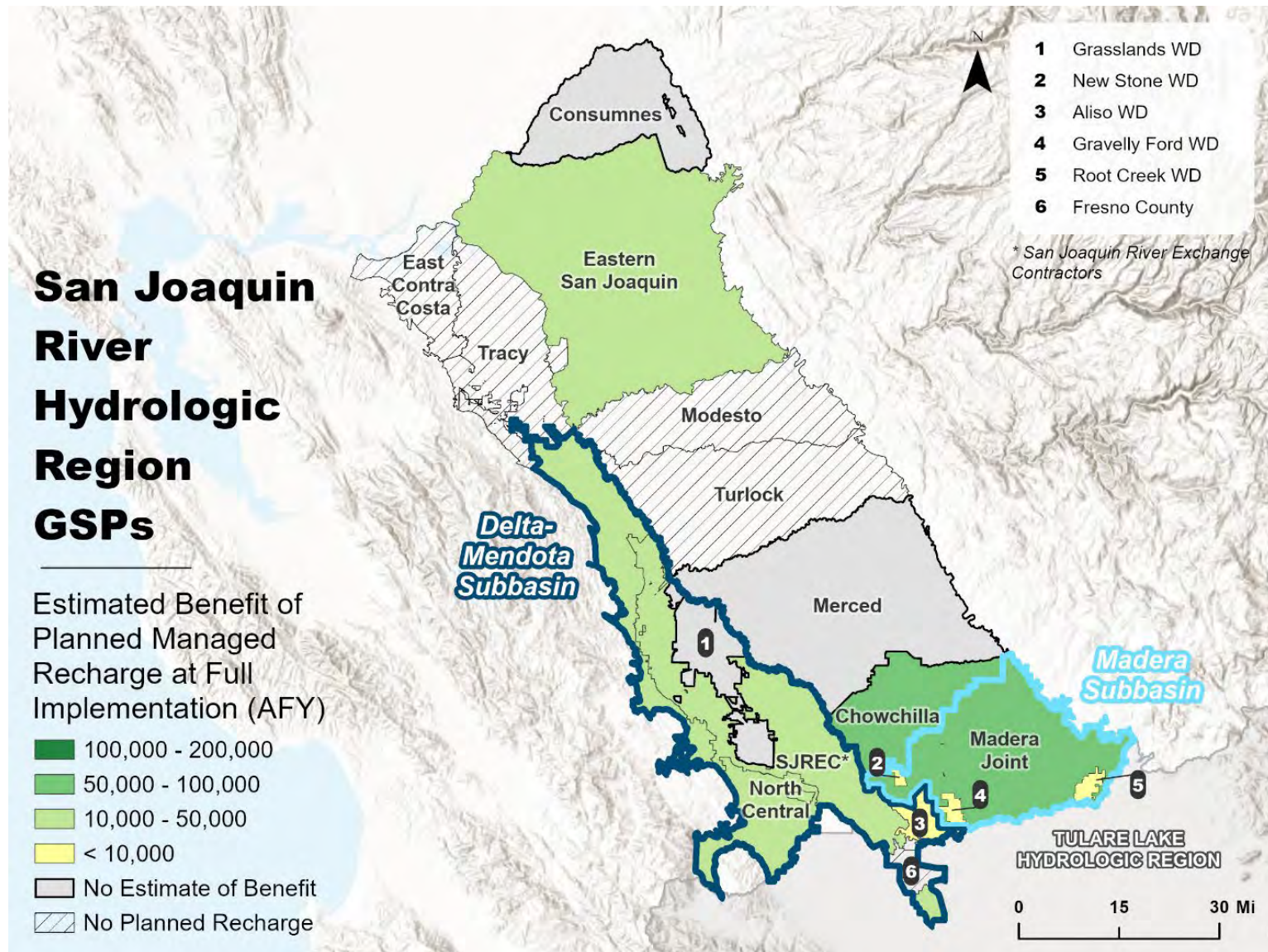
### 4.1 Projected Increase in Managed Groundwater Recharge

As described in Section 3, significant PMAs targeting recharge are planned in the San Joaquin River and Tulare Lake HRs (241,221 and 716,168 AFY estimated benefit at full implementation, respectively). Though managed recharge accounts for most of the PMAs planned in Sacramento River HR GSPs, the estimated benefit from recharge PMAs is only 11,275 in that HR because of the low incidence of overdraft in Sacramento River groundwater basins.

**Figure 4-1** is a map of the San Joaquin River HR showing GSPs with planned recharge by estimated benefit at full implementation. The GSPs with the most recharge planned are in the Madera subbasin. Other significant managed recharge projects are planned for GSP areas in the northern and southwestern parts of the region.

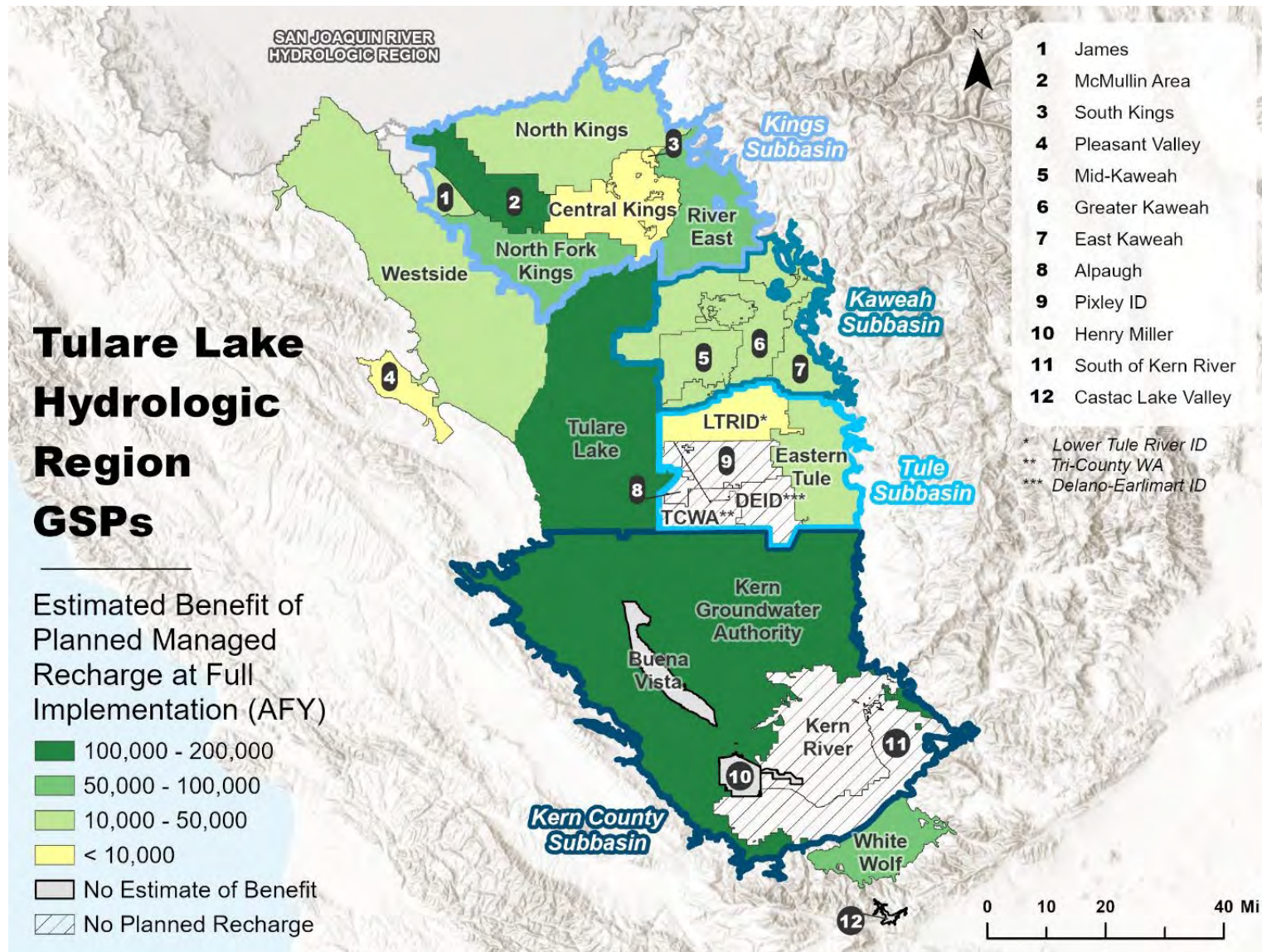
**Figure 4-2** shows GSPs by planned managed recharge in the Tulare Lake HR. Managed recharge is expected to increase throughout this HR, but the highest amount is planned for the southern and central parts of the region.





**Figure 4-1. Map Of GSPs With Planned Recharge In San Joaquin River Hydrologic Region (Bold Boundaries Designate Multi-plan Basins)**





**Figure 4-2. Map Of GSPs With Planned Recharge In Tulare Lake Hydrologic Region (Bold Boundaries Designate Multi-plan Basins)**

## Projected Demand Reduction from Land Fallowing/Conversion and Pumping Restrictions/Allocations

Several strategies for reducing demand using land fallowing or conversion will be used in the Tulare Lake HR, as described in Section 3. **Figure 4-3** illustrates how much and where these strategies are expected to benefit groundwater stores. Few similar strategies are being used in the Sacramento River and San Joaquin River HRs.



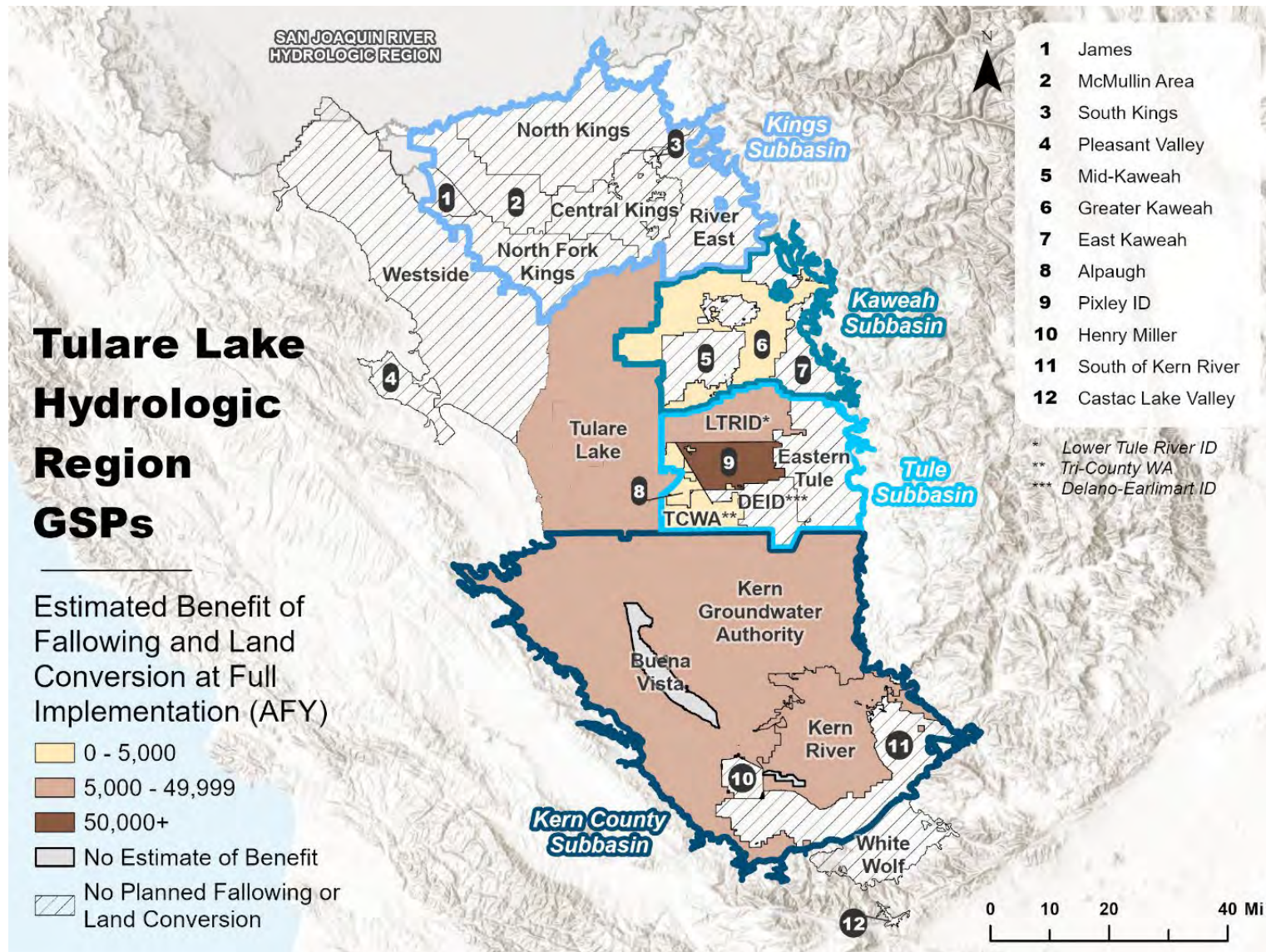
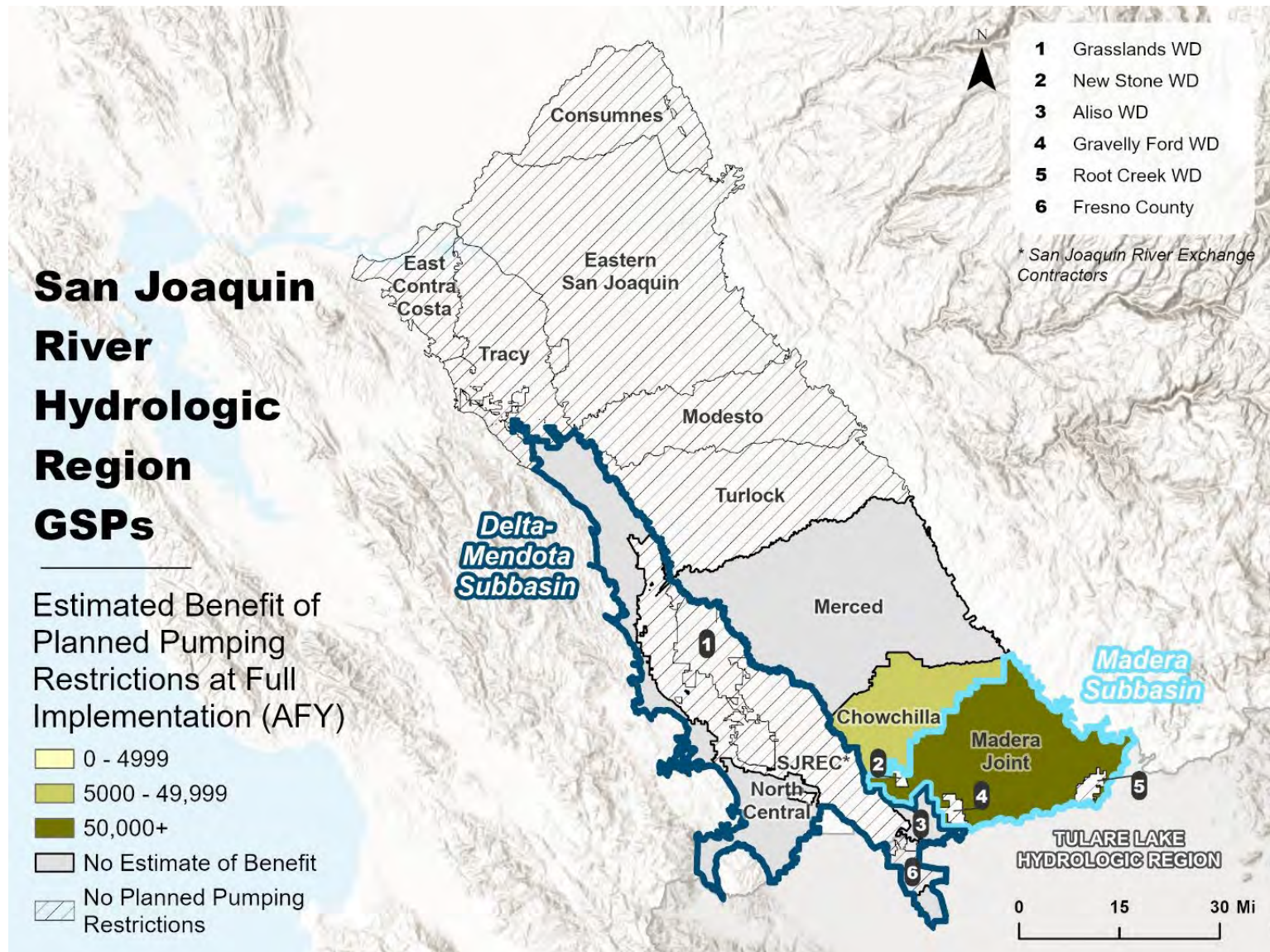


Figure 4-3. Map Of GSPs With Planned Fallowing and/or Land Use Conversion In Tulare Lake Hydrologic Region (Bold Boundaries Designate Multi-plan Basins)

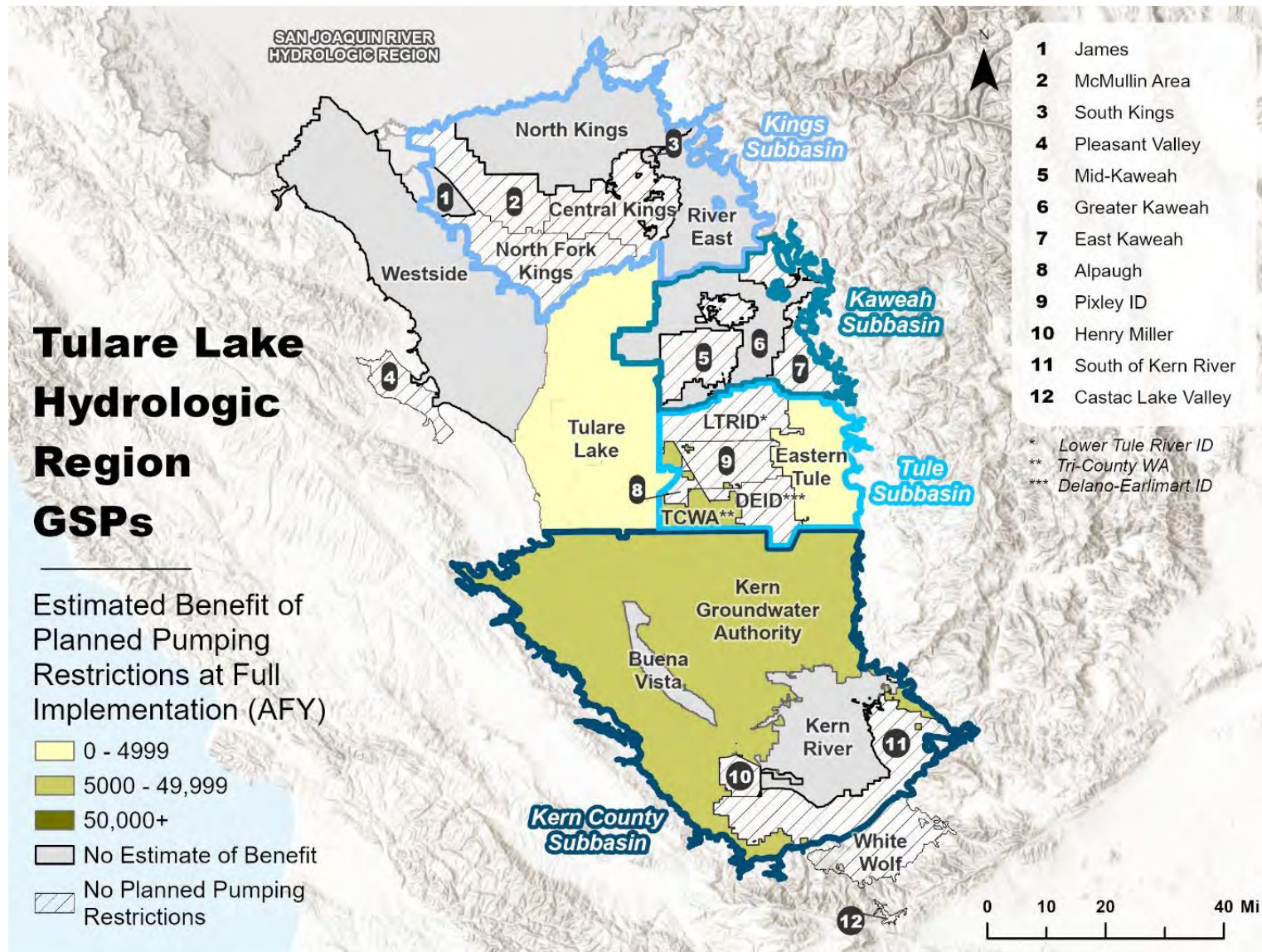
Groundwater pumping restrictions and allocations will be used as demand reduction strategies in both the San Joaquin River HR (with 117,550 AFY of estimated benefit) and the Tulare Lake HR (with 59,800 AFY of estimated benefit). The distribution of GSPs using these strategies is shown for the San Joaquin River HR in **Figure 4-4** and for the Tulare Lake HR in **Figure 4-5**. This strategy is the most uncertain in terms of estimated benefit; most of the GSPs that included it in their planned PMAs do not provide estimated benefit for these management actions. Even though there are more GSPs in the Tulare Lake HR that plan to use it than the San Joaquin HR (13 vs. 5), only four estimated the benefit to groundwater.





**Figure 4-4. Map Of GSPs With Planned Fallowing and/or Land Conversion In San Joaquin River Hydrologic Region (Bold Boundaries Designate Multi-plan Basins)**





**Figure 4-5. Map of GSPs with Planned Pumping Restrictions/Allocations in Tulare Lake Hydrologic Region (Bold Boundaries Designate Multi-plan Basins)**

## 4.2 Summary of Aquifer information from GSPs and other DWR Resources

**Appendix B** provides pertinent HCM information from each of the Central Valley GSPs evaluated for this study. The Appendix B information pulled directly from the GSP for each subbasin includes:

- Descriptions of principal aquifers and aquitards
- Cross-section location maps, and
- Geologic cross-sections

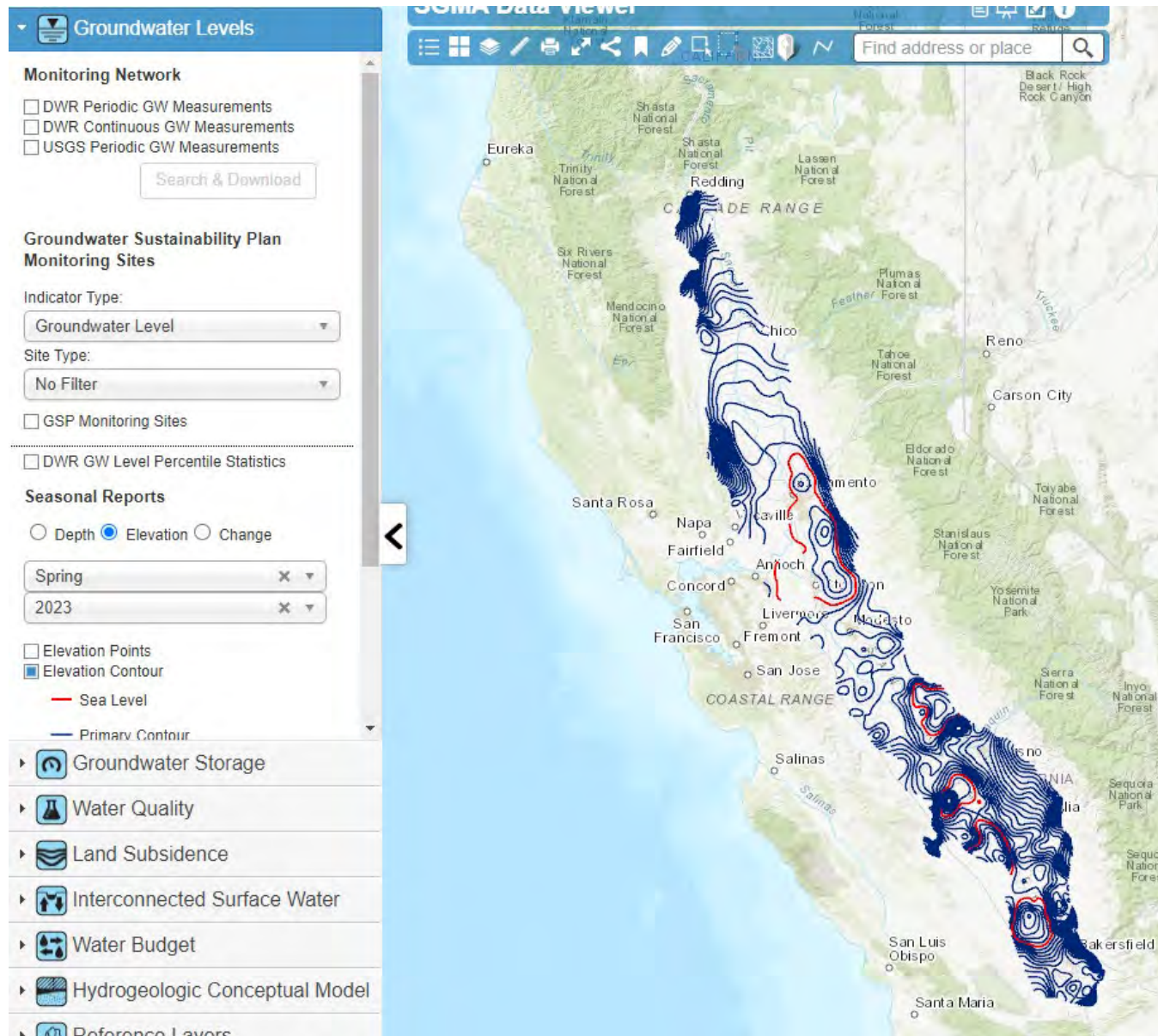
The technical team compared the geologic cross-section locations with the flight lines that were followed in performing the Statewide AEM survey. If a flight line was near a GSP HCM profile, then the AEM texture profile was brought in for direct comparison with the GSP profile to improve the understanding of the nature and distribution of the underlying aquifer and aquitards. Although the Appendix B information represents the GSAs best understanding of the local groundwater system, this information does not allow for observation of broader hydrologic region-wide and/or Central Valley-wide trends in the nature and distribution the natural infrastructure, including the depth, thickness and lateral extent aquifers and aquifers. An understanding of these features on a larger scale will become increasingly important as the team evaluates salinity movement and management alternatives at the large salt planning scales, e.g., for a Salt Management Region.

For this reason, it is recommended that, in addition to reviewing the detailed Appendix B hydrogeologic information, in future P&O Study planning efforts, the technical team should consider accessing, downloading and incorporating regional and valley wide hydrogeologic information as it develops predictive modeling tools. Listed below are three links which are viewable and available for download on DWR's SGMA Data Viewer:



1. Regional and valley wide aquifer groundwater levels and depth to groundwater

<https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels>

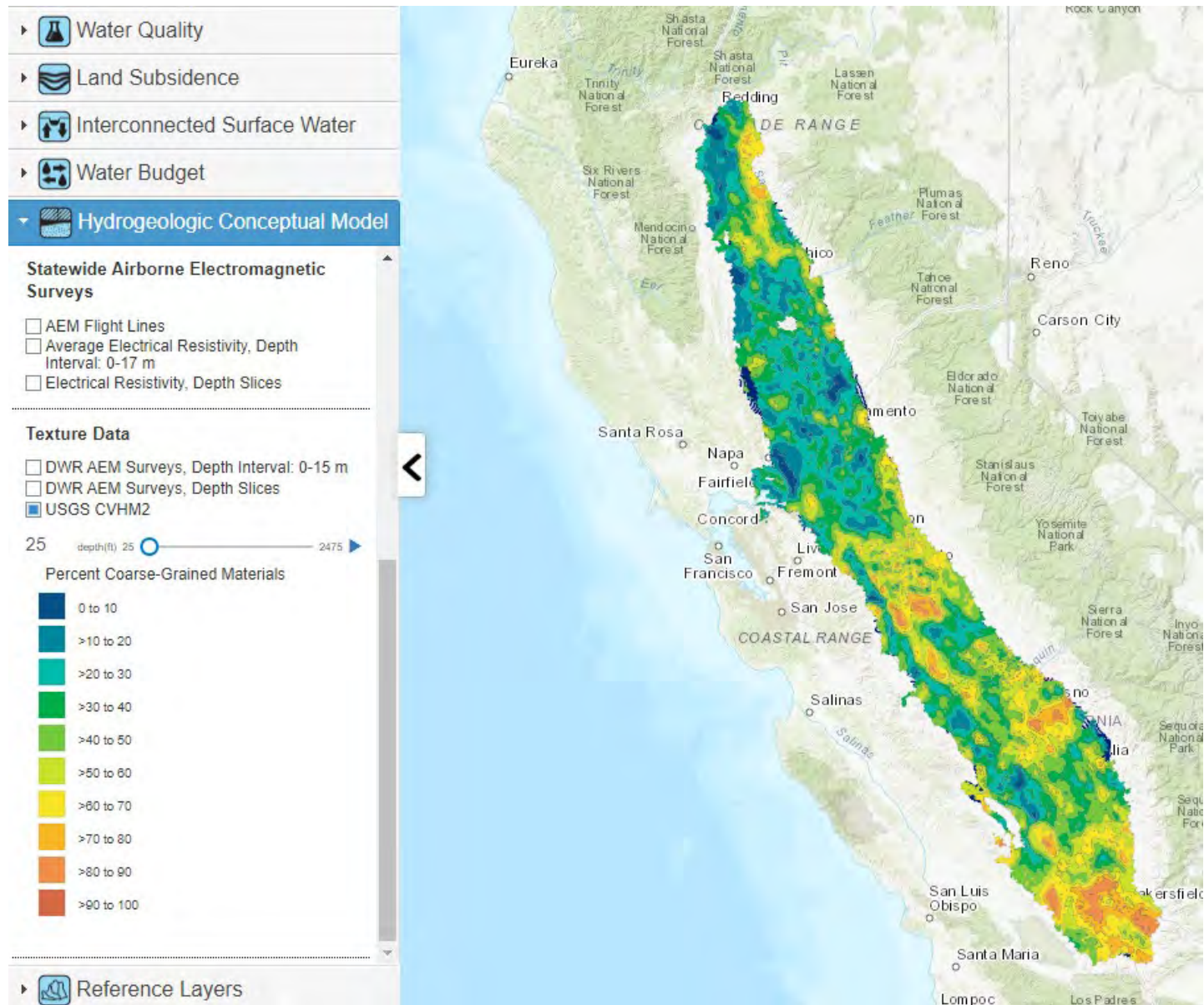




**Figure 4-6. Groundwater Elevation Contours in Central Valley, Spring 2023**

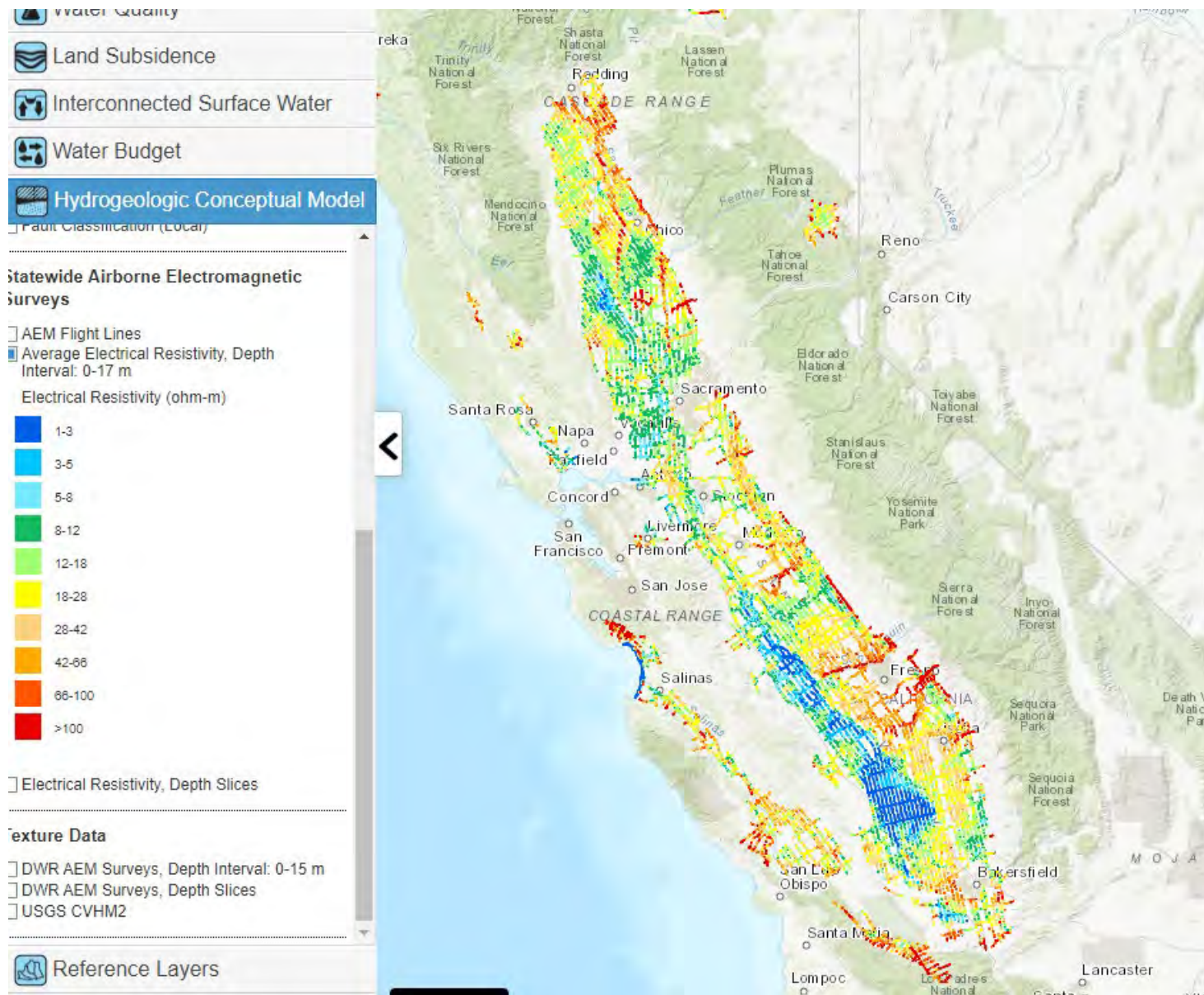
2. Regional and central valley wide aquifer texture (clay, silt, sand and gravel) both from wells logs (CVHM2 Textural data set) and

<https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#hcm>



**Figure 4-7. Soil Texture Distribution in Central Valley, Upper 25 Feet**

3. Statewide AEM Survey Information <https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#hcm>



**Figure 4-8. Average Electrical Resistivity in Central Valley, Upper 17 Meters**

## 4.3 Central Valley Wide Observations

### 4.3.1 Summary

As described in Section 3 and shown in **Figures 4-1 through 4-5**, supply augmentation and demand reduction strategies are most identified and planned in GSPs where actions are needed to address overdraft. In these areas, water management and conditions are expected to change the most. Such changes will potentially affect salt movement and management needs as well.

GSPs have identified different water management strategies depending on applicable local conditions, e.g. water supply sources, hydrogeologic conditions, projected climate changes and existing or expected regulations and water rights. Where surface water represents most of the water supply, such as in the Sacramento River HR, water management strategies are focused on surface water than groundwater. For this reason, PMAs in that HR include managed recharge, for which surface water supplies can be used, but exclude pumping restrictions or allocations. Because groundwater represents about half of water supply in the San Joaquin River and Tulare Lake HRs, groundwater management actions such as pumping restrictions are more commonly planned along with recharge and land use changes.

Recharge can only be used where soils and underlying geologic formations are suitable. For example, much of the Westside GSP area is underlain by clay that would not allow for efficient aquifer recharge; therefore, this area has focused on groundwater pumping restrictions and other surface water management strategies to manage groundwater instead of recharge from a GSP-wide management perspective, though there are several small private recharge basins in the plan area and ASR targeted in specific areas.

Regional climate and climate change projections also influence groundwater management strategies. Whereas GSPs in the Sacramento River HR rely on natural recharge to maintain groundwater levels, GSPs in the San Joaquin River and Tulare Lake HRs cannot rely on natural recharge nearly as much. In addition, climate is expected to not only change the amount of precipitation that falls annually, but its timing; because precipitation is expected to fall earlier in the spring, models show that more water will be available for winter recharge but less will be available for summer irrigation. The intensity and extent of this effect varies throughout the Central Valley.

Finally, many of the projected water budgets show a decrease in surface water supply overall. While this decrease has been attributed partly to the change in precipitation timing and amounts described above, it is also attributed to expected increased regulations on surface water, which vary between HRs and between GSPs within HRs. For example, the Bay Delta Plan includes the San Joaquin River and its tributaries, whereas other rivers in the San Joaquin River HR are exempt from complying with unimpaired flows. Water rights and contractual agreements can also change, altering surface water supplies. For example, Westside GSP notes their expected increase in Central Valley Project contract entitlements and reliability resulting from the 2018

Addendum to the Coordinated Operation Agreement and has, accordingly, planned to approach water management partly through surface water trading. These differences in expected surface water supply are reflected in GSP projected water budgets.

#### **4.3.2 *Status of GSP Information***

The information in the report is from the most recently available versions of GSPs accessible through DWR's SGMA online portal. GSPs are required to submit annual reports to DWR that include progress on GSP implementation including PMAs, filling data gaps, and coordination with other GSPs. They are also required to submit 5-year updates that include the same information plus progress on achieving milestones and groundwater conditions relative to sustainable management criteria as developed in each GSP. In addition, many GSPs are not final because they have not been approved by DWR and are still going through revisions. Therefore, the information in this report, if it is to be used in an ongoing manner, may need to be updated with information from finalized GSPs and updates to GSP components that change or affects PMAs and/or water budgets.

## **Appendix A   Selected GSP Information Summaries By Hydrologic Region**

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- A.1   Appendix A1 – GSP Information Summaries for Sacramento River  
Hydrologic Region**
- A.2   Appendix A2 – GSP Information Summaries for San Joaquin River  
Hydrologic Region**
- A.3   Appendix A3 – GSP Information Summaries for Tulare Lake  
Hydrologic Region**



## **A.1 Selected GSP Information Summaries for Sacramento River Hydrologic Region**

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## **A.2 Selected GSP Information Summaries for San Joaquin River Hydrologic Region**

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## **A.3 Appendix A3 – Selected GSP Information Summaries for Tulare Lake Hydrologic Region**

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## **Appendix B    Aquifer Information – Selection of Cross-Sections from HCMs and Nearest AEM Texture Profile**

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Text