DRAFT REPORT | MAY 2026

2025 Safe Yield Reevaluation

PREPARED FOR

Chino Basin Watermaster

PREPARED BY

WEST YOST
Water. Engineered.

2025 Safe Yield Reevaluation

Prepared for

Chino Basin Watermaster

Project No. 941-80-24-32

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LIST OF ACRONYMS AND ABBREVIATIONS

2015 SYRM	2015 Safe Yield Reset Methodology
2017 Court Order	April 28, 2017 Court Order on the Safe Yield of the Chino Basin
2020 SYR	2020 Safe Yield Recalculation
2022 R&R	Rules and Regulations
2025 CVM	2025 Chino Valley Model
2025 SYR	2025 Safe Yield Reevaluation
afy	Acre-Feet/Year
AP	Appropriative Pool
Basin	Chino Basin
CDA	Chino Basin Desalter Authority
CDFM	Cumulative Departure from Mean Precipitation
CF	Change Factor
CII	Commercial, Industrial, And Institutional
CMIP6	Coupled Model Intercomparison Project
CVM	Chino Valley Model
DEM	Digital Elevation Model
DIM	Dedicated Irrigation Meter
DIPAW	Deep Infiltration of Precipitation and Applied Water
DWR	Department of Water Resources
ET	Evapotranspiration
ET_o	Reference Evapotranspiration
ETS1	Evapotranspiration Segments Package
FHB	Flow and Head Boundary Package
FY	Fiscal Year
GLMC	Ground-Level Monitoring Committee
GSP	Groundwater Sustainability Plan
GWU	Groundwater Utilization
HCM	Hydrogeologic Conceptual Model
HFB	Horizontal-Flow Barrier
HK	Horizontal Hydraulic Conductivity
HSPF	Hydrologic Simulation Program – Fortran
iES	Iterative Ensemble Smoother
IEUA	Inland Empire Utilities Area
InSAR	Interferometric Synthetic Aperture Radar
IWU	Imported Water Utilization
Judgment	Stipulated Judgment
LST	Land Subsidence Threshold
MNW2	Multi-node Well Package
MPI	Material Physical Injury
MWD	Metropolitan Water District of Southern California

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MZ-1	Management Zone 1
NDVI	Normalized Difference Vegetation Index
NSE	Nash-Sutcliffe Efficiency
OBMP	Optimum Basin Management Program
ONAP	Overlying Non-Agricultural Pool
OWDS	Onsite Wastewater Disposal System
PBHSP	Prado Basin Habitat Sustainability Program
PEST	Parameter Estimation
PRISM	Parameter-Elevation Relationships on Independent Slopes Model
PST	Pumping Sustainability Threshold
RCH	Recharge Package
RDM	Robust Decision Making
RMSE	Root Mean Squared Error
SAR	Santa Ana River
SFR	Streamflow-Routing Package
SS	Specific Storage
SSP&A	S.S. Papadopulos and Associates
State Board	State Water Resources Control Board
SY	Specific Yield
TM	Technical Memorandum
TSY	Tentative Safe Yield
UOWU	Urban Outdoor Water Use
USGS	United Stated Geological Survey
UWMP	Urban Water Management Plan
VK	Vertical Hydraulic Conductivity
WEL	Well Package
WQMP	Water Quality Management Program
WY	Water Year

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SECTION 1
Introduction

This *2025 Safe Yield Reevaluation* (2025 SYR) report describes and documents the evaluation of the Safe Yield of the Chino Basin for the period of Fiscal Year (FY) 2021 through 2030.[1] The 2025 SYR was completed pursuant to the April 28, 2017 Court Order on the Safe Yield of the Chino Basin (2017 Court Order),[2,3] which was incorporated into Watermaster's Rules and Regulations (2022 R&R).[4] This 2025 SYR follows the 2022 Safe Yield Reset Methodology that was approved by the Court in December 2022. This section describes background information on the Court requirements to conduct the 2025 SYR, the scope of work of this effort, the peer review and stakeholder engagement, and the organization of this report.

1.1 BACKGROUND

The original Safe Yield of the Chino Basin (Basin) was defined in the Stipulated Judgment (Judgment) entered in 1978 (Chino Basin Municipal Water District vs. the City of Chino et al. [SBSC Case No. RCV 51010]). Figure 1-1 shows the adjudicated and hydrologic boundaries of the Basin. The Judgment defined the Safe Yield as "[t]he long-term average annual quantity of ground water... which can be produced from the Basin under cultural conditions of a particular year without causing an undesirable result," set an initial Safe Yield of 140,000 acre-feet/year (afy), and defined the allocation of pumping rights among the Parties. A physical solution was also established, requiring the Court-appointed Watermaster (the Chino Basin Watermaster, or Watermaster) to offset pumping in excess of these rights by acquiring and recharging supplemental water funded by assessments on over-producers.

In 2000, Watermaster developed the Optimum Basin Management Program (OBMP) and the Parties to the Judgment entered into the Peace Agreement and prepared the OBMP Implementation Plan. The OBMP Implementation Plan required that Watermaster recalculate the Safe Yield in 2011 and every ten years thereafter, acknowledging that the Safe Yield is influenced by changes in cultural conditions such as land use, water use, and groundwater pumping patterns.

1.1.1 Prior Safe Yield Recalculations

The initial Safe Yield recalculation was completed in 2015 for the period from FY 2011 through 2020. The methodology for this recalculation, known as the 2015 Safe Yield Reset Methodology (2015 SYRM), relied on long-term hydrology and incorporated data spanning 1921 to 2011. The 2015 SYRM involved recalibrating Watermaster's groundwater-flow model using the most recent data available, especially data collected since the implementation of the OBMP. To estimate the future net recharge in the Basin, the 2015 SYRM also considered a long-term historical record of precipitation along with anticipated future charges in cultural conditions, such as plans for pumping, stormwater recharge, and supplemental water recharge. Based on this process, a Safe Yield of 135,000 afy was calculated for the period from FY 2011 through 2020.

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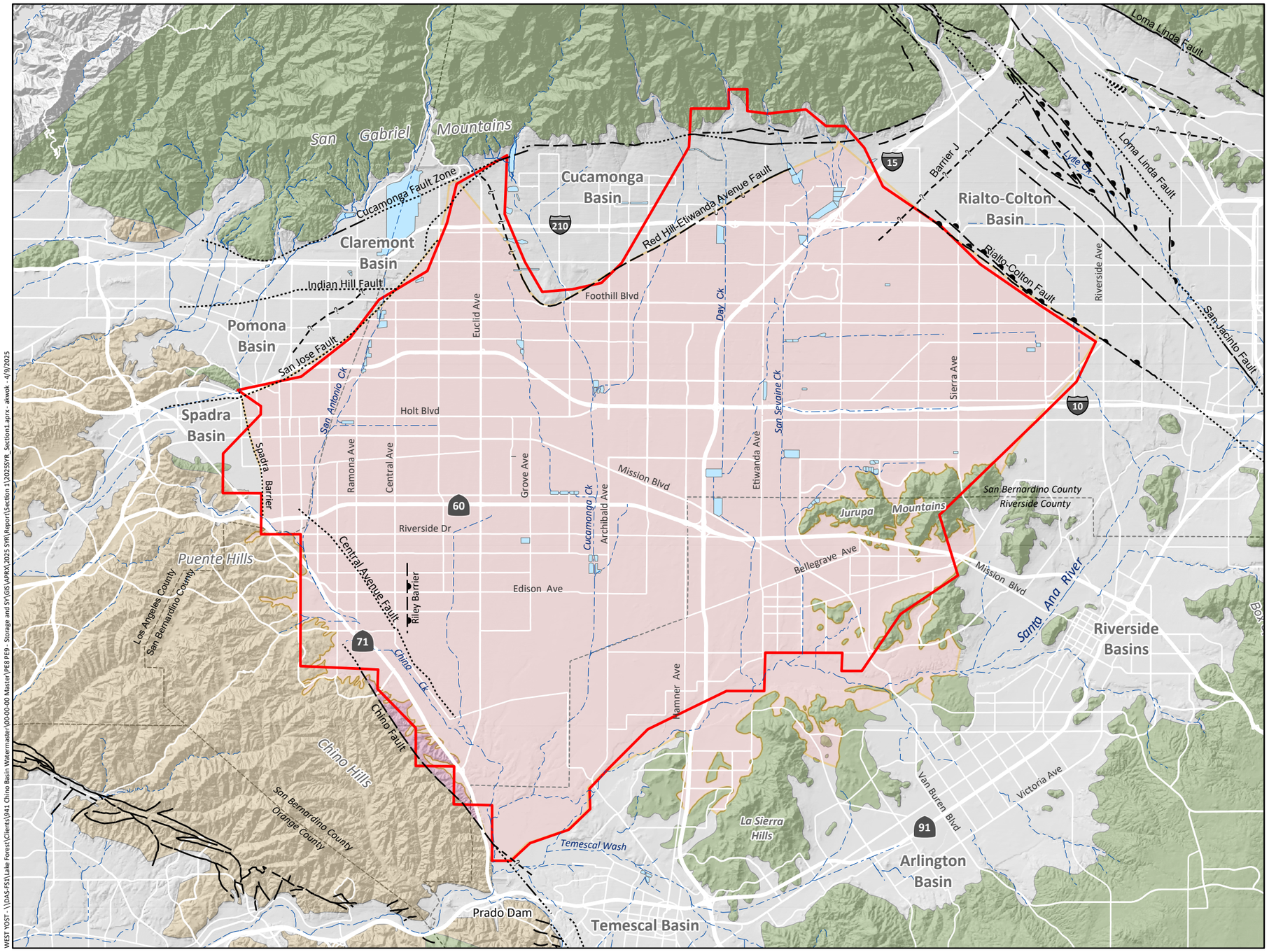
[1] 20200716 Notice of Lodging of [Proposed] Order re CBWM Motion re 2020 Safe Yield Reset.pdf

[2] *Orders for Watermaster's Motion Regarding* the *2015 Safe Yield Reset Agreement, Amendment of Restated Judgment, Paragraph 6,* Superior Court for the County of San Bernardino (2017).

[3] *Order Regarding the Appeal Parties Motion,* Superior Court for the County of San Bernardino (2019).

[4] 2022 Watermaster Rules and Regulations



WEST YOST - \\DAS-FS1\Lake Forest\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE8 PE9 - Storage and SY\GIS\APRX\2025 SYR\Report\Section 1\2025SYR_Section1.aprx - akwok - 4/9/2025

Chino Basin Adjudicated Boundary

Chino Basin Hydrologic Boundary

Rivers and Streams

Flood Control and/or Conservation Basins

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Plio-Pleistocene Sedimentary Rocks

Cretaceous to Miocene Sedimentary Rocks

Pre-Tertiary Igneous and Metamorphic Rocks

Faults

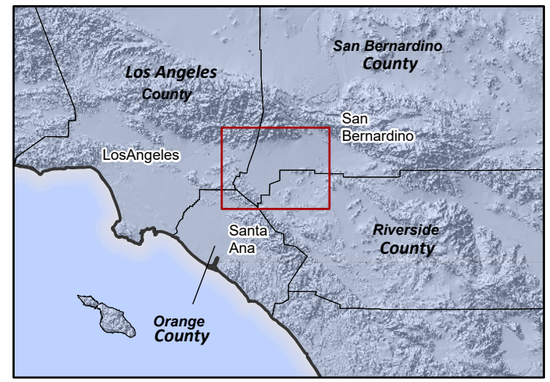
Location Certain

Location Approximate

Approximate Location of Groundwater Barrier

Location Concealed

Location Uncertain



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0 2 4 Miles

0 4 8 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Recalculation

Hydrologic and Adjudicated Boundaries of the Chino Basin

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Figure 1-1

Pursuant to the 2017 Court Order, Watermaster completed the 2020 Safe Yield Recalculation (2020 SYR) for the period of FY 2021 through 2030 using on the 2015 SYRM. Watermaster's groundwater-flow model was recalibrated using long-term historical data and was used to project a prospective net recharge to the Basin of 131,000 afy under then-current and projected cultural conditions for the period of FY 2021 through 2030. The 2020 SYR resulted in the Court adopting a Safe Yield of 131,000 afy for the period of FY 2021 through 2030.

1.1.2 2022 Safe Yield Reset Methodology

During the peer review process for the 2020 SYR, the parties and peer reviewers provided several comments and recommendations to address the uncertainty in future water plans in calculating the Safe Yield. These included recommendations to simulate multiple pumping scenarios to address predictive uncertainty more comprehensively. In addition to the comments on the 2020 SYR Report, the City of Chino opposed the 2020 Safe Yield Reset on the grounds that the process did not adequately address uncertainty.[5]

The 2017 Court Order[6] permits Watermaster, with recommendation and advice from the Pools and Advisory Committee, to supplement the 2015 SYRM by incorporating advancements in best management practices and hydrologic science. In response to recommendations arising from the 2020 SYR, objections to the 2020 SYR, and pursuant to the authority granted by the 2017 Court Order, Watermaster initiated a process in 2021 to update the 2015 SYRM.

The SYRM update process began in October 2021. Three workshops occurred during the period from October 2021 through July 2022, in which three draft technical memoranda were circulated for review and comment by the parties and technical peer reviewers. The final technical memorandum (TM) documenting the revised SYRM (called the 2022 Safe Yield Reset Methodology, or 2022 SYRM) was published on October 6, 2022[7] and approved by the Court in December 2022.[8] The 2022 SYRM includes the following steps:

(i) Use data collected since the implementation of the OBMP to re-calibrate the Watermaster's groundwater-flow model. The re-calibration period should be long enough to include wet and dry periods relative to the long-term historical precipitation record.

(ii) Conduct an uncertainty analysis of the re-calibrated groundwater-flow model to identify a plausible range of calibrated models.

(iii) Describe current and projected future cultural conditions, including but not limited to land use and water-management practices, such as: pumping, managed recharge, managed groundwater storage, impervious land cover, water recycling, and water conservation practices. Identify a possible range of projected future cultural conditions.

(iv) Using the most current research on future climate and hydrology, identify a possible range of projected future climatic conditions in the Santa Ana River watershed.

[5] 20200615 City of Chino's Opposition to CVWM Motion re 2020 Safe Yield Reset.pdf

[6] See pages 16-17 of the 2017 Court Order and Section 6.5(d) of the 2022 R&R.

[7] Final 2022 SYRM TM

[8] 20221219 Notice of Ruling and Entry of Orders.pdf

(v) Using the results of [3.] and [4.] above, prepare an ensemble of multiple projection scenarios of combinations of future climate/hydrology and cultural conditions (herein called the "Projection Ensemble"). Assign likelihoods to each scenario in the Projection Ensemble.

(vi) Simulate the range for the potential future water budget and groundwater conditions in the Chino Basin over no less than a 50-year future period. This is accomplished by using:

i. The range of calibrated models developed in [2.], and

ii. The Projection Ensemble developed in [5.] as model input data.

(vii) Using the results of [6.] above, characterize the range in the model results for:

i. Groundwater conditions, including: groundwater elevations, groundwater in storage, and groundwater flow directions, and

ii. The water budget, including: basin inflows, outflows, change in storage, and net recharge.

(viii) Using the set of net recharge results from [7.ii], determine a tentative Safe Yield as the likelihood-weighted average net recharge over the 10-year prospective period for which the Safe Yield is being redetermined (Tentative Safe Yield).

(ix) Evaluate whether the groundwater production at the Tentative Safe Yield estimated in [8] above will cause or threaten to cause "undesirable results" or "Material Physical Injury." If groundwater production at Tentative Safe Yield will cause or threaten to cause "undesirable results" or "Material Physical Injury," then Watermaster will identify and implement prudent measures necessary to mitigate "undesirable results" or "Material Physical Injury," set the value of Safe Yield to ensure there is no "undesirable results" or "Material Physical Injury," or implement a combination of mitigation measures and a changed Safe Yield.

1.1.3 2025 Safe Yield Reevaluation

The 2017 Court Order (restated in Section 6.5(f) of the 2022 R&R) requires that Watermaster update its groundwater model and evaluate the 2020 Safe Yield (131,000 afy) by June 30, 2025. Watermaster maintains and updates the Chino Valley Model (CVM) to facilitate this evaluation. The CVM, used for the 2020 SYR, has been updated for the 2025 SYR to implement the 2022 SYRM.

The 2025 SYR will apply the 2022 SYRM to evaluate the current Safe Yield for FY 2021 through 2030. If the Section 6.5(c) of the 2022 R&R outlines the potential next steps if the 2025 SYR results indicate that the reevaluated Safe Yield deviates by more than 2.5% from the current Safe Yield. This section states that the Safe Yield may be reset if:

(i) with the recommendation and advice of the Pools and Advisory Committee and in the exercise of prudent management discretion described in Section 6.5(e)(iii), below, Watermaster recommends to the court that the Safe Yield must be changed by an amount greater (more or less) than 2.5% of the then-effective Safe Yield.

(ii) The California State Water Resources Control Board develops water conservation measures prior to June 30, 2030, that result in a reduction in urban irrigation in the Chino Basin (i.e., reduced Evapotranspiration Adjustment Factors), as required by Water Code § 10609, et seq., that is reasonably likely to materially reduce recharge in the Chino Basin and such measures are determined to change the Safe Yield by more than 2.5% of the then-effective Safe Yield, and Watermaster moves the Court to reset the Safe Yield accordingly. (Orders Regarding Chino Basin Watermaster Motion Regarding 2020 Safe Yield Reset, Amendment of Restated Judgment, Paragraph 6, dated July 31, 2020 at 15.)

1.2 SCOPE OF WORK

The scope of work for the 2025 SYR includes the following key tasks:

- **Task 1 – Update Hydrogeologic Conceptual Model.** This task involves using the most current information to update the description of the Chino Basin hydrogeology and then translate the hydrogeologic description to the CVM.
- **Task 2 – Update Model and Input Data for Historical Period.** This task involves extending and updating the input data for the surface water and groundwater models through the historical calibration period to prepare for model recalibration.
- **Task 3 – Recalibrate Groundwater Model to Generate Calibrated Realizations.** This task involves recalibrating the CVM using historical data for the updated calibration period (FY 1992 through 2022) and employing uncertainty analysis methods like PESTPP-IES to generate a range of plausible calibrated model realizations.
- **Task 4 – Develop Planning Scenarios.** This task involves creating an ensemble of future projection scenarios that incorporate uncertainties in water demands, supply plans, and climate conditions through stakeholder engagement and analysis of available planning documents.
- **Task 5 – Conduct Planning Simulations to Update Projections of Net Recharge, Identify Undesirable Results and Associated Mitigation Measures, and Reevaluate Safe Yield.** This task utilizes the calibrated CVM realizations and projection scenarios to simulate future conditions, project net recharge, evaluate potential undesirable results or material physical injury (MPI), and develop recommendations for the Safe Yield and any potential mitigation measures.
- **Task 6 – Prepare Safe Yield Reevaluation Report.** This task involves documenting the entire 2025 SYR process, including methodologies, results, analyses, and recommendations in a comprehensive report.

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1.3 PEER REVIEW AND STAKEHOLDER ENGAGEMENT

Section 6.5(g) of the 2022 R&R requires the Pools to have the opportunity for peer review of the 2025 SYR. The 2025 SYR was developed with input from the parties and stakeholders through a series of workshops and TMs. Watermaster hosted 10 workshops to review gather feedback on interim results and various stages of the process. The workshops and TMs that supported this work are listed below.

- Workshops:
  - August 30, 2023 – Hydrogeologic Conceptual Model
  - October 24, 2023 – Scenario Design (#1)
  - March 7, 2024 – Scenario Design (#2)
  - May 29, 2024 – Calibration and Uncertainty Analysis (#1)
  - June 25, 2024 – Scenario Design (#3)
  - August 6, 2024 – Calibration and Uncertainty Analysis (#2)
  - August 27, 2024 – Scenario Design (#4)
  - November 20, 2024 – SYR Process and Evaluation of Material Physical Injury
  - March 25, 2025 – Preliminary Results
  - November 6, 2025 – Draft 2025 SYR Report
  - May 20, 2026 – Revised Draft 2025 SYR Report
- TMs/Reports:
  - Scenario Design TM #1
  - Scenario Design TM #2
  - Scenario Design TM #3
  - Analysis of Material Physical Injury and Undesirable Results for the 2025 SYR
  - 2025 Safe Yield Reevaluation Report (this report)

Each of the presentations and TMs (including draft documents) listed above are hosted on Watermaster's website[9] and were maintained for access throughout the 2025 SYR process. The written comments provided by the parties and stakeholders on the presentations and TMs were included as appendices in the TMs. Written comments from the March 25, 2025, November 6, 2025 workshop, and on the draft 2025 SYR report are documented with responses in Appendix E of this report.

1.3.1 Third-Party Peer Review of 2025 CVM and 2025 SYR

Following the March 25, 2025 workshop, the Watermaster Board directed staff to engage a third-party consultant to conduct an independent peer review of the 2025 CVM and the SYR assumptions and findings. Watermaster selected S.S. Papadopulos & Associates (SSP&A) to perform this review. The peer review was conducted from July through September 2025 and culminated with SSP&A presenting findings and recommendations to the Watermaster Advisory Committee and Board in September 2025 and

[9] https://cbwm.org/pages/syrm/

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submitting a report of the findings and recommendations in October 2025. The full peer review report, along with West Yost's responses, is provided in Appendix E.

At the Appropriative Pool (AP) Committee meeting on December 11, 2025, the AP requested that West Yost work with the AP's consultant, Thomas Harder and Company (THC) to develop a scope to address the peer review recommendations. West Yost met with THC staff in December 2025 to discuss a draft of the scope of work to respond to the peer review recommendations.

1.3.1.1 Implementation of Peer Review Recommendations

In January 2026, the Watermaster Board approved a scope of work to implement selected peer review recommendations and revise the 2025 SYR study and report.[10] The scope of work was developed to incorporate the major recommendations that would impact the evaluation of the Safe Yield and support the documentation of the surface-water model component of the 2025 CVM (i.e., the HSPF and R4 models – See Section 3). The scope of work included the following tasks:

- Task 1. Develop Integrated Water Budgets
- Task 2. Refine Calibration Data
- Task 3. Refine Model Mechanics and Numerical Stability
- Task 4. Prepare, Run, and Process Additional PESTPP-IES Configuration and Projection Ensemble
- Task 5. Update Report and Appendices
- Task 6. Conduct Stakeholder Workshop
- Task 7. Project Management and Meetings Workshops

This scope of work was initiated in February 2026. During the execution of Tasks 1 through 4, West Yost held four meetings with staff from Watermaster, THC, and SSP&A to review intermediate results, answer questions, and gather feedback. Revisions made to the 2025 SYR to implement the peer review recommendations are noted throughout the report.

1.4 REPORT ORGANIZATION

The remaining sections of this report are described below:

- **Section 2** – **Update of Hydrogeologic Conceptual Model**: This section describes the new information gathered and interpreted since the 2020 SYR on the hydrogeology of the Chino Basin, including the geologic setting, stratigraphy, base of aquifer, occurrence and movement of groundwater, aquifer system, aquifer properties, and land subsidence.
- **Section 3** – **Model Updates**: This section describes the updates made to the 2025 CVM including the surface water models, vadose zone models, and the groundwater-flow model.
- **Section 4** – **Model Calibration and Uncertainty Analysis**: This section documents the calibration of the CVM using a pilot point method and PESTPP-IES to generate multiple

[10] Business Item III.B. of the January 22, 2026 Watermaster Board meeting (Meeting Package)

calibrated model realizations and presents the results of the calibration process including the historical water budget, a discussion of uncertainty, and the selected calibrated realizations.

- **Section 5** – **Projection Ensemble:** This section describes the development of the projection ensemble including: stakeholder engagement and timeline, the characterization of uncertainty in future climate and cultural conditions, and the final Projection Ensemble.
- **Section 6 – 2025 Safe Yield Reevaluation:** This section describes the evaluation criteria, the calculation of net recharge, the analysis of results of the Projection Ensemble for MPI, and the reevaluated Safe Yield for FY 2021 through 2030.
- **Section 7 – Conclusions and Recommendations:** This section provides a summary of the findings from the 2025 SYR, including recommendations for future evaluations and/or management considerations based on these findings.
- **Appendix A – Supplemental Hydrogeologic Information**
- **Appendix B – Results from the Calibration and Uncertainty Analysis**
- **Appendix C – Scenario Design Information**
- **Appendix D – TSY Ensemble Results**
- **Appendix E – Peer Review and Stakeholder Comments and Responses**

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SECTION 2
Update of Hydrogeologic Conceptual Model

2.1 INTRODUCTION AND SCOPE

This section describes the new information and updates that were made to the geologic and hydrogeologic understanding and conceptual model for the groundwater basins that are simulated in the 2025 Chino Valley Model (2025 CVM), which include the Chino Basin, Cucamonga Basin, Six Basins, Spadra Basin, and Temescal Basin. Figure 2-1 shows these groundwater basins, the regional geology, and the model domain of the 2025 CVM.

The 2020 SYR Report described the hydrogeologic and hydrologic setting of the groundwater basins within the 2020 CVM domain, as well as the hydrogeologic conceptual model (HCM) that serves as the foundation for both the 2020 CVM and the 2025 CVM. An HCM is a description of the geologic and hydrologic framework governing the occurrence of groundwater and its flow through and across the boundaries of a basin and the general groundwater conditions in a basin or subbasin.[1]

The scope of Task 1 for the 2025 SYR includes: (i) review new data and information; (ii) update the HCM; and (iii) use the updated HCM to update the 2025 CVM. The following types of new data and information were used to update the HCM and the 2025 CVM:

- Geologic and lithologic information, such as new well lithologic logs and pump tests
- Remote sensing data
- Information on faults and basin boundaries that may affect groundwater flow

2.2 GEOLOGIC AND LITHOLOGIC INFORMATION

During the development of the 2025 CVM, Watermaster completed an inventory of new well information compiled since 2018, the cutoff for date for the update of the 2020 CVM. Watermaster maintains a comprehensive well inventory, which was augmented through contacting several agencies that have recently installed wells in the 2025 CVM domain. This effort yielded approximately 80 new well logs. Figure 2-2 is a map that shows the locations and depths of the new well logs (symbolized by CVM layer penetrated by the wells). Some of the new wells are located near each other or are nested wells, resulting in overlapping locations on the map.

The HCM relies heavily on lithological data from well driller's logs, which provide depth-specific descriptions of the thicknesses, type, and texture of the aquifer sediments that are used to characterize the basin hydrostratigraphy. For the 2025 CVM, the process of collecting and reviewing new well information was continued to update the HCM, building upon the approximately 1,150 logs reviewed for the development of the 2020 CVM and prior models.

Several of the new borehole lithologic logs were used to revise the hydrogeologic cross-sections of the HCM. Figure 2-3 shows the locations of the hydrogeologic cross-sections, with highlights indicating revisions since the 2020 CVM. Seven new wells, two in the Spadra Basin and five in the Chino Basin, were incorporated onto the cross-sections. Two wells that were used in the 2020 CVM were added to the cross-sections: Pomona well P-21 was added to more clearly delineate the Spadra Barrier (see Section 2.4), and the Monte Vista Water District Well 28 was added to more clearly delineate the layers

[1] Cal. Code Regs. Tit. 23, § 341(q)

in this region, as this lithology was used to develop a one-dimensional compaction model of the aquifer[2] to support Ground-Level Monitoring Program investigations of land subsidence. The revised cross-sections are in Appendix A.

The new hydrogeologic information, including the new well lithologic logs, were used for several updates to the 2025 CVM, including:

- Revising CVM layer elevations and thickness to improve the representation of the subsurface hydrostratigraphy.
- Integrating new information onto hydrostratigraphic sections to provide a visual representation of the subsurface hydrostratigraphy.
- Refining the understanding and characterization of the spatial distribution and values of aquifer properties.

2.3 REMOTE SENSING

Watermaster uses remote sensing datasets to support various monitoring efforts, such as the Prado Basin Habitat Sustainability Program and the Ground-Level Monitoring Program. To update the 2025 CVM, Watermaster reviewed the latest data from three remote sensing datasets: Interferometric Synthetic Aperture Radar (InSAR), Normalized Difference Vegetation Index (NDVI) and aerial photos of the Prado Basin, and a Digital Elevation Model (DEM). Watermaster reviewed the recent data for each of these datasets to inform updates to the 2025 CVM, each described in more detail below.

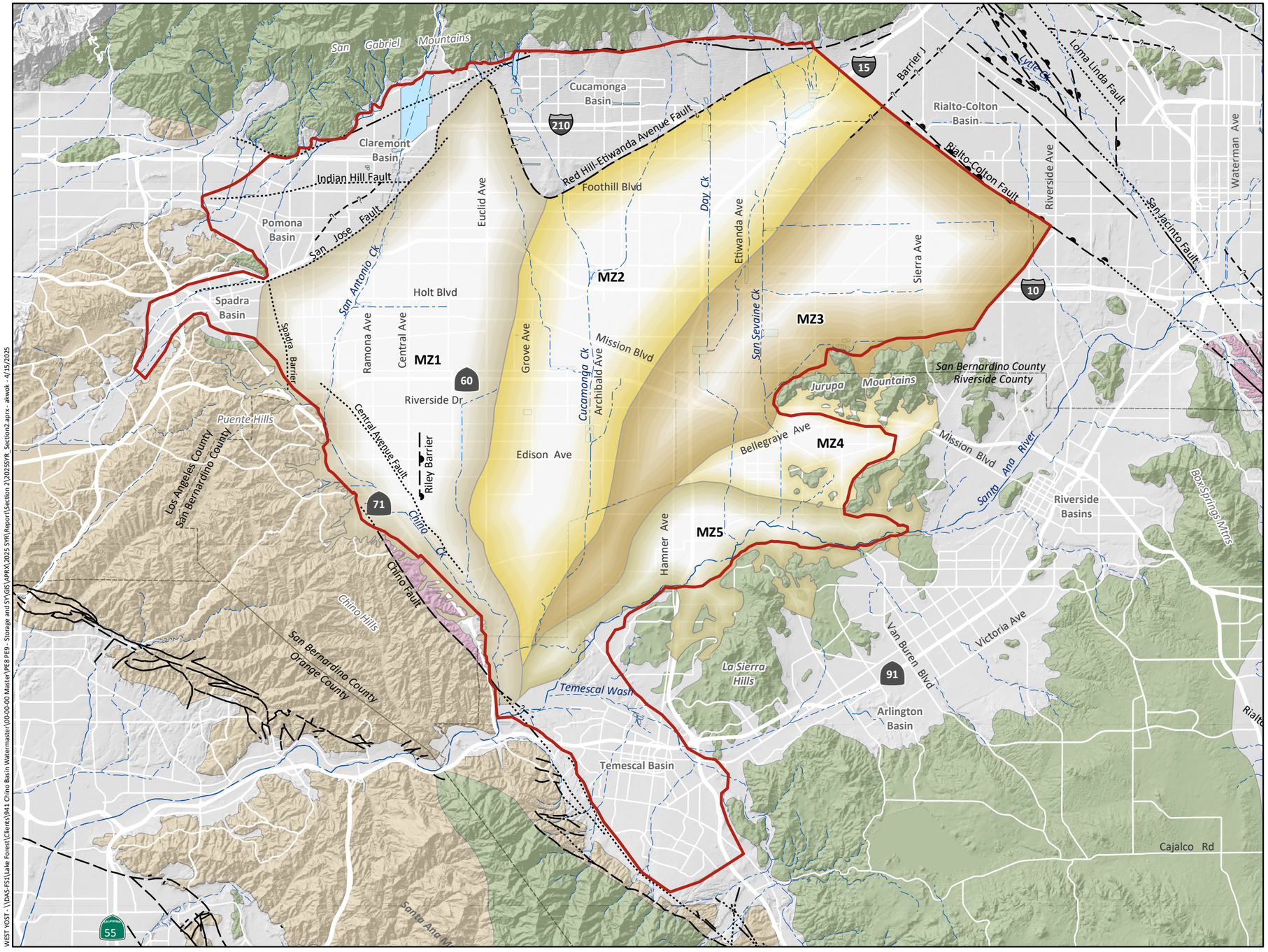
2.3.1 InSAR

Historically, the Watermaster has used InSAR as a monitoring technique to track vertical ground motion (e.g., land subsidence) as an element of its Ground-Level Monitoring Program. For instance, as groundwater levels rise, the aquifer-system sediments can expand under the increased heads, and the land surface can rise. Conversely, as groundwater levels decline, the aquifer-system sediments can compress or compact permanently, and the land surface can fall (i.e., land subsidence). Because of these aquifer-system mechanics that respond to rising and falling groundwater levels, InSAR has proven valuable in identifying the locations of subsurface faults and barriers to groundwater flow within the CVM domain.[3] This is because groundwater levels oftentimes deform differently on either side of fault barriers, which causes differential vertical ground motion across the fault barriers.

Recent InSAR data collected since the development of the 2020 CVM were reviewed to refine the location of certain fault barriers within the CVM domain. During the winter of FY 2023, InSAR measurements captured differential vertical ground motion in the northwestern corner of the CVM domain during a period of higher-than-average precipitation and recharge in the Six Basins and Cucamonga Basin. These data proved useful in refining the location of the West Cucamonga Barrier and the San Jose Fault in these areas.

[2] TM - 941 - 1D Model - Final.pdf

[3] Wildermuth Environmental, Inc. 2017. Strategic Plan for the Six Basins. Prepared for the Six Basins Watermaster. November 2017. Link



Chino Basin OBMP Management Zones

MODFLOW Model Boundary

Rivers and Streams

Flood Control and/or Conservation Basins

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Plio-Pleistocene Sedimentary Rocks

Cretaceous to Miocene Sedimentary Rocks

Pre-Tertiary Igneous and Metamorphic Rocks

Santa_Ana_River

Faults

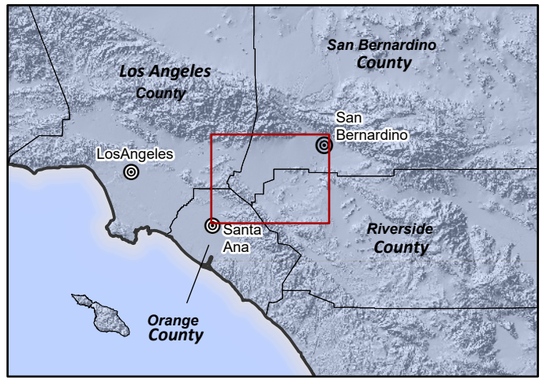
Location Certain

Location Approximate

Approximate Location of Groundwater Barrier

Location Concealed

Location Uncertain



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Prepared for:

Chino Basin Watermaster
2025 Safe Yield Recalculation

Geologic Map and Boundaries of the Chino Basin

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Figure 2-1

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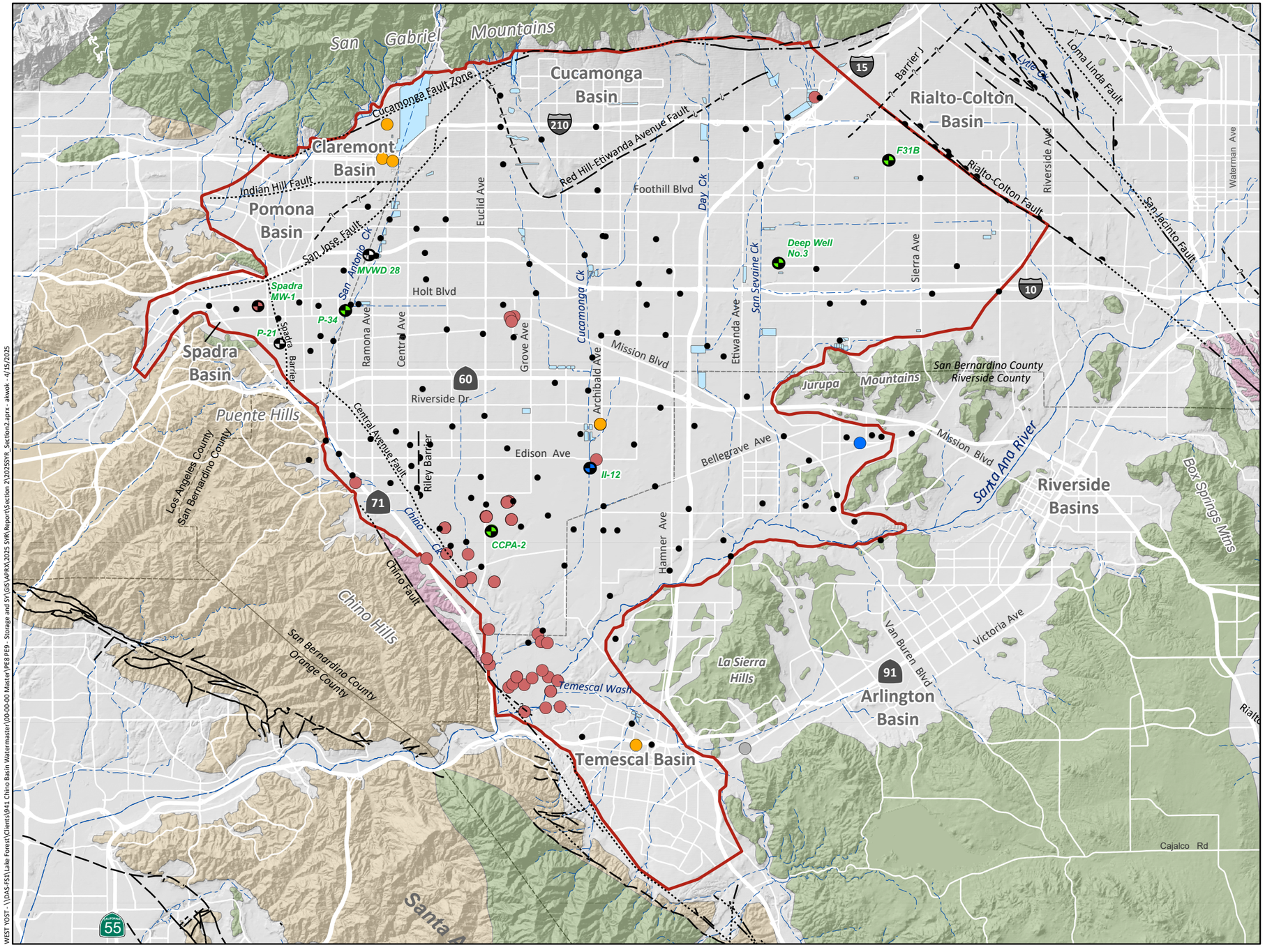

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- Borehole added to the HCM in the 2025 CVM
- Borehole Lithology Used for the 2020 HCM Cross-Section

New Borehole Data Acquired for 2025 CVM

Symbolized by Aquifer Layer

- Layer 1
- Layers 1-2
- Layers 1-3
- Layers 1-4
- Layers 1-5
- Well Outside CVM Domain

- MODFLOW Model Boundary
- Rivers and Streams
- Flood Control and/or Conservation Basins

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Plio-Pleistocene Sedimentary Rocks
- Cretaceous to Miocene Sedimentary Rocks
- Pre-Tertiary Igneous and Metamorphic Rocks

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



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N

0 3 6 Miles

0 4 8 Km

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2025 Safe Yield Recalculation

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Partners in Basin Management

Borehole Locations Used to Describe the Hydrogeologic Conceptual Model

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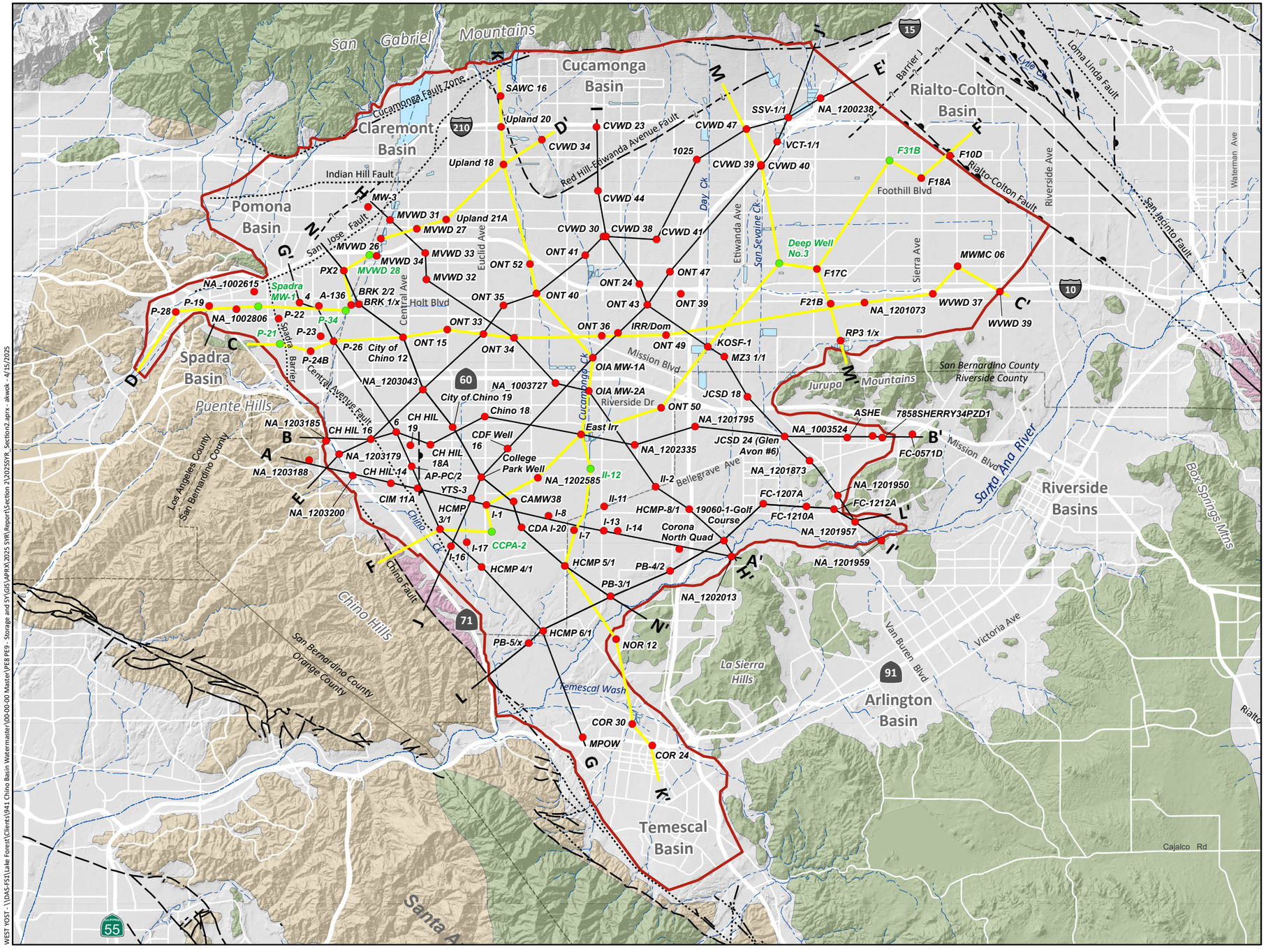
Figure 2-2



Hydrostratigraphic Cross-Section Profile Line Revised for the 2025 CVM

Hydrostratigraphic Cross-Section Profile Line Used for the 2020 and 2025 CVM

Borehole Used in Hydrostratigraphic Cross-Section

Borehole Added to Hydrostratigraphic Cross-Section for the 2025 CVM

MODFLOW Model Boundary

Rivers and Streams

Flood Control and/or Conservation Basins

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Plio-Pleistocene Sedimentary Rocks

Cretaceous to Miocene Sedimentary Rocks

Pre-Tertiary Igneous and Metamorphic Rocks

Faults

Location Certain

Location Approximate

Approximate Location of Groundwater Barrier

Location Concealed

Location Uncertain



Prepared by:

WEST YOST
Water. Engineered.

0 3 6 Miles

0 4 8 Km

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2025 Safe Yield Recalculation

Map View of the Hydrostratigraphic Cross-Sections

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Figure 2-3

WEST YOST - \\DAS-FS1\Lake Forest\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE8 PE9 - Storage and SY\GIS\APRX\2025 SYR\2025 SYR Report\Section 2\2025SYR_Section2.aprx - akwok - 4/15/2025

Figure 2-4 illustrates the vertical ground motion observed in the northwestern corner of the CVM domain between Spring 2022 and Spring 2023. The areas in the Six Basins and Cucamonga Basin exhibited uplift because of the large volumes of recharge and increases in groundwater levels north of the of the West Cucamonga Barrier and the San Jose Fault, while little to no ground motion occurred south of these fault barriers. These findings not only illustrate improved understanding about the location of the fault barriers but also suggest that groundwater flow is restricted across the fault barriers. These observations and insights were used to revise the hydrologic boundary of the Chino Basin and the delineation of the San Jose Fault and the West Cucamonga Barrier in the 2025 CVM. Figure 2-4 illustrates these changes by showing the hydrologic basin boundary in the 2020 CVM as a gray line and the revised boundary in the 2025 CVM as a red line.

2.3.2 NDVI and Aerial Photos

The Prado Basin Habitat Sustainability Program (PBHSP) is designed to monitor the extent and health of the riparian vegetation in the Prado Basin in the southern Chino Basin, which is the largest groundwater-dependent ecosystem in southern California. The PBHSP publishes annual reports to document the monitoring data, analyses, and interpretations. As part of the PBHSP, Watermaster routinely collects and evaluates NDVI data and aerial photographs of the Prado Basin to determine the extent, density, and health of riparian vegetation in Prado Basin over time. For the 2025 CVM update, Watermaster reviewed these datasets in the context of the estimation of groundwater evapotranspiration (ET) in this area, which is one of the key processes that governs the water budget of the Chino Basin. Appendix B of the 2020 SYR Report documented the assumptions and process to calculate ET from the Prado Basin in the 2020 CVM.

Based on the review of the new NDVI data and aerial photos, it was determined that no changes were necessary to the existing ET estimation process, or the delineation of the riparian vegetation as implemented in the 2020 CVM. The spatial extent and density of the riparian vegetation used in the 2020 CVM has remained consistent since 2020 CVM was completed.

2.3.3 DEM

The groundwater and surface water interactions between the Chino Basin and the Santa Ana River (SAR) are important dynamics that are simulated by the CVM. Accurately characterizing the geometry (e.g., stream-bottom elevations and slope) and location of the SAR are key data for the simulations. In the 2020 CVM, the geometry and location of the SAR were computed using a 10-meter DEM from the United Stated Geological Survey (USGS). For the development of the 2025 CVM, Watermaster gathered the most recent 1-meter DEM data (2018) and aerial photos of the SAR. With these data, Watermaster updated the streambed elevations, slopes, and stream cross-sections to characterize the SAR in the groundwater-flow model.

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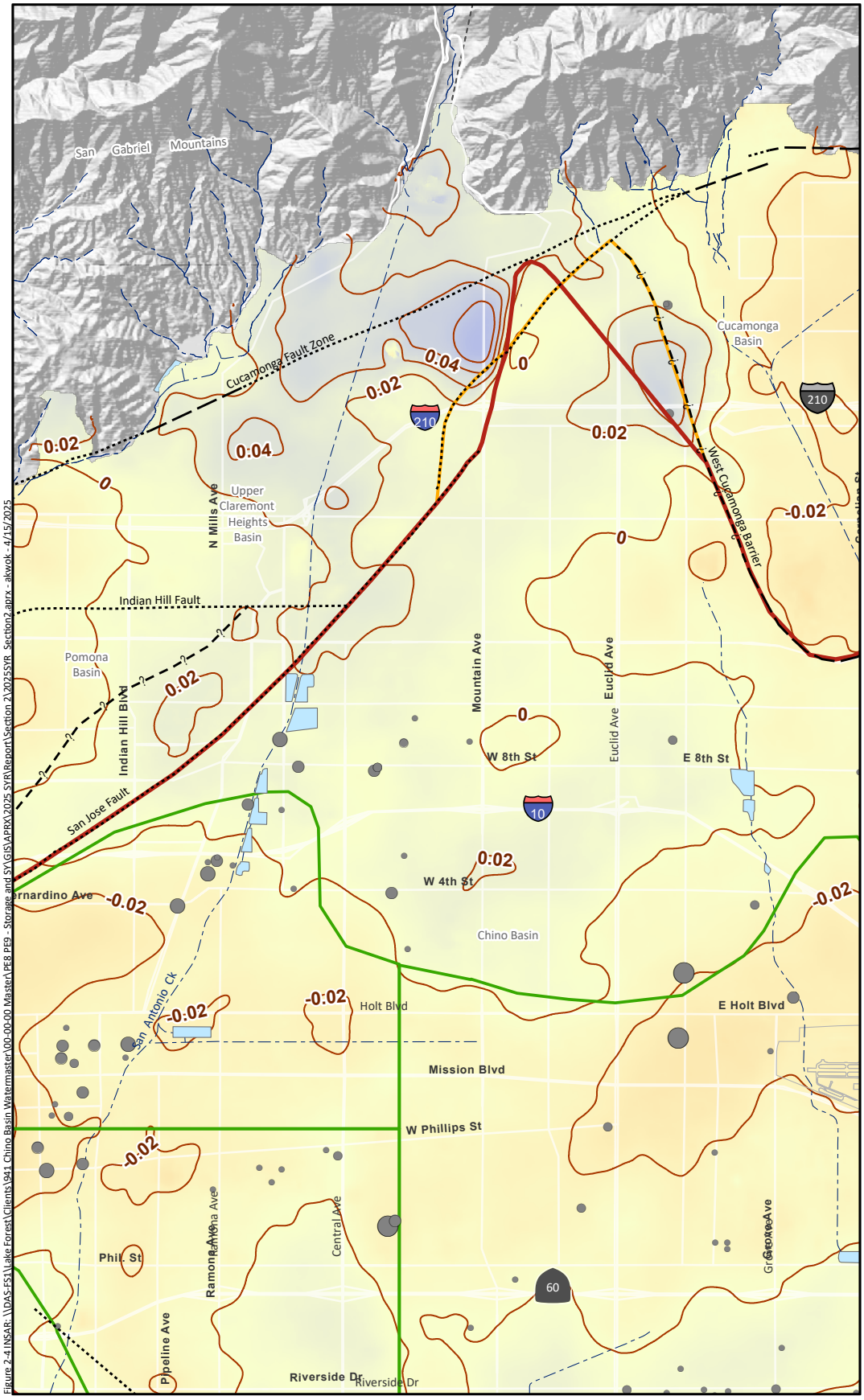


Figure 2-4 INSAR: \\DAS-FS1\Lake Forest\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE8 PE9 - Storage and SY\GIS\APRX\2025 SYR\Report\Section 2\2025SYR_Section2.aprx - akwok - 4/15/2025

Hydrologic Boundary for the 2020 CVM

Hydrologic Boundary for the 2025 CVM

Relative Change in Land Surface Elevation as Estimated by InSAR

March 2022 to May 2023

+ 0.2 ft

- 0.2 ft

InSAR contours (ft)

Groundwater Pumping (acre-feet)

April 1, 2022 to March 31, 2023

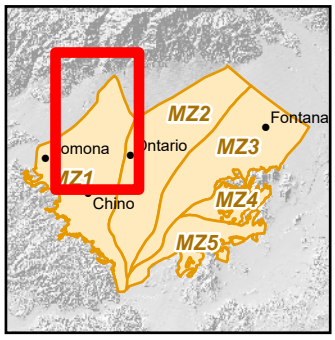
- 0.0 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,000
- >2,000

Recharge Basins

Areas of Subsidence Concern

Rivers and Streams

Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



Prepared by:

WEST YOST

2 Miles

3 Km

Prepared for:

Chino Basin Watermaster

2025 Safe Yield Recalculation

Vertical Ground Motion as Estimated by InSAR

Spring 2022 to 2023

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Figure 2-4

2.4 FAULTS AND BASIN BOUNDARIES

Watermaster reviewed other new information related to the location and characterization of faults and basin boundaries to further refine the HCM. The new information included:

- **Spadra Barrier:** The Spadra Barrier marks the boundary between the Chino Basin and the Spadra Basin. Groundwater levels in the Spadra Basin are approximately 50 to 200 feet higher than those in the Chino Basin. A review of groundwater-level data from wells near this boundary has refined the location of the Spadra Barrier, as shown in Figure 2-1. The revised extent and location of the Spadra Barrier aligns with a concealed fault mapped by a USGS study.[4] Additionally, the northern extent of the Central Avenue Fault, which runs parallel to the western edge of the Chino Basin south of the Spadra Barrier, has been revised to intersect with the Spadra Barrier.
- **Rialto-Colton Fault:** The Rialto-Colton Fault separates the Rialto-Colton Basin from the Chino and Riverside Basins. It is a known barrier to groundwater flow along much of its length, particularly in its northern reaches. Watermaster reviewed recent information on the characterization of this fault, including a 2014 USGS study[5] and the groundwater model report from the Integrated SAR Model.[6] The conclusion of this review was that no new significant findings emerged that would necessitate changes to the current location of this fault in the CVM or its influence on groundwater flow.
- **Boundary between the Chino and Temescal Basins:** The Temescal Basin is included within the domain of the 2020 CVM. Groundwater within the Chino Basin flows southwest towards the Prado Basin and converges with groundwater flowing northwest out of the Temescal Basin. These groundwaters mix and flow southwest toward Prado Dam. Watermaster reviewed the groundwater-flow model that was recently developed to support the 2022 Groundwater Sustainability Plan (GSP) for the Temescal Basin.[7] Based on the review of the GSP and model documentation, it was determined that no changes should be made for the 2025 CVM.

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[4] Morton, D., and Miller F. Geologic Map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California. 2006. http://pubs.usgs.gov/of/2006/1217/

[5] Teague, Nick, Brown, A.A., and Woolfenden, L.R., 2014, Geohydrologic and water-quality data in the vicinity of the Rialto-Colton Fault, San Bernardino, California: U.S. Geological Survey Data Series 813, 76 p., *http://dx.doi.org/10.3133/ds813*.

[6] Geoscience, 2020. Integrated Santa Ana River Model Report. Prepared for San Bernardino Valley Municipal Water District, 2020.

[7] 2022 Temescal Basin Groundwater Sustainability Plan

SECTION 3
2025 Updates to the Chino Valley Model

This section describes the updates that were made to the four models that compose the 2025 CVM: the Hydrologic Simulation Program – Fortran (HSPF) model, the R4 model, the HYDRUS-2D model, and the MODFLOW model. The purpose of each of these models is described below.

1. **Hydrologic Simulation Program – Fortran (HSPF)**. This model was implemented based on the HSPF code (Bicknell, et al., 2005), which is a numerical model developed to simulate hydrologic and water quality processes in natural and man-made water systems. The HSPF model uses meteorological data, land use data, and physical characteristics of the model domain to estimate surface runoff and subsurface inflow from the San Gabriel Mountains to the Chino Valley. The HSPF model was calibrated during the 2020 SYR and was not recalibrated during the 2025 SYR. However, the simulation period of the HSPF model was extended through FY 2023 to cover the calibration period of the 2025 CVM and one year of the projection period.
2. **R4**. This model was implemented based on the R4 code (WEI, 2007).[1] Like the HSPF model, the R4 model uses meteorological data, land use data, and physical characteristics of the model domain to simulate the surface-water processes, including rainfall, evapotranspiration, runoff, runoff routing, and deep infiltration of precipitation and applied water (DIPAW) within the Chino Valley. The simulated streamflow from the HSPF model is used as input data to the R4 model. The R4 model was calibrated during the 2020 SYR and was not recalibrated during the 2025 SYR. However, the simulation period of the R4 model was extended through FY 2023 to cover the calibration period of the 2025 CVM and one year of the projection period.
3. **HYDRUS-2D**. Seven HYDRUS-2D models were implemented based on the HYDRUS-2D code (Simunek, et al., 1999), which is a modeling environment for the analysis of water flow and solute and heat transport in variably saturated porous media. These models were used during the 2020 SYR to simulate the movement of DIPAW through the vadose zone and to estimate the lag time for DIPAW to reach the groundwater table at selected locations in the Chino Basin. The HYDRUS-2D models were not updated during the 2025 SYR, as the lag time was assumed to be spatially static; therefore, an update to the model was not deemed necessary.
4. **MODFLOW**. This model was implemented based on the MODFLOW-NWT code (Niswonger, et al., 2011). The MODFLOW model was used to simulate saturated groundwater flow in the Chino Basin, Spadra Basin, Cucamonga Basin, and Six Basins area. The results of the HSPF, R4, and Hydrus-2D models are used to inform the input values to the domain of the MODFLOW model, including boundary subsurface inflows; subsurface inflows from the San Gabriel Mountains; runoff to streams; percolation in recharge basins; and the magnitude and timing of DIPAW.

Figure 3-1 shows the boundaries of the 2025 CVM domains for the HSPF, R4, and MODFLOW models. The remainder of this section describes the revisions that were made to the 2025 CVM during the 2025 SYR.

[1] The model is in the public domain and can be downloaded from https://github.com/weiwater/R4

2025 CVM Domains

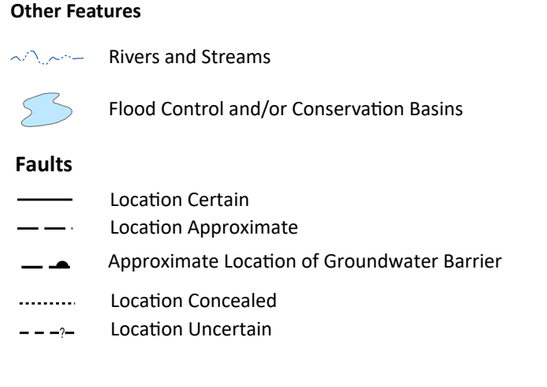
- HPSF Model Domain
- R4 Model Domain
- MODFLOW Domain

Other Features

- Rivers and Streams
- Flood Control and/or Conservation Basins

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



Prepared by:

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0 3 6 Miles

0 4 8 Km

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2025 CVM Domains for Surface-Water and Groundwater Models

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Figure 3-1

WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PEB PE9 - Storage and SY\GIS\APRX\2025 SYR\Report\Section 3\2025SYR_Section3.aprx - akwek - 6/10/2025

3.1 EXTENSION OF HISTORICAL SIMULATION PERIOD FOR THE 2025 CVM

The historical simulation period of the 2020 CVM was July 1, 1977 through June 30, 2018. For the development of the 2025 CVM, historical data was extended through June 30, 2023.

3.1.1 Time Series Data

Updated meteorological stresses, applied water, and recharged water data were used as input data for the extended simulation period of the R4 and HSPF models. The results of the HSPF and R4 models provide input data to the MODFLOW model, including surface-water runoff and mountain-front flow (from the HSPF model) and DIPAW, stormwater runoff and recharge, and subsurface boundary inflow (from the R4 model).

In addition to the output data from the R4 and HSPF models, time series data for groundwater pumping, managed aquifer recharge, and groundwater levels (to calculate time-variant specified-head boundary flows) were used to extend the historical simulation period of the MODFLOW model.

3.1.2 Land Use

The domains of the HSPF and R4 models, and the hydrologic sub-areas of these models, are shown on Figure 3-2. Land use data is an input into the HSPF and R4 models that the models use to estimate runoff, applied water, and deep percolation of precipitation and applied water. Since the development of the 2020 CVM, land use was collected in 2022 from Land IQ, a land use consulting firm that has documented recent land use changes in the southern Chino Basin. The southern portion of the Chino Basin is the only region where land use has changed significantly since the development of the 2020 CVM (the land use data for which ended in 2017) and was the only area where land use designations were updated from the 2020 CVM. Figures 3-3 and 3-4 show the land use in the Chino Basin in 2017 and 2022, respectively. Land use in the HSPF model domain was not updated for the 2025 CVM.

3.2 UPDATES TO THE MODFLOW MODEL

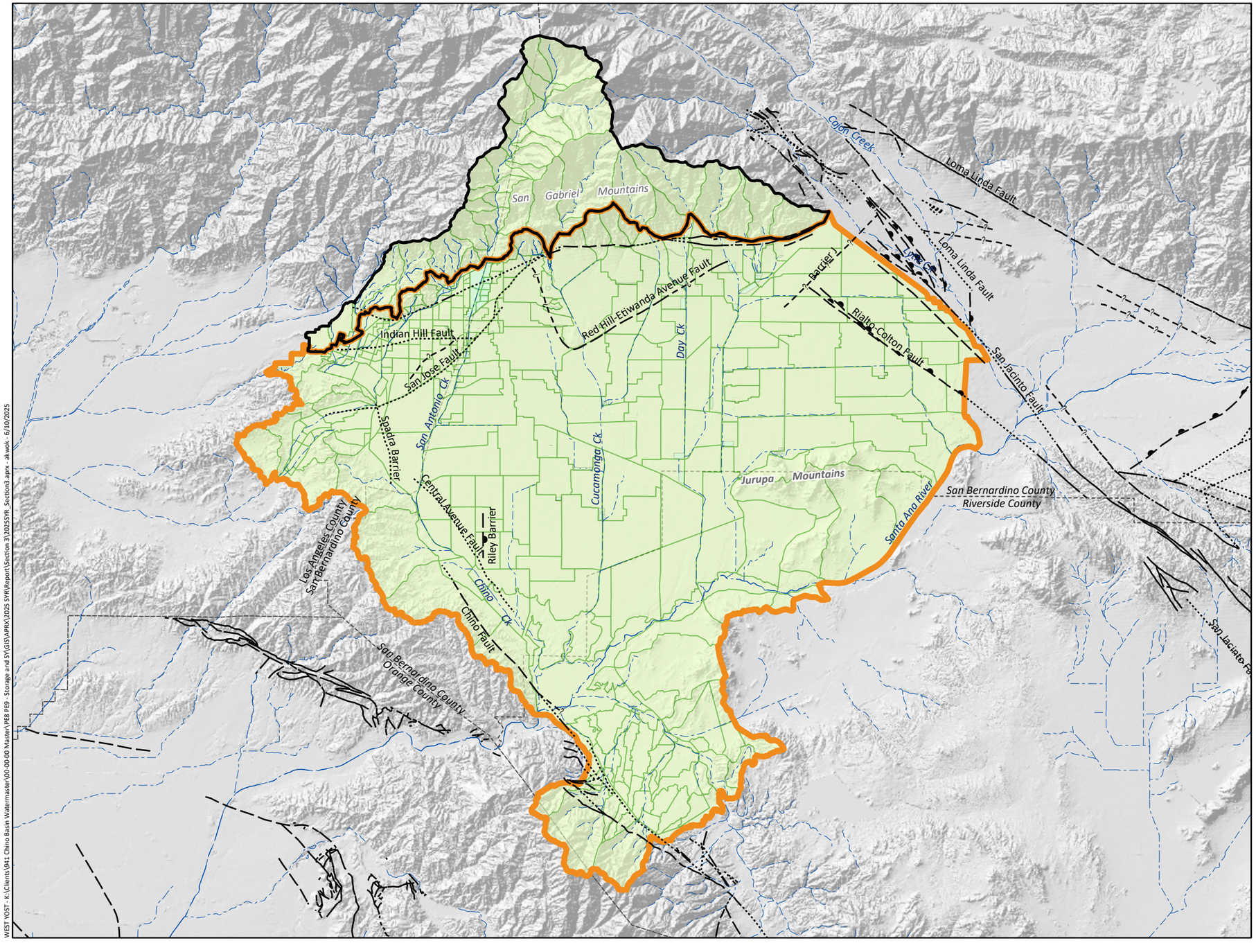
3.2.1 Model Domain and Grid

Like the 2020 CVM, the MODFLOW model of the 2025 CVM has a rectilinear grid consisting of five layers, 577 rows, and 648 columns, with a uniform row/column width of 196.86 ft (60 meters). The model has a total of 1,869,480 cells, among which 838,113 are active cells where groundwater elevations are simulated.

3.2.2 Model Layer Elevation and Thickness

The Chino Basin is simulated with five model layers. The Spadra Basin, Cucamonga Basin, Temescal Basin, and Six Basins are simulated with a single model layer. The model layer elevations were updated based on the geological cross-sections of the updated HCM that included lithological/geophysical logs from new wells constructed since the last CVM update (see Section 2 and Appendix A).

Layers 1, 3, and 5 represent regional aquifers from which most groundwater is pumped by wells. Layers 2 and 4 represent regional clay-rich aquitards. Figures 3-5 through 3-7 are maps that display the model layer thicknesses for the 2025 CVM for Layers 1, 3, and 5, respectively. The thicknesses of Layers 2 and 4 are not shown; they are typically less than 100 feet thick.



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Main Features

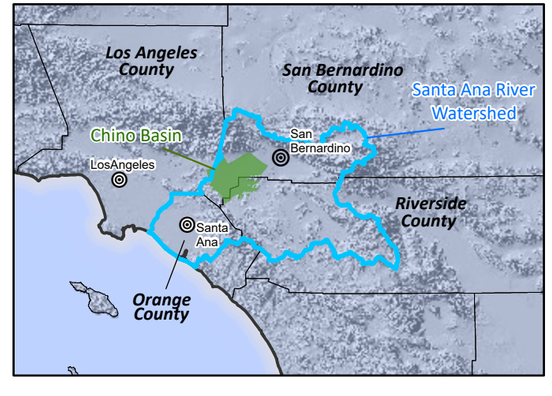
- HPSF Model Domain
- R4 Model Domain
- Hydrologic Sub Area

Other Features

- Rivers and Streams
- Flood Control and/or Conservation Basins

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



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N

0 3 6 Miles

0 4 8 Km

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Chino Basin Watermaster
2025 Safe Yield Reevaluation

Hydrologic Sub Areas in the HSPF and R4 Models

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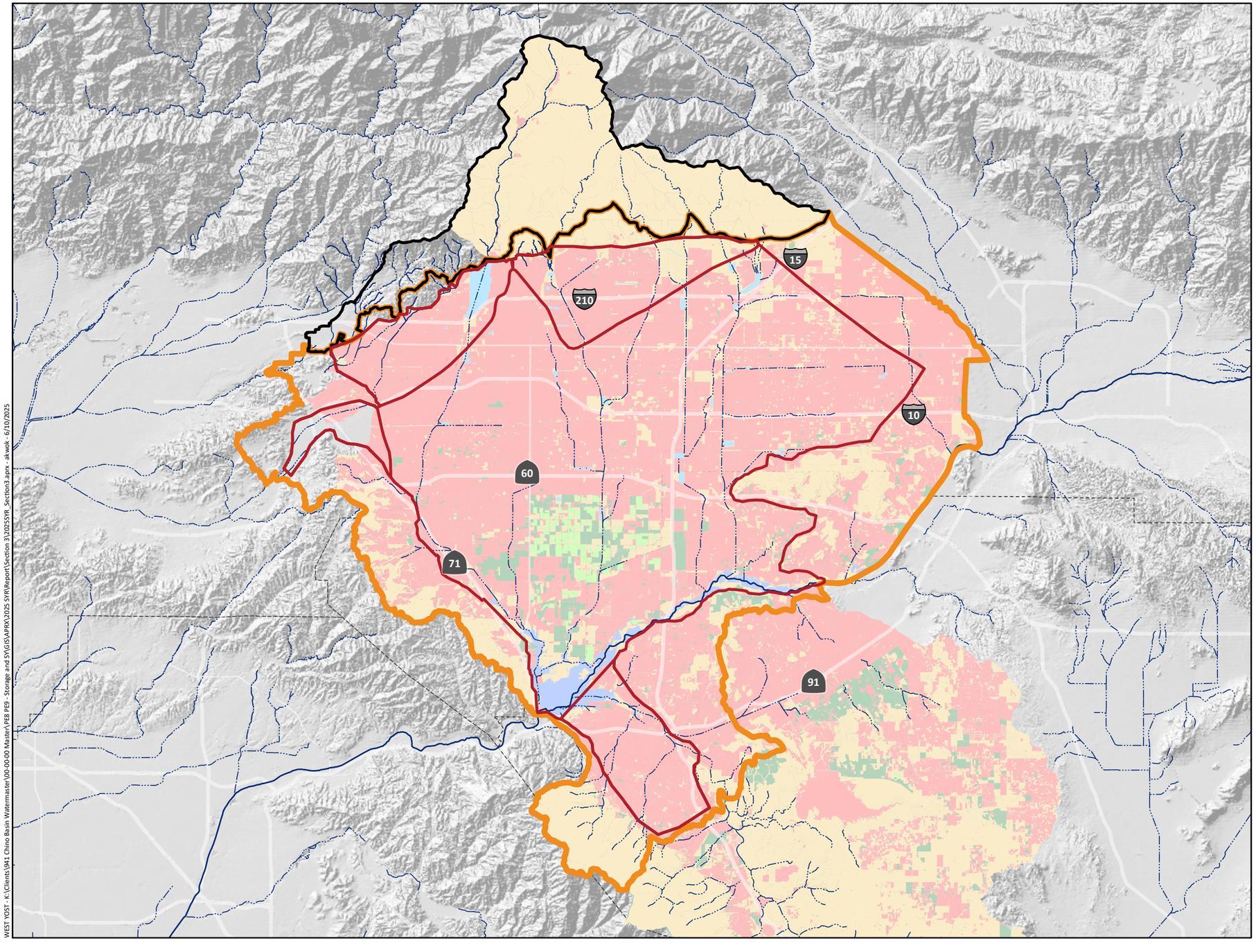
Figure 3-2

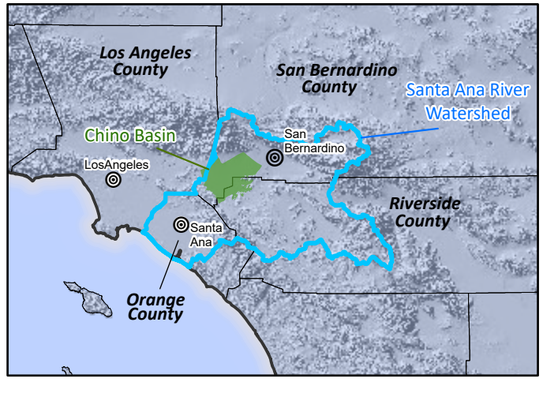


Land Uses

- Agriculture
- Dairy
- Urban
- Vacant
- Riparian Vegetation

Other Features

- MODFLOW Domain
- HPSF Model Domain
- R4 Model Domain
- Rivers and Streams
- Flood Control and/or Conservation Basins



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2017 Land Use within the Chino Basin

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Figure 3-3

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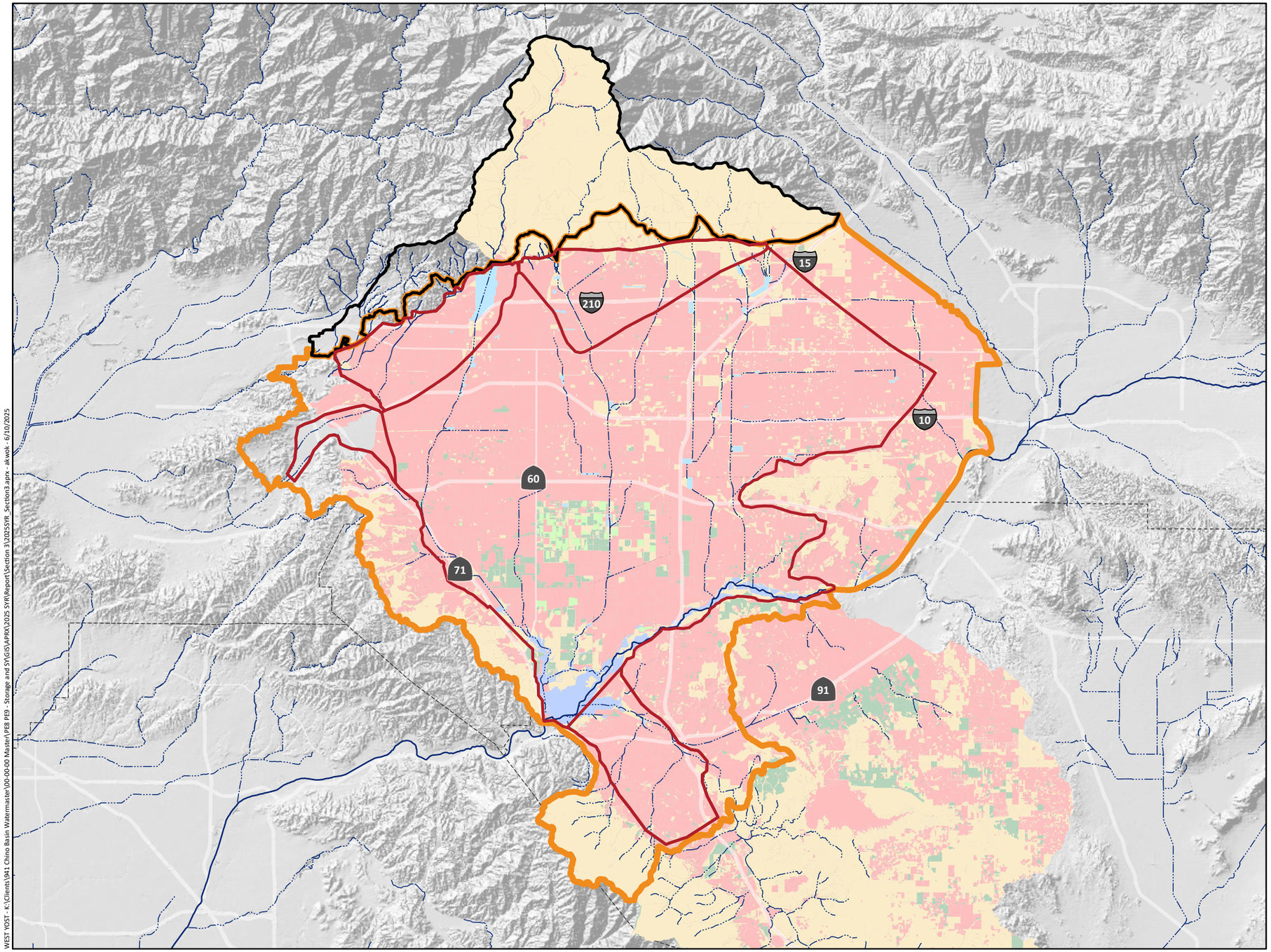
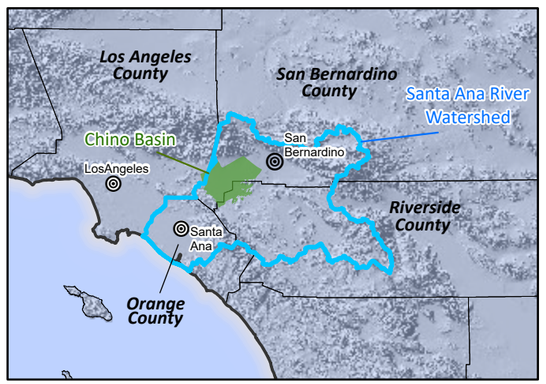


Land Uses

- Agriculture
- Dairy
- Urban
- Vacant
- Riparian Vegetation

Other Features

- HPSF Model Domain
- R4 Model Domain
- MODFLOW Domain
- Rivers and Streams
- Flood Control and/or Conservation Basins



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2022 Land Use within the Chino Basin

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Figure 3-4

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Layer 1 Thickness (ft)

–100- 100-ft contour interval

--50 - 50-ft contour interval

Other Features

2025 CVM Domain

Rivers and Streams

Flood Control and/or Conservation Basins

Faults

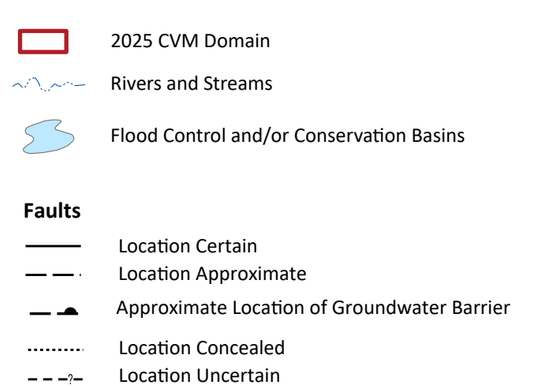
Location Certain

Location Approximate

Approximate Location of Groundwater Barrier

Location Concealed

Location Uncertain



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2025 CVM Layer Thickness
Layer 1

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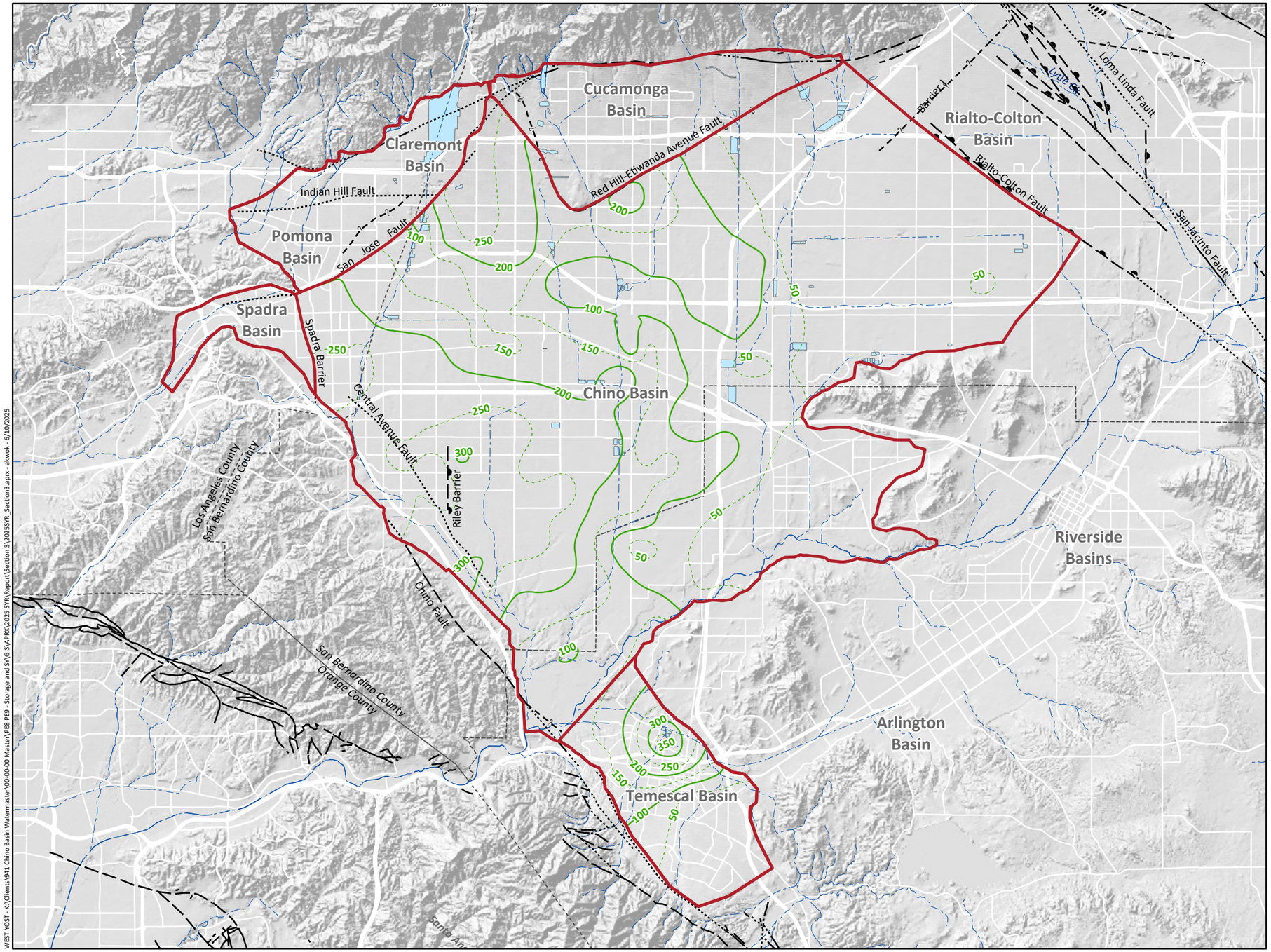
Figure 3-5

WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PEB PE3 - Storage and SY\GIS\APRX\2025 SYR\Report\Section 3\2025SYR_Section3.aprx - akwok - 6/10/2025



Layer 3 Thickness (ft)

–100– 100-ft contour interval

--50 - 50-ft contour interval

Other Features

2025 CVM Domain

Rivers and Streams

Flood Control and/or Conservation Basins

Faults

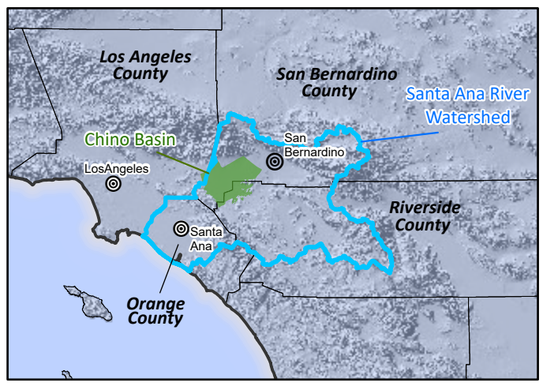
Location Certain

Location Approximate

Approximate Location of Groundwater Barrier

Location Concealed

Location Uncertain



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0 4 8 Km

Prepared for:

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2025 Safe Yield Reevaluation

2025 CVM Layer Thickness
Layer 3

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Figure 3-6

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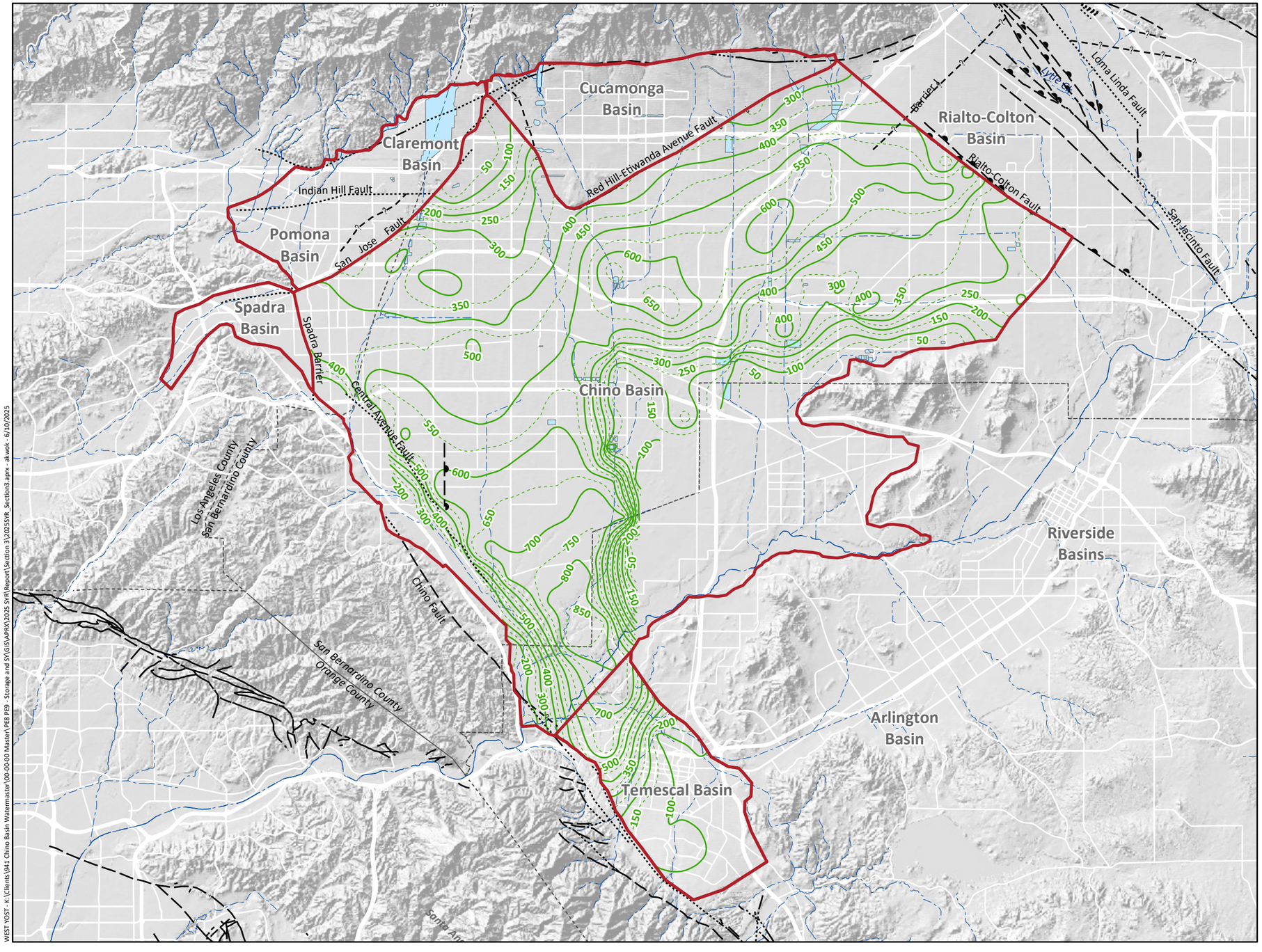


Layer 5 Thickness (ft)

–100- 100-ft contour interval

--50 - 50-ft contour interval

Other Features

2025 CVM Domain

Rivers and Streams

Flood Control and/or Conservation Basins

Faults

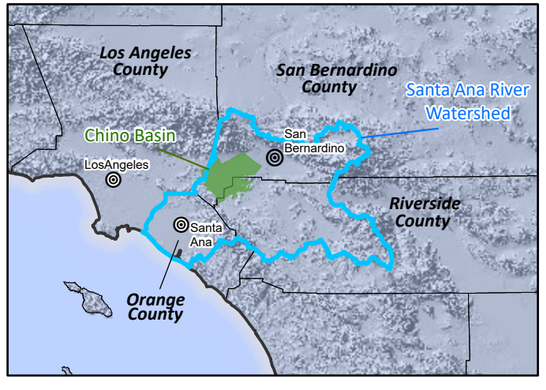
Location Certain

Location Approximate

Approximate Location of Groundwater Barrier

Location Concealed

Location Uncertain



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2025 Safe Yield Reevaluation

2025 CVM Layer Thickness
Layer 5

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Figure 3-7

WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PEB PE9 - Storage and SY\GIS\APRX\2025 SYR\Report\Section 3\2025SYR_Section3.aprx - akwok - 6/10/2025

3.2.3 Travel Time of DIPAW Through the Vadose Zone

The magnitude and timing of DIPAW arriving at the groundwater table are based on R4 model estimates of surface-water infiltration past the root zone with the arrival time lagged based on the HYDRUS-2D model estimates of travel time through the vadose zone. The estimated annual average DIPAW is used as input to the Recharge Package (RCH) of the MODFLOW model.

Figure 3-8 shows the location of the HYDRUS-2D models and the estimated lag time for the 2020 CVM. In the 2020 CVM, a constant lag time was applied within each color-banded zone, resulting in abrupt "jumps" in DIPAW arrival times at the zone boundaries. No updates were made to the HYDRUS-2D models in the 2025 CVM, based on the assumption that lag time remains spatially static under relatively stable land use conditions across most of the Basin. To eliminate jumps in timing of DIPAW across the Basin, the lag time for the 2025 CVM is based on linear-interpolation of the estimated HYDRUS-2D lag times from the 2020 CVM data. Figure 3-9 shows the location of the HYDRUS-2D models and the estimated lag time for the 2025 CVM.

3.2.4 Evapotranspiration of Groundwater

Evapotranspiration of groundwater[2] by phreatophytes in the Prado Basin and SAR areas was simulated with the Evapotranspiration Segments Package (ETS1) of the MODFLOW model. Appendix A.3 provides a detailed description of the data, literature, and assumptions that were used to construct the input file to the EST1 Package.

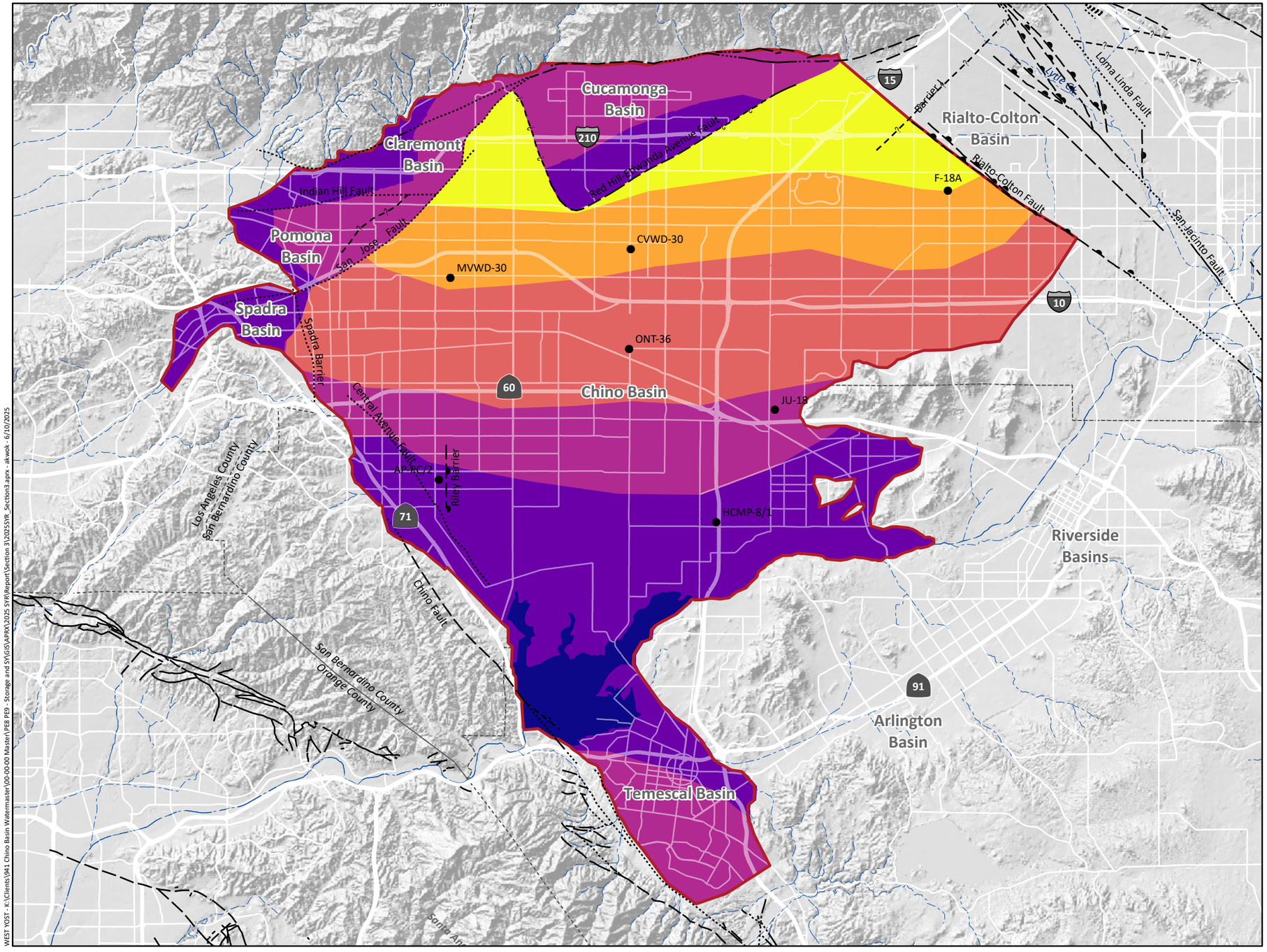
3.2.5 Santa Ana River and Tributaries

Streamflow and groundwater/surface-water interactions within the SAR and its tributaries were simulated using the Streamflow-Routing Package (SFR) of the MODFLOW model. The stream courses, streambed elevations, and streambed cross-sectional geometries were updated based on the review of historical aerial photos and the 2018 one-meter digital elevation model from the USGS (see Section 2). Figure 3-10 shows the locations of the streams simulated with the SFR package in the MODFLOW model of the 2025 CVM.

3.2.6 Groundwater Pumping

Groundwater pumping data compiled by the Watermaster were reviewed and extended to match the calibration period. The Well Package (WEL) of the MODFLOW model was used to simulate unmetered agricultural pumping from 1992 to the early 2000s that was estimated with water-duty methods. The Multi-node Well Package (MNW2) of the MODFLOW model was used to simulate metered pumping. Most metered data is available at monthly or quarterly intervals, with Watermaster's production database containing quarterly records.

[2] Evapotranspiration of surface water was simulated with the HSPF and R4 models.



Travel Time of DIPAW through Vadose Zone (years)

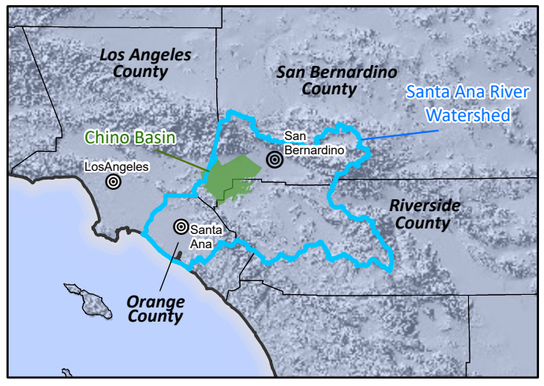
- 0 - 4
- 5 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 31 - 36

Other Features

- Boreholes Used in HYDRUS-2D
- 2025 CVM Domain
- Rivers and Streams
- Flood Control and/or Conservation Basins

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



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N

0 3 6 Miles

0 4 8 Km

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2025 Safe Yield Reevaluation

Travel Time of DIPAW through Vadose Zone - 2020 CVM

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Figure 3-8

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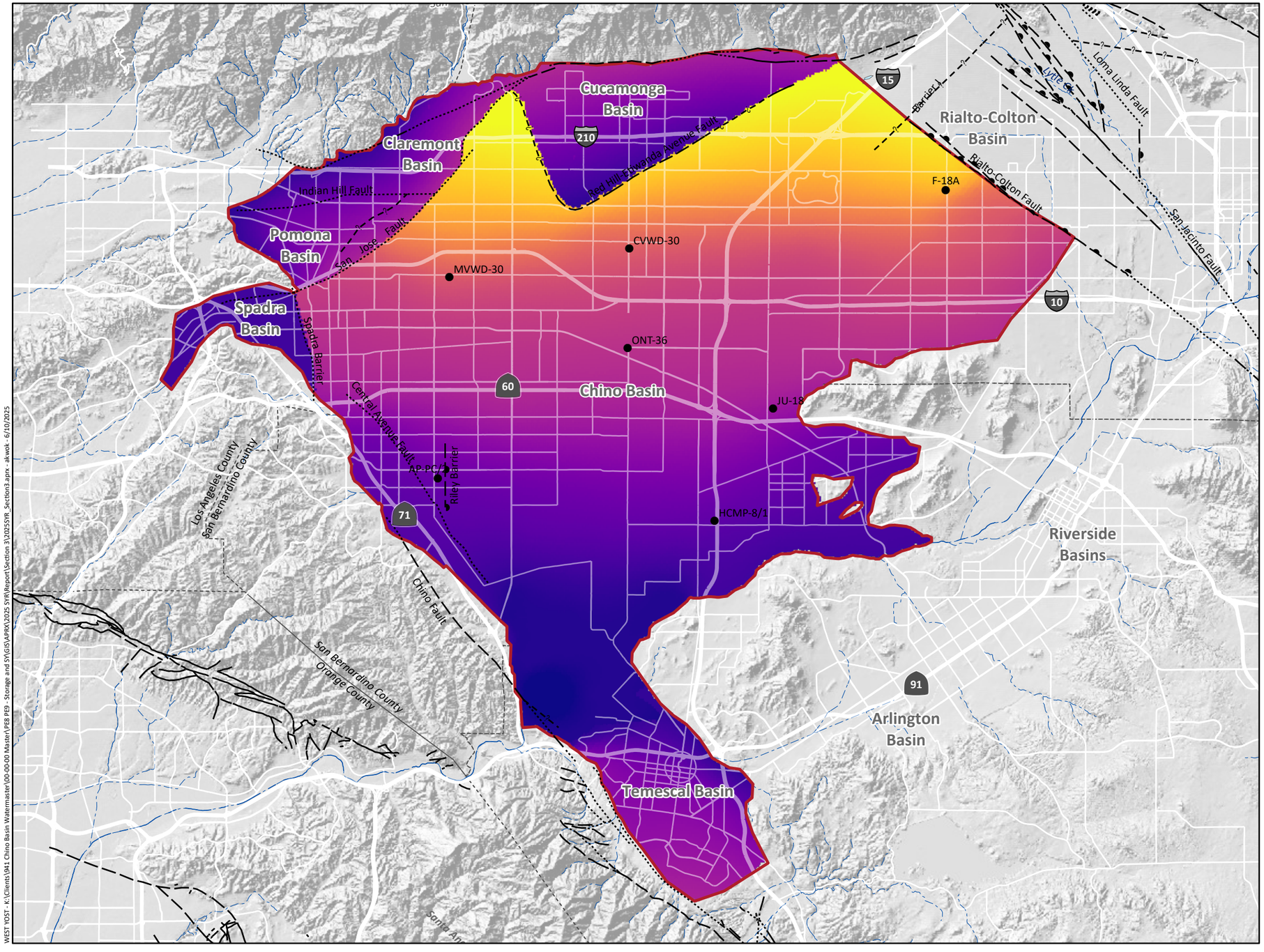


Travel Time of DIPAW through Vadose Zone (years)

36 years

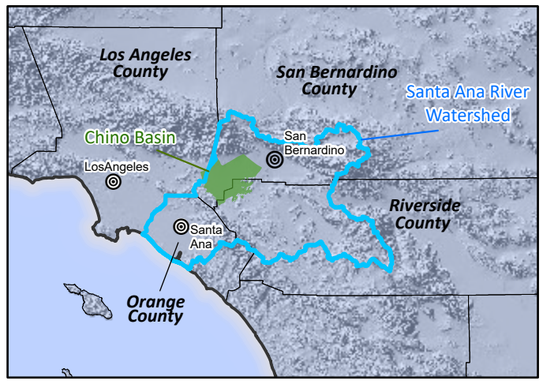
0 years

Other Features

- Boreholes Used in HYDRUS-2D
- 2025 CVM Domain
- Rivers and Streams
- Flood Control and/or Conservation Basins

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



Prepared by:

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N

0 3 6 Miles

0 4 8 Km

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Chino Basin Watermaster
2025 Safe Yield Reevaluation

Travel Time of DIPAW through Vadose Zone - 2025 CVM

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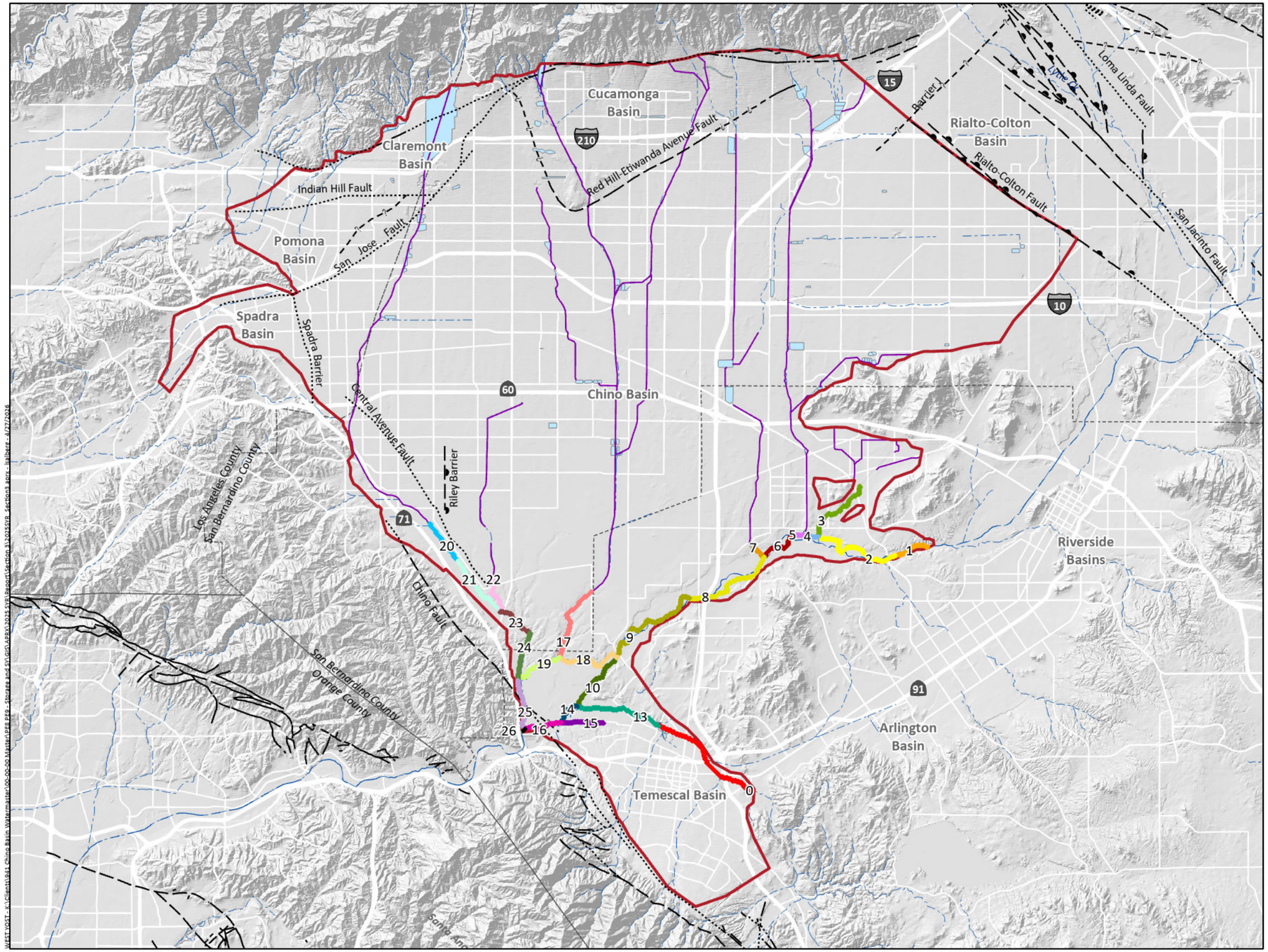
Figure 3-9

WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PEB #E9 - Storage and SY\GIS\APRX\2025 SYR\Report\Section 3\20255YR_Section3.aprx - akwok - 6/10/2025



Stream Segments

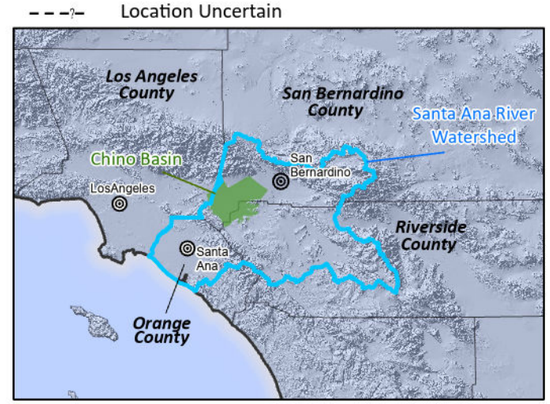
0	10	22
1	13	23
2	14	24
3	15	25
4	16	26
5	17	
6	18	
7	19	
8	20	
9	21	

Other Features

- 2025 CVM Domain
- Lined Channels
- Rivers and Streams
- Flood Control and/or Conservation Basins

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



Prepared by:

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Water. Engineered.

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0 3 6 Miles

0 4 8 Km

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2025 Safe Yield Reevaluation

Modeled Streams

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Figure 3-10

3.2.7 Fault Barriers

The Horizontal-Flow Barrier (HFB) Package of the MODFLOW model was used to simulate geologic faults that impede groundwater flow. Figure 3-11 shows the simulated faults of the 2020 CVM and the two modifications that were made to the simulated faults in the 2025 CVM. The first modification was adding a barrier between the Spadra Basin and Chino Basin based on the observation of abrupt change in depth of bedrock, difference in groundwater levels, and a USGS-mapped fault in that area. The second modification was shifting the fault lines north of CA-210 (i.e., the faults that separate the north portions of the Cucamonga and Six Basins from the Chino Basin) based on probable fault lines suggested by InSAR estimates of ground motion between Spring 2022 and Spring 2023 (see Section 2). Figure 3-12 shows how the faults were segmented in the 2025 CVM to apply parameters to each segment. The parameters applied to each segment were updated for the 2025 CVM and allowed to vary to consider the uncertainty in the fault properties (see Section 4 for more detail).

3.2.8 Subsurface Inflow

Subsurface inflow includes inflow from the San Gabriel Mountains to the Cucamonga and Six Basins and inflow from other adjacent groundwater basins to the basins simulated in the 2025 CVM. Figure 3-13 shows the locations of the subsurface inflow and the segmentation of these locations in the 2025 CVM. Subsurface inflow in these segments is simulated as a variable-flux boundary. The time series of subsurface inflow from the San Gabriel Mountains to the Six Basins and Cucamonga Basin was estimated by the streambed percolation estimated by the HSPF model. The time series of subsurface inflow from hillsides (e.g., Jurupa Hills, Chino Hills) to the basins simulated in the 2025 CVM was estimated by the DIPAW estimated with the R4 model.

Subsurface inflows from other regions into the 2025 CVM domain are identical to those described in Section 5 of the 2020 SYR Report. Figure 3-14 shows the locations of the time-variant specified-head boundaries for the 2025 CVM located at the western edge of Spadra Basin and at the Bloomington Divide. The time series for these specified-head boundaries are based on groundwater levels at wells near the basin boundaries, as documented in Section 5 of the 2020 SYR. The time series of subsurface inflows was extended to match the calibration period was used as input data for the Flow and Head Boundary Package (FHB) of the MODFLOW model. No changes were made to the methods to calculate subsurface inflow between the 2020 CVM and the 2025 CVM.

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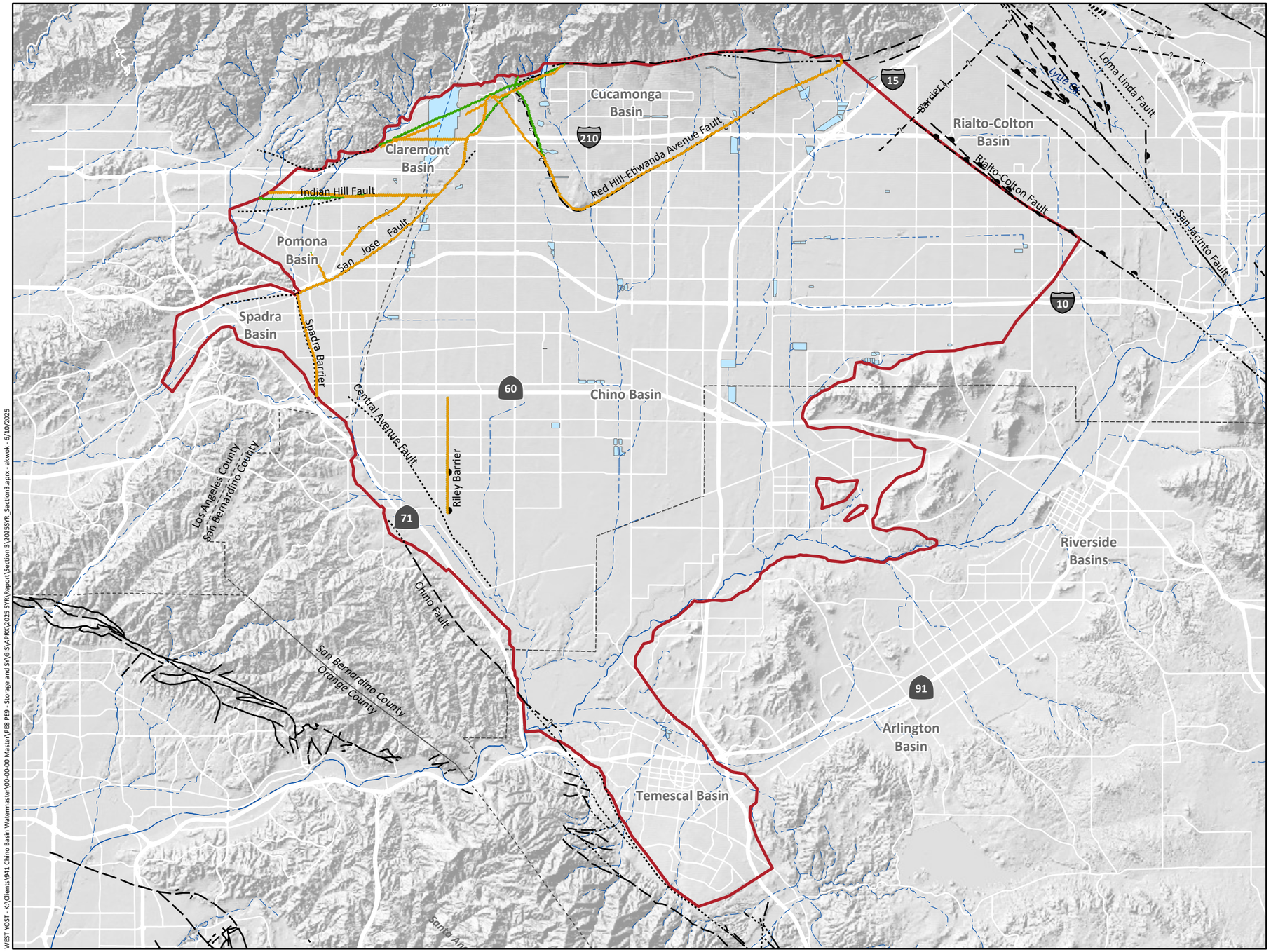


Simulated Faults

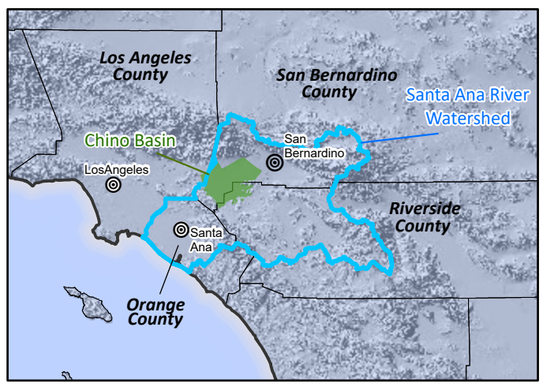
- Simulated Faults in 2020 CVM
- Simulated Faults in 2025 CVM

Other Features

- 2025 CVM Domain
- Rivers and Streams
- Flood Control and/or Conservation Basins

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



0 3 6 Miles

0 4 8 Km

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Prepared for: **Chino Basin Watermaster**
2025 Safe Yield Reevaluation

Simulated Faults of 2020 and 2025 CVM

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Figure 3-11

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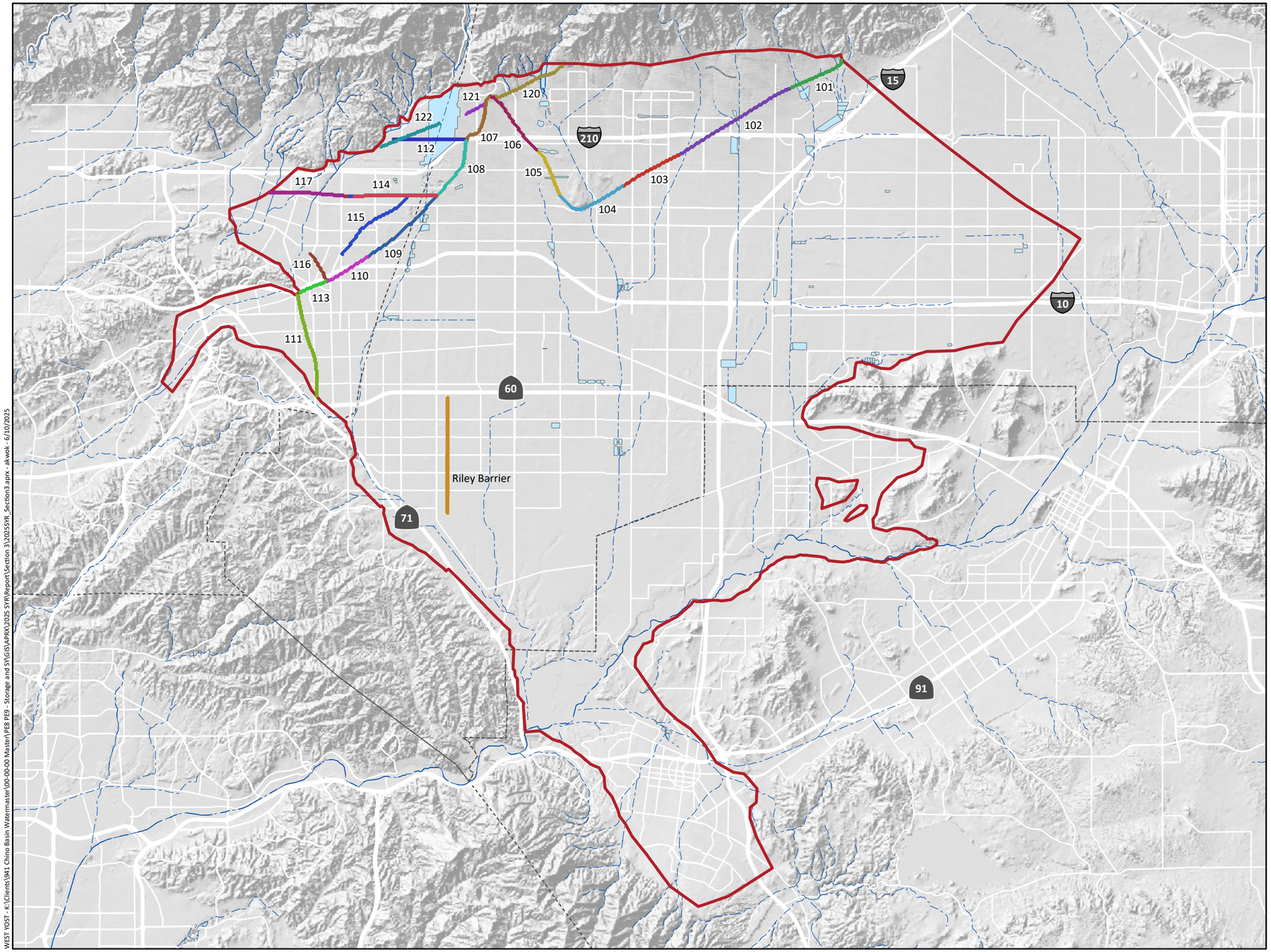
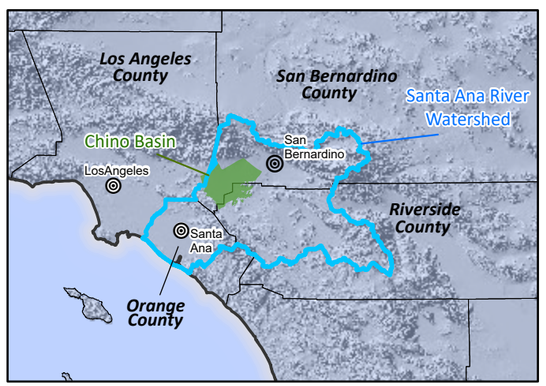


Simulated Faults Segments

- 101
- 102
- 103
- 104
- 105
- 106
- 107
- 108
- 109
- 110
- 111
- 112
- 113
- 114
- 115
- 116
- 117
- 120
- 121
- 122
- Riley Barrier

Other Features

- 2025 CVM Domain
- Rivers and Streams
- Flood Control and/or Conservation Basins



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Chino Basin Watermaster
2025 Safe Yield Reevaluation

2025 CVM
Segmentation of Simulated Faults

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Figure 3-12

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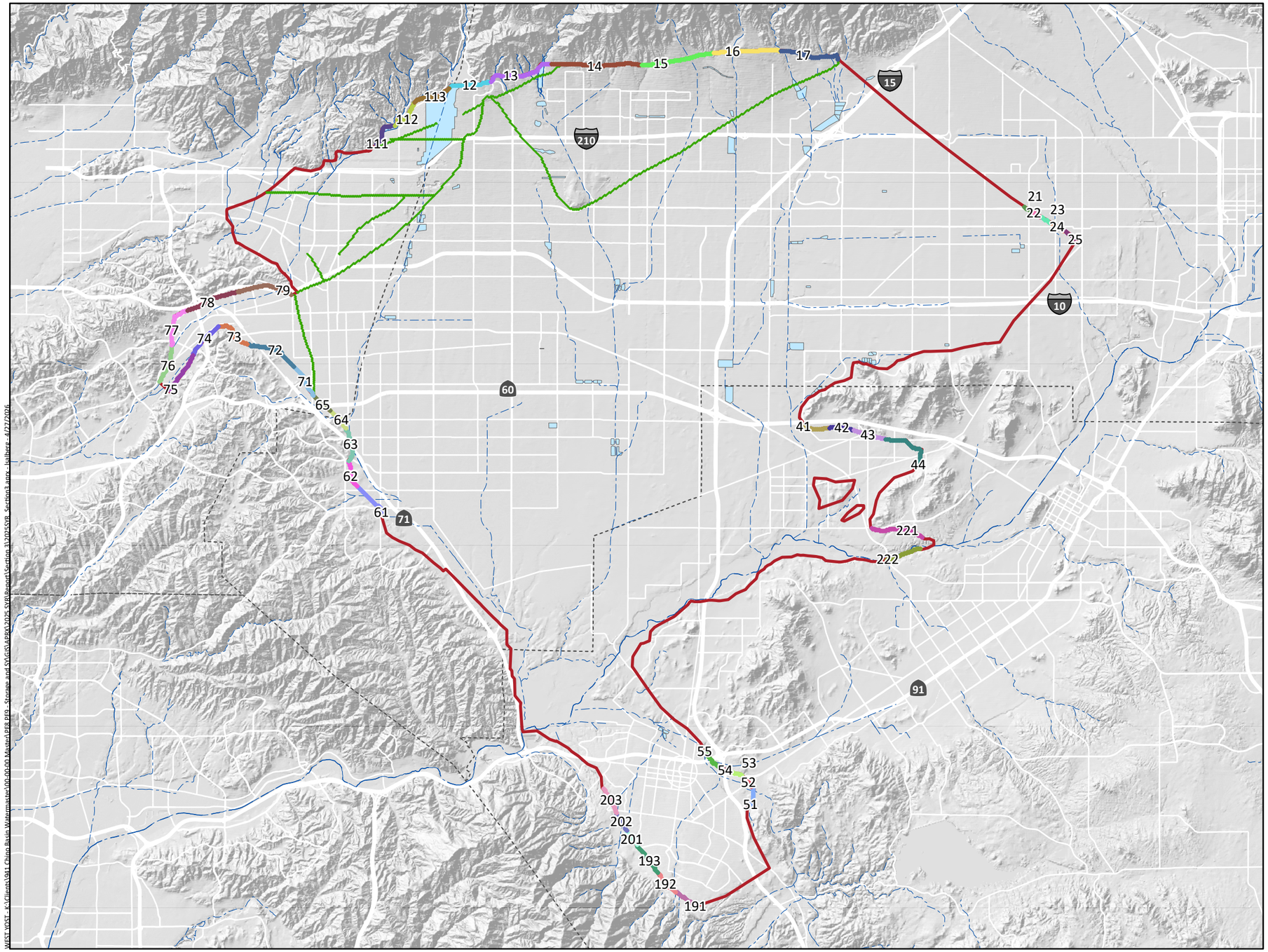


Boundary Inflow Segments

1 Boundary Inflow Segments (various colors)

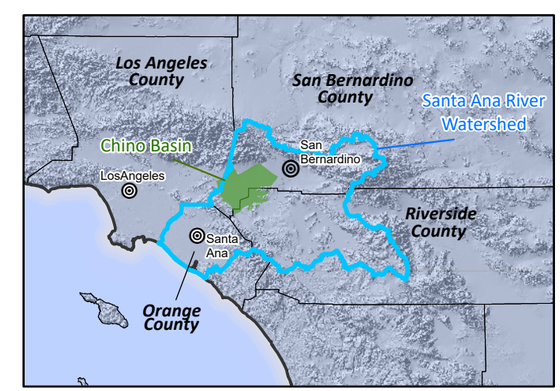
Other Features

2025 CVM Domain

Faults Simulated in 2025 CVM

Rivers and Streams

Flood Control and/or Conservation Basins



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0 4 8 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

2025 CVM
Subsurface Inflow Segments

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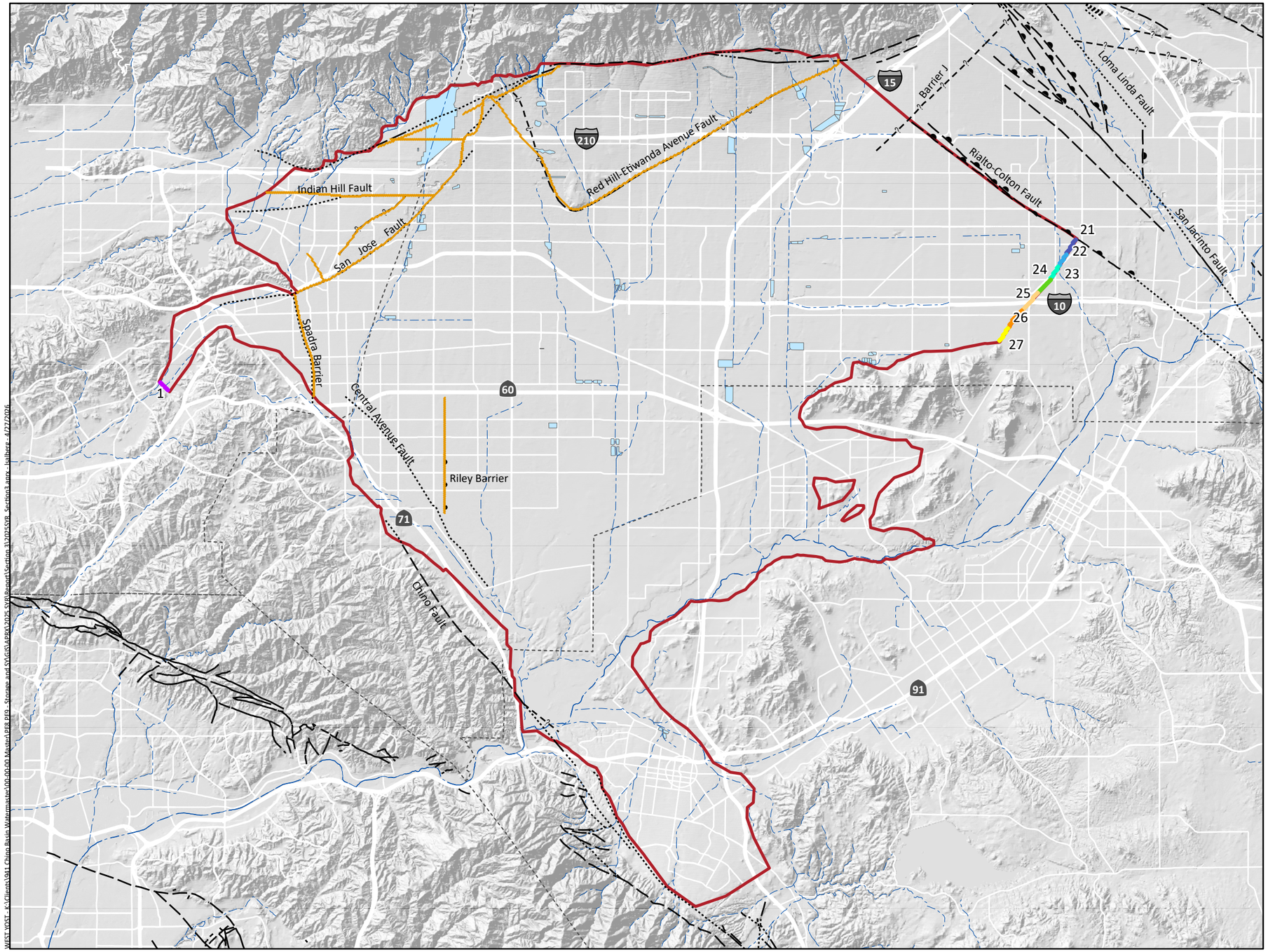
Figure 3-13

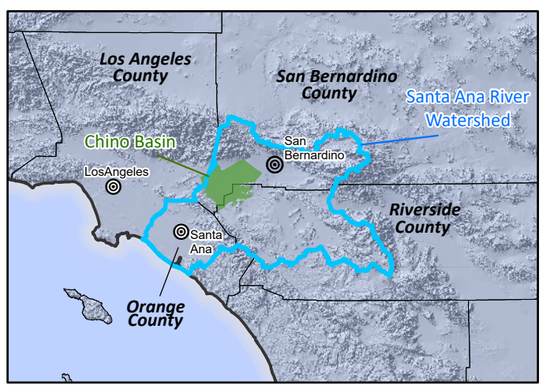


Specified-Head Boundaries

- 1
- 21
- 22
- 23
- 24
- 25
- 26
- 27

Other Features

- 2025 CVM Domain
- Simulated Faults in 2025 CVM
- Rivers and Streams
- Flood Control and/or Conservation Basins



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Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

2025 CVM
Specified-Head Boundaries

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Figure 3-14

SECTION 4
Model Calibration and Uncertainty Analysis

4.1 VALIDATION OF R4 MODEL

Section 4 documents the validation of the R4 model and the calibration and uncertainty analysis applied to the groundwater-flow (MODFLOW) model of the 2025 CVM.

The scope of revising the R4 model for the 2025 CVM specified a validation of the model using new data rather than a recalibration. The validation effort included extending and running the R4 model used in the 2020 CVM through FY 2022 and then assessing the results using the same criteria and statistics that were used to evaluate the calibration of the 2020 CVM. As the simulated outflows from the HSPF model are used as inflows for the R4 model, validation of the R4 model was assumed to be sufficient to assess the performance of both the R4 and HSPF models.

The peer review responses included the preparation of water budgets and additional documentation of the R4 model (see Appendix A).

4.1.1 Evaluation Criteria

R4 model validation used the same criteria and statistics that were used to evaluate the calibration of the R4 model in the 2020 CVM:

- Comparison of simulated streamflow with measured streamflow at two streamflow gauges in the Chino Basin (Chino Creek at Schaefer Avenue and Cucamonga Creek near Mira Loma). Figure 4-1 shows the locations of these two streamflow gauges.
- Comparison of urban outdoor water use (UOWU) simulated through the R4 root zone module with the UOWU estimated within the Inland Empire Utilities Service Area (IEUA) service area.
- Comparison of R4-simulated stormwater recharge in Chino Basin recharge basins with the stormwater recharge measured by the IEUA.

The calibration statistics for the R4 model in the 2020 CVM are documented in Section 6 of the 2020 SYR Report.

4.1.2 Validation Results

4.1.2.1 Simulated Streamflow

For the 2020 CVM, the R4 model was manually calibrated to match surface water discharges at the gaging stations shown in Figure 4-1. To evaluate the match of simulated versus measured streamflow in this validation exercise, the same statistics used in the 2020 CVM were applied: the Nash-Sutcliffe Efficiency (NSE) index[1] and the coefficient of determination (R^2).

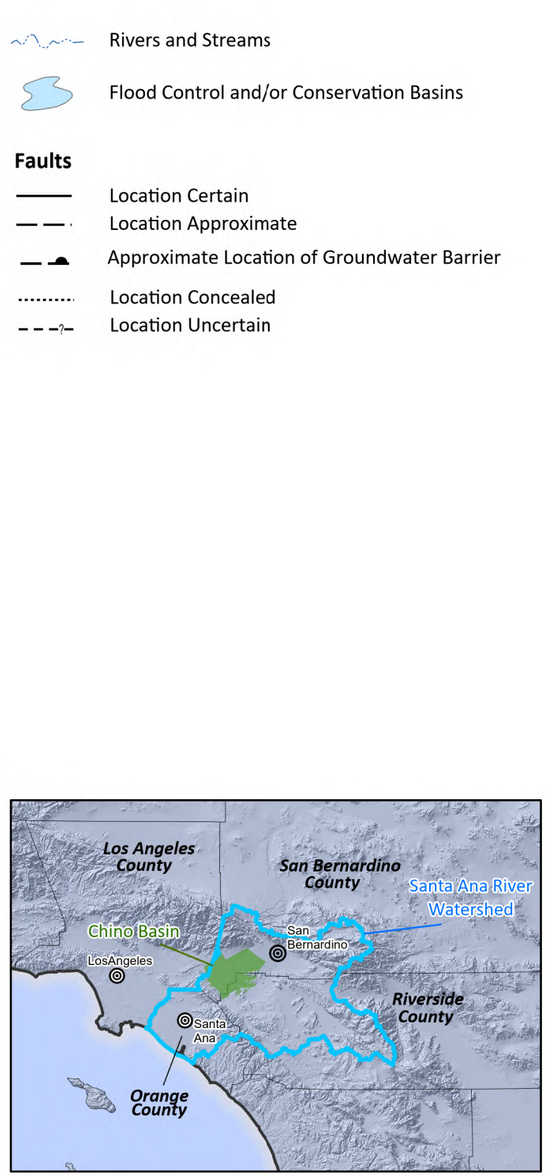
[1] Nash, J. E. and Sutcliffe, J. V. 1970. River flow forecasting through conceptual models: Part 1. A discussion of principles. J. Hydrology. 1970, Vol. 10, 3, pp. 282-290.

HPSF Model Domain
R4 Model Domain
2025 CVM Domain
Gaging Stations

Rivers and Streams
Flood Control and/or Conservation Basins

Faults

Location Certain
Location Approximate
Approximate Location of Groundwater Barrier
Location Concealed
Location Uncertain



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Location Map for Gaging Stations and Flood Control and Conservation Basins Used to Calibrate the HSPF and R4 Models

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Figure 4-1

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Table 4-1 below documents the R^2 and NSE statistics for simulated streamflow data at each of the gaging stations for the 2020 CVM and the 2025 CVM. These statistics are calculated for monthly streamflow over the period from July 1980 through the end of the model's respective calibration period (June 2018 for the 2020 CVM and June 2022 for the 2025 CVM).

Table 4-1. R4 Model Calibration Statistics for Streamflow in the 2020 CVM and 2025 CVM

Gaging Station	R^2		NSE	
	2020 CVM[(a)]	2025 CVM[(b)]	2020 CVM	2025 CVM
Chino Creek at Schaefer Avenue (USGS 11073360)	0.91	0.91	0.95	0.89
Cucamonga Creek near Mira Loma (USGS 11073360)	0.81	0.79	0.77	0.75

(a) The 2020 CVM was calibrated to monthly streamflow over the period of FY 1981 through FY 2018
(b) The 2025 CVM was calibrated to monthly streamflow over the period of FY 1981 through FY 2022

For Chino Creek at Schaefer Avenue (USGS 11073360), the R4 model achieved an R^2 of 0.91 and an NSE index of 0.95 in the 2020 CVM, indicating a very good[2] calibration match. With the inclusion of the additional years of data in the 2025 CVM, the R^2 statistic remained at 0.91 and the NSE index slightly decreased to 0.89. The match between R4-simulated streamflow and the measured data on Chino Creek at Schaefer Avenue remained good to very good for the R4 model in the 2025 CVM.

For Cucamonga Creek near Mira Loma (USGS 11073495), the R4 model achieved an R^2 of 0.81 and an NSE index of 0.77 for the 2020 CVM, indicating a very good calibration match. With the inclusion of the additional years of data in the 2025 CVM, the R^2 statistic decreased to 0.77 and the NSE index decreased to 0.75. These statistics for the R4 model in the 2025 CVM, though slightly lower, still indicate a good match between R4-simulated streamflow and the measured data on Cucamonga Creek near Mira Loma.

Figures 4-2 and 4-3 present scatter plots that illustrate the goodness of fit between measured and R4-simulated estimates of monthly surface water discharge on Chino Creek and Cucamonga Creek, respectively. These figures highlight the four additional years of data that were added for the R4 model validation and illustrate the successful validation of the R4 model in the 2025 CVM.

4.1.2.2 Simulated Urban Outdoor Water Use

The R4 rootzone module estimates irrigation demand by simulating a soil moisture balance that accounts for vegetation type, land use, precipitation, and irrigation practices. For the 2020 CVM, UOWU estimated by the R4 model was calibrated to match irrigation demand within the IEUA sewersheds, where urban irrigation demand is assumed to be equivalent to UOWU.

[2] Moriasi et al. (2007) classify model performance based on the Nash–Sutcliffe Efficiency (NSE) such that values greater than 0.75 are considered "very good," and values between 0.65 and 0.75 are considered "good" for monthly time-step simulations, based on a review of a range of hydrologic models.

IEUA provides monthly records of total water supply and wastewater flows, which are used to independently estimate UOWU across its service area. The monthly urban irrigation demand for each sewershed is calculated as the total potable water supply minus the combined outflows of wastewater treatment plant influent, onsite wastewater disposal system (OWDS) discharge, and dry-weather flows.

Table 4-2 below documents the R^2 and NSE statistics for simulated UOWU data in each of the sewersheds for the 2020 CVM and the 2025 CVM. These statistics are calculated for monthly simulated UOWU over the period of available data from January 1991 through the end of the model's respective calibration period (June 2018 for the 2020 CVM and June 2022 for the 2025 CVM).

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Figure 4-2. Scatter Plot of R4-Estimated Monthly Discharge and USGS-Estimated Discharge for Chino Creek at Schaefer Avenue

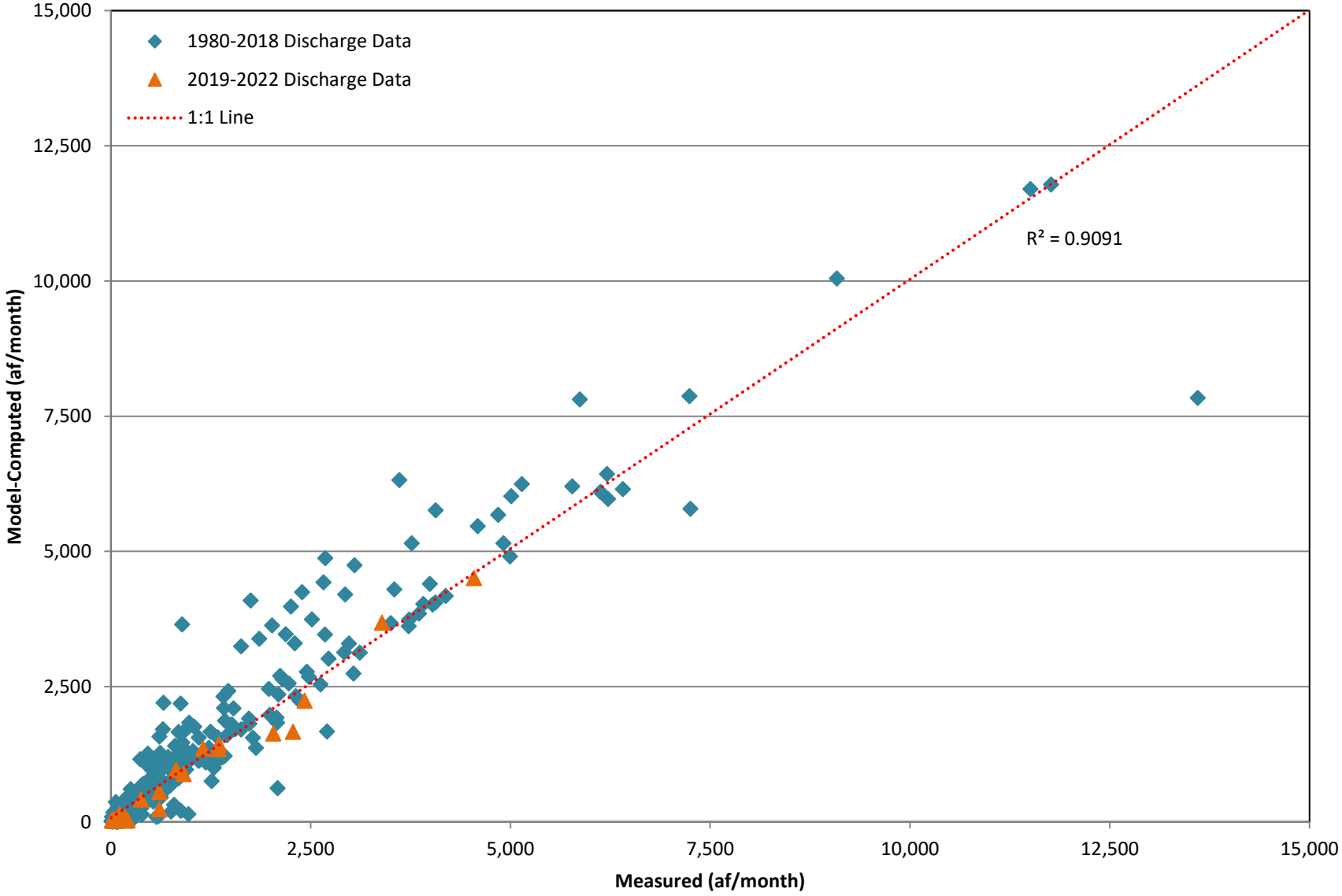

Figure 4-3. Scatter Plot of R4-Estimated Monthly Discharge and USGS-Estimated Discharge for Cucamonga Creek near Mira Loma

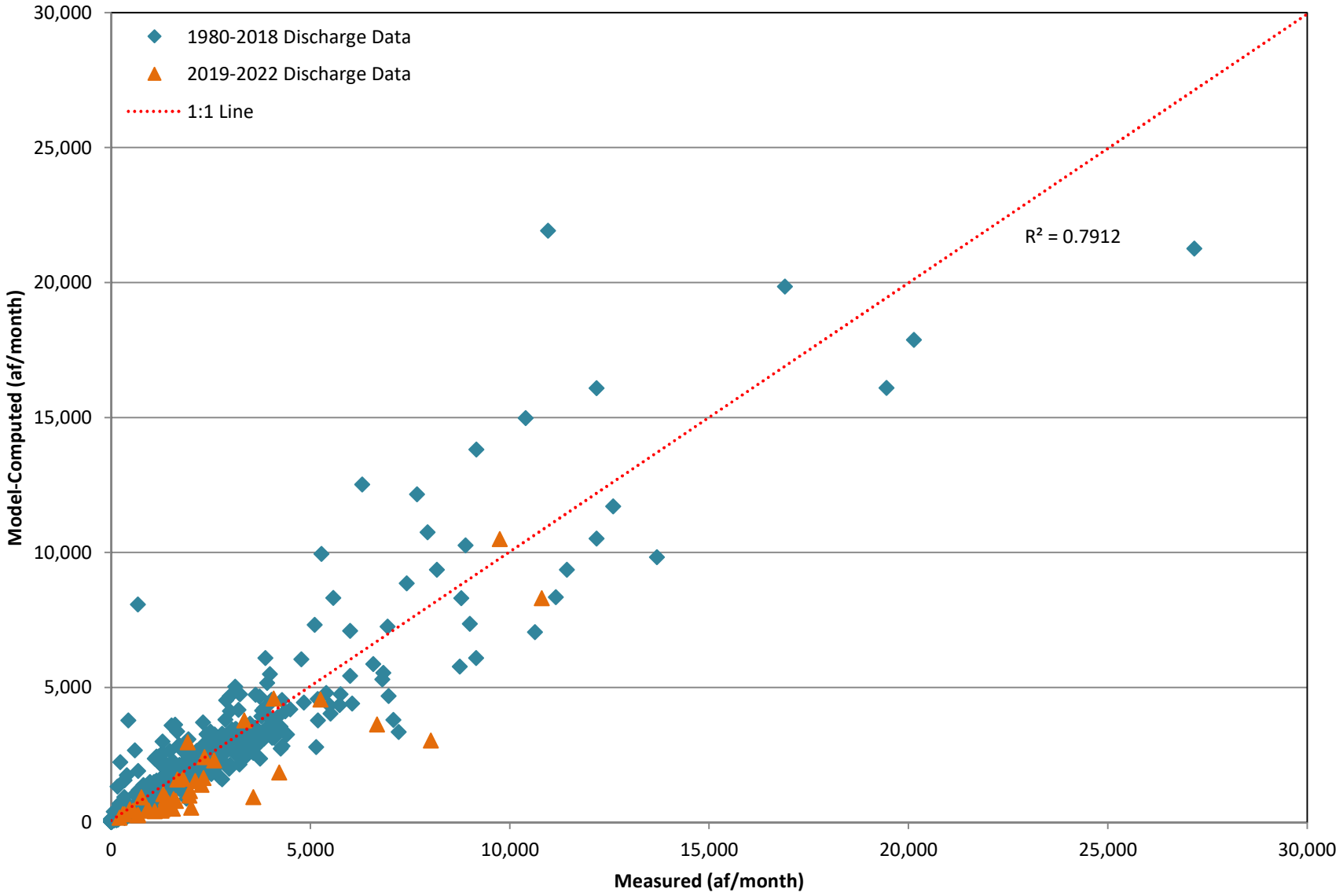

Table 4-2. R4 Model Calibration Statistics for Urban Outdoor Water Use in the 2020 CVM and 2025 CVM

Sewershed	R^2		NSE	
	2020 CVM[(a)]	2025 CVM[(b)]	2020 CVM	2025 CVM
RP1/RP4	0.76	0.76	0.74	0.74
CC/RP5	0.71	0.70	0.68	0.67

(a) The 2020 CVM was calibrated to monthly streamflow over the period of FY 1981 through FY 2018.
(b) The 2025 CVM was validated to monthly streamflow over the period of FY 1981 through FY 2022.

For the RP1/RP4 sewershed, the R4 calibration of urban irrigation demand achieved an R^2 of 0.76 and an NSE index of 0.74 in the 2020 CVM. When additional years of data were incorporated into the 2025 CVM, the R^2 and NSE remained at 0.76 and 0.74, respectively.

For the RP2/CC/RP5 sewershed, the R4 calibration of urban irrigation demand achieved an R^2 of 0.71 and an NSE index of 0.68 in the 2020 CVM. When additional years of data were incorporated into the 2025 CVM, the R^2 decreased to 0.70, while the NSE index slightly decreased to 0.67. The NSE indices indicate a good fit after adding the additional years of data.

Figures 4-4 and 4-5 are time-series charts that show the IEUA estimated total monthly water supply to the RP1/RP4 and RP2/CC/RP5 sewersheds, respectively, versus the R4-estimated urban irrigation supply. These charts illustrate the ability of R4 to replicate urban irrigation demand and its historical seasonality. Figures 4-6 and 4-7 are scatter plots that illustrate the IEUA estimated total monthly water supply versus the R4-estimated water supply for these sewersheds. Review of these figures and the R^2 and NSE statistics indicate the successful validation of the R4 model in the 2025 CVM.

4.1.2.3 Stormwater Recharge in Basins

The R4 model is calibrated to match estimates of stormwater recharge in flood control and conservation basins within the Chino Basin, using diversion estimates provided by IEUA as the comparison against observed data. Starting around FY 2006, IEUA began estimating stormwater diverted into the basins it operates using methods such as water-level sensors and assumed basin infiltration rates, with results reported as monthly totals.

For the 2020 CVM, the R4 model calibration targeted the IEUA diversion estimates and incorporated facility-specific information, including diversion rating curves, elevation-area-storage curves, outlet ratings, and depth-dependent infiltration rates. Calibration performance was assessed using R^2, which ranged from 0.14 to 0.88 across individual basins. Due to the limited number of monthly data points, NSE indices were not calculated. The quality of stormwater recharge calibration varied across facilities, with results ranging from unsatisfactory to very good. It is important to note that R4 model recharge calculations (which include evaporation, infiltration, and overflow) differ from IEUA's diversion estimates, which rely on measurements and assumptions that may not account for all these processes. As a result, the two sets of estimates are not directly comparable.

Figure 4-4. Total Water Supply to the RP1/RP4 Sewershed and the Efficacy of the Supply

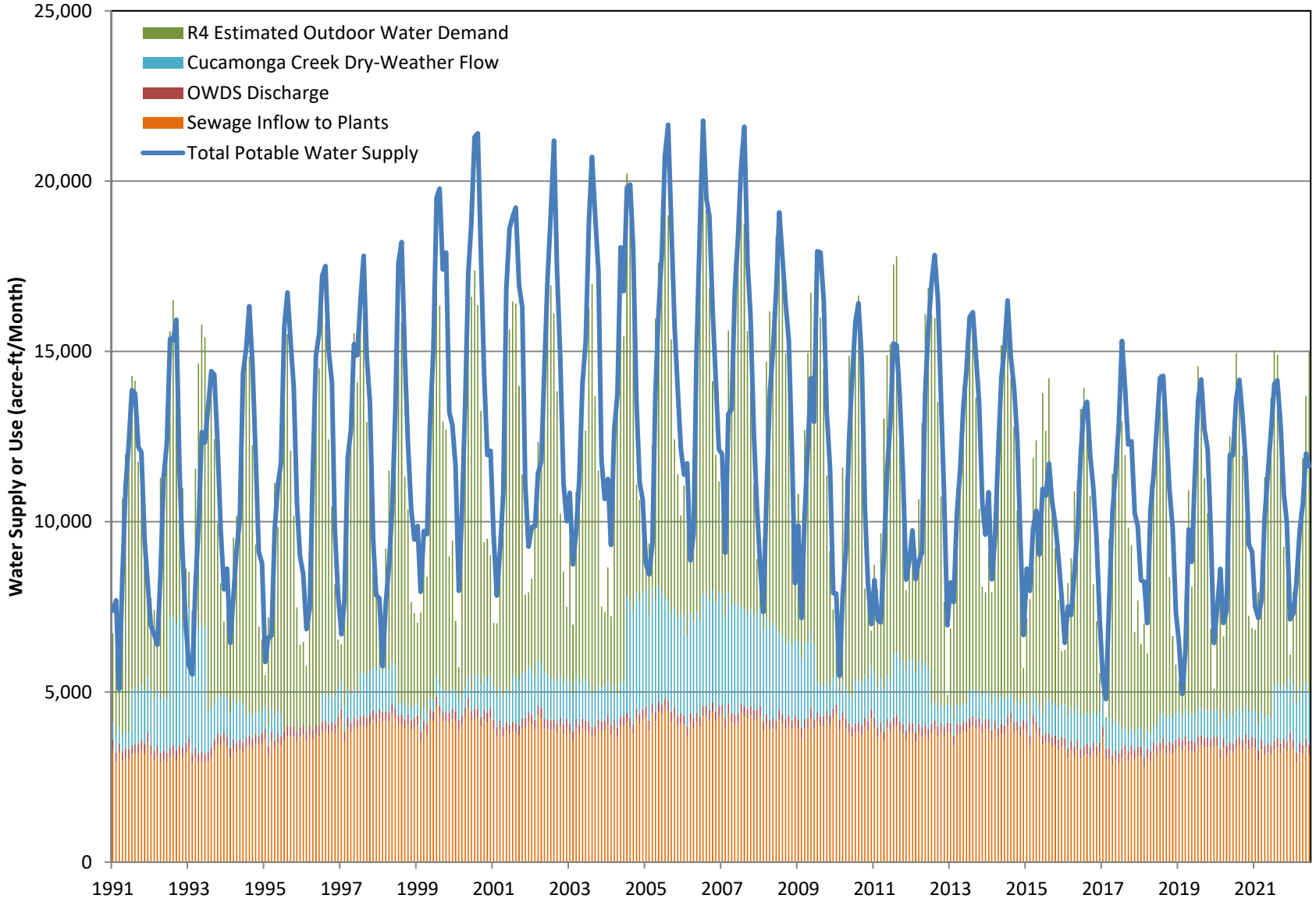

Figure 4-5. Total Water Supply to the RP2/CC/RP5 Sewershed and the Efficacy of the Supply

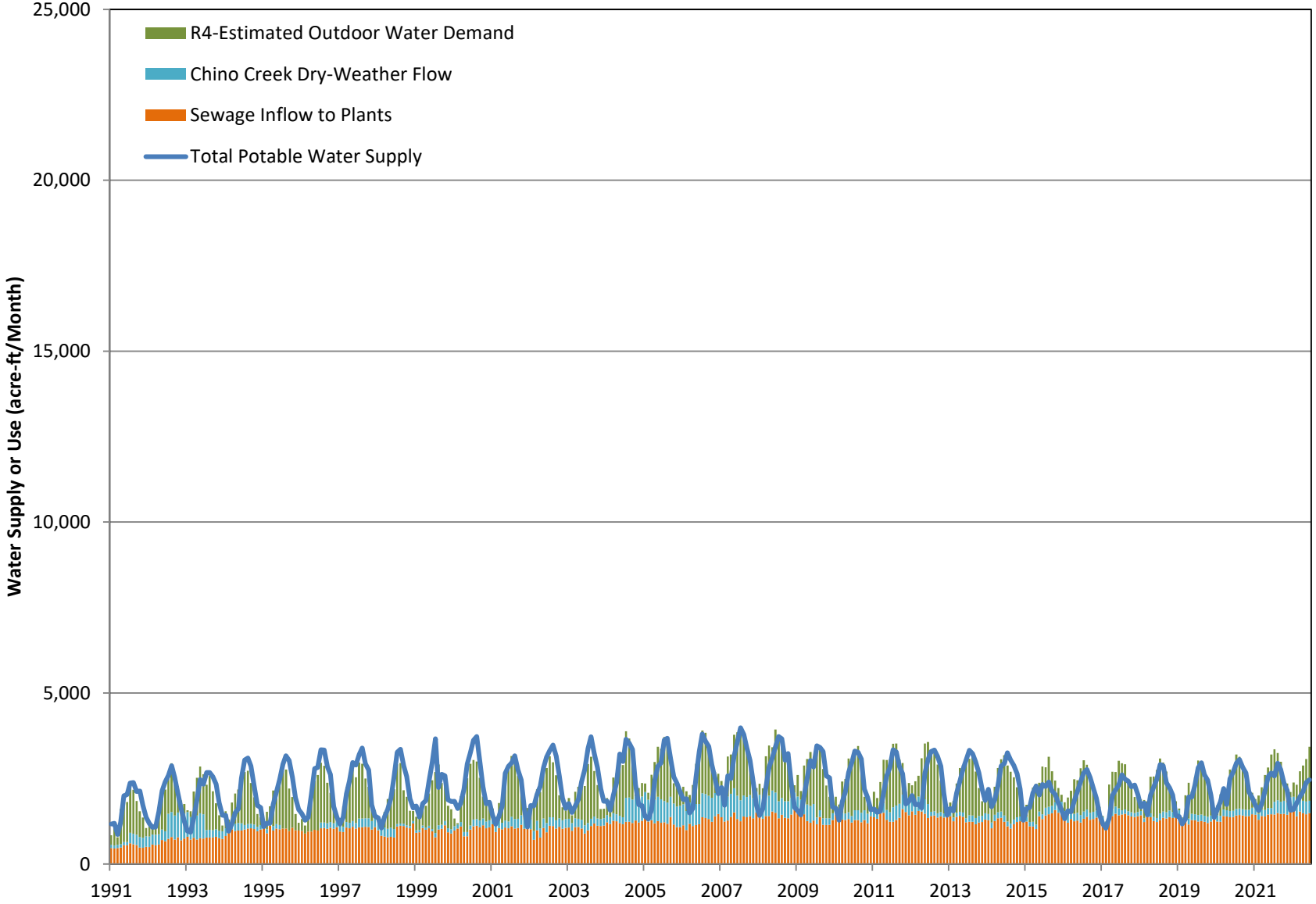

Figure 4-6. Scatter Plot of IEUA-Estimated Water Supply and the R4 Estimated Water Supply for the RP1/RP4 Sewershed

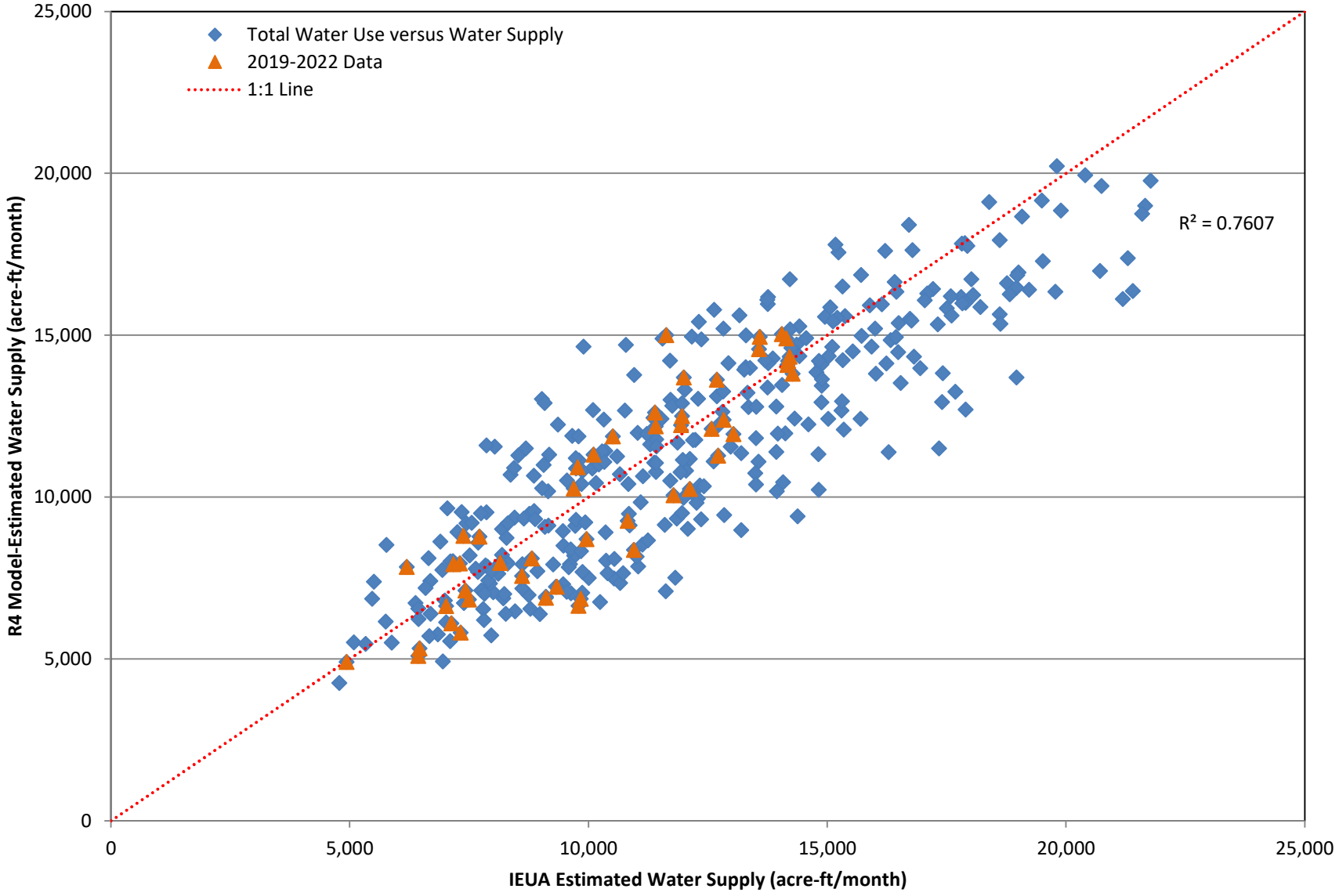

Figure 4-7. Scatter Plot of IEUA-Estimated Water Supply and the R-4 Estimated Water Supply for the RP2/CC/RP5 Sewershed

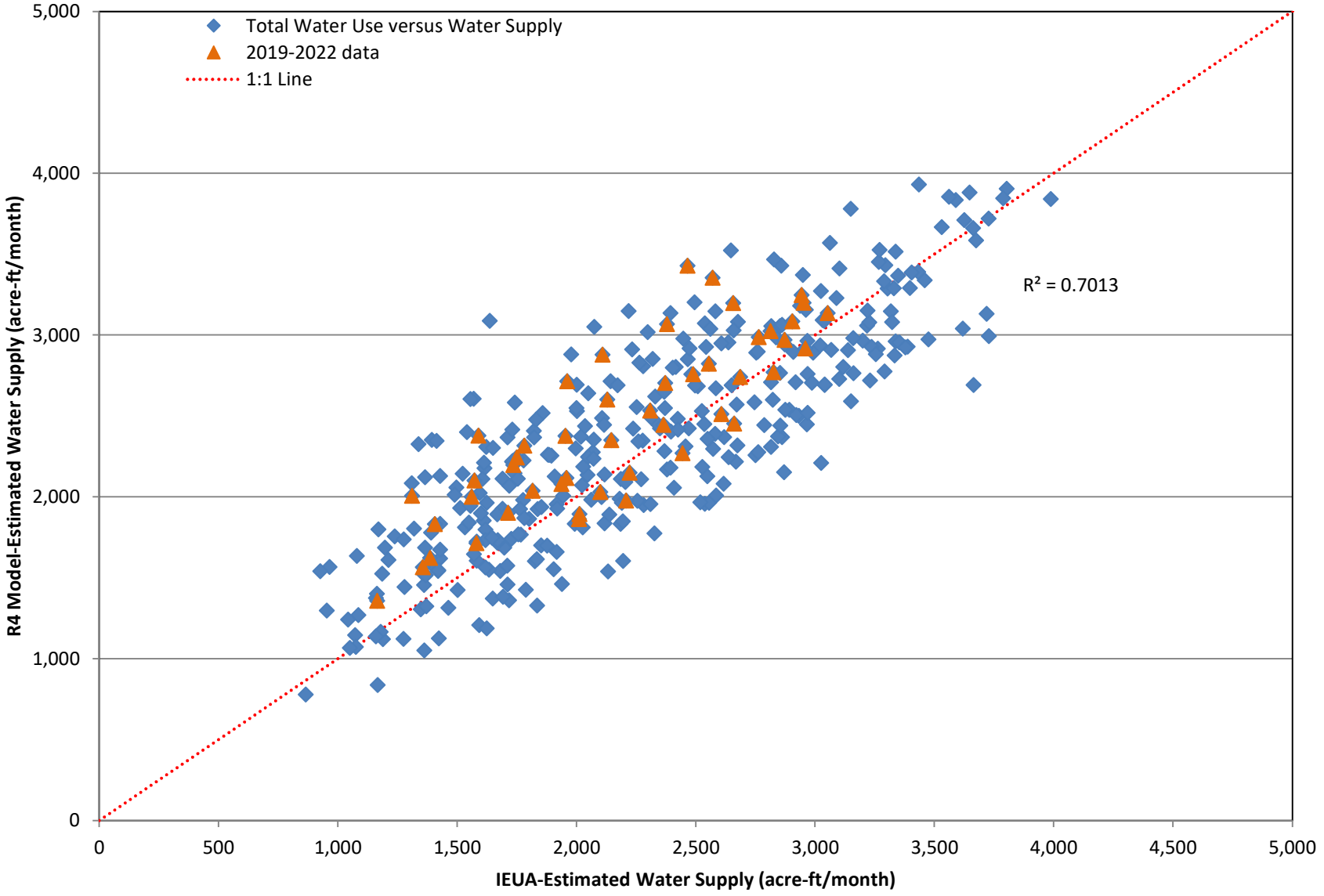

Table 4-3 compares the R^2 values based on monthly R4-simulated recharge and IEUA-estimated diversion volumes for the recharge basins, with corresponding scatter plots provided in Appendix B-1. Table 4-3 shows that the R^2 values were generally consistent after adding four additional years of data (FY 2018 through 2022). Specifically, four basins (Declez, RP3, Turner, and Upland) showed an increase in R^2 of more than 0.04, while three basins (Etiwanda Debris, Grove, and San Sevaine) showed a decrease of more than 0.04. The remaining seven basins exhibited minimal change in R^2, indicating stable model performance over the extended period.

Table 4-3. Calibration and Validation of R4 Model - Recharge Basins

Recharge Basin	R^2 (R4-Simulated Recharge versus IEUA-Estimated Diversions)	
	2020 CVM (2006-2018)	2025 CVM (2006-2022)
7th/8th Street Basins	0.68	0.68
Banana/Hickory Basins	0.27	0.29
Brooks Basin	0.84	0.80
Declez Basin	0.35	0.41
Etiwanda Debris Basin	0.67	0.49
Ely Basins	0.56	0.57
Grove Basin	0.34	0.19
Lower Day Basin	0.86	0.83
Montclair Basins	0.88	0.90
RP3 Basins	0.14	0.46
San Sevaine Basins	0.83	0.77
Turner Basins	0.64	0.78
Upland Basin	0.79	0.90
Victoria Basin	0.81	0.83

4.2 RECALIBRATION AND UNCERTAINTY ANALYSIS

This subsection describes the methods and results of conducting Steps 1 and 2 of the 2022 Safe Yield Reset Methodology (2022 SYRM):

1. Re-calibrate the Watermaster's groundwater-flow model
2. Conduct an uncertainty analysis of the re-calibrated groundwater-flow model to identify a plausible range of calibrated models

4.2.1 Methods

A calibrated realization in the context of hydrologic models refers to a specific set of model parameters that have been adjusted to provide a close match between simulated and observed conditions. Multiple calibrated realizations exist because there are often many different sets of model parameters that can

produce a good fit between the model outputs and the observed data. This phenomenon is known as "non-uniqueness" in model calibration. The 2022 SYRM TM outlined a method for updating the 2025 CVM and generating calibrated realizations. The method includes the elements listed below. The following sections describe the work conducted to execute these elements.

1. Update the HSPF and R4 surface-water models for the calibration period to generate input data to the MODFLOW model.
2. Update the MODFLOW model for the calibration period based on observation data and the results of HSPF and R4.
3. Select adjustable model parameters (e.g., horizontal hydraulic conductivity) and prepare input files to incorporate the spatial relationships and variability of those parameters into PESTPP-IES. This involves defining how the parameters are distributed and varied across the model domain using techniques such as pilot points, variograms, and covariance matrices.
4. Prepare observation data as calibration targets, such as time series of groundwater elevations at wells and stream discharge.
5. Use PESTPP-IES[3] to generate calibrated realizations.
6. Rank and select calibrated realizations for projection scenarios. Review the outcome of the model with calibration realizations and determine which calibrated realizations should be selected for projection scenarios, and whether more calibrated realizations should be added. Conduct peer review process to share calibration results. Repeat the PESTPP-IES process and review outputs until enough calibrated realizations are developed.

Elements 1 and 2 of this method were completed and documented in Section 3.

4.2.2 Update of Calibration Period

The calibration period of the 2020 CVM was July 1, 1977 through June 30, 2018. During the August 30, 2023 workshop, West Yost proposed a calibration period for the 2025 CVM of July 1, 1991 to June 30, 2022. This calibration period was selected because most groundwater-level data in the Chino Valley were collected after 1992.[4]

The calibration period contains both wet and dry periods as demonstrated through a time-series analysis of precipitation data across the Chino Valley from the Parameter-elevation Relationships on Independent Slopes Model (PRISM)5 dataset. Figure 4-8 below shows the time history of annual precipitation, long-term average annual precipitation, and a curve of cumulative departure from mean precipitation (CDFM) based on the analysis. The latter is a graphical representation used to analyze precipitation trends over time. Positive slopes of the CDFM curve indicate periods of above-average precipitation (i.e., wet years), while negative slopes indicate periods of below-average precipitation (i.e., dry years). As shown on

[3] Approaches to Highly Parameterized Inversion: PEST++ Version 5, a Software Suite for Parameter Estimation, Uncertainty Analysis, Management Optimization and Sensitivity Analysis

[4] At 152 wells in Chino Valley, there are 5,414 groundwater-elevation data points from fiscal year 1978 to 1991, and 752,473 data points from 1992 to 2022.

[5] PRISM Climate Group, Oregon State University, https://prism.oregonstate.edu

Figure 4-8, the selected calibration period for the 2025 CVM includes a wet period from 1992 to 1999 and a dry period from 1999 to 2022 with some intermittent wet years.

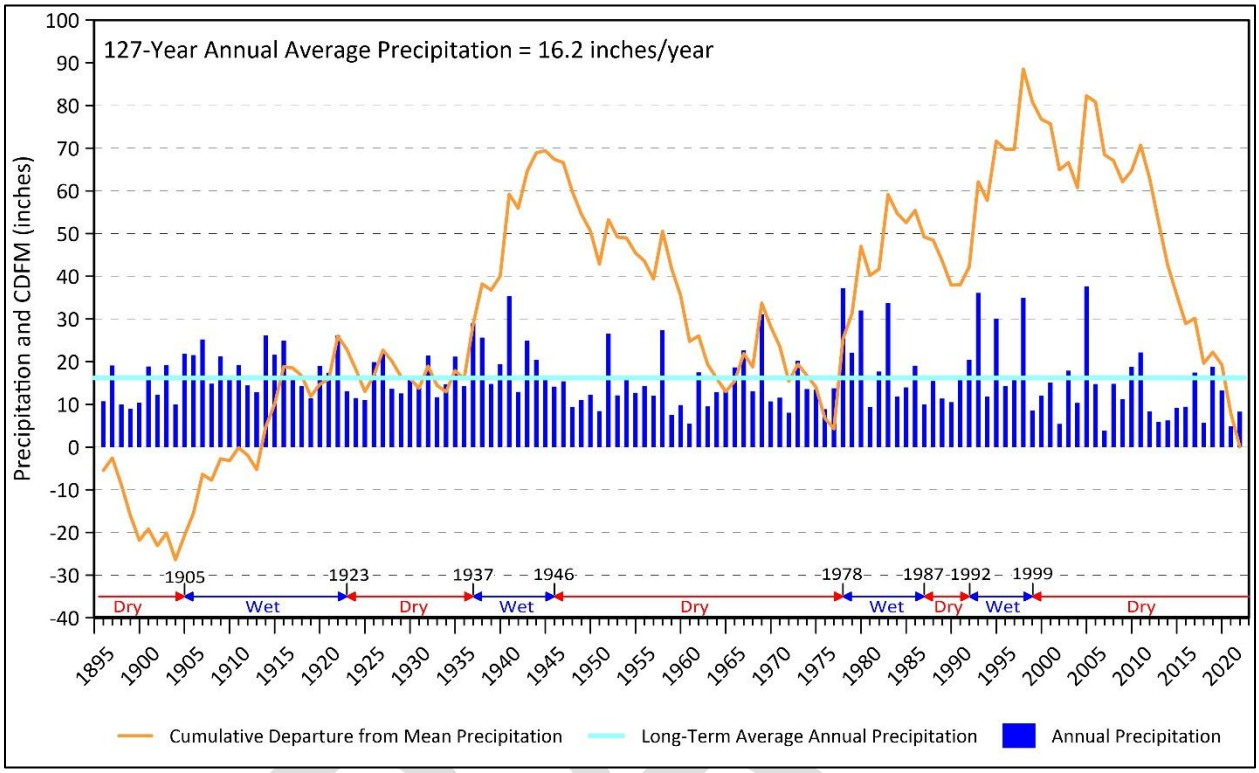

Figure 4-8. Precipitation Time Series in the Chino Basin, FY 1896-2022.

4.2.3 Select Adjustable Model Parameters and Prepare Input Files for PESTPP-IES

Many model input parameters are not well known and need to be adjusted through model calibration. For that purpose, the 2025 CVM uses the open-source computer code PESTPP-IES (Welter, et al., 2015; White, 2018; White, et al., 2020). PESTPP-IES is based on the Iterative Ensemble Smoother (iES) algorithm introduced by Chen and Oliver (2012; 2013). Using the iES algorithm, the required number of model runs for a calibration process depends on the desired number of calibrated realizations and does not depend on the number of adjustable parameters. The number of adjustable model parameters, however, still affects the required computing resources and computing time, as the information associated with each of the parameters needs to be stored and processed during the calibration process. Therefore, careful selection of a limited number of adjustable model parameters is still required. The rationale for the selected adjustable model parameters is given below.

4.2.3.1 DIPAW

Initial conditions for DIPAW are based on the outputs from the R4 rootzone module adjusted for lag time through the vadose zone (see Section 3). The DIPAW input was first applied without spatial multipliers (i.e., a uniform scaling factor across the model domain), consistent with the assumption that the R4-derived recharge estimates (after lag adjustment) were physically representative. However, in response to peer review comments, the parameterization was refined to allow for spatial variability using pilot points.

In the updated approach, arrays of annual average DIPAW values were scaled using spatially distributed multipliers defined at 240 pilot points and interpolated across the model domain. These multipliers were treated as adjustable model parameters within the calibration process. After each iteration, updated multiplier values were estimated, applied to the DIPAW fields, and used as input to the subsequent groundwater flow simulation.

The initial values of the DIPAW multipliers were defined using a normal distribution with a mean of 1.0 and a standard deviation of 0.125, such that approximately 95 percent of values fall between 0.75 and 1.25. A multiplier greater than one indicates simulated DIPAW exceeding the R4-based estimate (after lag adjustment), while a multiplier less than one indicates lower simulated DIPAW relative to that estimate. A multiplier of greater than one means that the simulated DIPAW is greater than estimated by the R4 model adjusted for lag time, and a multiplier of less than one means that the simulated DIPAW is less than estimated by the R4 model adjusted for lag time.

Although the R4 model is well-calibrated and the DIPAW estimates are considered physically defensible, inclusion of these multipliers allowed the calibration process to account for minor local or temporal variability that may not be explicitly represented in the R4 model. This approach does not alter the overall mass balance or conceptual consistency of the recharge estimates; rather, it provides limited flexibility for PESTPP-IES to reconcile small differences between the R4-estimated recharge and observed groundwater responses, ensuring numerical stability and improved spatial consistency in the calibrated realizations.

4.2.3.2 Evapotranspiration

Each array of monthly maximum ET rate was assigned a scalar multiplier as an adjustable model parameter. After each iteration of the calibration process, new values of the scalar multipliers were estimated, the associated maximum ET rates were scaled with the scalar multipliers, and then the scaled maximum ET rates were used as input to the groundwater flow simulation of the subsequent calibration iteration. Initially, the range of scalar multipliers for the maximum ET rate were allowed to vary within a range characterized by a normal distribution with a mean of 1.0 and a standard deviation of 0.1, which means that 95 percent of the multipliers would fall between 0.8 and 1.2.

4.2.3.3 Subsurface Inflow

The subsurface inflow boundary is divided into 45 segments as shown in Figure 3-14. Each segment was assigned a scalar multiplier as an adjustable model parameter to scale its inflow time series. The scalar multipliers for the inflow time series were defined using a normal distribution on a log scale with a mean of 1.0 and a standard deviation of 0.5 orders of magnitude, meaning that 95 percent of the values fell between 0.1 and 10. After each iteration of the calibration process, new values of the scalar multipliers were estimated, the associated initial inflow values were scaled with the scalar multipliers, and the scaled inflow values were then used as input to the groundwater flow simulation of the subsequent calibration iteration.

4.2.3.4 Specified Head Boundary

Two specified head boundaries were simulated with the FHB of the MODFLOW model. Figure 3-15 shows the segments of the specified head boundaries – one near Rialto and the other on the southern tip of the Spadra Basin. The specified head values at those boundaries were estimated based on nearby head measurements. Each specified head boundary was added as an adjustable model parameter. A positive addend increases the specified head, increasing the net flux into the active model domain for the stress period, and vice versa for a

negative addend. After each iteration of the calibration process, the addends were updated and then added to the initial specified head values of the respective boundary. The addends were allowed to vary between +/- 35 feet for the Bloomington Divide and between +/-10 feet at the western edge of the Spadra Basin, based on the range of historically observed variation. The Bloomington Divide was segmented into seven sections to allow for more flexibility in the heads at this boundary.

4.2.3.5 Santa Ana River and Its Tributaries

The Santa Ana River and its tributaries are divided into 24 segments as shown in Figure 3-10. The streambed hydraulic conductivity for each segment was treated as an adjustable model parameter. This property governs the rate of water exchange between the stream and the underlying aquifer, thereby influencing stream–aquifer interactions. It was initially set to 1 ft/day, and during model calibration, it was allowed to vary within a range of 0.1 to 100 ft/day. After each iteration of the calibration process, the streambed hydraulic conductivity values were updated, and used in the groundwater flow simulation of the subsequent calibration iteration.

4.2.3.6 Faults

The horizontal-flow barriers that represent faults are divided into 45 segments as shown in Figure 3-13. The hydraulic conductivity of the flow barrier in each segment is an adjustable model parameter. These conductivity values determine how easily groundwater can move across the faults, thus influencing flow connectivity between adjacent hydrogeologic units. In the model, the conductivity factors were varied across several orders of magnitude, depending on the characteristics of each barrier. After each iteration of the calibration process, the hydraulic conductivity values of the segments were updated and then used in the groundwater flow simulation of the subsequent calibration iteration.

4.2.3.7 Aquifer Properties and Pilot Points

Hydrogeological properties of the model include the horizontal hydraulic conductivity (HK), vertical hydraulic conductivity (VK), specific storage (SS), and specific yield (SY) of model layers. To represent the spatial variability of these properties, each layer was assigned several pilot points, each with an initial estimated value.

Pilot points serve as adjustable control locations within the model domain for the calibration process. Each pilot point's value for a specific hydrogeological property was treated as an independent parameter that PESTPP-IES modified during calibration. After each iteration[6], PESTPP-IES estimates updated values at these pilot point locations based on the differences between simulated and observed data.

These updated pilot point values were then spatially interpolated to assign values to all individual model cells within the corresponding layer. The Kriging method, a robust geostatistical interpolation technique, was employed for this spatial distribution. Kriging leverages the spatial correlation structure of the

[6] In the context of PESTPP-IES, an iteration represents one complete cycle of the calibration process. During each iteration, PESTPP-IES adjusts the model parameters (like the pilot point values) based on the calculated differences between simulated and observed data. The model is then run again with these adjusted parameters, producing a new set of simulated results. This process is repeated to progressively refine the parameter values and improve the model's fit to the observed data.

hydrogeological property (often defined through a variogram) to provide optimal estimates at unsampled locations (the model cell centers) based on the values at the pilot points. This method ensured that the interpolated values honor the pilot point values and reflect the assumed spatial continuity of the property.

The strategic use of pilot points, even in limited numbers, allowed for the efficient representation of complex spatial heterogeneity in hydrogeological properties across the entire model domain. By adjusting the values at these key locations, PESTPP-IES indirectly influenced the property values in all model cells through the Kriging interpolation.

The density and number of pilot points directly influence the level of spatial variability that the model can simulate. A higher density of pilot points allows for the representation of more complex and localized variations in hydrogeological properties. Ideally, with a sufficiently large number of well-placed pilot points, the precise location of individual points becomes less critical, and the interpolation method's influence diminishes as the pilot points effectively sample the spatial variability.[7]

Calibration using pilot points is specifically designed to capture the inherent heterogeneity required to adequately reproduce the observed hydrologic behavior. The pilot point parameters act as 'receptacles' for the information contained within the history-matching dataset (the observed data). Therefore, the effective placement of pilot points is crucial; they should be located in areas where they can best receive and propagate information relevant to the calibration targets. To investigate the impact of the number of realizations and the density and number of pilot points on the model's estimated net recharge values, three distinct scenarios for pilot point placement were implemented within PESTPP-IES, as described in Section 4.3.4.2.

4.2.4 Prepare Observation Data as Calibration Targets

Two types of observation data were collected and used for model calibration. The first type is the groundwater elevation time series at selected wells. The second type is the stream discharge time series observed at gaging stations. For the purposes of model calibration, a subset of the measured groundwater elevations was selected based on the principle that the selected data should be both temporally and spatially evenly distributed to avoid biasing the calibration with measurements from specific times or areas with more concentrated data collection. The selected observation data were used as calibration targets and each of the selected data is assigned a weight value. The monthly average daily stream discharge data was created based on the observed daily stream discharge data.

During the model calibration process, the differences between the (observed) calibration targets and the model calculated counterparts (i.e., the residuals) were calculated and then multiplied by the corresponding weights. These weighted residuals were squared (to avoid mutual cancelation of positive and negative residuals) and summed. The sum of the squared weighted residuals is known as the objective function, Phi (Φ).

PESTPP-IES minimizes Phi by adjusting model parameters through an iterative process. For the 2025 CVM, head values were assigned a weight value ranging from 0.5 to 10 depending on the confidence and importance of the data. For example, the piezometer at the Pomona Extensometer has highly precise and

[7] https://help.pesthomepage.org/index.html?pilot-point-emplacement.html

accurate, depth-specific, head measurements, and the measured head values were assigned a weight value of 10. All stream discharge values were assigned a weight value of 2×10^{-5}, reflecting the fact that stream discharge measurements are typically several orders of magnitude larger than head measurements. These weight values were selected so that the sum of the weighted residuals of stream discharge (in units of ft^3/day) and the sum of the weighted residuals of hydraulic head (in units of ft) lie in the same order of magnitude. This arrangement enabled PESTPP-IES to pick up adequate information for model calibration from both head and stream discharge time series.

4.2.4.1 Groundwater Elevation Time Series

A total of 102 wells in the Chino Basin, Spadra Basin, Cucamonga Basin, and the Six Basins area were selected for model calibration. The selection was based on two criteria – their screened intervals must be available, and they must have relatively long-term groundwater-elevation measurements within the calibration period. Figure 4-9 shows the locations of the selected calibration wells. Table 4-4 shows the number of wells in each of the model layers where the wells are screened (calibration wells can be screened across multiple model layers). These wells have a total of 572,938 groundwater-elevation measurements during the calibration period. Some of the wells were equipped with transducers that measure and record groundwater elevations at high frequency (e.g., sometimes as short as 15 minutes).

A total of 7,781 groundwater-elevation measurements were selected as calibration targets. This reduction was necessary to ensure computational efficiency, to avoid "over-weighting" the frequently measured wells (e.g., wells with transducers), and to preserve temporal representativeness across the model domain. Including all available measurements would have resulted in excessive clustering of calibration targets at certain locations, potentially biasing the parameter estimation process and overwhelming the influence of observations from sparsely monitored areas. To address this, a data thinning strategy was applied to retain a representative subset of observations that captures the key temporal trends and seasonal variability of groundwater elevations at each site, while reducing redundancy. This approach allowed the model to be calibrated against meaningful and distributed information without compromising performance or interpretability. Figure 4-10 shows an example of groundwater-elevation measurements and selected calibration targets.

For single-layer observation wells (i.e., those with screened intervals across a single model layer), the selected groundwater-elevation measurements and the corresponding simulated head values of the given layer are used for the calculation of the objective function.

For multi-layer observation wells (i.e., those with screened intervals across multiple model layers), the selected groundwater-elevation measurements and the corresponding layer-weighted simulated head values were used for the calculation of the objective function. The following equation was used to calculate the layer-weighted simulated head values:

$$h = \frac{\sum_{l=1}^{n} h_l \cdot w_l}{\sum_{l=1}^{n} w_l} \quad (1)$$

where n is the number of layers of the model; l is the layer number; h_l is the simulated head in layer l; and w_l is the weight of layer l. For a particular well, the initial weight of a layer is calculated based on the product of the screen length in that layer and the HK value of the model cell where the well is located. After each calibration iteration, the layer weights are adjusted based on the updated HK values.

Table 4-4. Number of Monitoring Wells by Screened Model Layer				
Model Layer	Chino Basin	Spadra Basin	Cucamonga Basin	Six Basins
1	42	2	5	18
2	17	0	0	0
3	32	0	0	0
4	10	0	0	0
5	24	0	0	0
Any layer	77	2	5	18

4.2.4.2 Stream Discharge Time Series

Daily streamflow data for streamflows at Prado Dam were obtained from the Santa Ana River Watermaster Annual Reports, and selected portions of the dataset were used as calibration targets. High stream discharge observations were excluded from the calibration because they are short-duration events dominated by surface runoff, not groundwater interaction. These peaks are difficult to measure accurately and are poorly represented in the groundwater-flow model focused on long-term groundwater/surface-water interactions. Including them could have distorted the parameter estimates and reduced model reliability under typical flow conditions.

4.2.5 Use PESTPP-IES to Generate Calibrated Realizations

Calibration of the 2025 CVM was conducted in two phases. In the first phase, a manual calibration was conducted with a few key model parameters. In the second phase, PESTPP-IES was used to generate calibrated realizations using all adjustable model parameters.

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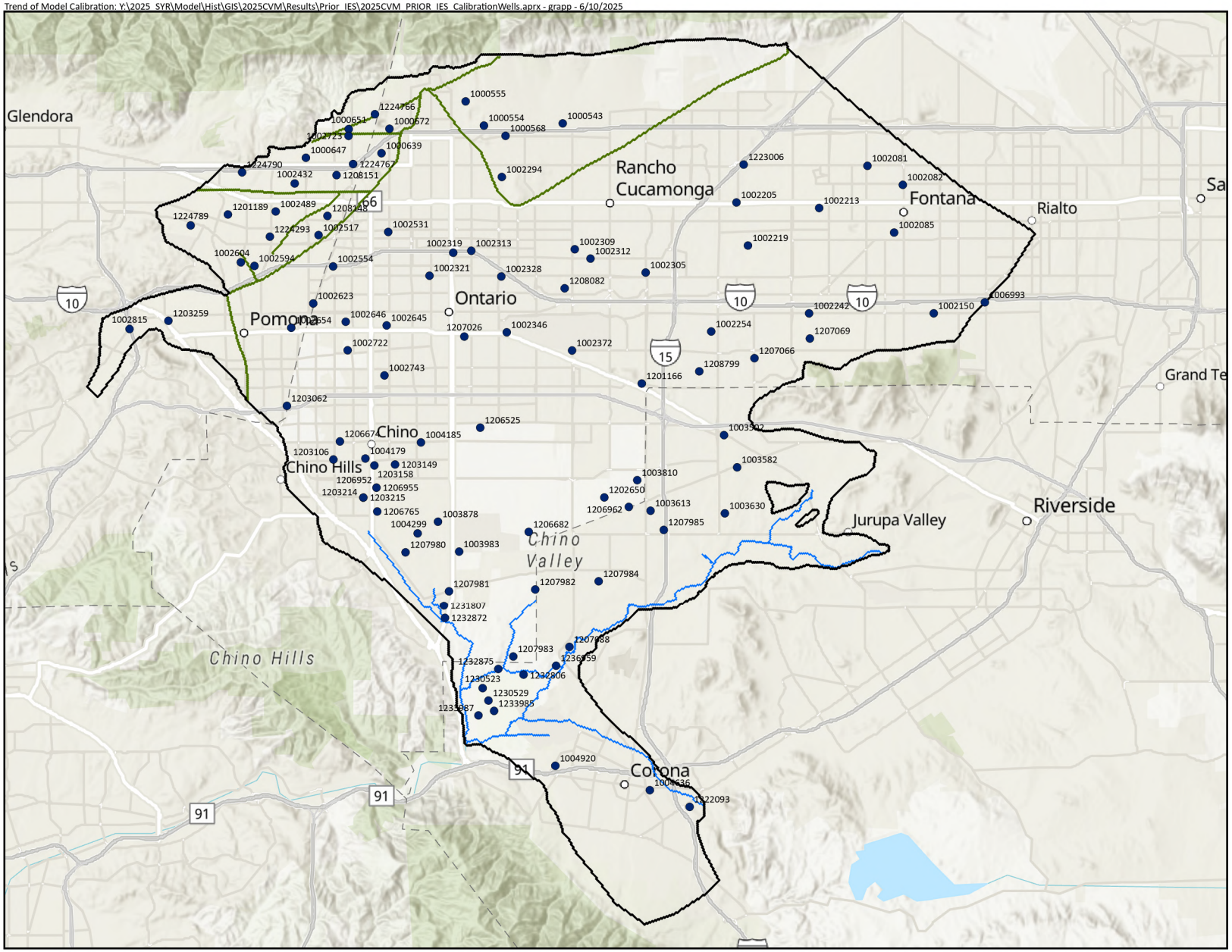
Trend of Model Calibration: Y:\2025_SYR\Model\Hist\GIS\2025CVM\Results\Prior_IES\2025CVM_PRIOR_IES_CalibrationWells.aprx - grapp - 6/10/2025



Model Boundary
Faults
Streams
Calibration Wells



Prepared by:

WEST YOST

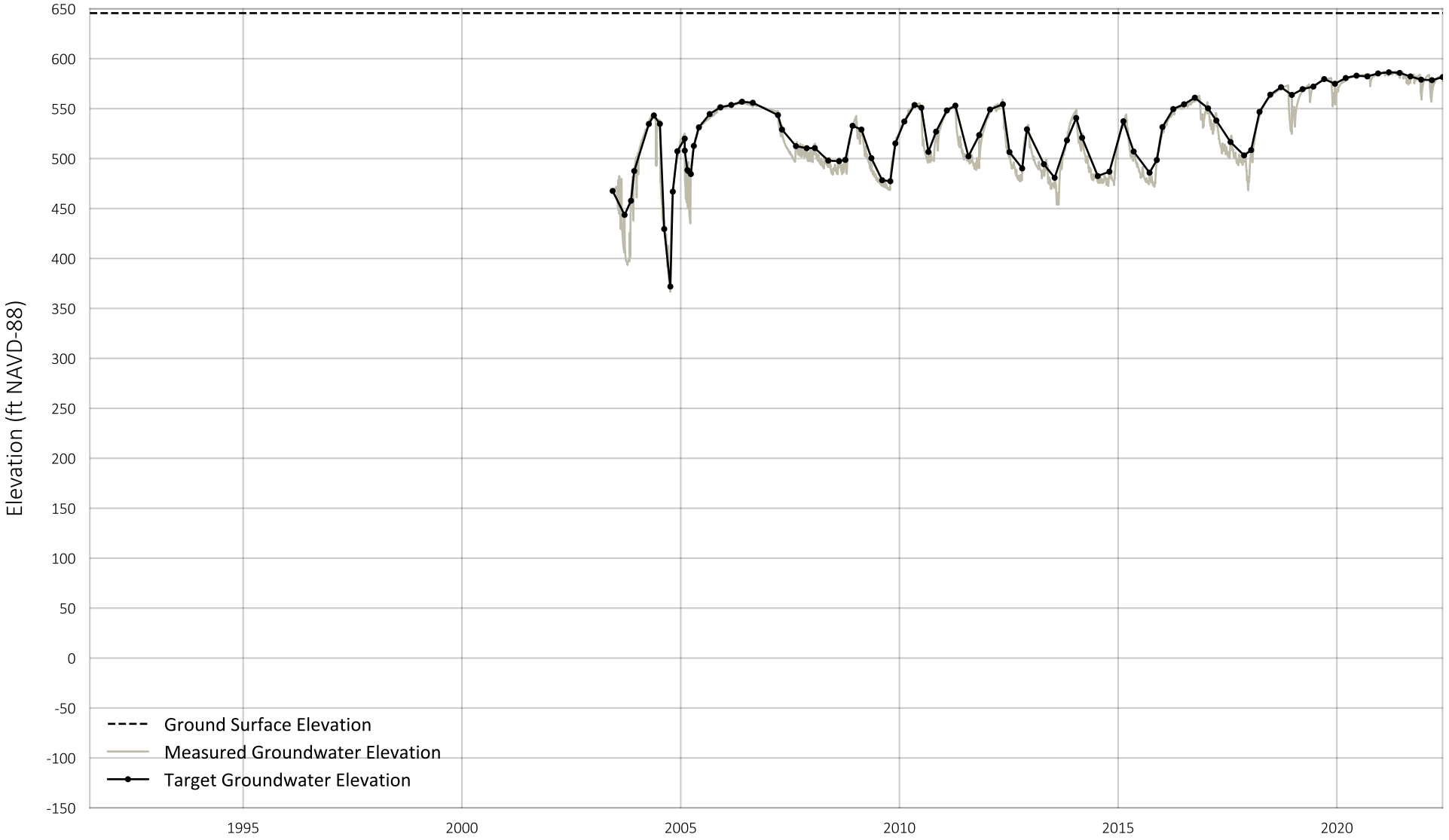
0 2 4 Miles
0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

2025 CVM Calibration Wells with HydroDaVE Well ID

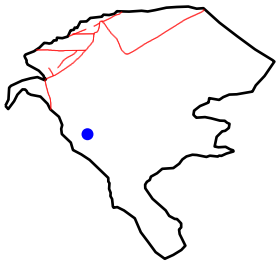
DRAFT **Figure 4-9**



Prepared by:

WEST YOST
Water. Engineered.

Well Location



Statistics

Target Groundwater Elevation (ft)
Mean = 526.27
Standard Deviation = 39.66

An Example of Groundwater Elevation Measurements and Selected Calibration Targets

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Figure 4-10

4.2.5.1 Manual Calibration

In the first phase, a manual calibration was performed to adjust hydraulic conductivity values for faults and streambeds, as well as scalar multipliers for boundary inflow and DIPAW. The purpose of this manual calibration was twofold: to identify any potential problems or errors within the model setup and to "precondition" key model parameters, setting them to more reasonable starting values before the automated calibration phase using PESTPP-IES.

During this phase, the specific storage values of the 2020 CVM and the estimated maximum ET rates were used without any modification. The aquifer properties HK, VK, and SY of the 2020 CVM were assigned to pilot points that are placed in each model layer based on the density of groundwater elevation observation wells. The aquifer properties at pilot points were interpolated to model cells with the Kriging method. Guidance for the emplacement of pilot points outlined in the Parameter Estimation (PEST) homepage[8] was generally followed for the placement of pilot points.

Manual calibration of the model involved numerous iterative cycles. In each cycle, simulated head and stream discharge time series were compared against the calibration targets. The differences observed in this comparison then guided the adjustment of parameter values. After each parameter adjustment, the model was run again. This process was repeated until the sum of weighted squared residuals could not be meaningfully reduced by additional model runs.

The calibrated hydraulic conductivity of faults ranges between 1×10^{-9} and 0.0017 ft/day. The calibrated streambed conductivity ranges between 0.23 and 10 ft/day. The calibrated multipliers for Subsurface Inflow range from 0.6 to 1.8. The calibrated multiplier for annual DIPAW values averaged approximately 0.94.

Appendix B-2 shows the maps of aquifer properties used in the manually calibrated model. Appendix B-3 contains the time series of simulated hydraulic heads versus the calibration targets of the manually calibrated model.

Figure 4-11 shows a scatter plot of the simulated hydraulic heads versus the calibration targets in the Chino Basin, Spadra Basin, Cucamonga Basin, and Six Basins. The root mean squared error (RMSE) is 18.88 ft for calibration targets in the Chino Basin, and 25.93 ft for all calibration targets. The linear regression equation is derived based on all calibration targets. All points are distributed closely around the regression line, which matches closely with the 1:1 line, indicating good inverse modeling performance and a robust calibration. The R^2 of 0.9989 suggests that 99.89 percent of the observed variance is explained by the model. Overall, these results indicate that the calibration is improved over the 2020 CVM.

Figure 4-12 is a map of average residuals at the calibration wells. The mean and median residuals for all calibration targets are 1.47 ft and 0.63 ft, respectively. These values are close to the expected value of zero, indicating that the prediction of groundwater elevations is not biased. Figure 4-13 shows a map of RMSE. Figure 4-14 shows a map of the trend of residuals between the average simulated hydraulic heads and calibration targets. Wells with overpredicted head values (i.e., average simulated heads greater than the average calibration targets) are colored blue, while wells with underpredicted head values (i.e., average simulated heads less than the average calibration targets) are colored yellow. A spatial bias in the simulated head can be identified if the overpredicted and/or underpredicted wells cluster in areas.

[8] https://help.pesthomepage.org/index.html?pilot-point-emplacement.html

The random distribution pattern of the overpredicted and/or underpredicted wells shown in Figure 4-14 indicates that the simulated heads are not spatially biased at the basin scale.

Figure 4-15 is a time-series chart that compares model-estimated stream discharge versus total Prado inflow estimated by the Santa Ana River Watermaster. Figure 4-16 is a scatter chart of model-estimated versus observed discharge values. The red dashed line represents the 1:1 line, while the blue dashed line is the regression line, which has a slope of 1.1765. This indicates that the model tends to overpredict discharge during rare, very high-flow events. During these events, it is expected that the discharge will be overpredicted due to the operations of Prado Dam, which would temporarily reduce discharge during high-flow events. The coefficient of determination (R^2) is 0.92, demonstrating a strong correlation between simulated and observed discharge.

4.2.5.2 Automated Calibration

In the second phase, PESTPP-IES was used to adjust all adjustable model parameters to conduct the uncertainty analysis. PESTPP-IES does not seek a single set of parameters (i.e., a parameter realization) that is deemed to "calibrate" a model. Instead, it seeks a suite of parameter realizations which each result in an acceptably good match between observed and simulated conditions, and collectively express parameter uncertainty. Through a series of successive iterations, PESTPP-IES adjusts parameter realizations so that each meets the user-defined calibration criteria. Specifically, it modifies each realization within the ensemble such that, when the model is run with that parameter set, the simulated-to-measurement fit is sufficient for the model to be considered as "calibrated." The result is an ensemble of parameter realizations, which can be interpreted as samples from the posterior probability distribution of the parameters.

The effects of the number of desired calibrated realizations and the number and spatial distribution of pilot points on model-estimated net recharge were evaluated using five distinct pilot point scenarios:

- **Pilot Point Scenario 1:** Irregularly spaced pilot points were placed in each model layer based on the density of groundwater elevation monitoring wells. This scenario included a total of 2,701 adjustable parameters, of which 2,245 were pilot points. PESTPP-IES was configured to run for six iterations, with the number of desired calibrated realizations set to 100. During the calibration process, some realizations were excluded by PESTPP-IES—likely due to poorly performing parameter combinations—because their model run times exceeded twice the average runtime of successful realizations.
- **Pilot Point Scenario 2:** This scenario used the same pilot point layout and number of adjustable parameters as Scenario 1 (2,701 adjustable parameters, including 2,245 pilot points). The only change was an increase in the number of desired calibrated realizations from 100 to 400 to better explore parameter uncertainty and posterior variability.
- **Pilot Point Scenario 3:** In this scenario, regularly spaced pilot points were placed at 10-row by 10-column intervals across each model layer. This configuration significantly increased the number of adjustable parameters to 25,326, including 24,870 pilot points, enabling a more detailed exploration of spatial heterogeneity. The number of desired calibrated realizations was set to 400.
- **Pilot Point Scenario 4:** This high-resolution scenario involved 159,146 adjustable parameters, including 158,690 pilot points, and targeted 400 realizations. However, due to

the extreme computational demand, the PESTPP-IES run failed, exceeding available memory and runtime limitations.

- **Pilot Point Scenario 5:** This scenario was developed to implement several of the recommendations from the peer review, including:
  - Added spatially variable DIPAW multipliers
  - Reduced observation noise
  - Targeted 100 realizations to reduce runtime
  - Reduced head closure criteria
  - Increased weighting of streamflow observations

This scenario resulted in 32,800 adjustable parameters.

Pilot Point Scenario 5 was selected for use in projection simulations. It provided a balance between parameter complexity and computational feasibility, allowing the model to represent smaller-scale heterogeneities more effectively than the lower-resolution scenarios.

The following section provides a detailed description of Pilot Point Scenario 5.

4.2.5.2.1 Pilot Point Scenario 5

In this scenario, pilot points for aquifer properties were placed at a spacing of every ten model rows/columns in each model layer. This scenario incorporates a total of 32,800 adjustable parameters including 32,332 pilot points: 8,624 for HK, 8,067 for VK, 6,338 for SS, 2,061 for SY, and 7,440 for DIPAW multipliers.

PESTPP-IES was configured to run for five iterations. The number of desired calibrated realizations was 100. Like previous scenarios, some realizations were dropped by PESTPP-IES during the calibration process. Figure 4-17 shows the range of the calculated net recharge for fiscal year 1992 to 2022 for the 97 realizations that remained active at the end of the third iteration. Runs with a larger number of adjustable parameters tended to be more complex, increasing both the calibration time and the likelihood of model instability or physically unrealistic behavior in some realizations. PESTPP-IES identified and removed such failing realizations, resulting in a smaller final ensemble.

Figure 4-18 shows a histogram of calculated mean net recharge for the 97 realizations that remained active at the end of the second iteration. The average net recharge of all active realizations for the calibration period was about 135,200 acre-feet/year (afy).

The realization with average net recharge closest to the ensemble mean at the end of the third PESTPP-IES iteration was selected to graphically illustrate the calibration results. Appendix B-4 presents maps of the calibrated aquifer properties for this realization. Appendix B-5 provides time series charts that compare simulated hydraulic heads versus the calibration targets.

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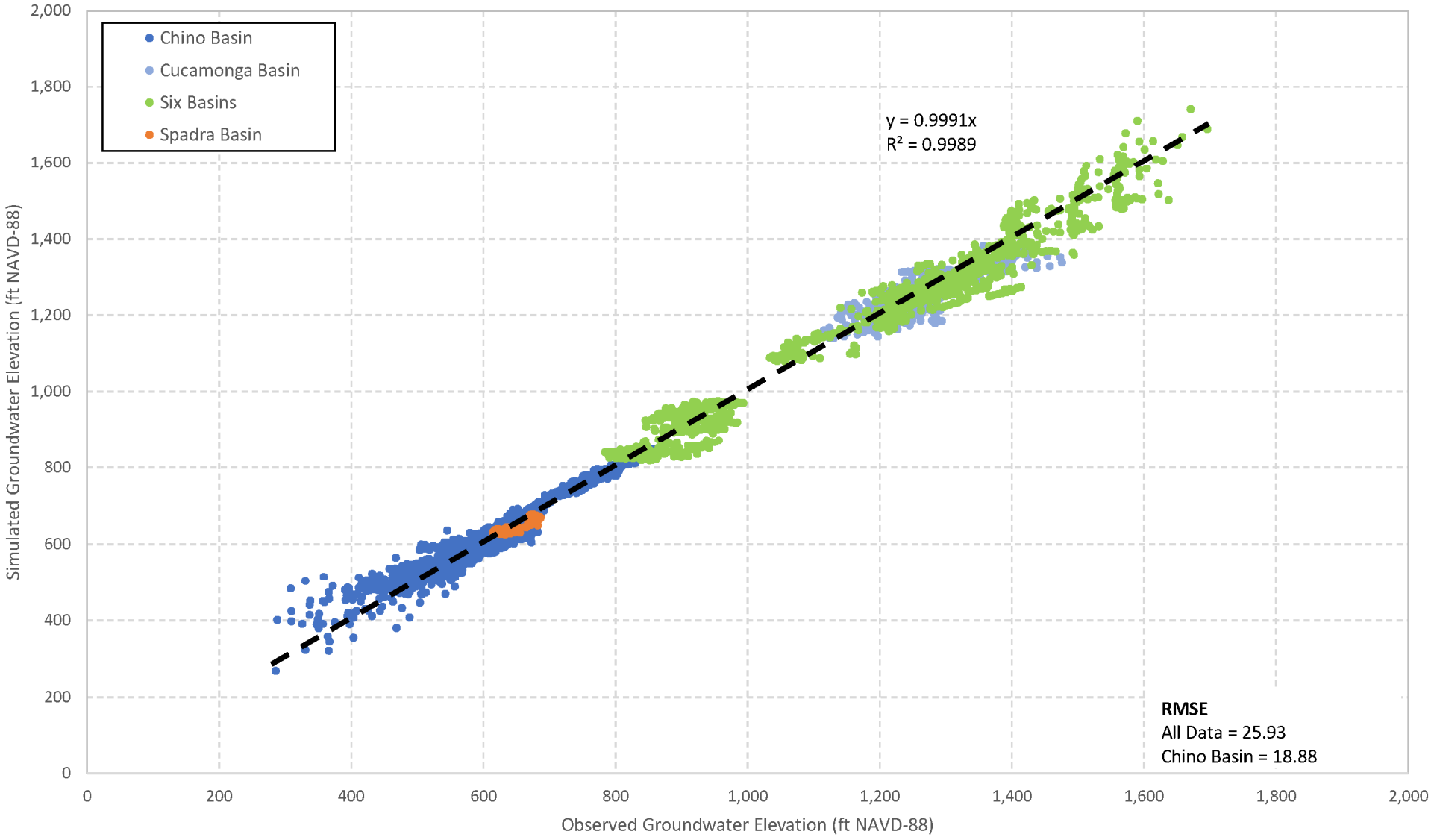
Figure 4-11
Comparison of Simulated and Measured Groundwater Levels in Wells of the 2025 CVM Manual Calibration



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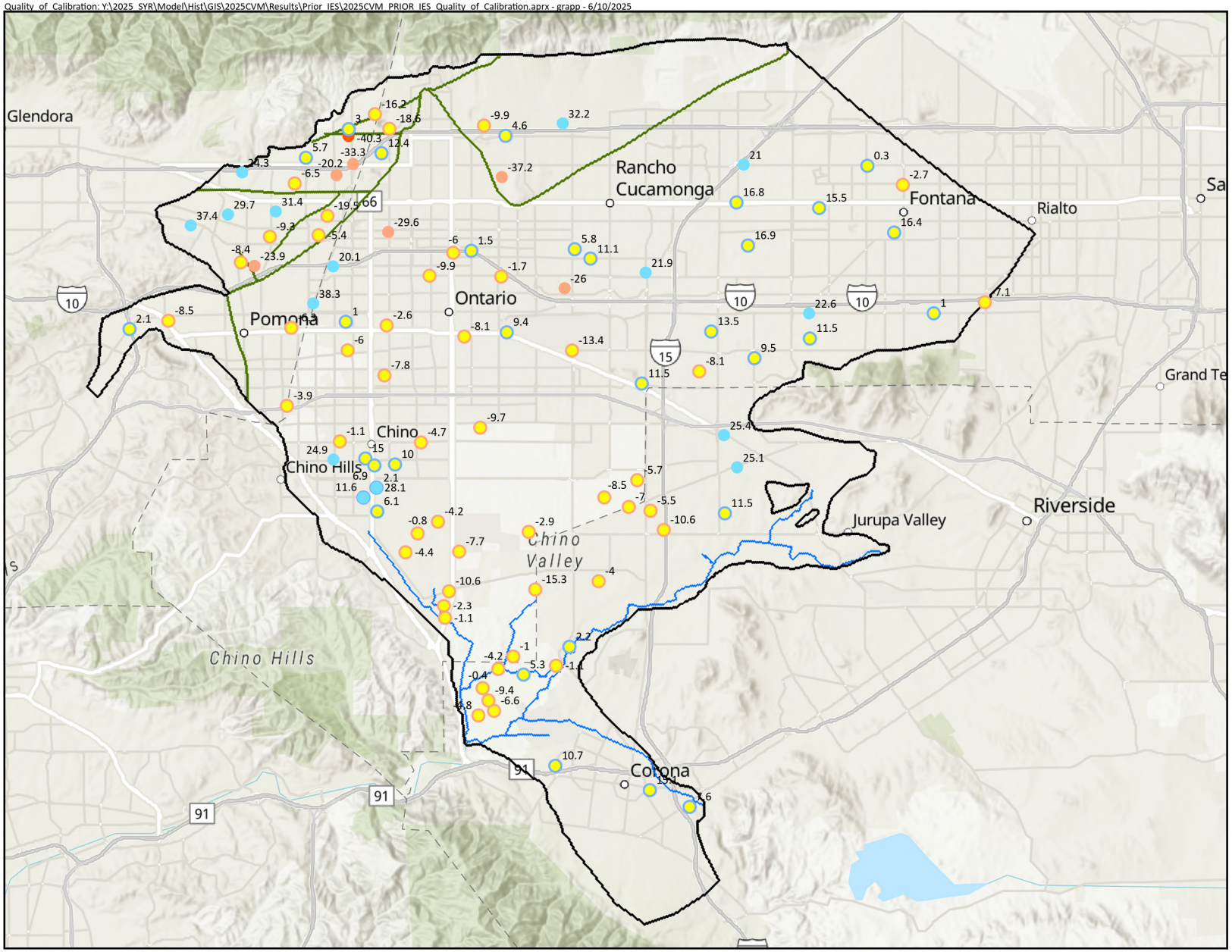


- Model Boundary
- Faults
- Streams

Residuals [ft]

- Poor (< -40)
- Fair (-40 to -20)
- Good (-20 to 0)
- Good (0 to 20)
- Fair (20 to 40)
- Poor (> 40)



Prepared by:

WEST YOST

N

0 2 4 Miles

0 3 6 Km

Prepared for:

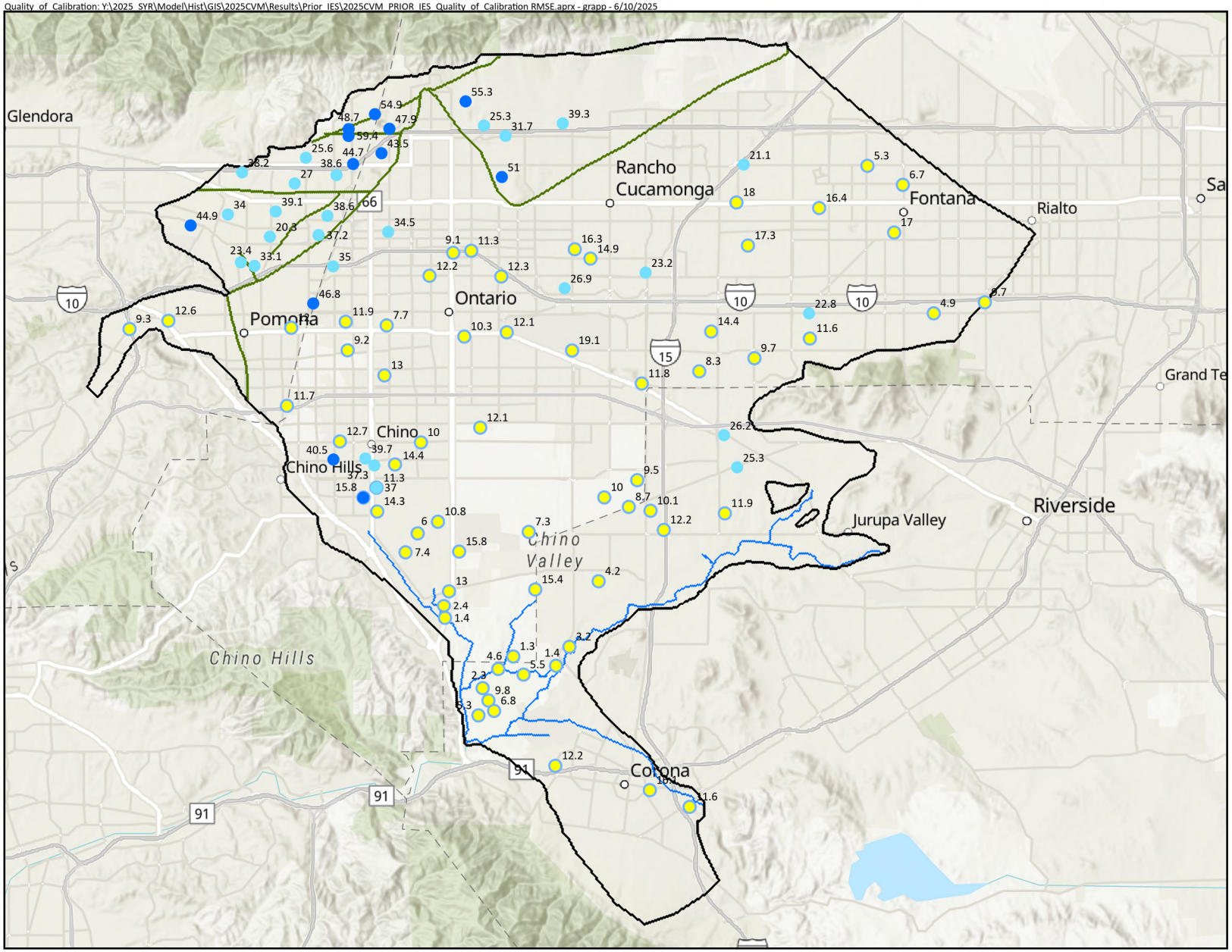
Chino Basin Watermaster

2025 Safe Yield Reevaluation

2025 CVM: Manual Calibration Residuals of Groundwater Elevation

DRAFT **Figure 4-12**

Quality_of_Calibration: Y:\2025_SYR\Model\Hist\GIS\2025CVM\Results\Prior_IES\2025CVM_PRIOR_IES_Quality_of_Calibration RMSE.aprx - grapp - 6/10/2025



Model Boundary
Faults
Streams

RMSE [ft]
- Good (0 - 20)
- Fair (20 - 40)
- Poor (> 40)



Prepared by:

WEST YOST

N

0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

2025 CVM: Manual Calibration RMSE of Groundwater Elevation

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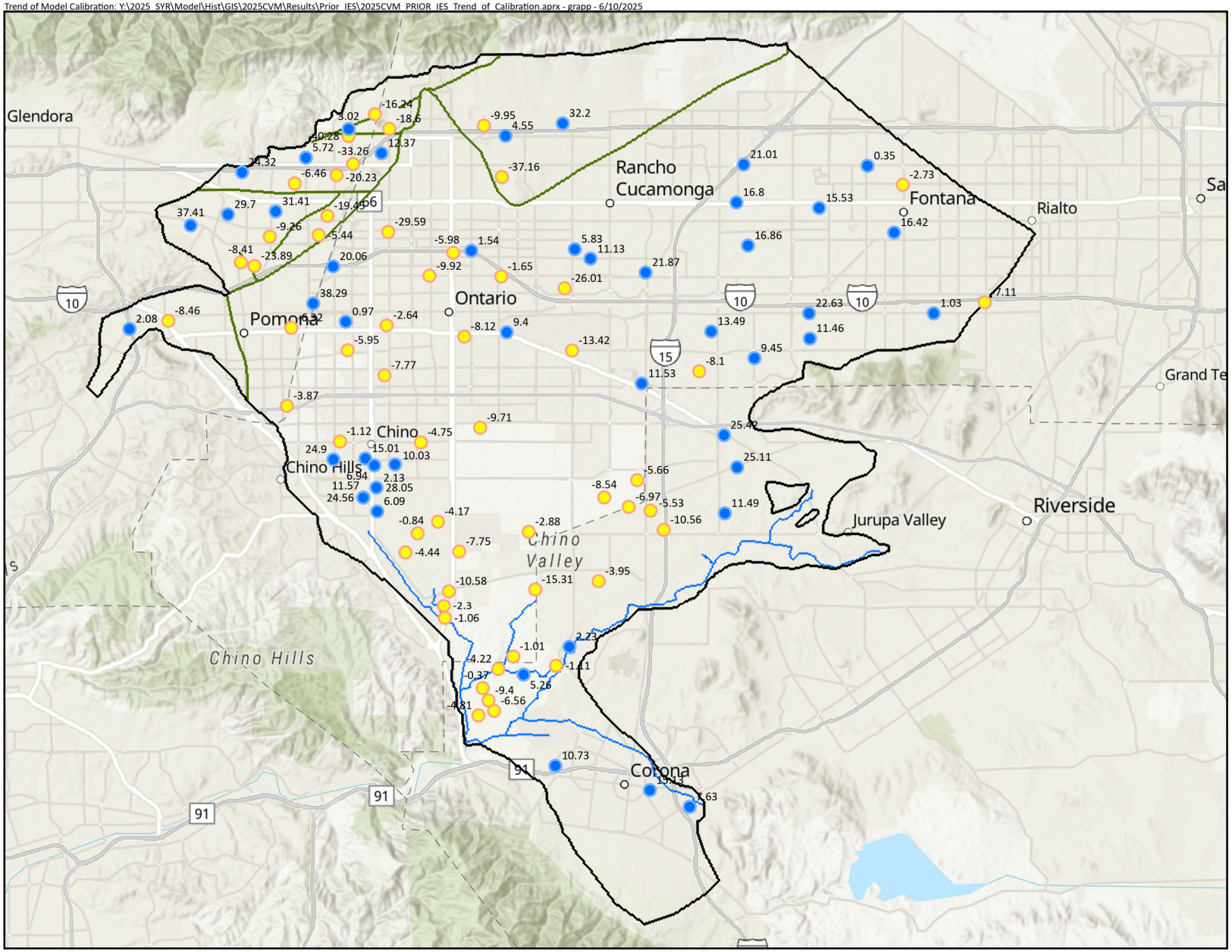
Trend of Model Calibration: Y:\2025_SYR\Model\Hist\GIS\2025CVM\Results\Prior_IES\2025CVM_PRIOR_IES_Trend_of_Calibration.aprx - grapp - 6/10/2025



Model Boundary
Faults
Streams

Residuals [ft]

Underpredicted (< 0)
Overpredicted (> 0)



Prepared by:

WEST YOST

N

0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

2025 CVM: Manual Calibration
Trend of Groundwater Elevation Residuals

DRAFT **Figure 4-14**

Figure 4-15
Comparison of MODFLOW Estimated Streamflow and Santa Ana River Watermaster Estimated Streamflow to Prado Dam

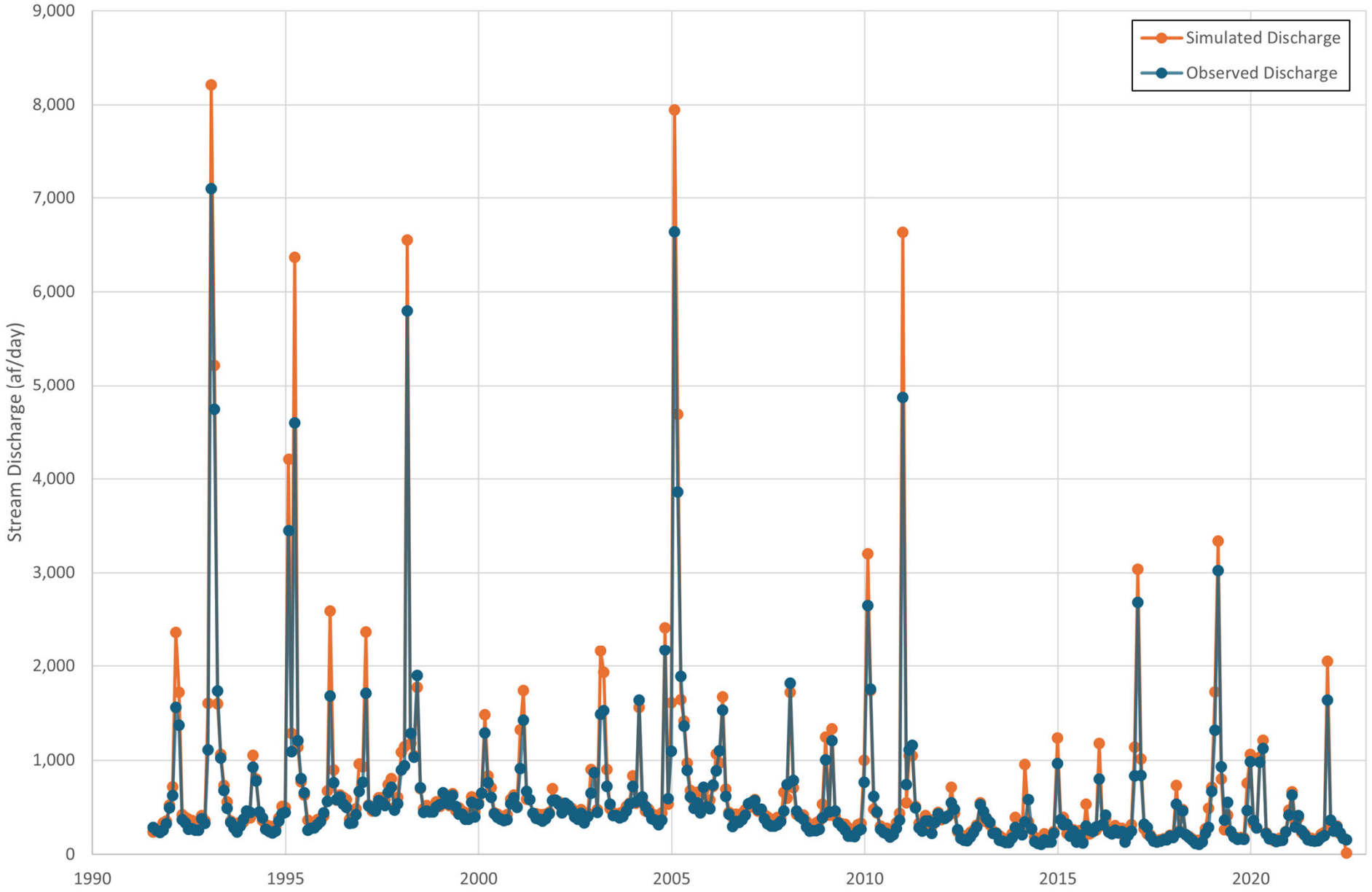


Figure 4-16
Comparison of MODFLOW Estimated Streamflow to Santa Ana River Water Master Estimated Streamflow to Prado Dam

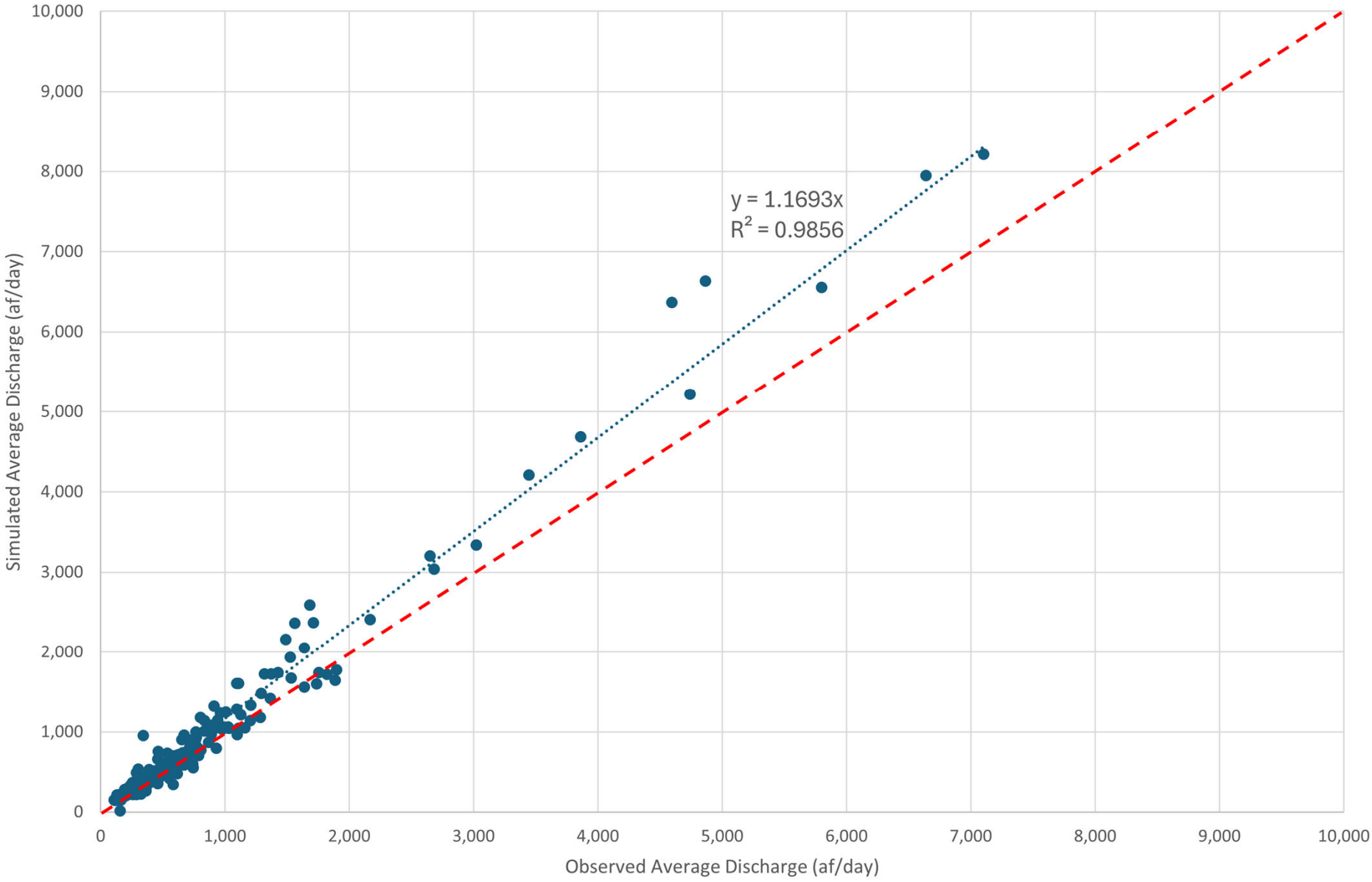


Figure 4-17
Simulated Net Recharge for the Chino Basin
Pilot Point Scenario 5 (97 Realizations)

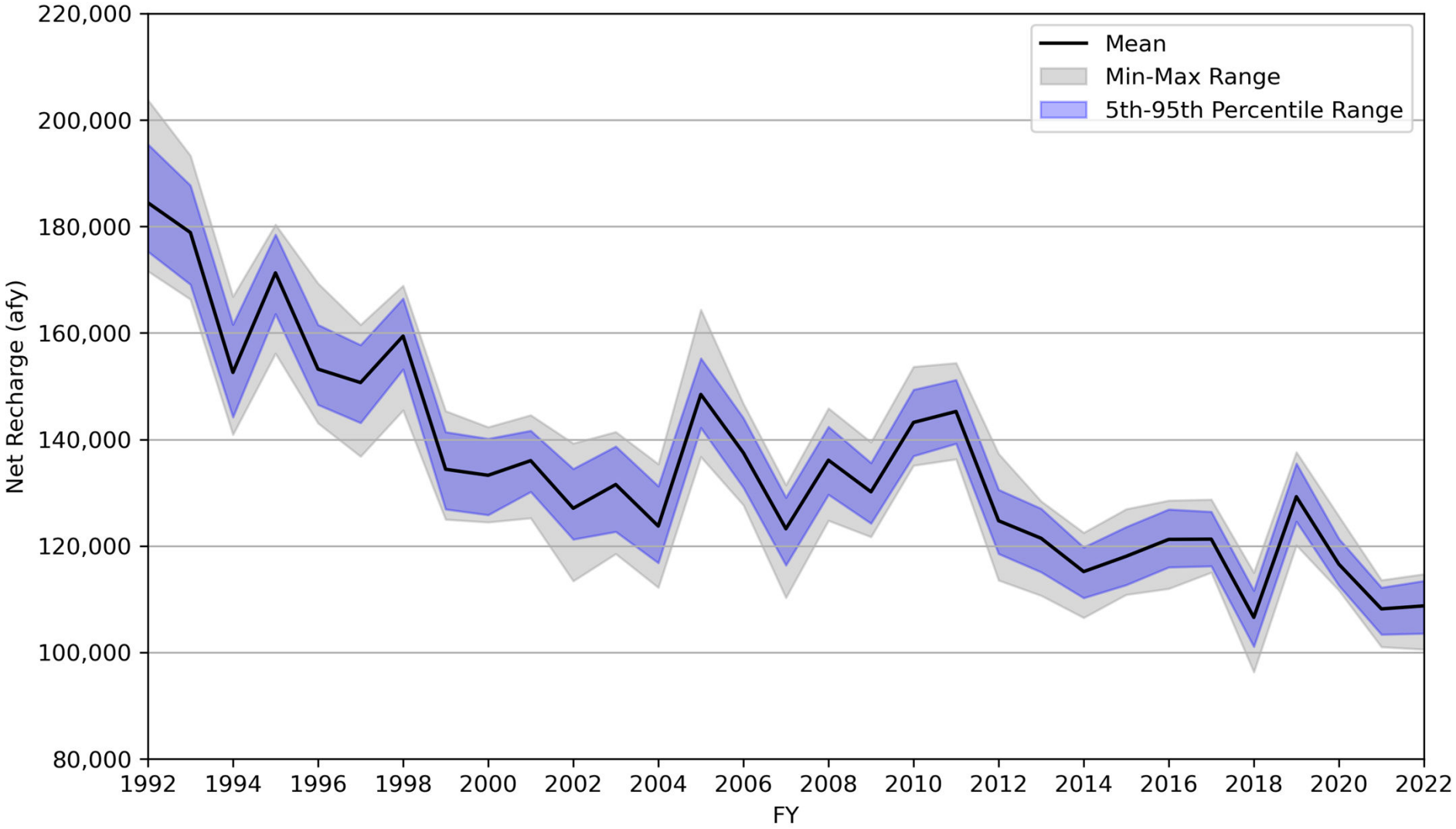


Figure 4-18
Mean Net Recharge in the Chino Basin, FY 1992-2022
Pilot Point Scenario 5 (97 Realizations)

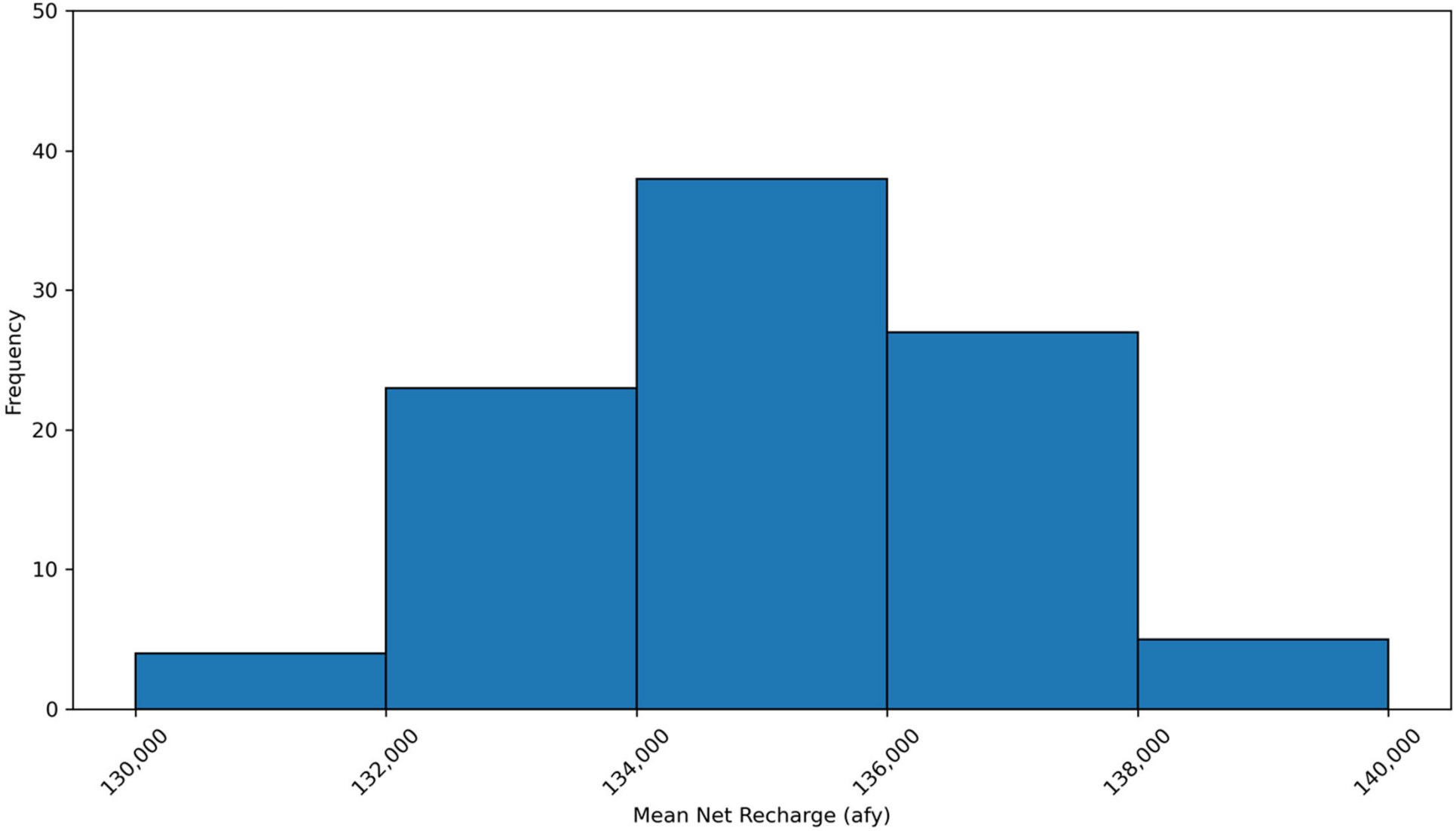


Figure 4-19 is a scatter plot of the simulated hydraulic heads versus the calibration targets at wells in the Chino Basin, Spadra Basin, Cucamonga Basin, and Six Basins. The RMSE is 21.4 ft for calibration targets in the Chino Basin, and 32.8 ft for all calibration targets. The linear regression line is derived based on all calibration targets. All points are distributed closely around the regression line, which matches closely with the 1:1 line, indicating good inverse modeling performance and a robust calibration. The coefficient of determination (R^2) of 0.998 suggests that 99.8 percent of the observed variance is explained by the model. Overall, this chart indicates that the calibration (for this calibrated realization) is improved over the manual calibration. Figure 4-20 is a map of residuals between the average simulated hydraulic heads and average calibration targets at the calibration wells. The mean and median residuals for all calibration targets are -36.2 ft and -0.6 ft, respectively. Figure 4-21 is a map of RMSE between the average simulated hydraulic heads and average calibration targets. Figure 4-22 is a map of the trend of residuals between average simulated hydraulic heads and calibration targets.

Table 4-5. Summary of Adjustable Parameters for Scenario 5

Adjustable Parameter Type	Number of Adjustable Parameters
DIPAW multiplier	7,440
Boundary Inflow multiplier	45
Addend to specified head values	8
Maximum ET Rate multiplier	372
Streambed conductivity	24
Hydraulic conductivity of faults	21
HK values at pilot points in model layers 1 to 5	8,424
VK values at pilot points in model layers 1 to 5	8,067
SY values at pilot points in model layer 1	2,061
SS values at point points in model layers 2 to 5	6,338
Total	**32,800**

4.2.6 Rank and Select Calibrated Realizations for Projection Scenarios

From the simulated scenarios, five calibrated realizations were chosen from the Pilot Point Scenario 5 for projection simulations. These five realizations include: one with the mean historical net recharge closest to the ensemble mean net recharge, and four realizations with net recharge values closest to one and two standard deviations above and below the ensemble mean, respectively.[9] For simplicity, the chosen realizations are labeled Realizations A through E based on their ranked net recharge over the historical period, as shown in Table 4-6.

[9] The calibrated realization with the average net recharge closest to one standard deviation below the mean net recharge was excluded due to unreasonable groundwater levels in MZ-1. The next-closest calibrated realization was chosen to use as Realization B.

Table 4-6. Summary of Net Recharge Statistics and Chosen Realizations, Pilot Point Scenario 5

Net Recharge Statistic (FY 1992-2022)	Volume, afy
Average, All Realizations	135,210
Standard Deviation, All Realizations	1,750
Maximum, All Realizations	139,190
Minimum, All Realizations	131,180
Average, Realization A	131,840
Average, Realization B	133,210
Average, Realization C	135,190
Average, Realization D	136,940
Average, Realization E	138,890

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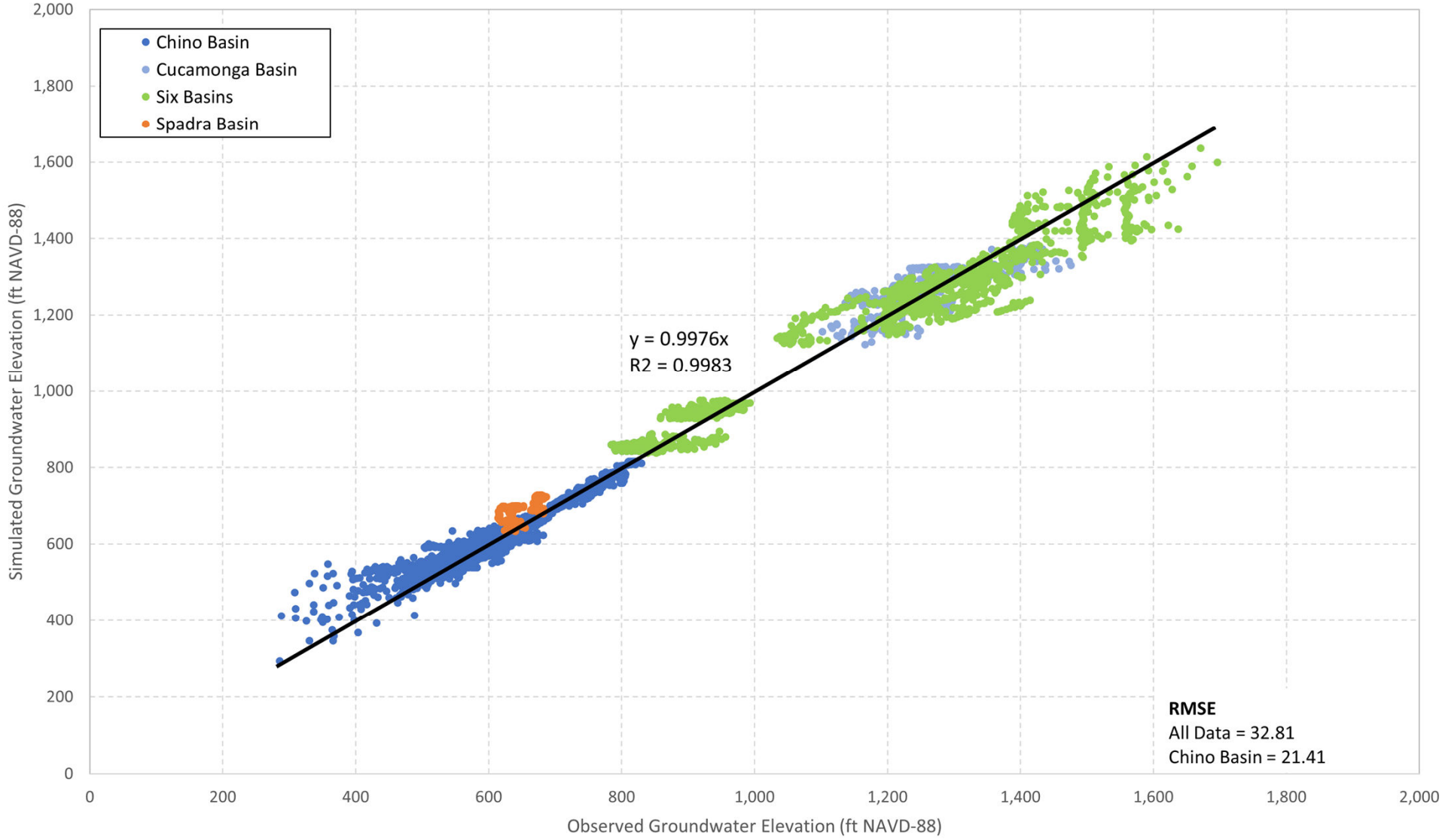
Figure 4-19
Comparison of Simulated and Measured Groundwater Levels in Wells of the 2025 CVM
Pilot Point Scenario 3, Realization 3.39



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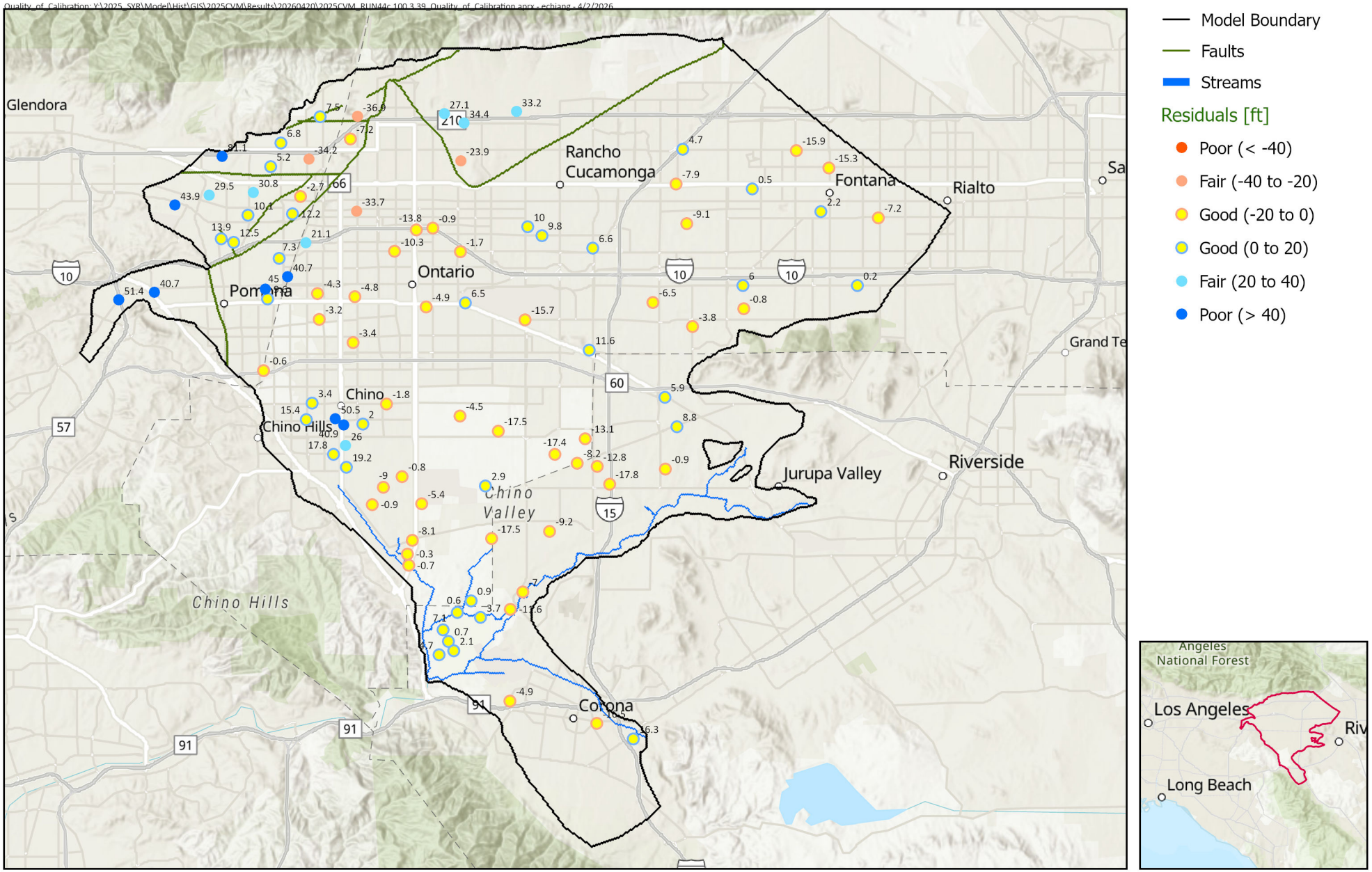

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WEST YOST

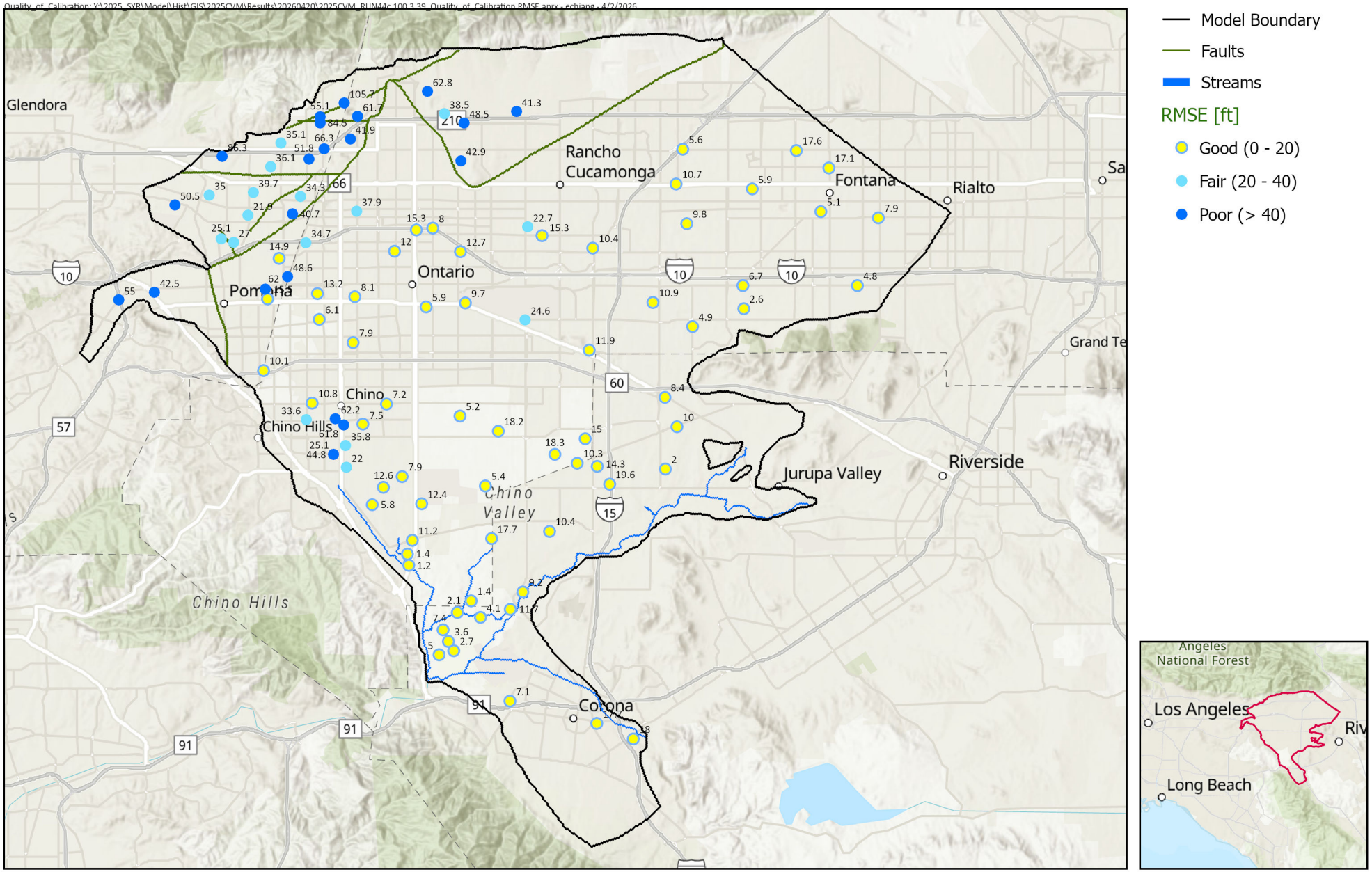
Prepared for:

Chino Basin Watermaster

2025 Safe Yield Reevaluation

2025 CVM: Run_44c.3.39
Residuals of Groundwater Elevation

DRAFT **Figure 4-20**



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Prepared for:

Chino Basin Watermaster

2025 Safe Yield Reevaluation

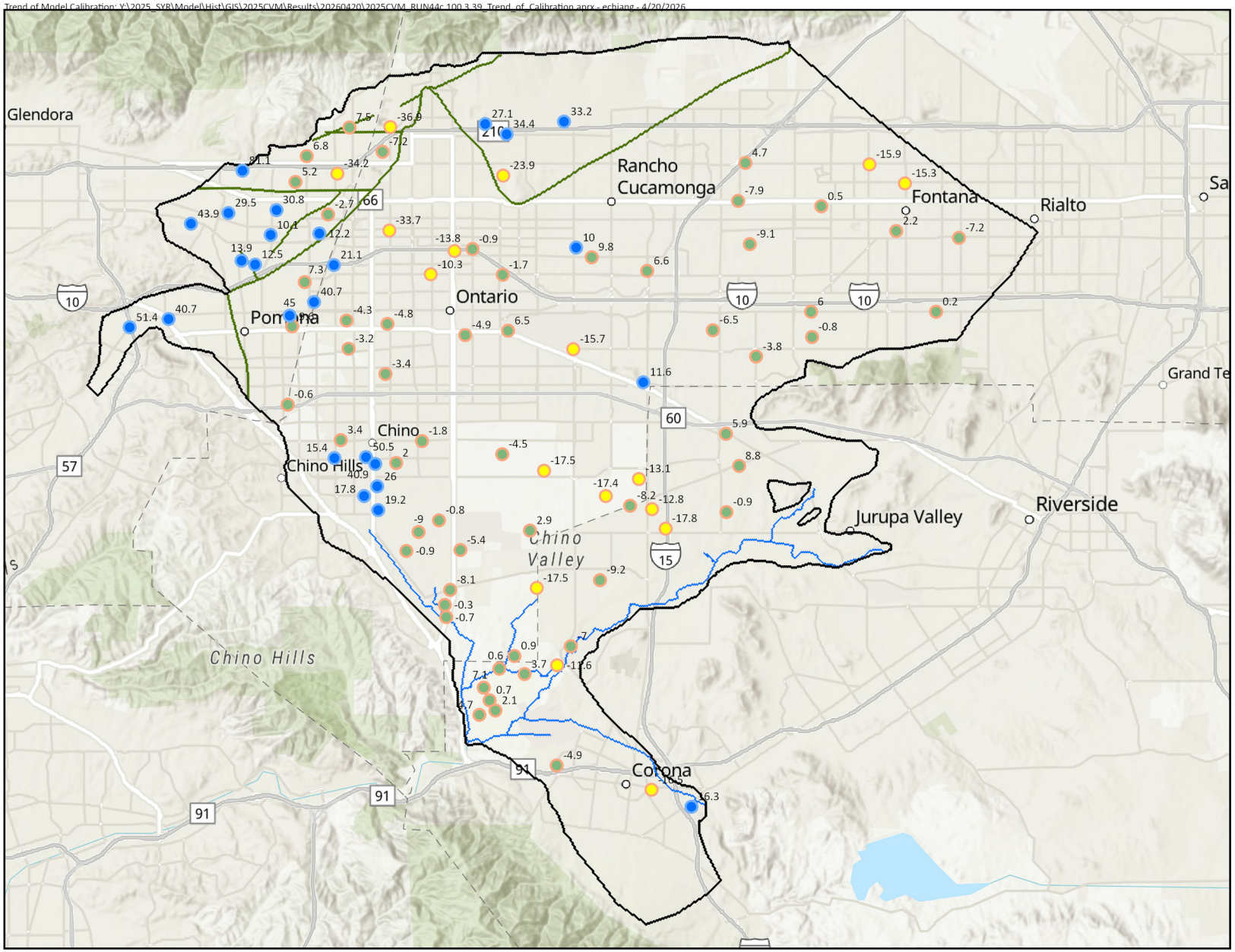
2025 CVM: Run_44c.3.39

RMSE of

Groundwater Elevation

DRAFT **Figure 4-21**

Trend of Model Calibration: Y:\2025_SYR\Model\Hist\GIS\2025CVM\Results\20260420\2025CVM_RUN44c.100.3.39_Trend_of_Calibration.aprx - echiang - 4/20/2026



Model Boundary
Faults
Streams

Residuals [ft]

Underpredicted (< -10)
Good (-10 to 10)
Overpredicted (> 10)



Prepared by:

WEST YOST

N

0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

2025 CVM: Run_44c.3.39
Trend of Groundwater Elevation Residuals

DRAFT **Figure 4-22**

Figure 4-23 illustrates the selected calibrated realizations along with the histogram based on the calculated mean net recharge for the 97 realizations. Figure 4-24 compares the net recharge time series of the selected realizations to the range of all realizations. Figure 4-24 suggests that the range of the simulated net recharge is well represented by these scenarios.

4.3 WATER BUDGET AND COMPARISON TO THE 2020 CVM

This section describes the major water budget components in the Chino Basin based on the selected realizations of the 2025 CVM and compares them to those from the 2020 CVM for the overlapping historical simulation period (FY 1992 through 2018).

4.3.1 Water Budget for Selected Realization

Table 4-7 displays the annual time series of recharge, discharge, change in storage, and net recharge from July 1, 1991 through June 30, 2022 for Realization C. Recharge and discharge components labeled with a column heading of "I" represent inputs directly provided to the 2025 CVM, with some variability introduced through PESTPP-IES as previously described. Components labeled with "R" are computational results generated by the CVM.

Water budget results for the other realizations are provided in Appendix B-6. The major water budget components for all five selected realizations, and their comparison to corresponding components in the 2020 CVM, are discussed below.

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Table 4-7 Water Budget for the Chino Basin for the Calibration Period - Realization C (af)

Fiscal Year	Recharge												Discharge					Change in Storage		Net Recharge
	R*	I*	R*	R*	R*	R*	I*	R*	I	I	I		I	I	R*	R*				
	Subsurface Inflow						Deep Infiltration of Precipitation and Applied Water	Streambed Infiltration	Managed Aquifer Recharge			Total Recharge	Groundwater Pumping		Riparian Veg ET	Rising Groundwater	Total Discharge	Annual	Cumulative	
	Bloomington Divide	Chino/Puente Hills, Jurupa Hills, and Rialto Basin	Net Temescal Basin	Six Basins	Cucamonga Basin	Spadra Basin			Stormwater	Recycled Water	Imported Water		Overlying Non-Ag and Appropriative Pools	Overlying Agricultural Pool						
1992	14,344	5,585	4,931	3,613	34,022	2	109,846	48,766	3,598	0	5,568	230,274	102,664	77,336	15,032	21,895	216,927	13,347	13,347	187,779
1993	11,400	6,329	1,224	3,871	22,592	7	116,845	62,942	6,619	0	14,224	246,053	88,040	83,284	16,345	33,059	220,728	25,325	38,672	182,425
1994	11,108	6,269	2,568	3,588	20,226	16	113,515	38,878	1,486	0	16,448	214,104	93,564	72,115	15,567	29,577	210,823	3,280	41,952	152,511
1995	10,517	6,742	979	3,272	18,960	27	124,095	58,217	4,662	0	10,375	237,846	98,173	62,171	16,354	32,260	208,958	28,887	70,840	178,857
1996	10,677	6,844	2,185	3,334	18,401	47	113,798	42,352	2,425	0	82	200,146	109,609	71,220	17,260	31,625	229,715	-29,568	41,271	151,179
1997	10,892	6,791	2,083	3,025	18,003	77	111,261	45,906	3,305	0	16	201,360	112,998	68,968	16,664	30,950	229,580	-28,220	13,051	153,729
1998	10,635	6,716	296	3,040	17,746	103	108,263	57,609	5,780	0	8,352	218,540	104,141	45,302	17,361	34,956	201,760	16,780	29,831	157,871
1999	11,184	6,402	1,224	3,045	17,552	104	106,820	39,774	1,007	984	5,839	193,936	118,738	46,730	17,915	33,495	216,878	-22,943	6,888	135,703
2000	11,749	6,051	686	2,854	17,358	109	102,989	41,748	1,985	3,630	997	190,156	133,609	46,538	18,635	31,437	230,220	-40,064	-33,176	135,457
2001	11,835	6,161	1,130	2,696	17,201	114	108,385	41,886	3,162	6,221	6,538	205,328	129,866	41,429	18,031	33,794	223,120	-17,792	-50,967	140,744
2002	12,442	5,532	1,862	2,636	16,975	119	96,541	37,081	1,148	7,444	6,493	188,273	139,934	38,650	17,267	33,376	229,227	-40,954	-91,921	123,693
2003	12,538	5,060	445	2,633	16,860	114	104,168	47,500	6,284	7,112	6,548	209,263	133,793	36,507	17,669	35,713	223,681	-14,418	-106,340	142,220
2004	12,886	5,158	-11	2,571	16,777	112	90,494	40,399	3,357	8,942	7,607	188,293	139,028	36,809	17,054	35,532	228,423	-40,130	-146,470	119,157
2005	12,090	6,416	-2,262	2,788	16,527	126	101,357	56,121	17,648	9,377	12,259	232,446	123,538	34,503	17,711	42,322	218,075	14,371	-132,099	150,777
2006	12,412	6,104	1,945	3,065	16,314	109	93,910	46,940	12,940	1,303	34,567	229,610	133,372	30,812	17,267	38,185	219,636	9,975	-122,124	138,288
2007	12,614	5,745	1,925	2,595	16,130	101	95,850	37,511	4,745	2,993	32,960	213,168	152,223	29,919	16,671	32,461	231,274	-18,106	-140,231	128,083
2008	12,955	5,712	1,243	2,490	16,101	100	87,021	42,368	10,205	2,340	0	180,534	157,812	26,280	15,525	29,901	229,518	-48,984	-189,214	132,768
2009	12,936	5,850	548	2,464	16,080	102	87,114	42,567	7,512	2,684	0	177,857	165,801	23,386	14,591	28,175	231,952	-54,095	-243,309	132,408
2010	13,016	5,221	-224	2,469	16,024	96	84,874	49,258	14,273	7,210	5,000	197,216	137,948	22,038	14,685	28,360	203,030	-5,813	-249,123	141,962
2011	13,157	5,414	-1,044	2,494	15,904	99	90,611	54,210	17,052	8,065	9,465	215,427	123,354	18,042	15,260	31,779	188,436	26,992	-222,131	150,858
2012	13,074	5,156	520	2,545	15,671	100	82,795	38,777	9,271	8,634	22,560	199,102	136,731	22,412	14,179	27,781	201,102	-2,000	-224,131	125,948
2013	12,674	5,124	599	2,424	15,591	110	78,155	37,018	5,271	10,479	0	167,444	139,128	24,074	13,861	23,355	200,418	-32,974	-257,106	119,748
2014	12,761	4,976	358	2,512	15,501	112	70,190	38,336	4,299	13,593	795	163,433	148,475	22,131	13,040	22,083	205,729	-42,295	-299,401	113,923
2015	12,929	4,463	-17	2,253	15,282	96	67,966	39,760	8,001	10,840	0	161,574	134,339	17,552	12,693	22,189	186,773	-25,198	-324,599	115,853
2016	12,639	3,804	-182	2,307	15,106	92	71,756	42,284	9,236	13,222	0	170,264	129,492	16,908	12,541	22,196	181,136	-10,872	-335,471	122,306
2017	13,091	4,432	-104	2,222	14,968	100	59,607	48,012	11,575	13,934	13,150	180,989	127,244	16,191	12,829	24,272	180,535	453	-335,018	116,804
2018	12,830	3,833	1,330	2,122	14,553	100	62,531	34,772	4,494	13,212	33,763	183,538	123,992	16,776	12,318	21,489	174,574	8,964	-326,054	102,757
2019	12,711	5,110	-440	2,201	14,352	97	66,005	52,509	12,861	11,145	6,510	183,060	116,396	15,478	13,215	24,472	169,561	13,499	-312,555	127,719
2020	13,013	4,853	614	2,153	14,155	112	67,024	44,348	9,967	12,953	18,103	187,294	132,618	15,722	12,913	25,250	186,503	792	-311,763	118,076
2021	12,825	4,996	1,299	2,254	14,194	121	66,692	35,576	4,911	15,728	2,229	160,822	146,973	14,929	11,912	22,623	196,437	-35,616	-347,379	108,331
2022	12,735	4,626	140	2,258	14,053	119	62,103	35,340	8,108	15,042	1,742	156,265	148,608	14,077	10,965	20,873	194,523	-38,258	-385,637	107,643
Statistics for the Calibration Period 1992 through 2022																				
Total	382,671	171,477	25,849	83,793	529,179	2,842	2,802,580	1,378,762	217,187	207,086	282,191	6,083,616	3,982,201	1,108,289	473,327	905,436	6,469,254	-385,637		4,215,577
Percent	6.3%	2.8%	0.4%	1.4%	8.7%	0.0%	46.1%	22.7%	3.6%	3.4%	4.6%	100.0%	61.6%	17.1%	7.3%	14.0%	100.0%			
Average	12,344	5,532	834	2,703	17,070	92	90,406	44,476	7,006	6,680	9,103	196,246	128,458	35,751	15,269	29,208	208,686	-12,440		135,986
Median	12,674	5,532	614	2,571	16,130	101	90,611	42,352	5,780	7,210	6,510	193,936	132,618	29,919	15,525	29,901	210,823	-14,418		132,768
Maximum	14,344	6,844	4,931	3,871	34,022	126	124,095	62,942	17,648	15,728	34,567	246,053	165,801	83,284	18,635	42,322	231,952	28,887	70,840	187,779
Minimum	10,517	3,804	-2,262	2,122	14,053	2	59,607	34,772	1,007	0	0	156,265	88,040	14,077	10,965	20,873	169,561	-54,095	-385,637	102,757

Note: column heading R means model results and column heading I means model input. Asterisks indicate components that had volumes or related parameters that were allowed to vary during the uncertainty analysis.

Figure 4-23
Mean Net Recharge in the Chino Basin, FY 1992-2022
Chosen Realizations of 2025 CVM

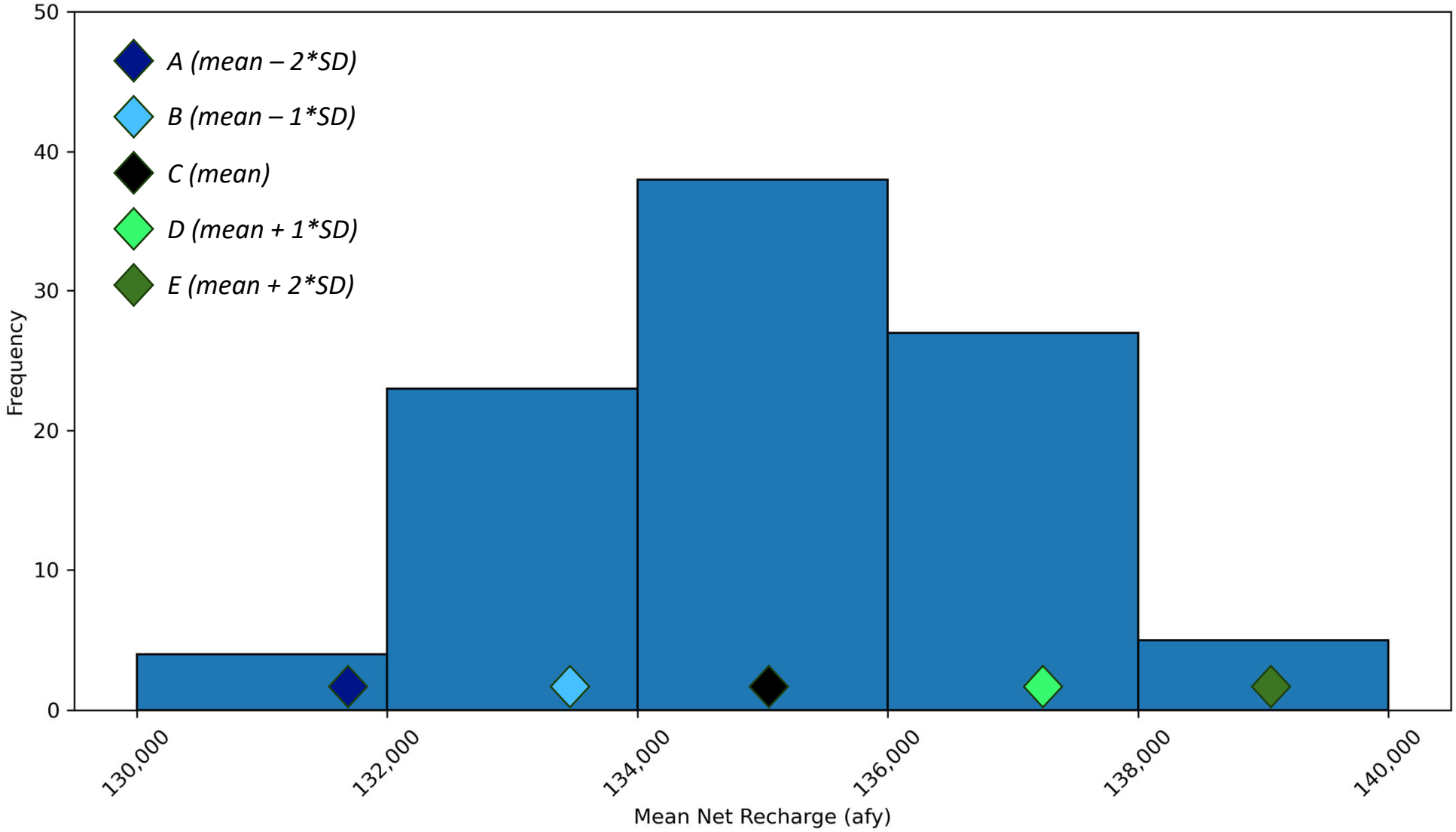
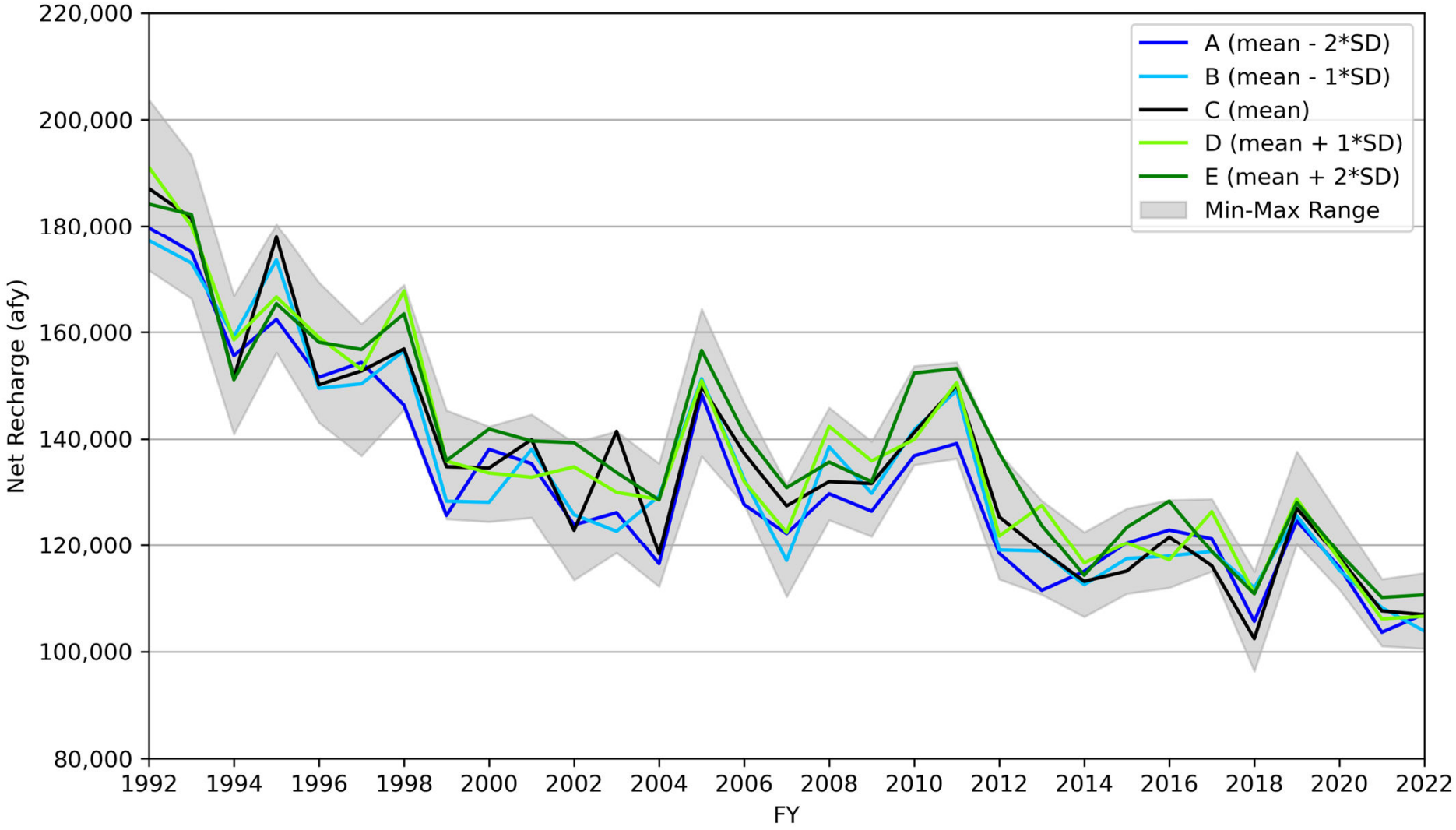


Figure 4-24
Simulated Net Recharge for Chosen Realizations of the 2025 CVM



4.3.2 Comparison of 2025 CVM Realizations to 2020 CVM

Table 4-8 compares the average annual water budget components for the FY 1992–2018 period for the 2025 CVM and the 2020 CVM. Measured components (such as managed aquifer recharge and groundwater pumping) that were not allowed to vary, are nearly identical in both models, and are therefore not included in Table 4-8. Figures 4-25 through 4-27 present time series of each of the components listed in Table 4-8, illustrating the range and mean of the volumes in the 2025 CVM compared to the corresponding time series from the 2020 CVM.

Differences between the 2020 CVM and the 2025 CVM water budgets are expected, given the recalibration and uncertainty analysis described above. Cumulative changes in the model structure, parameterization, calibration period, and the use of the PESTPP-IES tool have all contributed to the range of model outcomes. These differences are not attributable to any single factor but reflect refinements in the model processes that more accurately represent the range of possible conditions in the 2025 CVM.

Table 4-8. Comparison of Water Budget Components - 2020 and 2025 CVM

Component[a]	Figure	Mean Annual Volume, FY 1992-2018 (afy)		
		2020 CVM	2025 CVM[a]	2025 CVM minus 2020 CVM
Net Inflow from Six Basins	4-25	4,960	4,160	-800
Net Inflow from Cucamonga Basin	4-25	9,920	16,900	6,980
Net Inflow from Temescal Basin	4-25	2,120	2,580	460
Net Inflow from Spadra Basin	4-25	460	60	-400
Inflow from Bloomington Divide	4-25	14,760	10,530	-4,230
Other Subsurface Inflows	4-25	7,330	5,270	-2,060
Groundwater Pumping[b]	-	166,140	160,700	-5,440
Managed Aquifer Recharge	-	21,820	21,750	-70
DIPAW to Saturated Zone	4-26	98,030	94,140	-3,890
SAR Infiltration	4-26	31,920	45,420	13,500
ET	4-26	18,170	15,900	-2,270
Rising Groundwater	4-26	19,670	30,860	11,190
Total Recharge	4-27	190,990	214,430	23,440
Total Discharge	4-27	203,970	221,820	17,850
Net Recharge	4-27	139,600	138,300	-1,300
Change in Storage	4-27	-12,980	-7,400	5,580

(a) Volumes reflect the mean of all five calibrated realizations.
(b) Differences in groundwater pumping reflect the adjustment of the basin boundaries and refinements of the unmetered pumping in the 2025 CVM.

The following subsections describe each of the three figures comparing the 2020 CVM and the 2025 CVM.

4.3.2.1 Subsurface Inflows (Figure 4-25)

Figure 4-25 compares the subsurface inflow components of the Chino Basin, including net inflows from the Six Basins, Cucamonga Basin, Temescal Basin, Spadra Basin, the Bloomington Divide, and other subsurface inflows. The "other subsurface inflows" category includes contributions from the Chino/Puente Hills, Jurupa Hills, and Rialto Basin. Overall, the magnitude of these components is similar between the 2020 CVM and the 2025 CVM; however, relatively larger differences are observed for inflow from the Cucamonga Basin and across the Bloomington Divide. These differences reflect updated conceptualization, parameterization, or calibration of boundary conditions in the 2025 CVM, and highlight areas where subsurface flow remains more uncertain.

4.3.2.2 Other Variable Water Budget Components (Figure 4-26)

Figure 4-26 shows the variable water budget components beyond the Subsurface Inflows, including DIPAW to the saturated zone, infiltration from the SAR and its tributaries, ET, and rising groundwater outflows.

The estimated DIPAW in the 2025 CVM is approximately 3,900 afy lower than in the 2020 CVM. This difference reflects the impact of the spatial DIPAW multipliers introduced in the uncertainty analysis and the adjustment of the Chino Basin boundaries (see Section 3), which resulted in an approximately one percent reduction in area of the Chino Basin.

Both infiltration from the SAR and rising groundwater outflow are higher in the 2025 CVM by 13,500 afy and 11,200 afy, respectively, reflecting the overall increase in streambed hydraulic conductivity in the 2025 CVM. These increases suggest that groundwater/surface-water interactions are more extensive than previously represented. ET outflows from the basin are about 2,300 afy lower in the 2025 CVM compared to the 2020 CVM.

4.3.2.3 Summary of Water Budget (Figure 4-27)

Figure 4-27 compares total recharge, total discharge, net recharge, and the cumulative change in storage between the 2020 CVM and the 2025 CVM. The average volumes of all components are lower in the 2025 CVM compared to the 2020 CVM.

Net recharge represents the exploitable inflow to a groundwater basin over a given period (whether under historical conditions or future projections) and reflects the combined effects of hydrology, cultural conditions, and water management practices during that time. Net recharge is the sum of the natural recharge components (i.e., excluding supplemental water recharge) minus the sum of the natural discharge components (such as ET and rising groundwater). The methodology for computing net recharge is described in Section 1 of the 2020 SYR Report.

The average net recharge across the five selected realizations in the 2025 CVM is 138,300 afy for the 1992-2018 period, approximately 1,300 afy lower than that estimated in the 2020 CVM.

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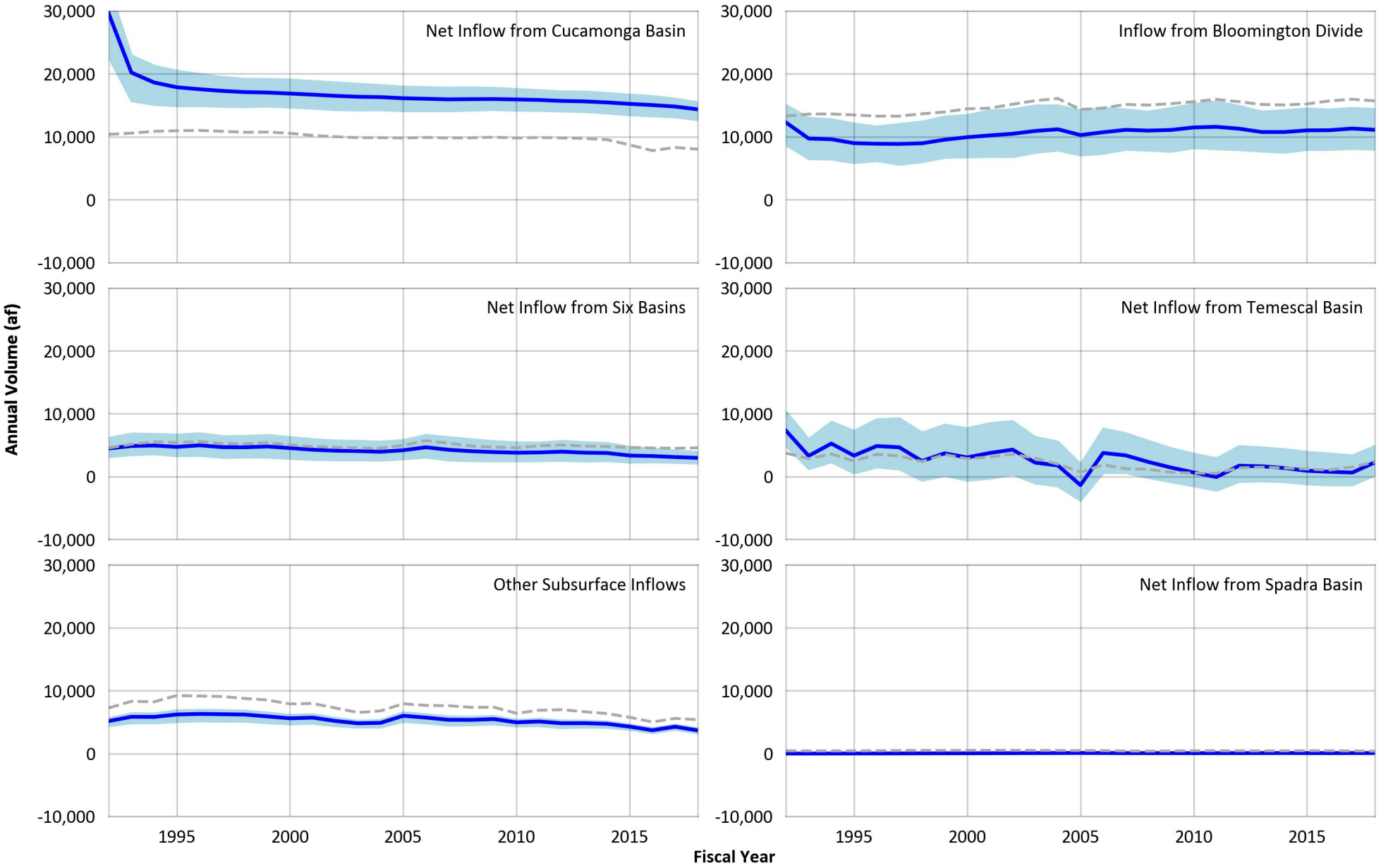

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Comparison of Subsurface Inflows - 2020 and 2025 CVM

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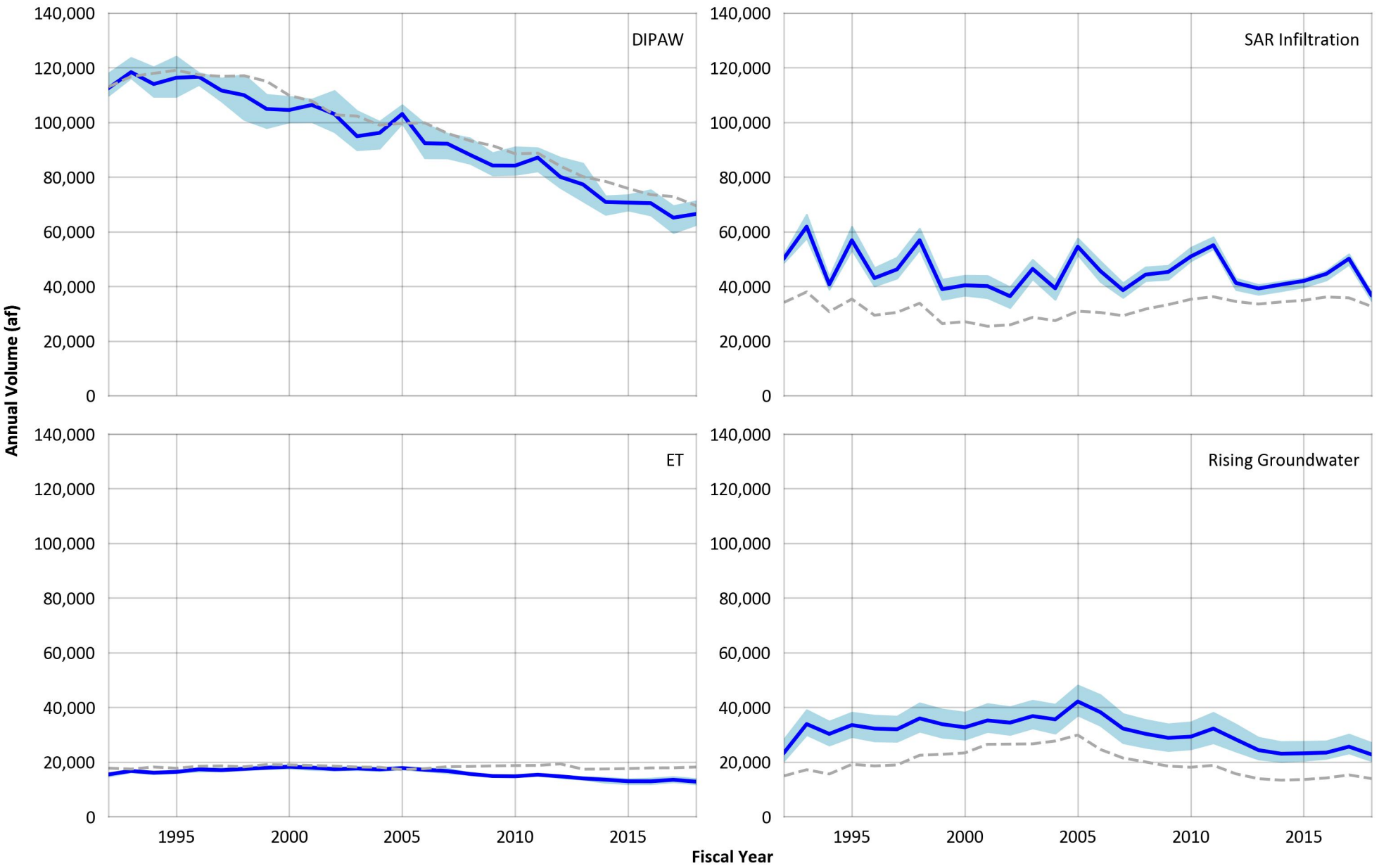
Figure 4-25



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Comparison of Other Variable Water Budget Components - 2020 and 2025 CVM

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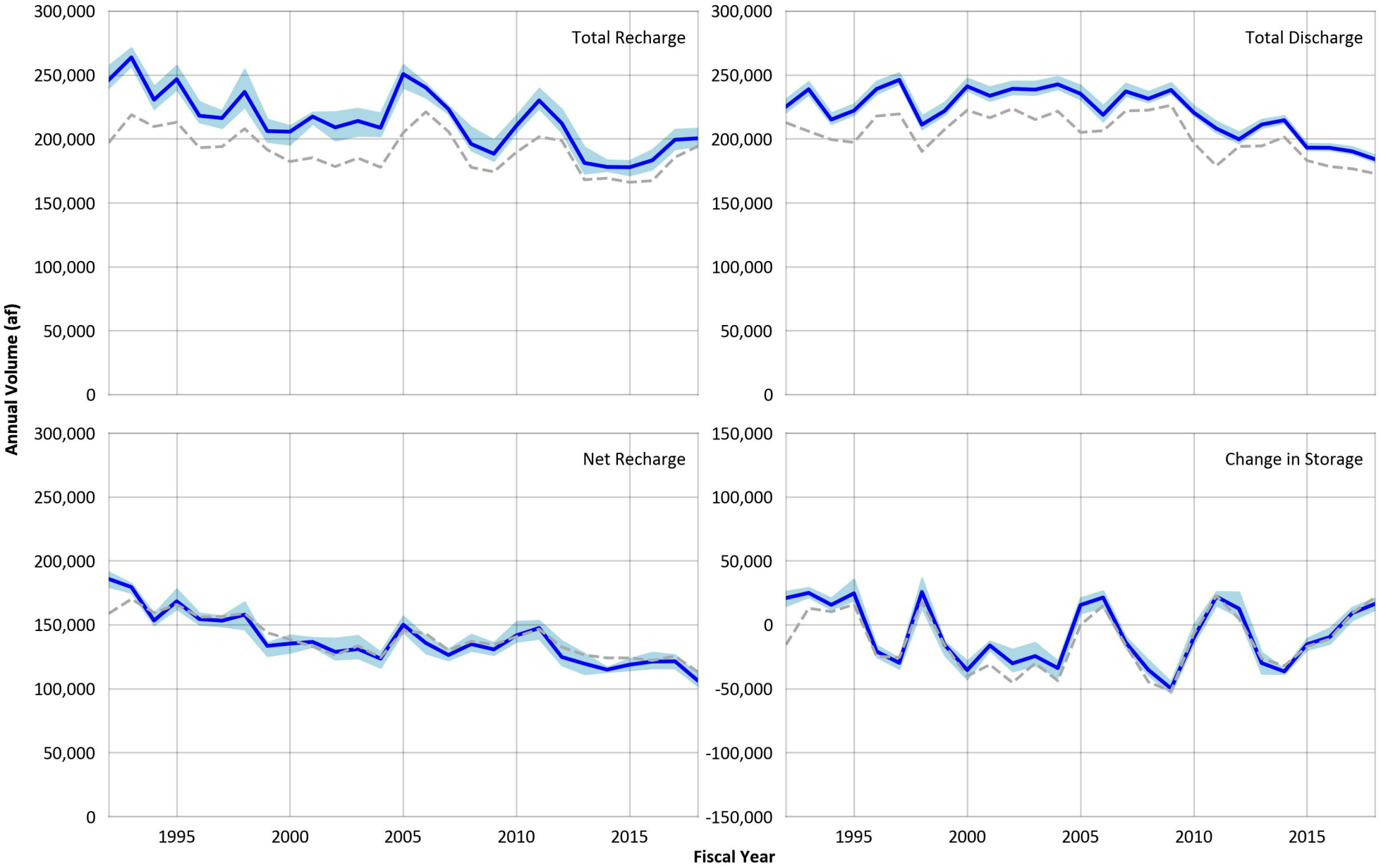
Figure 4-26



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Comparison of Net Recharge and Discharge - 2020 and 2025 CVM

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Figure 4-27

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SECTION 5
Projection Ensemble

The Projection Ensemble is a series of planning scenarios that describe a reasonable range of future climate and cultural conditions in the Chino Basin through the planning horizon (2024-2080). The Projection Ensemble is used as input data for the 2025 CVM to simulate the potential range in future hydrologic conditions in the Chino Basin, including the water budget and changes in groundwater levels.

This section describes the objectives, methods, and results of the development of the Projection Ensemble, including the likelihoods associated with each Projection Scenario.

5.1 OBJECTIVES OF THE PROJECTION ENSEMBLE

The Projection Ensemble is designed to represent a reasonable range of uncertainty in future climate and cultural conditions, including the water demands and supply plans (Water Plans) of the water purveyors in the Chino Basin, pursuant to Steps 3 through 5 of the 2022 SYRM:[1]

- *Describe current and projected future cultural conditions, including but not limited to land use and water-management practices, such as: pumping, managed recharge, managed groundwater storage, impervious land cover, water recycling, and water conservation practices. Identify a possible range of projected future cultural conditions.*
- *Using the most current research on future climate and hydrology, identify a possible range of projected future climatic conditions in the Santa Ana River watershed.*
- *Using the results of [3.] and [4.] above, prepare an ensemble of multiple Projection Scenarios of combinations of future climate/hydrology and cultural conditions (herein called the "Projection Ensemble"). Assign likelihoods to each scenario in the Projection Ensemble.*

Recognizing that it is not feasible to include every possible permutation of future climate and cultural conditions in the Projection Ensemble, the objectives of the Projection Ensemble are to: (i) bracket a reasonable range in future climate and cultural conditions and (ii) result in the maximum potential range in the future hydrologic responses of the Chino Basin (i.e., high and low groundwater levels; high and low net recharge). This approach is based on Robust Decision Making (RDM)[2] principles, which inform strategies that perform well across a wide range of plausible futures.

This strategy informs parties about both the central tendency and potential extremes (high and low groundwater levels; high and low net recharge) of the Chino Basin's future hydrologic response. Understanding these extremes and their drivers can inform groundwater management strategies to avoid undesirable results and MPI and optimize basin management.

[1] See Attachment C of the 2022 Update of the Chino Basin Safe Yield Reset Methodology

[2] Robust Decision Making | RAND

5.2 STAKEHOLDER ENGAGEMENT AND TIMELINE

The development of the Projection Ensemble involved a collaborative process with multiple stakeholder workshops and technical documents to ensure that the scenarios were representative of the possible range in future conditions. This process involved:

- **Workshops**: Watermaster hosted four workshops with parties and other stakeholders to gather input during the development of the Projection Ensemble, to review accompanying Scenario Design TMs, and discuss stakeholder feedback:
  - **Workshop #1** (October 24, 2023). The objective of Workshop #1 was to identify key drivers for the Water Plans of the Chino Basin water purveyors. These drivers included economics, demographics, technology, policy, and climate. Stakeholders provided feedback on the methods and assumptions for quantifying the potential impacts of water conservation regulations, variation in precipitation, and temperature fluctuations.
  - **Workshop #2** (March 7, 2024). The objectives of Workshop #2 were to present a proposed *qualitative* Projection Ensemble, gather feedback on the Projection Ensemble, and gather input on proposed methods to *quantify* the Projection Scenarios.
  - **Workshop #3** (June 25, 2024). The objectives of Workshop #3 were to summarize feedback and responses from the Scenario Design TM #2 and Workshop #2 and to describe the proposed *quantitative* Projection Ensemble. Stakeholders provided feedback on the Water Plan Scenarios and the proposed methods for simulating future climate conditions.
  - **Workshop #4** (August 27, 2024). The objectives of Workshop #4 were to summarize feedback and responses from the draft Scenario Design TM #3 and Workshop #3 and to describe updates made to the proposed *quantitative* Projection Ensemble. Stakeholders provided feedback on the Water Plan Scenarios and the proposed Climate Scenarios.
- **Targeted Outreach to the Appropriative Pool Parties**: During the scenario design process, West Yost reached out to the Appropriative Pool (AP) parties to solicit input on the scenario development. Many AP parties[3] provided input and reviewed draft Water Plan Scenarios that were developed for each party.
- **Technical Memoranda**: Three TMs were prepared to document the development of the Projection Ensemble:
  - **Scenario Design TM #1** outlined the approach for developing Water Plan projections and presented questions for the first workshop.
  - **Scenario Design TM #2** documented feedback from the first workshop, described the proposed Water Plan projections, presented recommended climate datasets, and outlined the Projection Ensemble.

[3] All AP retailers were contacted to provide input on the scenario design process. The AP parties that provided input included the Cities of Chino, Chino Hills, Ontario, Pomona, Upland, Cucamonga Valley Water District, Jurupa Community Services District, the Chino Desalter Authority, Monte Vista Water District, and Fontana Water Company.

— **Scenario Design TM #3** documented feedback from previous TMs and workshops and quantitatively described the proposed Projection Ensemble.

Parties provided feedback on the TMs, the proposed Projection Ensemble, and the data used to prepare the Projection Ensemble. All written input was responded to in the Scenario Design TMs. General themes of the verbal feedback from the workshops were addressed in subsequent Scenario Design TMs and workshops.

- **Website**: Throughout the Scenario Design process, Watermaster maintained a webpage[4] on its website with links to the timeline, draft and final TMs, and workshop materials.
- **Updates at Watermaster Meetings**: Updates on the 2025 SYR process, including the development of the Projection Ensemble, were provided at monthly Pool Committee, Advisory Committee, and Board meetings. Updates included announcing distribution of TMs, future workshop dates, summaries of workshops, and other status updates.

5.2.1 Timeline for Development of the Projection Ensemble

The timeline for the development of the Projection Ensemble was:

- **October 20, 2023:** Scenario Design TM #1 was distributed to the parties.
- **October 24, 2023**: Scenario Design Workshop #1.
- **December 1, 2023**: Stakeholders provided written comments on Scenario Design TM #1.
- **March 5, 2024:** Scenario Design TM #2 was distributed to the parties.
- **March 7, 2024**: Scenario Design Workshop #2.
- **April 12, 2024**: Stakeholders provided written comments on Scenario Design TM #2.
- **Spring 2024**: West Yost requested information from five AP retailers to inform the development of Water Plan projections. This included the estimated response to the urban water-use objectives being developed to comply with Assembly Bill 1668 and Senate Bill 606 in 2018 ("Making Conservation a California Way of Life").
- **June 25, 2024**: A draft of Scenario TM #3 was distributed, and Scenario Design Workshop #3 was held.
- **July 19, 2024**: Stakeholders provided written comments on draft Scenario Design TM #3.
- **August 27, 2024**: A revised draft of Scenario TM #3 was distributed, and Scenario Design Workshop #4 was held.
- **September 27, 2024**: Stakeholders provided written comments on draft Scenario Design TM #3.
- **Fall 2024:** West Yost submitted draft Water Plan Scenarios to nine AP parties for their input. West Yost held meetings with five of the nine parties to discuss the Water Plan Scenarios and gather feedback.

[4] Chino Basin Watermaster - 2017 Safe Yield Court Order Implementation

- **February 12, 2025**: The final Scenario Design TM #3 was published, including responses to all written stakeholder comments on Scenario Design TM #2 and prior drafts of Scenario Design TM #3.

5.3 CHARACTERIZING UNCERTAINTY IN FUTURE CLIMATE

Future climate will directly and indirectly impact the hydrology of the Chino Basin by influencing water use, the availability of water supplies, and recharge. For instance, hotter and drier weather can lead to increased water demands, reduced natural recharge, and reduced water supplies (including surface waters used for artificial recharge). Future climate is also inherently uncertain due to natural variability in short-term weather conditions, incomplete knowledge of future climate trends, and the limitations of models used to forecast climate.

To incorporate the uncertainty of future climate into the 2025 SYR, as required in Step 4 of the 2022 SYRM, three "Climate Scenarios" were developed to represent the "possible range of projected future climatic conditions": *Average, Hot/Dry,* and *Cool/Wet*. Each Climate Scenario includes a time series for projected precipitation and reference evapotranspiration (ET_o) from FY 2024 through 2080. Each time series was derived from historical observations that were adjusted to incorporate the uncertainty in short-term weather patterns and long-term climatic trends.

The development of Climate Scenarios for the 2025 SYR involved two main steps. The first step was to prepare a 57-year time series of precipitation and ET_o for the period 2024-2080 based on historical data. The second step was to modify the time series to produce the three Climate Scenarios (i.e., a possible range in future climate conditions). The following subsections describe the development of the Climate Scenarios.

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5.3.1 Use of Historical Precipitation and ET_o Data

The historical record of precipitation and ET_o data[5] from FY 1950-2022[6] was used to develop a reasonable range of potential future climate conditions in the Chino Basin (i.e., *Average, Hot/Dry,* and *Cool/Wet*) for the projection period of FY 2024-2080. Each Climate Scenario is based on a continuous 7-year historical period to represent FY 2024-2030 and a continuous 50-year historical period to represent FY 2031-2080. Details for each period are outlined below:

1. **FY 2024-2030**: This 7-year period represents the final years over which the current Safe Yield was calculated. Precipitation and ET_o during this period will have the greatest influence on net recharge and the evaluation of Safe Yield for the period 2021-2030. Hence, the historical data was analyzed and used to prepare a potential range for future precipitation and ET_o for the period FY 2024-2030:
   - The **Average Climate Scenario** used historical precipitation and ET_o data from FY 1968-1974, the 7-year period that most closely matches the annual average precipitation over the period FY 1950-2022.
   - The **Hot/Dry Climate Scenario** used historical precipitation and ET_o data from FY 2012-2018, the driest 7-year period over the period FY 1950-2022.
   - The **Cool/Wet Climate Scenario** uses historical precipitation and ET_o data from FY 1977-1983, the wettest 7-year period over the period FY 1950-2022.
2. **FY 2031-2080**: All three Climate Scenarios used the same continuous 50-year historical period from FY 1959-2008. This 50-year period was selected because its annual average precipitation (15.2 in) is similar to the long-term annual average precipitation from 1915-2011 (15.4 in), includes a mix of wet and dry periods, and falls within the period for which the Department of Water Resources (DWR) developed climate change factors (FY 1915-2011).

5.3.2 Incorporating DWR Climate Change Factors

To incorporate for future climate trends, we initially explored the use of climate data from the sixth iteration of the Coupled Model Intercomparison Project (CMIP6). As documented in Scenario Design TM #2, CMIP6 models offer improvements in representing atmospheric processes, have denser grids, and better simulate historical conditions compared to CMIP5 models. We processed the precipitation and

[5] Estimates of daily precipitation over the Chino Basin were developed from precipitation stations and gridded precipitation data products produced by the PRISM Climate Group and the National Oceanic and Atmospheric Administration. Estimates of daily ET_o over the Chino Basin were developed from the Pomona and Riverside California Irrigation Management Information System stations using a spatial-temperature interpolation algorithm, supplemented by evaporation data from Puddingstone Reservoir. Details can be found in Sections 3 of the 2020 SYR Report.

[6] 1950-2022 was chosen to derive the data for the climate scenarios because (1) it is consistent with the historical time series of climate data processed for the R4 model in the 2020 SYR; (2) includes multiple dry and wet periods; (3) overlaps the period for which the DWR developed change factors (through 2011); and (4) the average annual precipitation over the 2025 CVM domain and watershed area are approximately equal to their respective long-term precipitation averages. See Figure 3-13 from the 2020 SYR Report and Figure 4-8 from this report.

temperature datasets that Cal-Adapt[7] generated from the downscaled[8] CMIP6 scenarios. The data processing and review identified discrepancies between the CMIP6 datasets and the historical precipitation datasets for the overlapping historical period in the Chino Basin. We reviewed these discrepancies with the Cal-Adapt team and were unable to resolve the discrepancies in time to use the CMIP6 models in the 2025 SYR.

Instead, we followed the DWR recommended approach for incorporating climate change into groundwater sustainability planning (e.g., DWR, 2018).[9] The DWR-recommended approach employs Change Factors (CFs) derived from spatially downscaled climate data from CMIP5.[10] CFs are used to adjust historical climate datasets to reflect projected future conditions, which preserves historical variability while incorporating future climate change trends. The DWR provides CFs for the following four climatic conditions:

1. 2030 Central Tendency (2030 CT)
2. 2070 Central Tendency (2070 CT)
3. 2070 Wet with Moderate Warming (2070 WMW)
4. 2070 Dry with Extreme Warming (2070 DEW)

To incorporate climate change in the Climate Scenarios, we applied distinct climatic conditions to each scenario. All Climate Scenarios used the 2030 Central Tendency CF but differ in their 2070 CF as follows: the Average Climate Scenario used the 2070 Central Tendency CF, the Hot/Dry Climate Scenario used the 2070 Dry with Extreme Warming CF, and the Cool/Wet Climate Scenario uses the 2070 Wet with Moderate Warming CF.

Since the DWR CFs represent snapshots of climate conditions at specific future points (e.g., the 2030 CF represents 2030 conditions and the 2070 CFs represent 2070 conditions), a continuous time series of CFs for each year between 2024–2080 was developed for each Climate Scenario.

- 2024–2030: The CF was equal to the 2030 CF.
- 2031–2070: Unique CFs were calculated for each year using linear interpolation between the 2030 and 2070 CFs.
- 2071–2080: The CF was equal to the 2070 CF.

These CF time series were then applied to the precipitation and ET_o datasets presented in Section 5.3.1 to generate the time series of precipitation and ET_o for each Climate Scenario.

[7] https://analytics.cal-adapt.org/

[8] Memo on Evaluating Global Climate Models for Studying Regional Climate Change in California

[9] California Department of Water Resources. 2018. Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development. Accessed on 15 Aug 2024 at https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Climate-Change-Guidance_Final_ay_19.pdf

[10] Memo on Evaluating Global Climate Models for Studying Regional Climate Change in California

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5.3.3 Summary of Climate Scenarios

Table 5-1 summarizes the three Climate Scenarios used in the 2025 SYR:

Table 5-1: Datasets Used for Climate Scenarios

Climate Scenario	Precipitation and ET	
	FY 2024 through 2030	FY 2031 through 2080
Average	Historical period with average precipitation[(a)] (FY 1968-1974) and ET_o modified with 2030 CT	Historical period (FY 1959-2008) modified using 2030 CT and 2070 CT
Hot/Dry	Historical period with lowest precipitation (FY 2012-2018)[(b)] and ET_o	Historical period (FY 1959-2008) modified using 2030 CT and 2070 DEW
Cool/Wet	Historical period with highest precipitation (FY 1977-1983) and ET_o modified with 2030 CT	Historical period (FY 1959-2008) modified using 2030 CT and 2070 WMW

(a) Calculated based on continuous seven-year periods taken from the historical (PRISM) data for FY 1950 through 2022.
(b) CFs are only available through 2011; therefore, precipitation and ET_o were not adjusted for this period.

Figure 5-1 shows the time series for annual precipitation averaged across the Chino Basin over the historical period (1950-2023) and for each Climate Scenario over the projection period (2024-2080). For the 2024-2030 period, note the wide range in annual precipitation between Climate Scenarios that is designed to simulate the potential range in shorter-term weather variability. During the early part of the 2031--2080 period, there are smaller differences in precipitation between scenarios because of the strong influence of 2030 CT which is identical for each scenario. The mean precipitation over the historical period was 14.3 inches. The mean precipitation for the *Average*, *Hot/Dry*, and *Cool/Wet* Climate Scenarios are 15.3 inches, 13.8 inches, and 18.3 inches, respectively.

Figure 5-2 shows the CDFM for the three Climate Scenarios for FY 2024 through 2080. CDFMs are calculations of the accumulated differences between the annual precipitation relative to the long-term mean. To characterize the differences in precipitation between scenarios through the projection period, the CDFM for each scenario is calculated relative to the mean of the Average Climate Scenario (15.3 inches). This results in the CDFM for the Average Climate Scenario equaling zero at the end of the projection period, whereas the Hot/Dry and Cool/Wet scenarios are less than and greater than zero, respectively, at the end of the projection period. Generally, an upward trending CDFM curve indicates wetter-than-average period, while a downward trending CDFM curve indicates a drier than average period. Figure 5-2 illustrates that, over the projection period, the Hot/Dry Climate Scenario is projected to receive approximately 86 inches less precipitation than the Average Climate Scenario, while the Cool/Wet Climate Scenario is projected to receive about 171 inches more.

Figure 5-3 shows the time series for annual ET_o in the Chino Basin over the historical period (1950-2023) and for each Climate Scenario over the projection period (2024-2080). These ET_o estimates represent the annual ET_o averaged across the Chino Basin. The mean ET_o over the historical period was 53.3 inches. The mean ET_o for the *Average*, *Hot/Dry*, and *Cool/Wet* Climate Scenarios are 56.7 inches, 58.4 inches, and 55.4 inches, respectively.

Figure 5-1. Historical and Projected Annual Precipitation by Climate Scenario

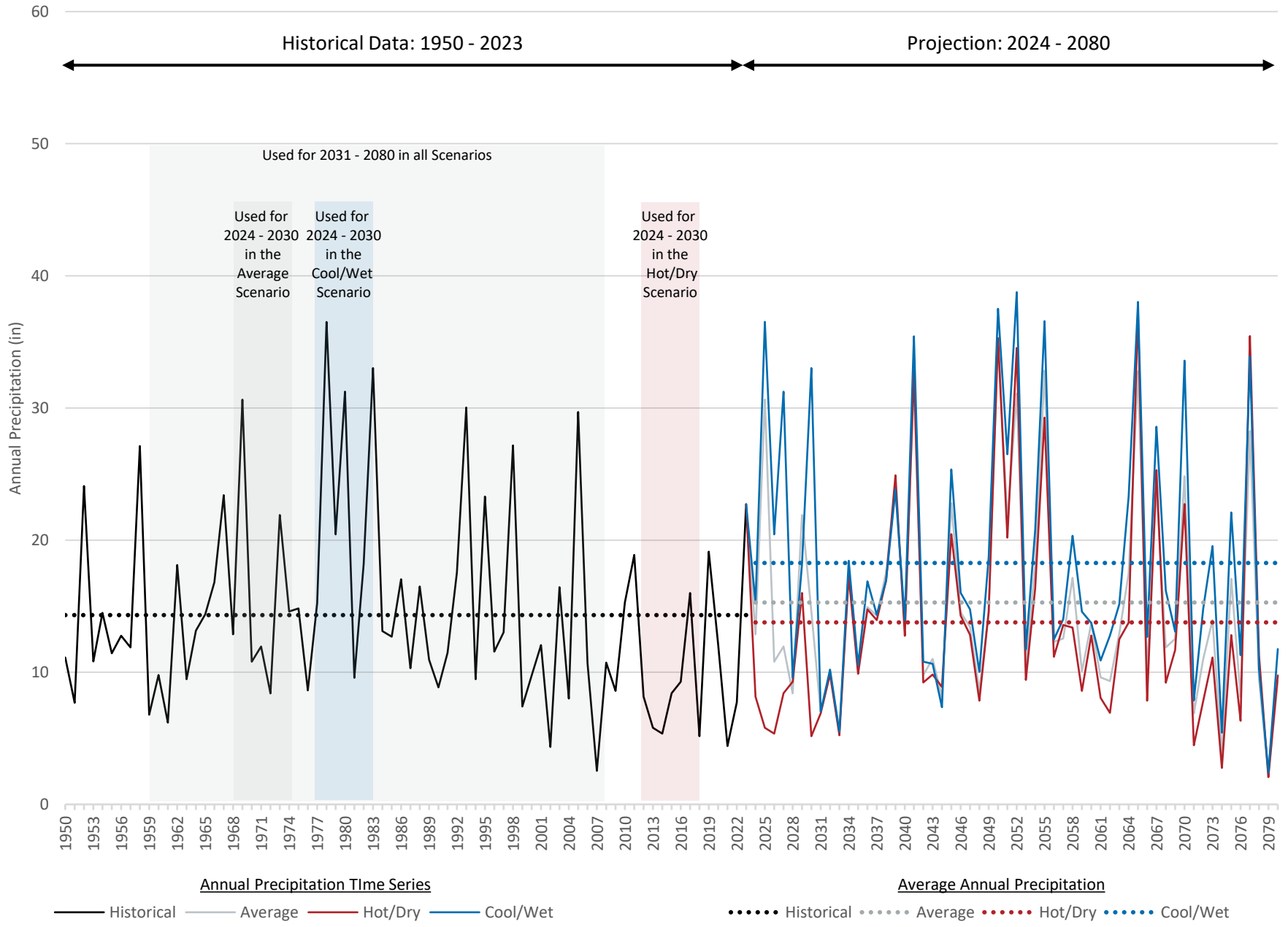


Figure 5-2. Cumulative Departure from Mean Precipitation by Climate Scenario

Calculated Relative to Mean of Average Climate Scenario (15.3 inches/year)

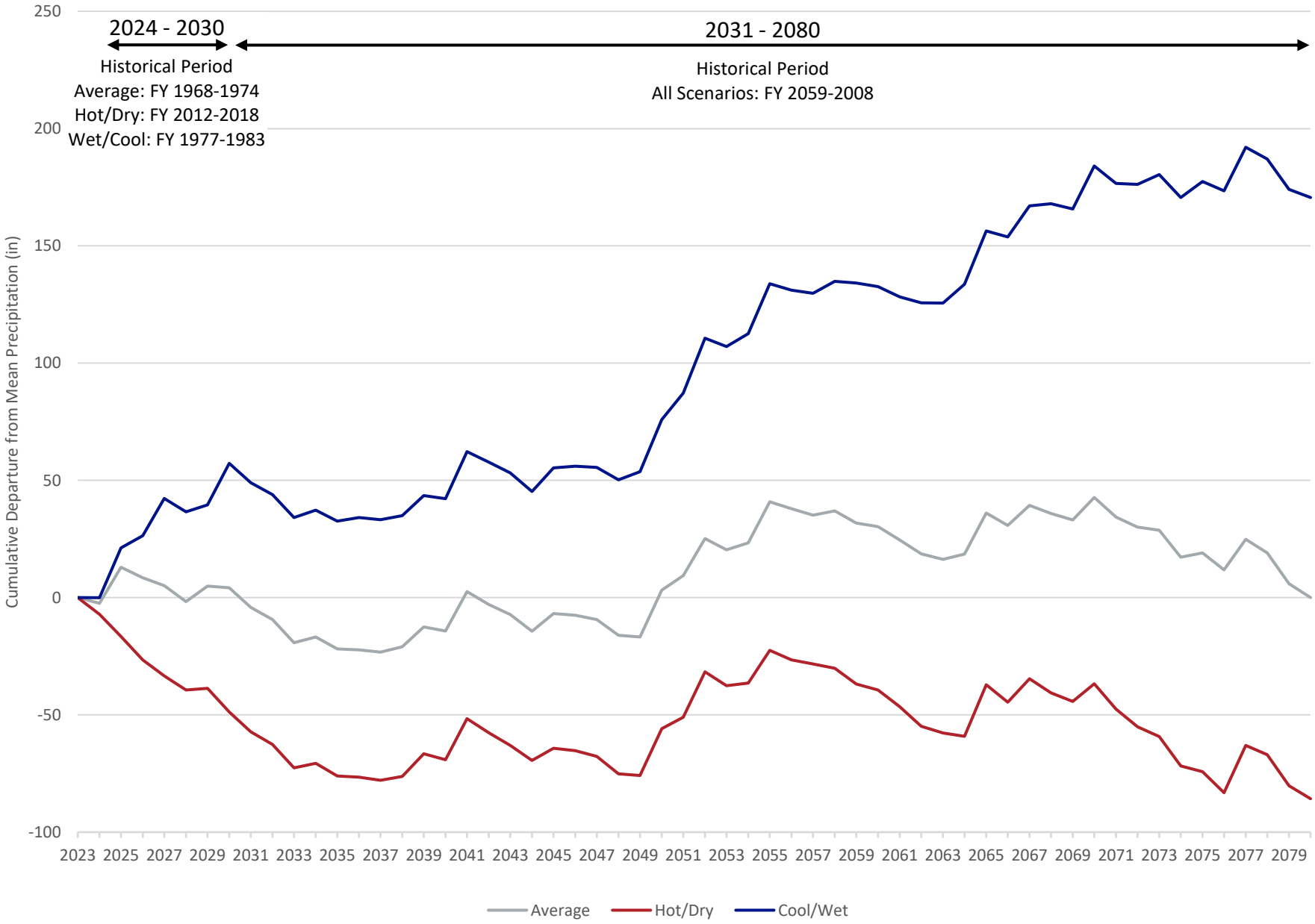
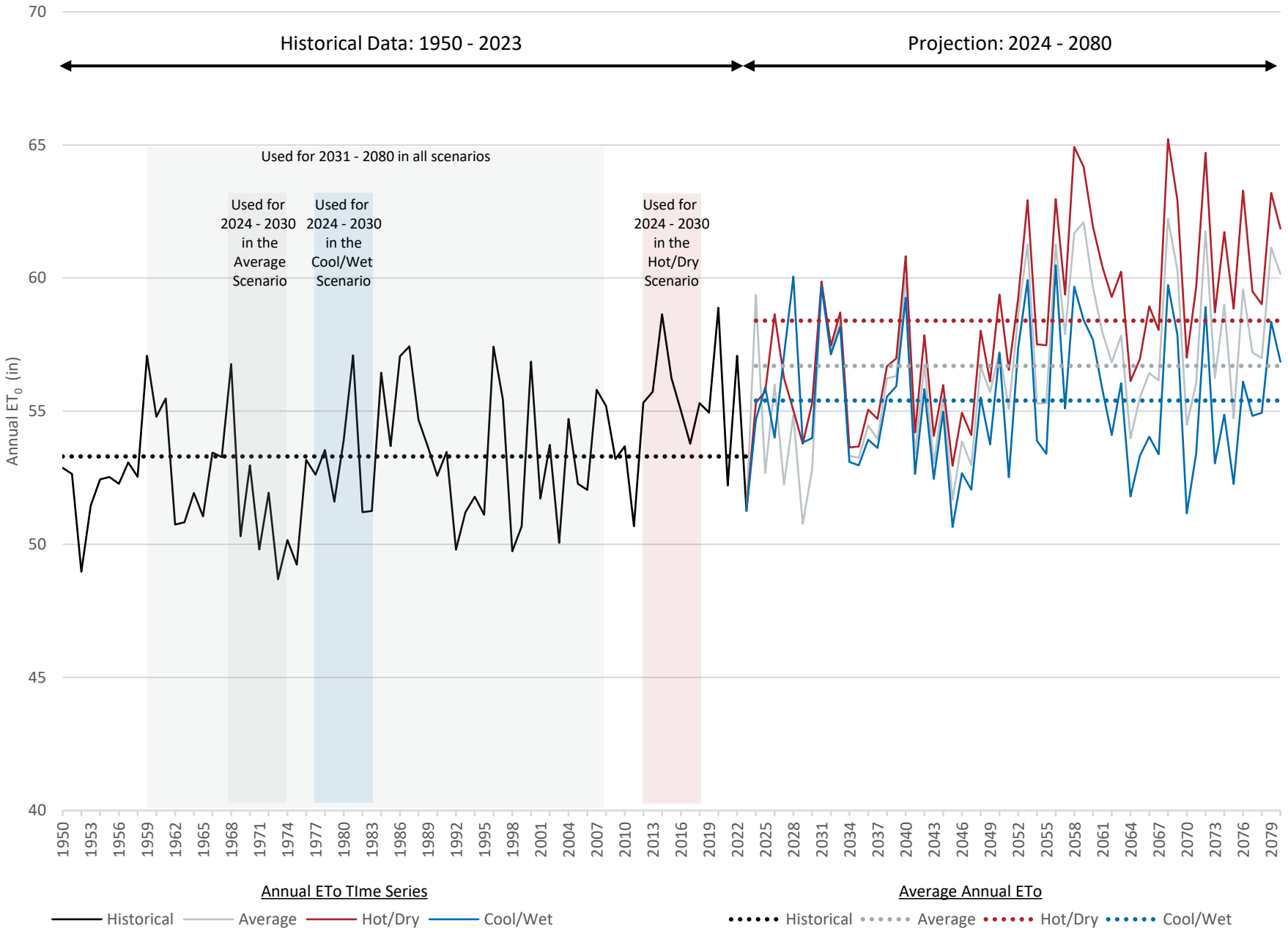


Figure 5-3. Historical and Projected Annual ET_o by Climate Scenario



5.4 CHARACTERIZING UNCERTAINTY IN FUTURE CULTURAL CONDITIONS

Cultural conditions—including but not limited to land use, groundwater pumping, managed aquifer recharge, groundwater storage, and water conservation efforts—play a critical role in shaping the behavior of the groundwater basin. However, projecting future cultural conditions is inherently uncertain due to the complex interplay of various drivers that influence water and land management practices over time. These uncertainties arise from several sources, including:

- Changes in economic conditions influence population growth, land-use changes, and water demands.
- Innovations in water management, conservation technologies, and data monitoring tools may emerge and enable new water management (e.g., conservation) strategies or alter the feasibility of existing strategies.
- Future changes in laws, policies, or regulations governing land-use and water management are difficult to predict, yet they can significantly alter water-use practices and priorities.
- The ongoing and unpredictable effects of climate change—including changes in precipitation, temperature, evapotranspiration, and extreme weather events—can substantially affect recharge rates, outdoor water demands, water availability, and water management strategies.

Simulating multiple future Water Plans (i.e., water demand and supply projections) provides a framework for evaluating how the groundwater basin might respond under a range of plausible future conditions.

In alignment with Step 3 of the 2022 SYRM, three Water Plan Scenarios—Expected Demand, High Demand, and Low Demand—were developed to characterize the potential range of future cultural conditions. The development of these scenarios began with the creation of Reference Water Plans, which represent each party's best estimate of future water use in the absence of the recently adopted Conservation Regulation. Building upon these Reference Water Plans, Watermaster worked with the parties to identify and quantify the primary sources of uncertainty - demand, groundwater utilization, and imported water utilization. These elements were then systematically varied to construct the Water Plan Scenarios, each of which reflects distinct assumptions about future conditions and behaviors. The following subsections describe the formulation of the Reference Water Plans (Section 5.4.1), the primary elements of uncertainty considered in scenario development (Section 5.4.2), and the methodology used to develop the three Water Plan Scenarios (Section 5.4.3).

5.4.1 Reference Water Plans

Before developing the Water Plan Scenarios, Reference Water Plans were prepared for each party. The Refence Water Plans represent the best estimate of future cultural conditions in the absence of the conservation regulations adopted by the State Board on July 3, 2024 (Conservation Regulation).[11] The Conservation Regulation was not included in the Reference Water Plans because it had not been finalized at the time of their development. Instead, anticipated responses to the regulation are incorporated, to

[11] Final text of Conservation Regulation

varying degrees, into the Water Plan Scenarios. These Reference Water Plans were used as the foundation for the development of the three Water Plan Scenarios.

5.4.1.1 Overlying (Agricultural) Pool

The Reference Water Plans for the parties in the Overlying (Agricultural) Pool (Agricultural Pool) were developed based on the estimated "buildout"[12] of urban land uses by 2040. Watermaster estimated Agricultural Pool production at buildout using historical data and projections for wells expected to operate in the future. In addition to these wells, several agricultural areas are irrigated with recycled water, some of which are anticipated to remain in use. Figure 5-4 shows the Agricultural Pool wells that are expected to produce in the future beyond buildout of the Basin and the projected pumping at these wells. The total projected water use by the Agricultural Pool is approximately 11,100 afy in 2025, decreasing to 4,000 afy in 2040, when most of the basin is assumed to reach buildout, and remaining stable thereafter.

5.4.1.2 Overlying (Non-Agricultural) Pool

The Reference Water Plans for the parties in the Overlying (Non-Agricultural) Pool (ONAP) (excluding those also in the AP, such as Ontario and Monte Vista Water District (MVWD)) were developed based on historical trends or the party's response to Watermaster's annual data request. Excluding pumping from General Electric Company, which injects approximately the same volume of water that it pumps, the total projected pumping by the ONAP is about 1,430 afy in 2025 and remains constant over time.

5.4.1.3 Appropriative Pool

To develop the Refence Water Plans for the retailer members in the AP, we began by reviewing the Water Plans obtained as part of the Watermaster's annual data collection and evaluation process. The AP retailers included:

- City of Chino (Chino)
- City of Chino Hills (Chino Hills)
- City of Norco (Norco)
- City of Ontario (Ontario)
- City of Pomona (Pomona)
- City of Upland (Upland)
- Cucamonga Valley Water District (CVWD)
- Fontana Water Company (FWC)
- Golden State Water Company (GSWC)
- Jurupa Community Services District (JCSD)
- Marygold Mutual Water Company (MMWC)

[12] Buildout refers to the point at which all available land within a designated area has been fully developed to its planned capacity, based on zoning regulations, infrastructure constraints, and land-use policies. At buildout, population growth within the area is typically limited to changes in household density (e.g., converting single-family homes to multi-family units) rather than new land development.

- Monte Vista Water District (MVWD)
- Santa Ana River Water Company (SARWC)
- San Antonio Water Company (SAWCo)
- West Valley Water District (WVWD)

The "major" AP retailers, indicated in italics above, collectively produce the majority of Chino Basin groundwater (historically 56-65 percent, excluding the Chino Desalter Authority), serve most of the Basin area, and are subject to the Conservation Regulation.

We then worked closely with major AP retailers to refine these plans to consider historical overestimates in demands[13], define water supply priorities when projected supplies exceed demands, and develop monthly projections from the annual estimates. Our consultations with the major AP retailers were crucial for understanding the assumptions behind their initial demands projections and ensuring the Refence Water Plans accurately reflected actual demands aligned with this modeling effort's goals. Based on their input, we adjusted the projected demands and corresponding supplies, primarily resulting in reduced demands. The Reference Water Plans for the major AP retailers can be found in Appendix C.

For AP parties other than the major AP retailers and non-retail parties (e.g., BlueTriton Brands, Inc.), Reference Water Plans were developed based on historical averages, similar to the method used to develop Reference Water Plans for the Overlying Non-Agricultural Pool.

The Refence Water Plans indicate that projected pumping for all AP parties is about 134,400 afy in 2025, 161,800 afy in 2040, and 166,500 af in 2045.

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[13] Scenario Design TM #1 documented the projected demands from prior groundwater studies compared to actual demands, concluding that historical projections are consistently greater than actual demands.

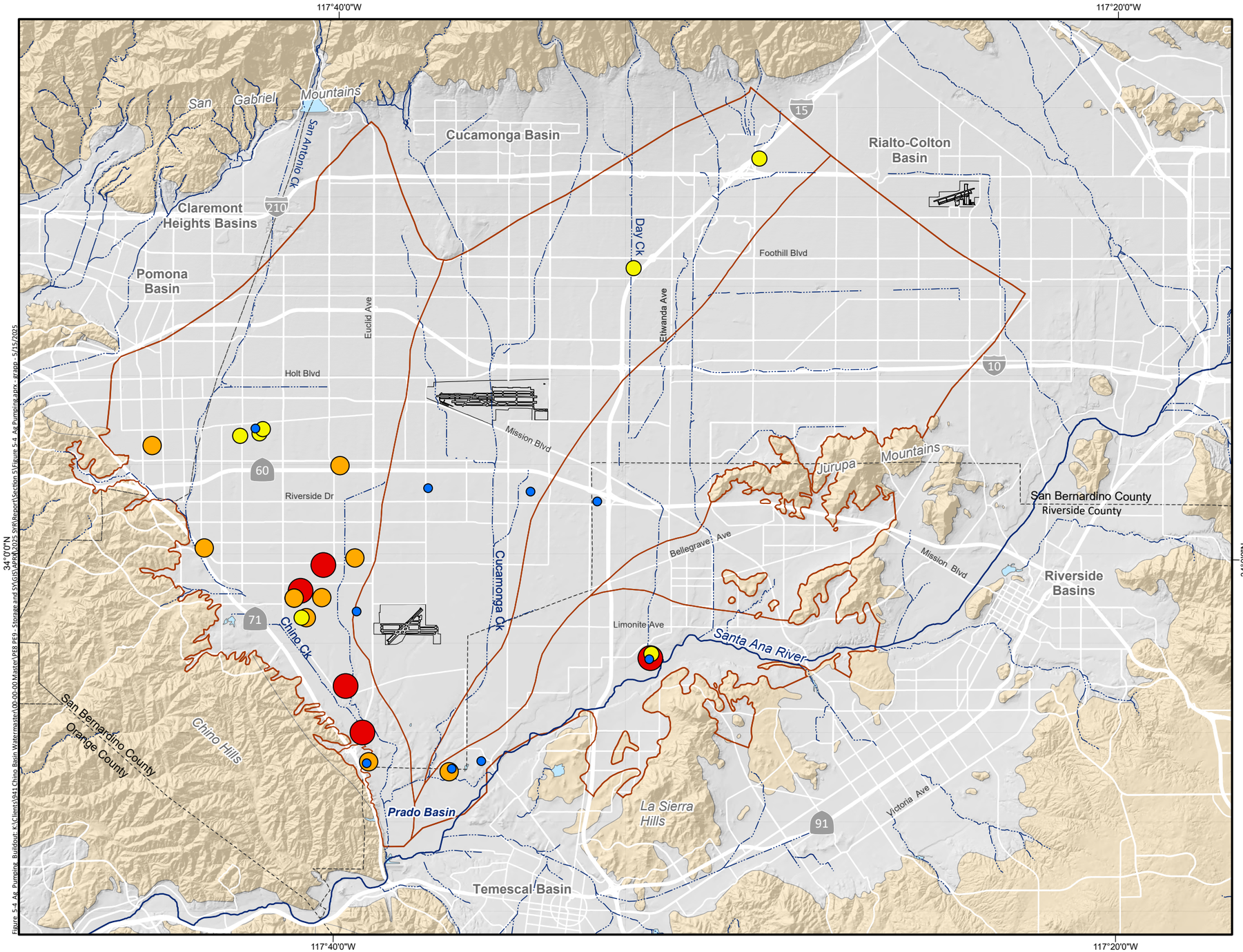

Figure_5-4_Ag_Pumping_Buildout_K:\Clients\941 Chino Basin Watermaster\00-00 Master\PB8 PE9 - Storage and SY\GIS\APRX\2025 SYAR\Report\Section 5\Figure 5-4_Ag Pumping.aprx - dkapp - 5/15/2025

Projected Active Agricultural Wells at Buildout

Projected Annual Pumping (afy)

- 0 - 5
- 6 - 10
- 11 - 50
- 51 - 250
- > 250

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Hydrology

- Streams & Flood Control Channels
- Flood Control & Conservation Basins
- OBMP Management Zones



Prepared by:

WEST YOST
Water. Engineered.

Author: AK

Date: 5/15/2025

N

0 3 6 Miles

0 4 8 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Active Agricultural Wells at Buildout

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Figure 5-4

5.4.1.4 Summary of Reference Water Plans

The Aggregate Reference Water Plans for the Watermaster Parties is shown in Table 5-2. As stated above, the Reference Water Plans assume no response to the Conservation Regulation.

Table 5-2. Aggregate Reference Water Plan for the Watermaster Parties

Water Supply	2020[(a)]	2025	2030	2035	2040	2045
Volume, afy						
Chino Basin Groundwater	151,365	146,897	155,317	159,266	168,447	171,961
Non-Chino Basin Groundwater	48,308	52,682	53,077	53,371	53,762	53,954
Local Surface Water	26,620	13,154	13,154	13,154	13,118	13,154
Imported Water	59,637	71,398	74,901	81,651	87,287	87,799
Recycled Water for Direct Use	20,857	25,091	27,088	28,385	29,982	30,482
Total	**306,787**	**309,222**	**323,537**	**335,826**	**352,596**	**357,350**
Percent of Total Supply						
Chino Basin Groundwater	49	48	48	47	48	48
Non-Chino Basin Groundwater	16	17	16	16	15	15
Local Surface Water	9	4	4	4	4	4
Imported Water	19	23	23	24	25	25
Recycled Water for Direct Use	7	8	8	8	9	9
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

(a) Historical data compiled for Water Year 2020 for the Chino Basin SGMA Annual Report.

5.4.2 Primary Elements of Uncertainty in Cultural Conditions

In the initial stages of the scenario design process, Watermaster presented an overview of cultural conditions and their impact on the hydrology of the Chino Basin. Following this presentation, input was gathered from the parties to achieve the following two objectives (1) ensure that the list of cultural conditions considered all major impacts to groundwater conditions and (2) identify the most significant sources of uncertainty related to cultural conditions and the parties' Water Plans. Based on the feedback from Scenario Design TM #1 and the October 24, 2023 workshop, three primary elements were identified for addressing uncertainty: (1) demands; (2) groundwater utilization; and (3) imported water utilization.

5.4.2.1 Historical Variation in Water Demands and Use of Water Supplies

To understand the year-to-year variability in historical Water Plans, we compiled the historical water demand and supply data from the Chino Basin parties. Figure 5-5 shows the historical data on water supplies used to meet demands data compiled from Water Year (WY) 2015 through 2023. Over this period, total water demand ranged between 271,000 af (WY 2023) to 307,000 af (WY 2020). There was no discernible upward or downward trend in total water demand over the period. However, the historical use of water supplies varied depending on hydrologic conditions. The nine-year period included three wetter-than-average years (WYs 2017, 2019, and 2023), while the other six years experienced below-average precipitation. Total groundwater use declined from 67 percent of total supplies in dry years

to 63 percent in wet years. Conversely, total imported and local surface water use increased from 25 percent of total supplies in dry years to 31 percent of total supplies in wet years.

5.4.2.2 Uncertainty in Demands

Demands refers to the total quantity of potable and non-potable water required to meet the needs of the parties. During the first scenario design workshop, the parties emphasized that uncertainty in the following factors will have the largest influence on demand projections:

- Growth (e.g., population, economic, buildout, infrastructure improvements)
- Water conservation efforts
- Climate

5.4.2.2.1 Growth

Growth plays a significant role in projecting demand; however, it is inherently uncertain due to factors such as changes in migration patterns, economic conditions, and policy and governance. For example, the recent urban densification legislation[14] in California, aimed at increasing housing supply, has the potential to impact the pace and type of land use changes associated with growth.

Feedback from the parties emphasized that growth primarily affects demand projections through the timing of buildout. If buildout occurs faster than expected, demand is likely to rise more quickly than projected. Conversely, if buildout occurs slower than expected, demand is likely to rise more gradually than projected.

5.4.2.2.2 Conservation Regulation

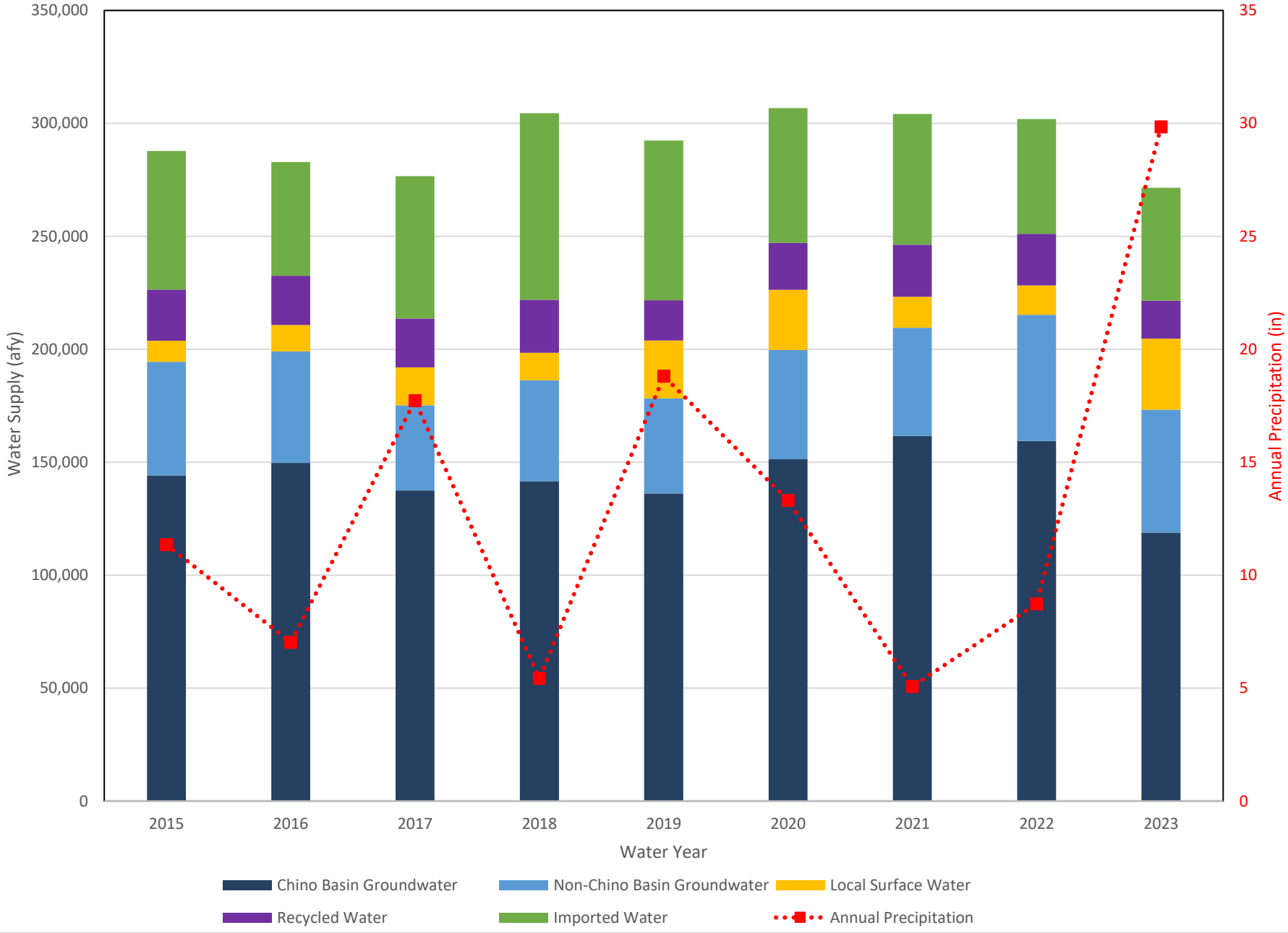
Since 2018, the State Water Resources Control Board (State Board) and the DWR have been developing new water use efficiency standards for urban retail water suppliers to implement the 2018 Urban Water Use Objectives legislation (Assembly Bill 1668 and Senate Bill 606) and the related "Making Conservation a California Way of Life" regulation.[15] The State Board adopted the Conservation Regulation on July 3, 2024. The Conservation Regulation took effect in January 2025, with compliance expected to be assessed beginning in 2027.

The Conservation Regulation requires water agencies to calculate their total urban water use annually and compare it to an agency-specific overall water use objective. This objective is the sum of four components: (1) residential water use, including indoor, outdoor, and residential agricultural use; (2) water losses; (3) outdoor irrigation for commercial, industrial, and institutional properties with dedicated irrigation meters (Commercial, Industrial, And Institutional (CII) with Dedicated Irrigation Meter (DIMs)); and (4) bonus credits for recycled water use. Each component is determined using statewide efficiency standards and local service area factors such as population, climate, and landscape area. These efficiency standards become stricter over time, meaning that even if local conditions remain unchanged, the overall water use objective is required to gradually decrease.

[14] e.g., Assembly Bill 2011 (2022) and Assembly Bill 2243 (2024)

[15] Making Conservation a California Way of Life Fact Sheet

Figure 5-5. Historical Water Supplies of the Chino Basin Parties, Water Year 2015 through 2023



Based on feedback from the parties, there is significant uncertainty regarding how customers will respond to the Conservation Regulation and how this will ultimately impact demand. Since compliance with the regulation is not required until 2027, no historical data exists to evaluate customer behavior or the State's actions in cases of non-compliance. Several Parties facing significant required reductions have indicated that, even with additional funding, achieving full compliance would remain challenging.

This introduces substantial uncertainty in forecasting the anticipated scale of response to the Conservation Regulation. Should the actual response exceed projections, water demand will likely be lower than estimated. Conversely, if the response falls short of projections, water demand will likely exceed anticipated levels.

5.4.2.2.3 Climate Change

Climate trends influence water demand projections. Typically, water use increases during hot and dry periods and decreases during cooler, wetter conditions (e.g., WY 2023 in Figure 5-5). However, the projected demands in the Reference Water Plans assume an "average hydrologic year"[16] and do not account for interannual variability. Extended droughts or unusually wet periods impact water demands; the effects can be complex in urbanized areas such as the Chino Basin where statewide policies[17] can influence the response to extreme conditions. Moreover, uncertainty surrounding future climate conditions, including the potential for more frequent and extreme weather events due to climate change, further complicates efforts to accurately forecast long-term water demand.

5.4.2.2.4 Impacts of Demand Deviations on Groundwater Levels and Net Recharge

Water demand is subject to considerable uncertainty due to factors such as growth, regulatory responses, and climate variability. Factors that could lead to higher-than-expected demand include:

- Greater-than-expected growth due to economic or other conditions
- The scale of the response to the Conservation Regulation is less than anticipated (e.g., less stringent enforcement, weaker consumer response)
- Extended periods of below-average precipitation compared to current assumptions for future climate

An increase in demand would likely result in greater utilization of one or more water-supply sources. If this additional demand is met through increased groundwater pumping, it could lead to declining groundwater levels. In turn, lower groundwater levels may increase net recharge through mechanisms such as enhanced recharge along the SAR due to increased hydraulic gradients and reduced discharge of rising groundwater in the Prado Basin. Additionally, if outdoor irrigation demand remains elevated due to limited response to the Conservation Regulation, associated DIPAW would also remain elevated, potentially affecting groundwater levels.

[16] An average hydrologic year is a representative year in which precipitation, temperature, and other hydrologic conditions reflect the long-term historical average for Chino Basin.

[17] E.g., the 2015 Statewide mandatory water reductions

Conversely, factors that could lead to lower-than-expected demand include:

- Slower-than-expected growth due to economic or other conditions
- The scale of the response to the Conservation Regulation is greater than anticipated (e.g., more stringent enforcement, stronger consumer response)
- Extended periods of above-average precipitation compared to current assumptions for future climate

A reduction in demand would likely decrease the utilization of one or more water supply sources. If this results in reduced groundwater pumping, it could lead to higher groundwater levels. The higher groundwater levels could lower net recharge by decreasing infiltration along the SAR and increasing discharge of rising groundwater in Prado Basin. Additionally, if outdoor irrigation demand declines in response to the Conservation Regulation, associated DIPAW would also decrease, which could further reduce net recharge and affect groundwater levels.

5.4.2.3 Groundwater Utilization

Groundwater utilization (GWU) represents the amount of Chino Basin groundwater that the parties use to satisfy their water demands. When projecting future groundwater utilization, parties consider both current conditions and anticipated trends. Key factors influencing these projections include:

- Regional hydrologic conditions
- Pumping capacity
- Groundwater quality and treatment infrastructure
- Policy
- Conveyance infrastructure
- The cost of groundwater compared to other water supplies

Factors that could lead to higher-than-expected groundwater utilization include:

- Unanticipated improvements to infrastructure for treatment, pumping, and conveyance that would increase accessibility to groundwater
- The timing and scale of new groundwater regulations (e.g., quality) and the responses to these regulations that result in fewer disruptions to projected pumping activities than expected
- Greater-than-expected recharge (either natural or managed) that would increase groundwater availability locally or basin-wide through a combination of greater pumping rights and greater pumping capacity because of higher groundwater levels

The probable effect of higher-than-expected groundwater utilization would be decreased utilization of supplemental water supplies, potentially resulting in lower groundwater levels and higher net recharge.

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Factors that could lead to lower-than-expected groundwater utilization include:

- Unexpected groundwater-quality, regulatory, or infrastructure challenges that prevent or increase costs of pumping in the near-term or long-term
- Less-than-expected recharge (either natural or managed) that would decrease groundwater availability locally or basin-wide through a combination of reduced pumping rights and reduced pumping capacity because of lower groundwater levels

The probable effect of lower-than-expected groundwater utilization would be increased utilization of supplemental water supplies, potentially resulting in higher groundwater levels and lower net recharge.

5.4.2.4 Imported Water Utilization

Imported water utilization (IWU) represents the amount of imported water that the parties use to satisfy their water demands. When projecting their expected IWU, parties evaluate both current conditions and anticipated trends. Key factors influencing these projections include:

- Cost and availability of imported water
- Imported water reliability estimates documented by the Metropolitan Water District of Southern California (MWD)
- Regional hydrologic conditions
- Water-quality challenges with their other water supplies
- Infrastructure
- Policy

IWU also depends on the volume of wet-water recharge used to satisfy replenishment obligations. Pursuant to the Judgment, Watermaster levies and collects assessments each year in amounts sufficient to purchase replenishment water to replace pumping by a Pool during the preceding year in excess of that Pool's allocated share of Safe Yield (Overlying Agricultural and ONAPs) or Operating Safe Yield (Appropriative Pool). Each party's obligation is determined after accounting for any transfers or recovery of stored water.

With Watermaster approval, parties in the Overlying Non-Agricultural and Appropriative Pools may transfer stored water and/or unused Safe Yield rights among themselves to reduce their replenishment obligations. After the end of each fiscal year, Watermaster compiles pumping and transfer data from all parties to determine the final replenishment obligations for that year.

Projected future replenishment obligations are influenced by several factors, including current and projected Safe Yield, augmentation of production rights (e.g., Reoperation credits from pumping at Chino Desalter Authority wells), and transfer activity among parties.

Factors that could lead to an increase in expected IWU include:

- MWD's successful planning and implementation of infrastructure and operations to improve imported water supply reliability greater and/or faster than expected

- Relatively wetter and cooler conditions across the western U.S. (i.e., California and the Colorado River watershed)
- The percentage of replenishment obligations met via wet-water recharge is greater than anticipated

The probable effect of higher-than-expected IWU would be to reduce groundwater pumping and increase the use of supplemental water for recharge, potentially leading to higher groundwater levels and lower net recharge.

Factors that could lead to a decrease in the expected IWU include:

- MWD's planning and implementation of infrastructure and operations necessary to improve imported water supply reliability is less and/or slower than expected
- Relatively drier and warmer conditions across the region (i.e., California and the Colorado River watershed)
- The percentage of replenishment obligations met via wet-water recharge is less than anticipated

It is important to note that MWD's planning efforts and regional hydrologic conditions are not necessarily correlated; MWD's successful planning and implementation of imported water infrastructure may still result in higher imported water availability even under drier Climate Scenarios.

The probable effect of lower-than-expected IWU would be to increase groundwater pumping and reduce the use of supplemental water for recharge, potentially leading to lower groundwater levels and higher net recharge.

5.4.3 Water Plan Scenarios

Building on the preceding analysis, three Water Plan Scenarios were formulated to bracket the plausible range of future cultural conditions (i.e., water demands, groundwater utilization, and imported water use) and to evaluate their resulting effects on net recharge and groundwater levels in the Chino Basin:

- **Expected Demand Scenario:** Represents the most likely estimate of the future water demands and the mix of water supplies required to meet them.
- **High Demand Scenario:** Assumes higher-than-expected demands, higher-than-expected groundwater utilization, and lower-than-expected IWU. This scenario results in the highest total demand and groundwater pumping, which would likely lead to lower groundwater levels and higher net recharge compared to the Expected Demand Scenario.
- **Low Demand Scenario:** Assumes lower-than-expected demands, lower-than-expected groundwater utilization, and higher-than-expected IWU. This scenario results in the lowest total demand and groundwater pumping, which would likely lead to higher groundwater levels and lower net recharge compared to the Expected Demand Scenario.

Figure 5-6 presents a flowchart illustrating the process that was used to develop the three Water Plan Scenarios and Table 5-3 summarizes the differences between the scenarios. This section describes the development of the Water Plan Scenarios.

Table 5-3. Water Plan Scenario Descriptions

Water Plan Scenario	Description			Approximate Buildout Year	Response to Conservation Regulation (Major AP Retailers)		Utilization Adjustment for Major AP Retailers[b]	Change in CDA Pumping Relative to Reference Plans	Change in Pumping for Other Parties[c] Relative to Reference Plans	Water Supply Plan (Average, 2025-2045)			Minimum Percentage of Replenishment Obligations Met with Wet-Water (Imported Water) Recharge
	Demand	Groundwater Utilization (GWU)	Imported Water Utilization (IWU)		Minimum Residential Conservation Reductions Met	Minimum CII w/ DIMs Conservation Reductions Met				Total Demand (afy)	Percentage of Demands met with Chino Basin Groundwater	Percentage of Demands met with Imported Water	
1	Expected	Expected	Expected	2040	60%	70%	0%	0%	0%	319,000	49%	22%	7%
2	High	High	Low	2037	35%	50%	+8%	0%	+5%	332,000	51%	21%	0%
3	Low	Low	High	2045	80%	90%	-8%	0%	-5%	310,000	46%	25%	20%

(a) Percentages are relative to the nominal reductions calculated for each party.
(b) Utilization adjustment is the percentage of the Chino Basin groundwater pumping (based on the party's Reference Water Plan) that is added to the pumping for each of the major AP retailers; the same volume is subtracted from imported water use.
(c) Other parties include all parties in the Overlying Ag Pool (active wells only), Overlying Non-Ag Pool, and AP parties not included in the major AP retailers.

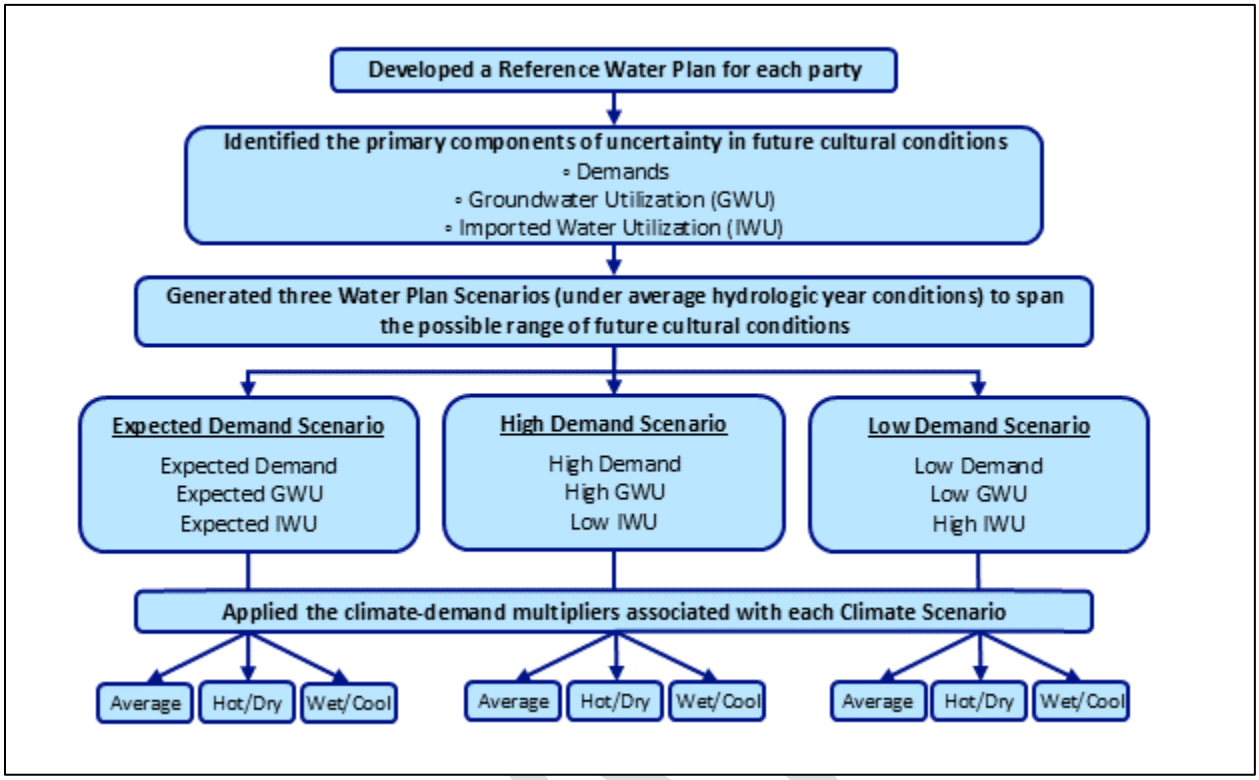


Figure 5-6. Process to Develop the Water Plan Scenarios

5.4.3.1 Response to the Conservation Regulation

To construct the three Water Plan Scenarios, we first estimated the required reductions in water demand for the major AP retailers, relative to their respective Reference Water Plans, to reflect varying levels of compliance with the Conservation Regulation. The methodology for projecting responses and calculating associated demand reductions is detailed in Appendix C and summarized below.

For each major AP retailer, nominal water use objectives were calculated for residential uses (including indoor, outdoor, and residential agriculture) and for outdoor irrigation at CII properties with DIMs. The reductions required to meet these objectives were then determined for each retailer. The total projected demand reductions needed to achieve the nominal objectives across all major AP parties are presented in Table 5-4.

Table 5-4. Reductions in Demand Required to Meet the Water Use Objectives

Water Use Objective	Reductions, afy				
	2025	2030	2035	2040	2045
Residential Uses	3,400	8,800	20,500	26,500	27,100
CII with Dims	0	5,600	12,400	18,100	18,100
Total	**3,400**	**14,400**	**32,900**	**44,600**	**45,200**

To address the uncertainty surrounding the impact of the Conservation Regulation on future water demands, we worked closely with the parties to develop three potential response scenarios, summarized in Table 5-5, that represent a range of possible outcomes. The Expected Demand Scenario represents the parties' anticipated level of compliance with the Conservation Regulation. The High Demand Scenario assumes a limited response, leading to higher-than-expected demand. The Low Demand Scenario assumes a robust response, resulting in lower-than-expected demand. Based on input from the parties, all demand reductions are assumed to result in an equivalent decrease in the use of imported water, with two exceptions: the City of Chino and the City of Upland, which indicated that all demand reductions will instead be met through decreased groundwater pumping.

Table 5-5. Summary of Conservation Regulation Responses in Water Plan Scenarios

Water Plan Scenario	Minimum percentage of the reductions required to meet nominal objectives in residential water uses	Minimum percentage of the reductions required to meet nominal objectives in CII w/DIMs	Reduction in Demand, afy				
			2025	2030	2035	2040	2045
Expected Demand	60	70	2,000	9,200	20,900	28,600	28,900
High Demand	35	50	1,200	5,900	13,300	18,300	18,500
Low Demand	80	90	2,700	12,000	27,500	37,500	38,000

5.4.3.2 Groundwater and Imported Water Utilization

Next, we adjusted GWU and IWU for the major AP retailers. For each major AP retailer, 8 percent of their Chino Basin groundwater pumping, as outlined in their Reference Water Plans, was calculated. In the High Demand Scenario (High GWU/Low IWU), this volume was shifted from imported water use to groundwater pumping. Conversely, in the Low Demand Scenario (Low GWU/High IWU), the same volume was shifted from groundwater pumping to imported water use. No changes were made to the Expected Demand Scenario.

5.4.3.3 Pumping Adjustments for Other Parties

This category encompasses all parties within the Agricultural Pool (with active wells), the ONAP, and AP parties not classified as major AP retailers. In the Expected Demand Scenario, pumping levels remained consistent with those outlined in the Reference Water Plans. For the High Demand Scenario, pumping in the Reference Water Plans was increased by 5 percent. For the Low Demand Scenario, pumping in the Reference Water Plans decreased by 5 percent.

5.4.3.4 Buildout

To address the uncertainty of the effect of the growth on demands, we adjusted the rate that demands will increase over time by varying the assumed buildout year across scenarios. The Expected Demand Scenario assumes demand increases at the same rate as in the Reference Water Plans with buildout at approximately 2040. The High Demand Scenario assumes a faster-than-expected buildout (approximately 2037). The Low Demand Scenario assumes a slower-than-expected buildout (approximately 2045).

5.4.3.5 Replenishment Obligation

Finally, varying assumptions were developed for how parties would satisfy their replenishment obligations using managed storage and imported water recharge. Managed storage is calculated based on water rights (including Safe Yield, Reoperation, supplemental water recharge, and other credits), groundwater production, and the expected behavior of the parties to satisfy replenishment obligations. A replenishment obligation arises when a party's groundwater production exceeds its production rights. Parties can satisfy this obligation either by drawing from their managed storage accounts (if available) or by paying Watermaster to procure imported water for wet-water recharge. Historical data gathered from Watermaster's Assessment Packages indicates that the parties have used managed storage to meet about 80 percent of replenishment obligations.[18]

During the scenario design process, Watermaster requested projections from the AP parties on the anticipated method to satisfy replenishment obligations. The average response of the AP parties, weighted by managed storage volume, indicated that the parties expect to satisfy about 93 percent of their replenishment obligations via use of managed storage and 7 percent via wet-water recharge. These findings were used to develop the following assumptions:

- The Expected Demand Scenario (Expected Demand/Expected GWU/Expected IWU) assumes parties will satisfy 7 percent of their obligations via wet-water recharge and 93 percent through managed storage.
- The High Demand Scenario (High Demand/High GWU/Low IWU) assumes parties will satisfy 100 percent of their obligations via managed storage.
- The Low Demand Scenario (Low Demand/Low GWU/High IWU) assumes parties will satisfy 20 percent of their obligations via wet-water recharge and 80 percent through managed storage.

If managed storage accounts are insufficient to satisfy the projected replenishment obligation, the balance will be accounted for with wet-water recharge. Projected managed storage is an iterative calculation. Initial estimates for the scenarios are refined and updated based on groundwater-flow model results, as these are necessary to project net recharge and Safe Yield. Additional details on managed storage for the Projection Scenarios are provided in Section 6.

[18] See Section 7.3.1.2 of the 2020 SYR Report

5.4.3.6 Variability of Demands due to Climate Scenarios

The projected demands in the three Water Plans described above are based on average hydrologic year conditions. When each Water Plan Scenario is combined with a Climate Scenario to form a Projection Scenario, the associated demands are further adjusted to account for the specific precipitation and ET_o patterns of that Climate Scenario. The effects of precipitation and temperature on demand are assumed to be independent. Additionally, the demand for individual supplies (e.g., Chino Basin groundwater) is expected to adjust proportionally to changes in other supplies.

5.4.3.6.1 Variability of Demands due to Precipitation

Water demands tend to vary with annual precipitation, largely due to the impact of weather on outdoor irrigation. Historical data (Figure 5-5) show that total demands can be up to 7 percent lower than average in wet years and up to 5 percent higher in dry years. In its 2020 Urban Water Management Plan (UWMP), IEUA estimated that extended dry periods (lasting three or more years) could result in demand increases of approximately 9 percent by 2040[19]. These projections are consistent with findings from other regional studies[20] and many of the 2020 UWMPs developed by the parties in Chino Basin.

Recent data and experience suggest that conservation measures, such as local or statewide mandates[21], can mitigate the typical increase in water demand during dry years. However, the demand adjustment methodology used in this analysis does not directly incorporate these potential reductions, leading to a broader plausible range in future demands. The uncertainty regarding the impact of future conservation measures is addressed by the three Water Plan Scenarios, which reflect varying levels of response to the Conservation Regulation. The potential for low-demand/dry-year scenarios is thus captured within the broader range of future conditions evaluated in the proposed Projection Scenarios.

To reflect how demand responds to changes in precipitation, the methodology applies adjustment factors, referred to as "precipitation-demand multipliers", to the projected demands under average hydrologic year conditions. These multipliers are determined based on the classification of years as Dry, Wet, or Normal, using the projected precipitation time series. Year types are defined using thresholds derived from historical annual precipitation data:

- **Dry years:** precipitation falls below the 33rd percentile.
- **Wet years**: precipitation exceeds the 66th percentile.
- **Normal years**: precipitation falls between the 33rd and 66th percentiles.

Precipitation-demand multipliers are applied based on the number of consecutive dry or wet years, as follows:

- The precipitation-demand multipliers for a single dry or wet year are 1.03 and 0.97, respectively, representing a ±3 percent change in demand.

[19] Section 2.6 of IEUA's 2020 UWMP

[20] Miro, Michelle E., David G. Groves, David Catt, and Benjamin M. Miller, Estimating Future Water Demand for San Bernardino Valley Municipal Water District. Santa Monica, CA: RAND Corporation, 2018. https://www.rand.org/pubs/working_papers/WR1288.html

[21] E.g., Executive Order N-7-22

- The precipitation-demand multipliers for a second consecutive dry or wet year are 1.06 and 0.94, respectively, representing a ±6 percent change in demand.
- The precipitation-demand multipliers for a third (or more) consecutive dry or wet year are 1.09 and 0.91, respectively, representing a ±9 percent change in demand.

Figure 5-7 demonstrates this approach applied to projected water demands in the Chino Basin under the Average Climate Scenario. The highest adjustment occurs in 2033, where demand is projected to increase by approximately 28,500 acre-feet, or 9 percent above the projected demand for an average hydrologic year. The lowest adjustment occurs in 2039 and 2050, where demand is projected to decrease by about 19,600 acre-feet, or 6 percent below the projected demand for an average hydrologic year.

5.4.3.6.2 Variability of Demands due to Temperature

Temperature drives water demands, primarily by influencing ET_o demands for irrigated landscapes and crops. IEUA estimates that a 3.6 °F increase in temperature may result in a 4.3 percent increase in demand (about 1.2 percent per °F).[22]

The parties that have developed 2020 UWMPs incorporate assumptions regarding the effects of future climate change on demand, as required by the California Water Code.[23] Accordingly, it is assumed that the Reference Water Plans already account for temperature-related impacts on demand under the Average Climate Scenario. Therefore, demands in the Water Plan Scenarios that are paired with the Average Climate Scenario were not adjusted for temperature.

For the Water Plan Scenarios paired with the Hot/Dry and Cool/Wet Climate Scenarios, the following steps were performed to account for the effect of temperature on demand:

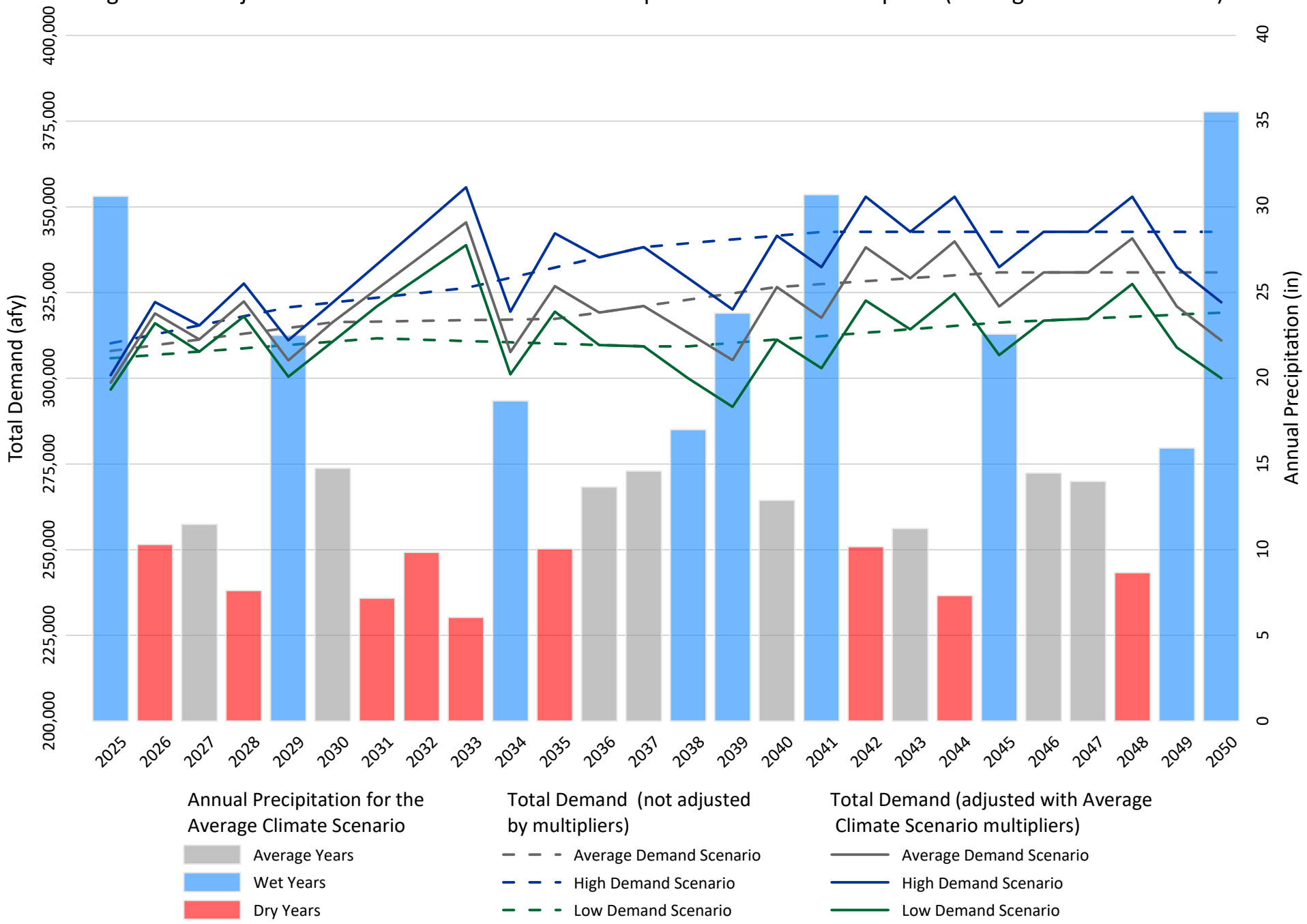
1. Conducted a regression analysis to quantify the relationship between temperature and reference ET_o. This was necessary because the R4 model uses ET_o as the sole temperature-related climate variable.
2. Estimated the average annual temperature for each year between 2024 and 2080 for each Climate Scenario based on the regression results.
3. Calculated the annual difference in temperature between the Average Climate Scenario and the Hot/Dry and Cool/Wet Climate Scenarios, respectively.
4. Adjusted demand in the Water Plan Scenarios:
    a. For the Hot/Dry Climate Scenario, demand was increased by 1.2 percent per °F difference relative to the Average Climate Scenario.
    b. For the Cool/Wet Climate Scenario, demand was decreased by 1.2 percent per °F difference relative to the Average Climate Scenario.

For the Water Plan Scenarios paired with the Hot/Dry and Cool/Wet Climate Scenarios, demands are projected to change by approximately ±1.5 percent by 2050, and up to ±2.8 percent by 2080.

[22] Table 2-3 of IEUA's 2015 IRP

[23] Appendix I. Considering Climate Change Impacts (ca.gov)

Figure 5-7. Projected Chino Basin Demands with Precipitation-Demand Multipliers (Average Climate Scenario)



5.4.3.7 Comparison of Water Plan Scenarios

Tables 5-6a, 5-6b, and 5-6c show the aggregate Water Plans for the three Water Plan Scenarios under average hydrologic year conditions (i.e., without applying multipliers for interannual variability in precipitation or ET). Individual Water Plans Scenarios for each of the nine major AP retailers are included in Appendix C. The key differences between the Scenarios are summarized below.

5.4.3.7.1 Demand

Figure 5-8 shows the projected total demand for the three Water Plan Scenarios under average hydrologic year conditions, compared to the 2020 SYR projections and the Reference Water Plans. The projected demand ranges for each scenario are as follows:

- Expected Demand Scenario: 308,000 af to 331,000 af
- High Demand Scenario: 310,000 af to 343,000 af
- Low Demand Scenario: 306,00 af to 316,000 af

5.4.3.7.2 Groundwater Utilization

Figure 5-9 shows the total projected Chino Basin groundwater pumping for the three Water Plan Scenarios under average hydrologic year conditions, alongside the 2020 SYR projections and the Reference Water Plans. Table 5-7 shows the historical and projected future pumping by party and scenario, also based on average hydrologic year conditions.

The projected range of Chino Basin GWU and the corresponding percentages of total demand met by groundwater for each scenario are as follows:

- Expected Demand Scenario (expected GWU):
  147,000 af (48 percent) to 163,000 af (49 percent)
- High Demand Scenario (greater-than-expected GWU):
  154,000 af (50 percent) to 177,000 af (52 percent)
- Low Demand Scenario (less-than-expected GWU):
  139,000 af (46 percent) to 148,000 af (47 percent)

5.4.3.7.3 Imported Water Utilization

Figure 5-10 shows the projected IWU for the three Water Plan Scenarios under average hydrologic year conditions, alongside the 2020 SYR projections and the Reference Water Plans. The projected range of IWU and the corresponding percentages total demand met by imported water for each scenario are as follows:

- Expected Demand Scenario (expected IWU):
  71,000 af (23 percent) to 73,000 af (22 percent)
- High Demand Scenario (less-than-expected IWU):
  65,000 af (21 percent) to 70,000 af (21 percent)
- Low Demand Scenario (greater-than-expected IWU):
  76,000 af (24 percent) to 78,000 af (25 percent)

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Table 5-6a. Aggregate Water Plans for the Expected Demand Scenario (Expected Demands, Expected Groundwater Utilization, Expected Imported Water Utilization)

Category	2025	2030	2035	2040	2045
Volume (afy)					
Chino Basin Groundwater	146,986	153,496	153,822	160,673	163,434
Non-Chino Basin Groundwater	51,317	51,032	50,586	50,652	50,878
Local Surface Water	13,154	13,154	13,154	13,118	13,154
Imported Water	71,398	71,583	71,376	72,198	72,925
Recycled Water for Direct Use	25,091	27,088	28,385	29,982	30,482
Total	307,946	316,353	317,323	326,624	330,873
Percentage					
Chino Basin Groundwater	48%	49%	48%	49%	49%
Non-Chino Basin Groundwater	17%	16%	16%	16%	15%
Local Surface Water	4%	4%	4%	4%	4%
Imported Water	23%	23%	22%	22%	22%
Recycled Water for Direct Use	8%	9%	9%	9%	9%
Total	100%	100%	100%	100%	100%

Table 5-6b. Aggregate Water Plans for the High Demand Scenario (High Demands, High Groundwater Utilization, Low Imported Water Utilization)

Category	2025	2030	2035	2040	2045
Volume (afy)					
Chino Basin Groundwater	154,306	162,948	169,251	175,976	176,797
Non-Chino Basin Groundwater	52,262	51,959	51,720	51,919	51,972
Local Surface Water	13,154	13,154	13,136	13,145	13,154
Imported Water	65,366	66,631	69,015	70,192	70,288
Recycled Water for Direct Use	25,091	27,412	29,184	30,357	30,482
Total	310,179	322,105	332,306	341,589	342,693
Percentage					
Chino Basin Groundwater	50%	51%	51%	52%	52%
Non-Chino Basin Groundwater	17%	16%	16%	15%	15%
Local Surface Water	4%	4%	4%	4%	4%
Imported Water	21%	21%	21%	21%	21%
Recycled Water for Direct Use	8%	9%	9%	9%	9%
Total	100%	100%	100%	100%	100%

Table5-6c. Aggregate Water Plans for the Low Demand Scenario (Low Demands, Low Groundwater Utilization, High Imported Water Utilization)

Category	2025	2030	2035	2040	2045
Volume (afy)					
Chino Basin Groundwater	139,427	142,583	142,887	144,146	147,907
Non-Chino Basin Groundwater	50,447	50,598	50,054	49,644	49,694
Local Surface Water	13,154	13,154	13,154	13,144	13,118
Imported Water	77,724	77,591	76,389	75,523	75,562
Recycled Water for Direct Use	25,091	26,755	27,829	28,841	29,982
Total	305,843	310,681	310,314	311,298	316,263
Percentage					
Chino Basin Groundwater	46%	46%	46%	46%	47%
Non-Chino Basin Groundwater	16%	16%	16%	16%	16%
Local Surface Water	4%	4%	4%	4%	4%
Imported Water	25%	25%	25%	24%	24%
Recycled Water for Direct Use	8%	9%	9%	9%	9%
Total	100%	100%	100%	100%	100%

Table 5-7 Historical and Projected Pumping for the Chino Basin Parties
(afy)

Party	Historical Pumping													Projected Pumping - Expected Demand, Expected GWU, Expected IWU[a]					Projected Pumping - Low Demand, Low GWU, High IWU						Projected Pumping - High Demand, High GWU, Low IWU				
											Statistics (2019-2023)																		
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Min	Max	Mean	2025	2030	2035	2040	2045	2025	2030	2035	2040	2045	2051	2025	2030	2035	2040	2045
Agricultural Pool																													
Aggregate Agricultural Pool Pumping	22,063	17,361	16,904	17,786	18,827	15,652	15,793	15,022	14,159	11,343	11,343	15,793	14,394	11,081	8,607	6,744	5,249	4,000	10,527	8,568	7,165	6,001	4,987	3,800	11,635	8,548	6,296	4,528	4,200
Overlying Non-Agricultural Pool																													
9W Halo Western OpCo L.P.	37	26	28	20	21	23	26	29	27	26	23	29	26	26	26	26	26	26	25	25	25	25	25	25	27	27	27	27	27
California Speedway Corporation	436	454	300	410	438	389	427	388	403	274	274	427	376	274	274	274	274	274	260	260	260	260	260	260	288	288	288	288	288
California Steel Industries, Inc.	1,417	1,279	1,187	1,298	1,266	1,419	1,065	1,302	671	1,058	671	1,419	1,103	1,103	1,103	1,103	1,103	1,103	1,048	1,048	1,048	1,048	1,048	1,048	1,158	1,158	1,158	1,158	1,158
General Electric Company	1,626	1,355	917	1,667	957	1,320	784	1,018	647	809	647	1,320	916	916	916	916	916	916	870	870	870	870	870	870	961	961	961	961	961
GenOn California South, LP	290	221	204	211	212	18	2	0	0	0	0	18	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Riboli Family and San Antonio Winery, Inc.	10	7	4	5	6	26	26	43	16	2	2	43	22	22	22	22	22	22	21	21	21	21	21	21	24	24	24	24	24
TAMCO	18	29	30	25	18	10	20	15	2	0	0	20	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal Overlying Non-Agricultural Pool Pumping	*3,834*	*3,371*	*2,670*	*3,636*	*2,919*	*3,204*	*2,350*	*2,795*	*1,767*	*2,168*	*1,618*	*3,277*	*2,457*	*2,341*	*2,341*	*2,341*	*2,341*	*2,341*	*2,224*	*2,224*	*2,224*	*2,224*	*2,224*		*2,458*	*2,458*	*2,458*	*2,458*	*2,458*
Appropriative Pool																													
BlueTriton Brands, Inc.	379	426	356	367	308	285	279	271	252	277	252	285	273	273	273	273	273	273	259	259	259	259	259	259	286	286	286	286	286
Chino, City Of	6,725	6,546	5,010	4,972	5,162	4,315	5,173	6,133	6,193	5,569	4,315	6,193	5,477	7,348	10,008	10,381	10,946	12,935	6,760	8,605	8,966	9,048	9,268	10,775	7,642	10,834	11,811	14,035	14,641
Chino Hills, City Of	7,522	3,745	1,633	2,246	2,839	1,608	1,472	2,529	2,694	2,218	1,472	2,694	2,104	2,315	2,315	2,315	2,315	2,315	2,130	2,130	2,130	2,130	2,130	2,130	2,500	2,500	2,500	2,500	2,500
Norco, City Of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ontario, City Of	21,980	17,676	22,849	24,840	26,280	20,722	18,395	21,751	19,670	16,933	16,933	21,751	19,494	26,358	29,612	30,222	37,187	37,187	24,249	26,508	27,066	28,913	33,333	33,333	28,467	32,544	37,234	41,116	41,116
Pomona, City Of	12,909	12,520	9,964	8,067	9,286	10,840	10,551	9,192	10,184	10,197	9,192	10,840	10,193	10,858	11,685	12,543	13,376	14,238	9,989	10,623	11,201	11,759	12,306	13,099	11,727	12,851	13,996	15,144	15,377
Upland, City Of	2,822	3,416	2,601	1,260	1,764	2,381	2,449	2,177	1,473	808	808	2,449	1,858	3,133	2,808	2,232	1,979	2,005	2,799	2,444	1,938	1,516	1,277	1,312	3,519	3,219	2,876	2,808	2,812
Cucamonga Valley Water District	16,122	14,640	20,537	16,562	6,838	9,624	23,318	26,226	27,281	13,515	9,624	27,281	19,993	13,900	13,400	12,400	10,400	10,400	13,333	12,853	12,201	11,237	9,868	9,868	14,467	13,786	11,974	10,932	10,932
Fontana Water Company	15,378	13,344	15,317	13,250	11,392	9,961	10,427	13,565	16,387	8,721	8,721	16,387	11,812	9,278	9,983	11,128	12,293	13,183	8,536	9,076	9,786	10,544	11,310	12,128	10,020	11,091	12,647	13,997	14,238
Jurupa Community Services District	18,407	12,805	9,284	11,498	15,286	13,894	12,760	11,161	12,094	7,522	7,522	13,894	11,486	10,131	12,414	13,011	14,002	14,002	9,408	10,016	10,568	11,041	11,417	10,723	10,858	13,967	16,118	16,880	16,880
Marygold Mutual Water Company	1,315	1,250	753	619	944	950	860	841	944	560	560	950	831	1,322	1,403	1,484	1,565	1,727	1,256	1,320	1,377	1,432	1,487	1,641	1,388	1,494	1,601	1,771	1,813
Monte Vista Irrigation Company	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monte Vista Water District[b]	7,163	7,402	8,371	7,086	6,483	6,631	6,710	7,674	7,185	5,293	5,293	7,674	6,699	6,500	6,500	6,500	6,500	6,500	5,980	5,980	5,980	5,980	5,980	5,980	7,020	7,020	7,020	7,020	7,020
Niagara Bottling, LLC	1,343	1,860	1,775	1,532	1,571	1,683	1,760	1,752	1,684	1,401	1,401	1,760	1,656	1,656	1,656	1,656	1,656	1,656	1,573	1,573	1,573	1,573	1,573	1,573	1,739	1,739	1,739	1,739	1,739
San Antonio Water Company	1,159	1,479	1,031	538	428	376	614	677	402	459	376	677	506	592	592	592	592	592	562	562	562	562	562	562	622	622	622	622	622
San Bernardino, County of (Shooting Park)	16	11	9	13	11	11	8	17	20	18	8	20	15	15	15	15	15	15	14	14	14	14	14	14	16	16	16	16	16
Santa Ana River Water Company	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Golden State Water Company	736	720	807	850	148	0	640	1,074	1,066	922	0	1,074	740	800	800	900	900	980	696	696	746	783	783	853	904	932	1,017	1,085	1,107
West End Consolidated Water Company	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Valley Water District	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal Appropriative Pool Pumping	*113,976*	*97,842*	*100,297*	*93,699*	*88,740*	*83,280*	*95,418*	*105,040*	*107,529*	*74,412*	*74,412*	*107,529*	*93,136*	*94,479*	*103,464*	*105,652*	*113,999*	*118,008*	*87,546*	*92,661*	*94,368*	*96,791*	*101,566*	*104,250*	*101,174*	*112,903*	*121,458*	*129,952*	*131,100*
Chino Desalter Authority																													
Total Desalter Pumping[c]	29,282	30,022	28,191	28,284	30,088	31,233	35,630	40,156	40,566	39,815	31,233	40,566	37,480	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000
Total Pumping	169,155	148,596	148,061	143,405	140,574	133,368	149,190	163,013	164,021	127,737	118,605	167,165	147,466	147,902	154,412	154,738	161,589	164,349	140,297	143,453	143,757	145,016	148,777	148,050	155,267	163,910	170,213	176,938	177,758
Less GE Injection	-1,626	-1,355	-917	-1,667	-957	-1,320	-784	-1,018	-647	-809	-1,320	-647	-916	-916	-916	-916	-916	-916	-870	-870	-870	-870	-870	-870	-961	-961	-961	-961	-961
Projected Net Total Basin Pumping														146,986	153,496	153,822	160,673	163,434	139,427	142,583	142,887	144,146	147,907	147,180	154,306	162,948	169,251	175,976	176,797
2020 SYR Projected Net Total Basin Pumping														144,596	151,808	164,600	173,805	173,805	144,596	151,808	164,600	173,805	173,805	173,806	144,596	151,808	164,600	173,805	173,805
Change in Projected Net Total Basin Pumping from the 2020 SYR														2,390	1,688	-10,778	-13,132	-10,371	-5,169	-9,225	-21,713	-29,659	-25,898	-26,626	9,710	11,140	4,651	2,171	2,992

[a] GWU = Groundwater utilization; IWU = Imported water utilization

[b] Projected pumping includes projected wholesale deliveries to Chino Hills originating from MVWD wells and assumes that MVWD does not pump any of Chino Hills' pumping rights via MVWD wells.

[c] Includes pumping from San Bernardino County wells that will come online in FY 2026 to remediate the Chino Airport plume and supplement Desalter Pumping.

Figure 5-8. Total Demands for Water Plan Scenarios

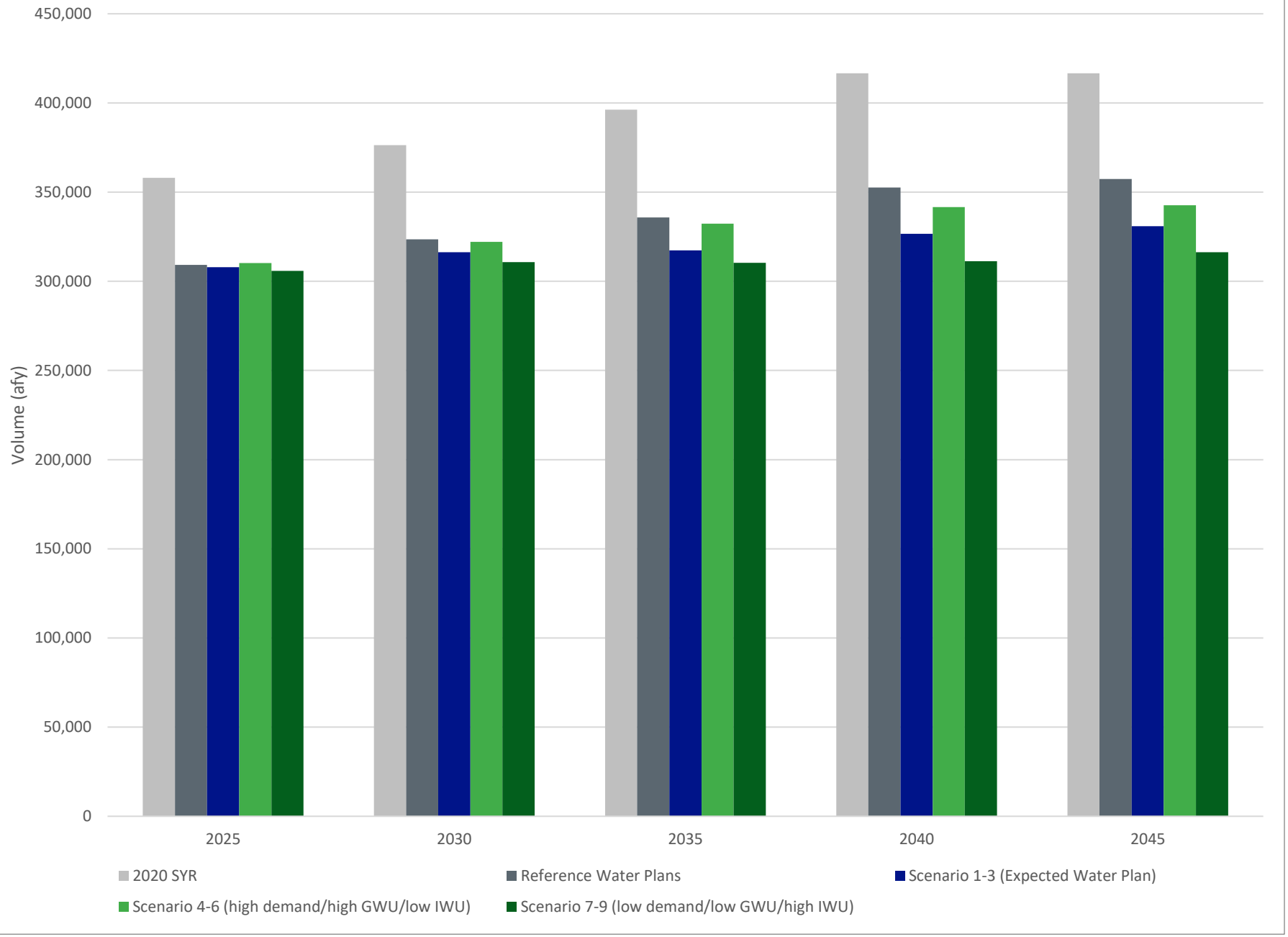


Figure 5-9. Total Chino Basin Groundwater Pumping Demands for Water Plan Scenarios

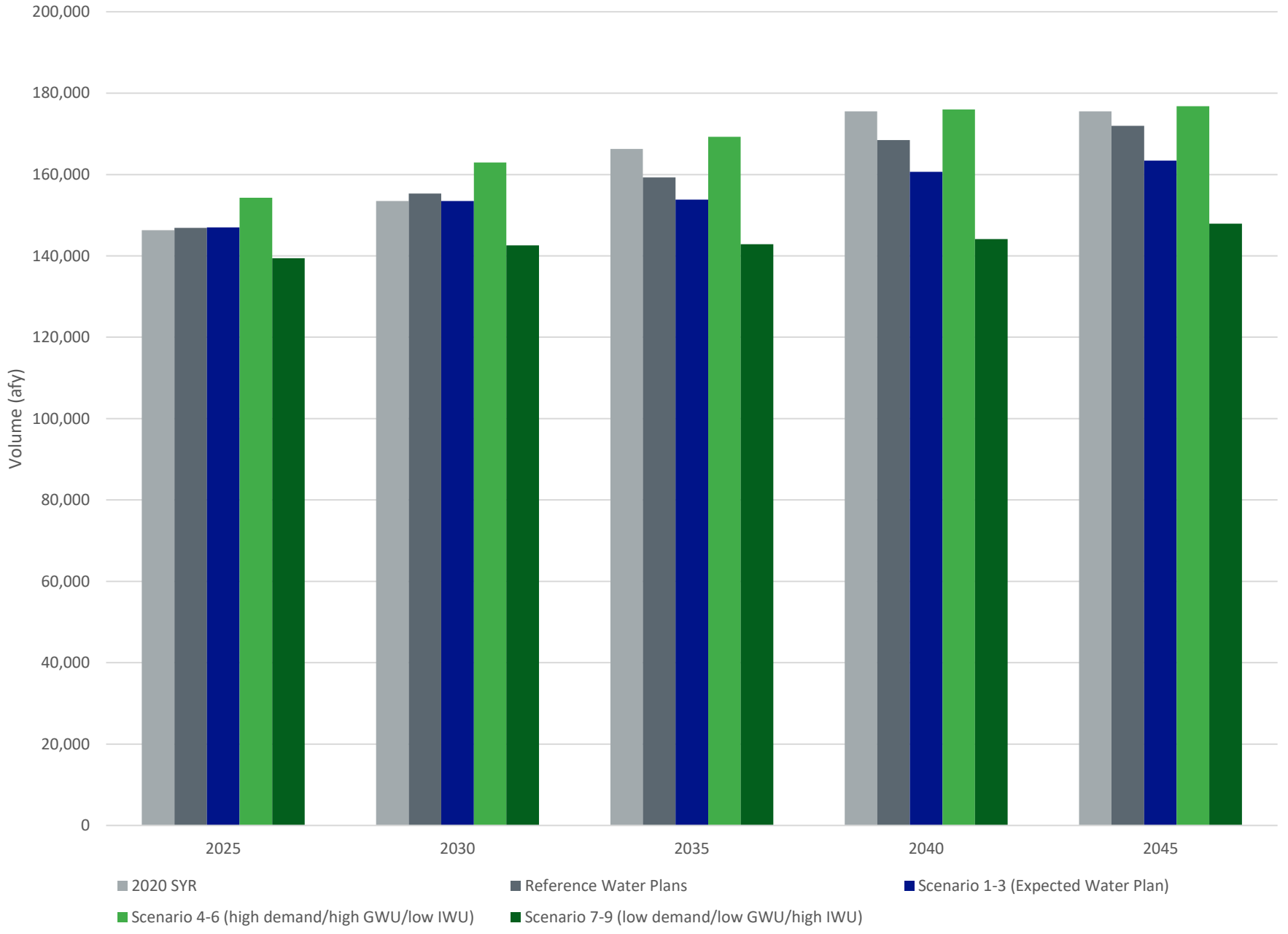
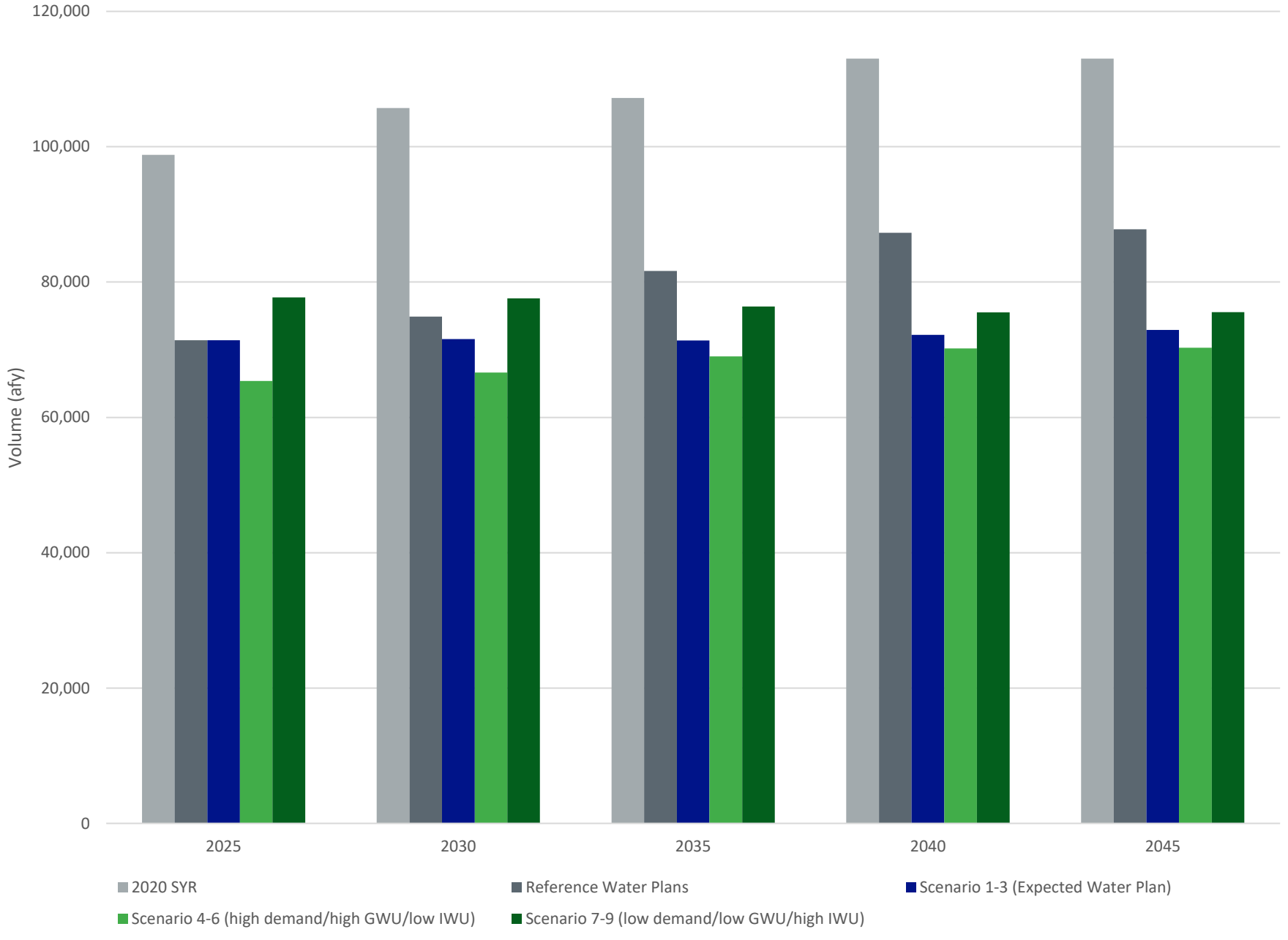


Figure 5-10. Total Imported Water Demands for Water Plan Scenarios



5.5 SUMMARY OF PROJECTION ENSEMBLE

Table 5-8 summarizes the nine Projection Scenarios, each representing a unique combination of three Climate Scenarios and three Water Plan Scenarios. These scenarios are designed to capture a broad range of plausible future conditions related to demand, groundwater utilization, and IWU.

Table 5-8. Projection Ensemble

Projection Scenario	Rationale	Water Plan Scenario[a]			Climate Scenario
		Demand	Groundwater Utilization	Imported Water Utilization	
1	Expected/Baseline	Expected	Expected	Expected	Average
2	Hot/Dry Climate	Expected	Expected	Expected	Hot/dry
3	Cool/Wet Climate	Expected	Expected	Expected	Cool/wet
4	Impact Of High Demands	High	High	Low	Average
5	Low Groundwater Levels	High	High	Low	Hot/dry
6	High Net Recharge	High	High	Low	Cool/wet
7	Impact Of Low Demands	Low	Low	High	Average
8	Low Net Recharge	Low	Low	High	Hot/dry
9	High Groundwater Levels	Low	Low	High	Cool/wet

(a) Each Water Plan Scenario is adjusted to reflect the unique precipitation and evapotranspiration (ET_o) patterns of the corresponding Climate Scenario as described in Section 5.4.3.2.

Scenario 1 serves as the "baseline" scenario and reflects expected conditions for both Water Plans and average future climate/hydrology.

Scenarios 2 and 3 modify the baseline to isolate the impacts of climate variability. Scenario 2 evaluates the effects of a hotter/drier climate, while Scenario 3 simulates a cooler and wetter future. Together, these scenarios characterize the influence of climatic uncertainty on net recharge and groundwater levels.

Scenarios 4 and 7 focus on the effects of future uncertainty in Water Plans, specifically how changes in demand and supply portfolios influence groundwater pumping, net recharge, and groundwater levels. Scenario 4 assumes high demands and high groundwater utilization with low IWU. Scenario 7 assumes low demands and low groundwater utilization with high IWU. Both scenarios use the average climate conditions.

Scenarios 5 and 9 explore the potential range of future groundwater levels. Scenario 5 represents a worst-case combination of high demand, high groundwater utilization, low IWU, and a hot/dry climate, likely resulting in the lowest groundwater levels. Conversely, Scenario 9 combines low demand, low groundwater utilization, high IWU, and a cool/wet climate, which is expected to result in the highest groundwater levels.

Scenarios 6 and 8 examine the plausible range in net recharge. Scenario 6, with high demands, high groundwater utilization, low IWU, and a Cool/wet climate, is likely to yield the highest net recharge of any Projection Scenario. Scenario 8 represents the opposite, with low demands, low groundwater utilization, high IWU, and a hot/dry climate, likely producing the lowest net recharge of any Projection Scenario.

Other combinations of Water Plan and Climate Scenarios are not expected to result in conditions (e.g., net recharge or groundwater levels) beyond the range captured by these nine scenarios.

5.6 LIKELIHOODS

Step 5 of the 2022 Safe Yield Reset Methodology directs Watermaster to "[a]ssign likelihoods to each scenario in the Projection Ensemble." This step acknowledges that not all Projection Scenarios have the same probability of occurrence, and that the simulated Basin responses should be evaluated within this probabilistic context. For example, if a single Projection Scenario with a low likelihood of occurrence is projected to result in MPI, it may warrant less concern than a higher-likelihood scenario with a similar impact.

To incorporate scenario likelihoods into the analysis, scalar weighting factors are applied independently to the Water Plan Scenario and Climate Scenario components of each Projection Scenario. If all scenarios are considered equally likely, each component is assigned a weight of 1. If a component is believed to be twice as likely as another, it is assigned a weight of 2. The total likelihood weight for each Projection Scenario is calculated as the product of the Water Plan Scenario weight and the Climate Scenario weight.

The Expected Demand Water Plan Scenario (which includes expected demand, expected groundwater utilization and expected IWU) is considered more likely than either the High Demand or Low Demand Water Plan Scenarios. Therefore, a scalar weight of 2 is applied to the Expected Demand Water Plan Scenario (Projection Scenarios 1, 2, and 3), while a weight of 1 is applied to the High and Low Demand Water Plan Scenarios (Projection Scenarios 4 through 9). This implies that the Expected Demand Water Plan Scenario is twice as likely to occur as either the High or Low Demand Water Plan Scenarios occurring.

Similarly, the Average Climate Scenario is considered more likely than the Hot/Dry or Cool/Wet Climate alternatives. A scalar weight of 2 is assigned to the Average Climate Scenario, and a weight of 1 is assigned to both the Hot/Dry and Cool/Wet Climate Scenarios.

Table 5-9 summarizes the Projection Ensemble with the assigned likelihood weights. The total likelihood weight for each Projection Scenario is the product of its assigned Water Plan Scenario weight and Climate Scenario weight. For example, Scenario 1, which includes the Expected Demand Water Plan Scenario and the Average Climate Scenario, is assigned a total weight of 4 (Water Plan weight of 2 times Climate Scenario weight of 2).

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Table 5-9. Projection Ensemble with Likelihood Weights

Projection Scenario	Water Plan Scenario			Climate Scenario	Likelihood Weights		
	Demand	Groundwater Utilization	IWU		Water Plan Scenario (a)	Climate Scenario (b)	Total (c) = (a) * (b)
1	Expected	Expected	Expected	Average	2	2	4
2	Expected	Expected	Expected	Hot/dry	2	1	2
3	Expected	Expected	Expected	Cool/wet	2	1	2
4	High	High	Low	Average	1	2	2
5	High	High	Low	Hot/dry	1	1	1
6	High	High	Low	Cool/wet	1	1	1
7	Low	Low	High	Average	1	2	2
8	Low	Low	High	Hot/dry	1	1	1
9	Low	Low	High	Cool/wet	1	1	1

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SECTION 6
2025 Determination of Tentative Safe Yield

6.1 BACKGROUND AND METHODS

Sections 6 and 7 present the findings of the 2025 Safe Yield Reevaluation and document the execution of Steps 6 through 9 of the 2022 SYRM:

6. *Simulate the range for the potential future water budget and groundwater conditions in the Chino Basin over no less than a 50-year future period. This is accomplished by using:*
   i. *The range of calibrated models [i.e., the chosen calibrated realizations], and*
   ii. *The Projection Ensemble as model input data.*
7. *Using the results of [6.] above, characterize the range in the model results for:*
   i. *Groundwater conditions, including: groundwater elevations, groundwater in storage, and groundwater flow directions, and*
   ii. *The water budget, including: basin inflows, outflows, change in storage, and net recharge.*
8. *Using the set of net recharge results from [7.ii], determine a Tentative Safe Yield as the likelihood-weighted average net recharge over the 10-year prospective period for which the Safe Yield is being redetermined (Tentative Safe Yield).*
9. *Evaluate whether the groundwater production at the Tentative Safe Yield estimated in [8] above will cause or threaten to cause "undesirable results" or "Material Physical Injury." If groundwater production at Tentative Safe Yield will cause or threaten to cause "undesirable results" or "Material Physical Injury," then Watermaster will identify and implement prudent measures necessary to mitigate "undesirable results" or "Material Physical Injury," set the value of Safe Yield to ensure there is no "undesirable results" or "Material Physical Injury," or implement a combination of mitigation measures and a changed Safe Yield.*

Section 6 describes the methods to implement Steps 6 through 9 and the results of Steps 6 through 8. Section 7 describes the results and conclusions of the execution of Step 9, including the determination of the viability of groundwater production at the Tentative Safe Yield (TSY).

6.1.1 Methods

Figure 6-1 shows a flowchart of Steps 6 through 9 of the 2022 SYRM. Steps 6 through 8 include the simulation of the Initial and TSY Ensemble and the calculation of the TSY for the 10-year period (FY 2021-2030). The assumed Safe Yield of the Chino Basin is a factor that determines the projections for managed storage, and therefore the imported wet-water recharge that is used to satisfy replenishment obligations when groundwater production exceeds production rights. Imported water recharge, in turn, impacts the water budget and groundwater levels in the Chino Basin, impacting net recharge and Safe Yield calculations for future decades. This feedback loop of net recharge, Safe Yield, managed storage, and imported water recharge requires that the modeling process be iterative to result in a stable net recharge volume. The Initial Projection Ensemble is necessary to ensure the TSY converges to a stable value to use in the TSY Ensemble. The managed storage for all realizations of the Initial Projection Ensemble assumes that managed storage is identical to historical managed storage through FY 2024, when the total balance was about 709,000 af.

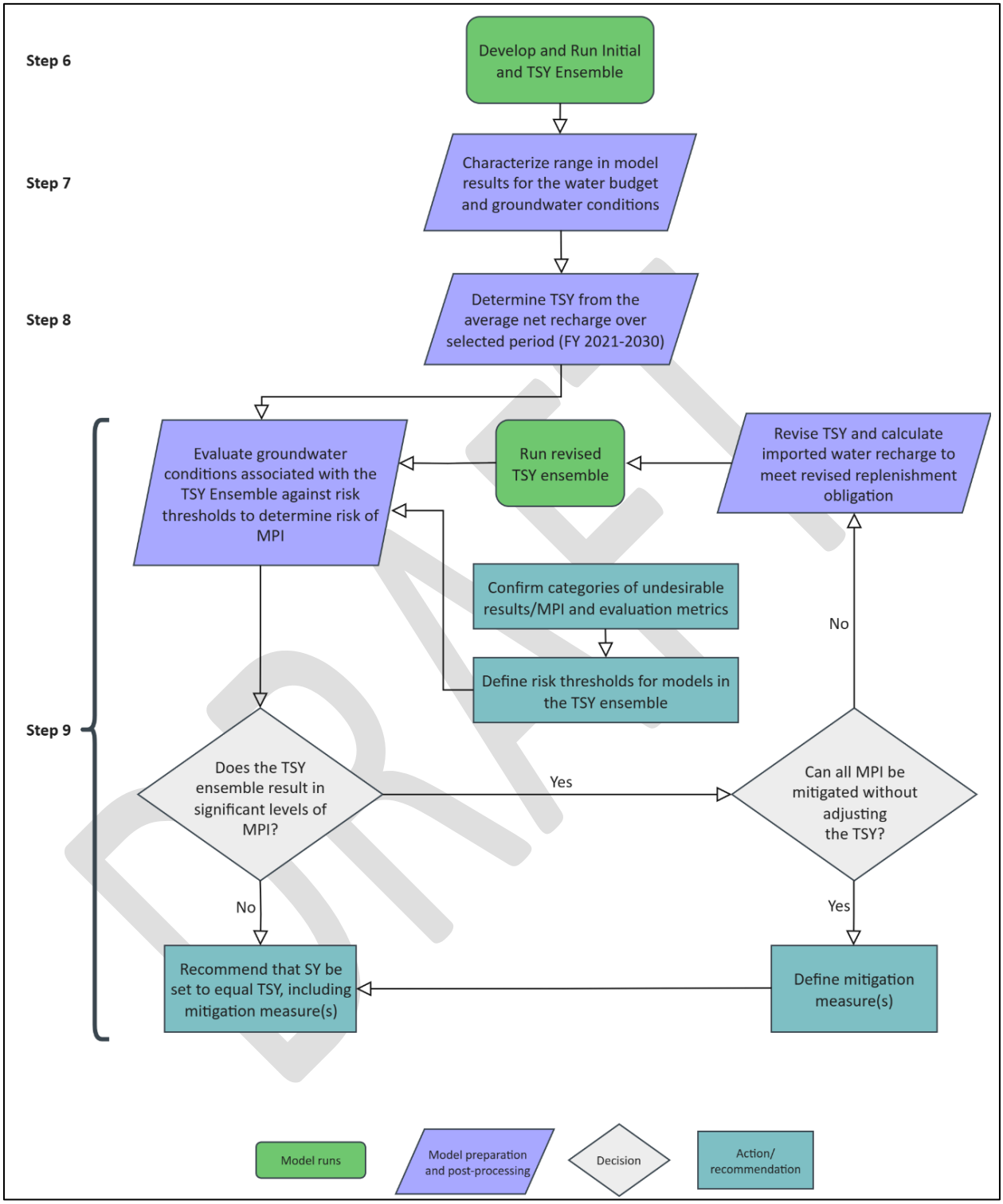

Figure 6-1. Flowchart Characterizing Steps 6 through 9 of 2022 Safe Yield Reset Methodology

6.1.2 Development of the TSY Ensemble

The TSY Ensemble is identical to the Initial Projection Ensemble except for revised calculations of managed storage and imported water recharge. Managed storage must be calculated using the TSY for FY 2021-2030 to calculate the imported water recharge to meet any replenishment obligations in FY 2021-2030.

6.1.2.1 Managed Storage

Managed storage for the TSY Ensemble is calculated using the following assumptions:

- Managed storage for all Projection Realizations is identical to the historical managed storage through FY 2024, when the managed storage was about 709,000 af. This includes about 45,900 af in the balance of the DYYP.
- Pumping of water in the DYYP accounts is assumed to occur in FY 2026 through 2028, leaving a zero balance in the DYYP account at the end of FY 2028.
- For all Projection Realizations in the TSY Ensemble, the Safe Yield assumed for FY 2021-2030 is the TSY.
- For subsequent decades, the Safe Yield is assumed to be the average net recharge for that decade in that projection realization.
- Recycled water recharge is assumed to occur as projected by the IEUA as of 2023—16,850 afy of recharge.
- Reoperation water is allocated to the replenishment of desalter production, as provided in the Peace II Agreement and by a 2017 agreement among members of the AP following Court approval of the Safe Yield in 2017. Reoperation water will be allocated to the replenishment of desalter production through 2030.
- Managed storage is calculated based on comparing aggregate pumping to aggregate pumping rights; that is, individual parties' rights and replenishment obligations are not calculated. If aggregate pumping is greater than aggregate pumping rights, the difference is the replenishment obligation. This is handled as follows:
  - If aggregate pumping rights are greater than the projected aggregate pumping, then the under-pumping is credited to storage accounts and there is no wet-water recharge for replenishment.
  - If projected aggregate pumping exceeds aggregate pumping rights, a replenishment obligation exists. 80 to 100 percent of this obligation is debited from managed storage accounts, with the remainder fulfilled by wet-water recharge. The percentage debited to managed storage accounts is determined by the scenario (see Section 5).
  - If the calculated debit to managed storage accounts for the replenishment obligation exceeds available managed storage, the shortfall is added to wet-water recharge. For instance, a 30,000 af debit with only 20,000 af of managed storage available means 10,000 af will be added to wet-water recharge, leaving zero managed storage.

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Figure 6-2 shows the projected managed storage for the TSY Ensemble, depicting the range of projected managed storage due to the demand scenarios under the Expected Climate Scenario (i.e., Scenarios 1, 4, and 7), with the range between them shown in dark purple. The lighter purple shading encompasses the total range of projected managed storage for the entire TSY Ensemble.

At the end of FY 2030, total managed storage ranges from 490,000 af (Scenario 5) to 647,000 af (Scenario 9), with Scenario 1 resulting in about 574,000 af of managed storage. In Scenario 5 (High Demand, High GWU, Low IWU, Hot/Dry Climate), managed storage is projected to reach zero at around 2042. By 2050, total managed storage ranges from 0 (Scenarios 4 through 6) to 453,000 af (Scenario 9), with Scenario 1 resulting in about 152,000 af.

6.1.2.2 Imported Water Recharge

The only imported water recharge assumed in the TSY Ensemble in the Chino Basin is wet-water recharge due to replenishment obligations. For each year a replenishment obligation is accrued, the calculated volume of imported water recharge is assumed to occur in the following year. Imported water recharge is allocated to recharge basins for each month based on (1) the recommended pattern of supplemental recharge described in the 2023 Recharge Master Plan Update[1] (2023 RMPU) and (2) the assumed monthly availability of the recharge basins due to the competing uses of stormwater and recycled water recharge.

Section 6.4 of the 2023 RMPU included a recommendation for Watermaster to prioritize supplemental water recharge in the basins in OBMP Management Zone 1 (MZ-1) up to its recharge capacity, then to MZ-3, and finally to MZ-2. The distribution of recharge was calculated monthly until all imported water was allocated to recharge basins for the year.

Figures 6-3, 6-4, and 6-5 show the projected imported water recharge and managed storage for Scenarios 1, 5, and 9, respectively, showing the scenarios with the central tendency (Scenario 1), highest (Scenario 5), and lowest (Scenario 9) imported water recharge. The highest one-year imported water recharge occurs in Scenario 5 in FY 2073, where 50,500 af of imported water was recharged to satisfy the replenishment obligation that accrued in FY 2072.

6.2 RESULTS OF TSY ENSEMBLE

This subsection describes the range of projected groundwater conditions associated with the results of the TSY Ensemble. The naming convention to identify each member of the TSY Ensemble is the letter of the CVM realization (A through E) followed by the number of the Projection Scenario (1 through 9). Table 6-1 below lists the nine Projection Scenarios.

[1] 2023 Recharge Master Plan Update

Figure 6-2
Projected Managed Storage
2020 SYR and 2025 SYR

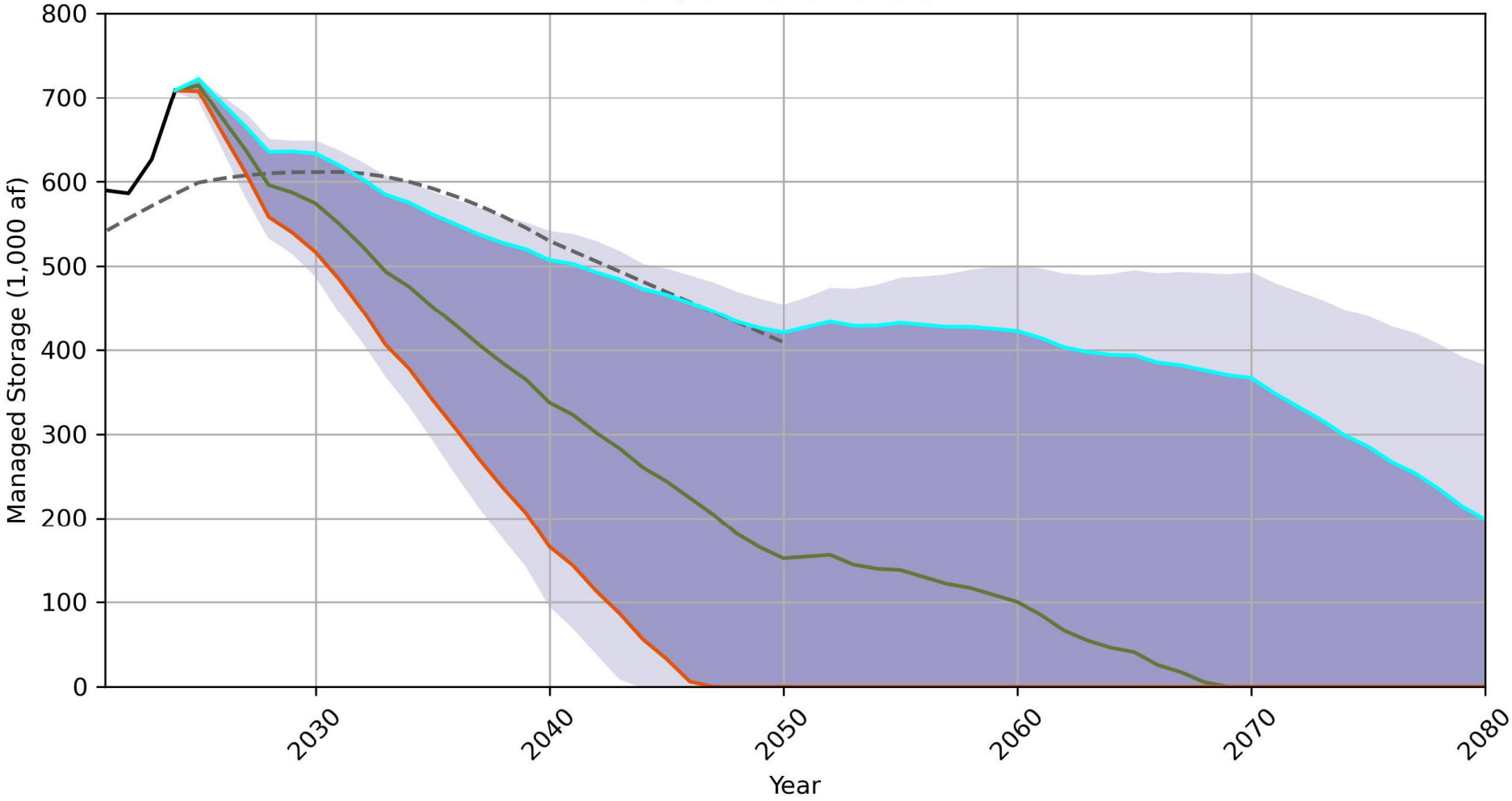

Figure 6-3. Projected Imported Water Recharge, TSY Ensemble Scenario 1

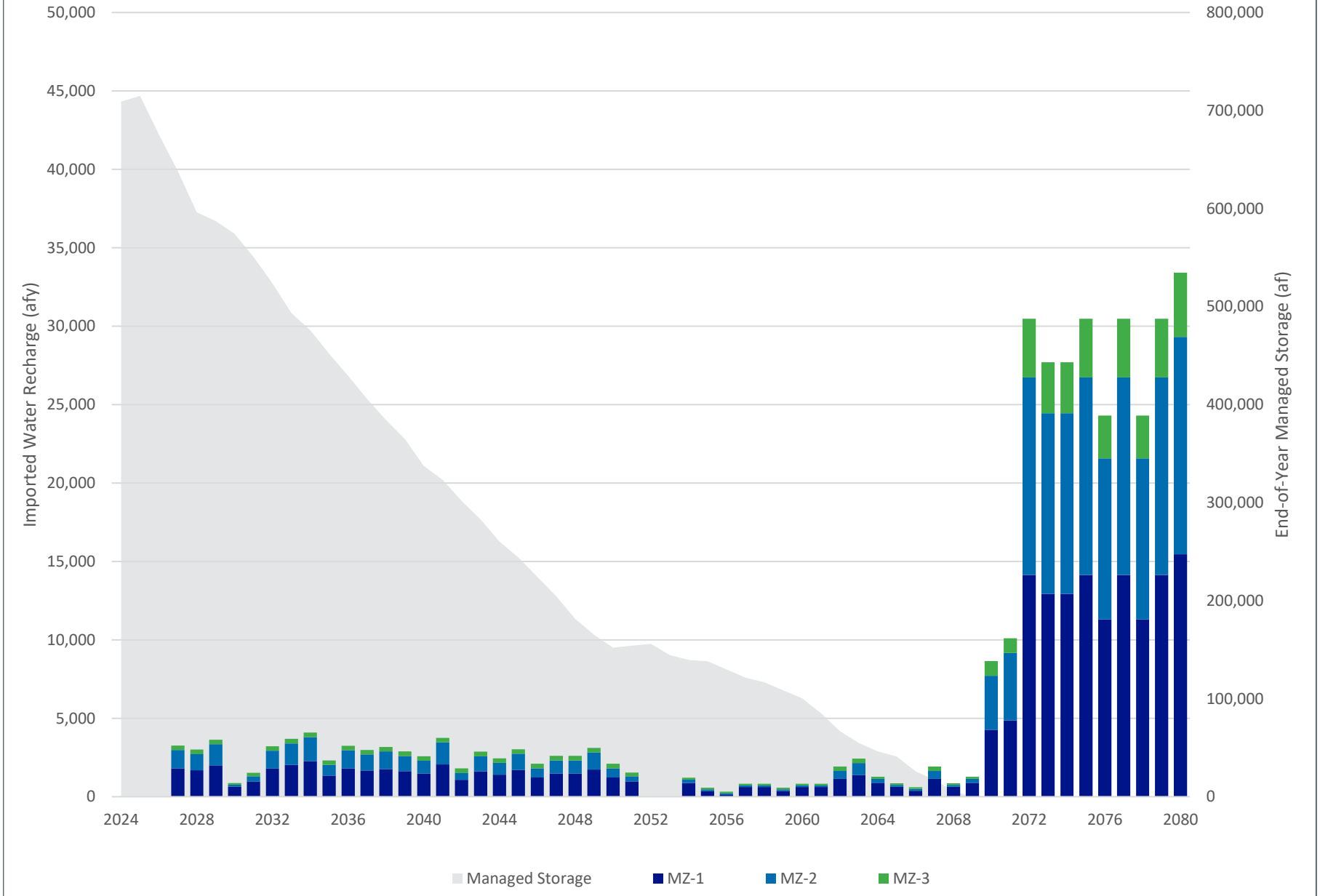

Figure 6-4. Projected Imported Water Recharge, TSY Ensemble Scenario 5

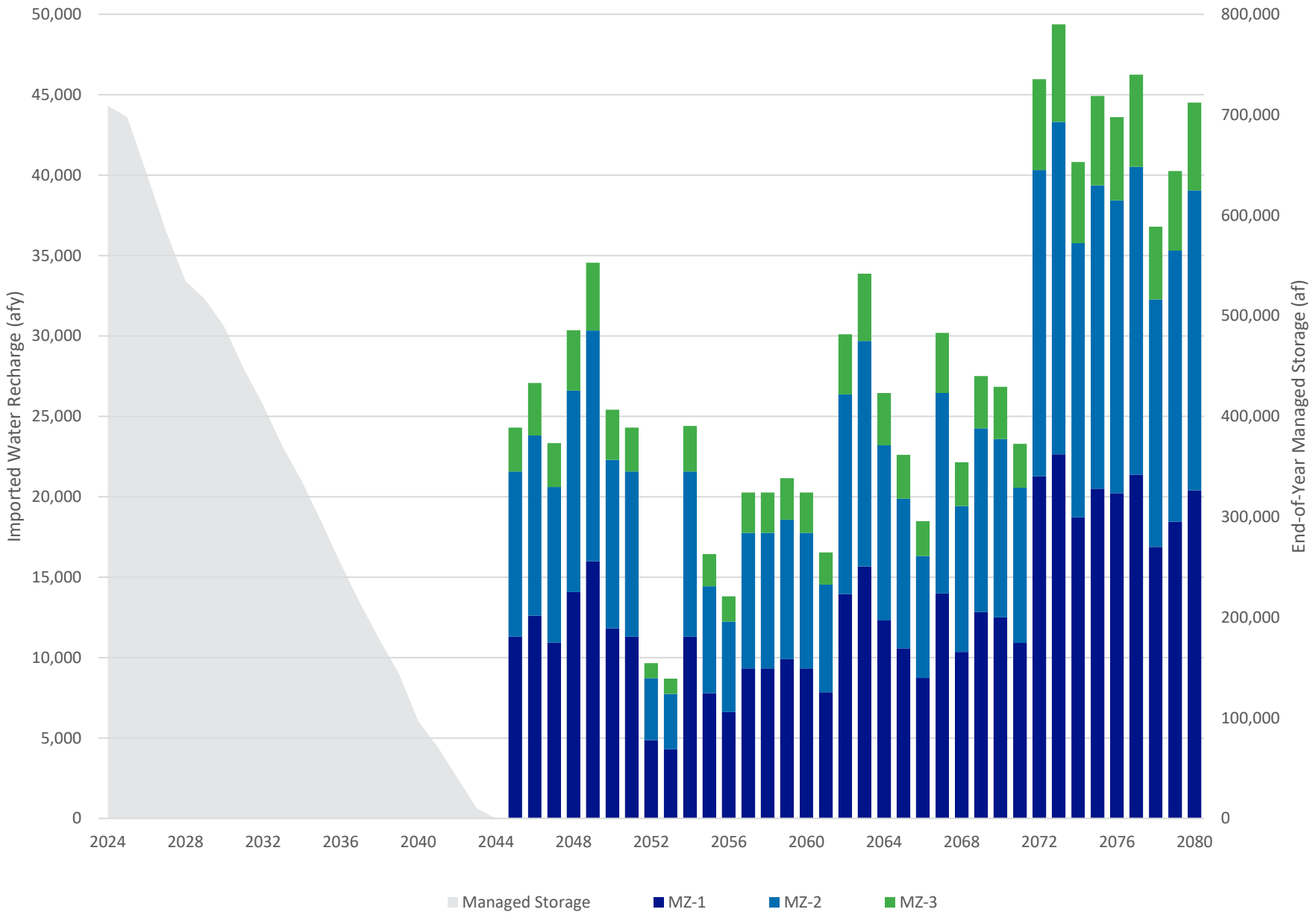

Figure 6-5. Projected Imported Water Recharge, TSY Ensemble Scenario 9

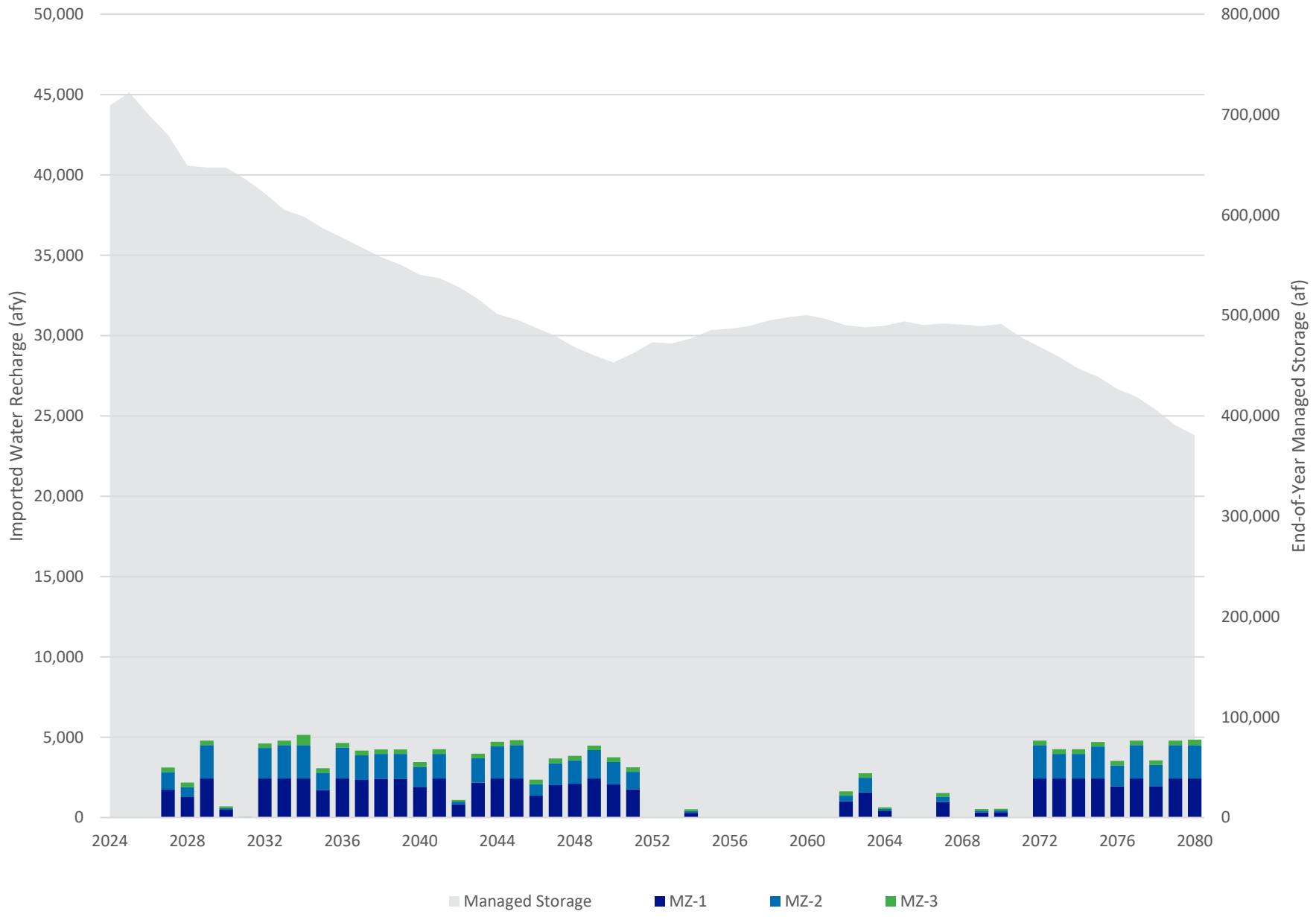

Table 6-1. Projection Ensemble

Projection Scenario	Rationale	Water Plan Scenario[(a)]			Climate Scenario
		Demand	Groundwater Utilization	Imported Water Utilization	
1	Expected/Baseline	Expected	Expected	Expected	Average
2	Hot/Dry Climate	Expected	Expected	Expected	Hot/dry
3	Cool/Wet Climate	Expected	Expected	Expected	Cool/wet
4	Impact Of High Demands	High	High	Low	Average
5	Low Groundwater Levels	High	High	Low	Hot/dry
6	High Net Recharge	High	High	Low	Cool/wet
7	Impact Of Low Demands	Low	Low	High	Average
8	Low Net Recharge	Low	Low	High	Hot/dry
9	High Groundwater Levels	Low	Low	High	Cool/wet

(a) Each Water Plan Scenario is adjusted to reflect the unique precipitation and evapotranspiration (ET_o) patterns of the corresponding Climate Scenario as described in Section 5.4.3.2.

6.2.1 Water Budgets

Table 6-2 and Figure 6-6 show the water budget for Scenario D1 of the TSY Ensemble for FY 2021 through 2080. Water budgets for the other members of the TSY Ensemble can be found in Appendix D. The description of the recharge and discharge components and how each component was computed is described below or referenced in prior Sections. For each component where multipliers were applied to a time series during the uncertainty analysis (see Section 4), the average multiplier from the calibration period for that realization was used for the projection period. For example, if the average multiplier for a subsurface inflow time series from the calibration period was 1.2, the entire time series for future subsurface inflow was multiplied by 1.2 for all scenarios based on that calibrated realization.

The bullets below outline the water budget components shown in Figures 6-7 through 6-14, which depict for FY 1992 through 2080: the minimum and maximum range, 20th to 80th percentile range, and the likelihood-weighted average flows from the TSY Ensemble and the flows simulated in the 2020 SYR (1992-2050).

The projection period assumptions for FY 2023 through FY 2080, and the primary differences relative to the 2020 SYR, are summarized below:

- **Subsurface inflow (Figure 6-7):** Subsurface inflows were computed for the projection period using the same assumptions as the calibration period. The specified head boundary from the Riverside Basin through the Bloomington Divide was held equal to the monthly groundwater head values calculated along that boundary for FY 2022. Subsurface inflows remain relatively constant during the projection period. Differences from the 2020 SYR reflect the combined effects of updates to the model domain and boundary representation, recalibration, and the uncertainty analysis described in Sections 3 and 4.

- **DIPAW to the saturated zone (Figure 6-8):** DIPAW was calculated using the same general methods described for the calibration and uncertainty analysis in Section 4 and in greater detail in the 2020 SYR Report. This process includes using the R4 model to estimate the DIPAW to the vadose zone and applying lag time through the vadose zone to estimate the DIPAW to the saturated zone, which is an input to the MODFLOW model.

  DIPAW in the 2025 SYR is lower than in the 2020 SYR during FY 2021 through FY 2030 for several reasons: adjustment to the Chino Basin boundaries, recalibration and uncertainty analysis, addition of recent historical data, and revised projection assumptions. These drivers are summarized below and discussed in greater detail in Section

  - *Adjustment to Chino Basin boundaries*. As discussed in Section 3, updates to the Chino Basin model boundary based on new hydrogeologic data reduced the modeled Basin area by about one percent, which reduced the area contributing to DIPAW.
  - *Recalibration and uncertainty analysis*. As discussed in Section 4, the recalibration and uncertainty analysis changed the CVM simulation of the magnitude and spatial distribution of DIPAW to the saturated zone relative to the 2020 SYR.
  - *Recent historical data (FY 2019 through 2023)*. Historical data added since the 2020 SYR reflect recent hydrologic and water-use conditions that were generally drier and included less urban outdoor water use than was assumed for FY 2019-23 in the 2020 SYR.
  - *Revised projections for FY 2024 through 2080*. As discussed in Section 5 and Appendix C, the 2025 SYR projections incorporate updated water supply plans, assumptions regarding urban irrigation practices and continued conservation-related reductions in outdoor water use, and variable hydrology. These assumptions resulted in less projected applied-water infiltration than was assumed in the 2020 SYR for the period FY 2024-30. From FY 2031-80, projected DIPAW varies with hydrology and water-plan assumptions and generally fluctuates around a lower range than was projected in the 2020 SYR.

- **Managed aquifer recharge (Figure 6-9):** Managed aquifer recharge comprises stormwater, recycled water, and imported water. The calculation of these components is described in Section 5, and for imported water recharge associated with replenishment obligations, in Section 6.1.2.2. The upper end of the projected range of managed aquifer recharge is higher than in the 2020 SYR after about FY 2040. This occurs primarily in the High Demand scenarios, where managed storage accounts are projected to approach or reach zero. Once managed storage is reduced or depleted, a greater portion of replenishment obligations is satisfied through wet-water recharge, increasing projected imported water recharge.
- **Streambed infiltration (Figure 6-10):** Differences in streambed infiltration between the 2020 SYR and 2025 SYR reflect recalibration of groundwater/surface-water interaction, updates to model parameters and boundary conditions, and the use of variable future hydrology in the 2025 SYR.
- **Groundwater ET (Figure 6-11):** Differences between the 2020 SYR and 2025 SYR reflect updates to the ET representation in the 2025 CVM, including the updated treatment of riparian vegetation extent and density, as well as the recalibration and uncertainty analysis described in Section 4.

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- **Rising groundwater (Figure 6-12):** Differences between the 2020 SYR and 2025 SYR reflect recalibration of groundwater/surface-water interaction, updates to model parameters and boundary conditions, and the use of variable future hydrology in the 2025 SYR.
- **Net recharge (Figure 6-13):** See 6.2.1.11 below.
- **Annual change in storage (Figure 6-14):** The 2025 SYR shows greater year-to-year variability in change in storage than the 2020 SYR because the 2025 SYR uses variable hydrology and an ensemble of future climate and water-plan conditions, whereas the 2020 SYR relied on expected-value average hydrology for the projection period.
- **Cumulative change in storage from FY 1992-2080 (Figure 6-15):** Figure 6-15 shows six panels, one for each of the five calibrated realizations (showing all Projection Scenarios), and one for all Projection Realizations. The final panel shows the cumulative change in storage for three selected Projection Realizations: Scenarios D1, E9, and A5. These represent the median, maximum (smallest decline), and minimum (greatest decline) cumulative changes in storage over the period from FY 2021 to 2050, respectively.

  The cumulative change in storage over the modeled period (FY 1992 through 2080) ranges from -990,000 af (Scenario A2) to -14,000 af (Scenario E9). The likelihood-weighted average change in storage over this period is -595,000 af.

Projected storage declines occur primarily because projected groundwater production exceeds projected production rights in most scenarios and most years (see Figure 6-2 and Section 5). All Projection Scenarios assume that overproduction is satisfied primarily through debits to managed storage when managed storage is available. When overproduction is debited to managed storage rather than satisfied through wet-water recharge, the replenishment obligation is met, but no new water is added to the Basin. This results in a decline in physical groundwater storage until managed storage balances are reduced or depleted, at which point wet-water recharge increases to satisfy a larger portion of replenishment obligations (e.g., Scenario A5, where managed storage is depleted in the 2040s).

6.2.1.1 Net Recharge and TSY

Table 6-3 summarizes the recharge and discharge components, change in storage, and net recharge over the FY 2021-2030 period for the TSY Ensemble and the 2020 SYR. The values for the TSY Ensemble represent the likelihood-weighted average.

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Table 6-3. Water Budget Components for 2020 SYR and 2025 SYR TSY Ensemble, FY 2021-2030 (afy)[a]

Water Budget Component	2020 SYR	2025 SYR (Likelihood-Weighted Average)	2025 SYR minus 2020 SYR
Recharge Components			
Subsurface Inflow*	37,900	33,400	-4,500
DIPAW*	75,800	65,200	-10,600
Streambed Infiltration*	36,600	45,500	8,900
MAR - Stormwater*	13,500	13,800	300
MAR - Recycled and Imported	15,200	22,100	6,900
Total	**179,600**	**180,000**	**400**
Discharge Components			
Groundwater Pumping	148,500	151,900	3,400
Riparian ET*	18,700	12,600	-6,100
Rising Groundwater*	15,200	24,000	8,800
Total	**182,400**	**188,600**	**6,200**
Aggregate Components			
Change in Storage	-2,700	-8,600	-5,900
Net Recharge[b]	130,600	121,200	-9,400

(a) For clarity, values are rounded to the nearest 100 afy and may not sum precisely.
(b) Net recharge is calculated from the net volume of only those recharge and discharge components designated with an asterisk.

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Figure 6-6. Water Budget for the Chino Basin - Scenario D1

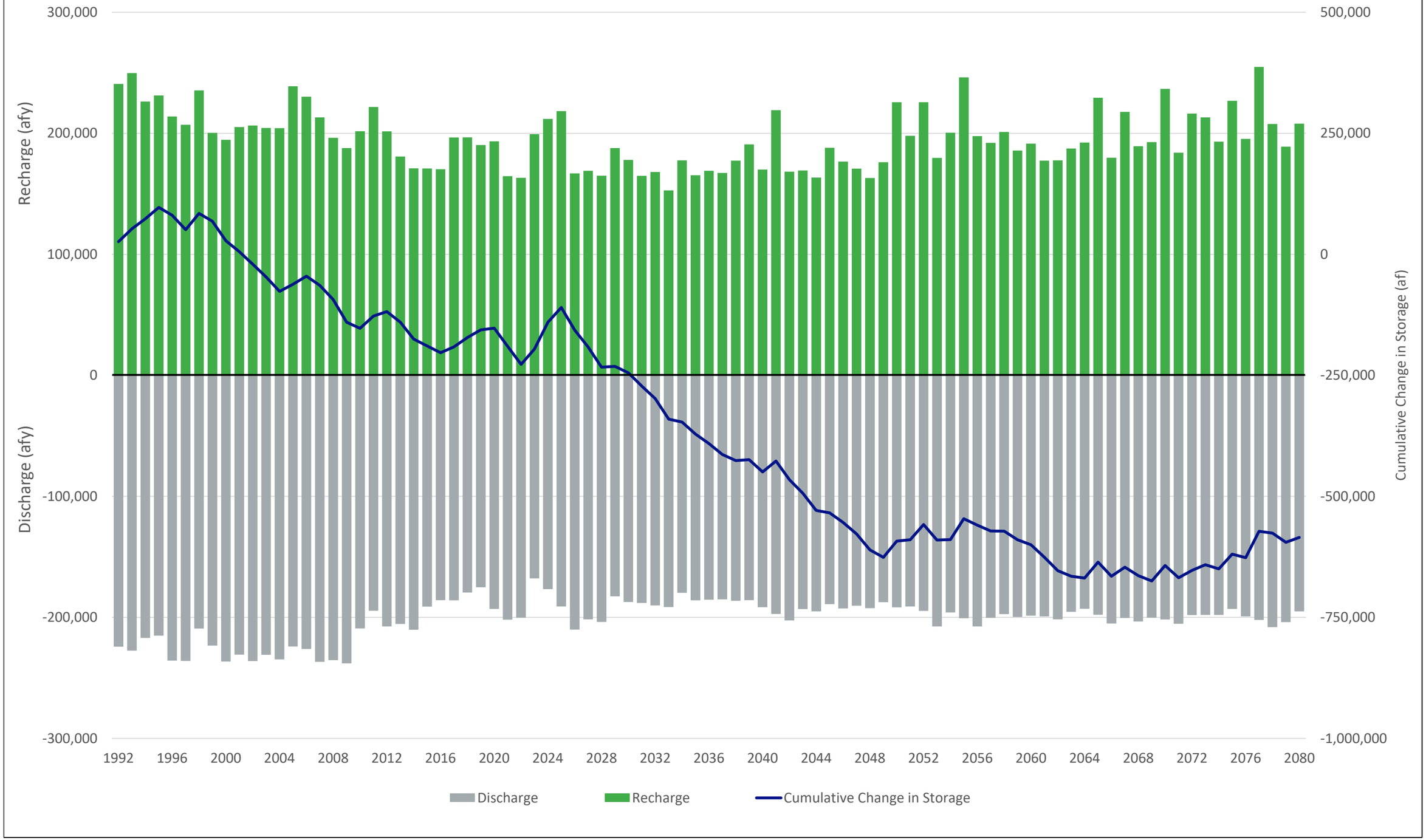


Figure 6-7
Comparison of Subsurface Inflows
2020 SYR and 2025 SYR

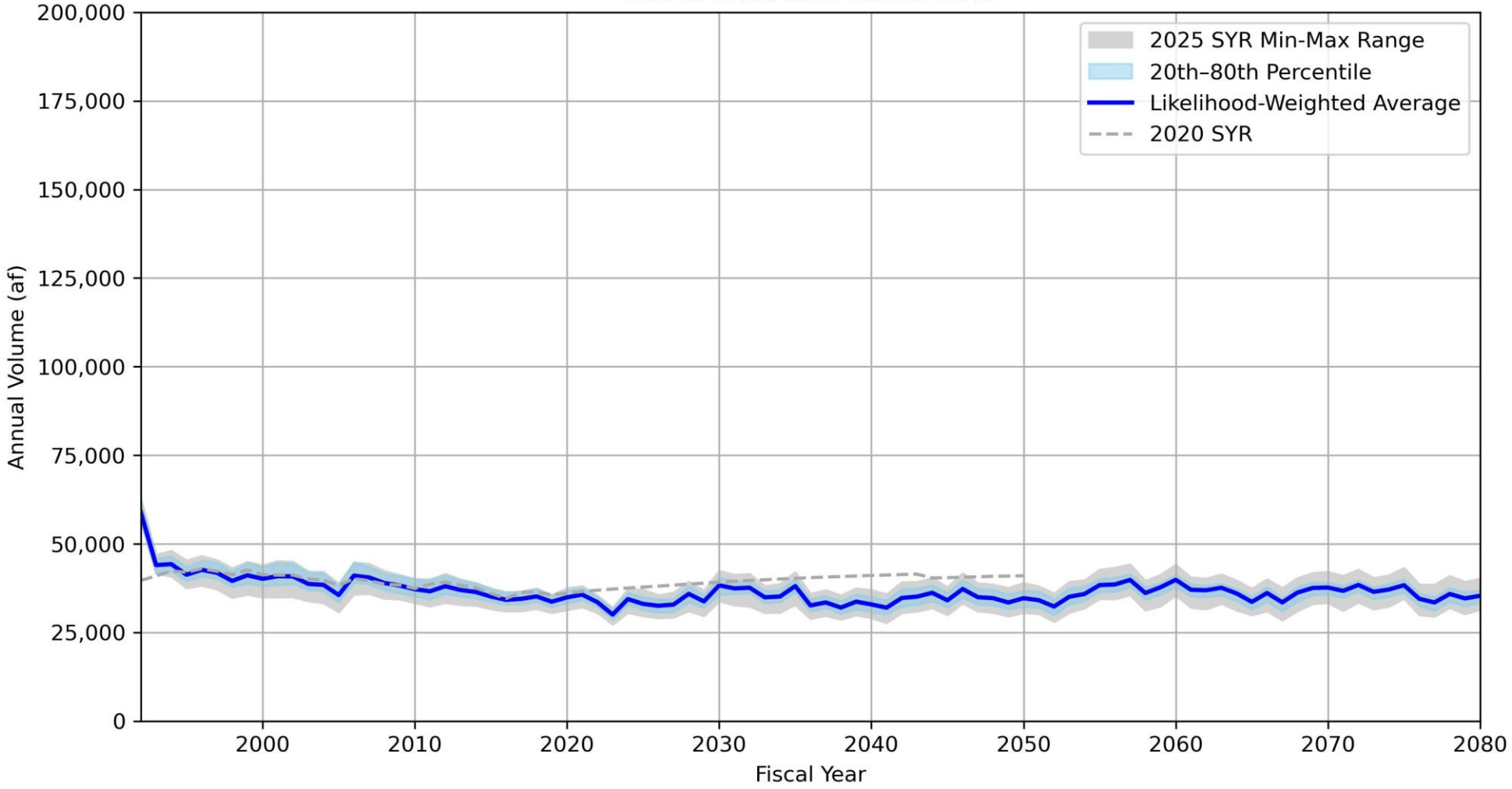


Figure 6-8
Comparison of DIPAW
2020 SYR and 2025 SYR

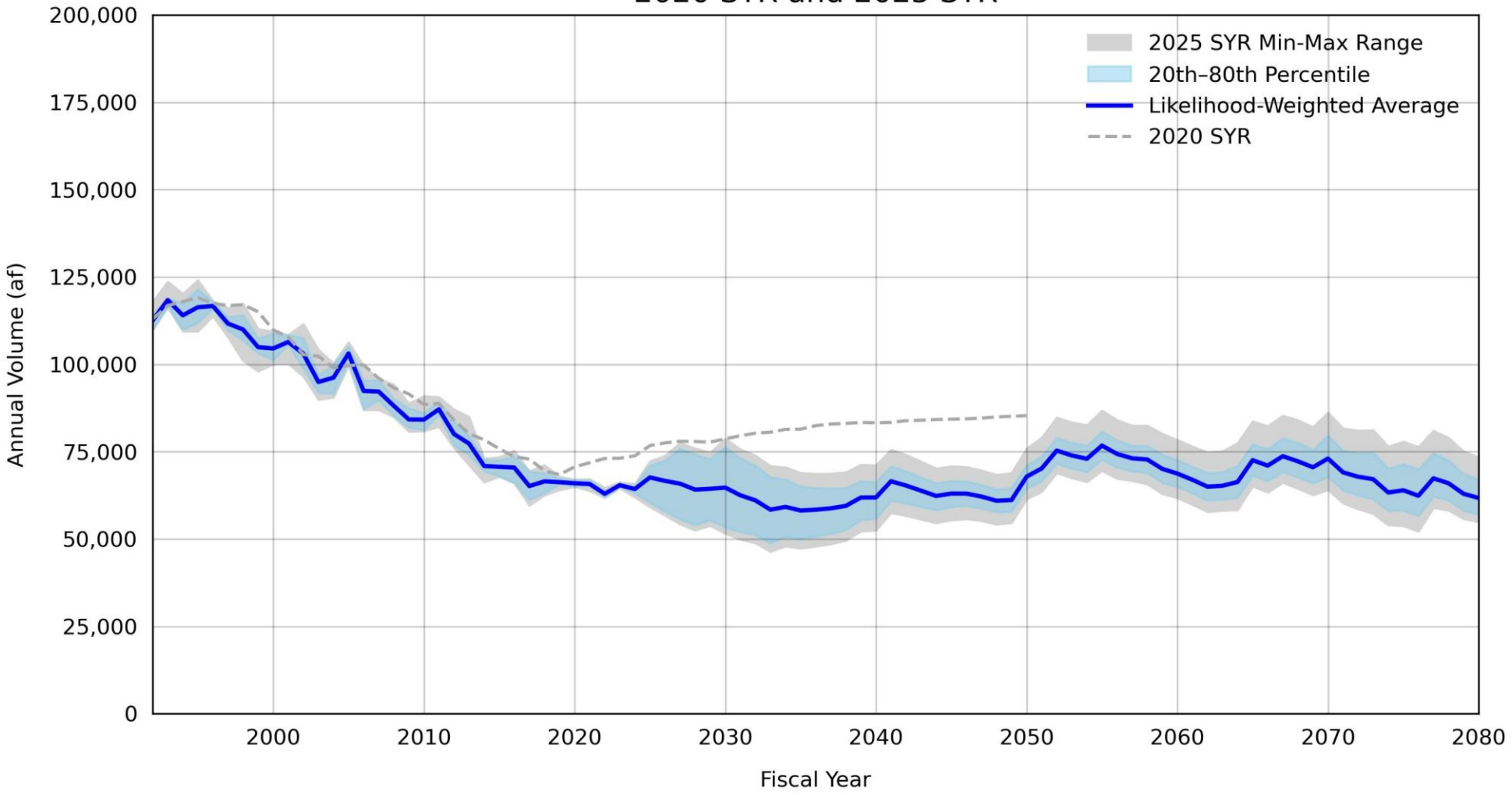


Figure 6-9
Comparison of Managed Aquifer Recharge
2020 SYR and 2025 SYR

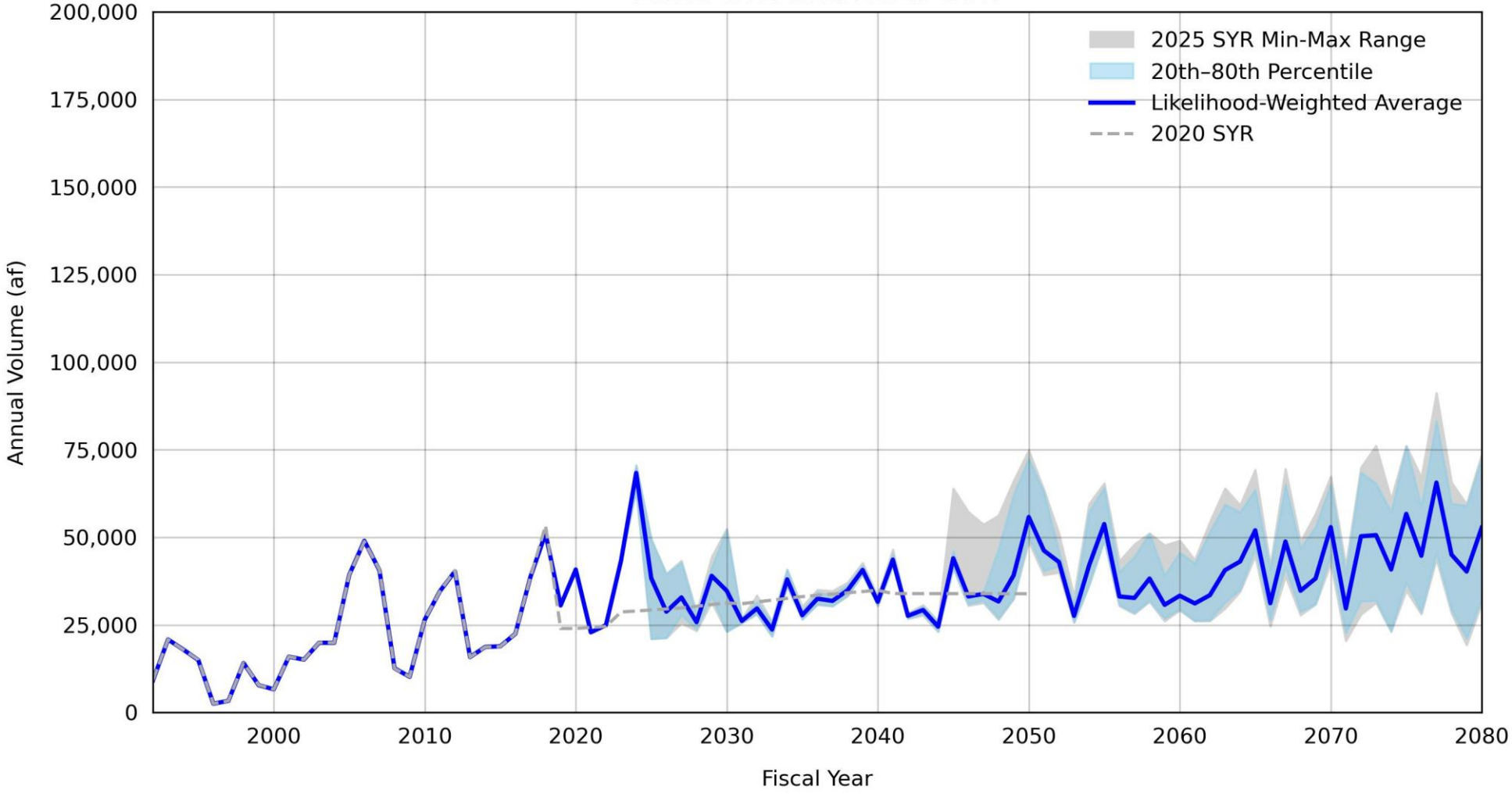


Figure 6-10
Comparison of SAR Infiltration
2020 SYR and 2025 SYR

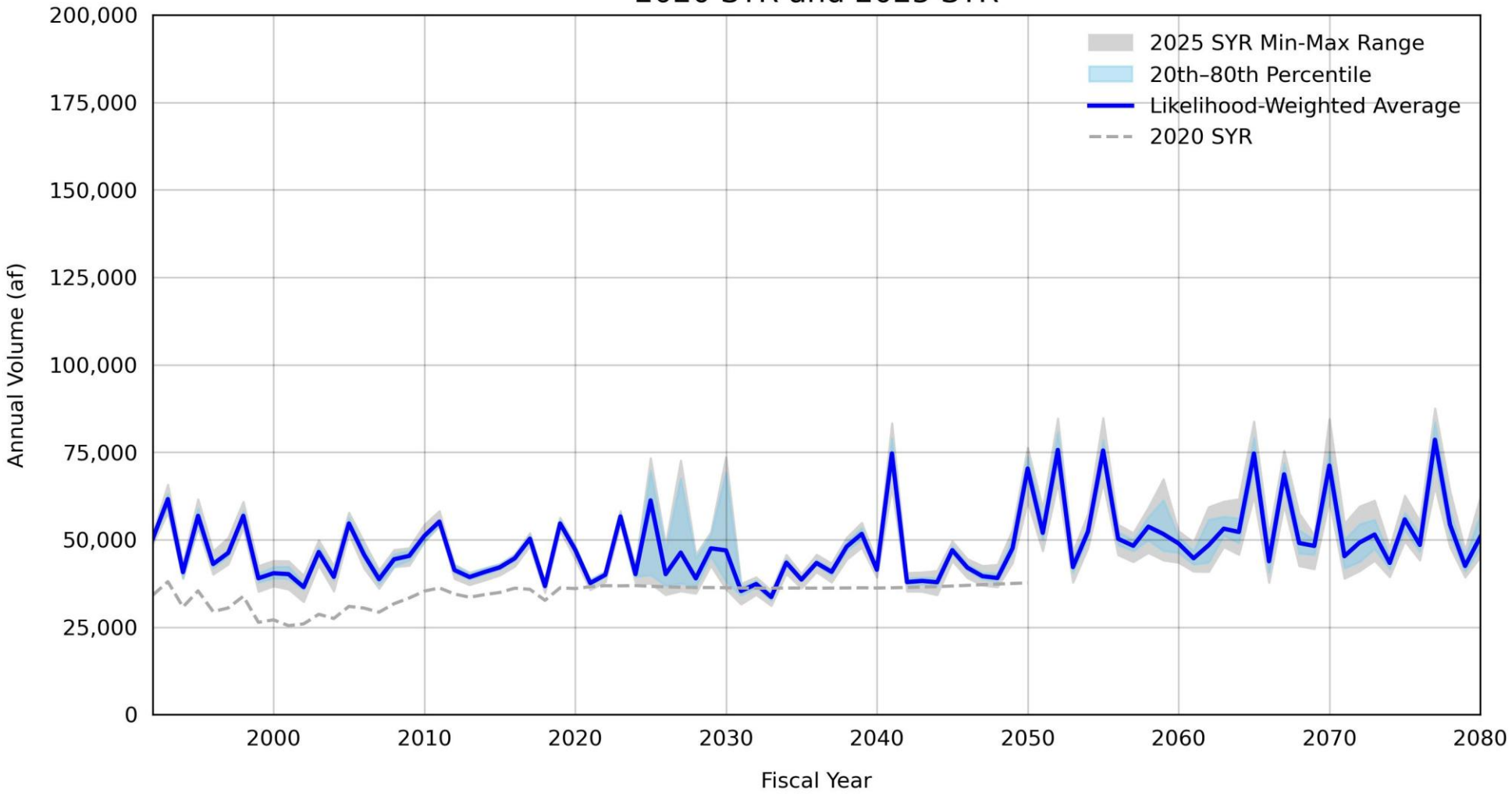


Figure 6-11
Comparison of ET
2020 SYR and 2025 SYR

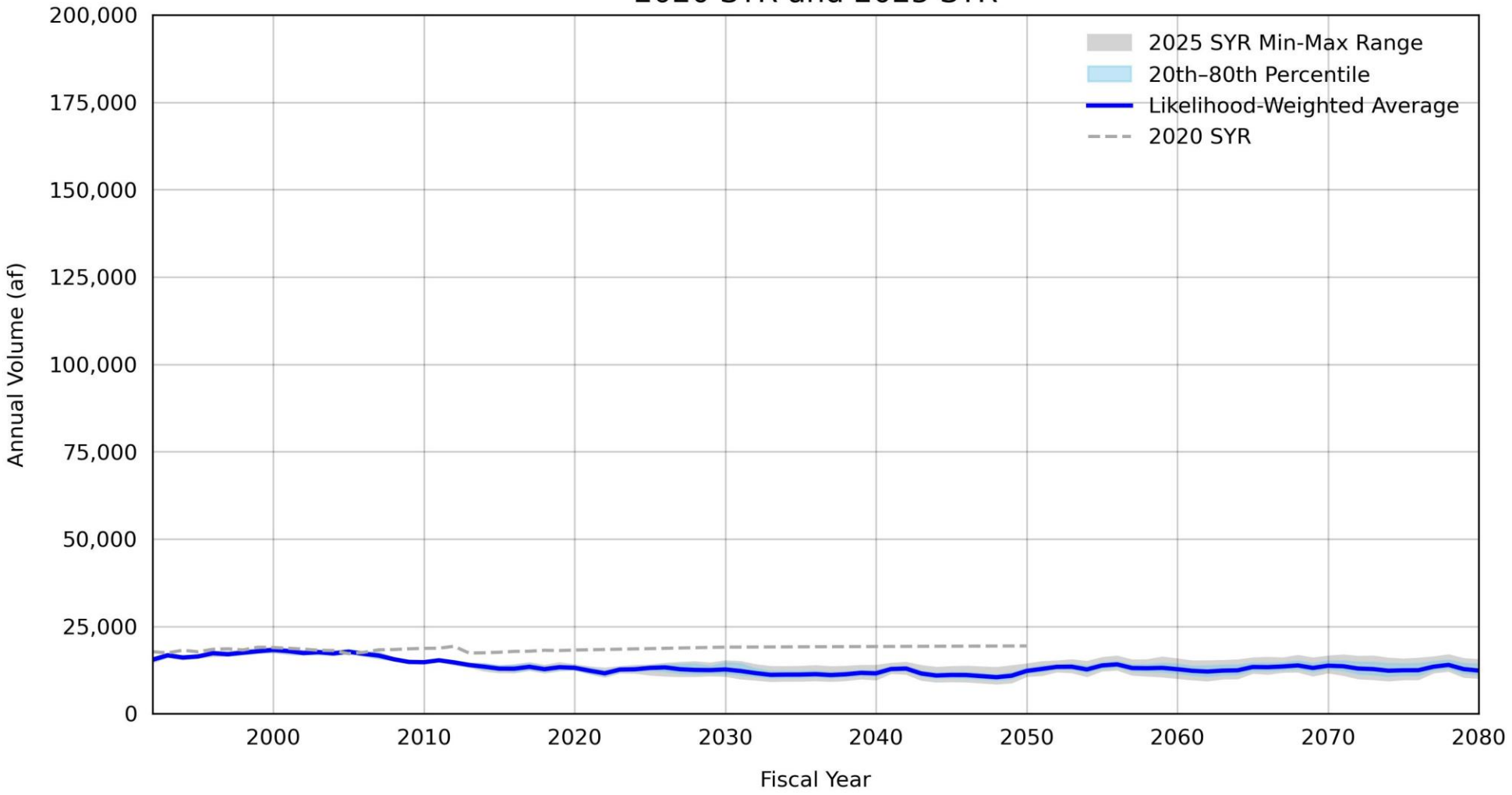


Figure 6-12
Comparison of Rising Groundwater
2020 SYR and 2025 SYR

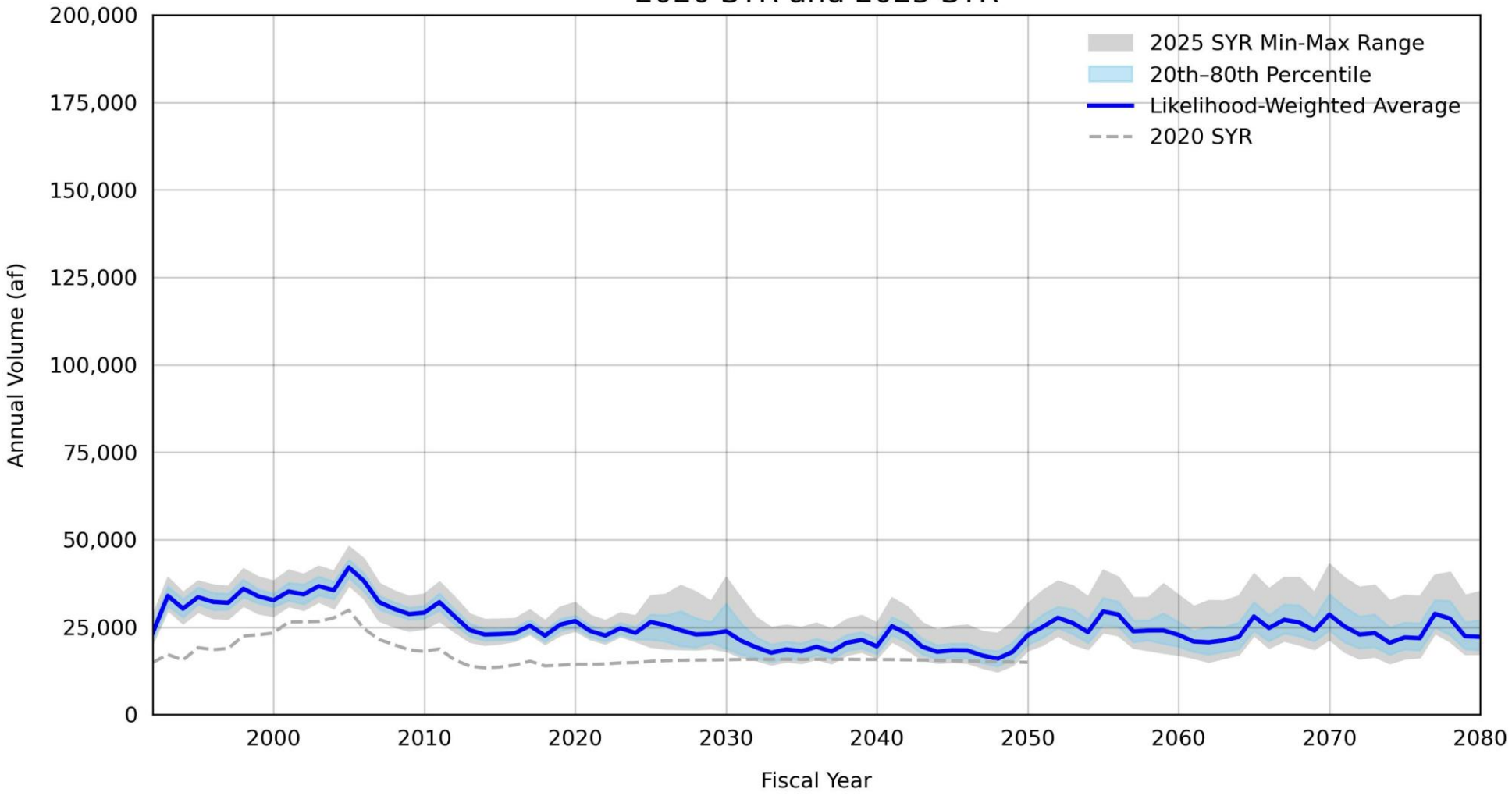


Figure 6-13
Comparison of Net Recharge
2020 SYR and 2025 SYR

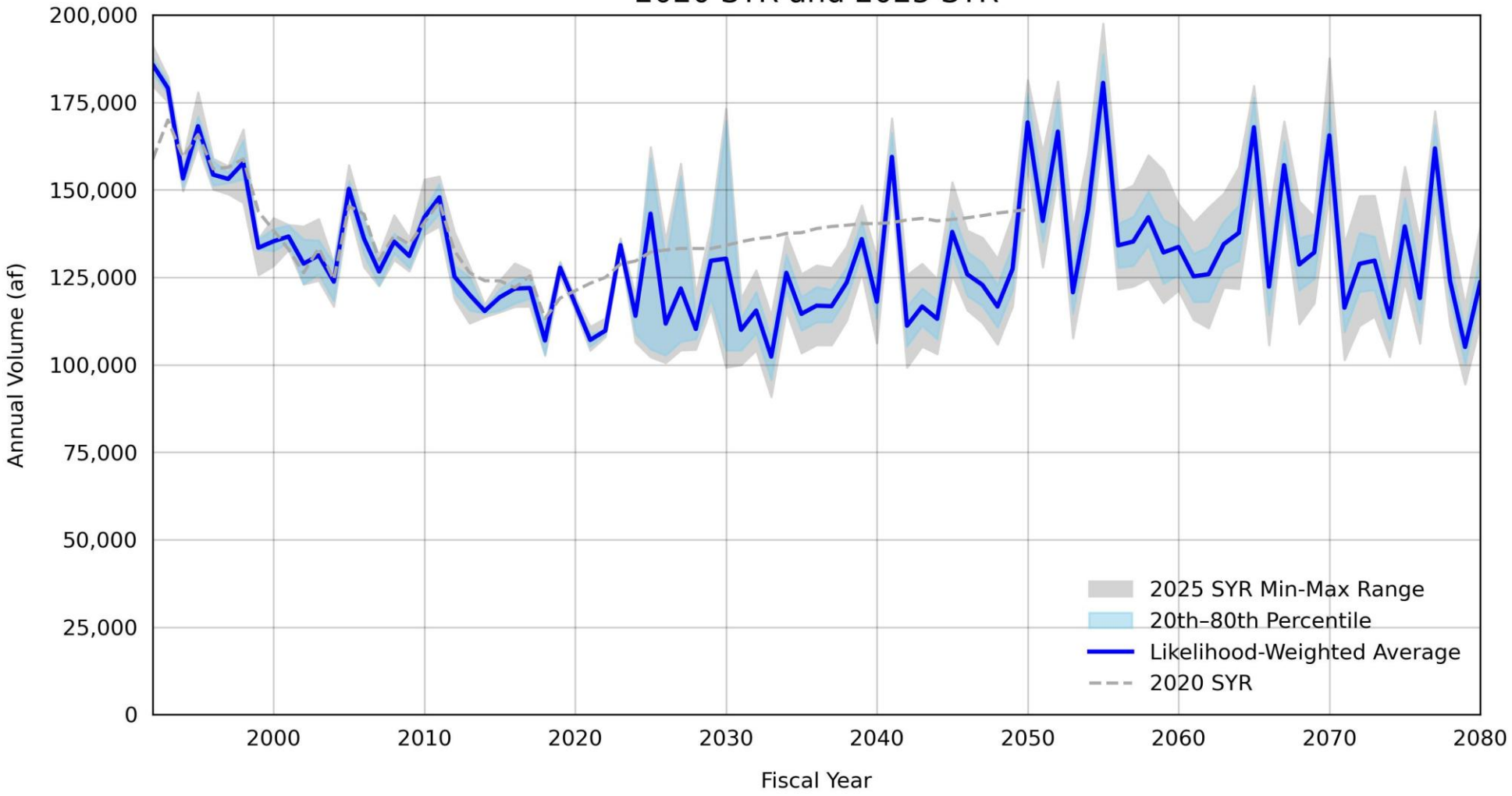


Figure 6-14
Comparison of Change in Storage
2020 SYR and 2025 SYR

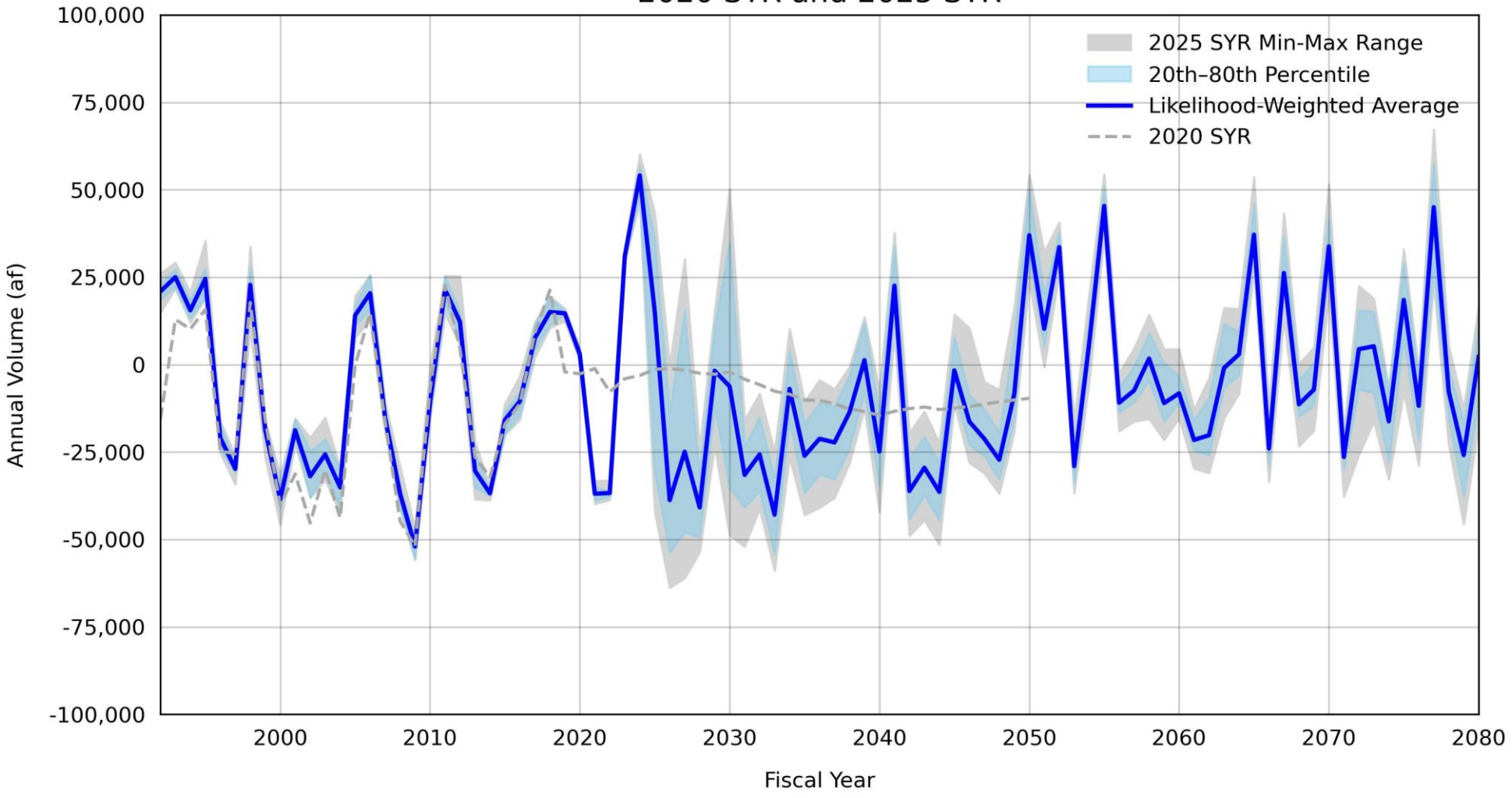
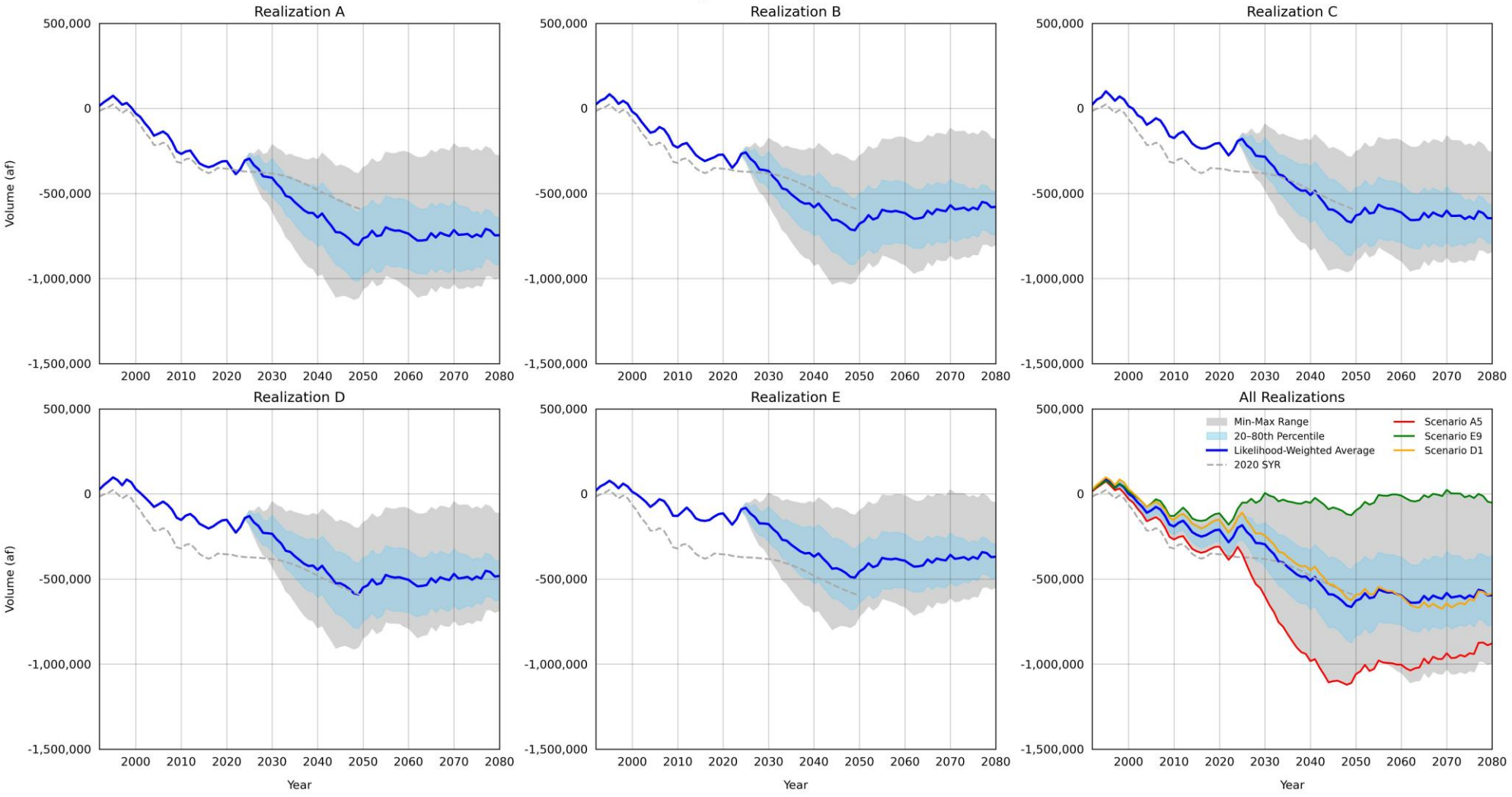


Figure 6-15
Cumulative Change in Storage - TSY Ensemble



The differences between the water budget components reflect a combination of the model recalibration and uncertainty analysis (see Section 4), the three years of historical pumping and recharge data (FY 2021-2023), and revised pumping and recharge assumptions. **The TSY for the 2025 Safe Yield Reevaluation is 121,200 afy, which is the likelihood-weighted average net recharge for the TSY Ensemble for the FY 2021-2030 period.**

Compared to the 2020 SYR, the 2025 SYR likelihood-weighted average net recharge is lower by 9,400 afy. This difference reflects the combined effects of all recharge and discharge components shown in Table 6-3; however, the largest individual reduction is the decrease in DIPAW. Because DIPAW is both the largest recharge component included in the net recharge calculation and the largest negative difference between the 2020 SYR and 2025 SYR, the primary drivers of the difference in DIPAW are discussed below.

6.2.1.2 Drivers of the Difference in DIPAW Between the 2020 SYR and 2025 SYR

A primary reason that the TSY is lower than the Safe Yield calculated in the 2020 SYR is the reduction in DIPAW. As shown in Table 6-3, the likelihood-weighted average DIPAW for the 2025 SYR is 65,200 afy for FY 2021 through FY 2030, which is 10,600 afy lower than the 75,800 afy simulated in the 2020 SYR for the same period. This reduction accounts for more than the total 9,400 afy reduction in net recharge because the lower DIPAW is partly offset by increases in other net recharge components, including streambed infiltration and stormwater recharge, and by lower riparian ET.

The four drivers described in Section 6.2.1 do not act independently and cannot be apportioned exactly from the TSY Ensemble results. The updated Basin boundary, recalibration, and uncertainty analysis affect the same DIPAW time series that are then combined with updated historical hydrology, updated water-use data, and revised projection assumptions. Therefore, the following attribution is intended as an approximate screening-level comparison rather than a strict causal decomposition.

Over the common historical comparison period of FY 1992 through FY 2018, the combined effects of the Basin boundary adjustment, recalibration, and uncertainty analysis reduced simulated DIPAW by about 3,900 afy relative to the 2020 SYR. This model-update effect is equivalent to about 37 percent of the 10,600 afy difference in DIPAW between the 2020 SYR and 2025 SYR for FY 2021 through FY 2030. The remaining difference, about 6,700 afy, or 63 percent, is attributable to updated historical and projected conditions, including the addition of recent historical hydrology and water-use data and the revised projection assumptions for hydrology, water demands, and urban outdoor water use.

This apportionment is approximate because DIPAW is affected by interacting model and scenario assumptions and because recharge to the saturated zone is delayed by travel time through the vadose zone. The reduction in DIPAW is the largest single factor contributing to the lower 2025 TSY, but it is not the only factor affecting net recharge. The TSY is determined from the full net recharge calculation for the TSY Ensemble, including changes in subsurface inflow, streambed infiltration, stormwater recharge, riparian ET, and rising groundwater.

6.2.1.3 Average Net Recharge Across the TSY Ensemble

The reduction in DIPAW is the largest single factor contributing to the lower 2025 TSY, but it is not the only factor affecting net recharge. The net recharge result also reflects changes in subsurface inflow, streambed infiltration, stormwater recharge, riparian ET, and rising groundwater.

Figure 6-16 shows a heatmap to demonstrate the range of average net recharge volumes for the TSY Ensemble for FY 2021-2030. Average net recharge ranges from 108,000 afy (Scenario A8) to 135,800 afy (Scenario E6). This chart reveals several patterns to guide the future analysis of the TSY Ensemble:

- Average net recharge is generally lowest in Calibrated Realization A, and highest in Calibrated Realization E, consistent with the patterns shown over the calibration period (see Section 4 and Figure 4-24).
- The Hot/Dry Climate Scenarios (2, 5, and 8) indicate lower net recharge compared to the Average and Cool/Wet Climate Scenarios. There is high variability of the net recharge between the Climate Scenarios compared to the Water Plan Scenarios. This is due to the high variability of precipitation simulated for this period compared to the smaller changes in Water Plans.

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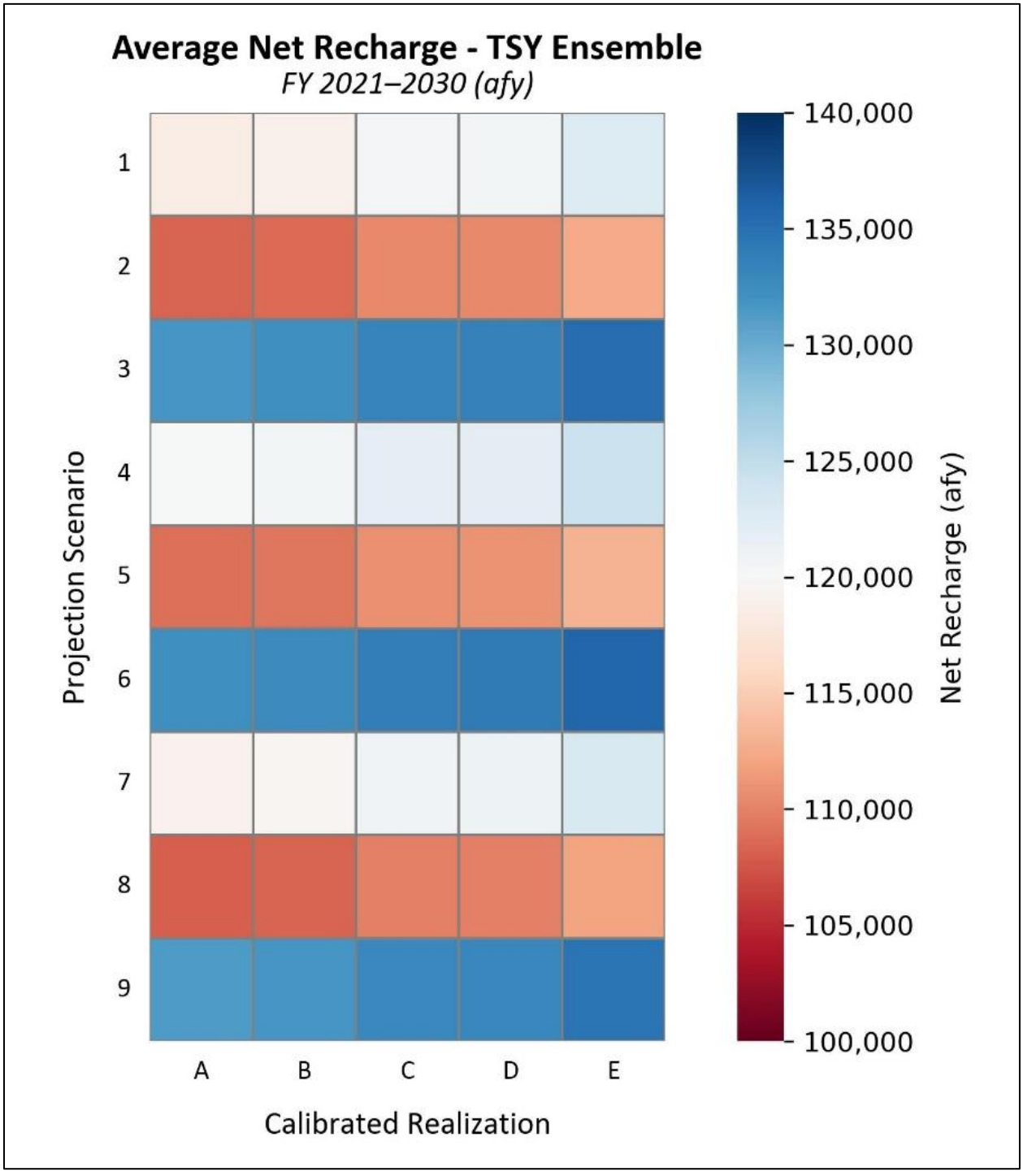

Figure 6-16. Average Net Recharge for the TSY Ensemble, FY 2021-2030

Figure 6-17 is a likelihood-weighted exceedance curve for the average net recharge of the TSY Ensemble over the period of FY 2021-2030. Figure 6-17 indicates the likelihood-weighted average net recharge (121,200 afy) and the current Safe Yield (131,000 afy). 33 percent of the TSY Ensemble (15 Projection Realizations) have an average net recharge above the current Safe Yield.

Table 6-4 compares the likelihood-weighted average water budget components of the TSY Ensemble for FY 2021-2030, FY 2031-2040, and FY 2041-2050. The average net recharge for FY 2031-2040 (118,000 afy) is less than FY 2021-2030 due to the relatively dry period of precipitation assumed for this period (i.e., FY 1959-1968). Average net recharge for FY 2041-2050 is greater than FY 2021-2030 due to (1) the relatively greater assumed precipitation over this period and (2) lower groundwater levels and increased pumping resulting in greater streambed infiltration.

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Figure 6-17. Likelihood-Weighted Exceedance Curve
Average Net Recharge for TSY Ensemble, FY 2021-2030

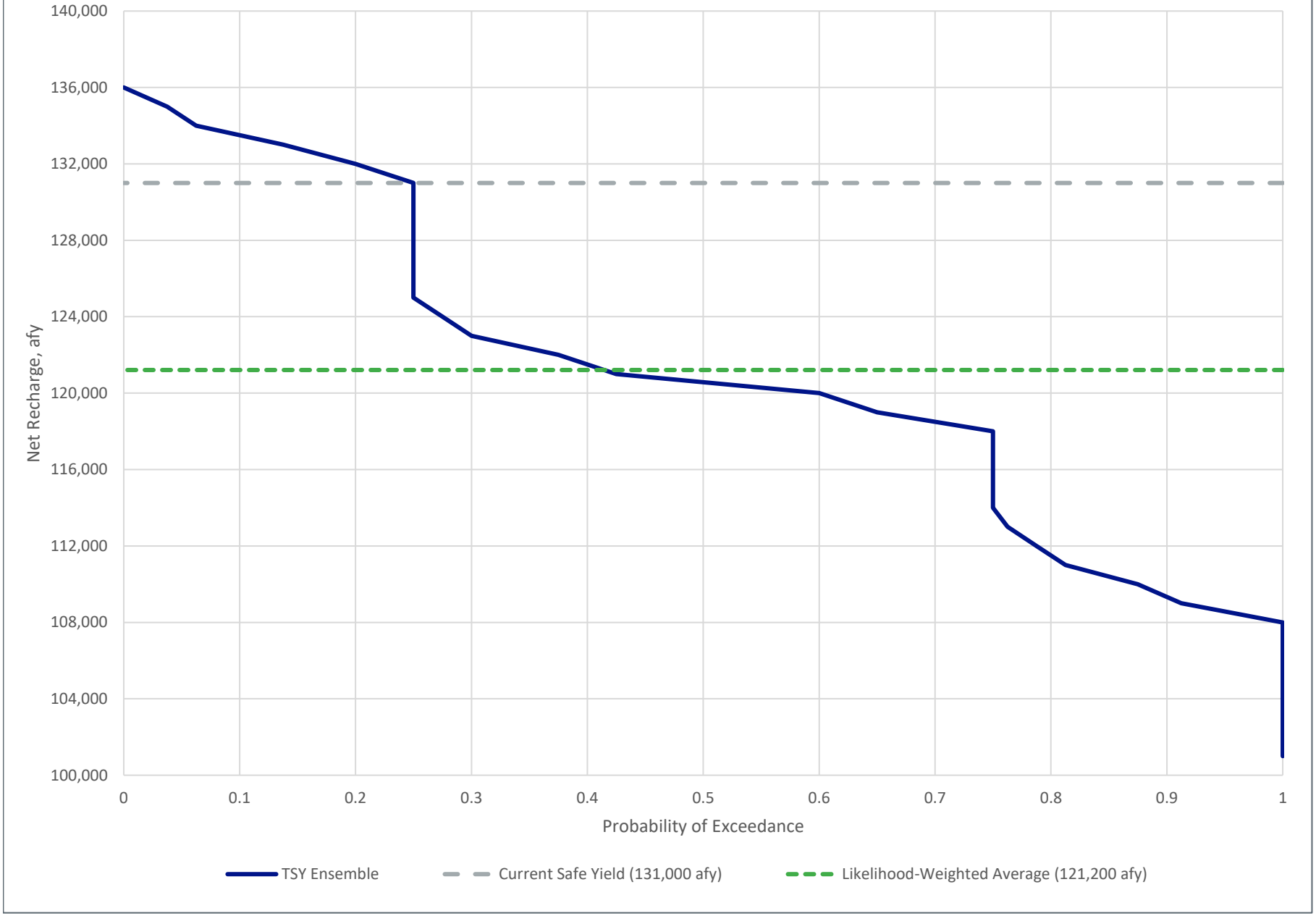

Table 6-4. Decadal Average Water Budget Components for 2025 SYR TSY Ensemble (afy)[a]

Water Budget Component	FY 2021-2030	FY 2031-2040	FY 2041-2050
Recharge Components			
Subsurface Inflow*	33,400	34,200	34,100
DIPAW*	65,200	60,000	63,600
Streambed Infiltration*	45,500	41,300	47,400
MAR - Stormwater*	13,800	13,200	15,900
MAR - Recycled and Imported	22,100	18,400	20,300
Total	**180,000**	**167,200**	**181,400**
Discharge Components			
Groundwater Pumping	151,900	157,800	162,100
Riparian ET*	12,600	11,400	11,500
Rising Groundwater*	24,000	19,400	19,600
Total	**188,600**	**188,600**	**193,100**
Aggregate Components			
Change in Storage	-8,600	-21,400	-11,700
Net Recharge[b]	121,200	118,000	130,000

(a) For clarity, values are rounded to the nearest 100 afy and may not sum precisely.
(b) Net recharge is calculated from the net volume of only those recharge and discharge components designated with an asterisk.

6.2.2 Groundwater Conditions

This subsection describes the range in potential future groundwater conditions for all members of the TSY Ensemble but only includes maps for the three Projection Realizations that span the range of results (Scenarios D1, E9, and A5), as indicated on Figure 6-15.

6.2.2.1 Groundwater Levels

Figures 6-18 through 6-20 show the simulated groundwater levels at the beginning of the projection period (July 1, 2022) for Scenario D1 and Layers 1, 3, and 5, respectively. While there are differences between the groundwater levels for each of the calibrated realizations, the groundwater levels shown here are representative of the simulated conditions at the beginning of the projection period.

6.2.2.1.1 Groundwater Level Changes, FY 2022 to 2030

Table 6-5 summarizes the changes in groundwater levels for each of the Projection Realizations, indicating the minimum, maximum, and average groundwater level elevations in July 1, 2030, and the average difference in groundwater levels between July 1, 2022 and July 1, 2030.

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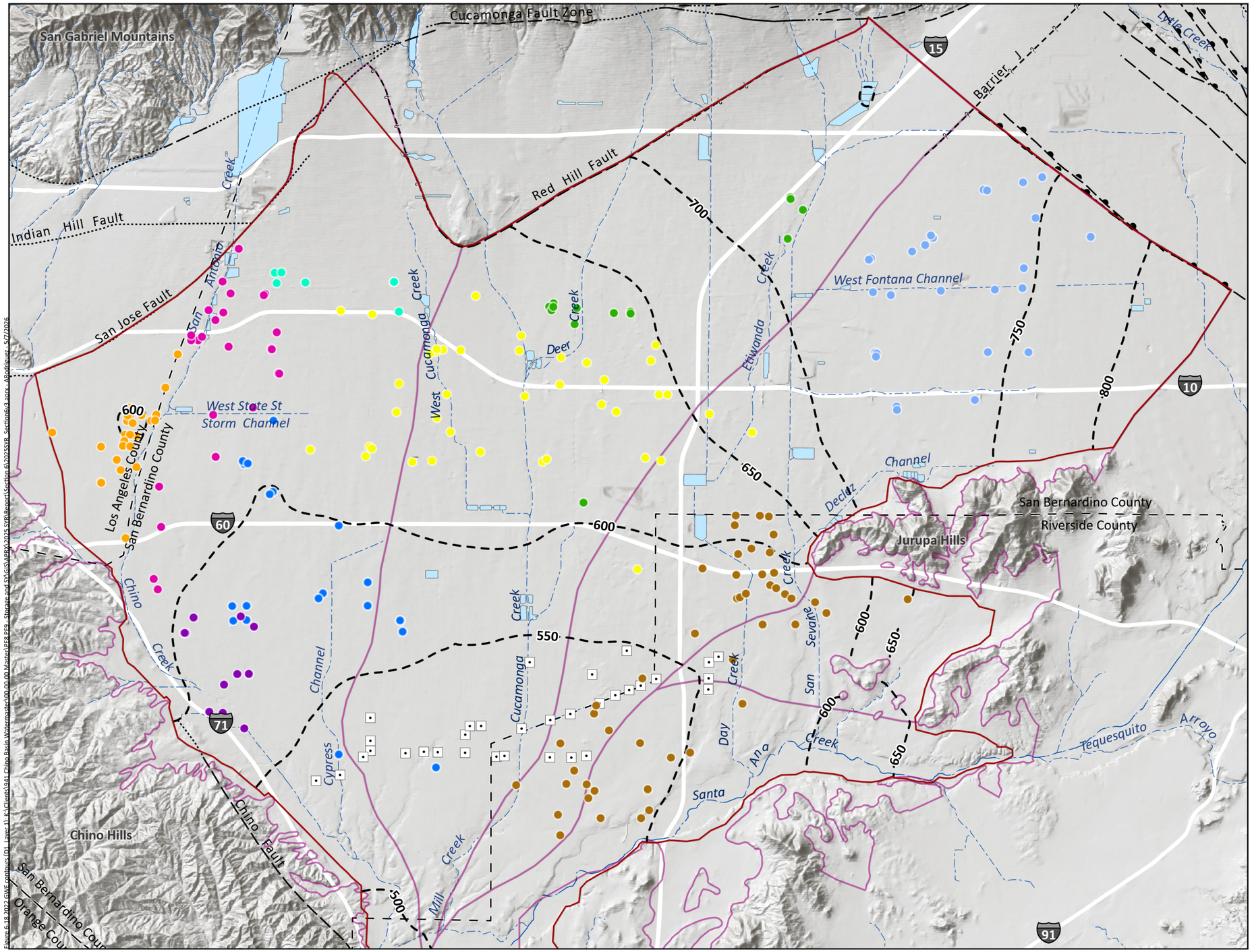


Hydraulic Head Contours (ft-amsl)

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by:

WEST YOST

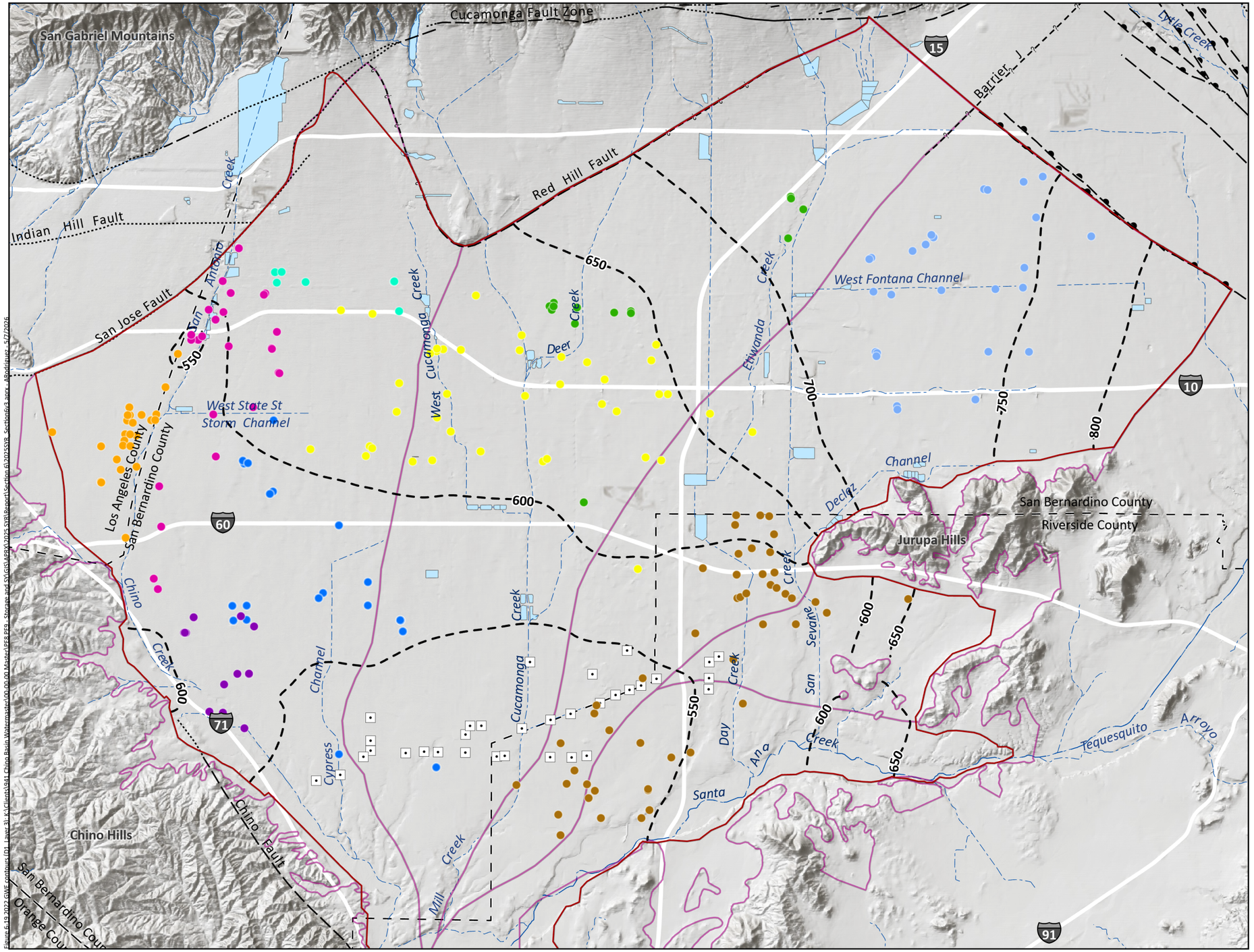
0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Hydraulic Head Contours -- Layer 1
Scenario D1 - July 2022
Figure 6-18



Hydraulic Head Contours (ft-amsl)

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by:

WEST YOST

N

0 2 4 Miles

0 3 6 Km

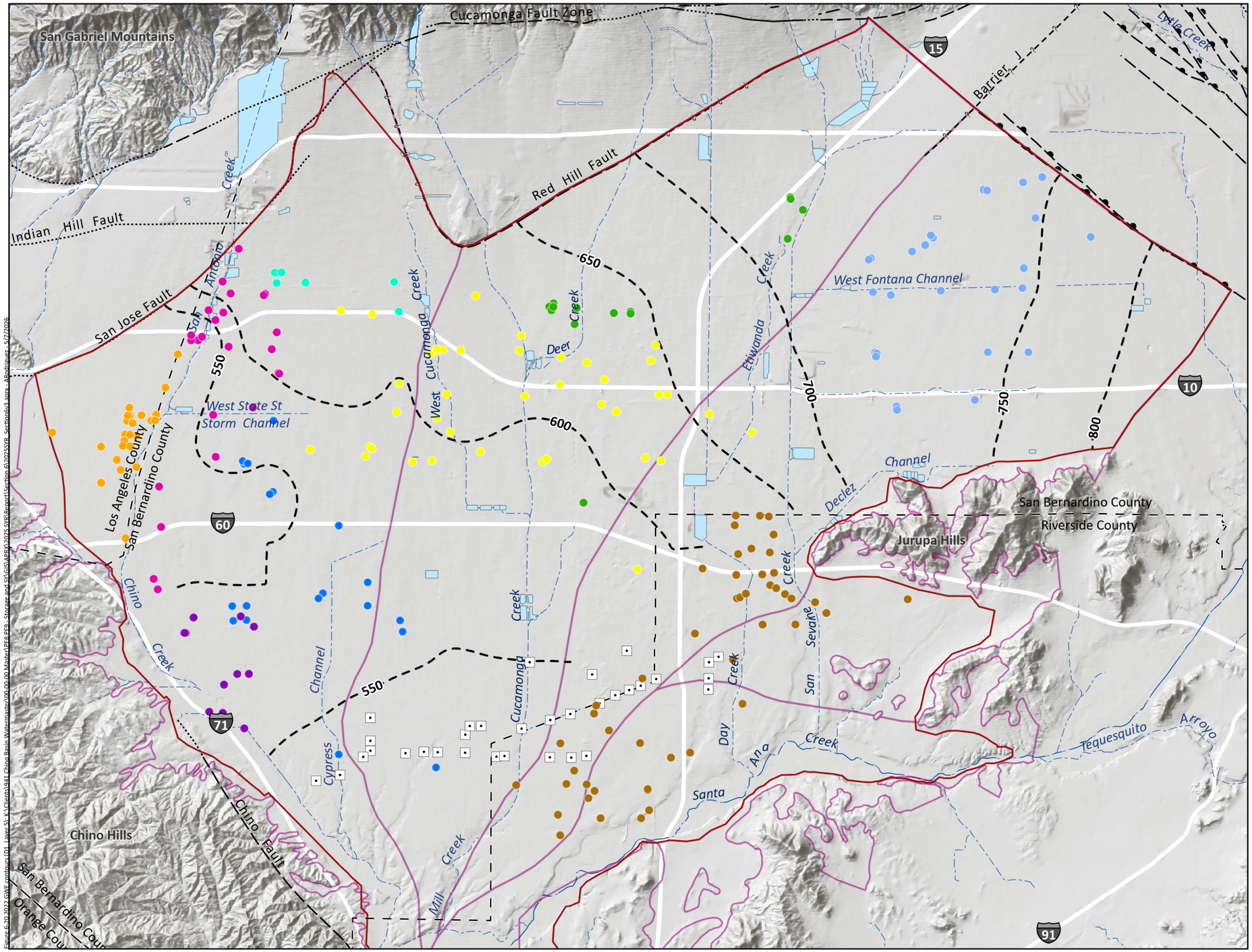
Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Hydraulic Head Contours -- Layer 3

Scenario D1 - July 2022

Figure 6-19



Hydraulic Head Contours (ft-amsl)

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by:

WEST YOST

0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Hydraulic Head Contours -- Layer 5
Scenario D1 - July 2022
Figure 6-20

Table 6-5. Summary of Groundwater Elevations Selected Projection Realizations, July 2030 (ft-amsl)			
Statistic	Scenario D1	Scenario E9	Scenario A5
Minimum Groundwater Elevation	480	480	477
Maximum Groundwater Elevation	840	841	844
Average Groundwater Elevation	624	635	608
Average Difference Compared to 2022	-0.1	13	-9

Figures 6-21 through 6-23 show the simulated changes in groundwater levels for the period of July 1, 2022 to July 1, 2030 for Layer 1 of Scenarios D1, E9, and A5, respectively.

- In Scenario D1 (Figure 6-21), groundwater levels average about the same as 2022. Groundwater levels generally remain within 10 feet of their levels in 2022.
- In Scenario E9 (Figure 6-22), groundwater levels average about 13 feet higher than 2022. Increases in groundwater levels are consistent across most of the Basin except for the western portion of the CDA wellfield near where the remediation wells near the Chino Airport are projected to begin pumping in FY 2027.
- In Scenario A5 (Figure 6-23), groundwater levels average about 9 feet lower than 2022. Groundwater level declines are focused in the western Chino Basin near the Ontario and Pomona wellfields, and near where the remediation wells near the Chino Airport are projected to begin pumping in FY 2027.

6.2.2.1.2 Groundwater Level Changes, FY 2022 to 2050

Table 6-6 summarizes the changes in groundwater levels for each of the Projection Realizations, indicating the minimum, maximum, and average groundwater level elevations on July 1, 2050, and the average difference in groundwater levels between July 1, 2022 and July 1, 2050.

Table 6-6. Summary of Groundwater Elevations Selected Projection Realizations, July 2050 (ft-amsl)			
Statistic	Scenario D1	Scenario E9	Scenario A5
Minimum Groundwater Elevation	467	477	447
Maximum Groundwater Elevation	840	841	844
Average Groundwater Elevation	609	629	588
Average Difference Compared to 2022	-16	7	-29

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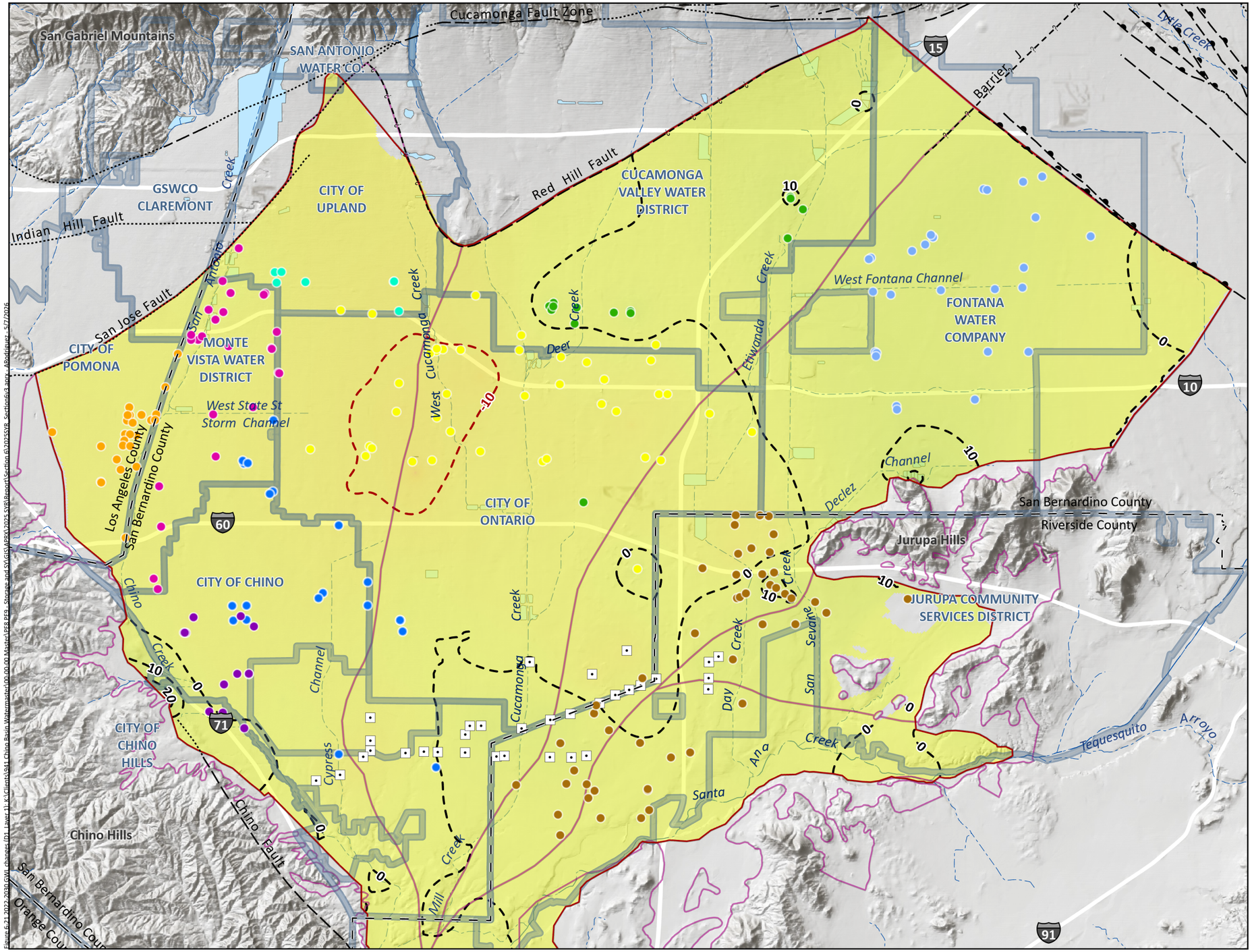


Hydraulic Head Change (ft-amsl) Positive Change
July 2022 to July 2030

Hydraulic Head Change (ft-amsl) Negative Change
July 2022 to July 2030

Hydraulic Head Change (ft) July 2022 to 2030

100 — Increase

-100 — Decrease

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins

Water Service Area



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by:
WEST YOST

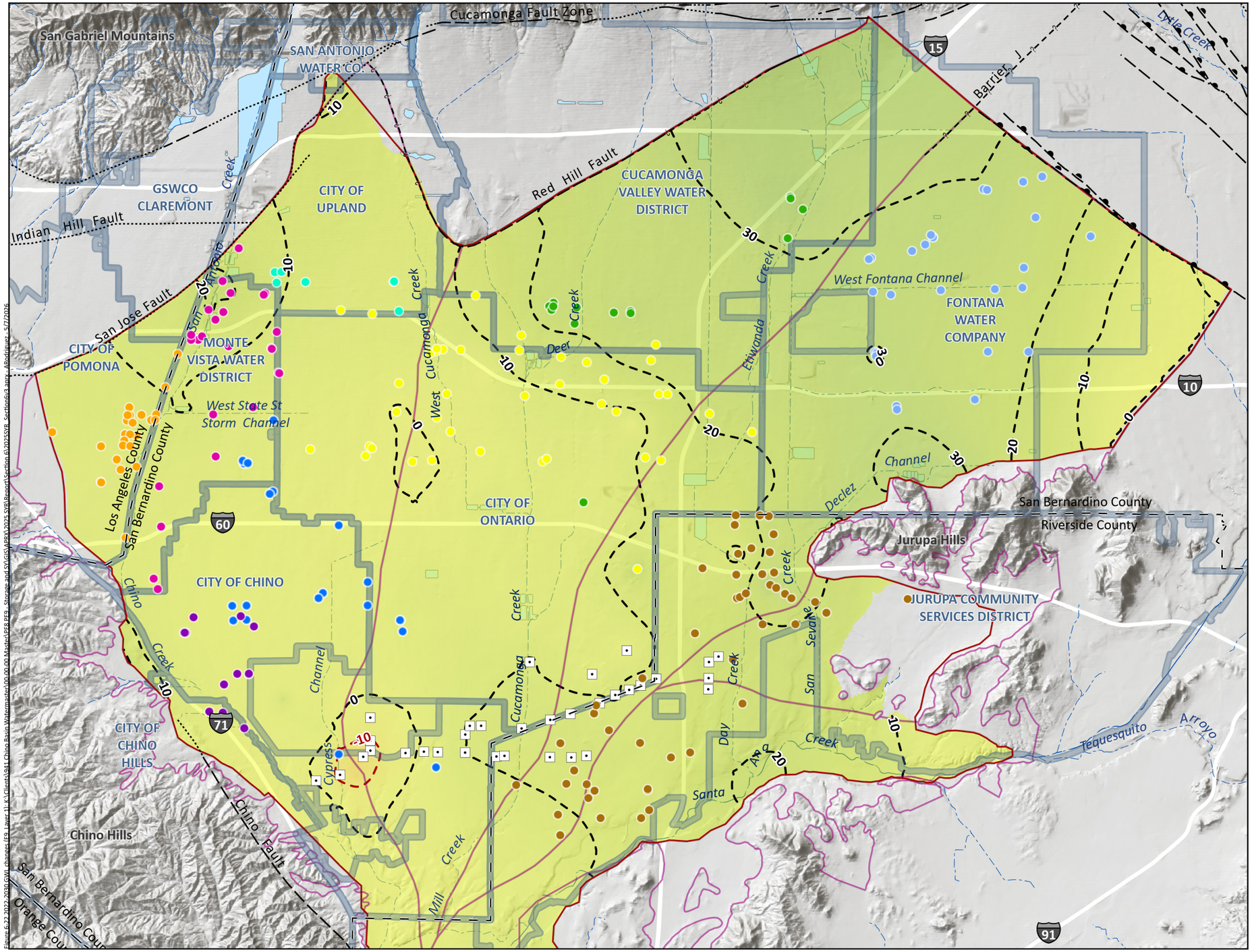
N

0 2 4 Miles

0 3 6 Km

Prepared for:
Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Hydraulic Head Change -- Layer 1
Scenario D1 - July 2030 minus July 2022
DRAFT
Figure 6-21



Hydraulic Head Change (ft-amsl) Positive Change
July 2022 to July 2030

Hydraulic Head Change (ft-amsl) Negative Change
July 2022 to July 2030

Hydraulic Head Change (ft) July 2022 to 2030

100 — Increase

-100 — Decrease

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins

Water Service Area



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier

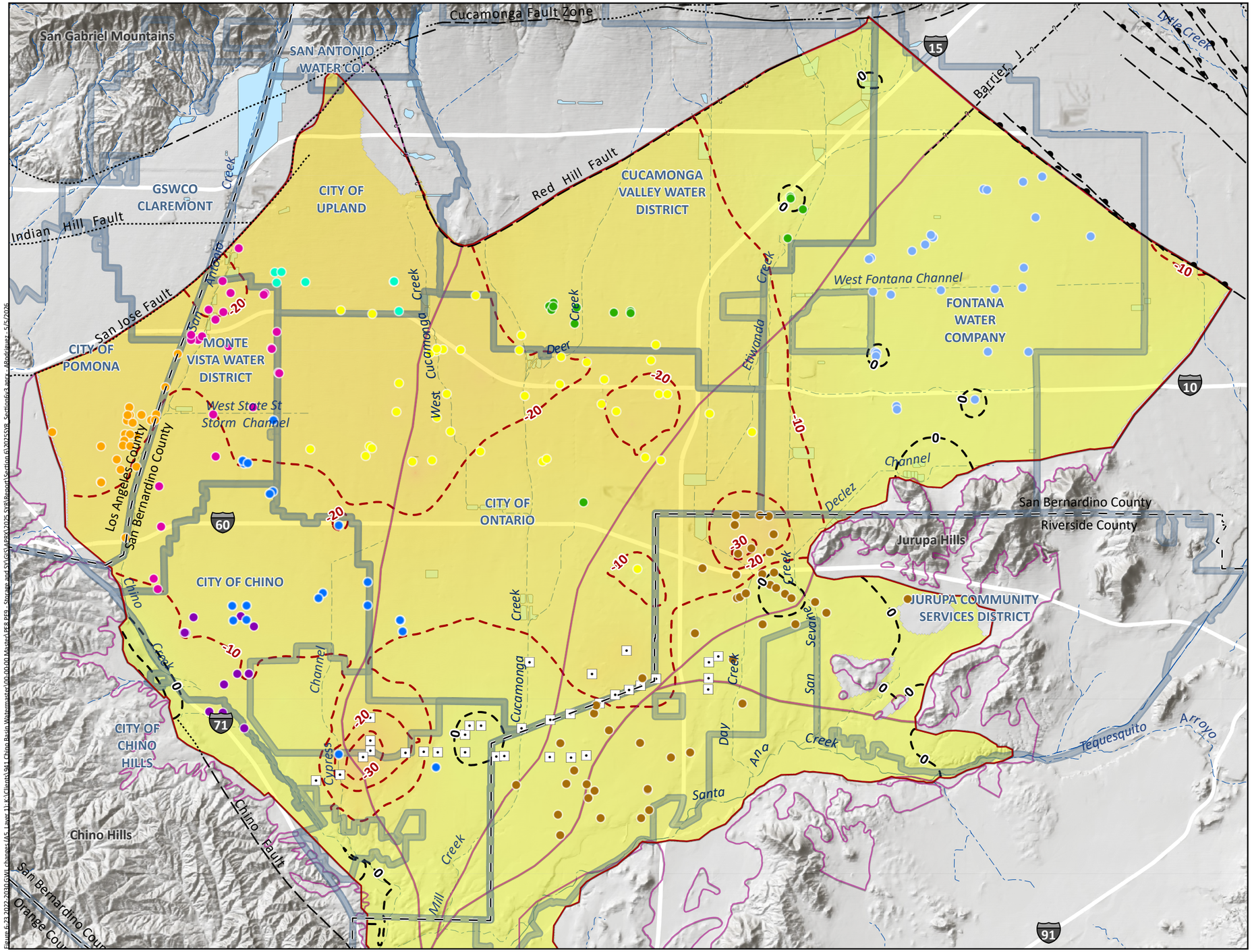


Prepared by:
WEST YOST

0 2 4 Miles
0 3 6 Km

Prepared for:
Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Hydraulic Head Change -- Layer 1
Scenario E9 - July 2030 minus July 2022
DRAFT
Figure 6-22



Hydraulic Head Change (ft-amsl) Positive Change
July 2022 to July 2030

Hydraulic Head Change (ft-amsl) Negative Change
July 2022 to July 2030

Hydraulic Head Change (ft) July 2022 to 2030

100 — Increase

-100 — Decrease

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins

Water Service Area



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by:
WEST YOST

0 2 4 Miles
0 3 6 Km

Prepared for:
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2025 Safe Yield Reevaluation

Projected Hydraulic Head Change -- Layer 1
Scenario A5 - July 2030 minus July 2022
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Figure 6-23

Figures 6-24 through 6-26 show the simulated changes in groundwater levels for the period of July 1, 2022 to July 1, 2050 for Layer 1 of Scenarios D1, E9, and A5, respectively.

- In Scenario D1 (Figure 6-24), groundwater levels average about 16 feet lower than 2022. Groundwater levels generally remain within 10 feet of their levels in 2022 in MZ-3, while groundwater level declines of up to 60 feet occur across the boundary between MZ-1 and MZ-2.
- In Scenario E9 (Figure 6-25), groundwater levels average about 7 feet higher than 2022. Increases in groundwater levels are consistent across most of the Basin except for central MZ-1 and near the Chino Airport, where declines are up to about 30 feet.
- In Scenario A5 (Figure 6-26), groundwater levels average about 29 feet lower than 2022. Groundwater level declines occur across the entire Basin, exceeding 90 feet near the boundary between MZ-1 and MZ-2.

6.2.2.2 Groundwater Flow Patterns

Groundwater flow patterns vary over time for members of the TSY Ensemble. Figures 6-27 through 6-29 show the simulated groundwater velocity vectors on July 1, 2030 for Layer 1 of Scenarios D1, E9, and A5, respectively. Figures 6-30 through 6-32 show the simulated groundwater velocity vectors on July 1, 2050 for Layer 1 of Scenarios D1, E9, and A5, respectively.

Overall, groundwater flow patterns mimic surface drainage patterns, flowing from the areas of high elevation in the north and east flanking the San Gabriel and Jurupa Mountains towards pumping wells and areas of discharge near the Santa Ana River within Prado Basin. The CDA wellfield draws groundwater from the upgradient Chino Basin and the Santa Ana River, weakening the Chino Basin's hydraulic connection to the Santa Ana River.

By 2050 in Scenario D1, groundwater flows in Layer 1 tend to focus on local minima in groundwater levels near the Ontario wellfield (see Figure 6-30).

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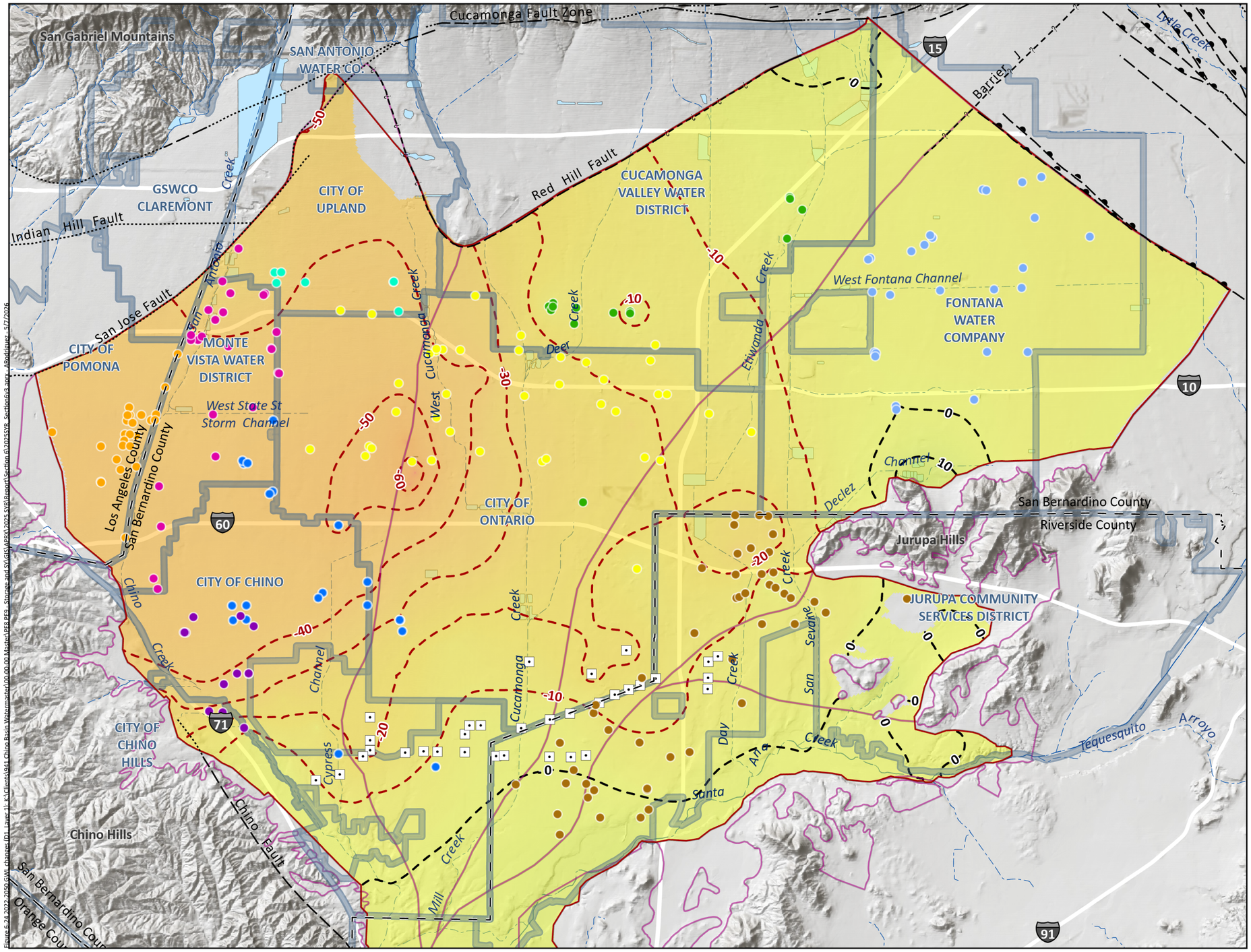


Hydraulic Head Change (ft-amsl) Positive Change
July 2022 to July 2050

Hydraulic Head Change (ft-amsl) Negative Change
July 2022 to July 2050

Hydraulic Head Change (ft) July 2022 to 2050

100 — Increase

-100 — Decrease

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins

Water Service Area



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



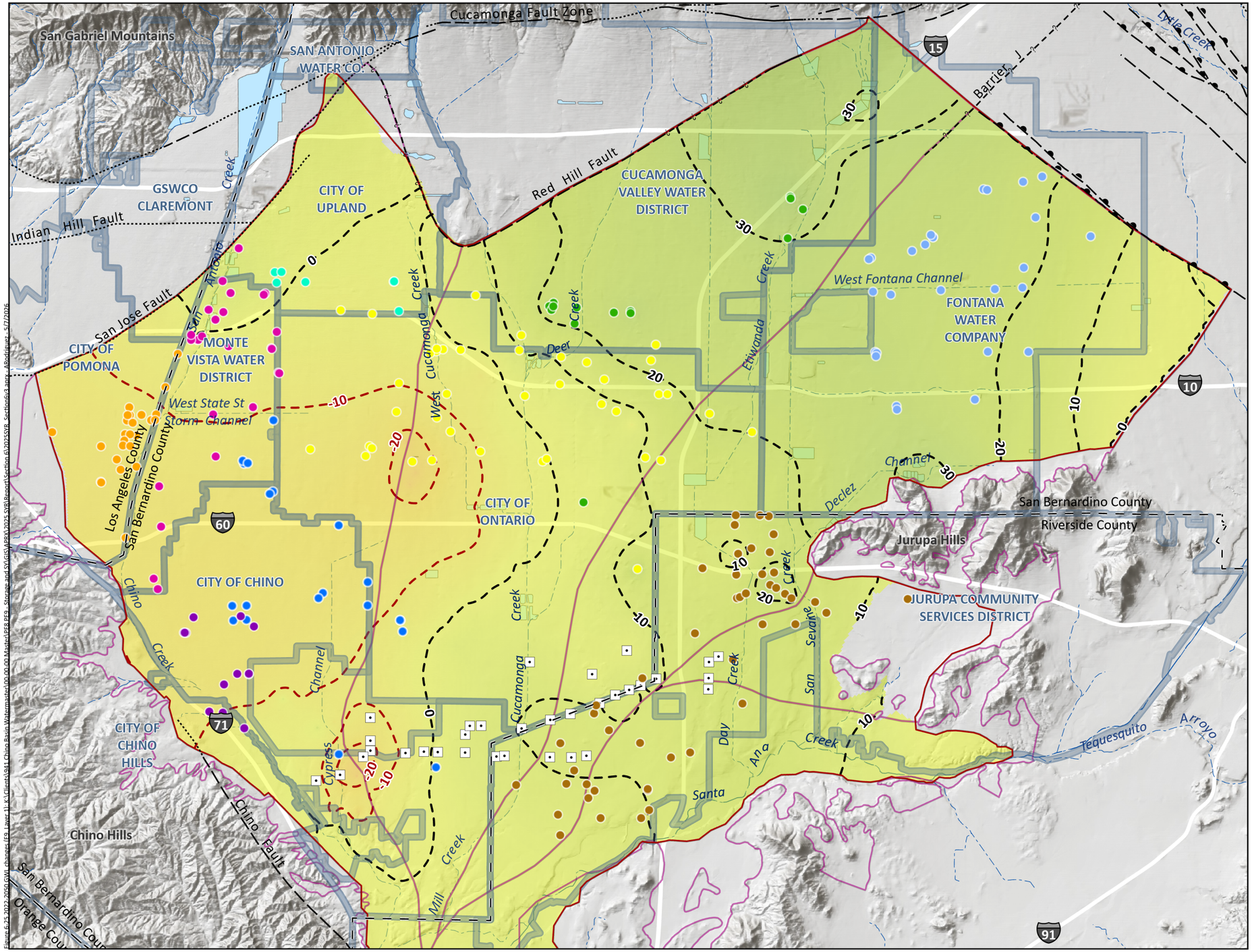
Prepared by: WEST YOST

0 2 4 Miles

0 3 6 Km

Prepared for:
Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Hydraulic Head Change -- Layer 1
Scenario D1 - July 2050 minus July 2022
DRAFT
Figure 6-24



Hydraulic Head Change (ft-amsl) Positive Change
July 2022 to July 2050

Hydraulic Head Change (ft-amsl) Negative Change
July 2022 to July 2050

Hydraulic Head Change (ft) July 2022 to 2050

100 — Increase

-100 — Decrease

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins

Water Service Area



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by:
WEST YOST

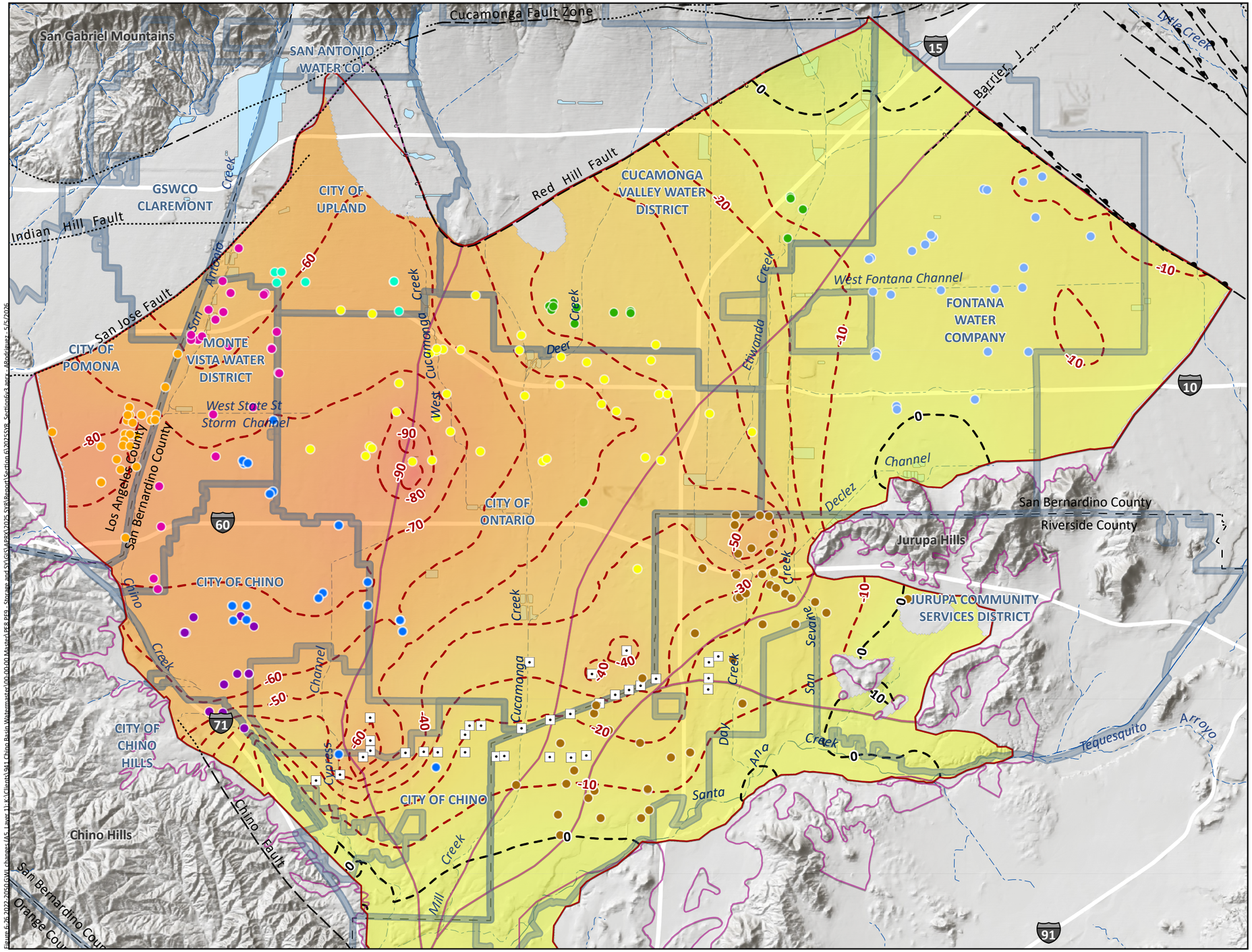
N

0 2 4 Miles

0 3 6 Km

Prepared for:
Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Hydraulic Head Change -- Layer 1
Scenario E9 - July 2050 minus July 2022
DRAFT
Figure 6-25



Hydraulic Head Change (ft-amsl) Positive Change
July 2022 to July 2050

Hydraulic Head Change (ft-amsl) Negative Change
July 2022 to July 2050

Hydraulic Head Change (ft) July 2022 to 2050

100 — Increase

-100 — Decrease

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins

Water Service Area



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by:
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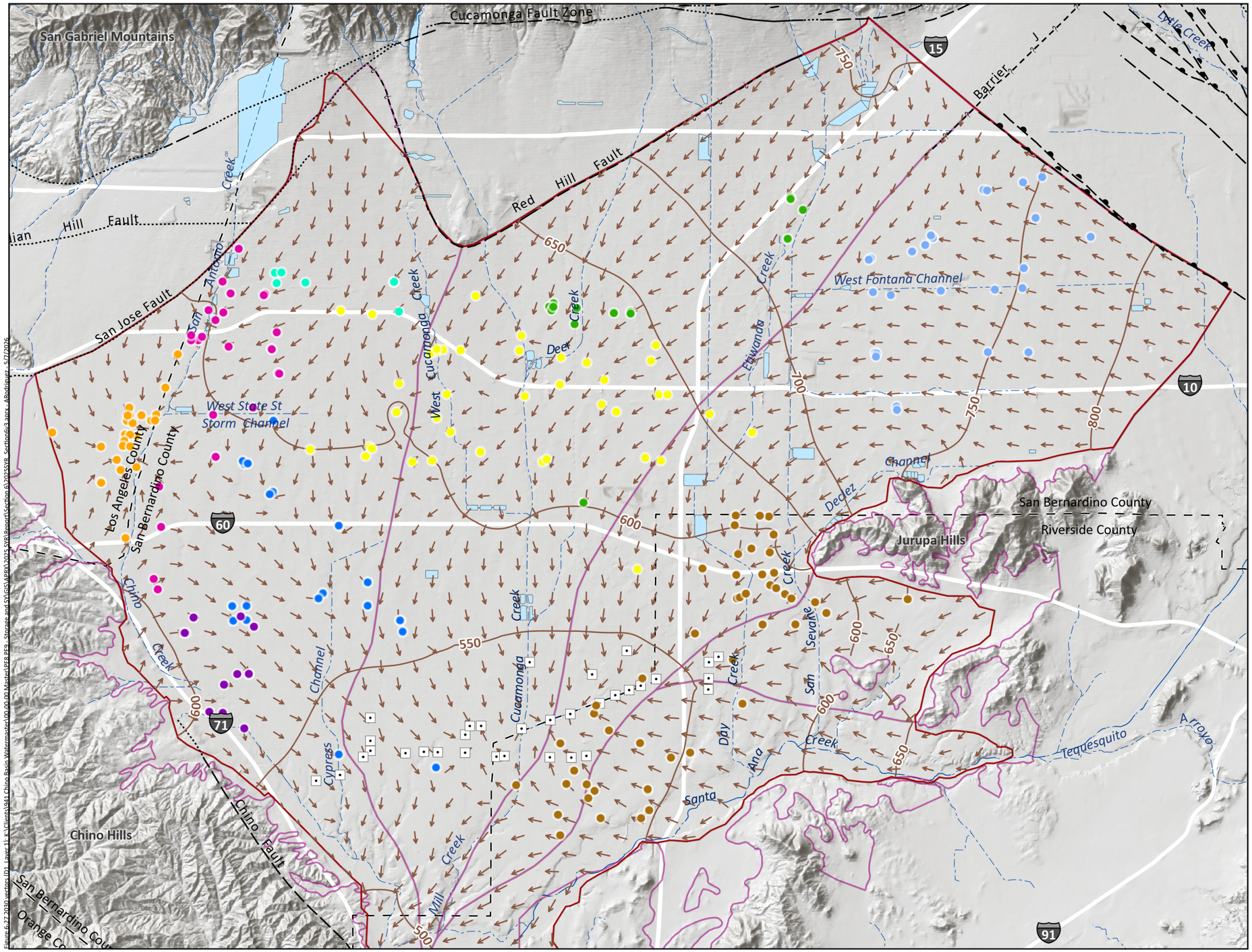
0 2 4 Miles
0 3 6 Km

Prepared for:
Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Hydraulic Head Change -- Layer 1
Scenario A5 - July 2050 minus July 2022
DRAFT
Figure 6-26



2030 Groundwater Flow Vector - Model Layer 1

2030 Groundwater Elevation Contours (ft-amsl) - Model Layer 1

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain

Prepared by:

WEST YOST

0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Groundwater Level Elevations and Flow Vectors for July 2030

Scenario D1, Layer 1

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Figure 6-27

2030 Groundwater Flow Vector - Model Layer 1

2030 Groundwater Elevation Contours (ft-amsl) - Model Layer 1

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

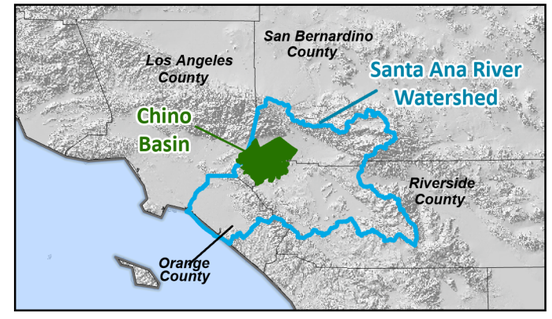
Rivers and Streams

Flood Control and or Conservation Basins

OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



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Prepared for: Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Groundwater Level Elevations and Flow Vectors for July 2030

Scenario E9, Layer 1

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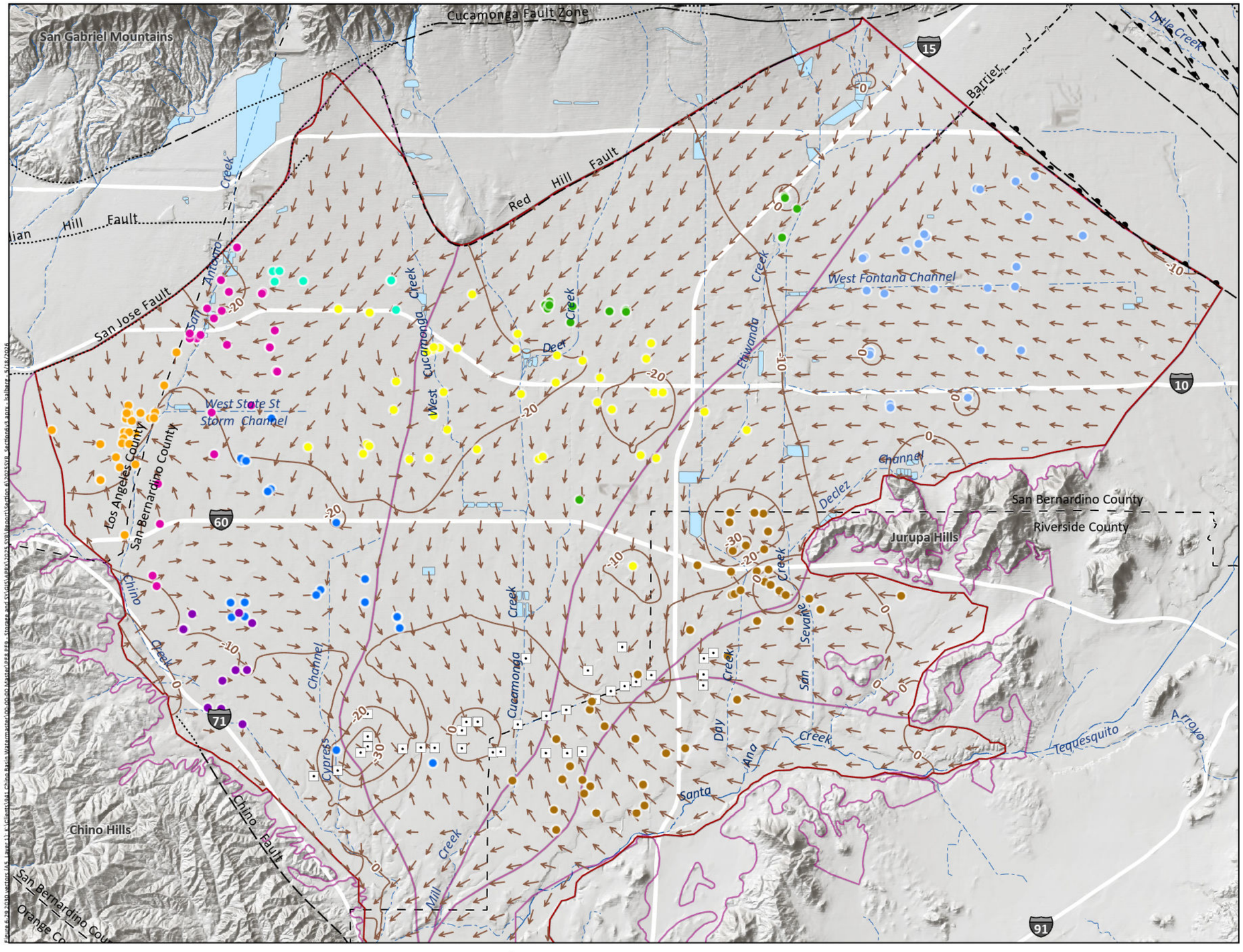
Figure 6-28



2030 Groundwater Flow Vector - Model Layer 1

2030 Groundwater Elevation Contours (ft-amsl) - Model Layer 1

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



Prepared by: WEST YOST

0 2 4 Miles

0 3 6 Km

Prepared for: Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Groundwater Level Elevations and Flow Vectors for July 2030

Scenario A5, Layer 1

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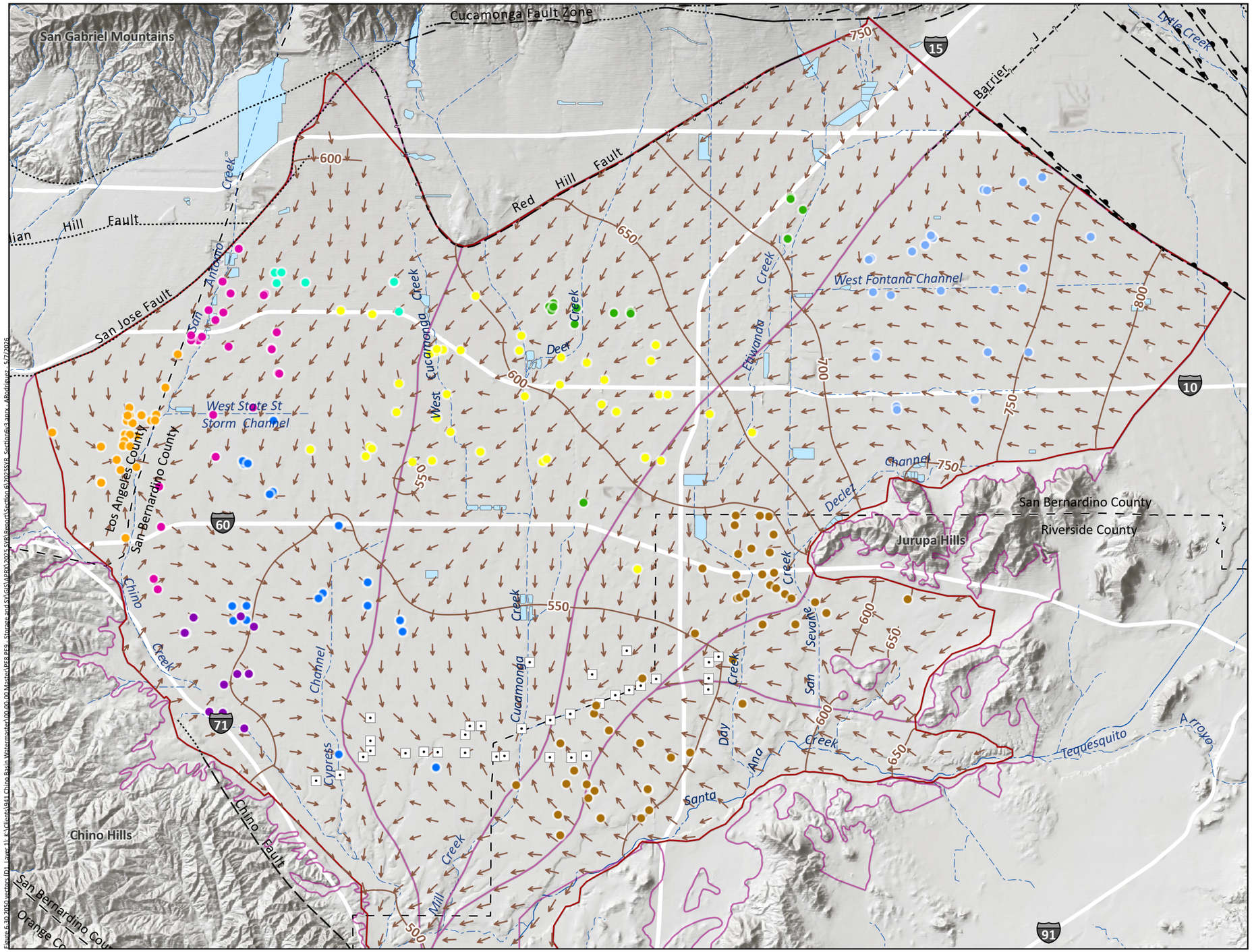
Figure 6-29



2050 Groundwater Flow Vector - Model Layer 1

2050 Groundwater Elevation Contours (ft-amsl) - Model Layer 1

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

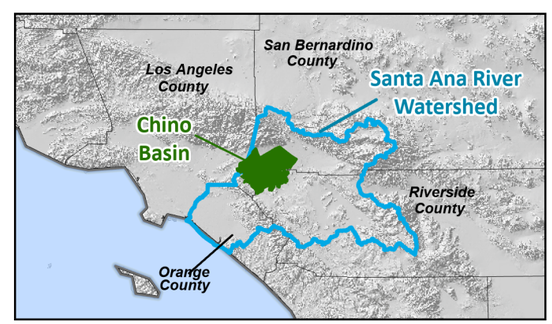
Flood Control and or Conservation Basins



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



Prepared by:

WEST YOST

0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Groundwater Level Elevations and Flow Vectors for July 2050

Scenario D1, Layer 1

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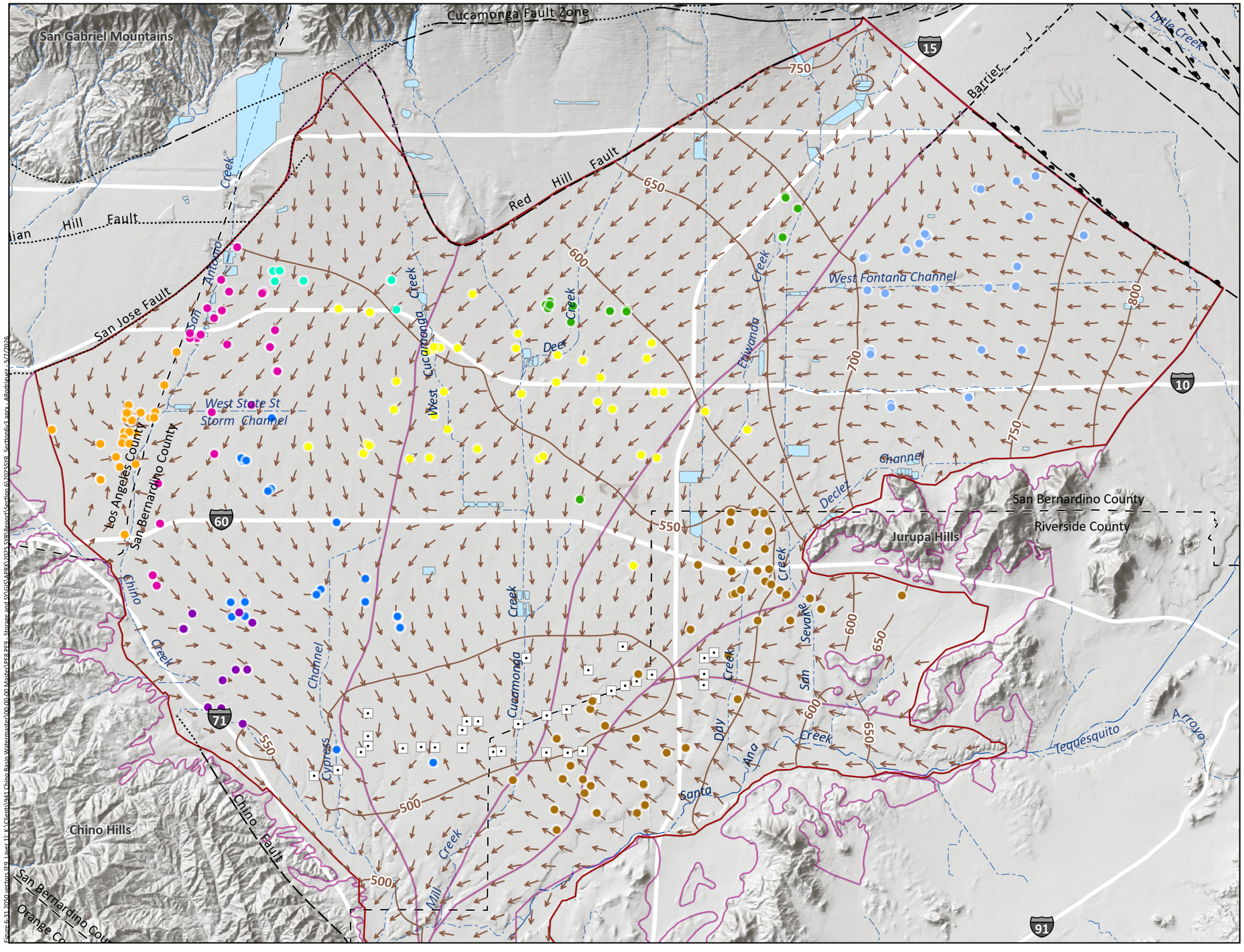
Figure 6-30



2050 Groundwater Flow Vector - Model Layer 1

2050 Groundwater Elevation Contours (ft-amsl) - Model Layer 1

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins



OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



Prepared by:

WEST YOST

0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Groundwater Level Elevations and Flow Vectors for July 2050

Scenario E9, Layer 1

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Figure 6-31

2050 Groundwater Flow Vector - Model Layer 1

2050 Groundwater Elevation Contours (ft-amsl) - Model Layer 1

Appropriative Pool Pumping Wells

- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Fontana Water Company
- Jurupa Community Services District
- Monte Vista Water District

Chino Desalter Well

Rivers and Streams

Flood Control and or Conservation Basins

OBMP Management Zones

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by: WEST YOST

Prepared for: Chino Basin Watermaster
2025 Safe Yield Reevaluation

Projected Groundwater Level Elevations and Flow Vectors for July 2050
Scenario A5, Layer 1

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Figure 6-32

SECTION 7
2025 Safe Yield Reevaluation

7.1 BACKGROUND AND OBJECTIVES

This section presents the findings of the 2025 Safe Yield Reevaluation and documents the execution of Step 9 of the 2022 SYRM:

> 9. *Evaluate whether the groundwater production at the Tentative Safe Yield estimated in [8] above will cause or threaten to cause "undesirable results" or "Material Physical Injury." If groundwater production at Tentative Safe Yield will cause or threaten to cause "undesirable results" or "Material Physical Injury," then Watermaster will identify and implement prudent measures necessary to mitigate "undesirable results" or "Material Physical Injury," set the value of Safe Yield to ensure there is no "undesirable results" or "Material Physical Injury," or implement a combination of mitigation measures and a changed Safe Yield.*

Although the term "undesirable result" is referenced in the Judgment definition of Safe Yield, it is not explicitly defined. Common law defines "undesirable result" as "a gradual lowering of the ground water levels resulting eventually in depletion of the supply."[1] However, prior Safe Yield recalculations have consistently assessed groundwater conditions based on the definition of Material Physical Injury (MPI), which effectively captures and addresses the risks associated with undesirable results. Therefore, the MPI framework will be used to encompass both "undesirable results" as used in the Judgment and MPI as defined in the Peace Agreement.

7.1.1 Categories of Material Physical Injury

The Peace Agreement defines MPI as "[…] *material injury that is attributable to Recharge, Transfer, storage and recovery, management, movement or Production of water or implementation of the OBMP, including, but not limited to, degradation of water quality, liquefaction, land subsidence, increases in pump lift and adverse impacts associated with rising groundwater*." Watermaster has used this definition to guide the scope of prior Safe Yield recalculations,[2] considering the potential for MPI from operating at the Safe Yield. The following lists each category of MPI and describes whether and how Watermaster will evaluate for MPI in Step 9 for 2025 SYR:

- **Degradation of water quality:** The Safe Yield is the sustainable pumping rate from the Chino Basin, and by itself, does not influence groundwater quality. Therefore, water quality is not analyzed herein as potential MPI that could be caused by the Safe Yield. Instead, the Watermaster addresses water quality challenges through other forums:
  - The Watermaster's responsibilities to manage groundwater quality are defined by the Optimum Basin Management Program (OBMP) with the advice of the Advisory and Pool Committees. The current forum by which water quality challenges are identified and addressed is the Water Quality Management Program (WQMP).
  - Salt and nutrient management in groundwater is regulated by the Regional Water Quality Control Board through the Chino Basin Maximum Benefit Program.

[1] See *City of Los Angeles v. City of San Fernando* (1975) 14 Cal.3d 199, 278 (disapproved of on other grounds by *City of Barstow v. Mojave Water Agency* (2000) 23 Cal.4th 1224); see also *City of Pasadena v. City of Alhambra* (1949) 33 Cal.2d 908, 929.

[2] 2020 Safe Yield Recalculation Report

- Point-source groundwater contamination plumes are regulated by the Regional Water Quality Control Board and monitored/mitigated by the responsible parties.

- **Liquefaction:** While operating at the Safe Yield may result in groundwater-level changes, the risk of liquefaction in the Chino Basin is considered insignificant because the water table is generally greater than 40 feet below the ground surface in areas with sensitive overlying infrastructure. Therefore, liquefaction is not analyzed herein as potential MPI that could be caused by the Safe Yield.
- **Land subsidence:** Operating at the Safe Yield may result in groundwater-level changes in areas of the Chino Basin that are prone to aquifer-system compaction, and hence, land subsidence and ground fissuring. Therefore, land subsidence is analyzed herein as potential MPI that could be caused by operating at the Safe Yield.
- **Increases in pump lift (i.e., pumping sustainability):** Operating at the Safe Yield may result in groundwater-level changes which could affect the ability of the parties to pump their wells in a manner to satisfy their water demands. Therefore, pumping sustainability is analyzed herein as potential MPI that could be caused by operating at the Safe Yield.
- **Adverse impacts associated with rising groundwater:** The primary adverse impact associated with rising groundwater is the potential loss of hydraulic control.[3] Operating at the Safe Yield may result in higher groundwater levels in the southern portion of the Chino Basin which could cause a loss of hydraulic control. Therefore, the potential loss of hydraulic control is analyzed herein as potential MPI that could be caused by operating at the Safe Yield.

Based on the above discussion, the 2025 Safe Yield Reevaluation will analyze the TSY Ensemble results for the MPI categories of: land subsidence; pumping sustainability; and the loss of hydraulic control.

7.1.2 MPI Analysis Methods

The general methods that were employed to evaluate the TSY Ensemble results for MPI included the following steps:

1. Characterize future groundwater conditions in the Chino Basin (*i.e.,* changes in groundwater levels and groundwater-flow directions) over the projection period (2023-2080) for each Projection Realization of the TSY Ensemble. The future groundwater conditions are described in Section 6.
2. Define the physical thresholds for the occurrence of MPI at representative monitoring locations for each MPI category (site-specific MPI threshold).

[3] The attainment of hydraulic control is measured by demonstrating, from groundwater elevation data, either that all groundwater north of the desalter well fields cannot pass through the CDA wellfields (total hydraulic containment standard) or that groundwater discharge through the CDA wellfields is, in aggregate, less than 1,000 afy (de minimis standard). The Regional Board has agreed that compliance with the de minimis standard will be determined from groundwater monitoring data and the results of periodic calibrations of the Watermaster groundwater model and interpretations of the calibration results.

3. Define the thresholds for the occurrence of MPI in each area or subarea of the basin (e.g., Areas of Subsidence Concern) based on the magnitude or ratio of site-specific MPI threshold exceedances for a Projection Realization (subarea MPI thresholds).
4. For each area or subarea, compare future groundwater conditions (from Step 1) against the site-specific MPI thresholds at representative monitoring locations (from Step 2) for each Projection Realization of the TSY Ensemble and determine whether MPI is predicted to occur using the subarea MPI thresholds (defined in Step 3).
5. For each area or subarea, determine if the potential for MPI (identified in Step 4) occurs in 50 percent or more likelihood-weighted Projection Realizations. If this occurs, describe the drivers of the MPI and discuss the potential methods to avoid the MPI, including mitigation measures and/or a changed Safe Yield.

7.2 MPI ANALYSIS FOR THE TSY ENSEMBLE

This subsection describes the analysis of MPI that could be caused by the projected groundwater conditions of the TSY Ensemble for the MPI categories of:

- Land Subsidence
- Pumping Sustainability
- Loss of Hydraulic Control

7.2.1 Land Subsidence

Historically, permanent land subsidence, accompanied in some places by damaging ground fissuring, occurred across the western portion of the Chino Basin. Subsequent studies determined that the primary subsidence mechanism was permanent compaction of the aquifer-system sediments due to declines of groundwater levels that exceeded historical lows in groundwater levels (i.e., preconsolidation stress).

Historical aquifer-system compaction and land subsidence have generally been confined to the western portion of the Chino Basin where the underlying aquifer system is relatively rich in compressible clay layers (i.e., aquitards of varying thickness and lateral extent). To avoid future permanent land subsidence and ground fissuring, the Watermaster developed and implements an adaptive Subsidence Management Plan that defined five Areas of Subsidence Concern across western Chino Basin. Figure 7-1 is a map showing the five Areas of Subsidence Concern.

The Subsidence Management Plan includes a monitoring/testing program to understand the occurrences and mechanisms of the aquifer-system compaction and land subsidence, and based on this understanding, provides guidance to the pumpers and the Watermaster for groundwater management activities to minimize or abate the future occurrences of aquifer-system compaction and land subsidence. The program has shown that recent aquifer-system compaction primarily occurs due to head declines in the deeper portions of the aquifer system in the Areas of Subsidence Concern.

In this study, the potential for MPI due to land subsidence is analyzed in each Area of Subsidence Concern via comparison of projected groundwater elevations versus historical lows in groundwater elevations (or elevations previously identified in the Subsidence Management Plan as the preconsolidation stress for an

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Area). The analysis preferentially focuses on the deeper portions of the aquifer system based on the results and conclusions of the monitoring/testing program.

7.2.1.1 Site-Specific MPI Thresholds for Land Subsidence

The first step to analyze for MPI associated with land subsidence (Step 2 of the MPI Analysis Methods) was to establish site-specific MPI thresholds at selected wells—herein referred to as land subsidence thresholds (LSTs). An LST is set at the historical low groundwater elevation measured at a well (or estimated based on trends in groundwater elevations at nearby wells). This was chosen to assume that groundwater elevations declining below the LST will cause new aquifer-system compaction in the vicinity of the well. The wells were preferentially chosen: (i) with well screens that penetrate the deeper portions of the aquifer system (the depths most susceptible to compaction) and (ii) to achieve an even spatial distribution across the Areas of Subsidence Concern. The exception is the PA-7 piezometer at the Ayala Park Extensometer in the Managed Area where, through extensive testing and data analysis, a "Guidance Level" elevation has been established as the preconsolidation stress threshold in the Subsidence Management Plan. Figure 7-1 is a map that shows the chosen wells and LST elevations across the five Areas of Subsidence Concern.

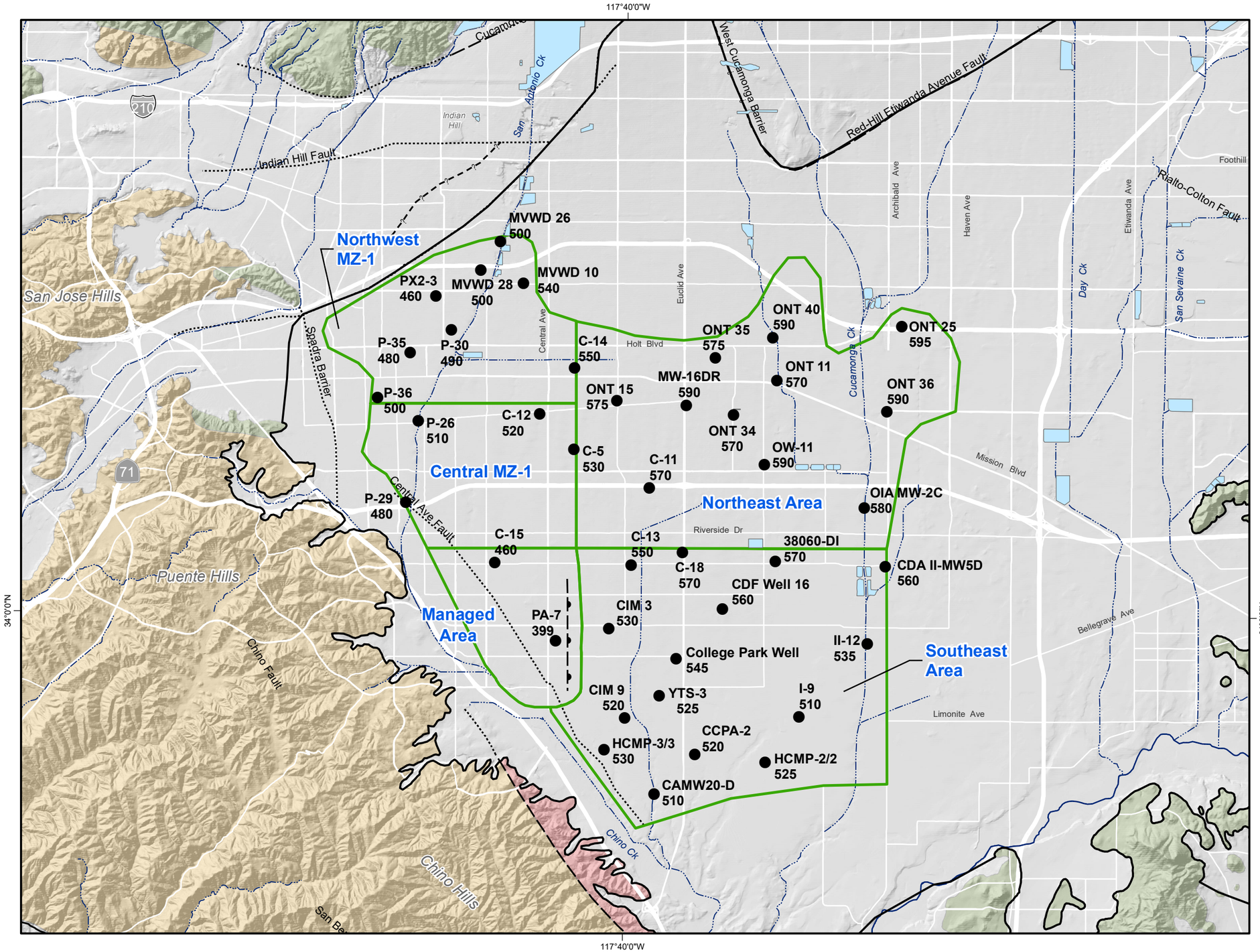
7.2.1.2 Subarea MPI Thresholds for Land Subsidence

The potential for MPI is identified by subarea (i.e., Area of Subsidence Concern). Therefore, the next steps to analyze for MPI associated with land subsidence (Steps 3, 4, and 5 of the MPI Analysis Methods) were to define the statical thresholds for the occurrence of MPI in each Area of Subsidence Concern, for each Projection Realization, and for the entire TSY Ensemble:

- In each of the Areas of Subsidence Concern (excluding the Managed Area), MPI was identified if, by 2050, the projected groundwater elevation for CVM Layer 3 is below the LST at 50 percent or more of wells in 50 percent or more of the Projection Realizations in the TSY Ensemble.[4]
- For the Managed Area, MPI was identified if, by 2050, the projected groundwater elevation at the PA-7 piezometer is lower than the Guidance Level (399 ft-amsl) in more than 50 percent of the Projection Realizations in the TSY Ensemble.

The year 2050 was chosen for this MPI analysis because it reflects the time when managed storage is typically at or near zero in most projection realizations, and hence, groundwater levels are projected to be lowest. These criteria collectively account for the uncertainty in simulated groundwater elevations.

[4] Chino Well 15 was included with the wells used to evaluate MPI in Central MZ-1.



Well Name
550
Well with Land Subsidence Threshold (ft-amsl)

Area of Subsidence Concern

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Plio-Pleistocene Sedimentary Rocks

Cretaceous to Miocene Sedimentary Rocks

Pre-Tertiary Igneous and Metamorphic Rocks

Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)

Hydrology

Streams & Flood Control Channels

Flood Control & Conservation Basins



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Author: LMS
Date: 7/14/2025
Document Name: LST Analysis

0 1 2 3 4 5 Miles
0 2 4 6 8 KM

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Chino Basin Watermaster
2025 Safe Yield Reevaluation

Site-Specific MPI Thresholds for Land Subsidence

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Figure 7-1

7.2.1.3 Results of MPI Analysis for Land Subsidence

Figures 7-2 through 7-5 are maps of each Area of Subsidence Concern (excluding the Managed Area) showing the likelihood-weighted average groundwater elevations for FY 2030 and 2050 relative to the LST for each monitoring well location. The wells are symbolized by color for distance above/below the LST. The figures also include:

- A "box-and-whiskers plot" that characterizes the distances above/below the LST for all wells by Projection Scenario (for all calibrated CVM realizations). Each dot represents one well in one Projection Realization. The red percentage at the bottom of the plot indicates the likelihood-weighted average percentage of groundwater elevations at all wells that are below the LST. These plots are useful in understanding the drivers of any identified MPI.
- A "heat map" of MPI by Projection Realization. Red squares indicate MPI associated with that Projection Realization. MPI for an Area of Subsidence Concern is identified if more than 50 percent of the Projection Realizations are determined to cause MPI (i.e., the projected groundwater elevation for CVM Layer 3 is below the LST at more than 50 percent of wells).

Figure 7-6 is a time-series chart of projected groundwater elevations at the PA-7 piezometer in the Managed Area for the TSY Ensemble and a heat map for all Projection Realizations. The chart shows that the likelihood-weighted average groundwater elevation at the PA-7 piezometer is always significantly higher (greater than 70 feet) than the Guidance Level (399 ft-amsl).

Based on the analysis above, the likelihood-weighted percentages of Projection Realizations that exceed the MPI threshold in FY 2050 for each Area of Subsidence Concern are:

- Central MZ-1: 7 percent
- **Northeast Area: 96 percent**
- Northwest MZ-1: 15 percent
- **Southeast Area: 97 percent**
- Managed Area: 0 percent

Hence, **the Northeast Area and the Southeast Area** have 50 percent or more likelihood-weighted Projection Realizations exceeding the subarea MPI threshold for land subsidence in FY 2050.

7.2.1.4 Discussion

Table 7-1 summarizes the MPI analysis for land subsidence, indicating the number of wells that have LSTs in each region, the average percentage of wells exceeding the LST for each scenario, and the likelihood-weighted average percentage of wells exceeding the LST for the TSY Ensemble. Figure 7-7 shows two heatmaps for all Projection Realizations depicting the number of Areas of Subsidence Concern with MPI (0 through 5) in FY 2030 and 2050.

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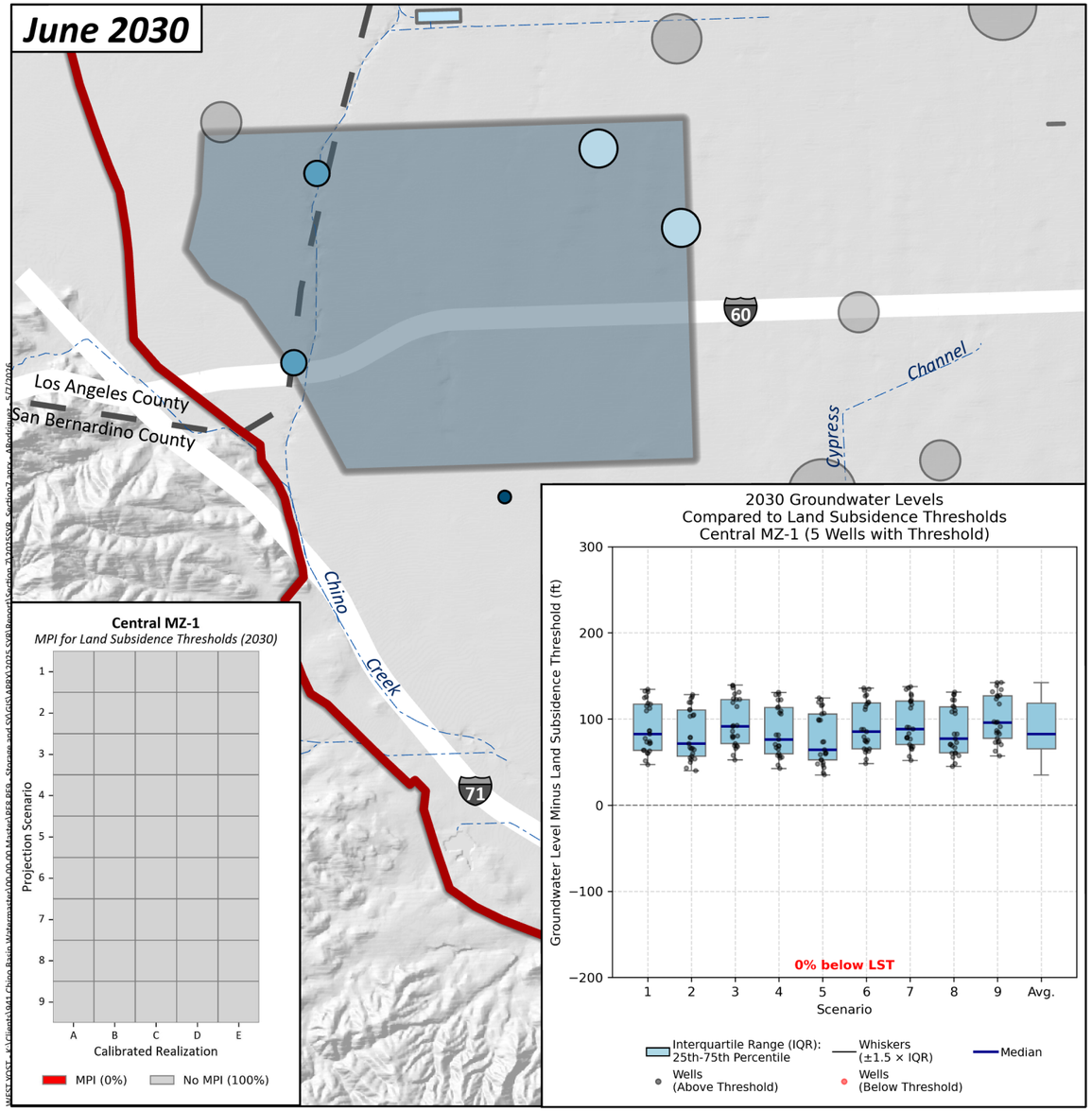
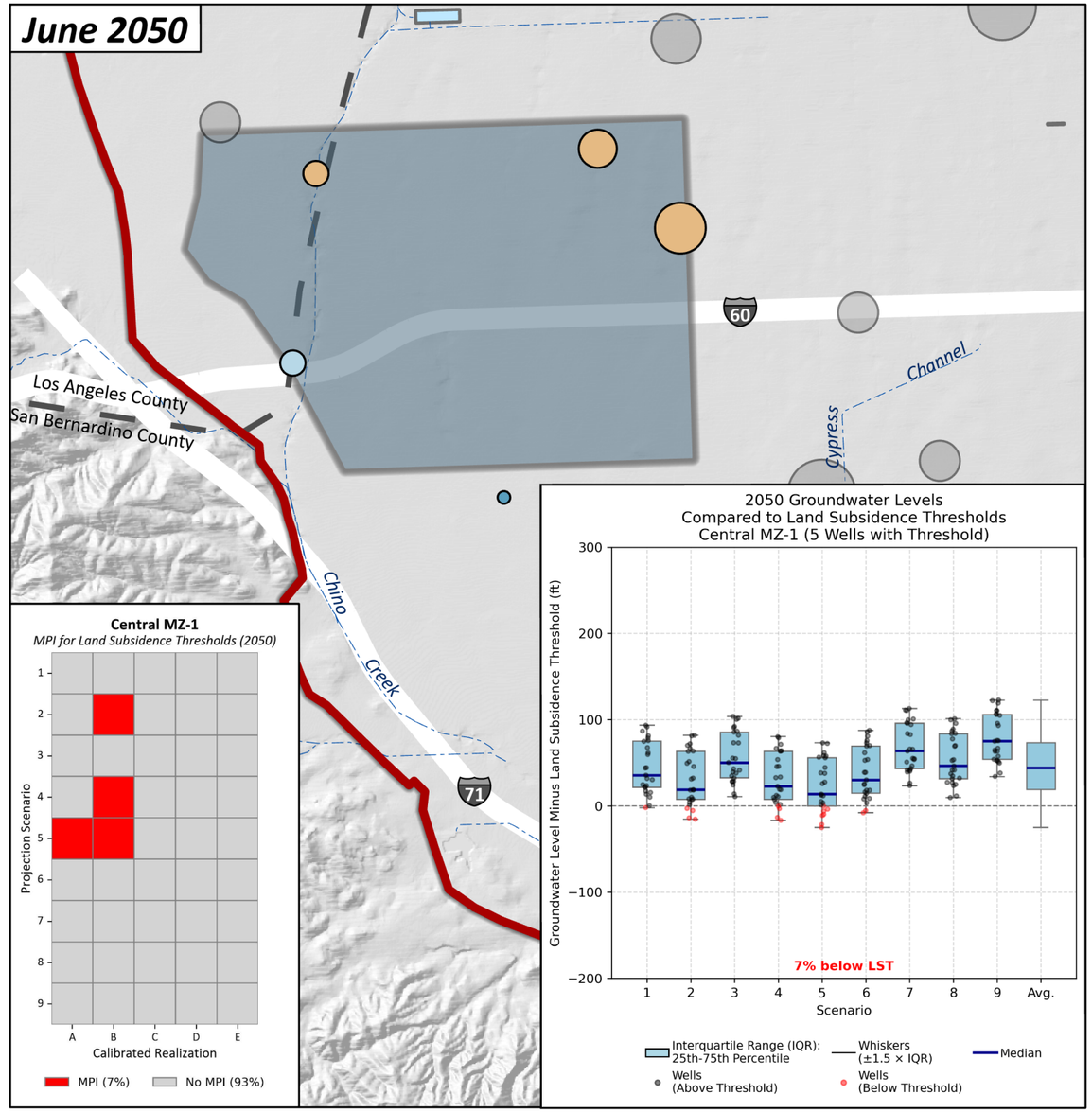
Table 7-1. Percentage of Wells Below Land Subsidence Thresholds, FY 2030 and FY 2050

Scenario	Likelihood Weight	Area of Subsidence Concern									
		Central MZ-1 5 wells with LST Figure 7-2		Managed Area 1 well Figure 7-6		Northeast Area 11 wells Figure 7-3		Northwest MZ-1 8 wells Figure 7-4		Southeast Area 15 wells Figure 7-5	
		2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
1	4	0	4	0	0	11	91	0	5	24	84
2	2	0	16	0	0	26	100	0	23	45	93
3	2	0	0	0	0	0	80	0	0	8	75
4	2	0	16	0	0	15	100	0	18	25	97
5	1	0	28	0	0	47	100	0	23	53	100
6	1	0	8	0	0	6	95	0	10	11	87
7	2	0	0	0	0	2	53	0	0	19	64
8	1	0	0	0	0	16	86	0	3	35	79
9	1	0	0	0	0	0	27	0	0	8	33
Likelihood-Weighted Average		0%	7%	0%	0%	12%	84%	0%	8%	25%	81%





0 0.5 1 Miles

0 1 2 Km

N

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Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Central MZ-1
- Rivers and Streams
- Flood Control and/or Conservation Basins

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Assessment of MPI due to Land Subsidence
2030 and 2050
Central MZ-1

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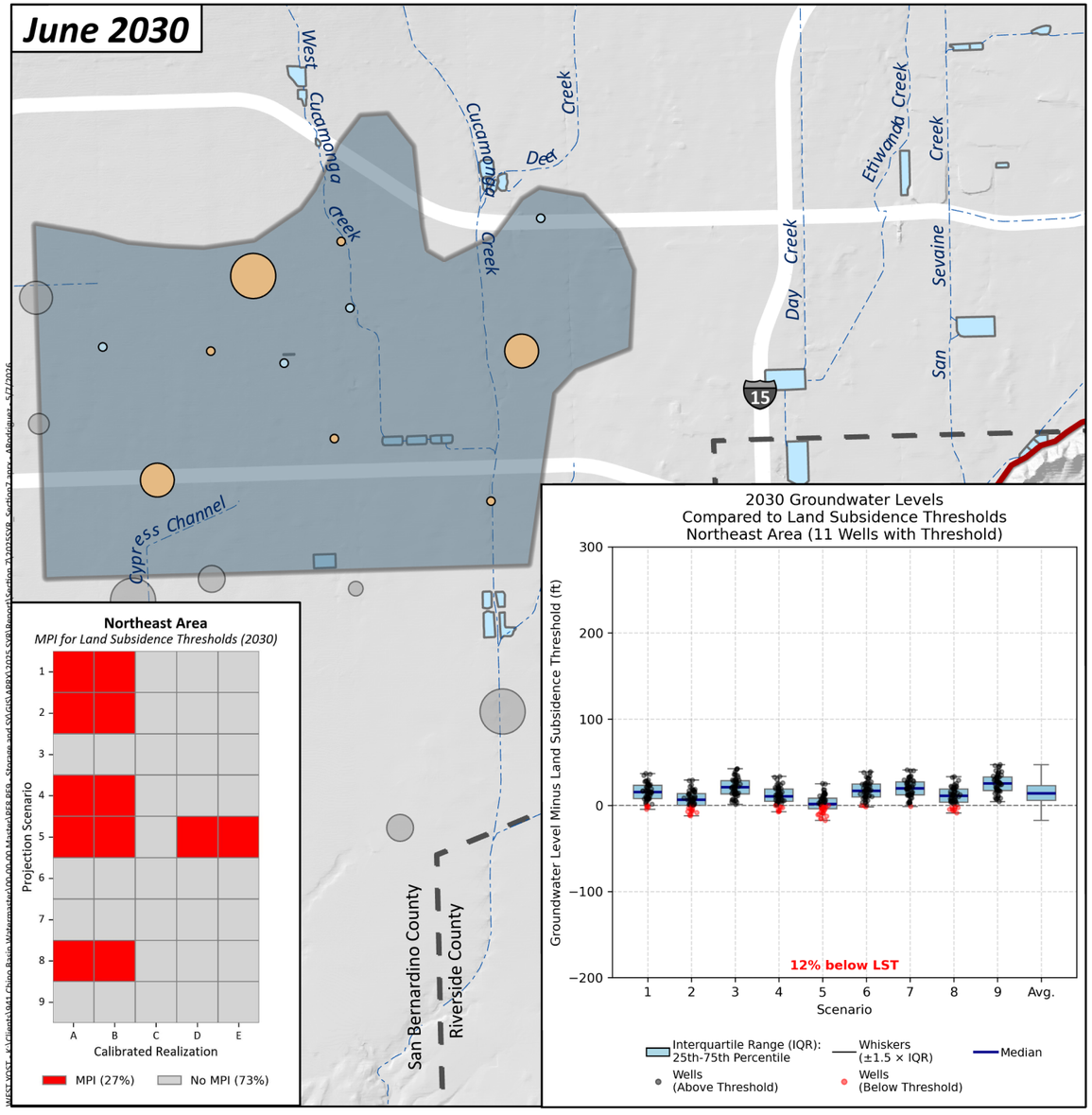
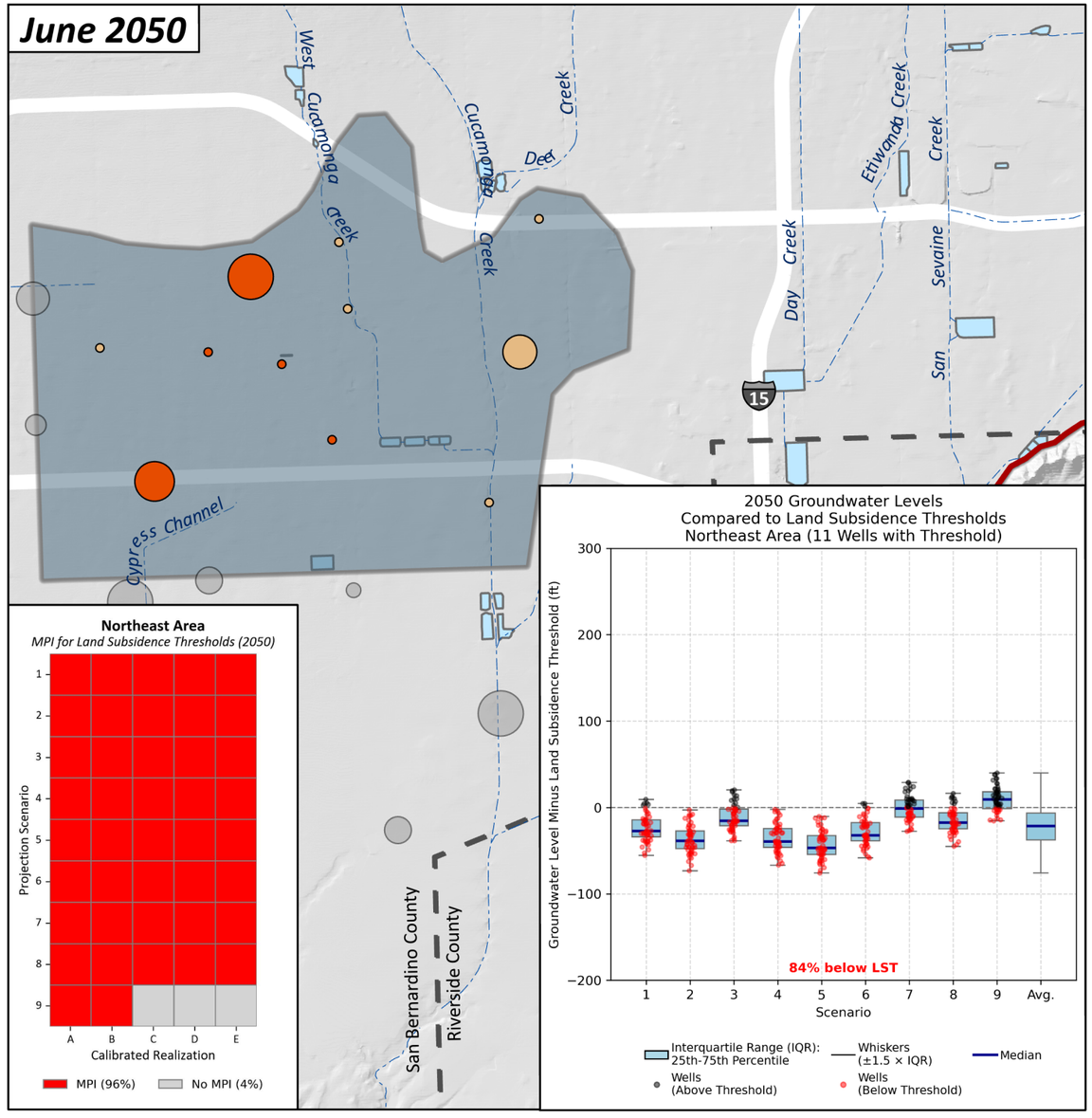
Figure 7-2

June 2030



June 2050



0 0.5 1 Miles

0 1 2 Km

N

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Northeast Area
- Rivers and Streams
- Flood Control and/or Conservation Basins

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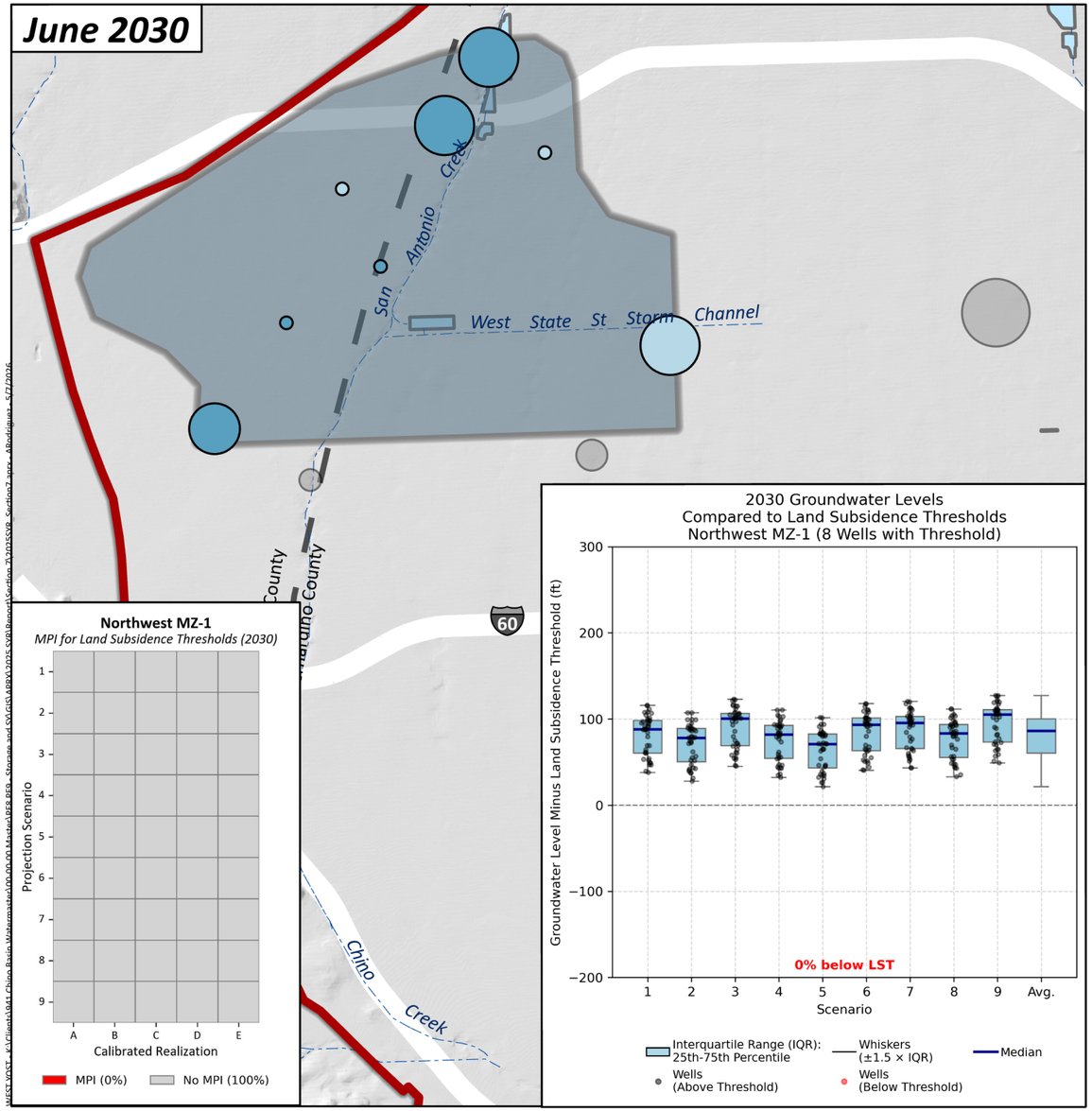
Assessment of MPI due to Land Subsidence
2030 and 2050
Northeast Area

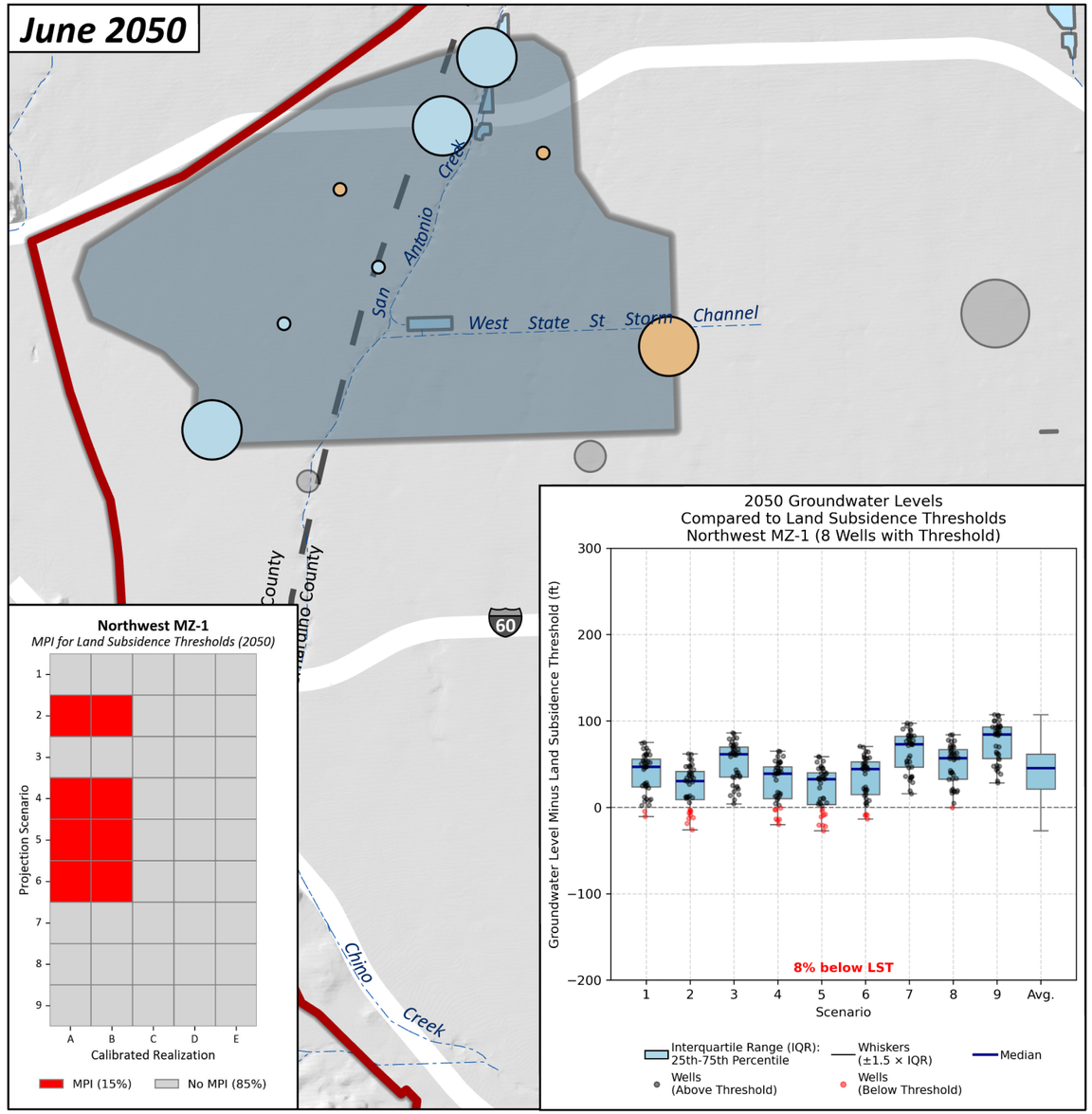
DRAFT

Figure 7-3

June 2030



June 2050



0 0.5 1 Miles

0 1 2 Km

N

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Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Northwest MZ-1
- Rivers and Streams
- Flood Control and/or Conservation Basins

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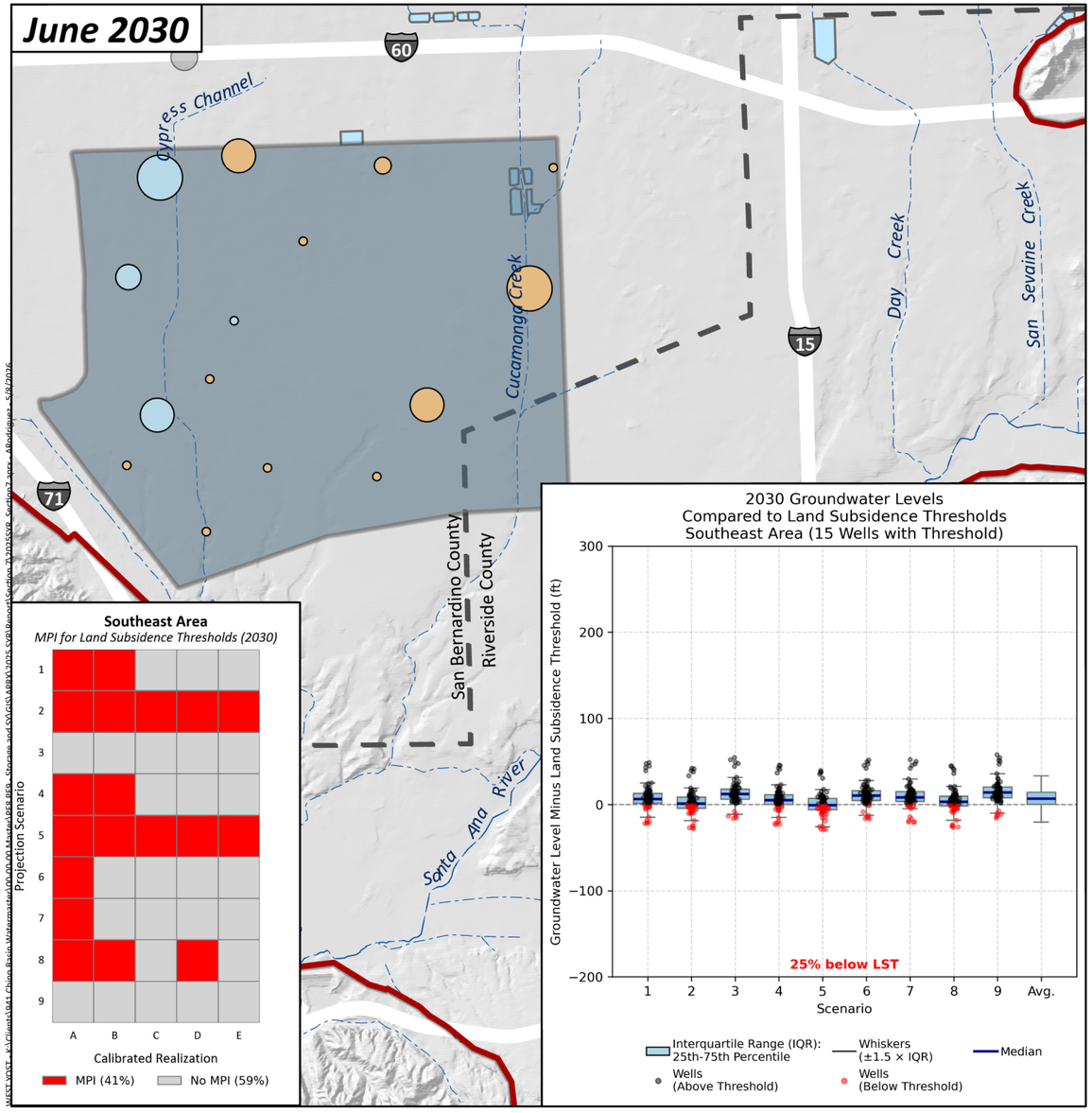
Assessment of MPI due to Land Subsidence
2030 and 2050
Northwest MZ-1

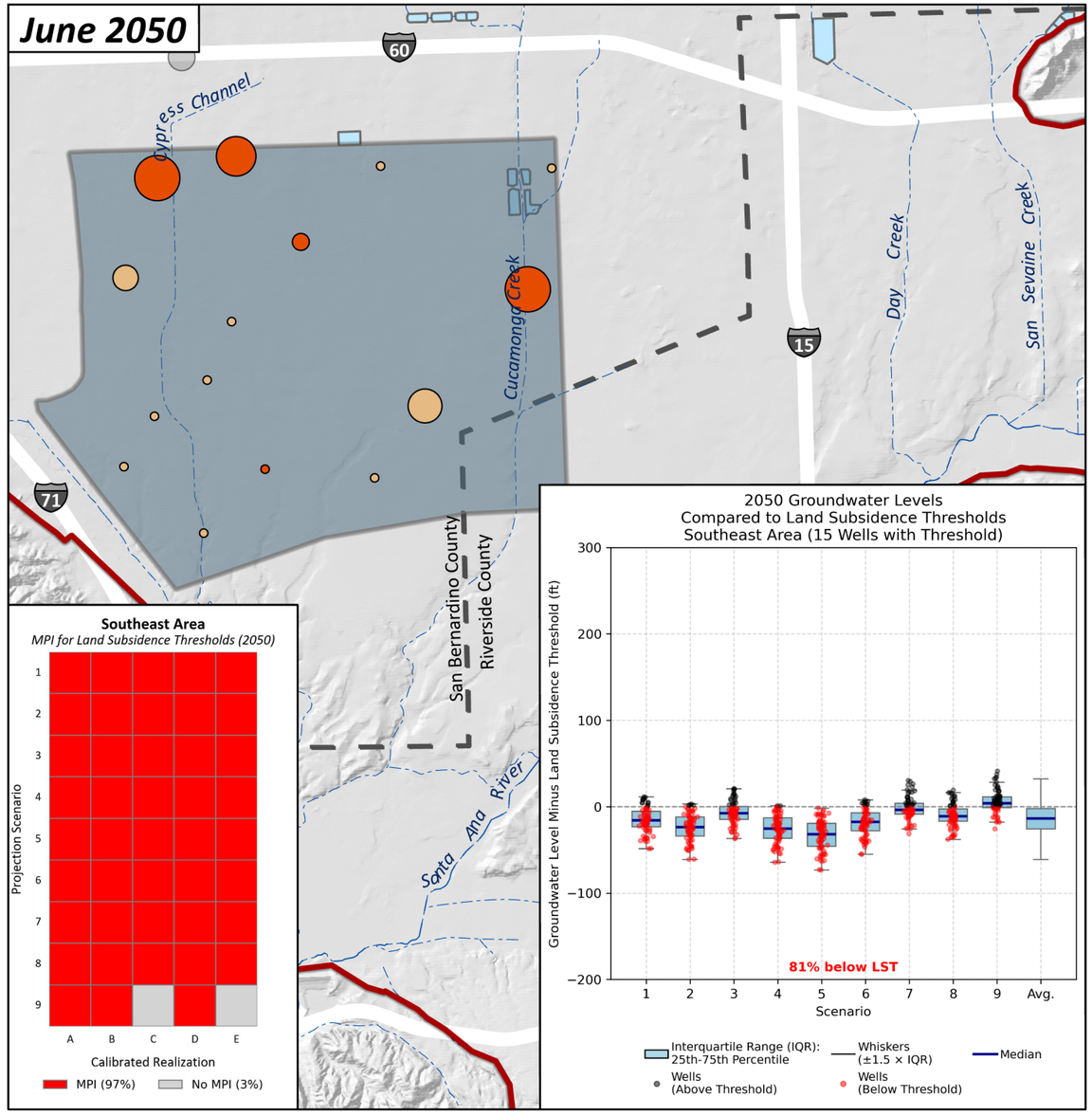
DRAFT

Figure 7-4

June 2030



June 2050



0 0.5 1 Miles

0 1 2 Km

N

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Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Southeast Area
- Rivers and Streams
- Flood Control and/or Conservation Basins

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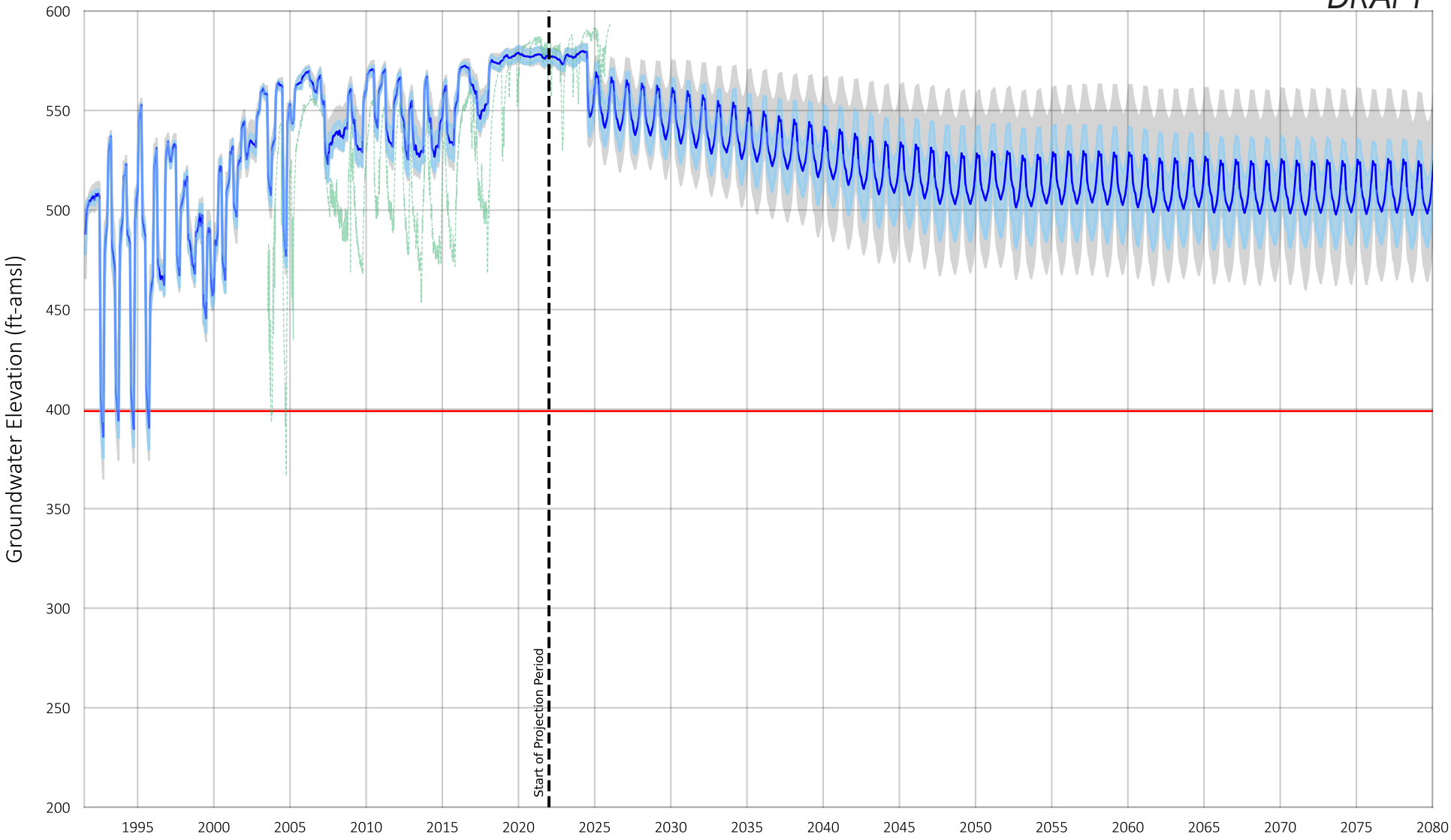
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
Southeast Area

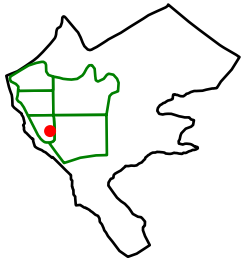
DRAFT

Figure 7-5

DRAFT



Well Location &
Areas of Subsidence Concern



Legend

- Guidance Level
- Measured Groundwater Elevation
- Likelihood Weighted Mean Groundwater Elevation
- Minimum/Maximum Range in Simulated Groundwater Elevations
- 20th to 80th Percentile of Simulated Groundwater Elevations

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Simulated Groundwater Levels
Well Name: AP-PA7
Well Owner: Chino Basin Watermaster
Screen Interval (ft-bgs): 438 - 448

Figure 7-6

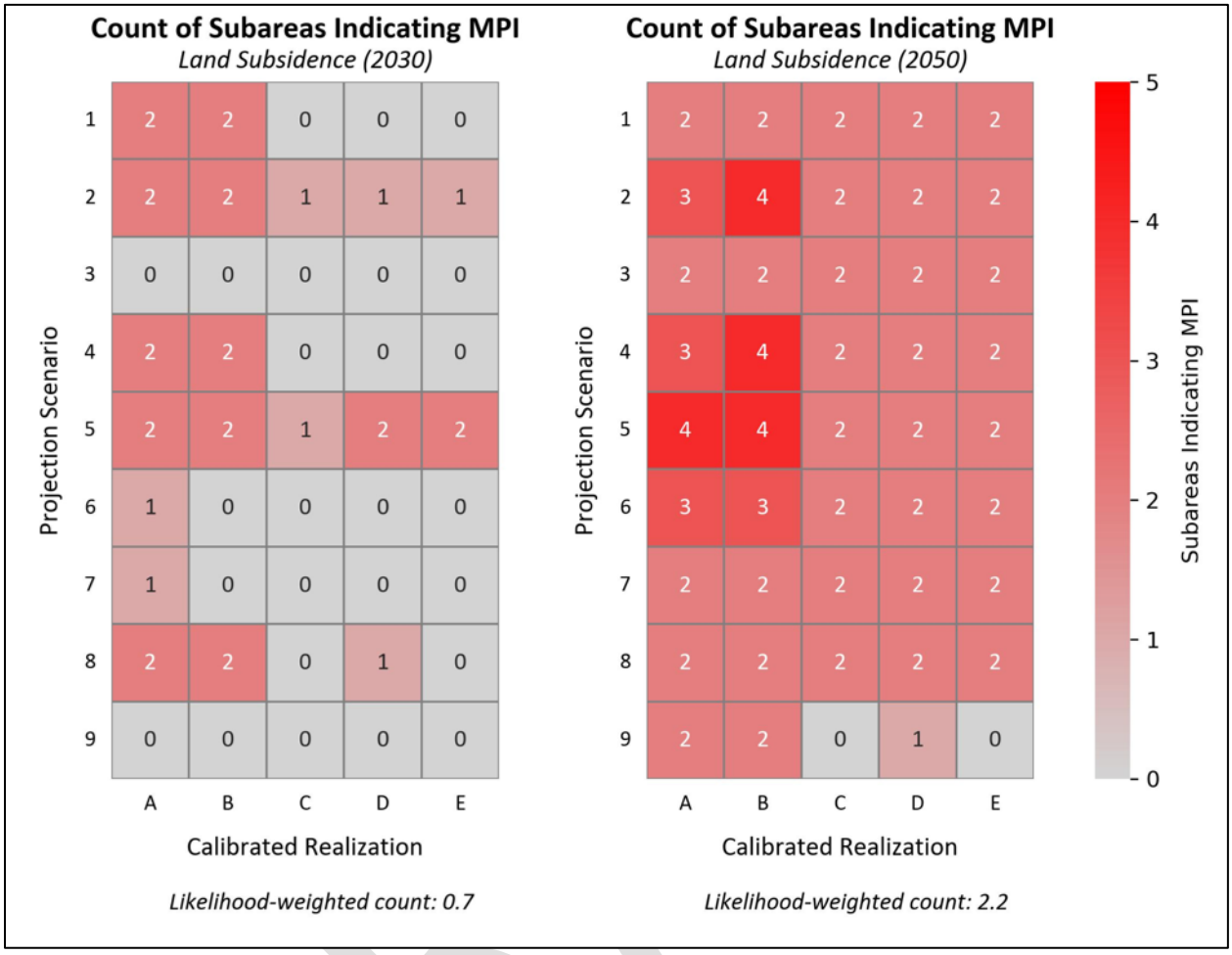


Figure 7-7. Count of Subareas Indicating MPI for Land Subsidence for the TSY Ensemble (FY 2030 and 2050).

Figure 7-7 shows that subsidence-related MPI increases from an average of 1.1 subareas in FY 2030 to 2.7 subareas in FY 2050. The degree of MPI varies between Projection Realizations, having the highest incidence in High Demand Scenarios (Projection Scenarios 4, 5, and 6) and the Hot/Dry Climate Scenarios (Scenarios 2 and 5).

7.2.1.4.1 Drivers of MPI for Land Subsidence

The primary drivers of MPI due to land subsidence are the extraction of water from managed storage (and high demand) and a hotter/drier climate.

Figure 7-8 shows the direct relationship between declining storage and the increasing MPI due to land subsidence, depicting the average change in storage from FY 2021-2050 versus the average number of subareas indicating MPI for land subsidence in FY 2050 for several subgroups of Projection Realizations.

- The High Demand Projection Realizations (Scenarios 4, 5, and 6) indicate MPI at an average of 3.3 subareas, compared to 1.5 subareas and 2.9 subareas for the Low Demand and Expected Demand Projection Realizations, respectively.

- The number of subareas indicating MPI increases by a factor of 0.6 (Low Demand) to 1.5 (Expected and High Demand) from FY 2030 to FY 2050.
- In all High Demand Projection Realizations, the balance of managed storage is zero by 2050, whereas the average managed storage is 380,000 af and 87,000 af in 2050 for the Low Demand and Expected Demand Projection Realizations, respectively.

Climate also drives subsidence-related MPI, but to a lesser degree than demand. The Hot/Dry Climate Projection Realizations (Scenarios 2, 5, and 8) indicate MPI at an average of 2.7 subareas, compared to 1.9 subareas and 2.3 subareas for the Cool/Wet and Average Climate Scenarios, respectively.

7.2.1.4.2 Potential Methods to Avoid or Mitigate MPI due to Land Subsidence

The analysis above indicates that the groundwater-level declines that could lead to subsidence-related MPI are mainly driven by future extractions of groundwater from managed storage. These extractions from managed storage may be accelerated under hot/dry climate conditions and/or greater than expected water demands, but the extractions from managed storage are predicted to be the primary driver of future land subsidence. As discussed below in Section 7.3.2, a changed Safe Yield ***is not*** the most effective method to mitigate the potential for subsidence-related MPI. Instead, the Watermaster has the ability to employ alternative methods to mitigate the potential for MPI due to land subsidence, which include: subsidence management planning and implementation; recharge master planning and implementation; and storage management planning and implementation for both local storage and regional storage and recovery programs. Each method is summarized below:

- **Subsidence Management**. The Watermaster implements a Court-approved, adaptive Subsidence Management Plan under the supervision and guidance of a technical advisory committee called the Ground-Level Monitoring Committee (GLMC). The Subsidence Management Plan includes an adaptive monitoring and reporting program and guidance for subsidence management in certain Areas of Subsidence Concern. For example, through an extensive aquifer-system monitoring and testing investigation, the Subsidence Management Plan includes a "guidance" groundwater elevation for the deep aquifer system in the Managed Area. Maintaining groundwater elevations above the "guidance" level will avoid future land subsidence. The Watermaster monitors and reports on groundwater elevations in the Managed Area, so the pumpers in this area can voluntarily modify their pumping patterns to keep groundwater elevations above the "guidance" level. Similar efforts could be employed in other Areas of Subsidence Concern to minimize or avoid subsidence-related MPI.
- **Recharge Master Planning**. The Watermaster periodically updates a Recharge Master Plan that designs, evaluates, and recommends recharge improvement projects with the goals to enhance basin yield, manage groundwater levels, and improve water quality. Future updates to the Recharge Master Plan could include projects that support groundwater levels in areas predicted to experience subsidence-related MPI. The Recharge Master Planning process also provides an avenue through which Watermaster can meet its Peace Agreement obligations to ensure sufficient recharge capacity and direct recharge in the Basin.[5]

[5] See Sections 5.1(e)(ii) and 5.1(e)(iii) of the Peace Agreement.

- **Storage Management**. The Judgment provides the Watermaster with the authority to manage and control storage for both local storage by the parties and regional storage and recovery programs. To guide Watermaster's efforts to manage storage pursuant to its obligations in the Judgment and Peace Agreement, the Watermaster has developed and periodically updates a Storage Management Plan. Future updates to the Storage Management Plan could include projects, programs, and/or provisions that support groundwater levels in areas predicted to experience subsidence-related MPI. In addition, the Storage Management Plan can help facilitate Watermaster to meet its Peace Agreement obligations to evaluate MPI due to transfers from storage.[6]

7.2.2 Pumping Sustainability

Pumping sustainability is the ability to produce groundwater from a specific well at a desired pumping rate, given the groundwater level at that well, the well construction details, and the current pumping equipment. Pumping sustainability thresholds (PSTs) are groundwater levels that are defined by the producer for each well. Watermaster collects this information from the larger Appropriative Pool parties and the Chino Basin Desalter Authority (CDA). The Appropriative Pool parties typically specify PSTs as an elevation representing a depth above the pump setting elevation of a well (e.g., 40 feet above the pump setting elevation). Groundwater pumping at a well is assumed to be sustainable if the groundwater elevation at that well remains above the PST. If the projected groundwater elevation declines below (exceeds) the PST, the well owner will either lower the pumping equipment in their well, reduce pumping, or a combination of the two. The PST is the site-specific MPI threshold for pumping sustainability.

7.2.2.1 Evaluation Criteria and Methods

MPI can be defined by a combination of the (1) number of impacted wells (i.e., wells that exceed the PST), (2) duration of impact, and/or (3) magnitude of impact (i.e., the difference between the projected groundwater level and the PST) within each management zone, area, or subarea. Because the concept of pumping sustainability is subjective and varies among different parties, it is necessary for Watermaster to develop a comprehensive definition of the pumping sustainability MPI thresholds.

7.2.2.1.1 Party Input to Develop Site-Specific and Subarea MPI Thresholds

The parties have discretion as to their individual definitions of pumping sustainability. Therefore, as part of this process, Watermaster requested responses to the following questions from 12 of the Appropriative Pool parties for which PSTs are defined[7]:

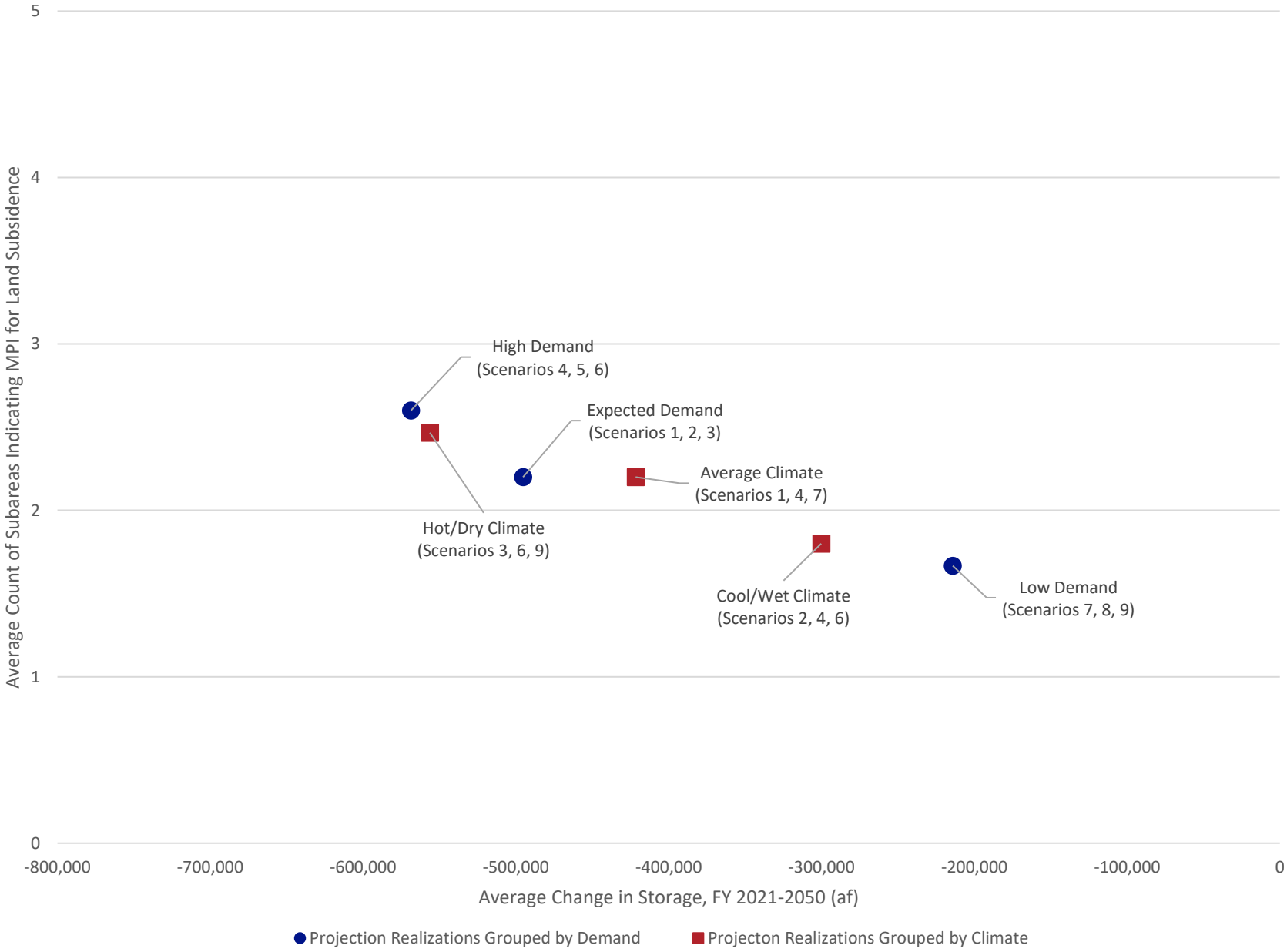
1. How many of your wells need to fall below the sustainability metric[8] before it becomes difficult to pump the desired amount of groundwater?
2. How long (in months or years) must the groundwater level at a single well remain below the sustainability metric before it becomes challenging to pump the desired amount of groundwater?

[6] See Section 5.1(e)(iv) of the Peace Agreement.

[7] Watermaster's Engineer contacted the Chino Desalter Authority, the cities of Chino, Chino Hills, Ontario, Pomona, and Upland, Monte Vista Water District, Jurupa Community Services District, Fontana Water Company, Cucamonga Valley Water District, Golden State Water Company, and San Antonio Water Company.

[8] This report uses the term "thresholds" to describe pumping sustainability, whereas the term "metrics" has been used historically by Watermaster and was used for the information request.

Figure 7-8. Change in Storage and Prevalence of MPI for Land Subsidence



Watermaster contacted the applicable Appropriative Pool parties to (1) answer the two questions above and (2) update or confirm information on their party's active production wells in the Chino Basin. Other parties (e.g., the State of California) were also invited to provide input related to the PSTs. A summary of the feedback from the parties is as follows:

- **Adaptive Management**: The parties employ various strategies to maintain production, such as adjusting pump settings, adding extensions, and regularly rehabilitating wells.
- **Uncertainty**: The parties indicated significant uncertainty in predicting the exact impact and duration of wells falling below sustainability thresholds. Challenges contributing to this uncertainty include water quality, demands, and availability of other supplies.
- **Mitigation Efforts**: The parties discussed measures like system resiliency and redundancy, to ensure continued pumping operations and groundwater supply.
- **Duration Below PST**: The time a well can remain below the PST before it becomes challenging to pump groundwater varies widely. Some parties indicate that wells can operate below the PST for years with careful monitoring, while others suggest that concerns arise within months, especially under different hydrologic conditions. The exact duration is often uncertain due to numerous influencing factors.

Table 7-2 documents the feedback received from the parties that responded to the request regarding pumping sustainability. Figure 7-9 shows the wells in the Chino Basin that have PSTs.

7.2.2.1.2 Subarea Threshold for MPI Due to Pumping Sustainability

The subareas for evaluating pumping sustainability are the wellfields for each of the AP parties for which PSTs are defined. The diversity of responses to questions regarding PSTs suggests that applying a single, generalized threshold to assess the risk of MPI due to pumping sustainability challenges may not be appropriate. Consequently, we evaluate the risk of MPI for the 12 retail AP parties using one of two approaches: (1) the party's individual definition of pumping sustainability, based on their responses to the above questions, or (2) if a party did not provide a clear response, by assessing the proportion of their well field that exceeds the PST for at least five consecutive years. Five years was chosen to acknowledge the uncertainty in simulated groundwater levels and ensure that short-term or anomalous conditions do not skew the assessment of sustainability.

Table 7-2 shows how the party feedback was interpreted to define criteria to evaluate MPI due to pumping sustainability for each party. The criteria include the minimum number of wells that exceed the PST and the consecutive time over which the wells must exceed the PST for MPI to occur. MPI for a party is identified if 50 percent or more Projection Realizations are determined to cause MPI based on the party-specific definition.

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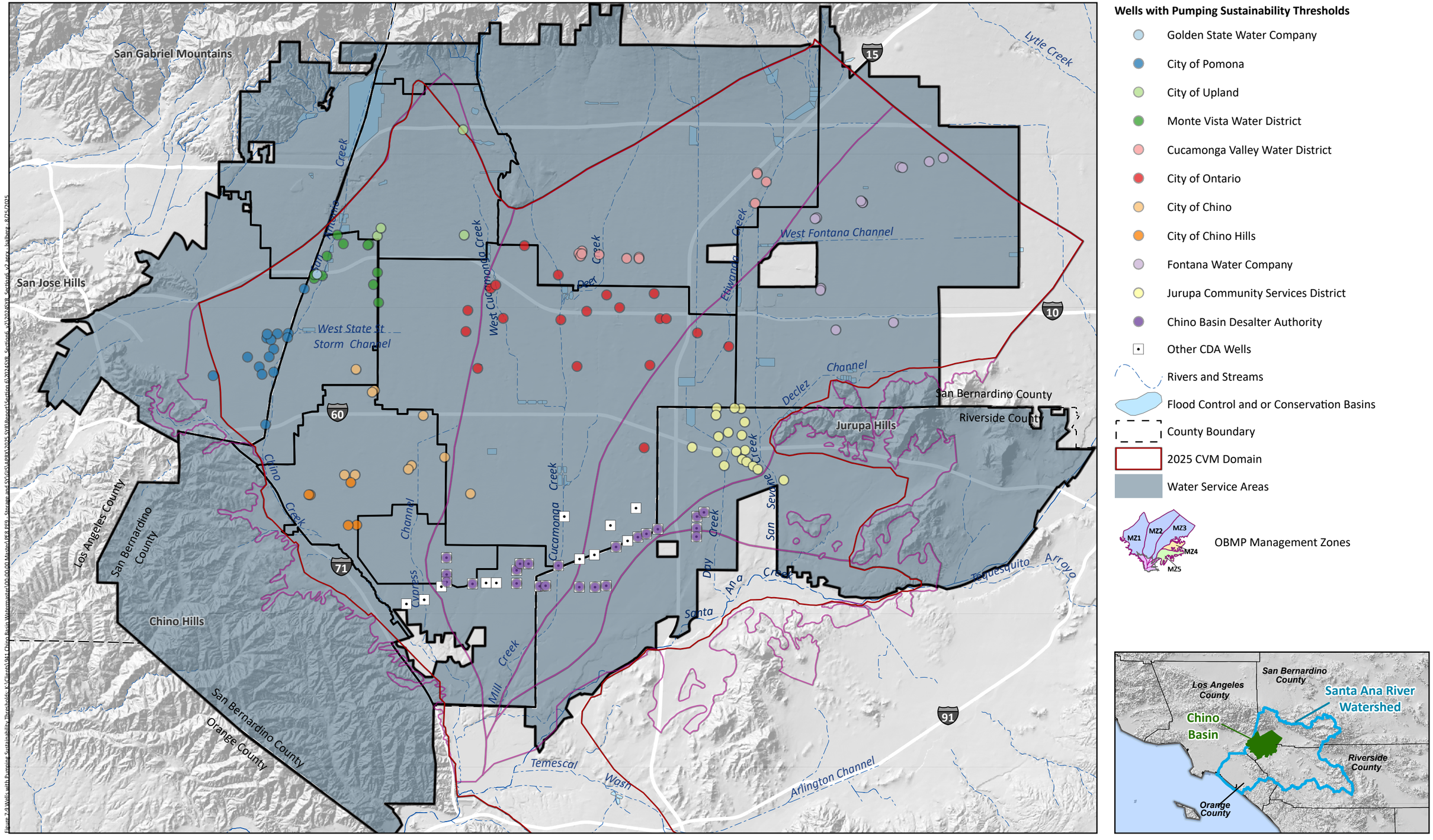

Figure 7-9 Wells with Pumping Sustainability Thresholds K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PER PF9 - Storage and SY\GIS\APRX\2025 SYR\Report\Section 6\2024SYR_Section6_v2\2024SYR_Section6_v2.aprx - lsalberg - 8/25/2025

Prepared by:

WEST YOST

N

0 2 4 Miles

0 3 6 Km

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Wells with Pumping Sustainability Thresholds

DRAFT

Figure 7-9

Table 7-2. Summary of Party Responses to Pumping Sustainability Threshold Information Request

Party	Response to Questions[a]		MPI Threshold		
	How many of your wells need to fall below the sustainability metric before it becomes difficult to pump the desired amount of groundwater?	How long (in months or years) must the groundwater level at a single well remain below the sustainability metric before it becomes challenging to pump the desired amount of groundwater?	Number of wells with PST	Minimum number of wells exceeding PST in one year	Number of consecutive years of exceedance to indicate MPI
CDA	CDA has a number of wells at the Chino II facility that fall below the sustainability metric. Current condition puts most of the Chino II wells below the +25 ft. pump submergence, if there is a further drop in water levels, CDA will be required to reduce future production in those wells. To date, we've experienced as much as a 46 ft reduction in static water levels, which has resulted in a loss of approximately 5,745 gpm since the wells were drilled.	It's difficult to say a time period. The sustainability metric is 25 feet is the preferred amount of pump submergence. CDA has been operating some wells with less than the 25 feet of submergence for years. This requires that you pay more attention to the pumping level and only becomes a problem when the pumping level gets within a few feet of the pump.	22	4	5
Chino	Currently having two out of three wells that provide water to their respective water treatment facilities fall below the sustainability metric would make it difficult to pump the desired amount of groundwater to effectively and efficiently operate the water treatment system.	One well may not significantly impair our ability to operate our water treatment systems. However, I suppose if a single well was unable to produce groundwater for a considerable amount of time, a year or more, then our operations may be impacted. This would be due to the fact that maintenance or repair may need to be performed on the other remaining wells during this time.	10	3	3
Chino Hills	Unknown at this time, as wells have not been on for a few years. Use prior information.	Unknown at this time, as wells have not been on for a few years. Use prior information.	5	2	5
CVWD	CVWD's pumping sustainability is determined by production strategy, historical water levels, and pump performance. CVWD's production strategy involves estimating the amount of water needed to fulfill expected demands at a specific point in time, accounting for availability of water sources and cost to produce. Therefore, loss of any supply means CVWD must make it up elsewhere. For example, if imported water were not available, any loss of Chino Basin well supply would be considered "falling below the sustainability metric". An analysis of historical water levels across CVWD's Chino Basin wells showed that over the last 10 years, water levels have changed (in either direction) by 10 feet. To be conservative, CVWD doubled that number. The spreadsheet shows the sustainability metric as pump setting + 20 feet.	This depends on the well and hydrologic scenario. If water levels and pump performance were dropping during "normal" conditions, CVWD would be concerned at 6 months. However, during a drought, CVWD would track monthly water levels.	12	3	5
FWC	- We currently have 15 Chino basins wells two of which are not currently in service because they are not yet completed. - In addition to the two new wells that are not yet completed, we also have three wells F7A, F24A,F24A, and F31A that are impacted by Nitrate and/or perchlorate. This makes their availability difficult to rely on. - These wells are not equipped with well head treatment. - F17B has been out of service for some time and still needs additional work. - That would leave us with 8 wells remaining that could be utilized to meet system demands. - There are many factors that come into play when determining how many wells can fall below the sustainability metric and for what duration before it would be detrimental to meeting our systems demands. - Reviewing our 5, 10, and 15 year peak averages I think we would be considerably impacted if we lost three of the remaining eight wells especially during our peak months. The peak conditions can last 3-4 months a year.		13	3	5
JCSD	The simple answer is 1. The long answer depends on what well. Example is well 25 loses production, we will lose a blend and be in a bad spot. Well, 18 loses production, and it's just a loss in production.	Here is the challenge. We have been able to lower our pumps to mitigate the impacts we have seen. So, we are currently operating below the levels we show as impacted. Because the basin water levels in our area are decreasing, we are impacted as a district. This is also impacting our ability to drill more wells and increase production in these areas. To simplify, I don't have a time. It is more about supply than specific well.	18	1 (JCSD Well 25)	5
MVWD	Perhaps 3 wells falling below the metric would make things difficult, but this is just a guess at best. There are too many unknown variables to provide an accurate answer.	There are too many unknown variables to provide an accurate answer.	11	3	5
Ontario	Ontario does not foresee pump sustainability issues and can always drop the pump/add extension to produce the desired amount of groundwater. Furthermore, we maintain resiliency and redundancy of our system and rehabilitate wells on a regular schedule. If wells are not producing, they will be abandoned, and other wells can be utilized to meet demand.	Ontario has not had pump sustainability issues from a water elevation standpoint, but rather geologic limitations requiring the wells to be rehabilitated. A few wells have operated near the pump setting for several years without degradation of performance or causing cavitation.	20	6	5
Pomona	One well.	One month. This is based off our need to purchase imported water.	15	1	1
Upland	Currently the Currently the City of Upland has three pumps that are producing water from the Chino Basin. To make it difficult to pump the desired amount of groundwater from the Chino basin all three wells would need to fall below the sustainability metric elevation.	- Well 7A would need to fall below the sustainability metric for 2 months to cause challenges to pumping the desired amount of ground water. - Well 8 would need to fall below the sustainability metric for 10 months to cause challenges to pumping the desired amount of ground water. - Well 20 would need to fall below the sustainability metric for 10 months to cause challenges to pumping the desired amount of ground water.	4	3	5

(a) The TM uses the term "thresholds" to describe pumping sustainability, whereas the term "metrics" has been used historically by Watermaster, and was used for the information request. Watermaster is transitioning to "thresholds" because it is considered a more accurate and descriptive term.

7.2.2.2 Results

As an initial assessment of the extent of MPI due to pumping sustainability, a snapshot of pumping sustainability was taken at summer conditions at the end of the decade (July 1, 2030) and when managed storage approaches zero for many Projection Realizations (July 1, 2050). Figures 7-10 through 7-20 show these snapshots of conditions in FY 2030 and 2050 for each of the 11 AP retailers for which PSTs were developed. Each figure shows the following:

- Active pumping wells in the TSY Ensemble, with symbol sizes indicating the likelihood-weighted volume of pumping for that year. For the party featured in the figure, all wells are shown, even those that are not projected to be pumping in any scenario of the TSY Ensemble.
- The colors of the featured party's wells indicate the difference between the likelihood-weighted average groundwater elevation at that well compared to its PST. Red colors indicate wells that have water levels below the PST; blue colors indicate wells that have water levels above the PST.
- A "box-and-whiskers plot" that characterizes the distances above/below the PST for all wells by Projection Scenario (for all calibrated CVM realizations). Each dot represents one well in one Projection Realization. The red percentage at the bottom of the plot indicates the likelihood-weighted average percentage of groundwater elevations at all wells that are below the PST.
- A "heat map" of MPI by Projection Realization. Red squares indicate MPI associated with that Projection Realization.

The likelihood-weighted percentage of Projection Realizations that meet the MPI threshold for pumping sustainability in FY 2050 for each subarea is:

- **CDA: 83 percent**
- Chino: 0 percent
- Chino Hills: 0 percent
- CVWD: 3 percent
- FWC: 33 percent
- GSWC: 6 percent
- **JCSD: 65 percent**
- MVWD: 0 percent
- Ontario: 0 percent
- **Pomona: 57 percent**
- **Upland: 100 percent**

CDA, **JCSD**, **Pomona**, **and Upland** have 50 percent or more likelihood-weighted Projection Realizations meeting the subarea MPI threshold for land subsidence in FY 2050.

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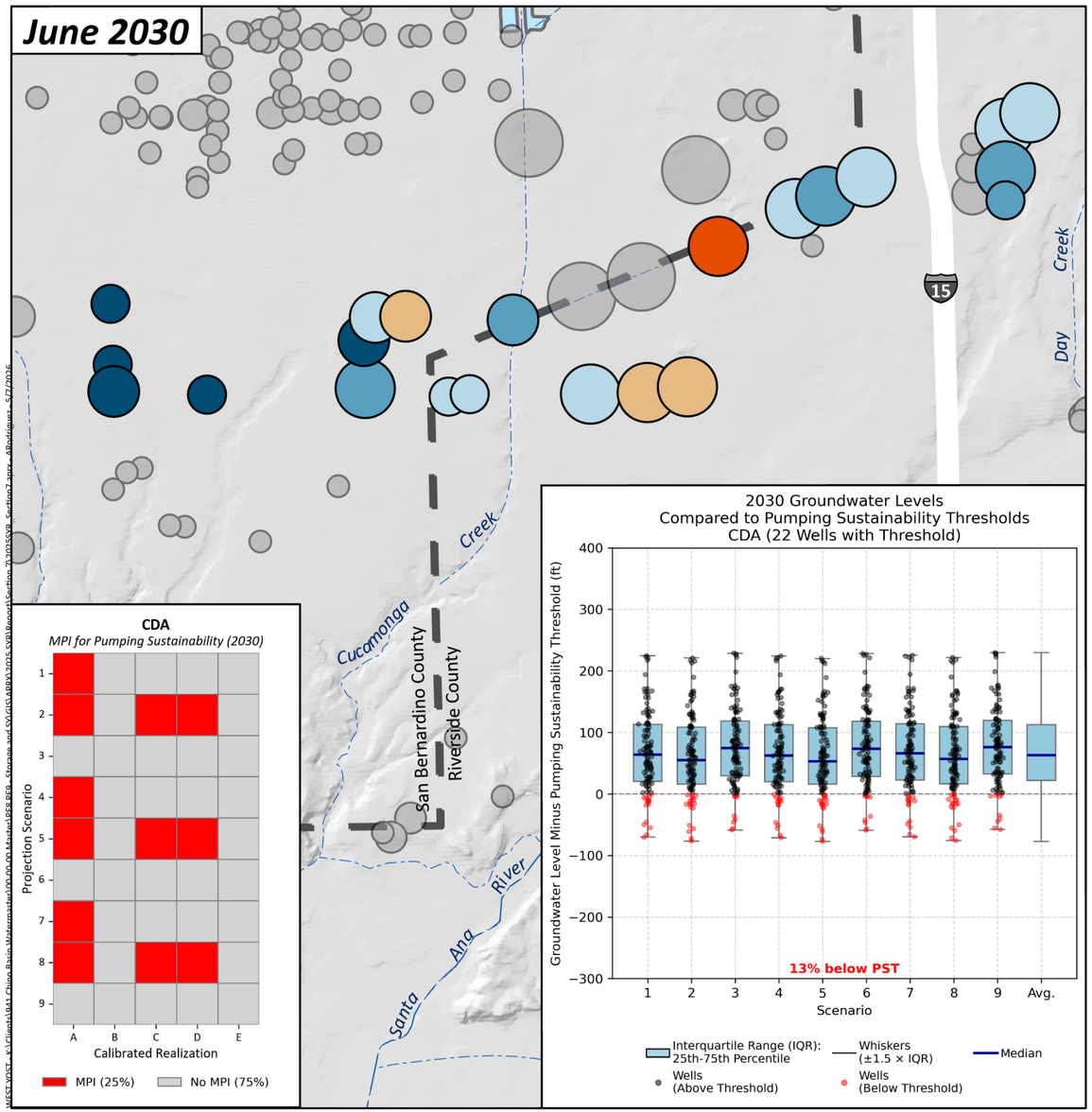
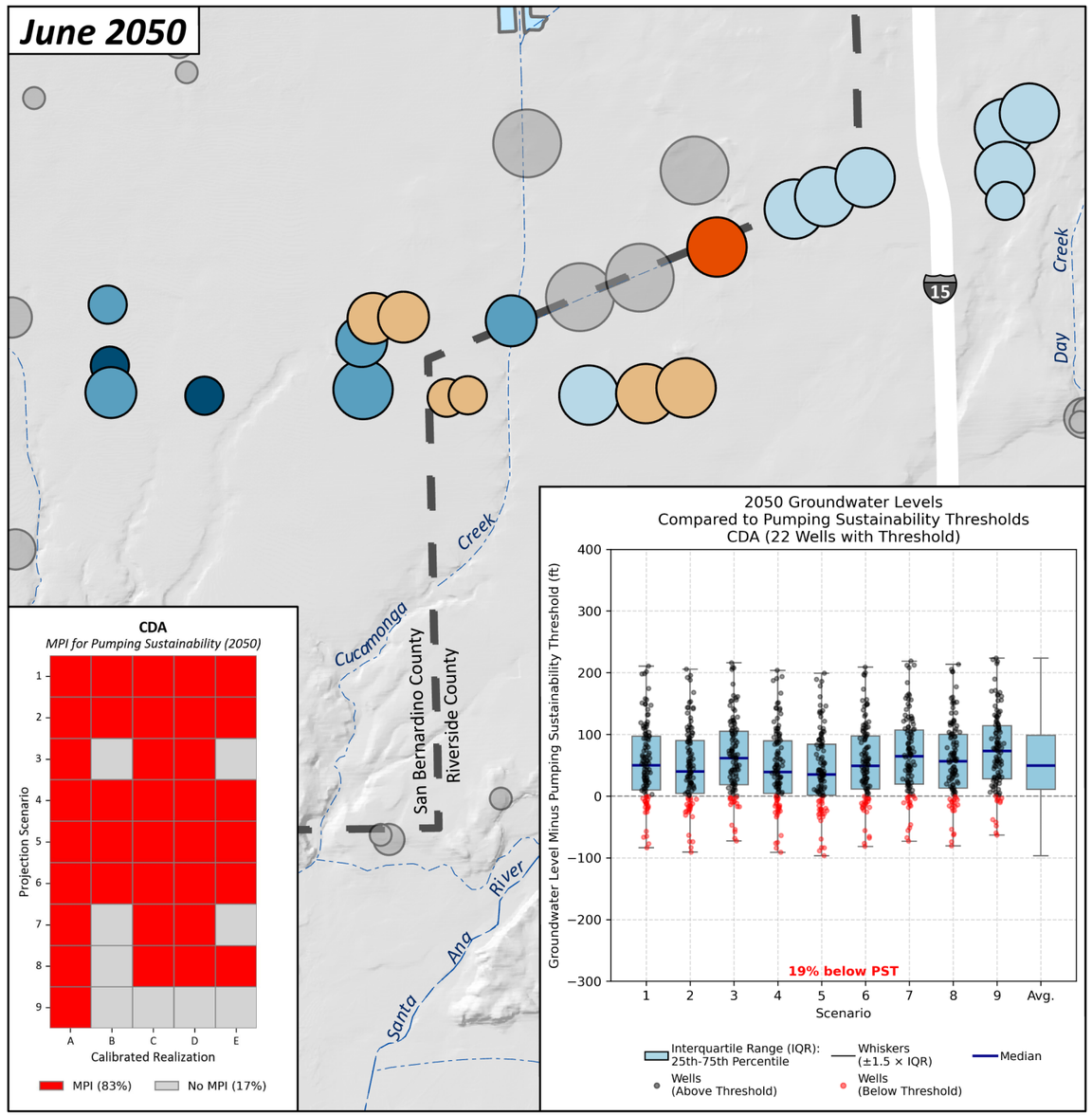
June 2030



June 2050



0 0.5 1 Miles

N

0 1 2 Km

Prepared by:

WEST YOST
Water. Engineered.

Likelihood-Weighted Average Groundwater Level Above/Below the Pumping Sustainability Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Rivers and Streams
- Flood Control and/or Conservation Basins

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Chino Basin Watermaster
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
Chino Basin Desalter Authority

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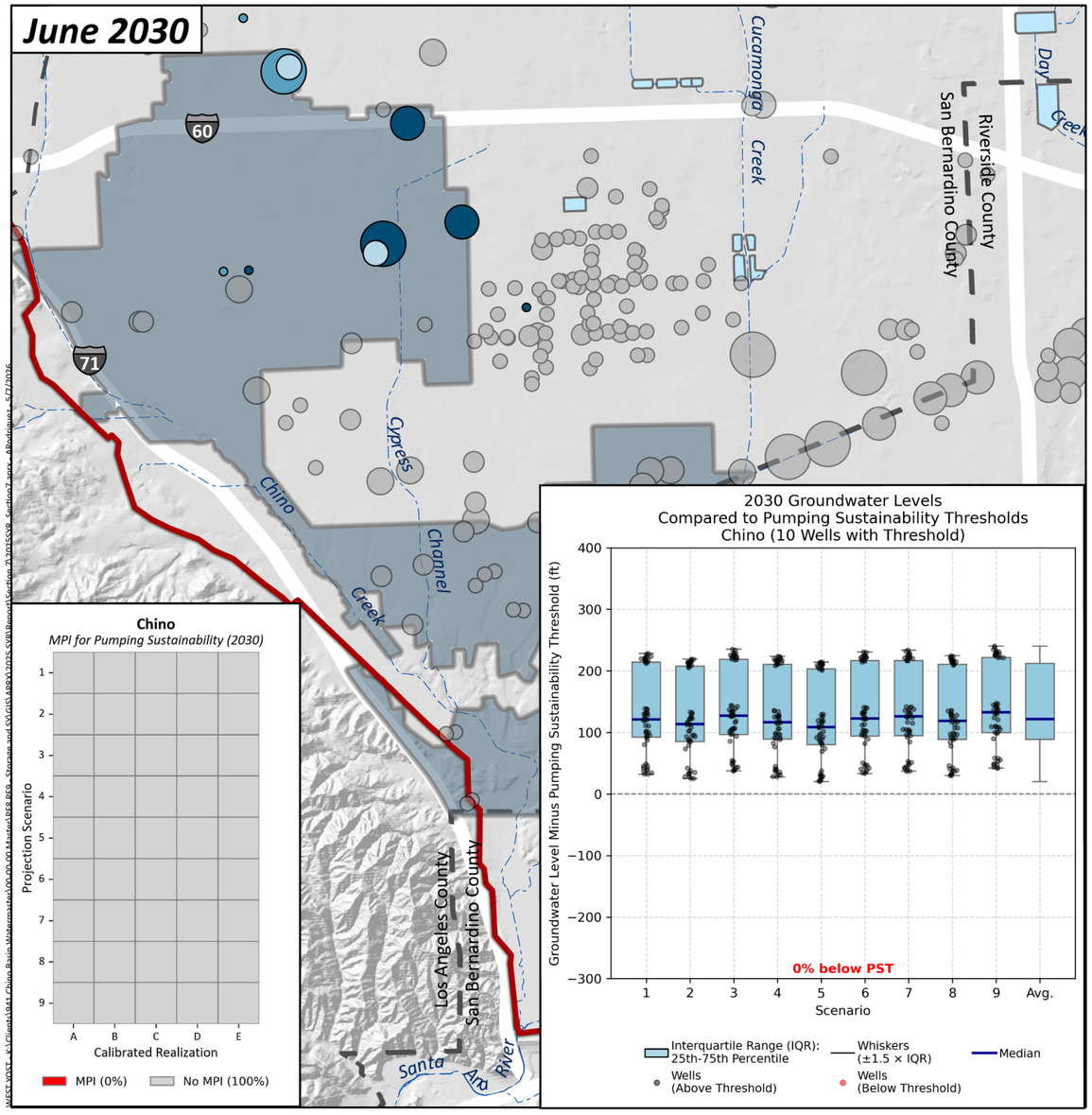
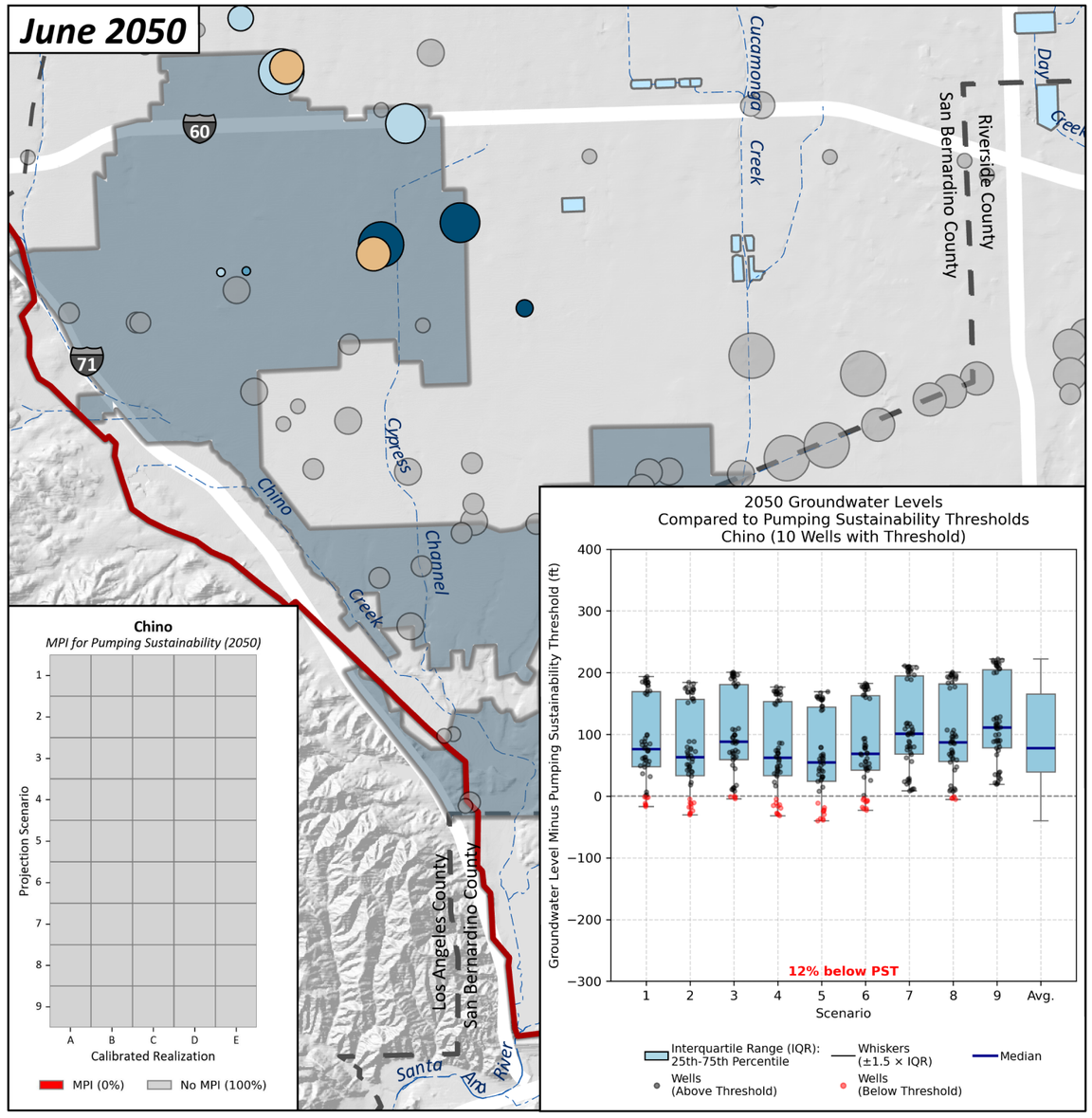
Figure 7-10





0 0.5 1 Miles

0 1 2 Km

N

Prepared by:

WEST YOST
Water. Engineered.

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- City of Chino
- Rivers and Streams
- Flood Control and/or Conservation Basins

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2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
City of Chino

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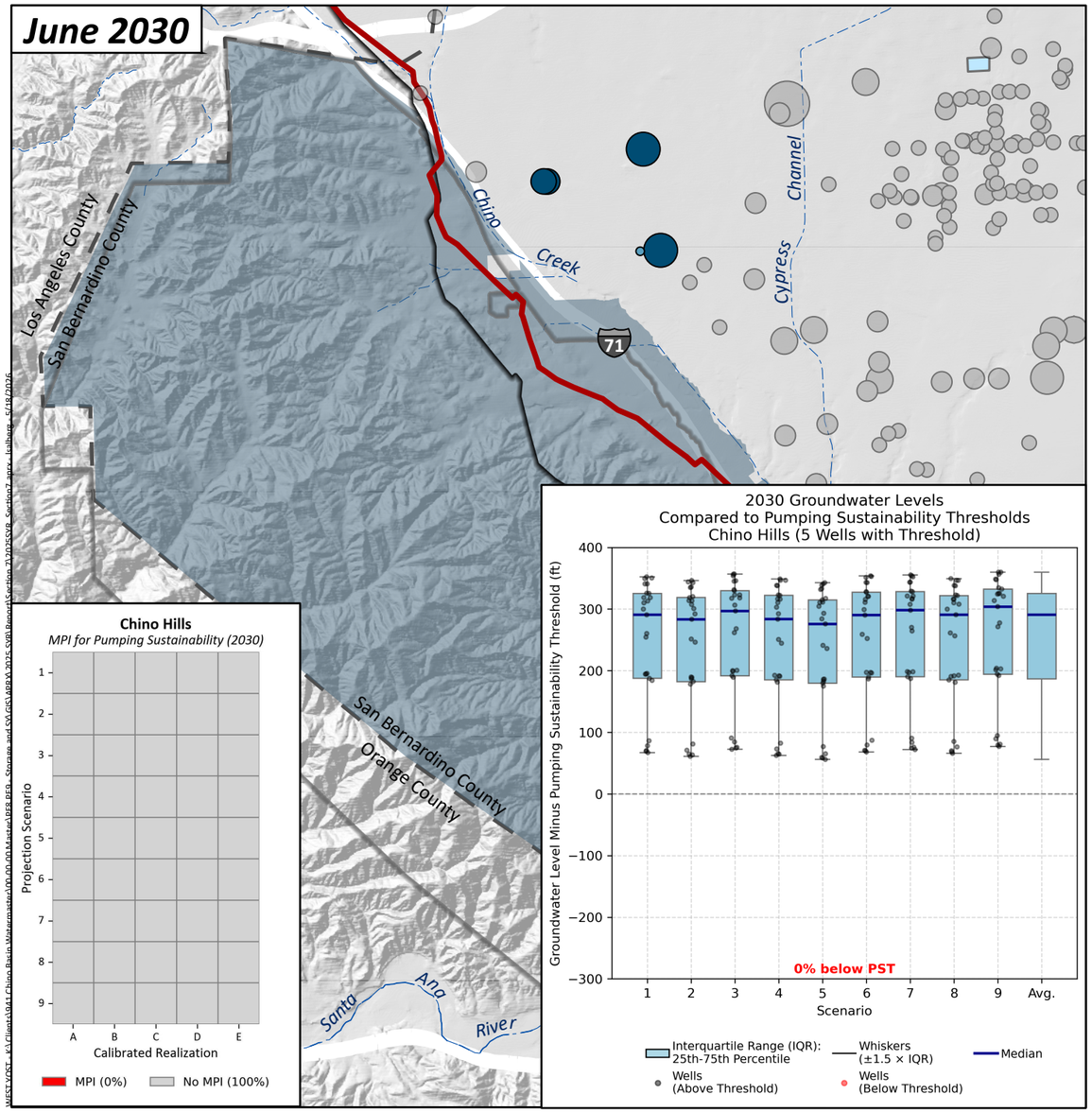
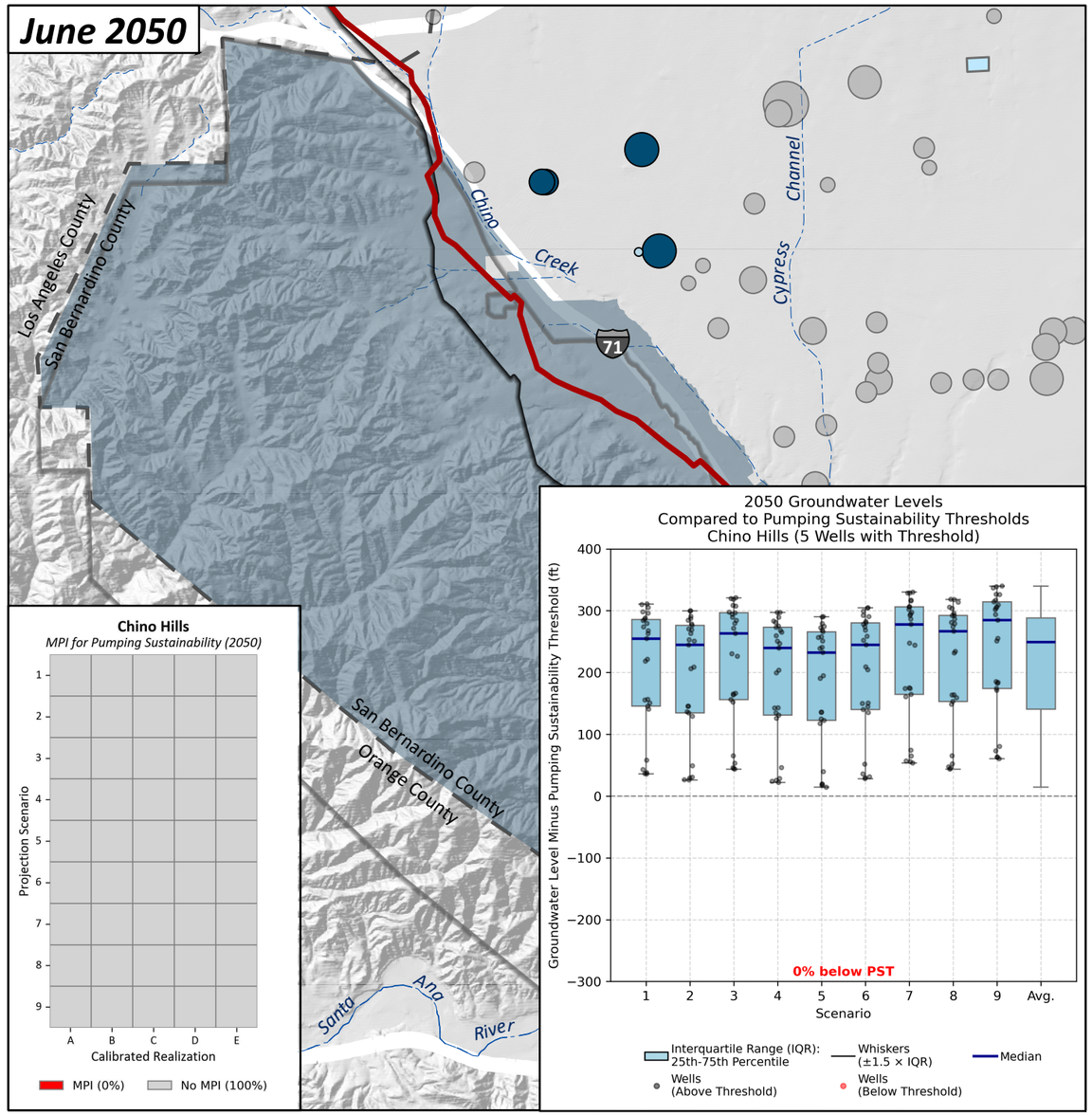
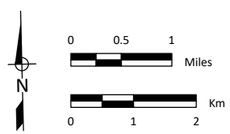
Figure 7-11

June 2030



June 2050





Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- City of Chino Hills
- Rivers and Streams
- Flood Control and/or Conservation Basins

Prepared by:

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Water. Engineered.

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
City of Chino Hills

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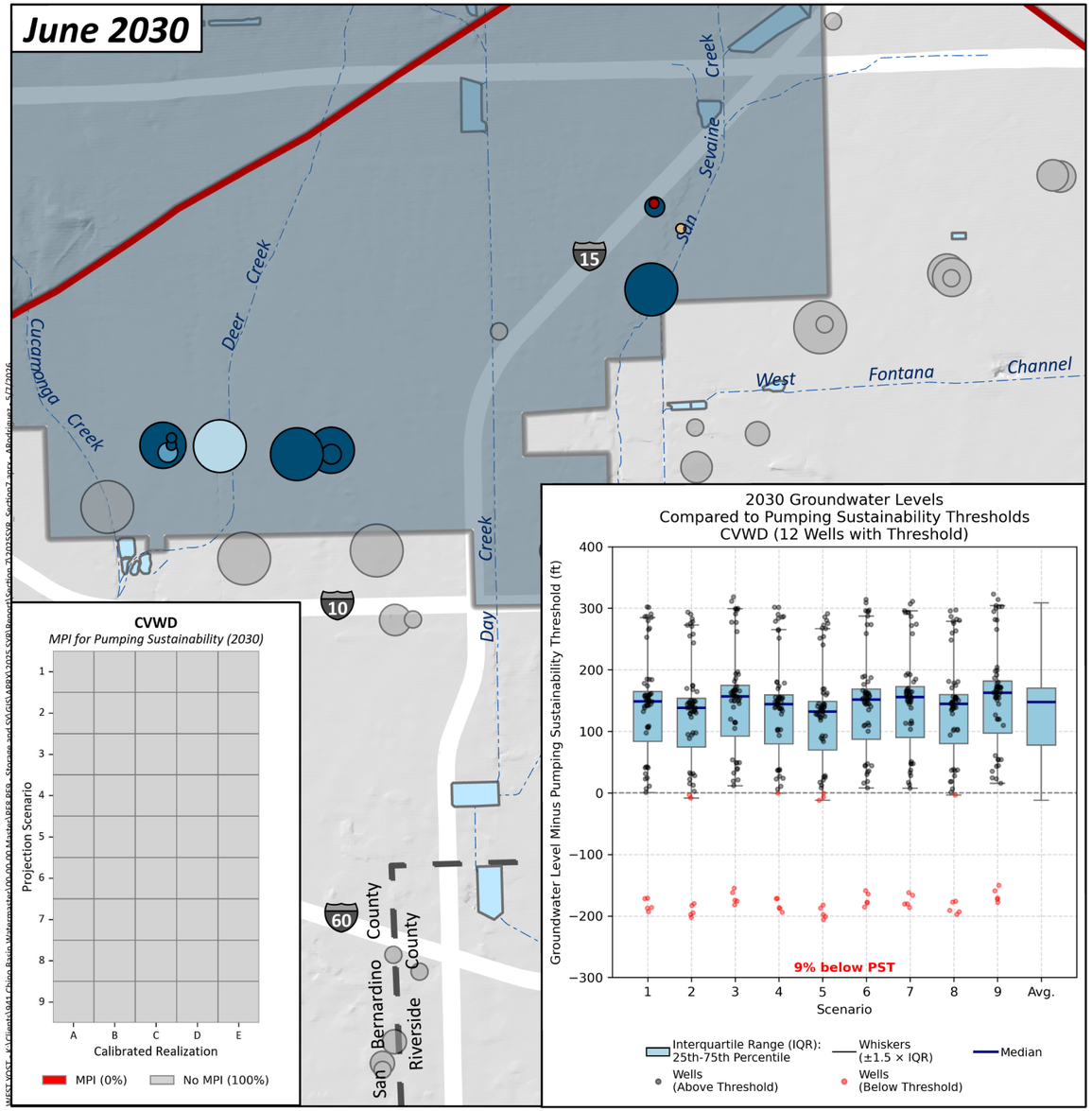
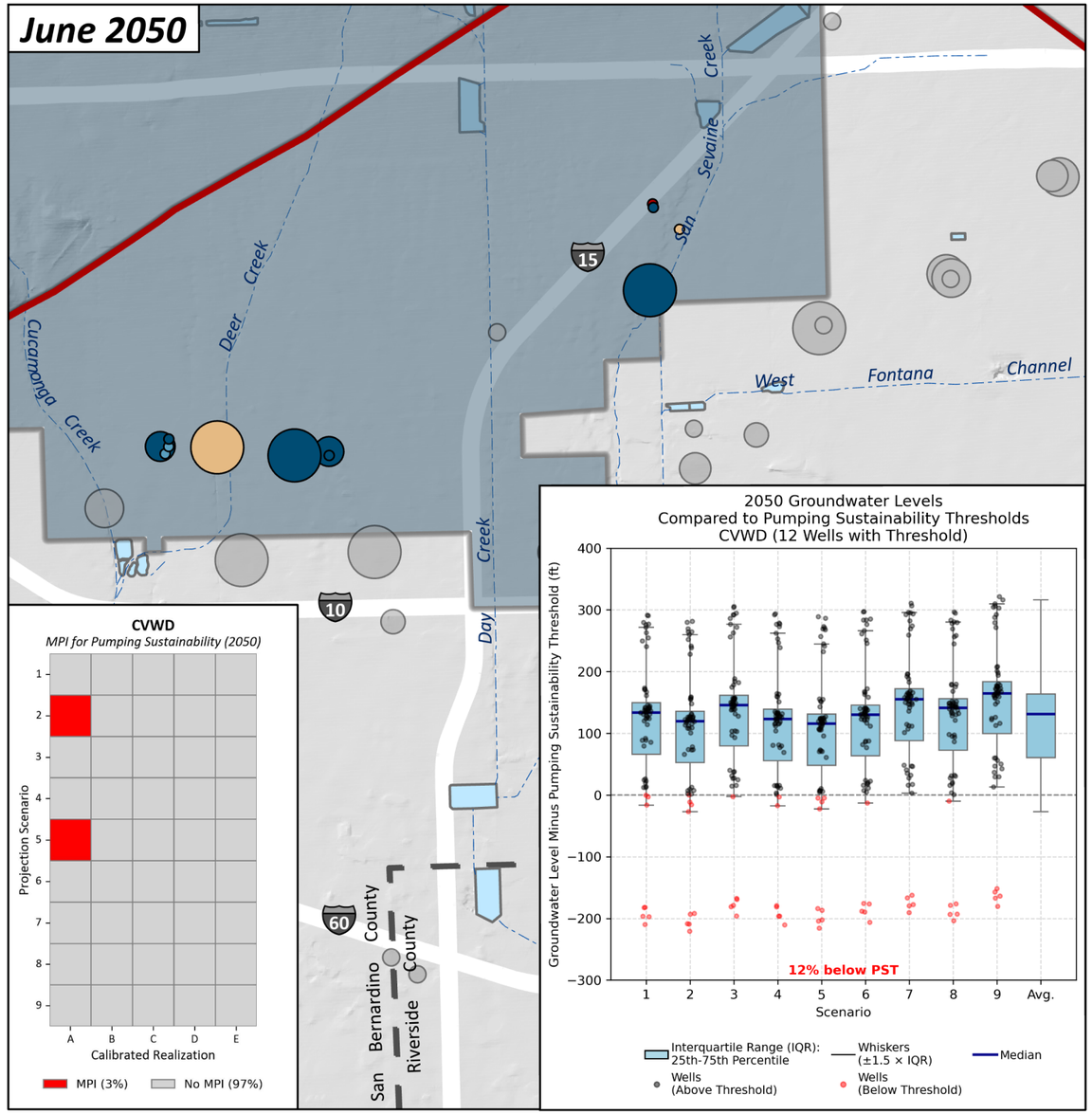
Figure 7-12

June 2030



June 2050



0 0.5 1 Miles

0 1 2 Km

N

Prepared by:

WEST YOST
Water. Engineered.

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Cucamonga Valley Water District
- Rivers and Streams
- Flood Control and/or Conservation Basins

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Chino Basin Watermaster
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence 2030 and 2050

Cucamonga Valley Water District

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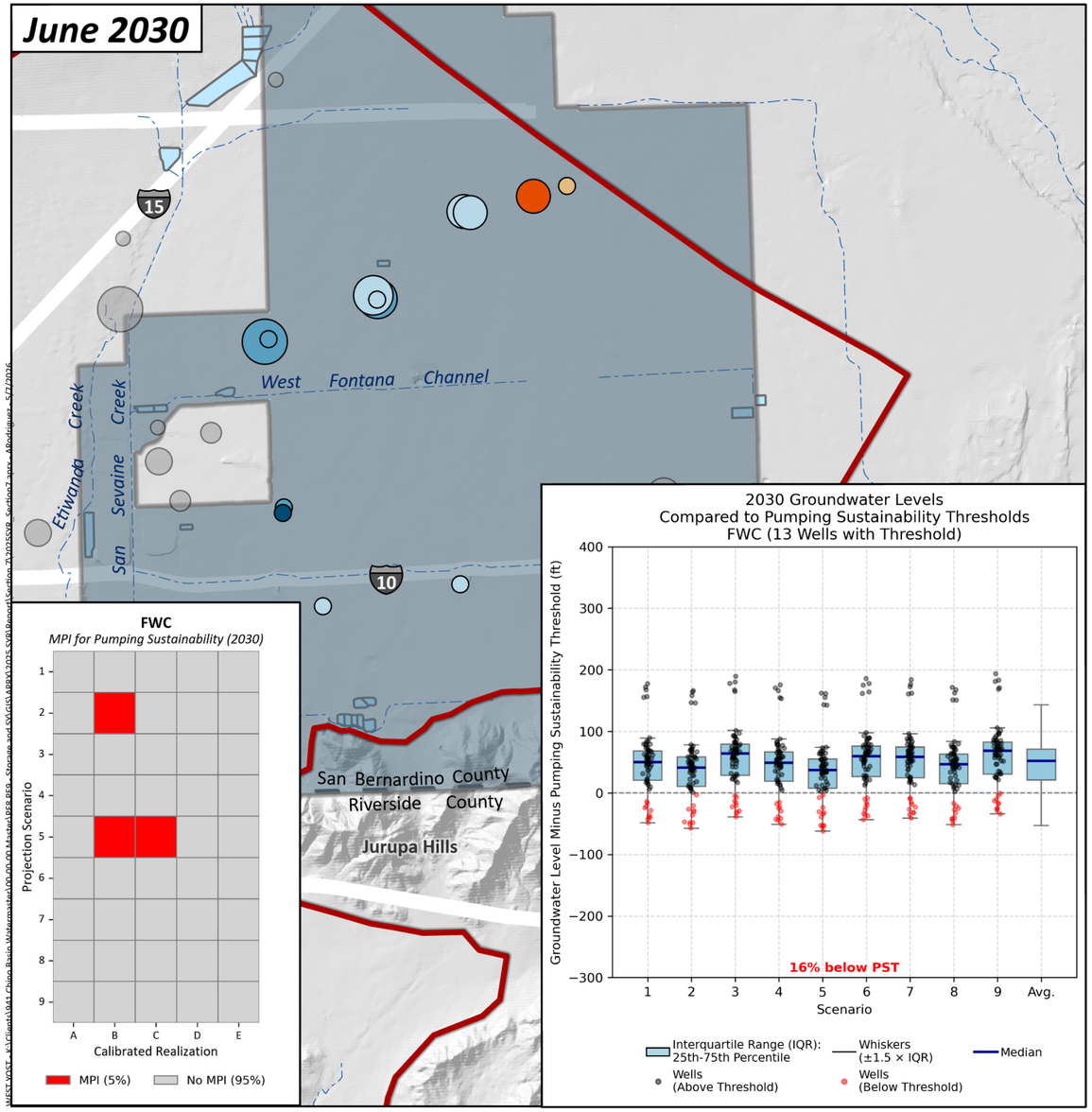
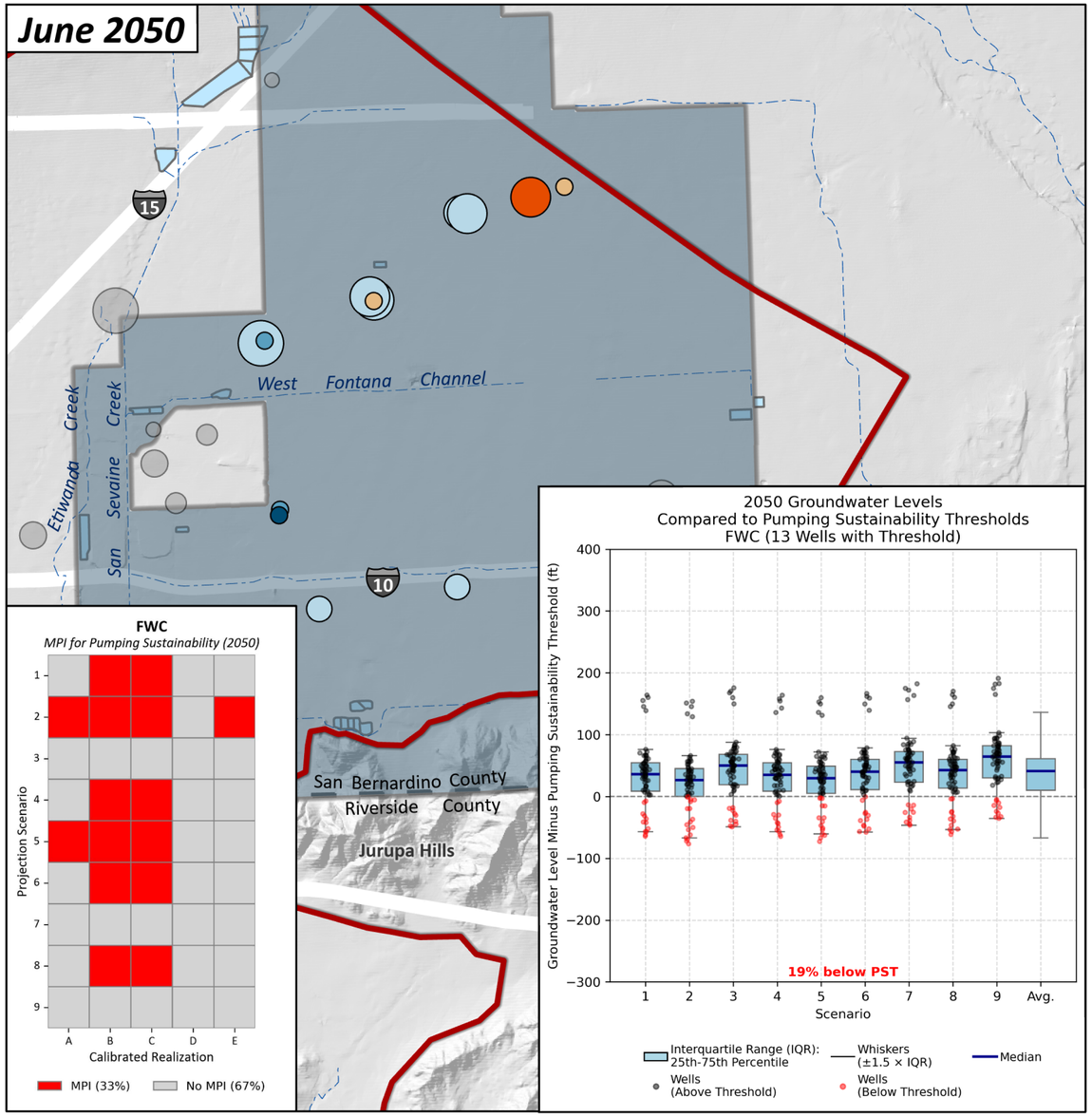
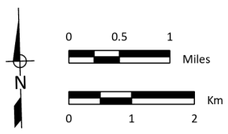
Figure 7-13

June 2030



June 2050





Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Fontana Water Company
- Rivers and Streams
- Flood Control and/or Conservation Basins

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2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
Fontana Water Company

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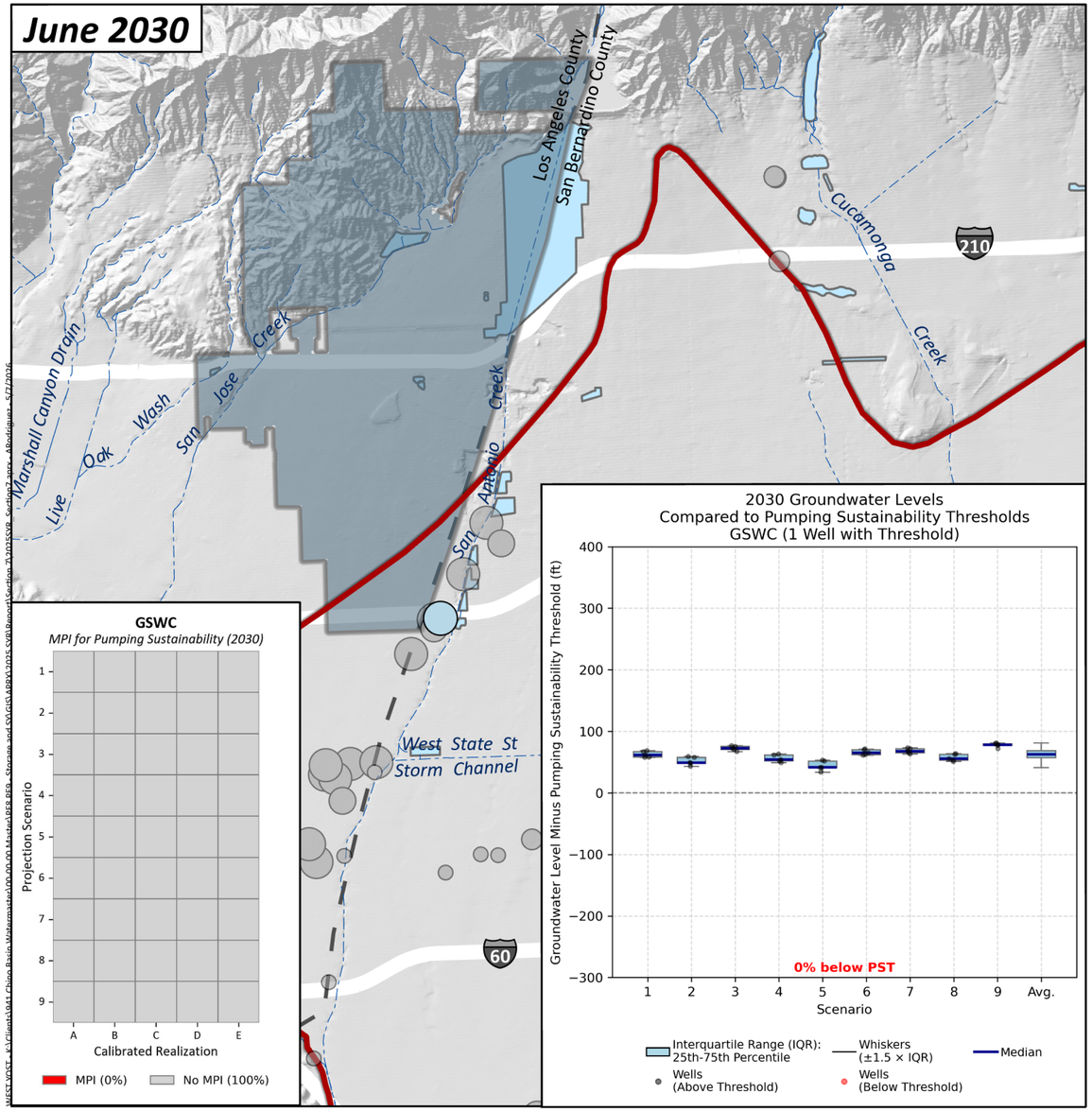
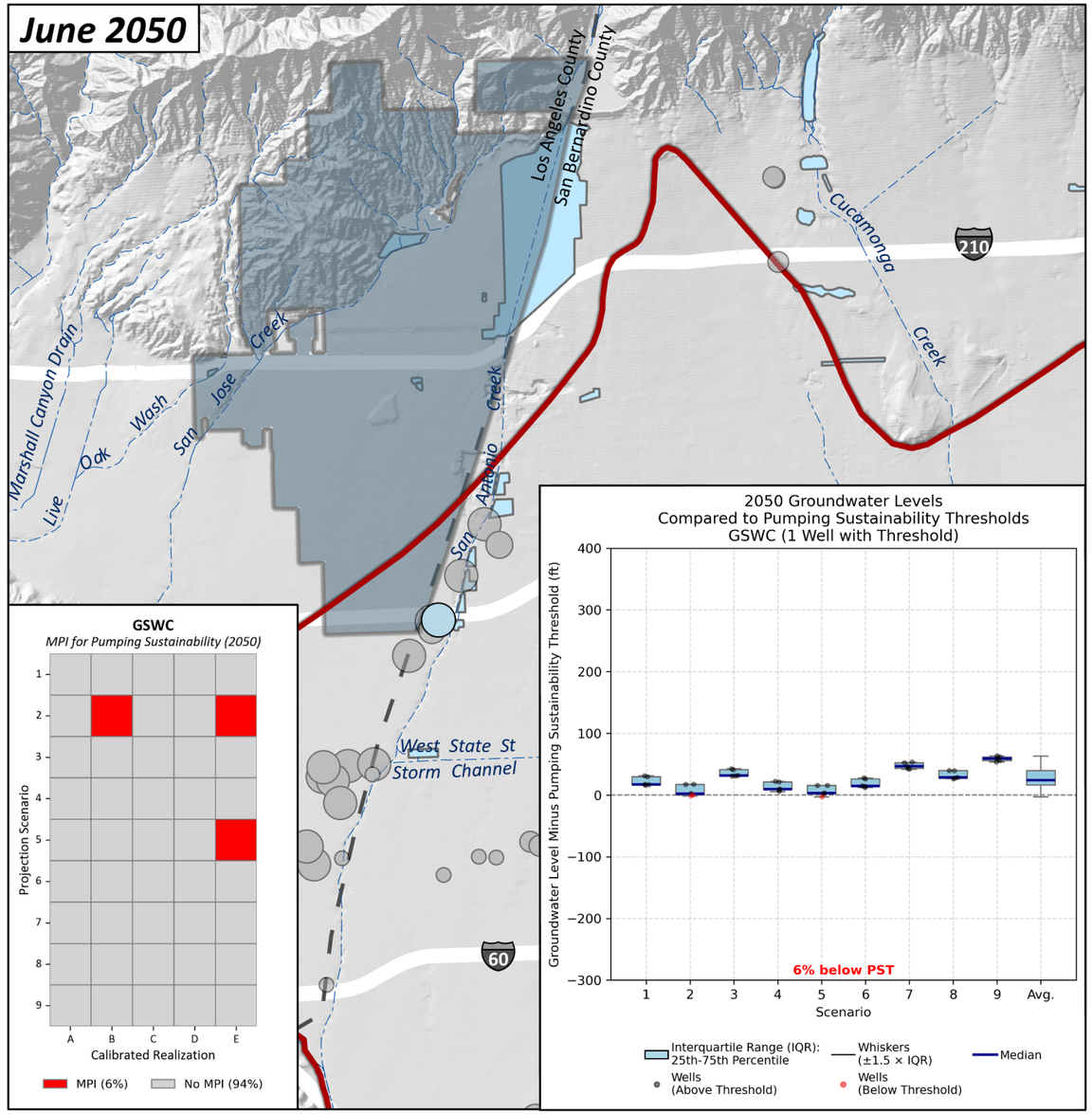
Figure 7-14





0 0.5 1 Miles

0 1 2 Km

N

Prepared by:

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Water. Engineered.

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Golden State Water Company
- Rivers and Streams
- Flood Control and/or Conservation Basins

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
Golden State Water Company

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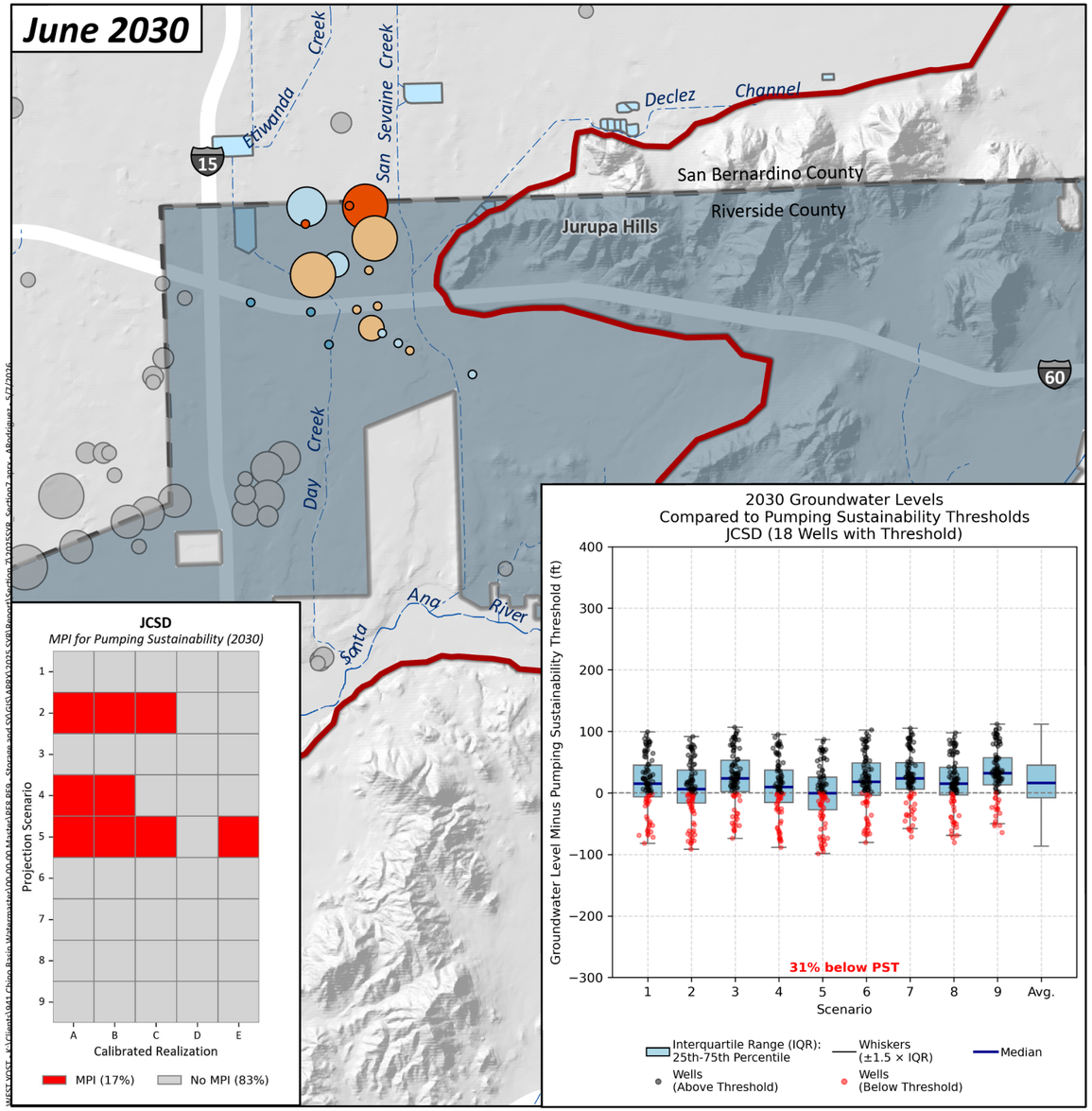
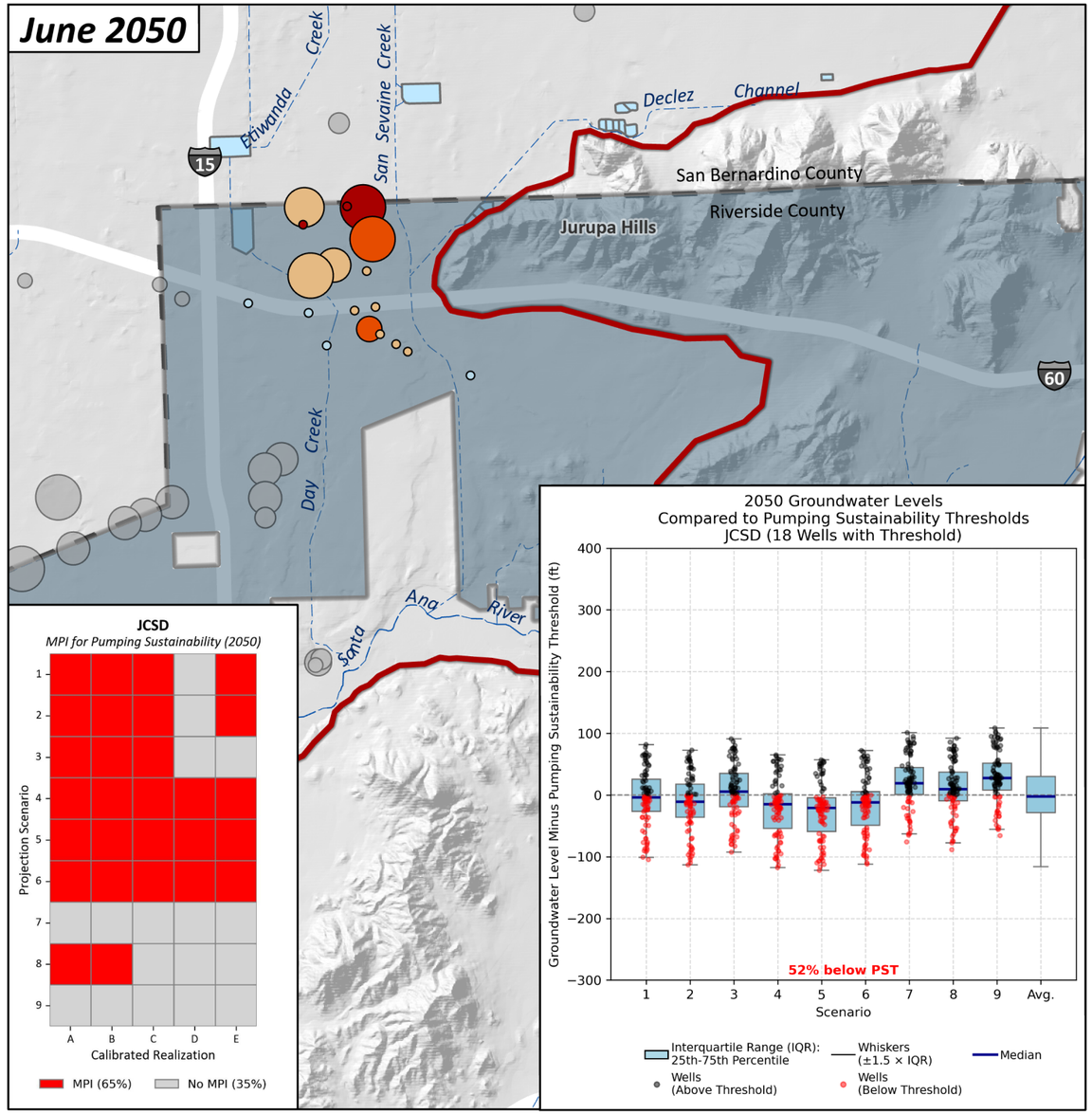
Figure 7-15

June 2030



June 2050



0 0.5 1 Miles

0 1 2 Km

N

Prepared by:

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Water. Engineered.

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Jurupa Community Services District
- Rivers and Streams
- Flood Control and/or Conservation Basins

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2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
Jurupa Community Services District

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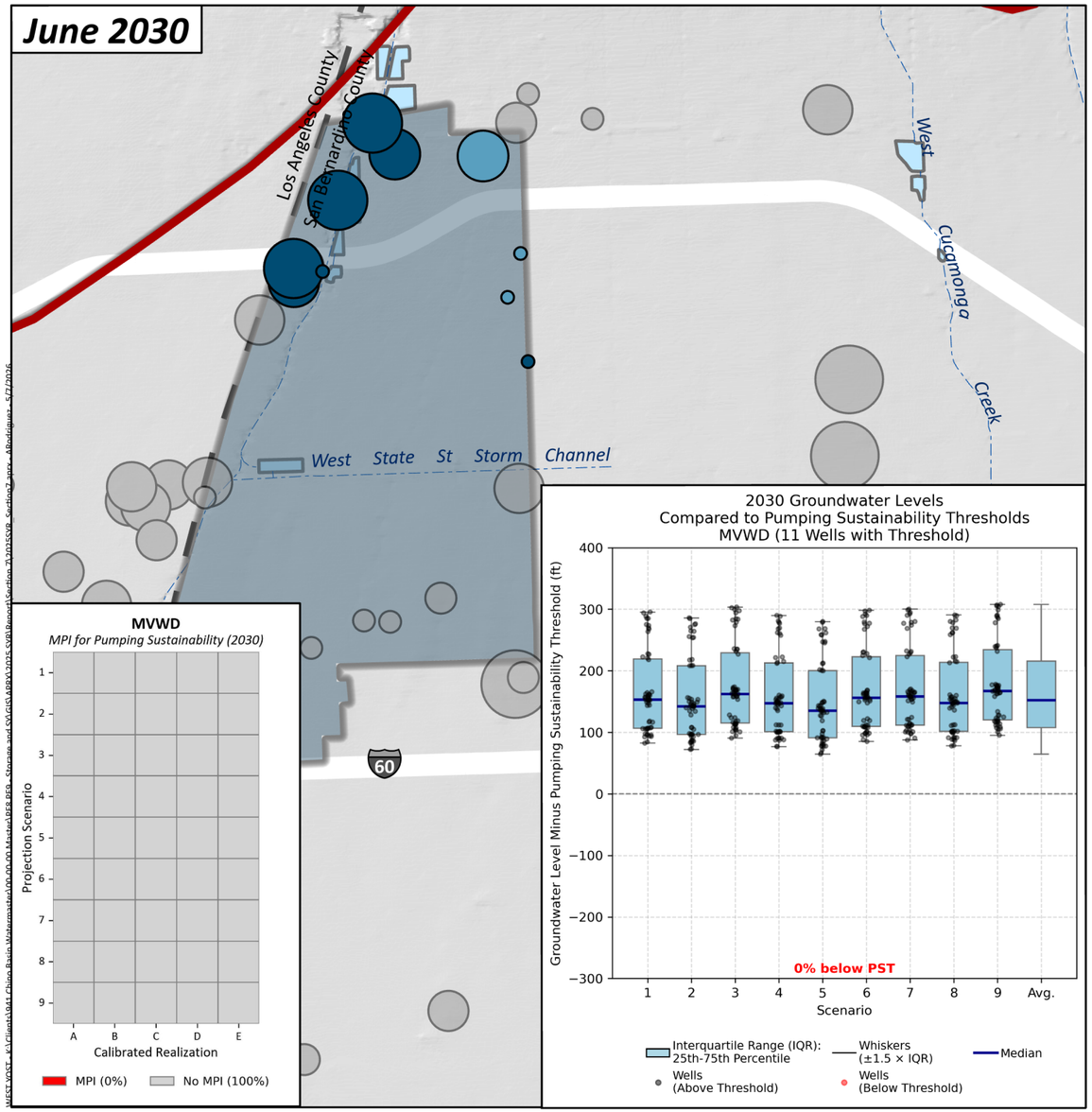
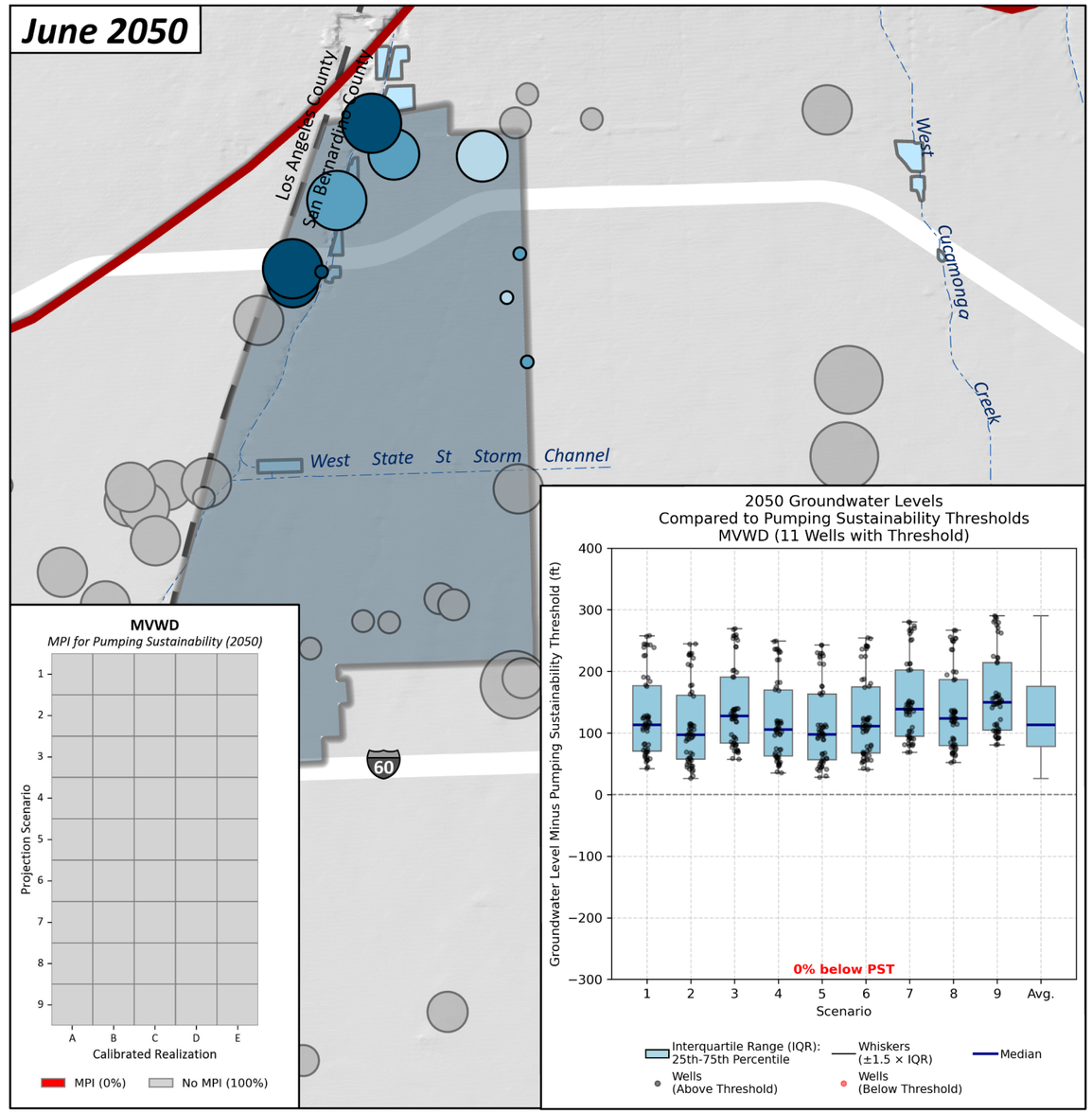
Figure 7-16





0 0.5 1 Miles

N

0 1 2 Km

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- Monte Vista Water District
- Rivers and Streams
- Flood Control and/or Conservation Basins

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Chino Basin Watermaster
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
Monte Vista Water District

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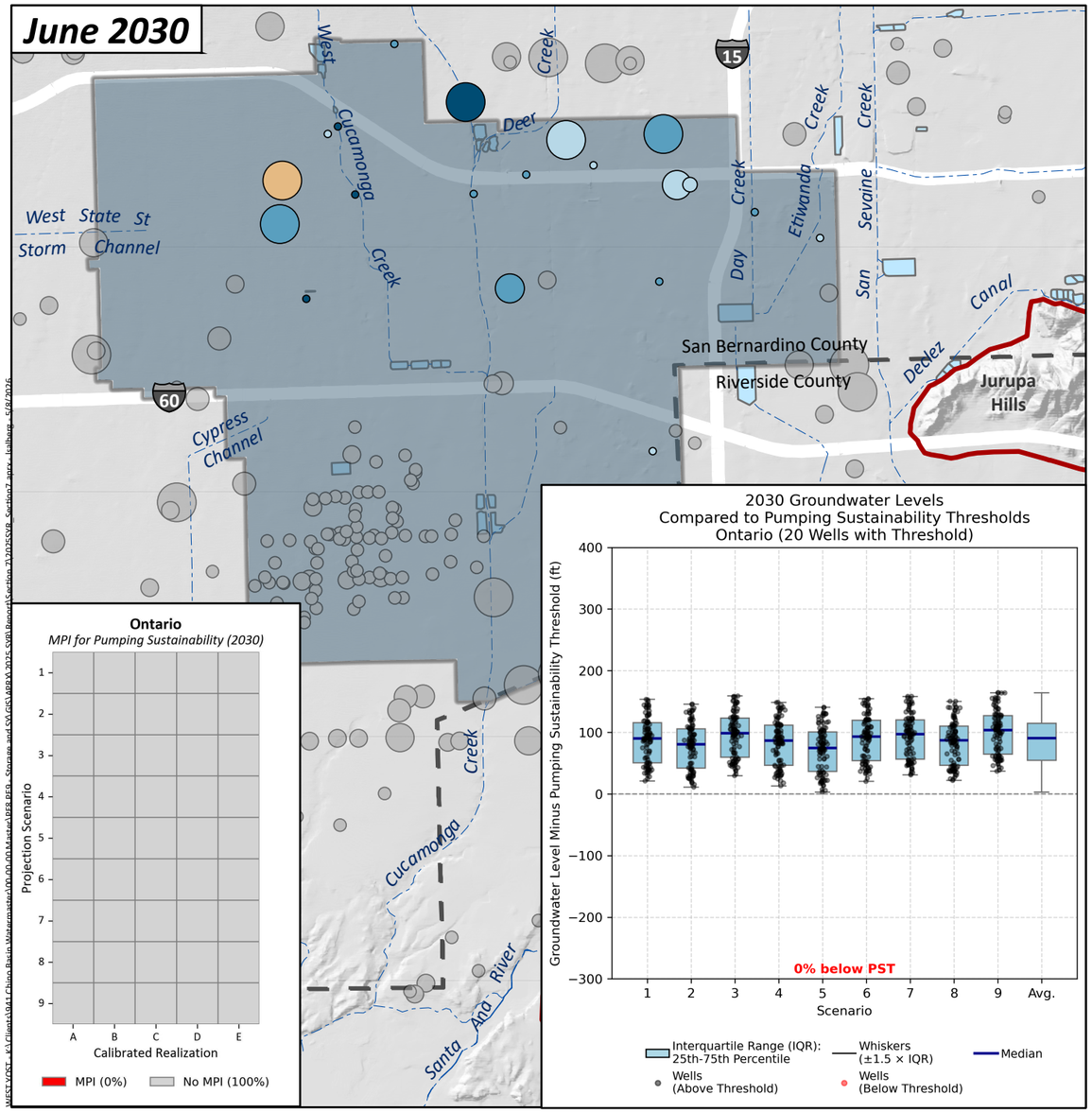
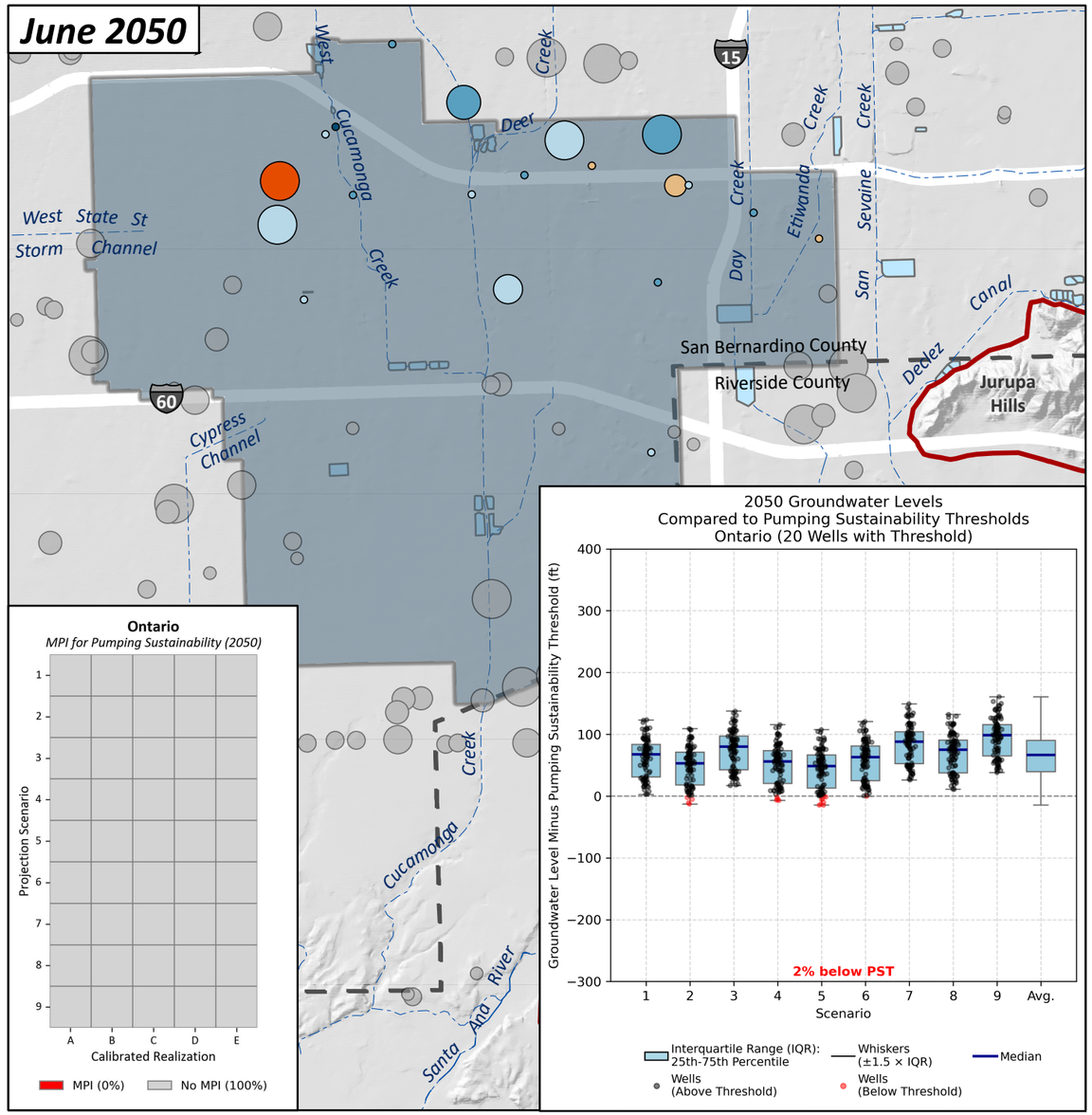
Figure 7-17

June 2030



June 2050



0 0.5 1 Miles

0 1 2 Km

N

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- City of Ontario
- Rivers and Streams
- Flood Control and/or Conservation Basins

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Chino Basin Watermaster
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
City of Ontario

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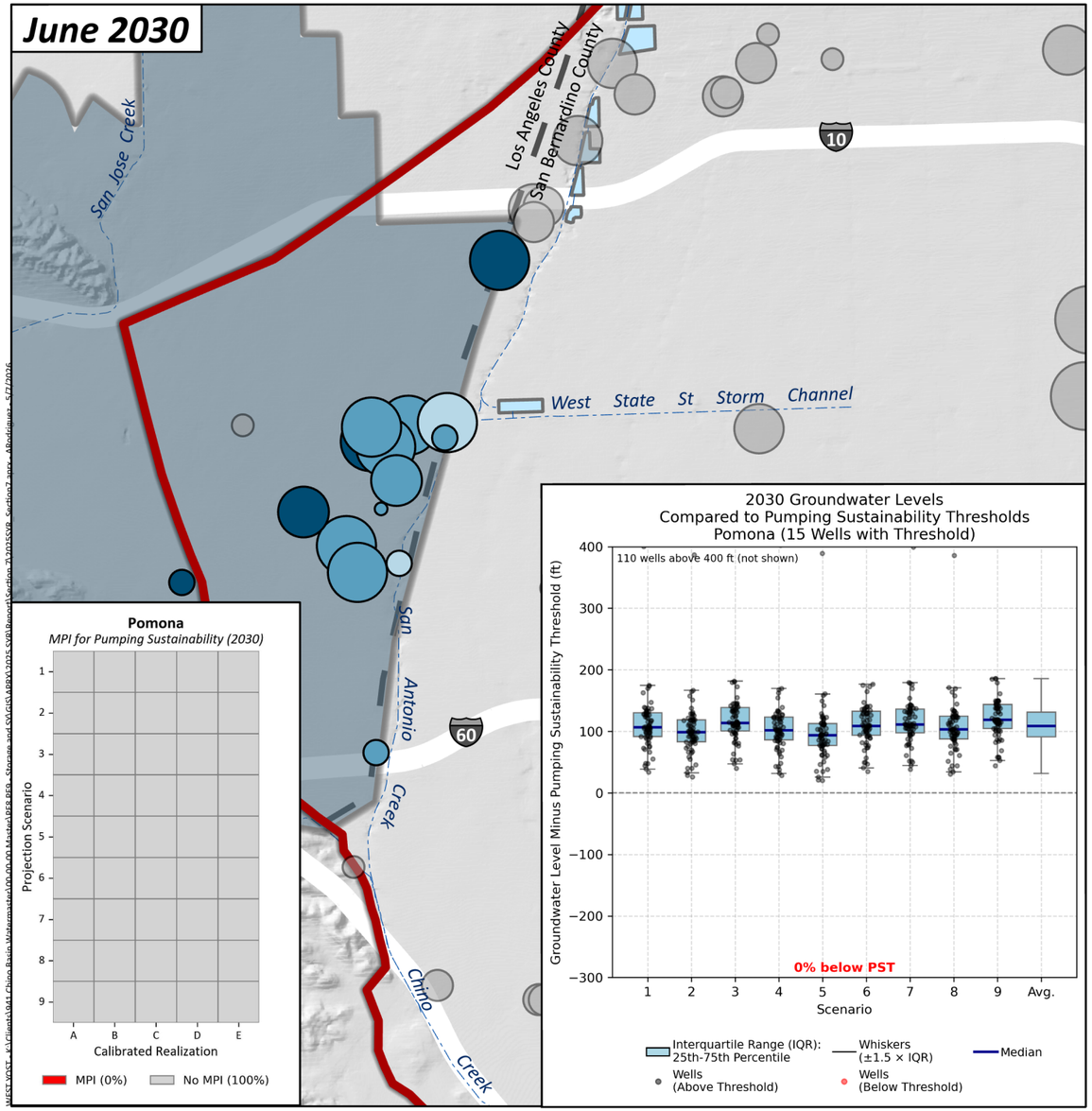
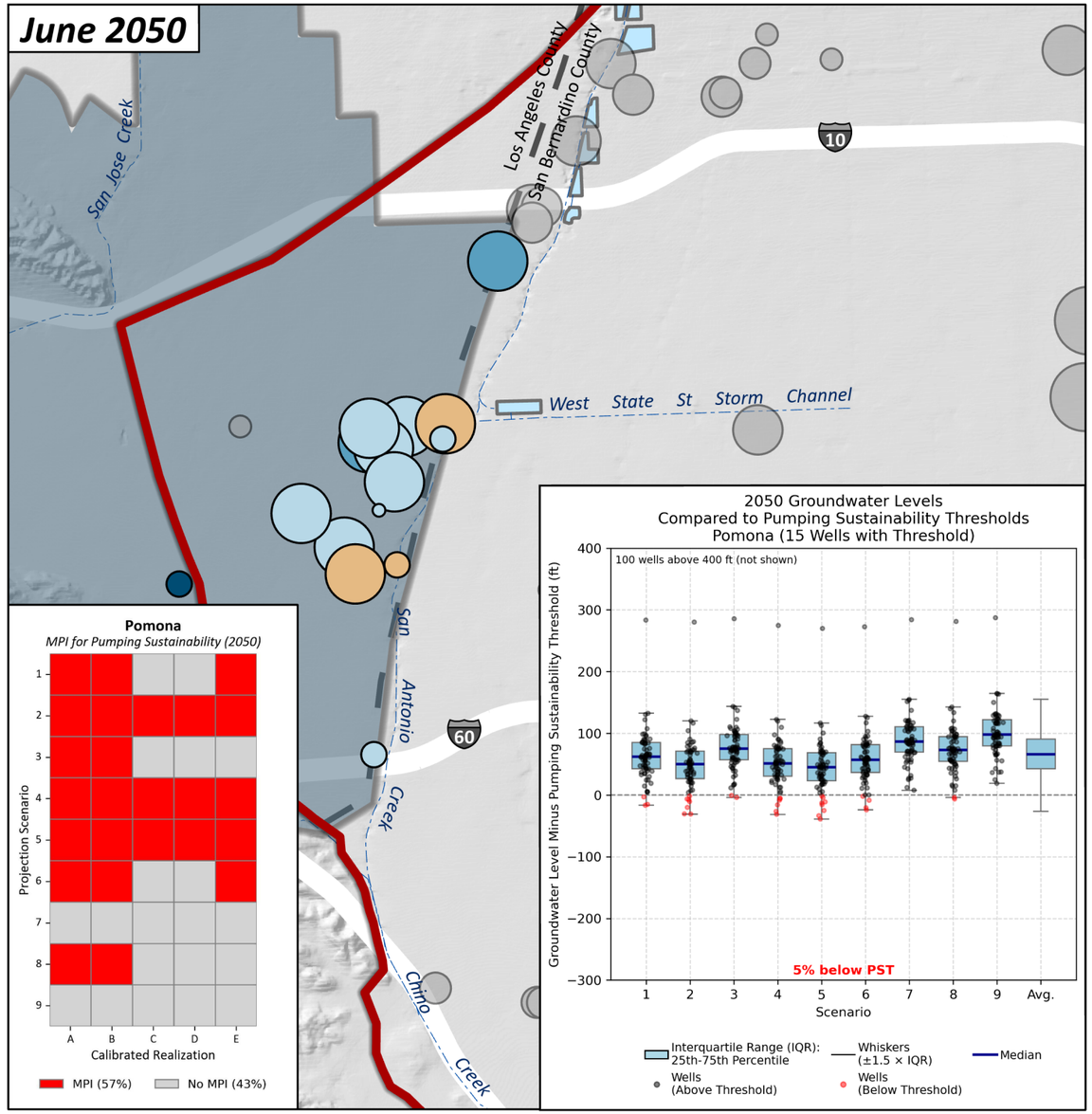
Figure 7-18

June 2030



June 2050



0 0.5 1 Miles
0 1 2 Km

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- City of Pomona
- Rivers and Streams
- Flood Control and/or Conservation Basins

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Prepared for: **Chino Basin Watermaster**
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
City of Pomona

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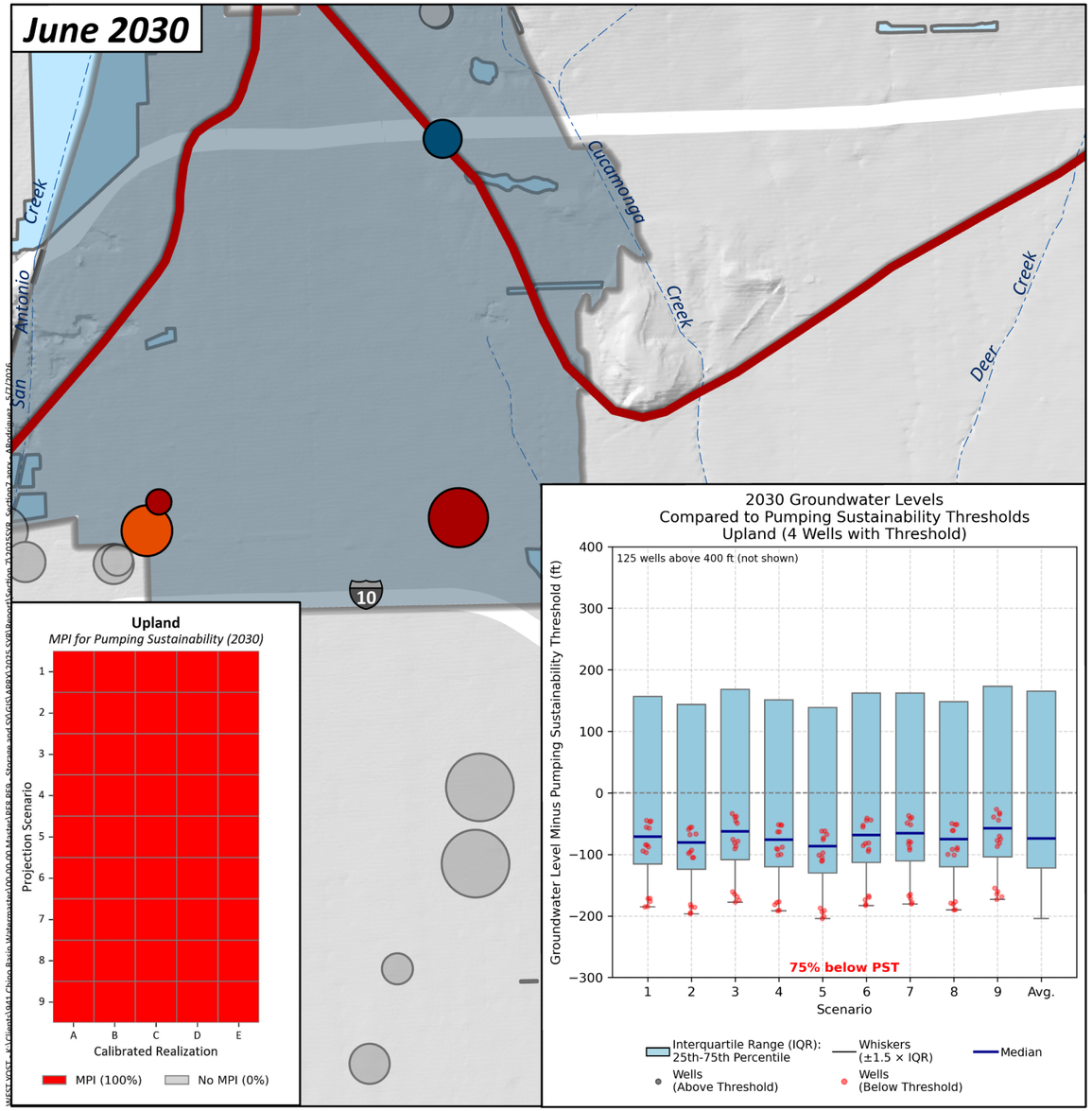
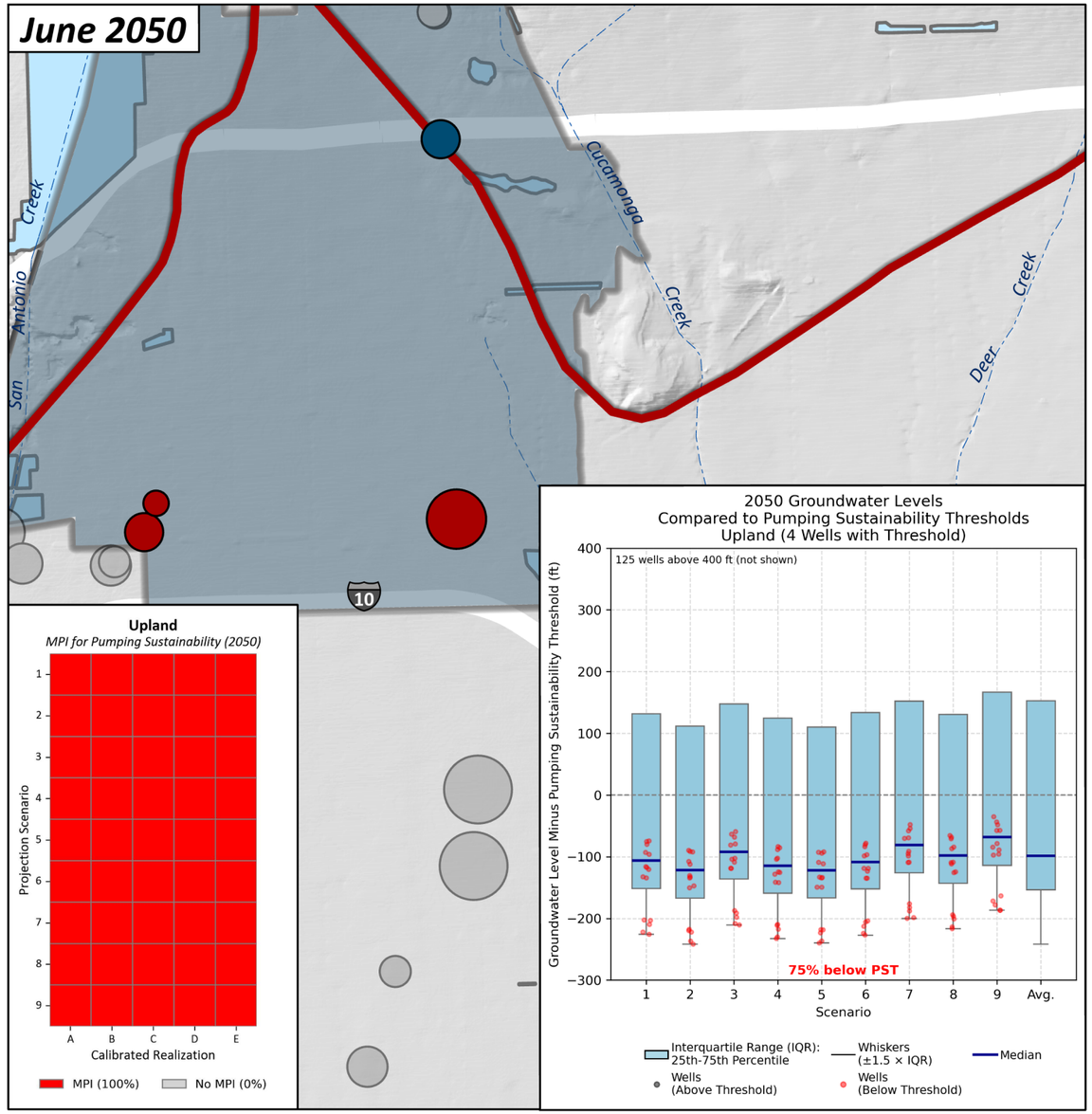
Figure 7-19

June 2030



June 2050



0 0.5 1 Miles

N

0 1 2 Km

Prepared by:

WEST YOST
Water. Engineered.

Likelihood-Weighted Average Groundwater Level Above/Below the Land Subsidence Threshold (ft)

- >100 ft
- 50–100 ft
- 0–50 ft
- 0 to -50 ft
- -50 to -100 ft
- <-100 ft

Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

Other Layers

- Other Wells
- 2025 CVM Domain
- City of Upland
- Rivers and Streams
- Flood Control and/or Conservation Basins

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Assessment of MPI due to Land Subsidence
2030 and 2050
City of Upland

DRAFT

Figure 7-20

7.2.2.3 Discussion

Table 7-3 summarizes the pumping sustainability analysis, indicating the number of wells for which each party has PSTs, the average percentage of wells exceeding the PST for each scenario, and the likelihood-weighted average percentage of wells exceeding the PST for the TSY ensemble. A review of hydrographs confirms that a PST exceedance in 2050 meets the five-year duration criterion to be considered MPI, in the absence of an agency-provided definition.

Figure 7-21 shows that subsidence-related MPI increases from an average of 1.5 subareas in FY 2030 to 3.5 subareas in FY 2050. The degree of MPI varies between Projection Realizations, having the highest incidence in High Demand Scenarios (Projection Scenarios 4, 5, and 6) and the Hot/Dry Climate Scenarios (Scenarios 2 and 5).

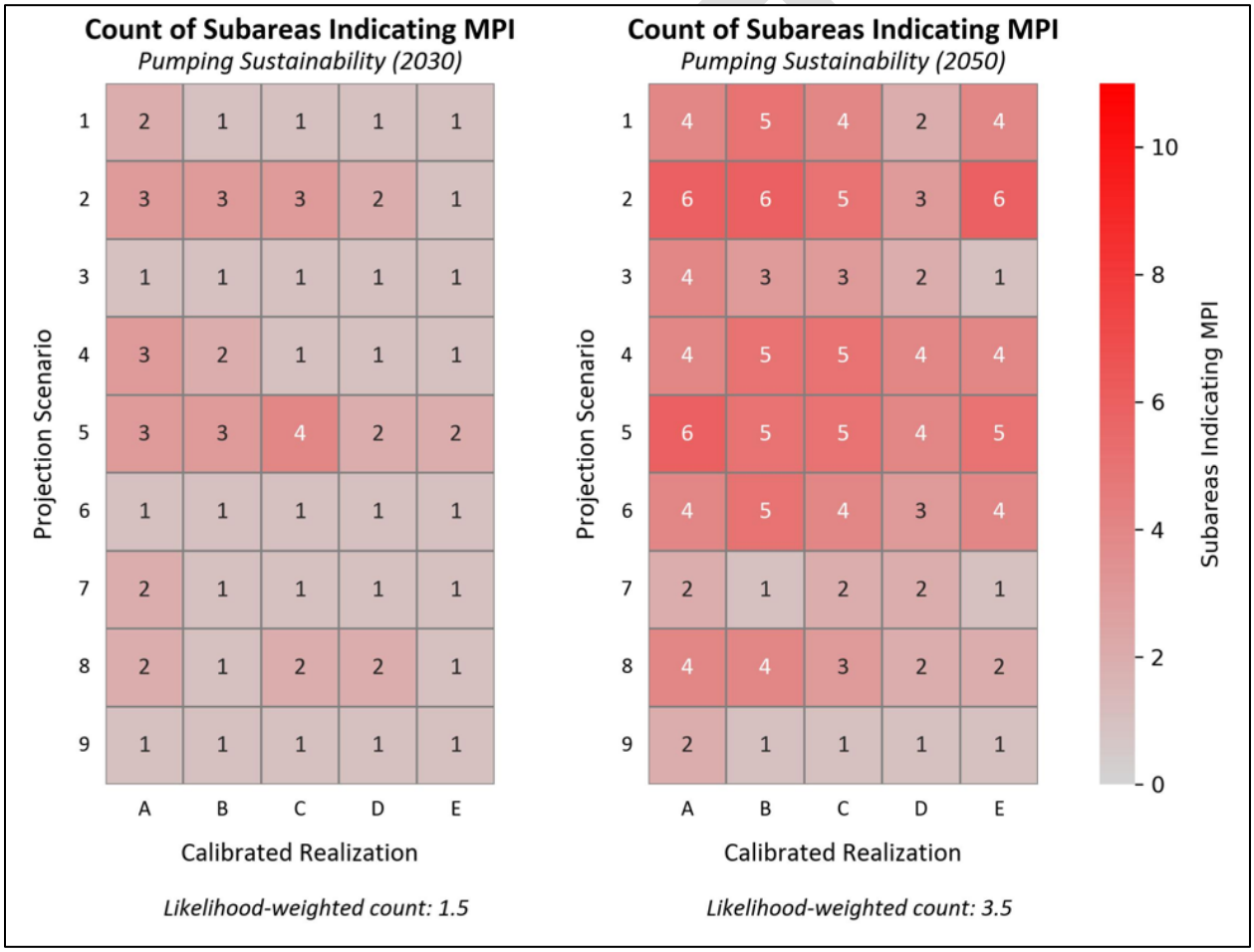


Figure 7-21. Count of Subareas Indicating MPI for Pumping Sustainability for the TSY Ensemble (FY 2030 and 2050).

7.2.2.3.1 Drivers of MPI for Pumping Sustainability

Based on the results presented above, the three primary drivers of MPI due to pumping sustainability are: extraction of water from managed storage; a hotter/drier climate; and the parties' localized well operations. In addition, there is significant uncertainty in the PSTs and groundwater levels in Upland's service area.

Table 7-3. Percentage of Wells Below Pumping Sustainability Thresholds, FY 2030 and FY 2050

		Party																					
		CDA 22 wells with PST Figure 7-9		Chino 10 wells 7-10		Chino Hills 5 wells 7-11		CVWD 12 wells 7-12		FWC 13 wells 7-13		GSWC 1 well 7-14		JCSD 18 wells 7-15		MVWD 11 wells 7-16		Ontario 20 wells 7-17		Pomona 15 wells 7-18		Upland 4 wells 7-19	
Scenario	Likelihood Weight	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
1	4	14	21	0	14	0	0	8	13	15	19	0	0	30	56	0	0	0	0	0	4	75	75
2	2	16	23	0	20	0	0	12	15	17	26	0	40	41	66	0	0	0	4	0	9	75	75
3	2	8	16	0	8	0	0	8	10	15	15	0	0	24	41	0	0	0	0	0	3	75	75
4	2	14	24	0	20	0	0	10	12	15	19	0	0	38	74	0	0	0	4	0	8	75	75
5	1	16	24	0	20	0	0	13	15	19	23	0	20	51	77	0	0	0	8	0	11	75	75
6	1	8	21	0	18	0	0	8	10	15	19	0	0	29	71	0	0	0	1	0	5	75	75
7	2	13	16	0	0	0	0	8	8	15	15	0	0	24	24	0	0	0	0	0	0	75	75
8	1	16	18	0	8	0	0	10	10	15	19	0	0	28	36	0	0	0	0	0	3	75	75
9	1	8	11	0	0	0	0	8	8	15	15	0	0	19	22	0	0	0	0	0	0	75	75
Likelihood-Weighted Average		13%	19%	0%	12%	0%	0%	9%	12%	16%	19%	0%	6%	31%	52%	0%	0%	0%	2%	0%	5%	75%	75%

Figure 7-22 shows the direct relationship between declining storage and the increasing MPI due to pumping sustainability, depicting the average change in storage from FY 2021-2050 versus the average number of subareas indicating MPI for pumping sustainability in FY 2050 for several subgroups of Projection Realizations.

- The High Demand Projection Realizations (Scenarios 4, 5, and 6) indicate MPI at an average of 4.5 subareas, compared to 1.9 subareas and 3.9 subareas for the Low Demand and Expected Demand Projection Realizations, respectively.
- The number of subareas indicating MPI increases by a factor of 0.5 (Low Demand) to 1.5 (Expected and High Demand) from FY 2030 to FY 2050.
- In all High Demand Projection Realizations, the balance of managed storage is zero by 2050, whereas the average managed storage is 409,000 af and 146,000 af in 2050 for the Low Demand and Expected Demand Projection Realizations, respectively.

Climate also drives MPI, but to a lesser degree than demand. The Hot/Dry Climate Projection Realizations (Scenarios 2, 5, and 8) indicate MPI at an average of 4.4 subareas, compared to 2.6 subareas and 3.3 subareas for the Cool/Wet and Average Climate Scenarios, respectively.

Localized operations of the CDA, JCSD, and Pomona wellfields also may have an impact on the MPI simulated in these subareas:

- **CDA:** The likelihood-weighted percentage of Projection Realizations indicating MPI for CDA increases from 25 percent in 2030 to 83 percent in 2050. This increase is not driven by CDAs pumping rates, which remain constant throughout the projection period. As shown in Figure 7-10, the wells indicating MPI are mostly in the center of the wellfield, near where more of CDAs pumping is concentrated. In several Projection Realizations, this pumping results in lower groundwater levels compared to the surrounding area. For example, Figure 6-26 shows groundwater level declines of over 40 feet near some of the future wells (II-13 and II-14) from 2022 to 2050, which is about 10 feet lower than the regional groundwater level declines in that area. This suggests that the MPI is driven by both regional changes in groundwater levels and the simulated pumping distribution in the CDA wellfield.
- **JCSD:** The likelihood-weighted percentage of Projection Realizations indicating MPI for JCSD increases from 17 percent in 2030 to 65 percent in 2050. This increase is driven by JCSD's pumping rates (especially those exceeding the Low Demand Water Plan Scenario [around 11,400 afy at buildout]), the broader basin-wide decline in groundwater levels, and the operational configuration of JCSD's wellfield. To support this finding, two of the 15 Projection Scenarios under the Low Demand Water Plan Scenarios indicated MPI (A8 and B8), while 11 of the Expected Water Plan Scenarios and all of the High Demand Water Plan Scenarios indicated MPI. Figure 7-16 shows that pumping is concentrated over about six wells within less than two miles of each other, suggesting that well interference may exacerbate drawdown at higher pumping rates.

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- **Pomona:** The likelihood-weighted percentage of Projection Realizations indicating MPI for Pomona increases from 0 percent in 2030 to 57 percent in 2050. This increase is driven by Pomona's pumping rates (especially those exceeding the Low Demand Water Plan Scenario [around 12,300 afy at buildout]), the broader basin-wide decline in groundwater levels, and the operational configuration of Pomona's wellfield. To support this finding, only two of the 15 Projection Scenarios under the Low Demand Water Plan Scenarios indicated MPI, while 10 of the Expected Water Plan Scenarios and 13 of the High Demand Water Plan Scenarios indicated MPI. Figure 7-19 shows that pumping is concentrated over about 12 wells within less than 2 miles of each other, suggesting that well interference may exacerbate drawdown at higher pumping rates.

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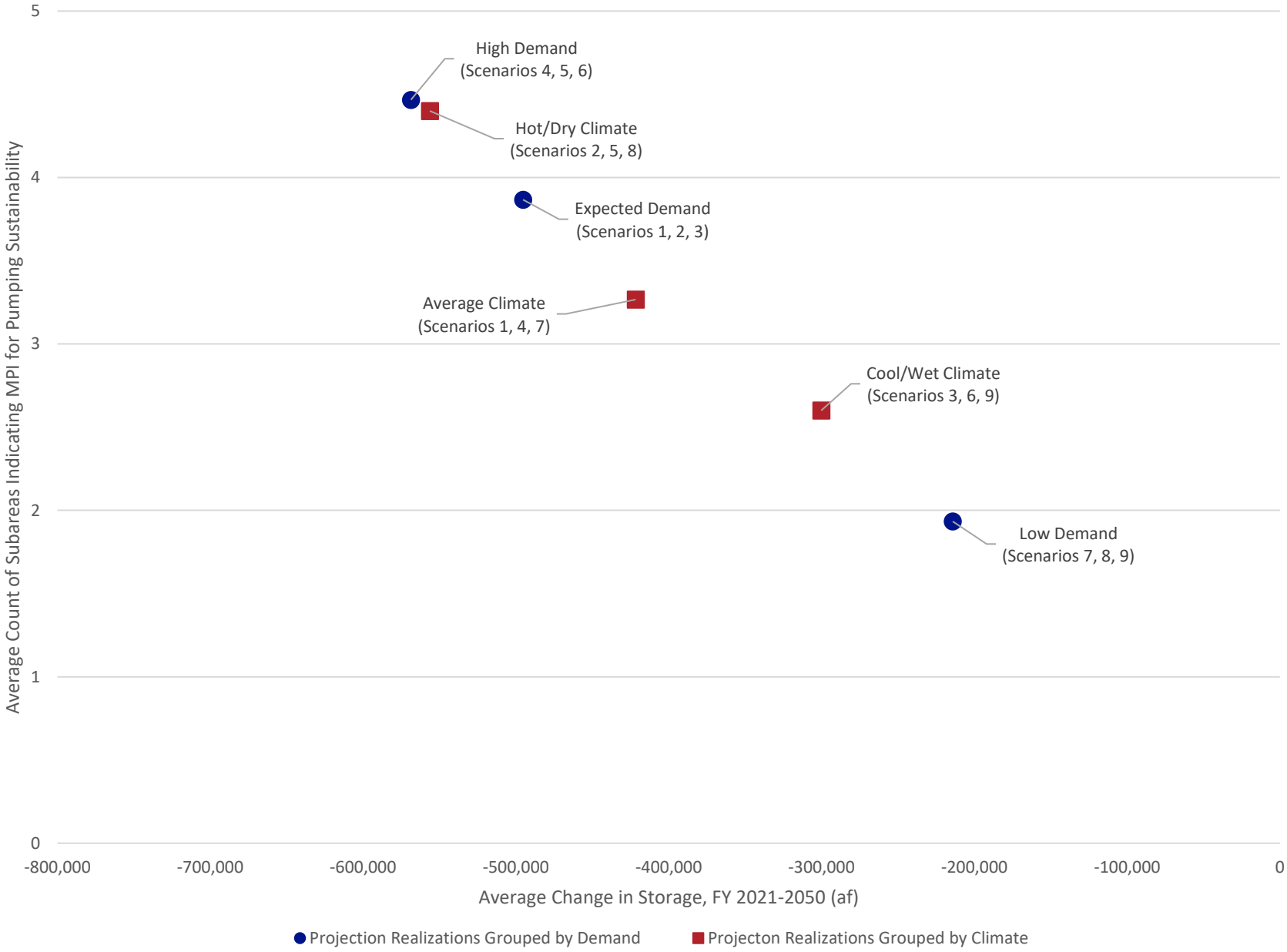
Figure 7-22. Change in Storage and Prevalence of MPI for Pumping Sustainability



The finding of MPI for Upland's pumping sustainability carries a low degree of certainty for two main reasons:

- Uncertainty in simulated groundwater levels: Groundwater data in this specific portion of the aquifer is sparse, leading to higher uncertainty in the simulated groundwater levels for this area.
- PSTs: Upland has not revised its PSTs for several years; the PSTs are based on their most recently collected pump settings. Upland has also not reported experiencing pumping sustainability challenges at existing groundwater levels.

Therefore, the MPI finding for Upland requires further examination and discussion with Upland before recommendations for mitigation can be made.

7.2.2.3.2 Potential Methods to Avoid or Mitigate MPI due to Pumping Sustainability

The analysis above indicates that the groundwater-level declines that could lead to pumping-sustainability-related MPI are mainly driven by future extractions of groundwater from managed storage and localized pumping patterns. These extractions from managed storage may be accelerated under hot/dry climate conditions and/or greater than expected water demands, but the extractions from managed storage are predicted to be the primary driver of future pumping sustainability challenges. As discussed below in Section 7.3.2, a changed Safe Yield ***is not*** the most effective method to mitigate the potential for pumping sustainability-related MPI. Instead, the Watermaster has the ability to employ alternative methods to mitigate the potential for MPI due to pumping sustainability, which include: recharge master planning and implementation; storage management planning and implementation for both local storage and regional storage and recovery programs; and pumping adjustments by the parties. Recharge master planning and storage management planning were described above as methods to address land subsidence. Pumping sustainability challenges can be mitigated within a wellfield by lowering pumping equipment, changing pumping patterns, or a combination of the two.

7.2.3 Hydraulic Control

The attainment of hydraulic control is measured by demonstrating, from results of a calibrated groundwater model (e.g., the 2025 CVM), either that all groundwater north of the CDA well fields does not discharge through the CDA well fields (total hydraulic containment standard) or that groundwater discharge through the CDA well fields is, in aggregate, less than 1,000 afy (de minimis standard). The Regional Board has agreed that compliance with the de minimis standard will be determined from groundwater monitoring data and the results of periodic calibrations of the Watermaster groundwater model and interpretations of the calibration results.

7.2.3.1 Methods to Evaluate the State of Hydraulic Control

Hydraulic control is evaluated based on calculating the total groundwater flow from north to south (southward flow) across a designated “line of hydraulic control.” This line is positioned approximately perpendicular to the regional groundwater flow direction across and area downgradient of the western portion of the CDA well field—an area which historically has shown incomplete capture of southward flowing groundwater by the CDA wells. The line of hydraulic control was originally delineated in the early

2000s based on model-simulated groundwater-flow vectors in the vicinity of the then-proposed CCWF.[9] Its purpose is to serve as a consistent boundary for simulating and quantifying the effectiveness of the CDA wellfield in minimizing quantity of groundwater flow from the Chino-North groundwater management zone to the Prado Basin management zone. Measured groundwater elevations at wells in the vicinity of the eastern portion of the CDA wellfield demonstrate the total hydraulic containment standard. Figures 7-23 and 7-24 show the pumping around the line of hydraulic control and the groundwater-flow vectors (D1) in Layer 1 for July 1, 2030 and July 1, 2050, respectively.

7.2.3.2 Results

Figure 7-25 is a six-panel chart showing the total southward flow across the line of hydraulic control for all the scenarios for the period of FY 2021 through 2080. Panels 1 through 5 show each of the five calibrated realizations, and the bottom-right panel shows the results from the entire TSY ensemble. Each chart shows time series of the mean flow (dark blue), the 20th to 80th percentile range (light blue shade), and the full range of data (gray shade) for the subset of models. Each panel also shows the de minimis threshold of 1,000 afy. Each of the panels also show the 2020 SYR projected flow through the CCWF for comparison (gray dashed line).

Under all members of the TSY Ensemble, the total southward flow through the CCWF declines in the latter half of the current decade when the Chino Airport remediation wells come online. For the FY 2021 through 2030 period, the likelihood-weighted average flow through the CCWF is approximately 530 afy, with a 20th to 80th percentile range of approximately 220 to 650 afy. While the upper bound of the full range exceeds the 1,000 afy threshold in some early years (with maximum values on the order of 1,300 to 1,800 afy in Realization D), the ensemble mean and central percentile range remain well below the de minimis threshold and show a declining trend through the decade.

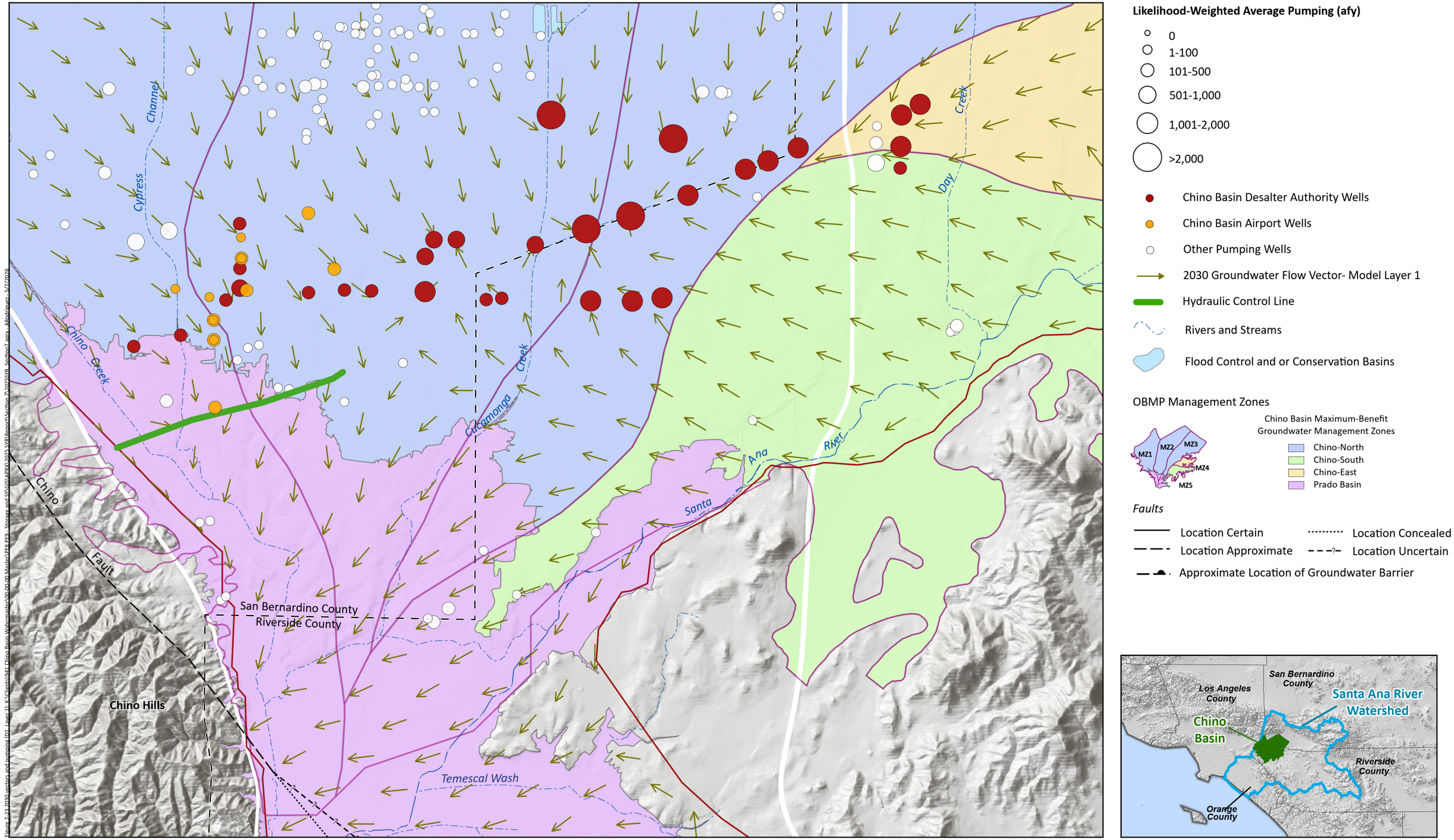
For the FY 2031 through 2080 period, simulated flows decrease substantially. The likelihood-weighted average flow is approximately 200 afy, with a 20t^{h} to 80th percentile range of approximately 60 to 270 afy. Most simulated values fall well below the 1,000 afy threshold, with only occasional exceedances in the upper bound of the full range in earlier years (Realization D), and most realizations remain below the threshold over time.

7.2.3.3 Discussion

Simulated flow through the CCWF remains below the de minimis threshold of 1,000 afy for all scenarios and time periods except for several scenarios based on Realization D. These exceedances represent extreme cases and are not reflected in the ensemble mean or central percentile range.

As indicated by the decline in flow across the CCWF for the entire TSY ensemble starting in the late 2020s, the operation of the new Chino Airport wells that are expected to come online in FY 2026 to FY 2029 is a significant driver in reducing the flow through the CCWF. This declining trend indicates that projected future conditions and management actions are not exacerbating southward flow across the line of hydraulic control. Hence, the risk of any member of the TSY ensemble resulting in a violation of hydraulic control is low, and there is no indication of MPI from the TSY ensemble.

[9] 2007 CBWM Groundwater Model Documentation and Evaluation of the Peace II Project Description



Prepared by:

WEST YOST

Prepared for:

Chino Basin Watermaster
2025 Safe Yield Reevaluation

Groundwater-Flow Vectors and Groundwater Pumping near Line of Hydraulic Control

Scenario D1 - 2030

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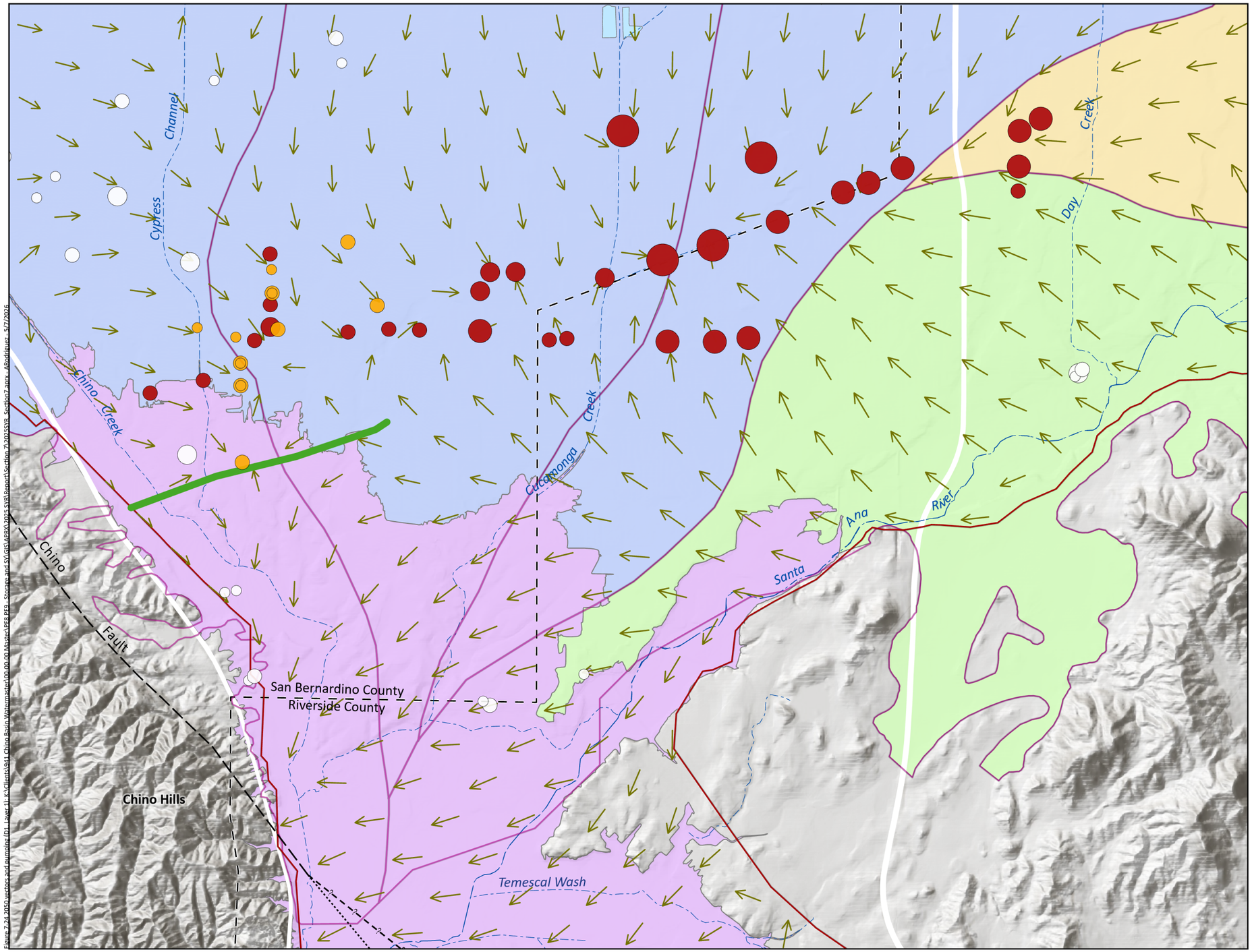
Figure 7-23



Likelihood-Weighted Average Pumping (afy)

- 0
- 1-100
- 101-500
- 501-1,000
- 1,001-2,000
- >2,000

- Chino Basin Desalter Authority Wells
- Chino Basin Airport Wells
- Other Pumping Wells
- 2030 Groundwater Flow Vector- Model Layer 1
- Hydraulic Control Line
- Rivers and Streams
- Flood Control and or Conservation Basins

OBMP Management Zones



Chino Basin Maximum-Benefit Groundwater Management Zones

- Chino-North
- Chino-South
- Chino-East
- Prado Basin

Faults

- Location Certain
- Location Concealed
- Location Approximate
- Location Uncertain
- Approximate Location of Groundwater Barrier



Prepared by:

WEST YOST

N

0 1 2 Miles

0 1.5 3 Km

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Chino Basin Watermaster
2025 Safe Yield Reevaluation

Groundwater-Flow Vectors and Groundwater Pumping near Line of Hydraulic Control

Scenario D1 - 2050

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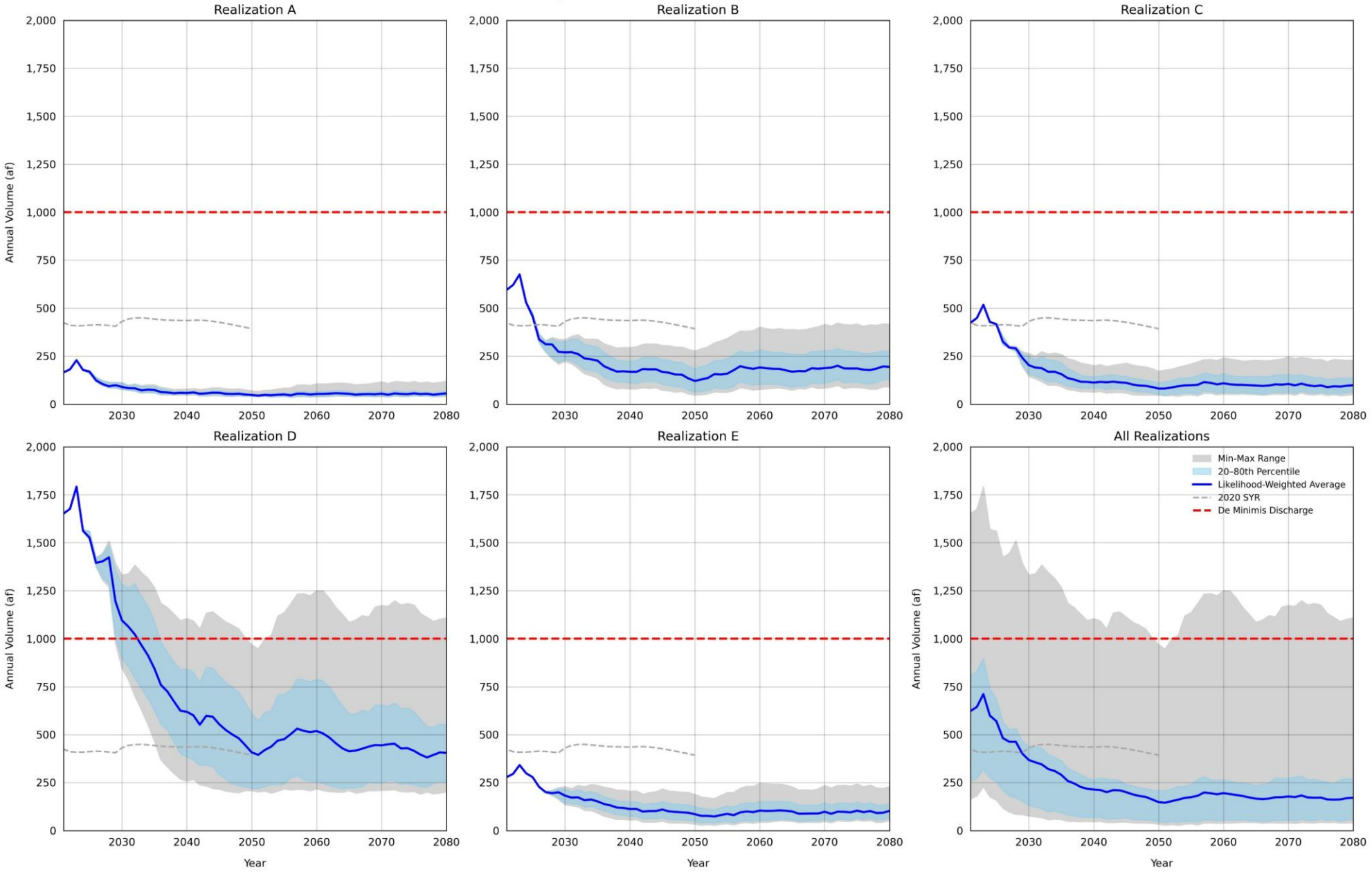
Figure 7-24

Figure 7-25
Flow through Chino Creek Well Field - TSY Ensemble



7.3 DETERMINATION OF VIABILITY OF TSY

This section describes the viability of production at the TSY based on the findings of the TSY Ensemble, the identification of drivers of potential future MPI, and potential mitigation methods, which completes Step 9 of the 2022 SYRM.

7.3.1 Summary of Findings

Figure 7-26 is a heatmap depicting all the Projection Realizations indicating the number of subareas indicating MPI. There are 17 subareas that were evaluated for MPI: 5 for land subsidence, 11 for pumping sustainability, and 1 for hydraulic control. Figure 7-26 shows that MPI across all categories increases from an average of 2.2 subareas in FY 2030 to 5.7 subareas in FY 2050. The degree of MPI varies between Projection Realizations, having the highest incidence in High Demand Scenarios (Projection Scenarios 4, 5, and 6) and the Hot/Dry Climate Scenarios (Scenarios 2 and 5).

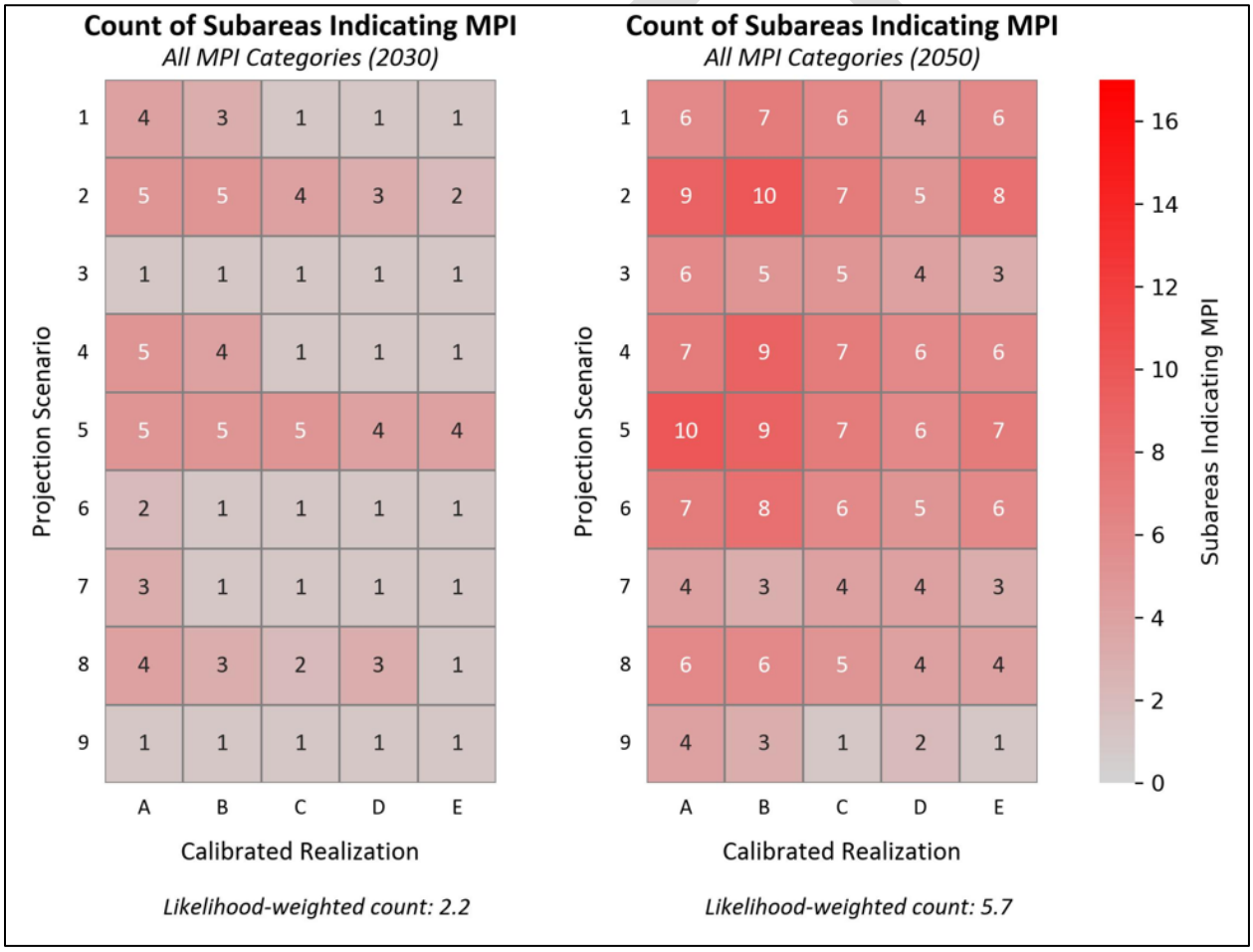


Figure 7-26. Count of Subareas Indicating MPI for All Categories for the TSY Ensemble (FY 2030 and 2050).

The risk of MPI increases as physical groundwater storage declines. Figure 7-27 is a scatter plot of change in physical storage (FY2021-2050) versus count of subareas indicating MPI for all categories for each Projection Realization. This plot shows a clear relationship between change in storage and MPI. While physical storage and managed storage are not identical, change in physical storage is a more direct indicator of changes in groundwater levels.

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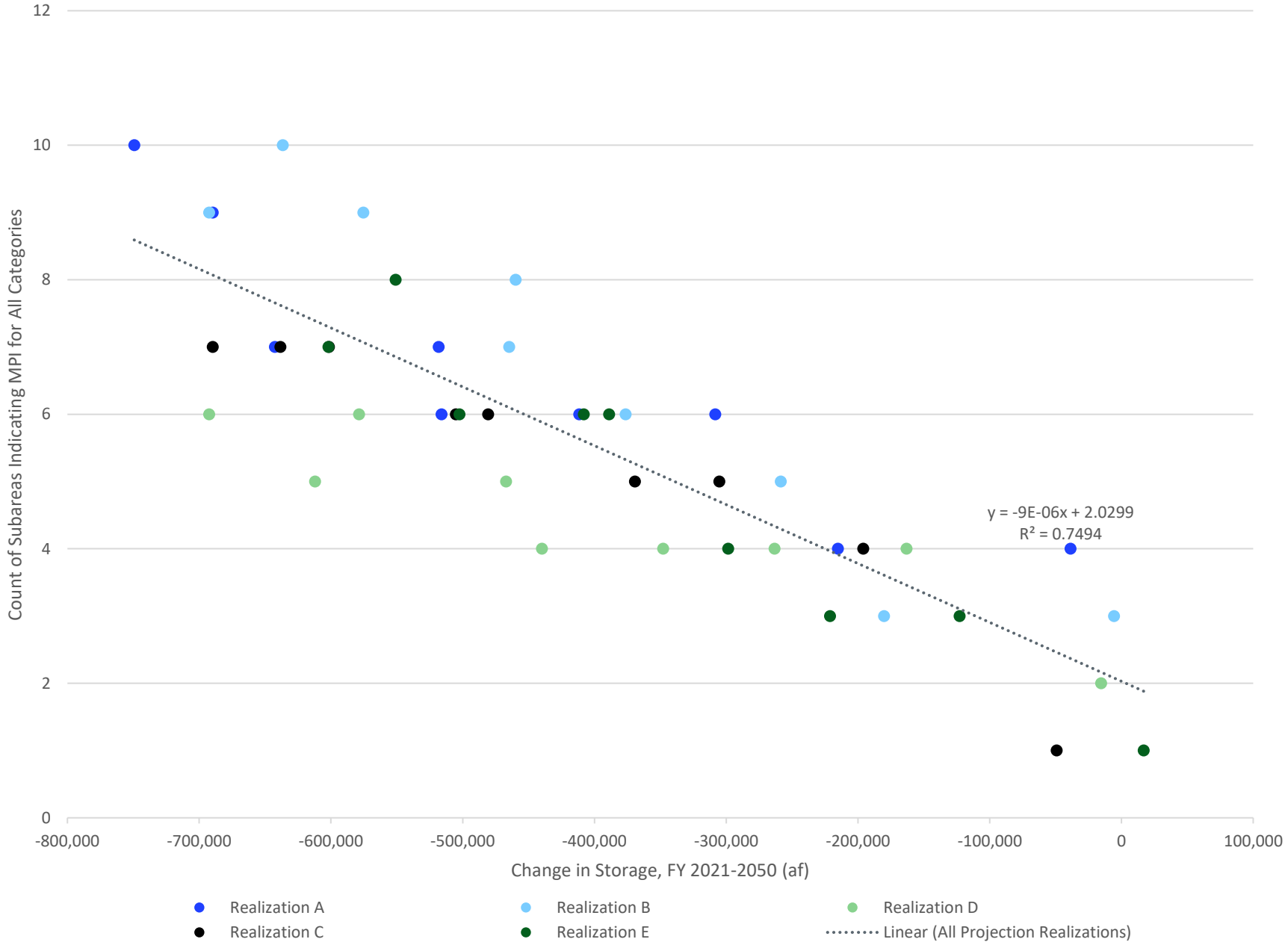
Figure 7-27. Change in Storage and Prevalence of MPI, TSY Ensemble



Managed storage is impacted by Reoperation credits (which are allocated to offset production from the Chino Basin Desalters through 2030) and the Safe Yield, which is determined as the 10-year averaged net recharge. Drawing water from managed storage means that parties are using their existing pumping rights or managed storage to offset pumping rather than acquiring "wet water" for replenishment. This enables groundwater pumping from the Chino Basin beyond the Safe Yield. If this pumping is greater than the net recharge, then it can result in a decline in physical storage. Therefore, the use of managed storage can increase the risk of MPI by causing groundwater levels to decline if pumping outpaces natural and artificial recharge. Figures 7-8 and 7-22 focus on the drivers of MPI for land subsidence and pumping sustainability, respectively, and demonstrate that high groundwater pumping and hot/dry climate conditions (which reduce natural recharge and increase demand) are primary drivers of reduced groundwater levels that can lead to MPI.

7.3.2 Evaluation of the Safe Yield

In Section 6, the TSY for the Chino Basin is estimated to be 121,200 afy for the period 2021-2030. Pursuant to Step 9 of the SYRM, the Watermaster must:

> 9. *Evaluate whether the groundwater production at the Tentative Safe Yield estimated in [8] above will cause or threaten to cause "undesirable results" or "Material Physical Injury." If groundwater production at Tentative Safe Yield will cause or threaten to cause "undesirable results" or "Material Physical Injury," then Watermaster will identify and implement prudent measures necessary to mitigate "undesirable results" or "Material Physical Injury," set the value of Safe Yield to ensure there is no "undesirable results" or "Material Physical Injury," or implement a combination of mitigation measures and a changed Safe Yield.*

In this section, the potential for future MPI associated with operating at the TSY was evaluated and shown to be localized and mainly driven by future extractions of groundwater from managed storage.

Reducing the Safe Yield from 121,200 afy would only have a minor effect on the potential for MPI, as the resulting increase in replenishment obligations would lead to more wet-water recharge, which in turn would result in localized higher groundwater levels that will spread to other regions of the basin over time. Even if the increases in recharge were to occur near locations with a higher risk of MPI, the increases may not be significant enough to mitigate MPI in these areas. Furthermore, some areas of projected MPI (e.g., JCSD) are not near recharge basins or are in areas where surface recharge has a limited effect on mitigating MPI.[10] Therefore, changing the Safe Yield ***is not*** the most effective method to mitigate the types of MPI indicated in the TSY Ensemble.

Recommendations for mitigating each category of MPI are described earlier in this section and include: subsidence management; recharge master planning; storage management; and adjusting localized pumping operations. Therefore, following the Court-ordered 2022 SYRM, **the Safe Yield is 121,200 afy for the 2021 through 2030 period**.

[10] See Section 3 of the 2013 Amendment to the 2010 Recharge Master Plan Update

7.3.2.1 Comparison to 2020 Safe Yield Recalculation Results

The reevaluated Safe Yield of 121,200 afy is 9,800 afy less than the current Court-approved Safe Yield of 131,000 afy for FY 2021 through FY 2030 (-7.5%). The detailed comparison of the 2020 SYR and 2025 SYR water-budget results is presented in Section 6.2.1.1. That section summarizes the changes in individual recharge and discharge components for FY 2021 through FY 2030, including the effects of the 2025 CVM updates, recalibration and uncertainty analysis, recent historical hydrology and water-use data, and revised Projection Ensemble assumptions.

As described in Section 6, the lower 2025 TSY is not attributable to a single factor. The largest difference for an individual water-budget component is lower DIPAW to the saturated zone, which is partly offset by increases in other net recharge components and decreases in some discharge components. Component-level differences between the 2020 SYR and 2025 SYR are discussed in detail in Section 6.

7.3.2.2 Contribution from Conservation Regulations

The difference between the current Safe Yield and the reevaluated Safe Yield exceeds the 2.5 percent threshold that allows the Watermaster to recommend to the Court to reset the Safe Yield. Watermaster's discretion on resetting the Safe Yield for the 2021-2030 period is defined in the April 2017 and July 2020 Court Orders, which are incorporated into the 2025 Rules and Regulations[11] (2025 R&R). Section 6.5(c) of the 2025 R&R states that in addition to the 10-year scheduled resets (the next one of which will occur by 2030), "*the Safe Yield may be reset in the event that:*

(i) with the recommendation and advice of the Pools and Advisory Committee and in the exercise of prudent management discretion described in Section 6.5(e)(iii), below, Watermaster recommends to the court that the Safe Yield must be changed by an amount greater (more or less) than 2.5% of the then-effective Safe Yield. [Court's Order, dated April 28, 2017; Court's Findings and Order, dated March 15, 2019 at 2.]

(ii) The California State Water Resources Control Board develops water conservation measures prior to June 30, 2030, that result in a reduction in urban irrigation in the Chino Basin (i.e., reduced Evapotranspiration Adjustment Factors), as required by Water Code § 10609, et seq., that is reasonably likely to materially reduce recharge in the Chino Basin and such measures are determined to change the Safe Yield by more than 2.5% of the then-effective Safe Yield, and Watermaster moves the Court to reset the Safe Yield accordingly. [Court's Orders, dated July 31, 2020 at 15.]"

As discussed in Section 5, the Conservation Regulation is projected to reduce aggregate water demands by about 1,200 to 2,700 afy in 2025, which is less than one percent of total demand, and by about 5,700 to 11,700 afy in 2030, which is about three percent of total demand. The effect of these demand reductions on net recharge during FY 2021 through FY 2030 would be smaller and delayed for several reasons. First, the Conservation Regulation went into effect in 2025, halfway through the ten-year period used to calculate the Safe Yield. Second, only the portion of reduced demand associated with outdoor irrigation affects DIPAW; reductions in other water uses do not translate directly to reduced DIPAW. Third, even where reduced outdoor irrigation lowers deep percolation past the root zone, the effect on recharge to the saturated zone is delayed by vadose-zone travel time for years or decades. Therefore, the

[11] 2025 Chino Basin Watermaster Rules and Regulations

Conservation Regulation is not reasonably likely to materially reduce saturated-zone recharge in the Chino Basin by enough to change the Safe Yield by more than 2.5 percent of the current Safe Yield for FY 2021 through FY 2030.

Therefore, our technical opinion is that the State Board's "water conservation measures" (i.e., Conservation Regulations) that were adopted prior to June 30, 2030, are *not* reasonably likely to materially reduce recharge in the Chino Basin to the degree that it would impact the Safe Yield by more than 2.5 percent of the current Safe Yield for the period of FY 2021 through 2030.

The primary drivers of the -7.5% difference between the current Safe Yield and the reevaluated Safe Yield are recent historically dry conditions and declines in historical and projected urban outdoor water use that are independent of the Conservation Regulation.

7.4 RECOMMENDATIONS

This section describes the recommendations resulting from the findings of the 2025 Safe Yield Reevaluation for: addressing data gaps to improve of the CVM; implementing mitigation measures for potential MPI identified in the TSY ensemble; and future operational optimization studies based on the 2025 CVM and TSY Ensemble results.

7.4.1 Addressing Data Gaps and Improving CVM

Through the development of the 2025 CVM and its calibration and uncertainty analysis, the 2025 CVM demonstrated statistical improvements in simulating historical groundwater behavior compared to the 2020 CVM, as described in Sections 2 through 4. The following recommendations could further improve the CVM as a decision-making tool for Watermaster and the parties:

- **Collect additional data in areas of the CVM with greatest uncertainty.** The calibration and uncertainty analysis identified four areas where additional monitoring and characterization would reduce uncertainty in future versions of the CVM:
    1. *Aquifer properties and sub-surface inflows in the northern Chino Basin.* The northern Chino Basin, including northern Fontana and Upland, has fewer wells relative to the rest of the Basin, which limits the understanding of boundary inflows and aquifer-system properties in these areas. Additional borehole lithology, geophysical data, aquifer-test data, and depth-specific groundwater-level measurements would improve the characterization of aquifer properties and boundary inflows and would improve future CVM re-calibrations.
    2. *San Gabriel Mountain inflows.* Additional monitoring should focus on better quantifying mountain-front recharge and surface-water inflows along the San Gabriel Mountain front. Potential improvements could include stream gaging at key mountain-front drainages, improved monitoring of flows into recharge/flood-control facilities, high-frequency groundwater-level measurements in wells near the mountain front, and targeted water-quality or isotope sampling and analysis studies. These data would improve estimates of boundary inflows (surface and sub-surface inflows), recharge timing, and groundwater-flow gradients in the northern CVM.
    3. *Aquifer properties in western Chino Basin.* The greater variability in simulated groundwater levels at various wells in this area is influenced by complex faulting and the

vertical hydrostratigraphic layering of the aquifer system that is unique to this portion of the Chino Basin and may not be well understood and well represented in the CVM, which limits the ability to achieve better model calibration. Additional borehole lithology, geophysical data, aquifer test data, and depth-specific groundwater-level measurements would improve the characterization of aquifer properties and groundwater flow (horizontal and vertical) in this area of the Chino Basin and would improve future CVM calibrations.

4. *Southern Chino Basin/Santa Ana River interaction.* While the net movement of water between the SAR and the southern Chino Basin remained similar to the 2020 CVM, the total water exchanged (total streambed infiltration plus total rising groundwater) increased by 47 percent in the 2025 CVM. Improving the measurements of the groundwaters/surface water interactions could improve future CVM updates and re-calibrations and better support future planning in the Chino Basin and the SAR watershed. Potential improvements could leverage existing monitoring in the Chino Basin and the SAR to understand rising groundwater and water quality, including paired streamflow measurements upstream and downstream of key reaches, stream-stage monitoring, shallow groundwater-level monitoring near the river, periodic seepage runs, streambed hydraulic-conductivity testing, and continued riparian vegetation/groundwater ET monitoring in Prado Basin.

- **Continue to collect historical data and projections regarding urban outdoor water use.** The difference in historical and projected DIPAW is the largest factor in the difference between the current Safe Yield (131,000 afy) and the reevaluated Safe Yield (121,200 afy). The Projection Ensemble was developed based on the best available information on the current patterns of outdoor water use and the projected impacts of the Conservation Regulation with input from the parties. However, as the Conservation Regulation took effect on January 1, 2025, it will take several years to measurably impact urban outdoor water use and even longer to impact recharge to the Chino Basin. This was a point of discussion during the 2025 SYR process.

  In advance of the 2030 Safe Yield Recalculation, it is recommended that Watermaster continue collaborating with the parties to better understand and quantify urban outdoor water use and the impact of the Conservation Regulation and other drivers on urban outdoor water use. This includes quantifying the nature of the how changes in outdoor water use are occurring, whether it be through less vegetation, improved irrigation efficiency, or other factors. Building upon the prior improvements in data collection will help improve the accuracy of and confidence in estimates of future urban outdoor water use and DIPAW.

7.4.2 Mitigation Measures

The possible mitigation measures to address the potential for MPI associated with the TSY Ensemble are discussed in the above sections and include:

- Subsidence management planning (to address MPI for land subsidence)
- Recharge master planning (to address MPI for land subsidence and pumping sustainability)
- Storage management (to address MPI for land subsidence and pumping sustainability)

- Revised operations of the parties experiencing pumping sustainability challenges

Watermaster should use the MPI results from the TSY Ensemble to identify the areas where these measures should be evaluated and, where appropriate, implemented through existing Basin management programs. These measures should be coordinated with the affected parties and should be targeted to the specific MPI mechanism, location, and operating condition identified in the TSY Ensemble.

7.4.3 Operational Optimization

During the development of the 2025 SYR, the AP expressed interest in using the 2025 CVM and TSY Ensemble results to evaluate operational strategies for pumping, recharge, and storage management. These strategies could be used to enhance Basin management, mitigate MPI, reduce losses from storage, and offset the effects of observed and projected declines in net recharge compared to historical levels.

The 2025 SYR was not designed to optimize Basin operations or identify a preferred combination of pumping, recharge, and storage-management actions. However, the findings of the 2025 SYR and prior studies[12] indicate that certain operational strategies could improve Basin conditions by increasing net recharge, supporting groundwater levels in key areas, strengthening hydraulic control, and/or reducing storage losses. The 2025 CVM and TSY Ensemble results provide a baseline from which Watermaster and the parties can evaluate the effectiveness of these strategies and guide future Basin management. Potential operational optimization activities are summarized in Table 7-4.

Activities identified as maintaining or enhancing Safe Yield have the potential to improve net recharge or reduce losses from storage. Any effect on Safe Yield would need to be quantified through future scenario development and model simulations.

[12] E.g., the 2023 Storage Framework Investigation

Table 7-4. Potential Basin-Management Activities to Avoid MPI and Maintain or Enhance Safe Yield

Activity	Description	Intended Outcome	
		Avoid/ Mitigate MPI	Maintain/ Enhance Safe Yield
Subsidence management	Develop and apply guidance criteria for pumping, recharge, and storage-recovery operations in Areas of Subsidence Concern to reduce the risk of groundwater levels declining below subsidence thresholds.	X	
Recharge master planning	Develop and implement projects and operating strategies to capture more stormwater and enhance recharge in strategic locations where recharge can support groundwater levels, reduce MPI risk, and improve net recharge.	X	X
Storage management planning and strategic management of local storage	Develop criteria for the storage, transfer, and recovery of water in local storage, including the location, timing, and rate of recovery, to avoid localized drawdown, reduce losses from storage, and maintain physical storage.	X	X
Revised local operations of parties	Work with parties experiencing pumping sustainability challenges to adjust wellfield operations, including pumping locations, rates, timing, equipment settings, and coordination among nearby wells, to reduce pumping interference and sustain production.	X	
Increased pumping in the southern Chino Basin to strengthen hydraulic control and minimize storage losses	Evaluate operationally feasible increases or redistribution of pumping in the southern Chino Basin, including the desalter well fields, to maintain hydraulic control, reduce rising-groundwater and evapotranspiration losses, and improve effective use of recharge and storage.	X	X
Strategic Storage and Recovery Programs	Design and implement Storage and Recovery Programs so that recharge and recovery occur at times and locations that increase effective yield, maintain hydraulic control, and avoid groundwater-level declines in areas where MPI could occur.	X	X

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