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Surface Water Recharge Evaluation
Preliminary Feasibility Study
Draft

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Acronyms and Abbreviations

Acronym / Abbreviation	Definition
AF	acre-feet
AFY	acre-feet per year
ASR	aquifer storage and recovery
bgs	below ground surface
CEQA	California Environmental Quality Act
City	City of San Diego
County	County of San Diego
DSOD	Division of Safety of Dams
DWR	California Department of Water Resources
GDE	groundwater dependent ecosystem
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
mg/L	milligrams per liter
MT	minimum threshold
NCCAG	Natural Communities Commonly Associated with Groundwater
NEPA	National Environmental Policy Act
O&M	operation and maintenance
PMAs	projects and management actions
Ramona MWD	Ramona Municipal Water District
RMW	Representative Monitoring Well
SDCWA	San Diego County Water Authority
SGMA	Sustainable Groundwater Management Act
SPV	San Pasqual Valley
SPV GSP Model	San Pasqual Valley Groundwater Sustainability Plan Integrated Groundwater/Surface Water Flow Model
TDS	total dissolved solids
TM	technical memorandum
TSS	total suspended solids
WY	water year

EXECUTIVE SUMMARY

The San Pasqual Valley Groundwater Sustainability Agency (GSA) – composed of the City of San Diego (City) and the County of San Diego (County) – approved and submitted to the California Department of Water Resources (DWR) the San Pasqual Valley Groundwater Sustainability Plan (GSP) in January 2022. As part of the GSP, a series of Projects and Management Actions (PMA) were identified that could be implemented in the Basin to support groundwater sustainability. This Preliminary Feasibility Study (Study) was developed as part of PMA 7 to conduct an Initial Surface Water Recharge Evaluation. This Study explores potential opportunities for future groundwater recharge projects in the Basin. The goal of the recharge projects is to improve resiliency in the Basin to stressors such as drought and climate change. The potential recharge projects are referred to as strategies throughout this Study.

To support this effort, six technical memoranda (TMs) were developed that focused on topics to help improve the GSA's understanding of the potential for groundwater recharge opportunities and project implementation. These TMs are included as Appendices A through F to this Study and are presented in the order they were developed.

Appendix A Evaluation Criteria describes the criteria used to evaluate each of the selected recharge strategies. Establishing evaluation criteria helped guide the development of potential recharge strategies, defined the information to be developed for each strategy for an equitable comparison and ranking, and set clear expectations with stakeholders as to the priorities for the potential recharge options. Public input was provided during stakeholder meetings to develop the criteria and rank their importance using weighting that would be applied to the evaluation results.

Additional analysis was conducted to understand potential water sources and recharge methods that could be considered for use in a future recharge strategy. Appendix B (TM2) includes the results of field data collection and a streambed investigation to provide site specific data needed to update the San Pasqual Valley Groundwater Sustainability Plan Integrated Groundwater/Surface-Water Flow Model (SPV GSP Model). The updated SPV GSP Model helped to understand the Baseline projections (i.e., groundwater projections if no recharge strategies are implemented) and opportunities for recharge. Appendix C (TM 3) identifies water sources for potential recharge, while taking into consideration the results of the streambed investigation.

Recharge strategies were developed in Appendix D (TM 4), which provides details on all considered recharge strategies. These strategies were developed by matching potential recharge sources with potential recharge methods. A total of six different recharge methods and three different water sources were considered. Conveyance systems were identified based on the water source and recharge method and generally consisted of using the streambed to convey water or constructing pipelines for conveyance. Strategies were designated using a number and a letter, with the number indicating the water source and the letter indicating the recharge method. Water sources were labeled 1: Stormwater in Santa Ysabel Creek, 2: Controlled Releases from Sutherland Reservoir, and 3: Deliveries from Ramona MWD's Untreated Water System. Recharge methods were labeled A: Existing Streambed, B: In-Stream Modifications, C: Infiltration Basins, D: Injection Wells, E: Managed Flood Irrigation, and F: In-Lieu Recharge.

Once the potential water sources, conveyance systems, and recharge methods were established, a total of 15 recharge strategies were identified. A comparative numerical analysis of the 15 recharge strategies was completed to identify a subset of four strategies that warranted further investigation. The four recharge strategies that were selected for modeling and further evaluation were as follows:

- **Strategy 1B**: Enhance streamflow infiltration in Santa Ysabel Creek with an in-channel detention structure (rubber dam)
- **Strategy 2A**: Augment Santa Ysabel Creek flows with controlled releases from Sutherland Reservoir
- **Strategy 3A**: Augment Santa Ysabel Creek flows with deliveries from Ramona MWD's untreated water treatment system
- **Strategy 3D**: Enhance groundwater recharge via injection wells with deliveries from Ramona MWD's untreated water system. Water treatment prior to injection was considered as part of the strategy.

The SPV GSP Model was used to simulate changes in Basin conditions for each of the four recharge strategies and compare them against a Baseline (no recharge strategy) simulation. The detailed results and assumptions for these projection simulations are provided in Appendix E (TM 5), and included changes to groundwater levels, changes in groundwater storage, recharge efficiency, changes in total dissolved solids (TDS) concentrations, and comparison to minimum thresholds. Lastly, model results were analyzed to assess potential benefits to groundwater dependent ecosystems (GDEs) for each of the recharge strategies, the results of which are provided in Appendix F (TM 6).

After conducting the analyses described in Appendices C through F, the evaluation criteria were applied to the recharge strategies, which were scored and ranked to identify which strategies were most favorable. The evaluation criteria were applied in a two-step process – the first step focused on projected benefits to the Basin, using the results from the SPV GSP Model. The second step considered the estimated cost and implementation requirements for the strategies. This two-step process helped demonstrate the variety of strengths of each recharge strategy. For example, Strategy 1B, the rubber dam, has the highest recharge efficiency of the four strategies when compared to Baseline, but the smallest reduction of the modeled deficient in groundwater storage when compared to Baseline, meaning it recharged the smallest volume of water as compared with the other recharge strategies. Strategies were ranked 1 (greatest benefit) through 4 (least benefit) for each criterion, separated out by benefits to the Basin (Criteria 1 through 6) and costs and implementation considerations (Criteria 7 and 8). Rankings were considered scores, and weighting was then applied to each of the scores to reflect Basin priorities. Under Step 1 of the evaluation process, the weighted scores were totaled for Criteria 1 through 6 (benefits to Basin), whereas under Step 2 the weighted scores were totaled and Criteria 7 and 8 (cost and implementation considerations). The two totals from Step 1 and Step 2 were then summed for a final score and ranking of the strategies.

In considering the two steps of the evaluation process, Strategy 2A ranked highest (most favorable) followed by Strategy 3A and Strategy 3D. Strategy 2A balanced moderate recharge benefits with a relatively low cost and implementation complexity. Strategy 3A and Strategy 3D provided high source water availability but had higher costs and implementation complexities related to the infrastructure and coordination required for implementation. Strategy 1B is ranked lowest (least favorable) overall because it would provide minimal additional volume of water to the Basin, has the highest estimated cost per acre-foot (AF), and would require construction in the San Ysabel Creek channel, along with ongoing operational monitoring to avoid negative impacts from the detention basin.

The ranking of recharge strategies was based on several factors and assumptions that were considered reasonable when this report was developed. Different operational approaches could change the rankings presented in this study. Decisions made with information presented in this report should be reevaluated as site conditions change, as new information and data become available, and as knowledge of the Basin's surface and subsurface conditions evolves. The evaluation conducted on the four strategies provides valuable insight into the potential benefits and drawbacks of the different approaches the GSA could take to recharge the Basin. Although a recharge project would only be considered for implementation if the Basin were to be at risk for experiencing undesirable results in the future, there are several steps in the planning process for the GSA to complete to determine the feasibility of implementing these strategies. Additionally, changes to how a strategy would be operated or under which conditions recharge activities would occur could change the outcomes of the ranking and feasibility. Therefore, this Preliminary Feasibility Study is intended to be a starting point in the planning process and helps to better understand choices available to the GSA, the potential benefits of the recharge strategies, general steps for reaching the construction phase, and facilitating planning. Future implementation of one or more of these strategies would require completion of additional planning steps that would help to refine the details of the strategy, evaluate how these refinements would affect the Basin, and other implementation and operational considerations. Each step of the planning process is critical for moving the project closer to implementation or in determining that the strategy is not a preferred action to address Basin sustainability.

1. INTRODUCTION

1.1 Background

The San Pasqual Valley Groundwater Sustainability Agency (GSA) – composed of the City of San Diego (City) and the County of San Diego (County) – approved and submitted to the California Department of Water Resources (DWR) the San Pasqual Valley Groundwater Sustainability Plan (GSP) in January 2022. The GSP provides guidance and quantifiable metrics to ensure the continued sustainable management of groundwater resources within the San Pasqual Valley Groundwater Basin (Basin) over the 20-year implementation period of the GSP. To accomplish this, the GSP includes a hydrogeological conceptual model, monitoring requirements, sustainability criteria, and several projects and management actions. The projects and management actions (PMAs) included in the GSP are intended to support sustainable groundwater management in the Basin by identifying opportunities to respond to changing future conditions and help avoid undesirable results. The Basin is currently sustainably managed, and no PMAs are needed at this time to achieve sustainability. As a result, PMAs such as groundwater recharge strategies do not need to be implemented to achieve sustainability at this time. However, developing some PMAs now can prepare the GSA for future implementation should conditions in the Basin change over time.

1.1.1 San Pasqual Valley Groundwater Basin

The Basin is located within the San Pasqual Valley, approximately 25 miles northeast of downtown San Diego. The San Pasqual Valley is sparsely populated and includes row crop, orchard, nursery, and dairy operations. The City owns approximately 90 percent of the land overlying the Basin and the City-owned land is designated and managed as an agricultural preserve as documented in City of San Diego Council Policy 600-45. The Basin underlies portions of Cloverdale Canyon, Rockwood Canyon, and Bandy Canyon along Highway 78. The main waterways in the Basin include Santa Ysabel Creek, Guejito Creek, which flows into Santa Ysabel Creek, and Santa Maria Creek. The confluence of Santa Maria Creek and Santa Ysabel Creek coincides with the start of the San Dieguito River, which flows southwest into Hodges Reservoir at the western end of the Basin.

Groundwater levels in the Basin have been monitored for more than 15 years. The eastern portion of the Basin has groundwater levels that are generally deeper and fluctuate in response to dry and wet periods. Groundwater levels in the western portion of the Basin are shallower and less prone to significant fluctuations. The average depth to groundwater in the eastern portion of the Basin over the last ten years (2013 through 2022) ranged from approximately 50 to approximately 80 feet below ground surface (bgs) depending on the location in the Basin. In contrast, depth to groundwater in the western portion of the Basin has ranged approximately 10 to approximately 40 feet bgs over that same period, depending on location in the western portion of the Basin.

Groundwater quality data indicates constituent concentrations are correlated and are affected by the quality of surface water flowing into the Basin. Historically, total dissolved solids (TDS) and nitrate have been the primary constituents of concern. Elevated nitrate concentrations are mostly caused by animal waste and fertilizer use in the Basin, whereas elevated TDS concentrations are mostly caused by evapoconcentration of salts in the Basin and TDS in waters that originate outside the Basin (City, 2014).

1.1.2 San Pasqual Valley Groundwater Sustainability Agency

As described briefly above, the GSA consists of the City, which has land use and water supply authority, and owns the land within its jurisdiction; and the County, which has land use responsibilities and implements the County's Groundwater Ordinance outside of the City's jurisdiction in the Basin. The City is implementing the GSP within City jurisdiction (90 percent of the Basin), and the County is implementing the GSP within County-only areas (10 percent of the Basin). The City and County remain committed to collaboratively implementing a single GSP for the entire Basin.

1.2 Purpose

This Preliminary Feasibility Study assessed potential groundwater recharge strategies in the Basin to support future Basin sustainability as defined in the GSP. The GSA will use this study and accompanying technical memoranda (TMs) to better understand the potential benefits to the Basin and feasibility of implementation of these recharge strategies, as a first step in the planning process. This document and the associated TMs (Appendices A through F) are designed to support informed decision making by the GSA regarding potential recharge opportunities in the Basin should future conditions require action be taken to support sustainable groundwater levels. The information included here is the first step of several, as outlined in Section 4, and should be considered a starting point for developing future recharge projects. This study, along with the associated TMs, are deliverables associated with the Initial Surface Water Recharge Evaluation undertaken by the GSA as the recommendation of Basin stakeholders.

1.3 Process for Developing the Preliminary Feasibility Study

The Initial Surface Water Recharge Evaluation, the outcomes of which are documented in several TMs and this Preliminary Feasibility Study, was identified as a Tier 0 PMA in the GSP, which means that it was one of several PMAs that could be implemented at any point after GSP adoption. Tier 0 PMAs can be developed regardless of the groundwater conditions in the Basin and are not an indication that the Basin is approaching potential unsustainability. The potential recharge opportunities evaluated in this Preliminary Feasibility Study are just some of several actions from the GSP that the GSA could implement to support Basin sustainability, should the need arise.

Each of the six TMs are attached as an appendix to this study and focuses on different aspects of potential recharge opportunities. These memoranda build upon each other, and refined the potential recharge strategies as they were developed and assessed. The six TMs are as follows:

- **TM 1: Evaluation Criteria (Appendix A)** – Review of evaluation criteria and options for water recharge and foundation for subsequent TMs to provide a basis for ranking and comparing the potential strategies
- **TM 2: Streambed Investigation (Appendix B)** – Field data collection and analysis to provide site-specific data to update the San Pasqual Valley Groundwater Sustainability Plan Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) and understand opportunities for recharge
- **TM 3: Water Sources for Potential Recharge (Appendix C)** – Identification and evaluation of options for source water that could potentially be used for recharge

- **TM 4: Potential Recharge Strategies (Appendix D)** – Assessment of potential recharge strategies and initial review of their feasibility, given the available water sources identified in TM 3
- **TM 5: Model Updates and Simulations (Appendix E)** – Documentation of model updates that incorporated data from TM 2 and simulation of recharge strategies selected for further evaluation from TM 4
- **TM 6: Evaluation of Benefits to GDEs (Appendix F)** – Evaluation of potential benefits of recharge strategies to groundwater dependent ecosystems (GDEs), based on modeled groundwater levels described in TM 5

During the development of the technical memoranda, four public workshops were held to allow stakeholders the opportunity to provide input, ask questions, and be updated on work progress. Drafts of the memoranda were also distributed to stakeholders to review in advance of and following the workshops.

The remainder of this document provides information on the four recharge strategies selected for further analysis, including a ranking of the strategies and next steps for the GSA to consider.

2. POTENTIAL RECHARGE STRATEGIES

This Study assessed potential recharge strategies that could be considered in the eastern portion of the Basin. The intent of all the evaluated recharge strategies is to support the sustainability goals described in the GSP. A recharge strategy includes three components: water source, conveyance system, and recharge method. This Study thoroughly evaluated each component to narrow down a list of potential recharge strategies that could benefit the Basin.

Potential sources of water were evaluated (described in detail in Appendix C), and three were identified as realistic opportunities to supply additional water to the Basin for recharge purposes. These sources include stormwater in Santa Ysabel Creek, controlled releases of water from Sutherland Reservoir, and deliveries from the untreated water system of Ramona Municipal Water District (Ramona MWD). Conveyance methods to transport the source water to the designated recharge area were evaluated for each recharge method, and included the existing Santa Ysabel Creek streambed, conveyance pipelines, and a combination of the streambed and pipelines. Groundwater recharge methods were evaluated for their potential benefits and challenges in the context of the Basin. An initial list of six recharge methods was identified that included infiltration through the existing streambed, in-stream modifications to increase water capture, infiltration basins, injection wells, managed flood irrigation, and in-lieu recharge.

Based upon the potential combinations of water source, conveyance system, and recharge methods discussed above, 15 possible recharge strategies were identified. The potential combinations were designated using a number and a letter, with the number indicating the water source and the letter indicating the recharge method. Water sources were labeled 1: Stormwater in Santa Ysabel Creek, 2: Controlled Releases from Sutherland Reservoir, and 3: Deliveries from Ramona MWD's Untreated Water System. Recharge methods were labeled A: Existing Streambed, B: In-Stream Modifications, C: Infiltration Basins, D: Injection Wells, E: Managed Flood Irrigation, and F: In-Lieu Recharge. A comparative analysis of the 15 strategies was then completed to identify benefits and constraints to determine which strategies warranted further analysis, as documented in Appendix D. Ultimately four recharge strategies were selected for further evaluation, including one from each of the three water sources. The four selected recharge strategies are as follows:

- **Strategy 1B**: Enhance streamflow infiltration in Santa Ysabel Creek with an in-channel detention structure (rubber dam). This strategy uses stormwater as the source, the streambed for conveyance, and infiltration in the existing streambed with in-stream modifications as the recharge method. With infiltration through the existing streambed, additional source water is introduced to the stream and allowed to infiltrate naturally into the underlying aquifer. Modifications to the streambed would increase the opportunity for additional infiltration. Examples of such modifications could include, but are not limited to, weirs, berms, and rubber dams.
- **Strategy 2A**: Augment Santa Ysabel Creek flows with controlled releases from Sutherland Reservoir. This strategy uses controlled releases of water from Sutherland Reservoir as the water source, the Santa Ysabel Creek streambed for conveyance, and infiltration in the existing streambed as the recharge method. This strategy does not include in-stream modifications.
- **Strategy 3A**: Augment Santa Ysabel Creek flows with deliveries from Ramona MWD's untreated water system. This strategy uses untreated water from Ramona MWD as the source water, conveyance pipelines as the conveyance method, and infiltration in the existing streambed as the recharge method.

- **Strategy 3D**: Enhance groundwater recharge via injection wells by treating and injected water from Ramona MWD's untreated water system. This strategy uses untreated water from Ramona MWD as the source water, conveyance pipelines as the conveyance method, and injection wells as the recharge method. Injection wells would pump treated source water directly into the aquifer system in the eastern portion of the Basin.

Once these four strategies were determined, each strategy's surface water recharge was simulated in an updated version of the SPV GSP Model to project benefits to groundwater levels and storage (described in Appendix E). These four recharge strategies were refined to improve the numerical and conceptual details of each during the modeling process. Output from the projection simulations were used to identify and refine a systematic approach for modeling the implementation of each selected recharge strategy. Details of this analysis, calculations, and projections can be found in Appendices C through E. The conceptual layout of these recharge strategies, as modeled, is provided in **Figure 2-1**.

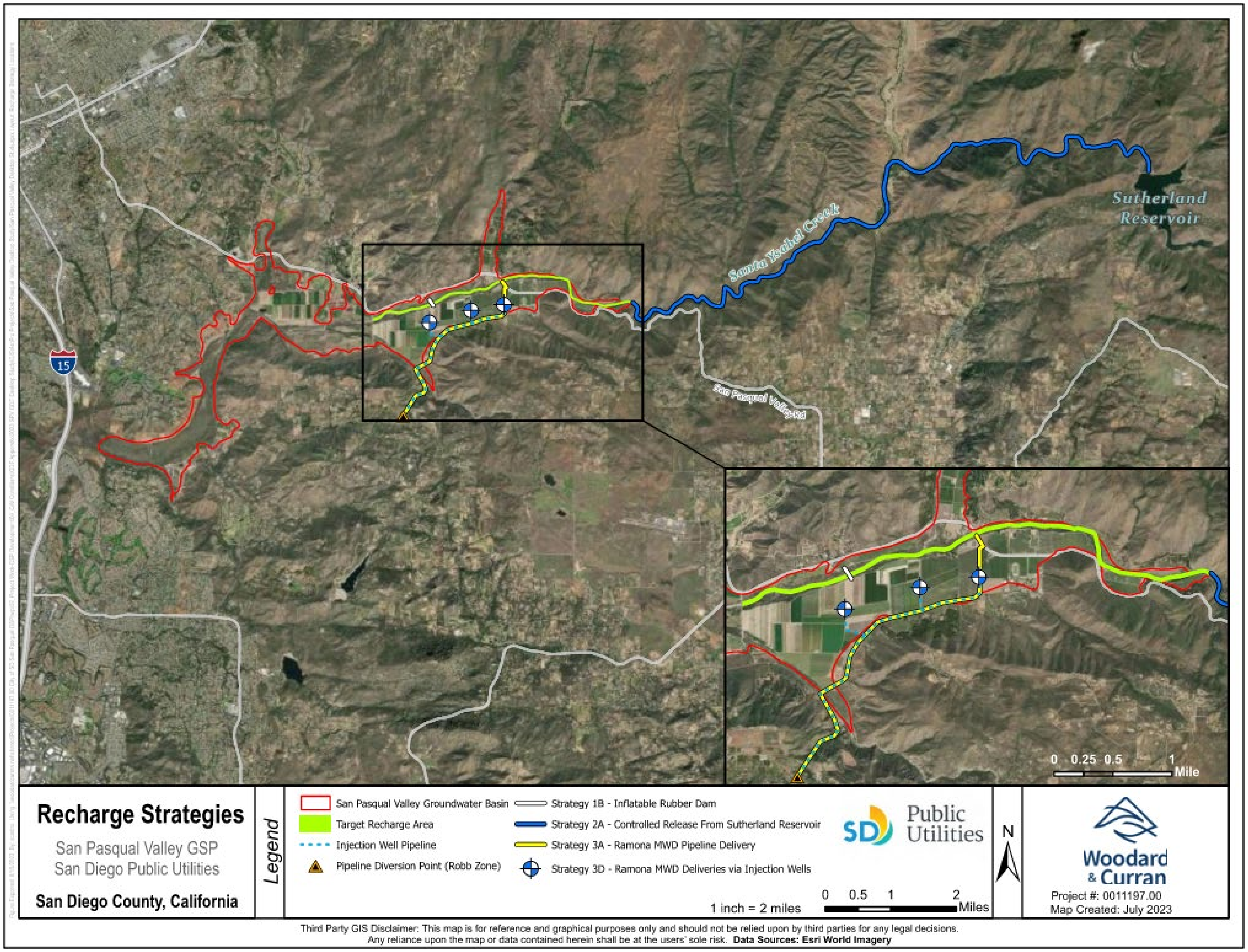


Figure 2-1: Conceptual Layout for Recharge Strategies

3. POTENTIAL RECHARGE STRATEGIES ANALYSIS

3.1 Baseline Simulation

The modeling approach first required establishing a simulation that did not incorporate any of the recharge strategies described above. This simulation is referred to as the "Baseline" simulation. The Baseline simulation was created by using the updated SPV GSP Model to simulate the same hydrology, land-use, and climate conditions described in the GSP (City and County, 2021). The 52-year projection period for the Baseline simulation and the strategy simulations includes WYs 2020 through 2071. The projection period incorporates projected changes in climate based on the Hadley Centre Global Environment Model v2-ES (HadGEM2-ES) global circulation model (GCM) with the Representative Concentration Pathway 8.5 emissions scenario. This GCM was selected during the development of the GSP for its warmer and drier tendencies, representing a conservative projection of climate change impacts. Full details regarding the assumptions associated with the projection period can be found in Section 5 of Appendix I of the GSP (City and County, 2021). Land use and the associated agricultural demand within the Basin were held constant at 2018 (existing) conditions for the entirety of the projection period. Thus, the Baseline simulation and recharge strategy simulations do not consider changes in land use that could occur in the future in response to droughts or other factors.

3.2 Evaluation Criteria

Eight criteria were used to evaluate the preliminary feasibility of the four recharge strategies (Table 3-1). Most of the evaluation criteria rely on comparing the Baseline simulation results against each strategy's projected groundwater recharge benefits. The numerical modeling results for groundwater elevation, depth to water, and water budget data were used to inform Evaluation Criteria 1 through 6, which relate to the physical benefits to the Basin from each recharge strategy. Evaluation Criteria 7 and 8 were used to assess cost and complexity of implementation (described in Appendix A).

As the evaluation progressed, the approach for some evaluation criteria was revised from the approach initially identified in Appendix A based on additional analysis and modeling considerations. Criterion 4 was revised to provide a better sense of the recharge efficiency in terms of the volume of water infiltrated versus water lost from excess streamflow past Ysabel Creek Road. Criterion 5 was revised from using a weighted scale for multiple groundwater quality constituents to using a simplified scale for a single groundwater quality constituent due to limited availability of water quality data for the Ramona MWD's untreated water system. Criterion 6 was simplified to compare the number of consecutive days modeled groundwater levels occurred below the GDE vegetation rooting depth instead of the average number of days. Finally, Criterion 7 was simplified to consider the capital cost per acre-foot (AF) of each of the strategies and consolidate the original Criteria 7a and 7b discussed in Appendix A. This was done because Criterion 7b, the economic benefit to agricultural operations from the recharge strategies, would be dependent on groundwater levels and recharge volumes already accounted for in Criteria 1 through 6.

The metrics and evaluation approach associated with the evaluation criteria are summarized in **Table 3-1**.

Table 3-1: Summary of Surface Water Recharge Evaluation Criteria

Criterion	Metric	Evaluation Approach
Criterion 1: Reduction of Modeled Deficit in Groundwater Storage	Average change in modeled groundwater storage in Eastern Subarea for WYs 2005 through 2071	Average change in modeled groundwater storage in a recharge strategy simulation minus that in the Baseline simulation over the 67-year simulation period
Criterion 2: Average Reduction of Depth to Water	Modeled depths to water at groundwater-level Representative Monitoring Wells (RMWs) during extended drought periods[a]	Sum of modeled depths to water at RMWs in the Baseline simulation minus those in a recharge strategy simulation divided by the number of simulation days, divided by the number of groundwater-level RMWs during extended drought periods
Criterion 3: Fewer Exceedances of Minimum Thresholds	Modeled groundwater levels at groundwater-level RMWs	Number of occurrences when modeled groundwater levels at RMWs are below minimum thresholds in the Baseline simulation minus that in a recharge strategy simulation over the 67-year simulation period
Criterion 4: Efficiency of Recharge Strategy	Percentage of water made available through recharge to the aquifer in Eastern Subarea for WYs 2005 through 2071	Calculated as 1 minus the loss, where loss is computed as the modeled streamflow across Ysabel Creek Road in a recharge strategy simulation minus that in the Baseline simulation divided by the total volume of surface water made available with the recharge strategy over the 67-year simulation period
Criterion 5: Average Reduction of Groundwater TDS Concentration	Estimated groundwater TDS concentrations at selected RMWs in Eastern Subarea for WYs 2005 through 2071	Estimated average groundwater TDS concentration in the Baseline simulation minus that in a recharge strategy simulation over the 67-year simulation period
Criterion 6: Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs	Modeled groundwater levels at GDE RMWs	Average number of consecutive days modeled depths to water occur below 30-feet bgs in the Baseline Simulation minus that from a recharge strategy simulation over the 67-year period
Criterion 7: Costs and Benefits of Implementation and Maintenance	Capital and water supply costs	Cost per AF of recharge relative to Baseline; Calculated as the preliminary cost (Class 5 cost estimate) per AF for each strategy
Criterion 8: Feasibility of Implementation and Maintenance	Identified permits, institutional challenges, and schedule for each strategy	Qualitative assessment based on the number and difficulty of permits, institutional challenges, and schedule, focused on relative difficulty compared to other strategies in this Study

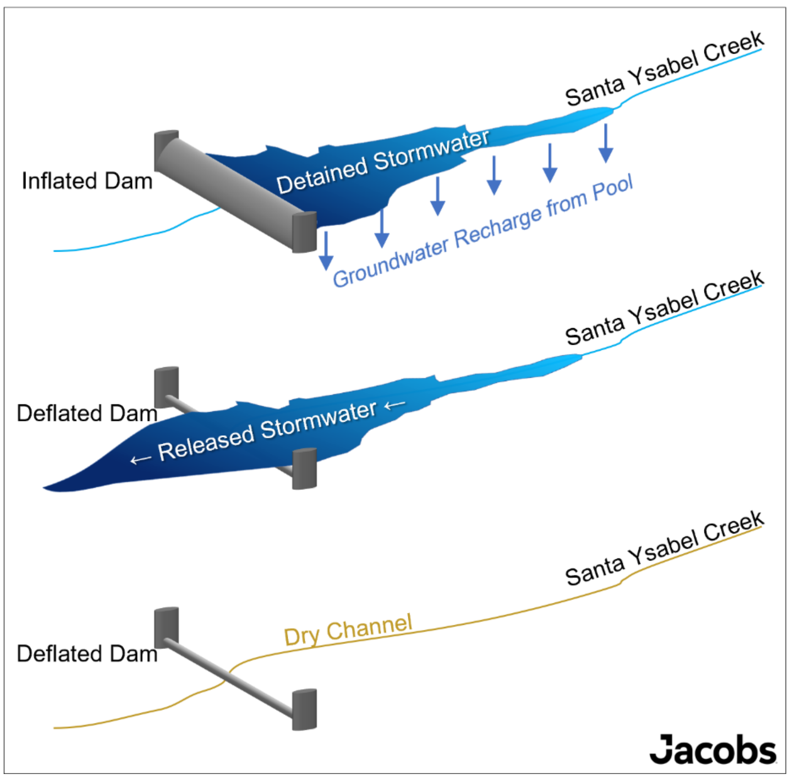
[a] Extended drought periods are defined as having three or more consecutive dry or critically dry years. Extended drought periods during the projected period include WYs 2029 through 2032, 2040 through 2043, 2054 through 2056, and 2061 through 2068.

3.3 Evaluation of Potential Recharge Strategies

The following subsections provide a brief overview of each recharge strategy and how they were evaluated against each of the eight evaluation criteria including their results.

3.3.1 Strategy 1B: Enhance Streamflow Infiltration with In-stream Modifications

The goal of Strategy 1B is to utilize a channel-spanning rubber dam across the existing streambed of Santa Ysabel Creek to capture water and increase recharge to the aquifer. The rubber dam would be inflated during selected periods to detain stormwater and increase the opportunity for additional infiltration and groundwater recharge behind the dam and deflated when Santa Ysabel Creek is dry or during higher-streamflow periods to allow stormwater in the creek to flow past the dam (**Figure 3-1**). Abutments would likely be needed every 100 to 150 feet across the width of the rubber dam to provide structural stability during periods when the dam is inflated (these abutments are not shown in **Figure 3-1**). The conceptual design has identified a recharge point within Santa Ysabel Creek at Ysabel Creek Road. The dam would span the entire channel with a height of 5 feet and a width of approximately 550 feet. Grading would be required to achieve those dimensions in this location.



**Abutments are not represented in this figure*

Figure 3-1: Conceptual Rubber Dam

The estimated stream backup is roughly 1,300 feet forming a pool size of approximately 7.8 acres with a stream gradient of approximately 0.0038 feet/foot (0.38%) (**Figure 3-2**). The map of the dam in **Figure 3-2** shows a hypothetical water pool formed with an inflated rubber dam in the existing channel of Santa Ysabel

Creek. Considerations related to potential increased flooding risks and waterlogging issues would be analyzed if the GSA were to decide to further advance this concept.

Based on the dimensions of the modeled dam and stream channel, a maximum pool volume was estimated of 11.3 AF. The Strategy 1B simulation indicated approximately 720 AF of groundwater recharge from the 44 model cells representing the detained stormwater pool, at an average of approximately 11 AFY over the 67-year historical and projection period, including WYs 2005 through 2071.

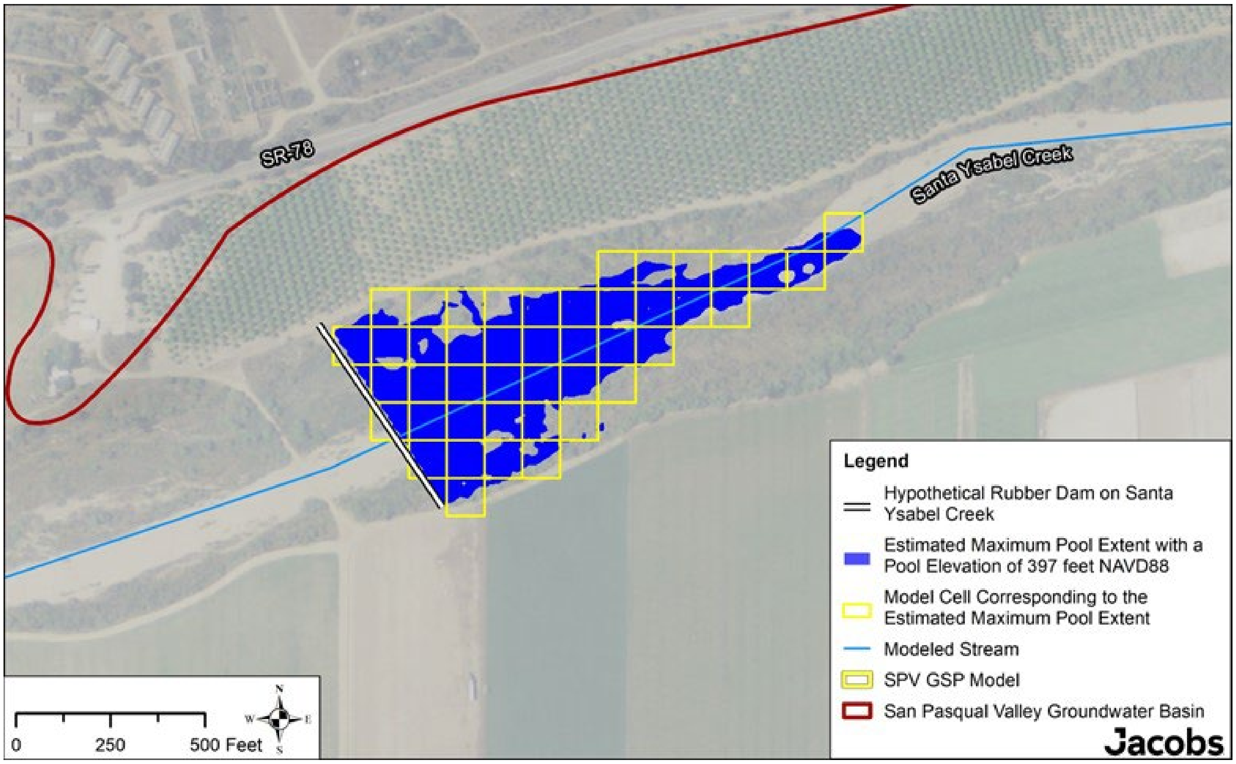


Figure 3-2: Concept Design for Rubber Dam Across Santa Ysabel Creek Channel

3.3.1.1 Strategy 1B Evaluation

Evaluation criteria were applied to Strategy 1B, and results are shown in **Table 3-2**. Evaluation Criteria 1 through 6 are based on modeling results described in Appendix E, which indicate this strategy would result in an additional 720 AF of groundwater recharge, as compared to the Baseline simulation. This would result in a slight decrease in groundwater storage and approximately the same depth to groundwater as the Baseline simulation, but would support four fewer exceedances of minimum thresholds (MTs), and provide a recharge efficiency of 110%. TDS concentrations would be expected to be slightly higher than in the Baseline simulation and there would be no change to the number of days where groundwater levels would reach GDE vegetation rooting depths, as compared to the Baseline simulation. Criterion 7 costs were developed based on the Class 5[1] cost estimates. Total project costs remained the same as reported in Appendix D because no costs were assigned to the water source, which is stormwater that would already flow in the channel. Criterion 8 feasibility was based on overall ease of implementation. Implementation would require additional permitting and environmental analysis due to the location of the dam in the creek channel, whereas operation of the dam would require ongoing monitoring of water levels behind the dam to determine when to raise and lower it to maximize recharge while avoiding damage to the creek and surrounding properties. However, construction could be relatively quick once the necessary permits are obtained.

Table 3-2: Strategy 1B Evaluation Results

Criterion	How Strategy 1B was evaluated	Result
Criterion 1: Reduction of Modeled Deficit in Groundwater Storage	Model output and direct comparison to Baseline simulation.	-1 AF (slight increase in modeled storage deficit as compared with Baseline)
Criterion 2: Average Reduction of Depth to Water	Model output and direct comparison to Baseline simulation	0 feet bgs (essentially no different than Baseline)
Criterion 3: Fewer Exceedances of Minimum Thresholds	Model output and direct comparison to Baseline simulation	4 fewer MT exceedances, as compared with Baseline
Criterion 4: Efficiency of Recharge Strategy	Model output and direct comparison to Baseline simulation and includes GoldSim (reservoir operations) model for Sutherland Reservoir	110% efficiency (greater than 100% because of reduced excess flow across Ysabel Creek Road as compared with Baseline)
Criterion 5: Average Reduction of Groundwater TDS Concentration	Model output and direct comparison to baseline model simulation	-0.3 mg/L (0.3 mg/L greater levels of TDS as compared with Baseline)
Criterion 6: Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs	Model output and direct comparison to baseline model simulation and an analysis of NCCAG (GDE) data	0 consecutive days (essentially no different than Baseline)
Criterion 7: Costs and Benefits of Implementation and Maintenance	Cost per acre-foot of water recharged over the 67-year simulation period, based on Class 5 cost estimates for construction of the dam	$24,975/AF, assuming total 720 AF recharged and total capital and supply cost of $17,982,000
Criterion 8: Feasibility of Implementation and Maintenance	Overall ease of implementation considering permitting, environmental considerations, schedule, and potential challenges to implementation	"Relatively medium" ease of implementation. Construction in creek channel would require environmental mitigation and permitting, and operation would need to consider several factors to avoid damage to creek or surrounding properties.

[1] A Class 5 cost estimate is a very high-level estimate to assist with capital planning and is the least accurate estimate that can be assigned, with Class 1 being the most accurate estimate for a project.

3.3.1.2 Additional Factors to Consider for Strategy 1B

Additional factors that were not addressed in this Study would need to be considered if Strategy 1B were to be implemented in the Basin. The projection simulations did not account for silt or debris that could deposit and collect behind the dam. Without routine maintenance, this could reduce infiltration rates and hinder operation of the rubber dam. Additionally, the projection simulations did not consider whether maintenance activities would affect the timing for when Strategy 1B could be implemented. Temporary flooding of the stream channel may have the potential to adversely impact the structural support of adjacent farm roads, which would need to be considered in the projection simulations. It would also be important to consider the stability of soils in the area at and surrounding the rubber dam if Strategy 1B were to be selected for further evaluation by the GSA to avoid erosion impacts to surrounding land uses and siltation of the stream channel.

In addition to considering potential impacts upstream of the dam, potential downstream impacts would need additional consideration, such as whether the releases of stormwater from the dam would create erosional problems at or downstream from the dam. Model projections assumed that the dam would be deflated to allow stormwater to pass if the pooled water depth behind the dam were to exceed 5 feet. It is possible that the dam would need to be deflated at a depth of less than 5 feet to avoid creating erosional problems at and downstream from the dam. The ramifications for establishing a maximum pool height behind the dam should be further explored if the GSA were to choose to further evaluate Strategy 1B.

3.3.2 Strategy 2A: Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases

Strategy 2A involves releasing water from Sutherland Reservoir into Santa Ysabel Creek to augment streamflow and increase infiltration through the streambed within the Basin (**Figure 2-1**). The maximum controlled releases from Sutherland Reservoir were estimated as the monthly maximum streambed infiltration volume of 900 AF minus the current month's streambed infiltration volume in the Baseline simulation. The updated SPV GSP Model and a reservoir operation model for Sutherland Reservoir were used to determine the magnitude and timing of Sutherland Reservoir releases such that releases occurred only in years where water was available from Sutherland Reservoir and any water released would fully infiltrate in the eastern portion of the Basin. Exceeding the infiltration capacity in the streambed would result in "excess streamflow" beyond Ysabel Creek Road that would not benefit the eastern portion of the Basin. Thus, release volumes and frequency were timed to avoid excess streamflow.

Based on the conditions under which this recharge strategy was modeled over the 67-year simulation period, the cumulative water from controlled releases from Sutherland Reservoir was approximately 2,400 AF. Under the current operation assumptions, there would not be enough available storage in Sutherland Reservoir to provide controlled releases to Santa Ysabel Creek during consecutive dry years. Additionally, this simulation assumed that the Sutherland Dam would be maintained to meet Division of Safety of Dams (DSOD) requirements that would allow Sutherland Reservoir to continue to capture and store the maximum amount of runoff for the duration of the projection period (through WY 2071). If in the future, DSOD inspections of Sutherland Dam result in a requirement for the City to maintain lower water levels at Sutherland Reservoir, less water may be available from Sutherland Reservoir than modeled.

3.3.2.1 Strategy 2A Evaluation

The evaluation criteria were applied to Strategy 2A, and results are shown in **Table 3-3**. Total reduction of modeled deficit in groundwater storage saw no change from the Baseline simulation (Criterion 1) but the modeled water table was a 1-foot higher in elevation on average, as compared to Baseline (Criterion 2). Over the simulation period, there were 41 fewer MT exceedances, as compared to Baseline (Criterion 3) and an overall 84% efficiency in recharge (Criterion 4). Simulation results also showed a reduction of 3.1 mg/L in TDS concentrations over Baseline (Criterion 5), as well as one fewer day over the 67-year simulation when modeled water levels were below the 30-foot thresholds for GDEs in applicable areas of the Basin (Criterion 6). For Criterion 7, total project costs were refined from those reported in TM 4 to reflect the total volume of water released from Sutherland Reservoir over the 67-year simulation period, as determined by the modeling criteria (2,400 AF). Although there would be no capital costs associated with Strategy 2A, water from Sutherland was assigned the same per-AF value as imported water ($1,584/AF), because imported water is the primary alternative water source that is used in the region when local supplies cannot meet demands. The costs did not incorporate costs for improvements at Sutherland Dam or repair of the outlet (City, 2020) that are planned independently of this study[2] and are currently in the City's Capital Improvement Plan, though these improvements may be necessary for this strategy to be implemented. Criterion 8 was based on overall ease of implementation. Implementation would not require additional construction or permitting but would require coordination with Ramona MWD to clarify the investment needs of the outlet works, and updates to the operation agreement of this outlet that is needed for Santa Ysabel Creek controlled releases. Although coordination and agreement negotiations would be required, the lack of additional infrastructure specific to this recharge strategy and permitting results in implementation that is anticipated to be relatively simple compared to the other strategies, and is rated "easy-medium" for Criterion 8.

The evaluation results for this strategy are sensitive to the Sutherland Reservoir operation assumptions. Strategy 2A results presented in **Table 3-3** assumed controlled releases to San Vicente Reservoir would be maintained at historical levels.

[2] It has been assumed that for the Sutherland controlled releases to Santa Ysabel Creek, Train 1 Path 1 will be used and the repair that is required in Train 1 (owned by Ramona MWD and operated by the City) will be implemented regardless of the strategy because the City will need to have a long-term method to meet the emergency drawdown requirements (City, 2020). The City is in the process of planning the Ramona Intake repairs along with the development of a comprehensive recommendations of repairs to the upstream and downstream outlet works. Once these efforts are completed, location and repair approach will be defined.

Table 3-3: Strategy 2A Evaluation Results

Criterion	How Strategy 2A was evaluated	Result
Criterion 1: Reduction of Modeled Deficit in Groundwater Storage	Model output and direct comparison to baseline model simulation.	0 AF (essentially no different than Baseline)
Criterion 2: Average Reduction of Depth to Water	Model output and direct comparison to baseline model simulation	1 feet bgs (slightly higher water table, as compared with Baseline)
Criterion 3: Fewer Exceedances of Minimum Thresholds	Model output and direct comparison to baseline model simulation	41 fewer MT exceedances, as compared with Baseline
Criterion 4: Efficiency of Recharge Strategy	Model output and direct comparison to baseline model simulation and includes GoldSim (reservoir operations) model for Sutherland Reservoir	84% efficiency
Criterion 5: Average Reduction of Groundwater TDS Concentration	Model output and direct comparison to baseline model simulation	3.1 mg/L (3.1 mg/L improvement in TDS as compared with Baseline)
Criterion 6: Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs	Model output and direct comparison to baseline model simulation and an analysis of NCCAG (GDE) data	1 consecutive day (very similar to Baseline)
Criterion 7: Costs and Benefits of Implementation and Maintenance	Cost per acre-foot of water recharged over the 67-year simulation period, based on the current value of imported water (using M&I untreated water rates, assumed as the alternate option for adding this volume of water to the Basin) and Class 5 cost estimates of project cost	$2,139/AF assuming 2,400 AF recharged over 67 years. Total capital and water cost of $5,133,000 (cost of water plus 35% allowance for implementation costs; no capital costs required)
Criterion 8: Feasibility of Implementation and Maintenance	Overall ease of implementation considering permitting, environmental, schedule, and potential challenges to implementation	"Easy-medium" implementation because no specific construction would be required, though would require coordination with Sutherland operations and Ramona MWD. Would require other planned improvements at Sutherland Dam, independent from this strategy, be implemented prior to this strategy.

3.3.2.2 Additional Factors to Consider for Strategy 2A

Additional factors not addressed in this Study would need to be considered if Strategy 2A were to be implemented in the Basin. The projection simulations did not account for conveyance losses that may occur in Santa Ysabel Creek between the outlet of Sutherland Reservoir and the Basin inflow location. The timing and magnitude of controlled releases from Sutherland Reservoir to Santa Ysabel Creek should be managed to maximize efficiency of deliveries to the Basin by minimizing conveyance losses upstream from the Basin to the extent practical, as well as minimizing excess streamflow across Ysabel Creek Road. Additional flows from controlled releases to Santa Ysabel Creek could have the potential to affect biological function due to the presence of flows during times when the creek would naturally be dry. Ecological factors that could affect operational decisions for Strategy 2A would need to be identified and incorporated into the decision process.

The projection simulations assumed that controlled releases to San Vicente Reservoir would continue to occur in the future. This assumption, although appropriate at the preliminary feasibility stage of study, limited the availability of water for controlled releases in the projection simulation of Strategy 2A. As part of the next steps in the planning process, future projection simulations associated with Strategy 2A should explore changes to operational assumptions such as modified releases to San Vicente Reservoir and modifications of agreements between agencies and project operators that could change the availability or timing of potential recharge events. These operational changes could result in different outcomes for the evaluation criteria and scoring. Infrastructure repair improvements would be required before releases supporting recharge in the Basin could be managed at Sutherland Reservoir. The strategy as described and modeled in this study assumes that releases of water from Sutherland Reservoir to Santa Ysabel Creek could be done without changes to existing infrastructure because it has been assumed that the necessary infrastructure improvements would need to be implemented regardless. This assumption was made because the City will need to have a long-term method to meet the dam's emergency drawdown requirements (2020, City).

3.3.3 Strategy 3A: Augment Santa Ysabel Creek Streamflow with Ramona MWD Deliveries

Strategy 3A utilizes untreated water from Ramona MWD to augment streamflow in Santa Ysabel Creek to increase streambed infiltration. Strategy 3A is focused on utilizing the streambed as the recharge method while bringing a new source of water to support the sustainability goals of the Basin. Untreated water from Ramona MWD would be conveyed through a pipeline to Santa Ysabel Creek, where flows would be discharged directly onto the stream channel.

The pipeline would convey untreated water from the Robb Zone diversion point in Ramona MWD's existing untreated water system to Santa Ysabel Creek near the San Pasqual Valley Road bridge in the eastern portion of the Basin, where it would discharge into the creek. Releases from the Robb Zone diversion point would occur at intervals that allow for full infiltration in the eastern portion of the Basin, avoiding excess streamflow, similar to Strategy 2A. The maximum infiltration rate in this portion of the creek is estimated to be approximately 375 AF per month and 1,100 AF per year, depending on streamflow conditions (Appendix E). Ramona MWD's untreated water system could supply an annual volume of up to 3,350 AF for use in the Basin (Appendix E). The proposed pipeline route from the Robb Zone diversion point to the Santa Ysabel Creek discharge location is illustrated in **Figure 3-3**. The maximum monthly delivery capacity from Robb Zone, ranging from a minimum of 248 AF in August to a maximum of 304 AF in March is presented in **Table 3-4** (Ramona MWD, 2022). These values were developed by Ramona MWD as a conservative capacity availability scenario to be used as an initial reference for this recharge strategy assessment.

Table 3-4: Assumed Maximum Monthly Delivery Capacity (AF) from Ramona MWD's Robb Zone

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
296	300	304	285	280	271	267	248	264	255	293	287	3,350

The maximum monthly and annual infiltration capacities were incorporated into the modeled operational rules to maximize recharge benefits to the Basin while minimizing excess streamflow across Ysabel Creek Road from implementing Strategy 3A. Under the modeled operational rules, and accounting for these infiltration capacities, the cumulative volume of water made available for recharge from Ramona MWD deliveries was approximately 9,000 AF over the 67-year simulation period.

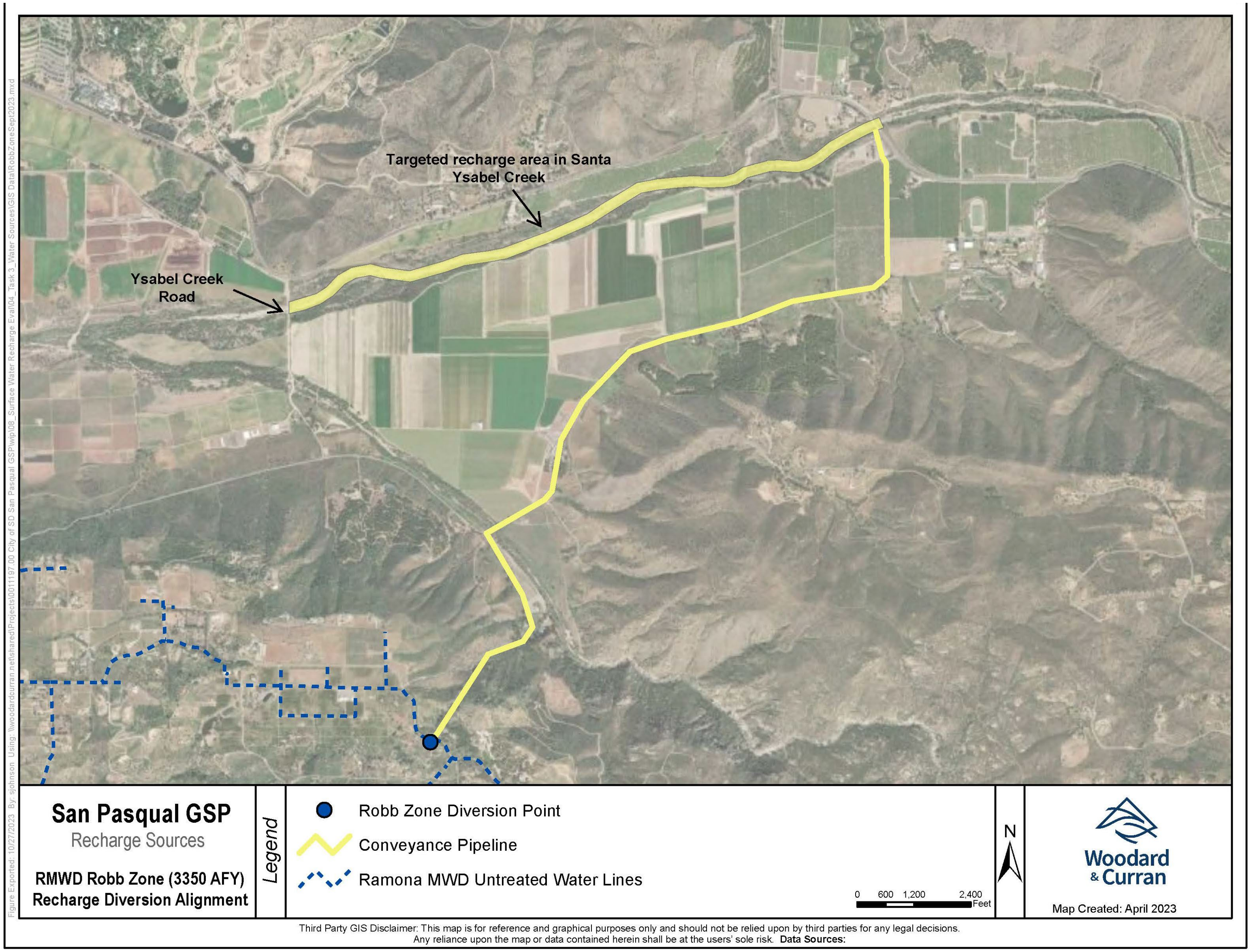


Figure 3-3: Strategy 3A Pipeline Route

3.3.3.1 Strategy 3A Evaluation

The evaluation criteria were applied to Strategy 3A, and results are shown in **Table 3-5**. Modeled total reduction of deficit in groundwater storage was calculated to be an improvement of 17 AF, as compared with Baseline (Criterion 1) with a modeled water table approximately 4 feet higher in elevation on average, as compared to Baseline (Criterion 2). Over the simulation period, there were 208 fewer MT exceedances as compared to Baseline (Criterion 3) and an overall 93% efficiency in recharge (Criterion 4). Simulation results also showed a reduction of 3.1 mg/L in TDS concentrations over Baseline (Criterion 5), as well as two fewer consecutive days over the 67-year simulation when water levels were below the 30-foot thresholds for GDEs in applicable areas of the Basin (Criterion 6). Evaluation Criteria 1 through 6 were based on modeling results as detailed in Appendix E. Evaluation Criterion 7, costs, were developed based on the Class 5 cost estimates generated (Appendix D) and refined to reflect the strategy as modeled. For Strategy 3A, total project costs were refined from those reported in TM 4 to reflect the total volume of water delivered from Ramona MWD to Santa Ysabel Creek over the 67-year simulation period, as determined by the modeling criteria (9,000 AF). Additionally, the pumping fee that Ramona MWD typically passes along to customers was applied to this revised total volume of water. Pipeline length remained the same as in TM 4, as did the per-AF cost of imported water, the source of the untreated Ramona MWD water. Criterion 8 was based on overall ease of implementation. Implementation would require construction of approximately 16,400 linear feet of 12-inch diameter pipeline, including a creek crossing. This strategy would require environmental analysis, coordination with Ramona MWD, construction of the pipeline, and permitting to discharge water into Santa Ysabel Creek for recharge. Implementation is expected to be somewhat difficult and could take more time to construct than Strategy 1B due to the length of the pipeline and terrain to cross between the Robb Zone diversion point and Bandy Canyon Road.

Table 3-5: Strategy 3A Evaluation Results

Criterion	How Strategy 3A was evaluated	Result
Criterion 1: Reduction of Modeled Deficit in Groundwater Storage	Model output and direct comparison to baseline model simulation.	17 AF improvement in deficit in groundwater storage, as compared with Baseline
Criterion 2: Average Reduction of Depth to Water	Model output and direct comparison to baseline model simulation	4 feet bgs (higher water table, as compared with Baseline)
Criterion 3: Fewer Exceedances of Minimum Thresholds	Model output and direct comparison to baseline model simulation	208 fewer MT exceedances, as compared with Baseline
Criterion 4: Efficiency of Recharge Strategy	Model output and direct comparison to baseline model simulation and includes GoldSim (reservoir operations) model for Sutherland Reservoir	93% efficiency
Criterion 5: Average Reduction of Groundwater TDS Concentration	Model output and direct comparison to baseline model simulation and additional analysis by GSA	3.1 mg/L (3.1 mg/L improvement in TDS as compared with Baseline)
Criterion 6: Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs	Model output and direct comparison to baseline model simulation and an analysis of NCCAG (GDE) data	2 consecutive days (similar to Baseline)

Criterion	How Strategy 3A was evaluated	Result
Criterion 7: Costs and Benefits of Implementation and Maintenance	Cost per acre-foot of water recharged over the 67-year simulation period, based on the current value of imported water (the source of the untreated Ramona MWD water) and Class 5 cost estimates of project, including Ramona MWD pumping costs	$4,500/AF, assuming 9,000 AF recharged over 67 years and total capital and water cost of $40,679,000
Criterion 8: Feasibility of Implementation and Maintenance	Overall ease of implementation considering permitting, environmental, schedule, and potential challenges to implementation	"Relatively medium-difficult" ease of implementation. Construction would require medium level of environmental analysis and permitting, but could encounter some challenges during design due to terrain and creek crossing to enter the valley

3.3.3.2 Additional Factors to Consider for Strategy 3A

Additional factors not addressed in this Study would need to be considered if Strategy 3A were to be implemented in the Basin. Ramona MWD may require a minimum volume or frequency of deliveries from its raw water system for this strategy to be financially and operationally viable. This volume would need to be negotiated with Ramona MWD and factored into future evaluation of this strategy, as the projection simulation for this strategy did not consider Ramona MWD volume requirements. It is also possible that having idle recharge infrastructure for parts of a year or over multiple years would not be desirable or would result in additional maintenance requirements, and that reducing infrastructure idling may need to be considered. Ramona MWD also operates a treated (potable) water system in the same vicinity as its raw water system and this system could also be used as a source of recharge water. For creek recharge, the potable water would need to be dechlorinated prior to recharge. The cost of potable water is higher than raw water, but as Ramona MWD receives a portion of its treated SDCWA supply from the Carlsbad Desalination Plant, the TDS is lower than raw water, which may be beneficial for recharge in the Basin. Additional projection simulations completed as part of the planning process for this strategy should be completed if the GSA were to choose to further evaluate Strategy 3A with other possible operational considerations, including the potential use of treated water, instead of the raw water that was modeled for Strategy 3A in this Preliminary Feasibility Study.

TDS was the only groundwater quality constituent for which data were readily available for the untreated water system of Ramona MWD when this Study was conducted. Groundwater quality degradation calculations, beyond those completed for TDS in Study, should be considered for additional constituents of interest if the GSA were to choose to further evaluate Strategy 3A. These calculations would be important to assess the potential for recharge strategies to degrade groundwater quality for a wider range of constituents. Additionally, the projection simulations did not consider whether permitting requirements would constrain operations in a way that would affect source water availability from the untreated water system of Ramona MWD. It would be important to assess permitting requirements that might affect operational decisions if the GSA were to choose to further evaluate Strategy 3A.

As with Strategy 2A, the projection simulations did not consider whether deliveries to Santa Ysabel Creek from the untreated water system of Ramona MWD could hinder biological function due to the presence of flows during times when the creek would naturally be dry. Ecological factors that could affect operational decisions for Strategy 3A would need to be identified and incorporated into the decision process. These and other operational factors could be incorporated as part of the planning process in future evaluations of recharge strategies involving deliveries from the untreated water system of Ramona MWD.

3.3.4 Strategy 3D: Injection Wells with Ramona MWD Deliveries

Strategy 3D utilizes injection wells to recharge water from Ramona MWD to increase groundwater levels in the underlying aquifer. Untreated water from Ramona MWD would be treated to meet injection standards and conveyed through a pipeline to three injection-well locations in the eastern portion of the Basin where water would be pumped into the aquifer to increase groundwater levels and storage. These locations were ultimately determined based on the thickness of aquifer material in this area, proximity to existing agricultural pumping wells, and proximity to proposed pipeline routes from Ramona MWD's conveyance system to the eastern portion of the Basin.

Injection wells were incorporated into the updated SPV GSP Model, which indicated the eastern portion of the Basin could accommodate three injection wells based on the size of the wells and the volume of water that could be injected without surfacing. Each injection well was assumed to have a 12-inch diameter casing with a 50-foot screened interval. The bottom of the screened interval was set to coincide with the bottom of the alluvial aquifer. The total water made available from Ramona MWD for delivery to injection wells over the 67-year simulation period was 24,874 AF. However, the updated SPV GSP Model was set up with an operational rule so that assigned injection rates for these three injection wells could be automatically reduced during the simulation by the modeling code to avoid having water levels inside the injection wells rise above land surface. Incorporation of this operational rule resulted in a total volume of water injected over the 67-year simulation period of 23,264 AF.

3.3.4.1 Strategy 3D Evaluation

The results of the evaluation criteria for Strategy 3D are shown in **Table 3-6**. Modeled total reduction of deficit in groundwater storage was calculated to be an improvement of 80 AF, as compared to Baseline (Criterion 1) with a modeled water table elevation that was 10 feet higher on average, as compared to Baseline (Criterion 2). Over the simulation period, there were 476 fewer MT exceedances as compared to Baseline (Criterion 3) and an overall 97% efficiency in recharge (Criterion 4). Simulation results also showed a reduction of 6.7 mg/L in TDS concentrations over Baseline (Criterion 5), as well as ten fewer consecutive days over the 67-year simulation when water levels were below the 30-foot thresholds for GDEs in applicable areas of the Basin (Criterion 6). Evaluation Criterion 7, costs, were developed based on the Class 5 cost estimates generated and refined to reflect the strategy as modeled. For Strategy 3D, total project costs were refined from those reported in Appendix D to reflect the change from 16 hypothetical injection wells to the three injection wells. Because the number of injection wells was reduced from those originally described in Appendix D, the conveyance pipeline was also modified from 28,000 linear feet to 17,300 linear feet. Additionally, the total volume of water delivered from Ramona MWD to the wells was updated to reflect the modeled outcomes of total volume injected over the 67-year simulation period (23,264 AF), though the cost per AF of imported water remained the same as described in Appendix D. Additionally, the pumping charges Ramona MWD typically passes along to customers was applied to this revised total volume of water, though per-AF pumping charges were also kept consistent with the rates used in Appendix D . Appendix D assumed a 3.0 million gallons per day (MGD) pretreatment facility would be required, and although the refined Strategy 3D reduced the total number of wells from 16 to three, the simulations still assumed maximum monthly flows, a 3.0 MGD pretreatment facility would still be required, and the associated costs were consistent with the cost used in Appendix D. Criterion 8 was based on overall ease of implementation. Implementation would require construction of a 12-inch diameter pipeline, including a creek crossing to reach the injection wells, drilling of the new wells, and construction of a pretreatment facility. Although no construction or discharge would occur in the creek bed like the other strategies considered, permitting is still expected to be fairly extensive for both construction and operation of this strategy, along with environmental analysis. Once constructed, operation would require trained staff to run the pretreatment facility and monitor and maintain the injection wells. Overall, implementing this strategy would be complex and would have the most challenging implementation of the four strategies.

Table 3-6: Strategy 3D Evaluation Results

Criterion	How Strategy 3D was evaluated	Result
Criterion 1: Reduction of Modeled Deficit in Groundwater Storage	Model output and direct comparison to baseline model simulation.	80 AF improvement in deficit in groundwater storage, as compared with Baseline
Criterion 2: Average Reduction of Depth to Water	Model output and direct comparison to baseline model simulation	10 feet bgs (higher water table, as compared with Baseline)
Criterion 3: Fewer Exceedances of Minimum Thresholds	Model output and direct comparison to baseline model simulation	476 fewer MT exceedances, as compared with Baseline
Criterion 4: Efficiency of Recharge Strategy	Model output and direct comparison to baseline model simulation and includes GoldSim (reservoir operations) model for Sutherland Reservoir	97% efficiency
Criterion 5: Average Reduction of Groundwater TDS Concentration	Model output and direct comparison to baseline model simulation and additional analysis by GSA	6.7 mg/L (6.7 mg/L improvement in TDS as compared with Baseline)
Criterion 6: Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs	Model output and direct comparison to baseline model simulation and an analysis of NCCAG (GDE) data	10 consecutive days (improvement as compared with Baseline)
Criterion 7: Costs and Benefits of Implementation and Maintenance	Cost per acre-foot of water recharged over the 67-year simulation period, based on the current value of imported water (the source of the untreated Ramona MWD water) and Class 5 cost estimates of project, including Ramona MWD pumping cost	$6,614 AF, assuming 23,264 AF recharged over 67 years and total project cost of $158,232,648. Does not include O&M of pretreatment facility
Criterion 8: Feasibility of Implementation and Maintenance	Overall ease of implementation considering permitting, environmental, schedule, and potential challenges to implementation	"Relatively difficult" ease of implementation due to the need for a new pretreatment facility, anticipated permitting, and similar challenges to implementation as Strategy 3A

3.3.4.2 Additional Factors to Consider for Strategy 3D

Additional factors not addressed in this Study would need to be considered if Strategy 3D were to be implemented in the Basin. As with Strategy 3A, Ramona MWD may require a minimum volume or frequency of deliveries from its raw water system for this strategy to be financially and operationally viable. It is possible that having idle recharge infrastructure for parts of a year or over multiple years would not be desirable or would result in additional maintenance requirements. Ramona MWD also operates a treated (potable) water system in the same vicinity as its raw water system and this system could also be used as a source of recharge water. For recharge via injection wells, use of a treated potable source eliminates the need to build a filtration and disinfection treatment plant prior to injection. The cost of treated water is higher than raw water, but as Ramona MWD receives a portion of its treated SDCWA supply from the Carlsbad Desalination Plant, the TDS is lower than raw water, which may be beneficial for recharge in the Basin. The GSA should consider whether the higher cost of treated water compared to raw water would be more economical than using raw water because it would allow the GSA to avoid the costs of constructing and operating a treatment facility necessary if raw water were used. As part of the next steps in the planning process, additional projection simulations should be completed if the GSA were to choose to further evaluate Strategy 3D with other possible operational considerations.

TDS was the only groundwater quality constituent for which data were readily available for the untreated water system of Ramona MWD when this Study was conducted. Groundwater quality degradation calculations, beyond those completed for TDS in Study, should be considered for additional constituents of interest if the GSA were to choose to further evaluate Strategy 3D. These calculations would be important to assess the potential for recharge strategies to degrade groundwater quality for a wider range of constituents. The projection simulations did not consider whether permitting requirements would constrain operations in a way that would affect source water availability from the untreated water system of Ramona MWD. It would be important to assess permitting requirements that might affect operational decisions if the GSA were to choose to further evaluate Strategy 3D. Additionally, the projection simulations did not consider whether deliveries to Santa Ysabel Creek from the untreated water system of Ramona MWD could affect biological function due to the presence of flows during times when the creek would naturally be dry. Ecological factors that could affect operational decisions for Strategy 3D would need to be identified and incorporated into the decision process.

Water treatment activities necessary for use of injection wells could potentially affect the rate at which water could be delivered to the injection wells, while other operational considerations could potentially cause downtime of the injection wells and reduce periods of operation and volumes of water that could be injected into the Basin. Such considerations could be incorporated into future projection simulations if the GSA were to choose to further evaluate Strategy 3D.

As mentioned in above in Section 3.3.4, the projection simulation was set up with an operational rule so that assigned injection rates for the injection wells could be automatically reduced during the simulation by the modeling code to avoid having water levels inside the injection wells rise above land surface. However, the projection simulations did not consider whether the localized mounding of the water table during injection could impact agricultural operations. Potential localized effects of injection on agricultural production should be assessed if the GSA were to choose to further evaluate Strategy 3D.

3.4 Summary and Ranking

Appendix A provides guidance for how the potential recharge strategies were originally envisioned to be evaluated. As noted above, the evaluation criteria were modified from Appendix A as more information became available during development of the strategies and the model updates. Similarly, the original approach to ranking the strategies based on the evaluation criteria was adjusted to reflect what was learned during the development process. When applied as originally described in Appendix A, the evaluation criteria did not provide a way to consider the benefits of a strategy against the implementation requirements for the strategy. The criteria favored total volume of water recharged heavily enough that Evaluation Criteria 7 and 8 had no effect on overall rankings. As a result, the evaluation process was refined to include a two-step process.

Under the two-step process, criteria related to recharge volume and modeled outputs (Criteria 1 through 6) were evaluated and ranked comparatively first. Next, cost and ease of implementation (Criteria 7 and 8) were evaluated and ranked. The two-step process allows for a comparison of strategies regarding volume of water that could theoretically be recharged to the aquifer, representing benefits to the Basin, and a separate look at the overall cost comparison and relative ease of implementing, representing implementation considerations. Although this is a change from the evaluation process as originally envisioned during development of Appendix A, which proposed a single evaluation across all eight criteria, the two-step process allows the GSA to better understand the nuances of what implementing each strategy could mean for the Basin and for the GSA as the implementation agency.

Using results of the evaluation presented in the previous sections, the strategies were ranked 1 through 4 for each of the criteria, with 1 representing the greatest benefit or most favorable result for that criterion, and 4 representing the least benefit or least favorable results for that criterion. Because a straight ranking system does not account for local priorities for the Basin, weighting was applied to each recharge strategy's score for each criterion. This weighting reflects the relative importance of the criterion and was established through discussion with the GSA and stakeholders during workshops.

The criteria weights were initially established in Appendix A and were developed using a matched-pairs-weighting method. As noted above, Appendix A did not include the two-step evaluation process used in this Study. As such, the weighting from Appendix A was normalized for use in this Study such that the weighting for Criteria 1 through 6 was adjusted proportionally to total 100%, and the weighting for Criteria 7 and 8 were adjusted proportionally to total 100%. The goal of the criteria weighting is to accurately reflect the priorities of the GSA, the adopted GSP, and Basin stakeholders. Based on the outcomes of the GSA and stakeholder exercises, for Criteria 1 through 6, the proposed weighting valued the top two criterion the same (25.7% each for Criterion 3 MT Exceedances and Criterion 4 Recharge Efficiency); valued the bottom three criterion the same (10% each, Criterion 2 Depth to Groundwater, Criterion 5 Reduction of TDS, and Criterion 6 Days Below GDE Rooting Depth); and distributed the other in the middle (18.6%, Criterion 1 Reduction of Modeled Groundwater Storage Deficit). For cost and implementation criteria in the second step ranking, they are weighted at 40% and 60%, for Criterion 7 Cost and Criterion 8 Ease of Implementation, respectively.

A summary of Evaluation Criteria 1 through 6, which relates to benefits to the Basin for all four strategies is provided in **Table 3-7**. From there, a ranking was assigned, which are shown in **Table 3-8**, and then the weighting was applied to each evaluation criteria, to generate a weighted score for each strategy. For Evaluation Criteria 1 through 6, the weighting reflects the high priority associated with avoiding undesirable results in the Basin, with preference given to projects that recharge the Basin efficiently, reduce exceedances of minimum thresholds, and improve groundwater storage. As shown in **Table 3-8**, Strategy 3D ranked the most favorable when considering recharge volumes and model outputs. This is due to the high volume of water that would be recharged under this strategy if the strategies were operated as modeled, coupled with the reliability of Ramona MWD water during times of drought or extended drought (when source water from Strategies 1B and 2A would be limited). Similarly, Strategy 3A ranked second most favorable when considering benefits to the Basin due to the relatively high volume of water that could be recharged and reliability of source water during drought. Strategy 2A ranked third most favorable considering the recharge volume and model output criteria because it provided less water than Strategies 3D and 3A, and was less reliable during extended drought periods. Strategy 1B provided the least volume of water in the model and was the least reliable source of water because it depends on stormwater that already enters the Basin and would only be implemented under very specific streamflow conditions in Santa Ysabel Creek. Therefore, Strategy 1B ranked least favorable when considering benefits to the Basin.

Table 3-7: Summary of Evaluation Criteria Results Related to Recharge Volume and Modeled Output for All Recharge Strategies

Recharge Strategy	Criterion 1 Reduction of Modeled Deficit in Groundwater Storage (AF)	Criterion 2 Average Reduction of Depth to Water (feet bgs)	Criterion 3 Fewer Exceedances of Minimum Thresholds (count)	Criterion 4 Efficiency of Recharge Strategy (percent)	Criterion 5 Average Reduction of Groundwater TDS Concentration (mg/L)	Criterion 6 Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs
1B–Enhance Streamflow Infiltration with In-stream Modifications	-1	0	4	110	-0.3	0
2A–Augment Streamflow with Sutherland Controlled Releases	0	1	41	84	3.1	1
3A–Augment Streamflow with Ramona MWD Deliveries	17	4	208	93	3.1	2
3D–Injection Wells with Ramona MWD Deliveries	80	10	476	97	6.7	10
For Criteria 1 through 6, larger positive values indicate larger benefits from implementing the recharge strategy.						

Table 3-8: Recharge Strategy Rank Related to Recharge Volume and Modeled Output

Recharge Strategy	Criterion 1 Reduction of Modeled Deficit in Groundwater 18.6%	Criterion 2 Average Reduction of Depth to Water 10%	Criterion 3 Fewer Exceedances of MT 25.7%	Criterion 4 Efficiency of Recharge Strategy 25.7%	Criterion 5 Average Reduction of Groundwater TDS Concentration 10%	Criterion 6 Fewer Consecutive Days Groundwater Levels are below 30 ft bgs 10%	Total Score (raw)	Weighted Total Score
1B–Enhance Streamflow Infiltration with In-stream Modifications	4	4	4	1	4	4	21	3.23
2A–Augment Streamflow with Sutherland Controlled Releases	3	3	3	4	2	3	18	3.16
3A–Augment Streamflow with Ramona MWD Deliveries	2	2	2	3	2	2	13	2.26
3D–Injection Wells with Ramona MWD Deliveries	1	1	1	2	1	1	7	1.26

A rank of 1 indicates the most favorable recharge strategy, whereas a rank of 4 indicates the least favorable recharge strategy for a given criterion. Percentages listed in the table header are weighting factors that have been normalized to sum to 100%.

Following the same process as Criteria 1 through 6, the strategies were scored for Criteria 7 and 8 based on the evaluation results described in Section 0, above. The weighting for Criteria 7 and 8 was then applied to generate a weighted score for each strategy, shown in **Table 3-9**.

When considering cost and implementation requirements (Criteria 7 and 8) shown in **Table 3-9**, the ranking is different than when considering only Criteria 1 through 6. For Criteria 7 and 8, Strategy 2A has the most favorable rank. It would provide the lowest cost per AF and would be the easiest to implement because it would not require construction of additional infrastructure. Because it would be the easiest to implement with no additional infrastructure, it would also be considered the most flexible from an adaptive management perspective. Strategy 3A ranks as the next most favorable when considering cost and implementation. Although there would be some additional challenges associated with implementing Strategy 3A as compared to Strategies 2A and 1B, due to permitting and agreements needed with Ramona MWD, these challenges are offset by the cost per AF of this strategy. Strategy 1B is ranked third most favorable in relation to Evaluation Criteria 7 and 8 because it has a high cost per AF (due to the low overall volume of water), and medium-difficult level of implementation associated with construction in the streambed and active management of the dam during operation. Although Strategy 3D provides a much higher overall volume of water compared to the other strategies, it also has a high capital cost. It also would be the most complex of the strategies to implement, requiring agreements with Ramona MWD, additional regulatory considerations for injection, and design and operation of a pretreatment facility. These complexities and the cost per AF result in the least favorable ranking when considering the cost and implementation criteria.

Table 3-9: Summary and Ranking of Evaluation Criteria Results Related to Cost and Implementation for All Recharge Strategies

Recharge Strategy	Summary of Cost and Implementation Criteria		Scoring and Ranking of Cost and Implementation Criteria			
	Criterion 7: Costs of Implementation and Maintenance ($/AF)	Criterion 8: Feasibility of Implementation and Maintenance	Criterion 7 40%	Criterion 8 60%	Total Score (raw)	Weighted Total Score
1B–Enhance Streamflow Infiltration with In-stream Modifications	24,975	Medium	4	2	6	2.8
2A–Augment Streamflow with Sutherland Controlled Releases	2,139	Easy-Medium	1	1	2	1
3A–Augment Streamflow with Ramona MWD Deliveries	4,500	Medium-Difficult	2	3	5	2.6
3D–Injection Wells with Ramona MWD Deliveries	6,614	Difficult	3	4	7	3.6
A rank of 1 indicates the most favorable recharge strategy, whereas a rank of 4 indicates the least favorable recharge strategy for a given criterion.						

Although the GSA may choose to consider benefits (Criteria 1 through 6) separate from cost and implementation (Criteria 7 and 8), it may be helpful to consider the combined results of the two-step process as well. The weighted scores from Step 1 were added to the weighted scores from Step 2 to generate a combined weighted score, shown in **Table 3-10**. The combined weighted score shows that Strategy 2A is the most favorable with a score of 4.2, followed by Strategy 3A and Strategy 3D, which tied with a score of 4.9. Strategy 1B ranked least favorable, with a score of 6.0 due to its low volume of water recharged and high cost per AF. Although there is a difference between the scores for Strategy 2A, Strategy 3A and Strategy 3D, these scores are still close, reflecting the potential benefits of each of the strategies. This approach provided a reasonable balance between the two steps of the scoring and ranking process.

Table 3-10: Overall Ranking of Strategies

Recharge Strategy	Step 1: Benefit Criteria (1-6) Weighted Score	Step 2: Cost and Implementation Criteria (7 & 8) Weighted Score	Overall Ranking: Combined Weighted Score*	Overall Ranking: Final Rank
1B–Enhance Streamflow Infiltration with In-stream Modifications	3.23	2.8	6.0	4
2A–Augment Streamflow with Sutherland Controlled Releases	3.16	1	4.2	1
3A–Augment Streamflow with Ramona MWD Deliveries	2.26	2.6	4.9	2 (tie)
3D–Injection Wells with Ramona MWD Deliveries	1.26	3.6	4.9	2 (tie)

*A lower weighted score indicates a more favorable strategy, while a higher weighted score indicates a less favorable strategy.

4. CONCLUSION AND NEXT STEPS

The results of the Initial Surface Water Recharge Evaluation provided in this report provide a foundation for understanding what may be involved with individually implementing four different recharge strategies and how they might perform under specific assumed hydrologic and operational conditions. The four recharge strategies evaluated include the following:

- Strategy 1B–Enhance Streamflow Infiltration with In-stream Modifications
- Strategy 2A–Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases
- Strategy 3A–Augment Santa Ysabel Creek Streamflow with Ramona MWD Deliveries
- Strategy 3D–Injection Wells with Ramona MWD Deliveries

As described in Section 3.3.4.2, the strategies were scored and ranked in accordance with the eight evaluation criteria, using a two-step process with criteria addressing modeled flow volume and water levels (Criteria 1 through 6) and criteria addressing cost and implementation (Criteria 7 and 8). When considering the weighted criteria results, Strategy 2A is the most favorable, followed by Strategy 3A and Strategy 3D, with Strategy 1B ranking as the least favorable option. The following list summarizes some of the factors that affected each strategy's score:

- Strategy 2A This strategy ranked highest for Criteria 7 and 8 because of its low cost and ease of implementation. This strategy is also the most favorable because it would require no infrastructure and would have the most flexibility to implement from an adaptive management perspective. As modeled, it is expected to provide fewer benefits to the Basin compared to Strategies 3A and 3D due to limits on the overall availability of water for recharge, and lack of available water for recharge during dry periods, ranking third when considering Criteria 1 through 6.

- Strategy 3A is expected to provide more benefits than Strategy 2A, as modeled, and ranked second when considering Criteria 1 through 6. The relatively high volume of source water from Ramona MWD helped offset the overall costs of the project. Having the second lowest cost per AF helped to balance having the second most complex implementation considerations of the strategies. This resulted in Strategy 3A being ranked second when considering the cost and implementation (Criteria 7 and 8).

- Strategy 3D indicated a higher overall benefit across the Basin compared to the other strategies, leading it to be ranked the most favorable for Criteria 1 through 6. Additionally, its high overall recharge volume helped to reduce the cost per AF, though per-AF costs are still higher than Strategies 2A and 3A. The cost and the challenges anticipated with implementation and operation resulted in it ranking as the least favorable for cost and implementation, and third most favorable in the overall ranking.

- Strategy 1B is ranked the least favorable overall because of the low recharge benefits, ranking last for Criteria 1 through 6. The high cost per AF that resulted from the low recharge volume caused it to be ranked third for cost and implementation.

The overall rankings and key attributes for each strategy are summarized in **Table 4-1**.

Table 4-1: Ranking of the Four Recharge Strategies Evaluated

Recharge Strategy	Attributes of Recharge Strategy
Strategy 2A–Augment Streamflow with Sutherland Controlled Releases	• No. 1 ranking (most favorable) • Easiest and lowest cost to implement • Recharge volumes limited by infiltration capacity in Santa Ysabel Creek and availability of water in Sutherland Reservoir in years where recharge would be triggered, as modeled
Strategy 3A–Augment Streamflow with Ramona MWD Deliveries	• No. 2 ranking (second most favorable, tied with Strategy 3D) • Relatively high volume of water available during most modeled years when recharge activities were triggered in the model • Recharge volume limited by infiltration capacity in Santa Ysabel Creek • Medium-high cost to construct and operate, but costs offset by flow volume that could be recharged • Recharge infrastructure could be idle for part of the year or span multiple years when managed recharge would not occur
Strategy 3D–Injection Wells with Ramona MWD Deliveries	• No. 2 ranking (second most favorable, tied with Strategy 3A) • High recharge volume, available during all modeled years when recharge activities were triggered in the model • High cost to construct and operate, but costs offset by flow volume that could be recharged • Most complex strategy to implement of the four recharge strategies • Recharge infrastructure could be idle for part of the year or span multiple years when managed recharge would not occur
Strategy 1B–Enhance Streamflow Infiltration with In-stream Modifications	• No. 4 ranking (least favorable) • Lowest recharge volume with limited benefit to the Basin • Relatively low cost to construct after permits are obtained compared to Strategies 3A and 3D, but low recharge volume resulted in high cost per-AF

The simulation results used to inform the ranking process are based on several factors and assumptions that were considered reasonable when this report was developed. Actual future conditions could be different from those projected or implied by the projections presented herein. Therefore, important planning decisions that use information in this report must be made with an understanding of uncertainty associated with future climate conditions, future policies and water agreements, and groundwater systems in general. These uncertainties may include changes to site conditions, availability of new information and data, and improved knowledge of the Basin's surface and subsurface conditions. Decisions around the strategies and potential implementation should also consider other relevant information, such as local and regional drivers, operational challenges and opportunities, and professional judgment. Changes to the conditions that trigger recharge activities or how the strategies operate could also result in rankings that are different than those presented in this study, and are recommended to be considered as part of the next phases of the planning process.

4.1 Next Steps

Implementing any one of these recharge strategies would involve a multistep process that requires careful planning, stakeholder engagement, environmental considerations, regulatory compliance, engineering standards, and technical expertise. Each step would help to move a strategy forward in the planning process and evaluation of feasibility. The following subsections are intended to provide a general framework for steps that would likely be needed to implement the four recharge strategies, should the GSA choose any combination of them as part of adaptive management to avoid undesirable results, as defined in the GSP (City and County, 2021). Specific requirements, regulations, and considerations could vary depending on the location, project scope, environmental conditions, and other factors. Therefore, the order of steps and activities could be different than what is presented in the roadmaps in the following subsections. Regardless of the strategy or combination of strategies that may be considered for further development or future implementation, additional engagement would be needed with experts in planning, hydrology, hydrogeology, engineering, operations, public outreach, regulatory compliance, and other relevant fields to ensure a successful project implementation. If during the evaluation process, the overall feasibility of a strategy is determined by the GSA to be unfavorable, activities related to the implementation of the strategy or strategies would stop and the strategy could be abandoned or altered.

4.1.1 Strategy 2A: Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases

The goal of Strategy 2A is to augment streamflow in Santa Ysabel Creek with controlled releases from Sutherland Reservoir. The frequency and volume infiltration would rely on the hydrologic conditions of the Santa Ysabel Creek and Sutherland Reservoir water availability (Appendix E). Initial estimates of potential Sutherland Reservoir releases were developed based on the following:

- Estimation of maximum controlled releases that Santa Ysabel Creek could infiltrate in the eastern portion of the Basin through time from Sutherland Reservoir and
- Estimation of how much of these maximum controlled releases would be available at the reservoir throughout the simulation period.

A general roadmap in the form of a flow chart (**Figure 4-1**) is provided to present steps that would need to be considered should Strategy 2A continue to be explored for future implementation. An associated table that provides additional detail on the elements shown in the flow chart is available in **Appendix G**.

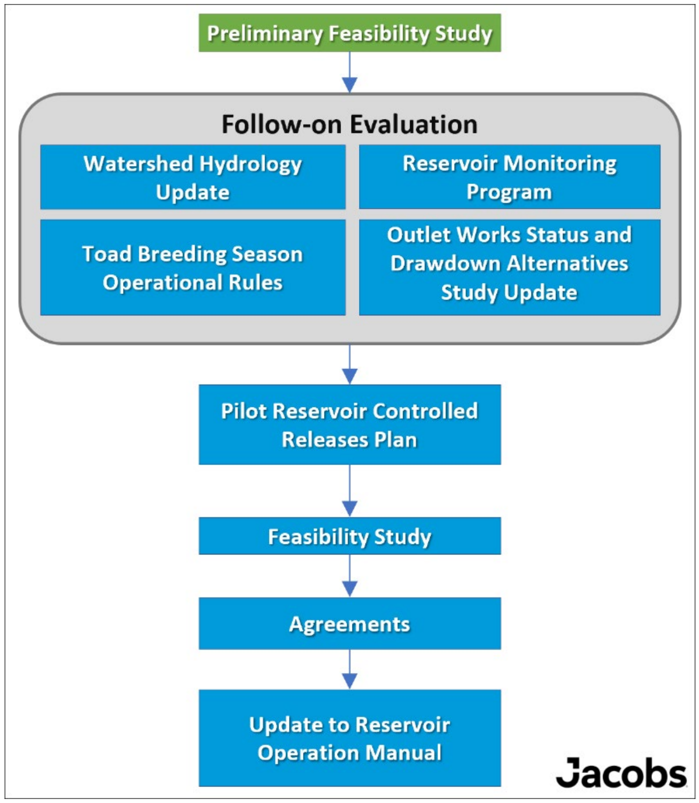


Figure 4-1: Implementation Roadmap for Strategy 2A

4.1.2 Strategy 3A: Augment Santa Ysabel Creek Streamflow with Ramona MWD Deliveries

The goal of Strategy 3A is to augment streamflow in Santa Ysabel Creek with deliveries from Ramona MWD's untreated water system. This strategy seeks to enhance infiltration in Santa Ysabel Creek and would introduce a "new" source of water to the Basin. The frequency and volume infiltration would rely on the hydrologic conditions of the Santa Ysabel Creek and water availability from Ramona MWD (Appendix E).

A general roadmap in the form of a flow chart (**Figure 4-2**) is provided to present steps that would need to be considered after this study if the GSA were to choose to further assess the feasibility of implementing Strategy 3A. An associated table that provides additional detail on the elements shown in the flow chart is available in **Appendix G**.

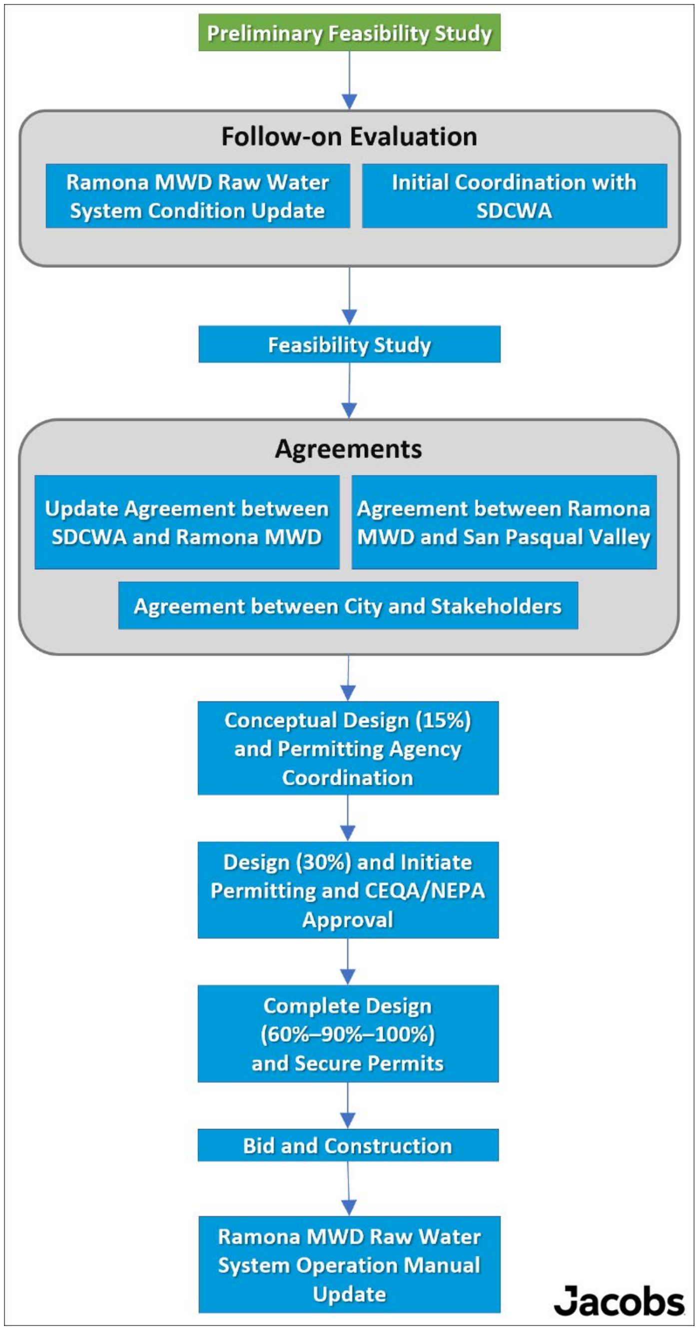


Figure 4-2: Implementation Roadmap for Strategy 3A

4.1.3 Strategy 3D: Injection Wells with Ramona MWD Deliveries

The goal of Strategy 3D is to enhance groundwater recharge by injecting water from Ramona MWD into the alluvial aquifer in the eastern portion of the Basin via injection wells (Appendix E). Water from the Robb

Zone of Ramona MWD's untreated water system would be conveyed through a new pipeline to a new water treatment facility and then through a new pipeline to each injection well.

A general roadmap in the form of a flow chart (**Figure 4-3**) is provided to present steps that would need to be considered after this study if the GSA were to choose to further assess the feasibility of implementing Strategy 3D. An associated table that provides additional detail on the elements shown in the flow chart is available in **Appendix G**.

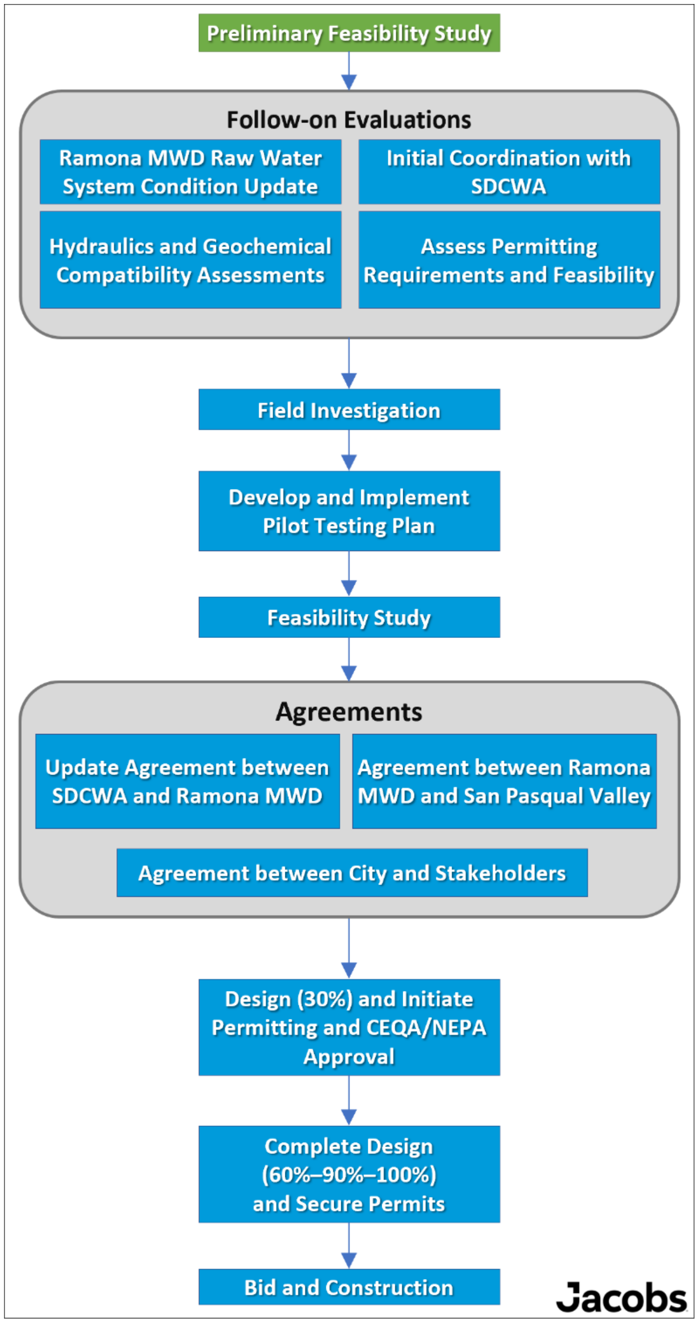


Figure 4-3: Implementation Roadmap for Strategy 3D

4.1.4 Strategy 1B: Enhance Streamflow Infiltration with In-stream Modifications

The goal of Strategy 1B is to enhance streambed infiltration along Santa Ysabel Creek using a permanent, channel-spanning, inflatable rubber dam. Strategy 1B is the only recharge strategy considered in this evaluation that relies on stormwater in the form of streamflow in Santa Ysabel Creek. The rubber dam would be inflated during selected periods to detain stormwater behind the dam to provide the opportunity for enhanced infiltration. The rubber dam would be deflated during certain conditions. Examples of such conditions include, but are not limited to, the following:

- During high-streamflow periods to avoid uncontrolled overtopping of the dam, which could result in erosion or damage to the structure,
- To allow for maintenance of the infiltration basin upstream from the dam, such as debris removal, soil ripping, and tilling,
- To allow surface water to flow past the dam for habitat flow requirements, and/or
- When Santa Ysabel Creek is dry

A general roadmap in the form of a flow chart (**Figure 4-4**) is provided to present steps that would need to be considered should Strategy 1B continue to be explored for future implementation. An associated table that provides additional detail on the elements shown in the flow chart is available in **Appendix G**.

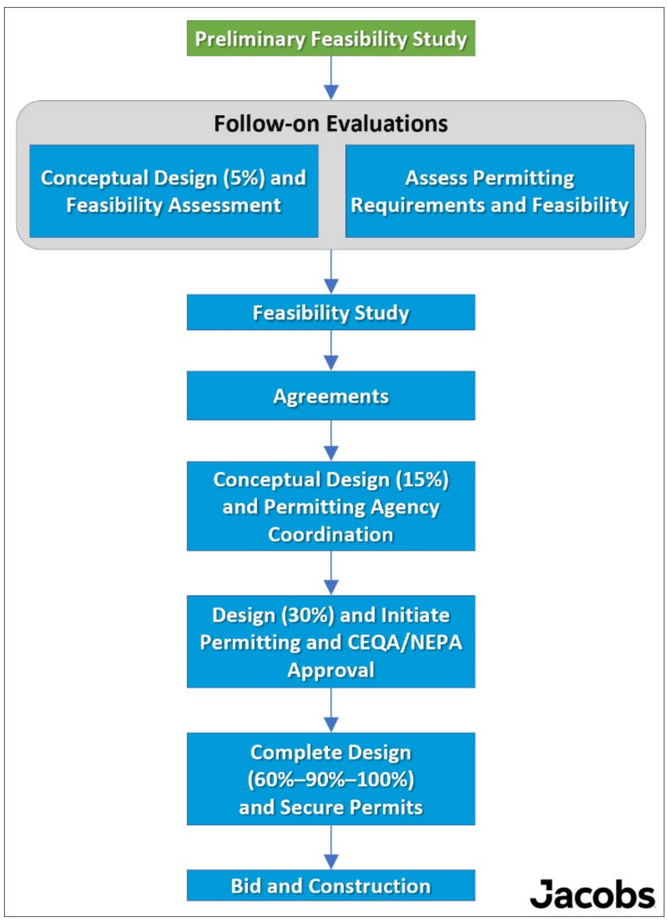


Figure 4-4: Implementation Roadmap for Strategy 1B

4.1.5 Closing Remarks

Implementing any one of these recharge strategies in California would involve a multistep process that requires careful planning, stakeholder engagement, environmental considerations, regulatory compliance, engineering standards, technical expertise, as well as integration with the adopted GSP and implementation strategy of the GSP. Information presented in this Preliminary Feasibility Study is based on several factors and assumptions that were considered reasonable when this report was developed. Actual future conditions could be different from those projected or implied by the projections presented herein. Therefore, important planning decisions that use information in this report must be made with an understanding of uncertainty associated with future climate conditions, future policies and water agreements, and groundwater systems in general. These decisions should also consider other relevant information, such as local and regional drivers, operational challenges and opportunities, professional judgment, and the status and plans presented in the adopted GSP. Implementation of one or a combination of any of the presented recharge strategies is intended to assist the GSA in maintaining Basin sustainability. Potential future implementation of any of the strategies presented in this Preliminary Feasibility Study should consider data collected and analysis conducted to assess the Basin's hydrologic condition and reevaluate the strategies utilizing this new data and information. Furthermore, a recharge project is just one of several projects and management actions identified in the GSP that the GSA could implement to maintain Basin sustainability. These recharge strategies should be considered in the context of other management actions that could be implemented in the Basin to arrive at a reasonable, feasible, and cost-effective approach to Basin sustainability.

5. REFERENCES

City of San Diego (City) and County of San Diego (County). 2021. *Final San Pasqual Valley Groundwater Basin Groundwater Sustainability Plan.* Prepared by Woodard & Curran. September.

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Ramona Municipal Water District (Ramona MWD). 2022. Availability of Untreated Water from Robb and Snow Zones monthly assessment. Spreadsheet: *RMWD Historical Untreated Sales.xlsx.* Water Operations Department. Systems Divisions. Provided on December 16, 2022.

APPENDIX A: TM 1: EVALUATION CRITERIA

TECHNICAL MEMORANDUM

TO: San Pasqual Valley Groundwater Sustainability Agency

PREPARED BY: Amber Ritchie, PG, CHG, Micah Eggleton, and Reza Namvar, PE

REVIEWED BY: Rosalyn Prickett, AICP, Sally Johnson, Nate Brown PG, CHG, and Paula Silva, PE

DATE: September 28, 2022

RE: Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 1: Development of Evaluation Criteria

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ACRONYMS & ABBREVIATIONS

AFY	Acre Feet per Year	MS4	Municipal Separate Storm Sewer System
CCGS	Cumulative Change in Groundwater Storage	NO3-N	Nitrate as Nitrogen
CVSW	Cumulative Volume of Surface Water	O&M	Operations and Maintenance
DTW	Depth to Water	PMA	Project and Management Action
DWR	Department of Water Resources	RMW	Representative Monitoring Well
ET	Evapotranspiration	SMC	Sustainable Management Criteria
GDE	Groundwater Dependent Ecosystem	SPV	San Pasqual Valley
GSA	Groundwater Sustainability Agency	SPV GSP Model	SPV GSP Integrated Groundwater/Surface Water Flow Model
GSP	Groundwater Sustainability Plan	TDS	Total Dissolved Solids
GW	Groundwater	USGS	United States Geological Survey
MT	Minimum Threshold	WY	Water Year
MWD	Municipal Water District		

1. INTRODUCTION

The San Pasqual Valley Groundwater Sustainability Agency (GSA) – comprised of the City of San Diego (City) and the County of San Diego (County) – approved and submitted to the California Department of Water Resources (DWR) the San Pasqual Valley Groundwater Sustainability Plan (GSP) in January 2022 (City of San Diego and County of San Diego, 2021). The GSP provides guidance and quantifiable metrics to ensure the continued sustainable management of groundwater resources within the San Pasqual Valley Groundwater Basin (Basin) over the 20-year implementation horizon. To accomplish this, the GSP includes a hydrogeological conceptual model, monitoring requirements, sustainability criteria, and several projects and management actions. The projects and management actions (PMAs) included in the GSP are intended to create opportunities for sustainable groundwater management in the Basin that respond to changing conditions and help prevent undesirable results. The Basin is currently sustainably managed, and no PMAs are needed to achieve sustainability. However, PMAs can improve understanding of the groundwater system to maintain sustainability into the future.

This technical memorandum is the first of several that focuses on PMA No. 7, which aims to complete an Initial Surface Water Recharge Evaluation. The GSA will use the Initial Surface Water Recharge Evaluation to determine the benefits to the Basin and feasibility of implementation of potential recharge projects. A preliminary assessment (see Appendix N of the San Pasqual Valley GSP) of Sutherland Reservoir as a surface water supply was conducted as part of the scoping for PMA No. 7. Because the City owns and operates the Sutherland Reservoir located upgradient from San Pasqual Valley, the City has the authority to explore surface water recharge options that may involve Sutherland Reservoir releases. As such, the City is responsible for public outreach, costs, and coordination with necessary entities related to PMA No. 7.

Ultimately, completing this Initial Surface Water Recharge Evaluation is estimated to take two years, and the resulting information will be provided in a Preliminary Feasibility Study.

The Preliminary Feasibility Study will summarize the initial evaluation of surface water recharge opportunities in San Pasqual Valley, and will include the following sections:

- Evaluation Criteria and Ranking Process (Task 1)
- Streambed Investigation (Task 2)
- Water Sources for Recharge (Task 3)
- Potential Recharge Strategies (Task 4)
- Modeling Approach and Results (Task 5)
- Potential Benefits to Groundwater Dependent Ecosystems (GDEs) (Task 6)

The purpose of this technical memorandum for Task 1 is to establish the evaluation criteria by which to determine the best surface water recharge strategy option(s) for the Basin. The following criteria will be used to rank the recharge strategies:

- Criterion 1: Reduction of Modeled Deficit in Cumulative Groundwater Storage
- Criterion 2: Maintenance of Shallower Groundwater Levels in the Basin
- Criterion 3: Reduction of Projected Groundwater Levels Below Minimum Thresholds
- Criterion 4: Efficiency of Recharge (in relation to losses through evapotranspiration [ET] and outflows)
- Criterion 5: Improvements in Groundwater Quality
- Criterion 6: Benefits to GDEs
- Criterion 7: Costs and Monetary Benefits of Implementation and Maintenance
- Criterion 8: Feasibility of Implementation and Maintenance

The following subsections provide details of the proposed conceptual recharge strategies, as well as additional context and descriptions for each evaluation criterion and the metric(s) used to rank and score the strategies. Baseline and proposed recharge strategies will be developed to produce the data required to estimate metrics for each strategy. The recharge strategies will be compared against the baseline to rank and ultimately score them.

Note that the scoring rubric for each criterion will be determined after the simulations have been completed, because the criteria must be appropriate for the scale of differentiation between the strategy results. For example, relatively minor differences (e.g., a few acre-feet per year [AFY]) in cumulative change in groundwater storage (CCGS) across all four strategies would lend itself to forced rank scoring, which ranks the strategies in numerical order from 1 to 4 based on the metric (e.g., 1 = smallest, 4 = largest). Greater differences (e.g., hundreds to thousands of AFY) between the strategies may be better scored according to a category ranking approach, which would rank the strategies on a defined scale (e.g., 1 for <500 AFY, 2 for 500 to 1,000 AFY, etc.). As described in Section 5, a criterion weighting exercise will be completed with the Core Team to establish the relative importance of each criterion.

2. RECHARGE STRATEGY CONCEPTS

The Initial Surface Water Recharge Evaluation will consider multiple strategies. Task 2 (Streambed Investigation), Task 3 (Water Sources for Recharge), and Task 4 (Potential Recharge Strategies) identified in the Preliminary Feasibility Study will help to define the recharge strategies necessary for further modeling and evaluation. Through the work completed on these tasks, each strategy will have a project description that includes the annual volume of additional recharge (which may be calculated as a long-term average), mapped location of anticipated groundwater recharge, and a description of the recharge facility. The annual volume of additional recharge from each strategy will be computed by the version of the San Pasqual Valley Groundwater Sustainability Plan Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) that will be updated with information from Task 2 (Streambed Investigation) of the Preliminary Feasibility Study.

The following are examples of strategies being considered, but the evaluation will not be necessarily limited to this list:

- Releases from Sutherland Reservoir
- Stormwater detention in small drainages
- Check dams in selected tributary creeks
- Stream channel modifications to increase infiltration capacity
- Additional strategies not yet identified

3. EVALUATION CRITERIA

The overall goal of the PMAs identified in the San Pasqual Valley GSP is to avoid undesirable results, which are defined in Section 8 of the GSP. Each recharge strategy will be modeled and evaluated based on the eight criteria described in **Table 1** and the following subsections (Sections 3.1 through 3.8). As a first step, a baseline simulation will be established using the updated SPV GSP Model (following integration of new streambed information collected in Task 2). This baseline strategy will provide modeled groundwater elevations, depths to water, and water budget data. Recharge strategy metrics will be computed and compared against these baseline metrics. Thus, the only difference between the input files of the baseline simulation and each recharge strategy simulation will be the intended change in parameters and boundary conditions related to the recharge strategy. All other assumptions regarding water year (WY) type and hydrology will remain unchanged. Conducting the evaluation in this manner will help isolate and quantify the modeled effect of implementing the recharge strategy and allow one to assess the evaluation criteria.

The SPV GSP Model in its current form has monthly stress periods, but the updated version of the SPV GSP Model for use with this recharge evaluation will include selected subperiods with daily stress periods to evaluate the recharge strategy. Because the updated SPV GSP Model will include additional stress periods, model runtimes of several hours to days for each simulation is a possibility. In an effort to efficiently perform the modeling to support the evaluation of the recharge strategies, the 15-year historical simulation period of WYs 2005 through 2019 will be used. This period contains a variety of WY types and will be adequate for developing the modeling workflow and conducting the initial analyses.

After the workflow process is developed and the initial results are reviewed and considered reasonable, it is anticipated the model will be run using the higher-priority recharge strategies that could be adequately assessed using monthly stress periods with up to a 67-year simulation period including WYs 2005 through 2071. This simulation period includes the historical and projected periods with climate change already incorporated into the projection portion of the simulation period, as described in the GSP. **Figure 1**illustrates the water budget reference volume for water budget values presented in the GSP. This reference volume includes the alluvium and residuum within the DWR-defined Basin. The water budgets prepared for the GSP focused on the Basin as a whole, per DWR requirements. However, because the eastern half of the Basin is where most of the groundwater recharge from streams occurs, a subarea water budget will also be prepared for the eastern portion of the Basin for the recharge evaluations.

For strategies that extend beyond the SPV GSP Model domain, CWASim may also be utilized to estimate some of the proposed metrics. CWASim is a GoldSim model originally developed for the San Diego County Water Authority by CH2M (now Jacobs) in support of the 2013 Regional Facilities Optimization and Master Plan Update. The CWASim model is a systems model that contains regional reservoirs, along with natural and constructed water conveyance facilities.

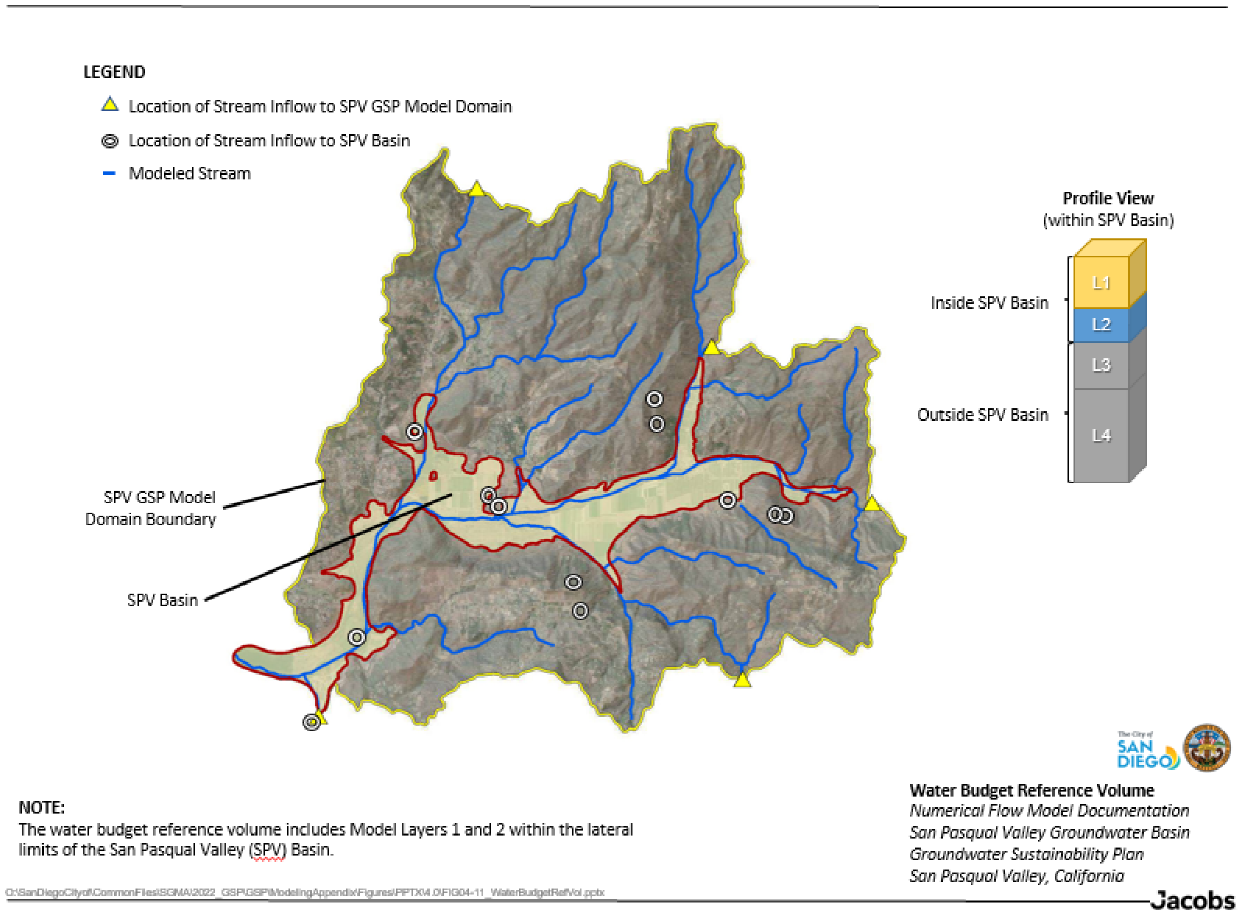

Figure 1: Water Budget Reference Volume

The western and eastern portions of the Basin have distinctly different depth to water (DTW) and GDE characteristics (refer to Section 8 of the GSP). For water budgeting purposes, this Surface Water Recharge Evaluation will consider that area (western edge of the confluence of Santa Ysabel Creek and Santa Maria Creek) as the subarea division (see **Figure 2**). Computing water budgets by subarea is appropriate because stream recharge generally occurs in the eastern half of the Basin and groundwater levels at domestic wells in the eastern half of the Basin are critical to protect during GSP implementation. Setting boundaries on the water budget reference volume allows a better understanding of each strategy's benefit without inadvertently "washing out" the modeled benefits from having too large of a reference volume.

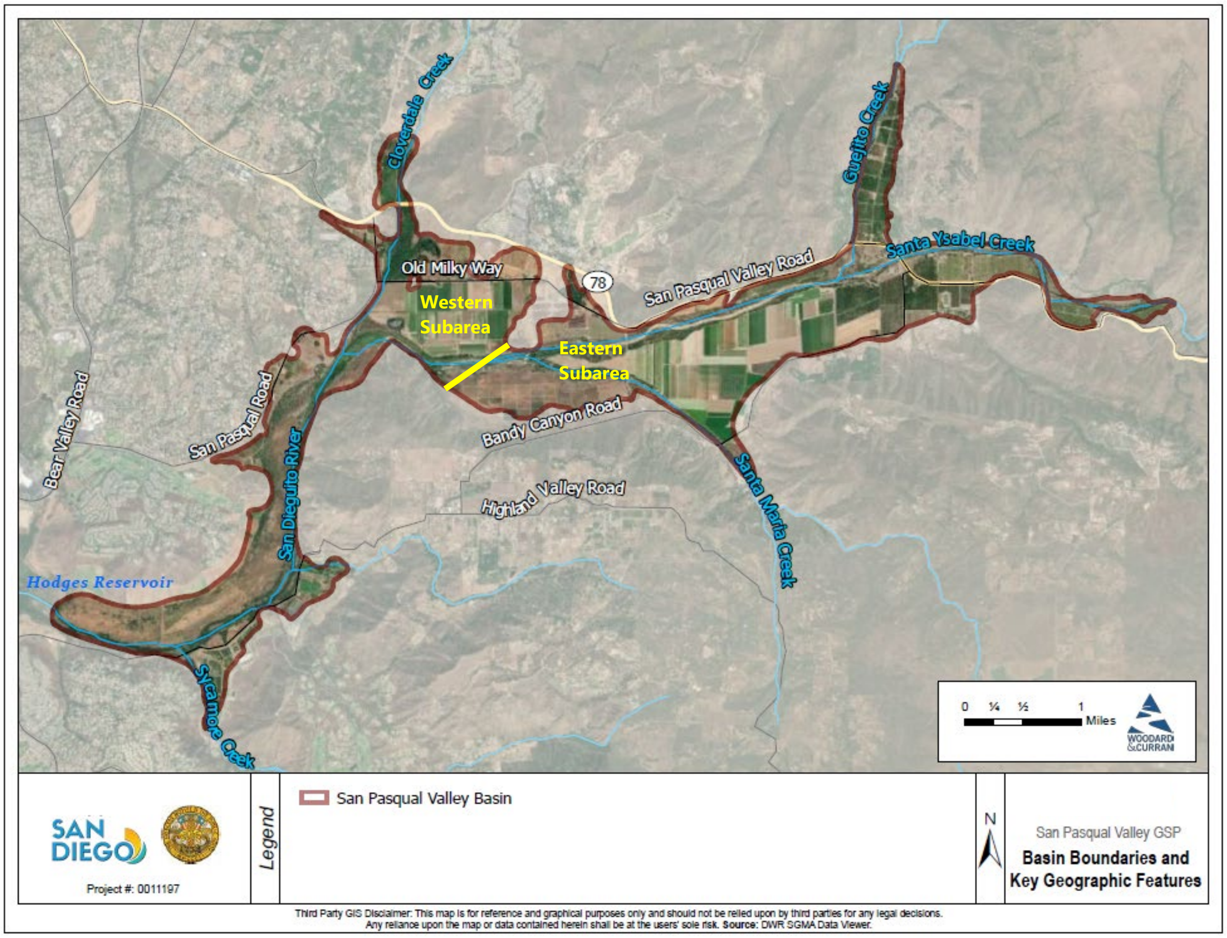

Figure 2: San Pasqual Valley Basin – Subareas

3.1 Criterion 1: Reduction of the Modeled Deficit in Cumulative Groundwater Storage

Criterion 1 ranks each of the recharge strategies on its effectiveness to reduce the modeled deficit in cumulative groundwater storage in the Basin, as described in the GSP. Although the Basin is currently sustainable, based on the sustainability indicators established in the GSP, the groundwater budgets computed by the SPV GSP Model during preparation of the GSP indicate an average deficit in the cumulative change in groundwater storage ranging from -245 AFY under historical conditions (WYs 2005 through 2019) to -53 AFY under current conditions (i.e., WYs 2015 through 2019). This deficit range represents 0.6 to 3 percent of the average of the groundwater inflows and outflows during the current and historical periods, and is likely within the acceptable margin of error for the water budget.

For each recharge strategy, the updated SPV GSP Model will be used to compute a water budget. The difference between the monthly and annual water budget volumes in the baseline and recharge-strategy simulations will be used to quantify the effect of the recharge strategy on the historical water budget. The metric for ranking each strategy for its effectiveness in improving water supply reliability will be on reduction of the deficit in the modeled cumulative change in groundwater storage. Tables and/or charts showing groundwater storage volume through time will be presented for the baseline simulation and each recharge strategy to facilitate evaluating which recharge strategies result in greater groundwater storage (and therefore, the greatest reduction on the deficit in the modeled cumulative change in groundwater storage). The reduction of modeled deficit in cumulative groundwater storage will be calculated as cumulative change in groundwater storage in a proposed strategy minus cumulative change in groundwater storage in the baseline. The results of each strategy will be compared and ranked.

3.2 Criterion 2: Maintenance of Shallower Groundwater Levels

Criterion 2 ranks each of the recharge strategies on its ability to maintain groundwater levels throughout the Basin. The historical observed groundwater levels in the Basin indicate that groundwater flow is east to west seasonally and for all water years. The seasonal high occurs in spring, with the seasonal low in fall. As of the first Annual Report for Water Years 2020/21 and 2021/22, groundwater levels do not exceed the minimum thresholds (MTs) or planning thresholds (PTs) in any of the representative monitoring network wells. However, the effect of future hydrology on groundwater levels is uncertain. Therefore, evaluating different surface water recharge strategies is an important step toward improving water supply reliability during GSP implementation.

WY 2021 groundwater gradients in the Basin show a reducing depth to groundwater towards the western part of the Basin, with an average difference of 65 feet in groundwater levels between the eastern and western portions of the Basin, as shown in **Figure 3**.

The metric for ranking each strategy for its effectiveness in providing enhanced groundwater recharge will be based on increases in modeled groundwater elevations at the representative monitoring wells (RMWs). Groundwater-level hydrographs will be presented for the baseline simulation and each recharge strategy to facilitate evaluating which recharge strategies result in higher groundwater elevations at the RMWs. The maintenance of shallower groundwater levels will be calculated as the average DTW difference in the RMWs in a proposed strategy relative to the baseline. The results of each strategy will be compared and ranked.

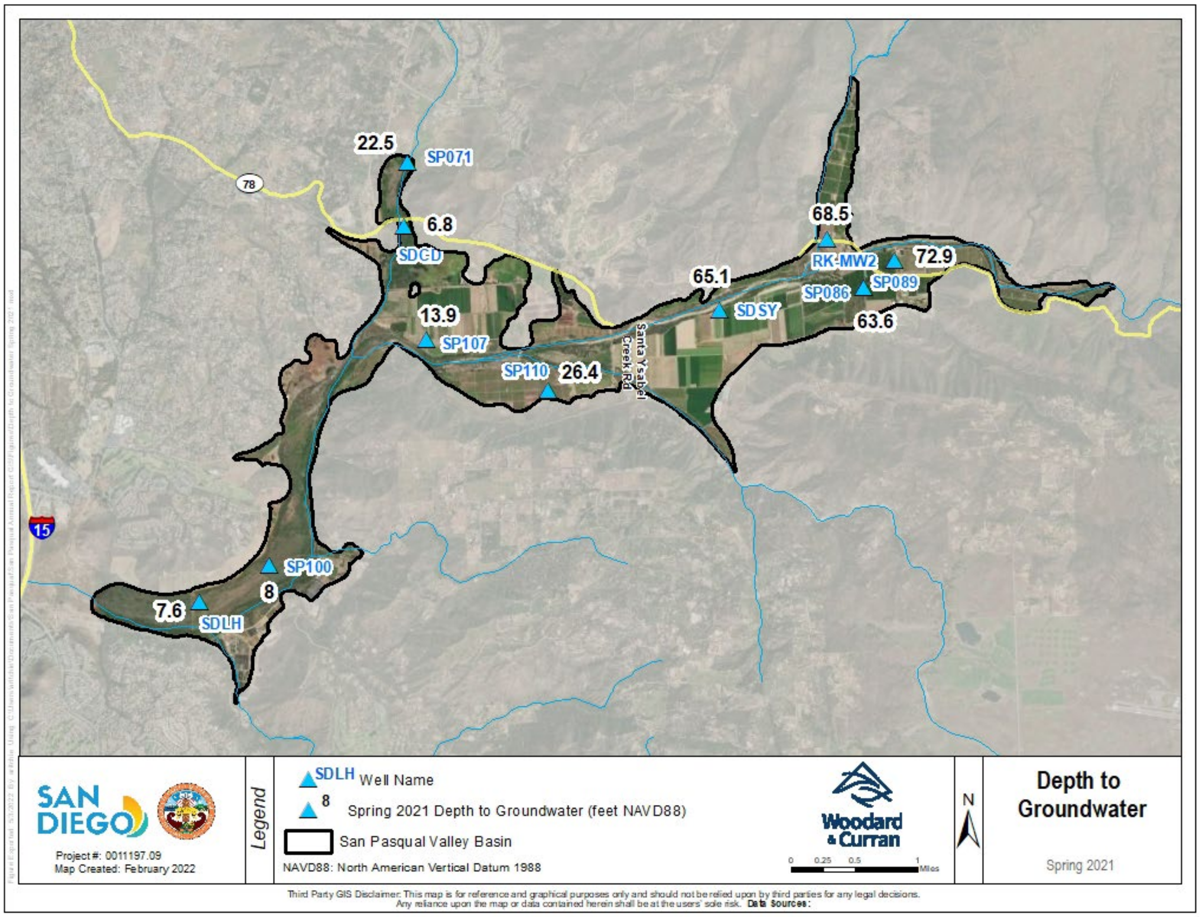

Figure 3: Groundwater Levels, Spring 2021

3.3 Criterion 3: Reduction of Projected Groundwater Declines to Minimum Thresholds (MT)

Criterion 3 ranks each of the recharge strategies based on its potential to keep modeled hydrographs at the groundwater level RMWs from going below MTs. Modeled groundwater levels at the RMWs under each recharge strategy will be ranked according to the ability of the modeled levels to stay above MTs. Groundwater levels that stay above the MTs will avoid the undesirable results defined in the GSP for chronic lowering of groundwater levels, reduction of groundwater storage, and depletions of interconnected surface water (in the western subarea).

The metric for ranking each strategy for its reduction in occurrences of groundwater levels below MTs will be based on modeled groundwater levels at RMWs as compared with the established MTs for each RMW. Groundwater-level hydrographs will be presented for the baseline simulation and each recharge strategy to facilitate evaluating which recharge strategies result in fewer instances of modeled groundwater levels below MTs. The number of occurrences of groundwater levels below the MTs in each proposed strategy will be compared to the projected number of occurrences of groundwater levels below the MTs in the baseline. The results of each strategy will be compared and ranked.

3.4 Criterion 4: Efficiency of Recharge

Criterion 4 ranks each of the recharge strategies based on its ability to increase groundwater storage relative to the volume of water made available for the groundwater recharge strategy, as shown in Equation 1:

$$Efficiency\ of\ Recharge = \frac{Volume\ Increase\ in\ Groundwater\ Storage\ in\ the\ Eastern\ Subarea}{Volume\ of\ Water\ Made\ Available\ for\ the\ Groundwater\ Recharge\ Strategy} \quad (1)$$

The efficiency of recharge quantifies the net benefit of implementing the recharge strategy from a groundwater storage perspective, with consideration of increased water losses from increased infiltration. The net benefit approach is appropriate because, as previously stated, increasing groundwater inflows in the eastern portion of the Basin will increase groundwater outflows in the western end of the Basin. So not all of the infiltrated water from a recharge strategy would be available for groundwater use because of increased groundwater outflows to evapotranspiration (ET) and subsurface outflow (i.e., losses). Recharge efficiencies will be presented for each recharge strategy to facilitate evaluating which recharge strategies would have the greatest potential for the most efficient improvement to groundwater storage.

The efficiency of recharge will be calculated as the cumulative change in groundwater storage (CCGS) divided by the cumulative volume of surface water made available for groundwater recharge (CVSW) in a proposed strategy relative to the baseline. The CVSW will be calculated as the total amount of surface water that is released, diverted, or captured as part of each recharge strategy (before loss to ET in conveyance to the Basin). The results of each strategy will be compared and ranked.

3.5 Criterion 5: Improvements in Groundwater Quality

Recharge strategies that result in less loading of total dissolved solids (TDS) or nitrate as nitrogen (NO3-N) to the groundwater may improve groundwater quality within the Basin. To evaluate the relative benefits of each of the recharge strategies with respect to groundwater quality, Criterion 5 will calculate mass loading of TDS and NO3-N to the Basin. The model-simulated recharge associated with each surface water source will be multiplied by its measured TDS and NO3-N concentrations. The result for each constituent will be summed and then divided by the total recharge from all surface water sources to obtain flow-weighted-average concentrations for TDS and NO3-N for each recharge strategy.

Groundwater quality maps included in the Annual Report for WYs 2020 and 2021 (Woodard & Curran, 2022) are shown in **Figure 4.** Capture and recharge of surface water in some portions of the watershed may have differing effects on groundwater quality at the RMWs shown in the figure. This criterion will qualitatively evaluate potential impacts to groundwater quality by comparing changes in source water quality with and without recharge strategies.

The recharge strategies will be evaluated and scored based on the differences among the resulting flow-weighted, average TDS and NO3-N concentrations relative to baseline conditions. Strategies with lower average NO3-N or TDS concentrations than baseline indicate the potential for groundwater quality improvement. Conversely, strategies with higher average NO3-N or TDS concentrations relative to baseline indicate the potential for further degradation of water quality. The results of each strategy will be compared and ranked.

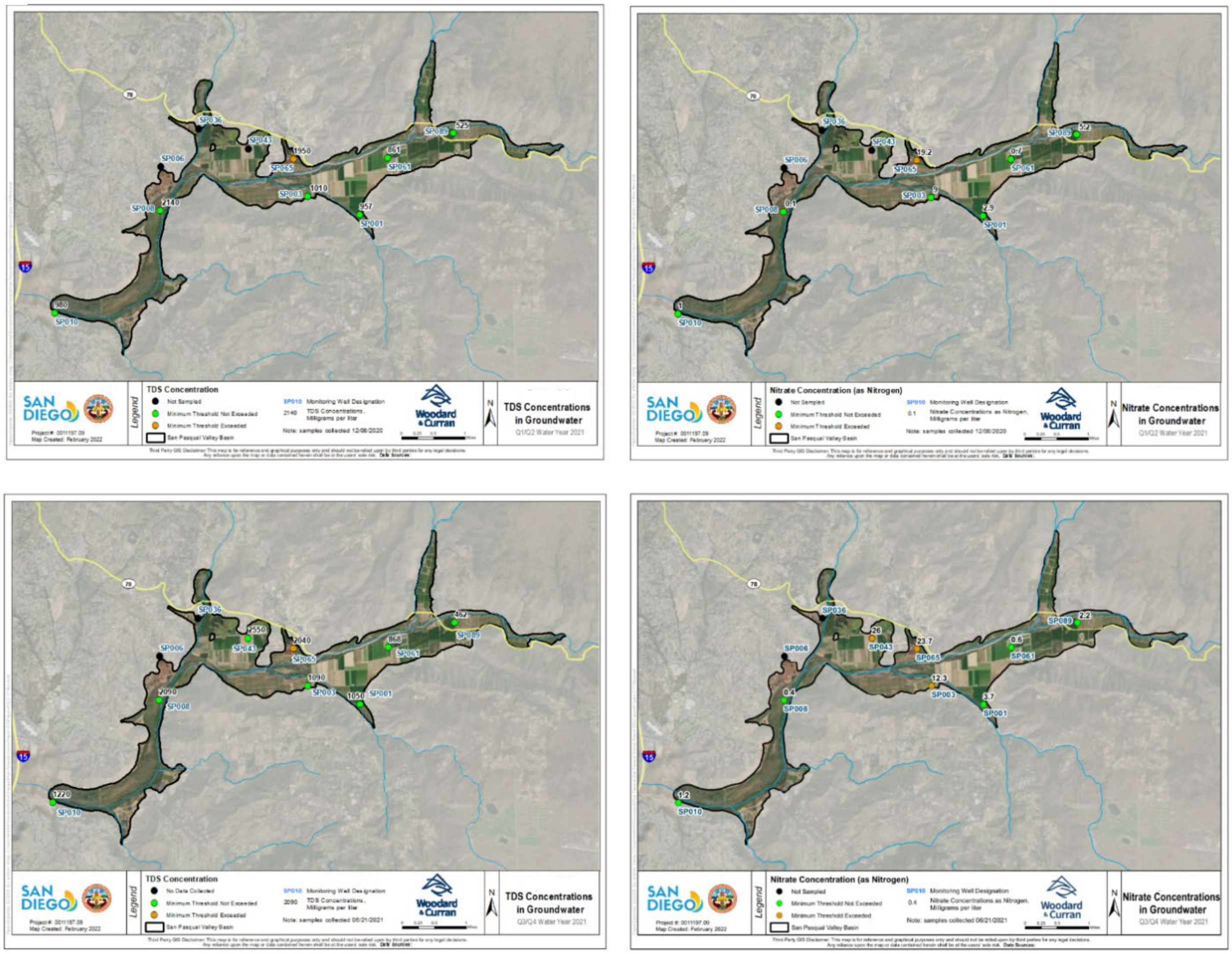

Figure 4: Groundwater Quality Results, Spring 2021

3.6 Criterion 6: Benefits to GDEs

Criterion 6 ranks each of the recharge strategies on its benefits to GDEs in the Basin. Potential GDEs largely consist of dense riparian and wetland communities along mapped drainage systems where monitoring well data indicate the average depth to groundwater of no more than 30 feet below ground surface (bgs). These GDEs are most prominent in the western portion of the Basin where groundwater is shallowest (see **Figure 5**). Many of the potential GDEs observed appear to rely on surface flows or stormwater runoff, as well as groundwater. The potential non-GDE vegetation largely exists in dry upland areas dominated by shallow-rooted grasses and invasive species. Areas that include wetland and riparian phreatophytes (i.e., deep-rooted plant species) along drainageways, where the average depth to groundwater is typically deeper than 30 feet bgs, were classified as wetland and riparian communities.

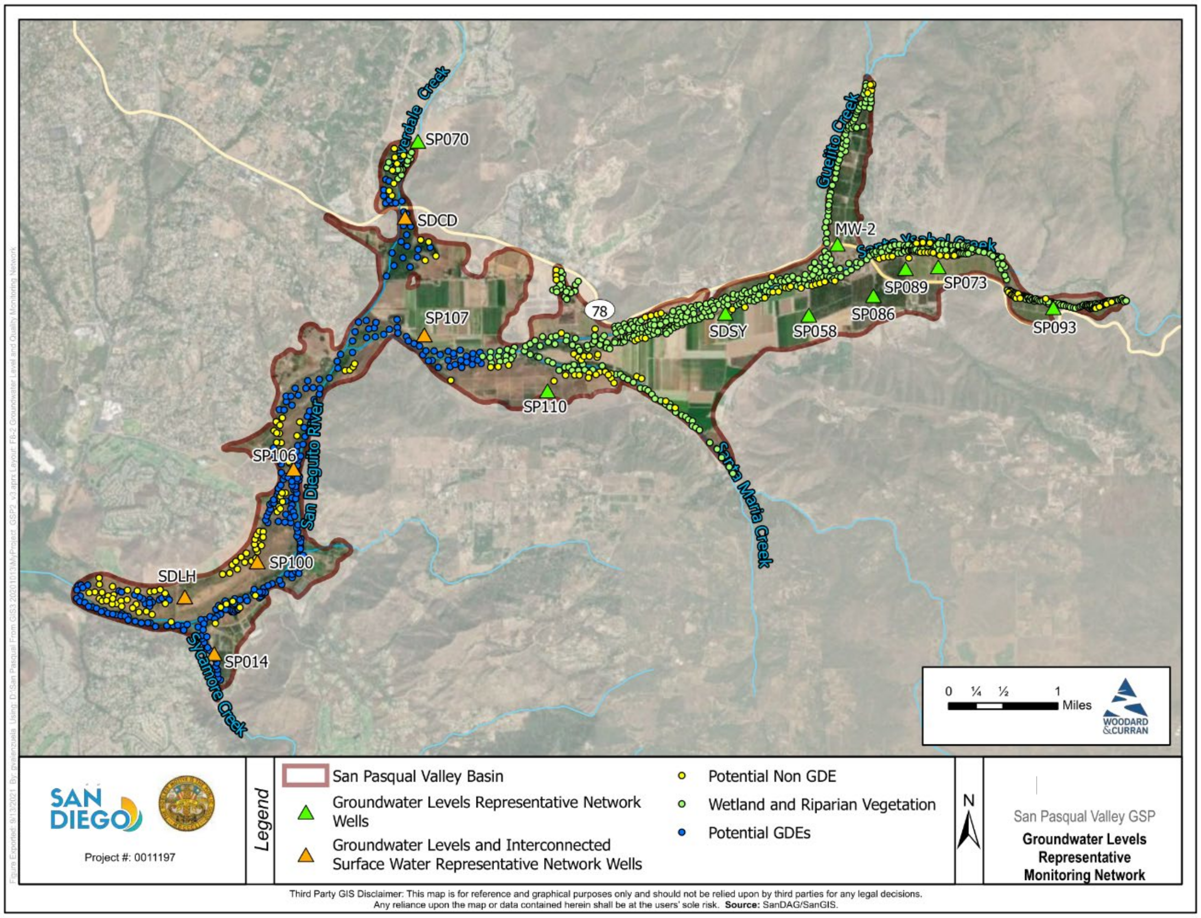

Figure 5: Groundwater Dependent Ecosystems in the Basin

Strategies will be scored based on their maintenance and/or improvement of GDE access to groundwater from baseline conditions. Established GDE's should have protected groundwater levels that do not draw down to depths where root zones can no longer access groundwater in the western portion of the Basin. Scoring for this criterion will award points if the RMWs near GDEs have greater consecutive days of groundwater access within rooting depths due to the surface water recharge activities. Outputs may include charts of water levels at the monitoring wells near the GDEs under each strategy to compare and contrast the impact of each strategy.

The potential benefits to GDEs will be calculated as the average number of consecutive days that simulated DTW extends below the target rooting depths for the GDEs RMWs in a proposed strategy relative to the baseline. The results of each strategy will be compared and ranked.

3.7 Criterion 7: Costs and Monetary Benefits of Implementation and Maintenance

Criterion 7 ranks each of the recharge strategies on its costs and monetary benefits of implementation and maintenance. The cost to implement each strategy will vary depending on the size and type of facilities, operational changes needed on existing facilities, and the ongoing operation and maintenance (O&M) activities. Projects often require a one-time capital outlay that can vary widely depending on the size of the project and could be prohibitive to implementation. However, these projects could provide different recharge benefits and have different long-term O&M costs that should also be considered. Unit cost considers costs over time per unit of supply and allows for comparison of projects with varying costs and volumes.

The primary economic benefit of recharge strategy implementation would be maintenance of the existing agricultural economy in San Pasqual Valley. The San Pasqual Valley GSP concluded that the basin is sustainable at forecasted pumping levels. The purpose of recharging the Basin is to maintain groundwater levels and quality such that the existing beneficial uses can continue. The monetary benefit of a recharge project would be potential for additional agricultural production from existing basin farmlands. This analysis will consider the benefits of increased agricultural production (namely citrus and avocados) from increased groundwater levels and water availability.

The unit cost of implementation and maintenance (Criterion 7a) will be calculated in acre-foot per year (AFY) for a proposed strategy relative to the baseline. The AFY calculation will be based on the CCGS for the strategy relative to baseline. The results of each strategy will be compared and ranked.

The unit benefit of implementation and maintenance (Criterion 7b) will be calculated in AFY for the additional potential agricultural production that would be made available through the recharge activities relative to the baseline. The San Pasqual GSP determined that agricultural production across the basin generally uses 5,484 AFY in normal year conditions[1]. The benefit calculation will use the AFY increase calculated above (based on CCGS) multiplied by the economic value of agricultural production in the region (on per acre basis).

3.8 Criterion 8: Feasibility of Implementation and Maintenance

Criterion 8 ranks each of the recharge strategies based on the feasibility of its implementation and maintenance when considering the legal, institutional, and regulatory requirements. For example, some strategies may require permits, regulatory approval, environmental studies or delineations, or other requirements before implementation. Although the preliminary costs of implementing each recharge strategy are captured in the criterion described in Section 3.7, these feasibility factors can increase the effort, labor, and time needed to implement each strategy.

In this criterion, the City may consider each strategy's effect on municipal supplies, both upstream and downstream. For example, releases from Sutherland Reservoir may reduce the amount of water supply available for municipal use from that reservoir, while capture and infiltration of wet weather flows in the

[1] Agricultural acreage and production from San Pasqual Valley GSP, Appendix I: Numerical Flow Model Documentation, Table 3-4 and Table 4-9.

Basin may reduce the amount of outflow (and associated municipal use) of water supply from Hodges Reservoir. Calculating and understanding these volumes may be helpful in comparing the strategies.

This qualitative evaluation is necessary to capture some of the key non-quantifiable factors that the City must consider. The feasibility of implementation and maintenance will consider the number and difficulty of permits, institutional challenges, and schedule for a proposed strategy relative to the baseline. The results of each strategy will be compared and ranked.

3.9 Summary

Table 1 provides a summary of each criterion, data source, metric, and evaluation approach that will be used to rank the four potential recharge strategies.

Table 1: Summary of Surface Water Recharge Evaluation Criteria

Criterion	Data Source	Metric	Evaluation Approach	Scoring	Weighting (%)
Criterion 1: Reduction of Modeled Deficit in Cumulative Groundwater Storage	• SPV GSP Model[a]	• Cumulative change in groundwater storage (CCGS)	• Calculated as CCGS (strategy) minus CCGS (baseline)	• Forced rank (e.g., 1 = smallest, 4 = largest) or possibly a category rank (e.g., 1 for <500 AFY, 2 for 500 – 1,000 AFY, etc.) • Approach to be finalized after model runs have been completed	13%
Criterion 2: Maintenance of Shallower Groundwater Levels in the Basin	• SPV GSP Model[a]	• Depth to water (DTW) at representative monitoring wells (RMW)	• Average difference of DTW between the strategy and baseline simulation at RMWs • Calculated as the sum of DTW [strategy] minus DTW [baseline] for each RMW divided by the number of simulation days, divided by the number of RMWs	• Forced rank (e.g., 1 = smallest, 5= largest]) or category rank (e.g., 1 for <10 feet, 2 for 10 – 20 feet, etc.) • Approach to be finalized after model runs have been completed	7%
Criterion 3: Reduction of Projected Groundwater Levels Below Minimum Thresholds	• SPV GSP Model[a]	• Modeled groundwater levels at all RMWs	• Number of occurrences of DTW below MTs (baseline) minus number of occurrences of DTW below MTs (strategy)	• Forced rank or category rank based on the differences relative to baseline (lower counts ranked higher) • Approach to be finalized after model runs have been completed	18%

Criterion	Data Source	Metric	Evaluation Approach	Scoring	Weighting (%)
Criterion 4: Efficiency of Recharge	• SPV GSP Model[a] • CWASim[b] • Possibly other hydrologic/hydraulic models	• Ratio of volume of CCGS to the cumulative volume of surface water (CVSW) made available for groundwater recharge	• Calculated as the difference in CCGS between the strategy and baseline simulations divided by CVSW [strategy])	• Forced rank or category rank based on the differences in the recharge efficiency (higher efficiencies would be ranked higher) • Approach to be finalized after model runs have been completed	18%
Criterion 5: Improvements in Groundwater Quality	• SPV GSP Model[a] • Measured total dissolved solids (TDS) and nitrate as nitrogen (NO3-N) concentrations in source water	• Potential change in source water flows and concentrations of TDS and NO3-N with the strategy versus baseline flows and concentrations	• Differences among the flow-weighted average TDS and NO3-N concentrations for the surface water recharge supply for each strategy relative to baseline. • Flow-weighted, average concentration calculated as: (Concentration [A] x GW recharge [A] + Concentration [B] x GW recharge [B] + Concentration [C] x GW recharge [C] + …) divided by (GW recharge [A]+ GW recharge [B]+ GW recharge [C] …) • A, B and C, refer to the surface water sources that recharge groundwater	• Forced rank or category rank based on the differences in the flow-weighted concentrations to baseline with individual scoring for TDS and NO3-N, which will be summed to one score for overall ranking (lower averaged concentrations ranked higher)	7%
Criterion 6: Benefits to GDEs	• SPV GSP Model[a] • GDE Pulse[c]	• Depth to water at GDE RMWs as compared with the root-zone depth of GDEs relative to baseline	• Revised estimates of target rooting depths will be determined for the GDE RMWs as an outcome of Task 6 • Compute the average number of consecutive days the modeled DTWs occur below target rooting depths for the GDE RWMs relative to baseline • Calculated as the sum of the consecutive days the modeled DTW persists below target rooting depths for each RMW divided by the total simulation days, divided by the number of GDE RMWs, as compared with baseline	• Forced rank or category rank based on the range of differences among the strategies (fewer average consecutive days would be ranked higher) as compared with baseline • Approach to be finalized after model runs have been completed	7%

Criterion	Data Source	Metric	Evaluation Approach	Scoring	Weighting (%)
Criterion 7: Costs and Benefits of Implementation and Maintenance	• City of San Diego • County of San Diego • Woodard & Curran • Jacobs	• 7a: Capital and maintenance costs • 7b: Economic value of agricultural production	• 7a: Cost per AF of recharge relative to baseline; Calculated as the preliminary cost (Class 5[d] cost estimates with maintenance costs amortized over the simulation period) per AF for each strategy • 7b: Benefit per AF of recharge relative to baseline; Calculated from average per acre value of agricultural productivity potentially made available through increased groundwater supply by AFY for each strategy	• Forced rank or category rank based on the range of costs • Approach to be finalized after preliminary costs have been developed	12% (7a: 6% + 7b: 6%)
Criterion 8: Feasibility of Implementation and Maintenance	• City of San Diego • County of San Diego • Woodard & Curran • Jacobs	• Identified permits, institutional challenges, and schedule for each strategy	• Qualitative assessment based on the number and difficulty of permits, institutional challenges, and schedule	• Force or category rank based on difficulty of implementation (higher ranking for projects that are easier to implement)	18%
TOTAL CRITERIA WEIGHTING					**100%**

[a] Refers to the SPV GSP Model described in Appendix I of the GSP (City of San Diego, 2021). This Surface Water Recharge Evaluation will update the SPV GSP Model with new information acquired in Task 2.

[b] A GoldSim model originally developed for the San Diego County Water Authority by CH2M (now Jacobs) in support of the 2013 Regional Facilities. Optimization and Master Plan Update (CH2M and Black & Veatch, 2014). The CWASim model was also used in the San Diego Watershed Basin Study completed in partnership between the City of San Diego Public Utilities Department and the Bureau of Reclamation (City of San Diego and Reclamation, 2017).

[c] GDE Pulse tool available from The Nature Conservancy (https://gde.codefornature.org/#/home).

[d] Class 5 cost estimate is considered a rough order of magnitude (ROM) estimate, typically used for the initial screening projects for capital expenditure planning.

4. CRITERIA WEIGHTING

An additional key element to the scoring of recharge strategies based on this multi-criteria evaluation approach is the weight given to each criterion, where weight reflects the relative importance of the criteria. The Core Team and stakeholders discussed the relative importance of the proposed criteria and participated in a criterion values activity during the June 8, 2022 stakeholder workshop[1]. Following the stakeholder workshop, the Core Team also contacted three individuals who had previously sat on the San Pasqual Valley GSP Advisory Committee, but were not in attendance at the workshop, to invite them to contribute to the criterion values activity.

The criteria weights were developed following the stakeholder workshop using a matched pairs weighting method, considering the input from all workshop participants. The goal of the criteria weighting is to accurately reflect the priorities of the San Pasqual Valley GSA, the adopted GSP, and Basin stakeholders. Based on the outcomes of the GSA and stakeholder exercises, the proposed weighting weighted the top three valued criterion the same (18% each); the bottom three valued criterion the same (7% each); and distributed the other two in the middle (12% and 13%). Note that Criterion 7 was divided into two parts (7a and 7b) and its weighting split evenly (6% + 6%).

The results of this exercise provided a weighting percentage that will be applied to each strategy's evaluation criteria scores (see summary in **Table 2**). **Figure 6** shows the relative weighting of each evaluation criterion. These scores will then be added together to obtain a total weighted score for each strategy that represents the overall performance of each strategy.

Table 2: Summary of Criterion Weighting

Criterion	Proposed Weighting
1: Reduction of modeled deficit in cumulative groundwater storage	13%
2: Maintenance of shallower groundwater levels in the Basin	7%
3: Reduction in projected groundwater declines to minimum thresholds (MTs)	18%
4: Efficiency of recharge	18%
5: Improvements in groundwater quality	7%
6: Benefits to groundwater-dependent ecosystems	7%
7a: Costs of implementation and maintenance	6%
7b: Benefits of implementation and maintenance	6%
8: Feasibility of implementation and maintenance	18%
TOTAL CRITERIA WEIGHTING	**100%**

[1] Results of the criterion values activity at the June 8, 2022 workshop are available in the workshop summary on the program website: https://www.sandiegocounty.gov/content/sdc/pds/SGMA/san-pasqual-valley.html

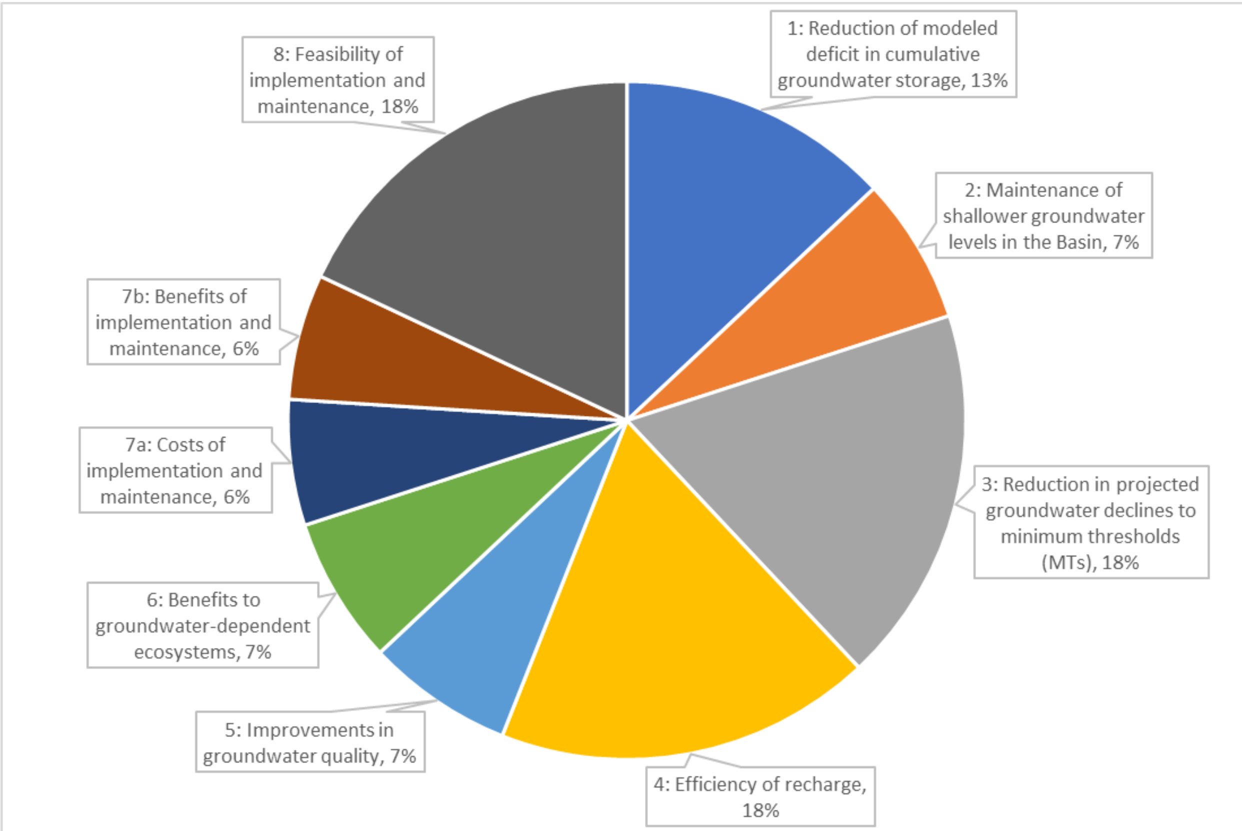

Figure 6: Results of Weighting Activity

5. REFERENCES

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APPENDIX B: TM 2: STREAMBED INVESTIGATION

TECHNICAL MEMORANDUM

TO: San Pasqual Valley Groundwater Sustainability Agency

PREPARED BY: Nate Brown/Jacobs, Craig Cooledge/Jacobs

REVIEWED BY: Jim Blanke/W&C, Sally Johnson/W&C

DATE: January 23, 2023

RE: Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 2: Streambed Investigation

TABLE OF CONTENTS

ACRONYMS & ABBREVIATIONS

DWR	Department of Water Resources
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
PMA	Project and Management Action
SPV	San Pasqual Valley
SPV GSP Model	SPV GSP Integrated Groundwater/Surface Water Flow Model
City	City of San Diego
County	County of San Diego
Basin	San Pasqual Valley Groundwater Basin
SFR	Streamflow Routing
USGS	United States Geological Survey
CIMIS	California Irrigation Management Information System
OneWater	MODFLOW-OWHM
cm/s	centimeters per second
ft/d	feet per day
RTK	Real Time Kinetics
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1998
SP	poorly graded sand
ML	sandy silt
SM	silty sand
TAF	thousand acre-feet
bgs	below ground surface

1. INTRODUCTION

The San Pasqual Valley Groundwater Sustainability Agency (GSA) – comprised of the City of San Diego (City) and the County of San Diego (County) – adopted and submitted to the California Department of Water Resources (DWR) the San Pasqual Valley Groundwater Sustainability Plan (GSP) in January 2022 (City and County, 2021). The GSP provides guidance and quantifiable metrics to ensure the continued sustainable management of groundwater resources within the San Pasqual Valley Groundwater Basin (Basin) over the 20-year GSP implementation period (**Figure 1-1**). To accomplish this, the GSP includes a hydrogeological conceptual model, monitoring requirements, sustainable management criteria, and several projects and management actions. The projects and management actions (PMAs) included in the GSP are intended to support sustainable groundwater management in the Basin that respond to changing conditions and help prevent undesirable results. The Basin is currently sustainably managed, so no additional PMAs are needed to achieve sustainability. However, implementing PMAs could improve resilience against challenging future hydrologic conditions, such as extended droughts.

This technical memorandum is the second of six that focuses on PMA No. 7, which aims to complete an Initial Surface Water Recharge Evaluation. The first technical memorandum describes the evaluation criteria by which surface water recharge strategies for the Basin will be considered (City, 2022). The purpose of this second technical memorandum is to provide background for and results of a streambed investigation in the Basin and provide recommendations for updating the San Pasqual Valley Groundwater Sustainability Plan Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) with information acquired from the streambed investigation. From this point forward in this technical memorandum, the version of the SPV GSP Model used during development of the GSP (City and County, 2021) will be referred to as SPV GSP Model v1.0, whereas the version that will be updated to support decisions associated with PMA No. 7 will be referred to as SPV GSP Model v2.0.

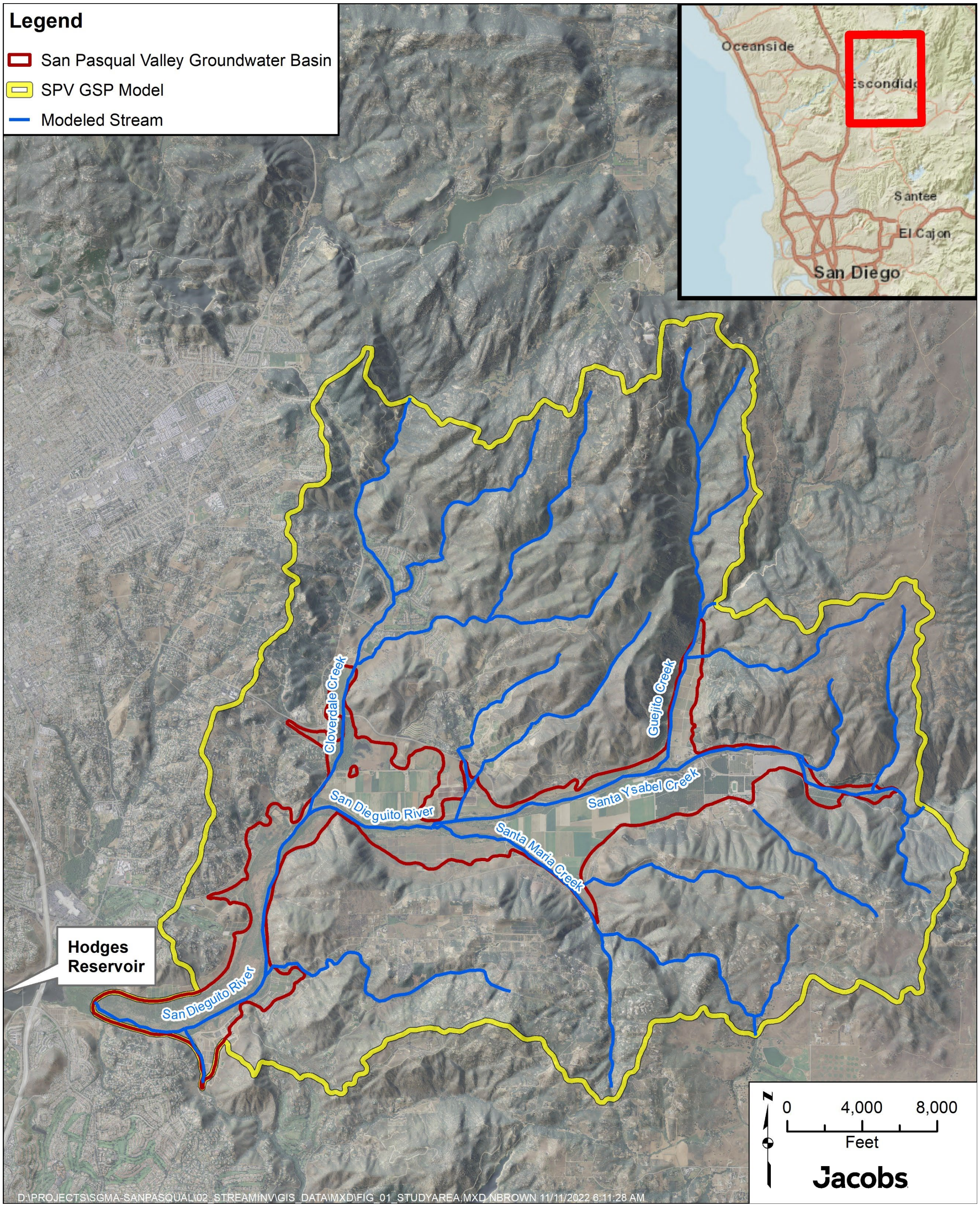

Figure 1-1. Model Domain and Streams

The GSA will use the Initial Surface Water Recharge Evaluation to help quantify potential benefits to the Basin and feasibility of implementation of potential recharge projects. Ultimately, this Initial Surface Water Recharge Evaluation is estimated to be completed by 2024, and the resulting information will be provided in a Preliminary Feasibility Study. The Preliminary Feasibility Study will summarize the Initial Surface Water Recharge Evaluation, and will include the following sections:

- Evaluation Criteria and Ranking Process (Task 1)
- Streambed Investigation (Task 2)
- Water Sources for Recharge (Task 3)
- Potential Recharge Strategies (Task 4)
- Modeling Approach and Results (Task 5)
- Potential Benefits to Groundwater Dependent Ecosystems (GDEs) (Task 6)

2. BACKGROUND

The stream network used in the SPV GSP Model v1.0 is represented in **Figure 1-1**. The eastern portion of the Basin is generally a groundwater recharge area, where the aquifer receives water primarily from streambed infiltration of Santa Ysabel, Guejito, and Santa Maria Creeks. San Dieguito River is formed at the confluence of Santa Ysabel Creek and Santa Maria Creek and flows west into Hodges Reservoir downgradient from the southwest boundary of the Basin. Processes of streamflow and groundwater/surface-water interaction along the modeled streams are simulated using the Streamflow Routing (SFR) package of the MODFLOW-OWHM (OneWater) code (Boyce et al., 2020). The SFR package requires definition of stream channel segments that are intersected with the groundwater flow model grid cells to create stream channel networks. Stream channel parameters required for the calculation of streamflow routing are specified throughout the SFR network, and include channel geometry, Manning's roughness coefficient and streambed vertical hydraulic conductivity. Manning's roughness coefficient is a measure of the resistance to surface flow in a channel, whereas the hydraulic conductivity is a measure of the physical capacity of porous subsurface materials to allow fluids to move through them. Thus, the hydraulic conductivity is a function of the interconnected pore space in the porous medium and the characteristics of the fluid (that is, fluid density and viscosity) flowing through that porous medium. For a given fluid (water in this case), hydraulic conductivity values are larger for sand and gravel (that is, water moves more easily through this material) and smaller for silt, clay, and solid rock (that is, water does not move as easily through this material).

As a starting point during GSP development, SFR parameter values were idealized for all stream segments. With this setup, stream channel widths were initially set to 50 feet, streambed vertical hydraulic conductivity was initially set to 10 feet per day (ft/d) (3.5×10^{-3} centimeters per second [cm/s]) based on an assumed silty sand value (Freeze and Cherry, 1979), and the Manning's roughness coefficient was initially set to 0.025 based on a winding main channel with little to no vegetation (Chow, 1959). SFR parameters were subsequently refined during the calibration process to better represent local channel widths and to improve model stability. Better estimates of channel widths were obtained and specified for each of the major creeks and rivers through review of Google Earth™ imagery. Additionally, stream channel conditions were evaluated to note the general characteristics of the channel and whether the channels contained significant vegetation, larger rocks or boulders, or were generally "clean". These channel characteristics were used to assign Manning's roughness coefficient values based on estimates from Chow (1959). **Table 2-1** presents the calibrated SFR parameters used to support developing the GSP (City and County, 2021).

Table 2-1. Summary of Stream Parameters in SPV GSP Model v1.0

Stream	Channel Width (feet)	Manning's Roughness Coefficient
Santa Ysabel Creek	50 to 150	0.035 to 0.05
Guejito Creek	15 to 40	0.05 to 0.08
Santa Maria Creek	15 to 80	0.035 to 0.08
Cloverdale Creek	20 to 60	0.05 to 0.08
Sycamore Creek	40	0.08
Other Creeks	15 to 100	0.03 to 0.08
San Dieguito River	100	0.08
Streams were modeled with rectangular channel geometries, a streambed thickness of 1 foot, and a streambed vertical hydraulic conductivity of 0.1 ft/d (3.5×10^{-5} cm/s).		

Ranges of SFR hydraulic conductivity were attempted during the calibration effort. However, the modeled groundwater levels were not very sensitive to this parameter and more importantly, adequate numerical mass balances were only possible when the SFR hydraulic conductivity values were set no greater than 0.1 ft/d (3.5×10^{-5} cm/s) (**Table 2-1**). The lack of sensitivity to this parameter is likely because most streams in the Basin do not regularly flow. Thus, simulations with different SFR hydraulic conductivity values for mostly dry stream beds did not provide substantially different results. Given that the key model output of interest for the GSP was the groundwater budget, achieving adequate numerical mass balances was of utmost importance. Therefore, during the development of the GSP, a compromise was made by assigning an SFR hydraulic conductivity value of 0.1 ft/d (3.5×10^{-5} cm/s) to achieve tighter mass balances, even though it was understood at that time that such hydraulic conductivities could in reality be greater. This compromise was deemed reasonable and appropriate during development of the GSP, especially given that no site-specific data regarding hydraulic conductivity of the streambed or underlying sediments above the water table were available to confirm or refute the assigned value.

The uncertainty and stakeholder interest in site-specific streambed characteristics provided the motivation for the streambed investigation of PMA No. 7 (Initial Surface Water Recharge Evaluation), which is focused on quantifying potential benefits of enhanced infiltration along Santa Ysabel Creek, the primary stream channel within the basin. Data that resulted from the streambed investigation are being used to reduce uncertainty in streambed infiltration characteristics and improve the reliability of the SPV GSP Model as a decision-support tool for PMA No. 7. The following section describes the scope of work for the streambed investigation.

3. SCOPE OF WORK AND METHODOLOGY

Streambed characteristics can vary significantly throughout a stream corridor, so the scope of work included stream channel surveying, streambed infiltration testing, and photographic surveys at several locations. The following subsections describe each of these activities.

3.1 Stream Channel Surveying

Stream channel geometry (shape of the channel) affects how water moves through the stream. Channel geometry is an important consideration for establishing the streamflow-width-depth relationship that ultimately controls how water moves through a stream channel and the driving force for groundwater/surface-water exchanges. During the development of the GSP, there was a lack of field data that quantified the stream channel geometries along the eastern portion of the Basin. Therefore, stream channel surveys were conducted at five transect locations in the eastern portion of the Basin. A "transect" represents a line perpendicular to and cutting across the stream channel along which streambed elevations are measured using surveying equipment. Streambed elevations can then be used to define the geometry or shape of the channel along each transect. Four transects across Santa Ysabel Creek (designated T-1 through T-4) and one transect across Guejito Creek (T-5) were established for this investigation, as shown in **Figure 3-1**. These transect locations were selected based on relevance and site access.

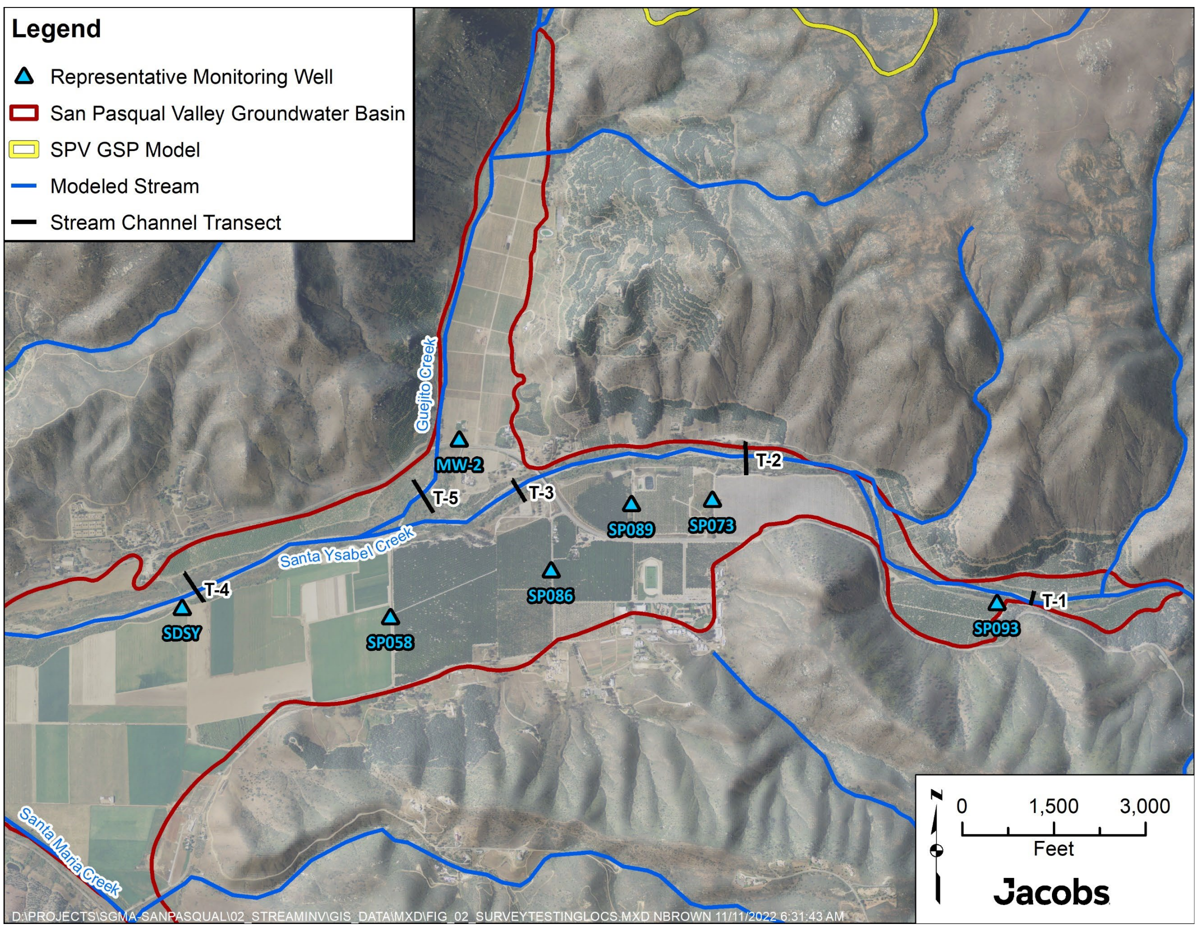

Figure 3-1. Stream Channel Transect Locations

The result from this survey is a set of stream channel profiles at four transect locations across Santa Ysabel Creek and one location across Guejito Creek in the eastern portion of the Basin, which are presented in Section 4.1. The stream channel survey data, along with other available topographic data, will be used to update modeled stream geometries in the SPV GSP Model, as described in Sections 4.1 and 5.1.Streambed Infiltration Testing

Infiltration is a key factor in understanding how much water enters the Basin via natural recharge. During the development of the GSP, there was a lack of field data that quantified infiltration characteristics of streams along the eastern portion of the Basin, where most of the stream infiltration and groundwater recharge occurs. Therefore, a plan for streambed infiltration testing was developed. The primary goal of the infiltration testing was to provide site-specific estimates of streambed vertical hydraulic conductivity. The vertical hydraulic conductivity of the streambed, along with the vertical hydraulic conductivity of the vadose zone below the streambed and above the water table, are variables used to compute an effective vertical hydraulic conductivity between the modeled stream and water table. This effective vertical hydraulic conductivity is an input variable to the SFR package used in the SPV GSP Model to simulate streamflow routing and groundwater/surface-water interaction along the modeled streams. This section details the testing that was completed along with additional details about testing method that needs to be considered when analyzing the data collected. Results from this testing are discussed in Section 4.2.

Several factors were considered during the planning effort when selecting the infiltration testing methodology:

- Infiltration testing had not been previously attempted in Santa Ysabel Creek and no field estimates of streambed infiltration capacity, streambed hydraulic conductivity, or flow requirements for infiltration testing were available. There was also no local precedent regarding a field method for performing the infiltration testing in the Santa Ysabel Creek streambed. Therefore, initial planning efforts focused on standard low-flow testing methodologies.
- Lighter equipment with simpler setups were favored over heavier equipment and more complicated setups to avoid streambed impacts and comply with approved setup locations.
- Testing methods that could be completed more efficiently were favored over more time consuming methods in order to avoid disruptions to agricultural operations during the fall harvest.
- Testing methods that require less source water were favored over more water-intensive methods due to current drought conditions.
- The infiltration characteristics along the channel of Santa Ysabel Creek could spatially and temporally vary considerably, given the intermittent nature of streamflow, erosion, and deposition through time[1]. Therefore; more than one infiltration test was desired to gain insight into the spatial variability of streambed characteristics across Santa Ysabel Creek in the eastern SPV.

Given these factors, 15 locations were selected for infiltration tests along the five transects shown in **Figure 3-2**. The naming convention for the infiltration testing locations is as follows: *T-[Transect Number][Relative Position]*. The relative position of the testing location is "C" for center, "L" for left, and "R" for right. For

[1] It has been well established in scientific literature and practice that infiltration rates can vary considerably, even over short distances (e.g., Johnson, 1963; Eggleston and Rojstaczer, 2001; Bagarello et al., 2009). Factors affecting the infiltration rate include sediment structure, condition of the sediment surface, distribution of initial soil moisture, chemical and physical nature of sediments, depth and turbidity of ponded water, depth to groundwater, temperature of ponded water and sediments, distribution of trapped air in sediments, atmospheric pressure, duration of ponded water, biological activity in sediment, vegetative cover, and type of equipment used for testing (Johnson, 1963).

example, T-3R is the infiltration testing location on the right side of Santa Ysabel Creek when facing the westerly downstream direction at Transect-3. The left and right testing locations were positioned on higher-elevation areas of the stream channel where streamflow would occur when streamflow is great enough to overtop the banks of the main lower-flow channel. Based on the observed vegetation on these higher-elevation areas and information verbalized from residents during stakeholder meetings and field testing, streamflow overtopping the banks of the main lower-flow channel is infrequent. Testing at the center locations was intended to provide infiltration data for the inferred stream thalweg (lowest elevation) of the main flow channel. As shown in **Figure 3-2**, each thalweg testing location is not necessarily at the center of the channel, as shown in the stream channel survey transects (Section 4.1).

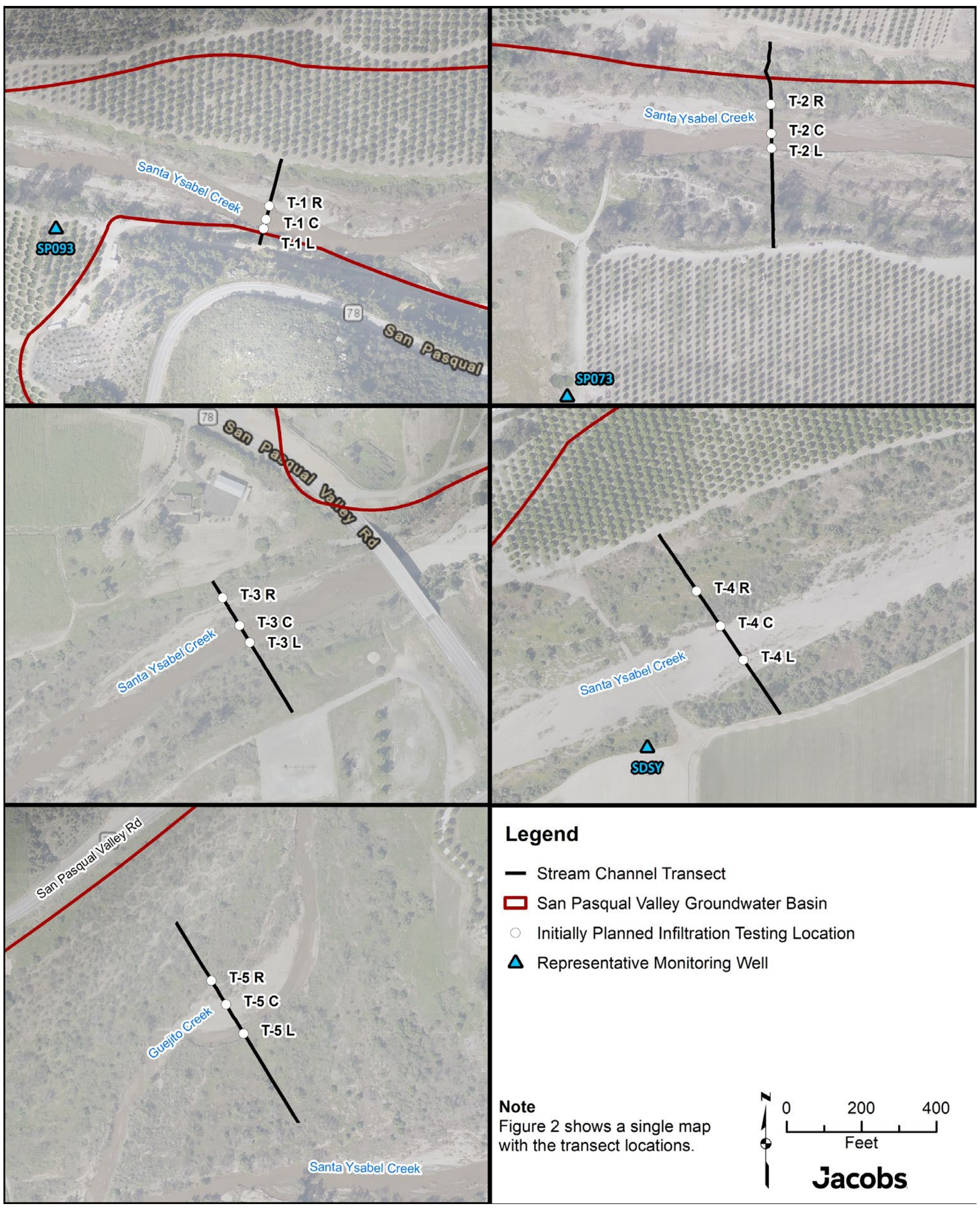

__Figure 3-2. Initially Planned Infiltration Testing Locations__

The Infiltration testing method initially envisioned for this effort was the *Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer* (D3385-18) (ASTM International, 2018). The setup and duration of this type of infiltration testing was deemed appropriate during the planning phase, given the uncertainties and consideration of the factors described above. This is a standard method that consists of installing two open cylinders (one inside the other) into the ground, partially filling the rings with water, and then recording the time-series flow rates into the inner ring while maintaining the water in both rings at a constant level. The volume of water added to the inner ring to maintain a constant water level is the volume of water of interest that enters the soil. The test is generally continued until the flow rate no longer changes by more than a few percent. The duration of testing typically ranges from dozens of minutes to a few hours at each test site, depending on subsurface conditions and preapproved timeframes to avoid disrupting agricultural operations.

One drawback to using standard-size (e.g., 12- to 24-inch diameter) ring infiltrometers to estimate vertical hydraulic conductivity of the streambed is that the divergent flow that occurs through the sediments must be accounted for (Johnson, 1963). In other words, not all water leaving the infiltrometer moves in a perfectly downward direction, but rather spreads horizontally as it moves down, and this divergent flow must be considered when performing infiltration tests and accounted for when interpreting the results.

As shown in **Figure 3-3**, use of a double-ring infiltrometer reduces divergent flow paths from the inner ring, as compared with divergent flow paths from single-ring infiltrometers. The single ring on the left and the inner ring on the right of **Figure 3-3** have the same dimensions and the underlying sediments in both images have the same infiltration characteristics. Infiltration of water from the outer ring establishes a wetted subsurface boundary that limits the lateral spread of water infiltrating below the inner ring. However, some degree of divergent flow still occurs, even with the double-ring infiltrometer, so it is necessary to account for this when estimating the vertical hydraulic conductivity of the streambed (Swartzendruber and Olson, 1961ab; Reynolds and Elrick, 1990; Fatehnia et al., 2016).

Data resulting from the double-ring infiltration test are used along with an equation developed by Fatehnia et al. (2016) to account for divergent flow that occurs below the inner infiltration ring to estimate the vertical hydraulic conductivity of the streambed. This is discussed in more detail along with the results in Section 4.2.

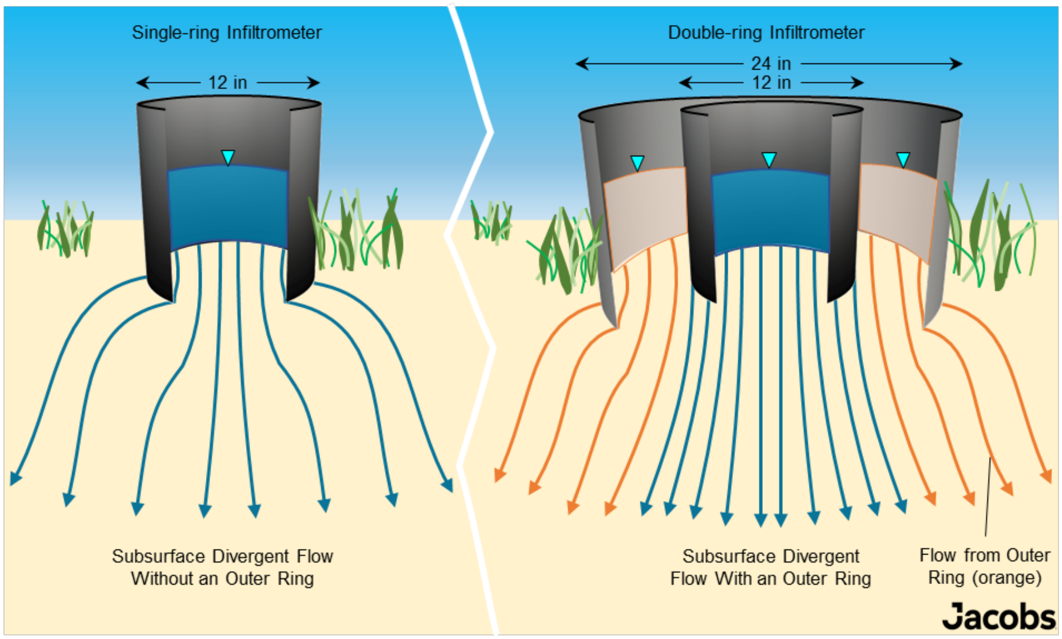

Figure 3-3. Depiction of Divergent Flow Paths with Standard Ring Infiltrometers

3.2 Photographic Surveys

A key characteristic in the Basin that requires better understanding is the occurrence of streamflow in Santa Ysabel Creek in the eastern portion of the Basin in response to rainfall events with different intensities and durations. Although some stream gauges exist upgradient from the Basin, no stream gauges exist within the Basin. Therefore, there are no Basin data to help quantify the nature and occurrence of streamflow therein. One way to help quantify streamflow characteristics within the Basin is with carefully timed photographic surveys. A photographic survey with a hand-held camera was conducted after a multiday rainfall event in January 2023. The key observation of interest was the farthest downstream location at which streamflow occurs in the Basin east of Ysabel Creek Road following the selected rainfall event. Although observations of streamflow conditions are not as informative as stream gauge data, they are inexpensive to obtain and provide useful information to support future model updates. Such observations can serve as a basis for comparison against the modeled extent of streamflow in Santa Ysabel Creek from similar rainfall events simulated with the SPV GSP Model. Section 4.3 describes the results of the photographic survey.

4. STREAMBED INVESTIGATION RESULTS

The following subsections describe the results of the stream channel surveying, streambed infiltration testing, and photographic surveys.

4.1 Stream Channel Surveying

Stream channel surveying of the five transects was conducted from June 27, 2022 through June 29, 2022 to develop channel profiles and understand the shape of the channel at each of these transects. GPS Real Time Kinetics (RTK) were used to establish control, based on Record of Survey 14236. The GPS RTK surveying method generally provides an accuracy of ±0.04 foot horizontally and ±0.01 foot vertically when surveying a hard, well-defined surface. However, for this streambed investigation, which included working in loose sand with rounded grade breaks, the elevation accuracy is on the order of ±0.10 foot.

Surveying data were horizontally georeferenced to the North American Datum of 1983 (NAD83) California State Plane Zone 6 system and vertically georeferenced to the North American Vertical Datum of 1988 (NAVD88) in units of U.S. survey feet. **Figures 3-1** and **3-2**, above, show the surveyed transect locations and **Figure 4-1** shows the surveyed stream channel profiles along each transect. These five channel profiles are shown on one chart to illustrate how their shapes compare. Each width profile is referenced as the distance from its left bank, when facing the downstream direction.

As shown in **Figure 4-1**, the Santa Ysabel Creek channel generally widens in a downstream direction from T-1 to T-4 and the steepness between the main lower-flow channel and its banks generally decreases in a downstream direction (the channel becomes wider and flatter as the valley opens up). These characteristics are consistent with the conceptual model of a stream entering the Basin in a somewhat constricted channel in the east with the stream corridor broadening in a downstream direction in the SPV.

These stream channel profiles, along with other available topographic data, will be used to update modeled stream geometries in the SPV GSP Model, as described in Section 5.1.

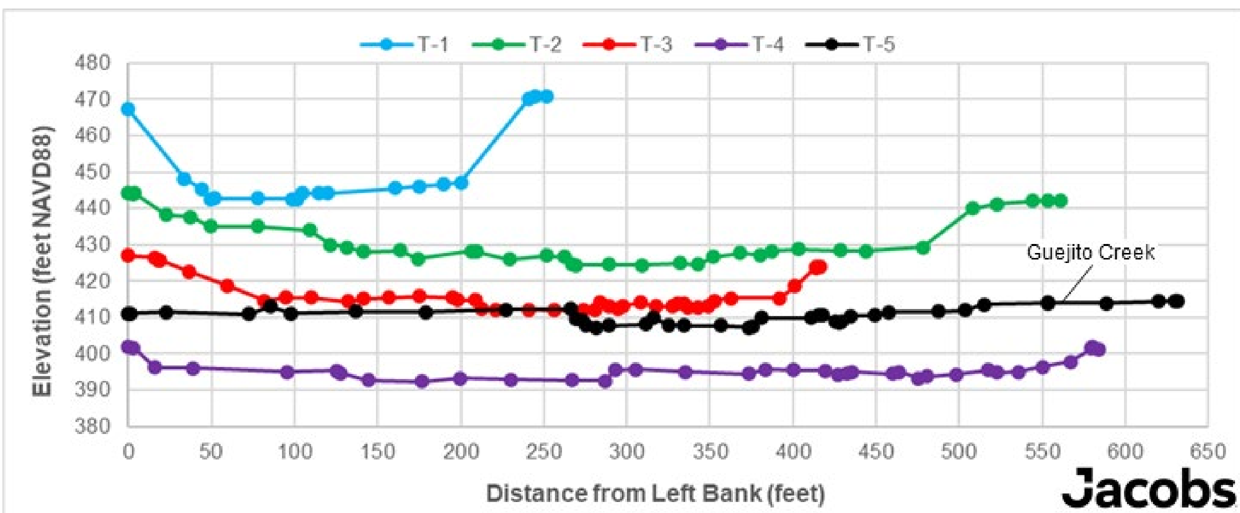

Figure 4-1. Stream Channel Profiles Along the Five Transects

4.2 Streambed Infiltration Testing Results

4.2.1 Modifications to the Infiltration Testing Methodology

An initial set of infiltration tests at T-1 and T-4 was attempted on July 18, 2022 through July 22, 2022 in accordance with ASTM D3385 (double-ring infiltrometer). These initial sets of infiltration tests at T-1 and T-4 (**Figures 3-1** and **3-2**) revealed that infiltration capacities were too great to effectively replenish the infiltration rings with hand-carried buckets of water and measure flow rates between trips to and from the support vehicle to refill buckets. Thus, a more continuous supply of water at higher flow rates was needed to complete the infiltration testing. As such, a modified procedure was developed by Jacobs to complete the testing.

The modified procedure is outlined in Attachment I within Attachment A of this memorandum. This constant-head procedure included the use of a water truck, temporary conveyance hosing to route water from the water truck to each test site, a flow meter, and a single-ring infiltrometer. Although the double-ring infiltrometer helps reduce divergent flow behavior, the single-ring infiltrometer was selected for the modified method, given the factors described in Section 3.2 and the continued uncertainty in flow rate requirements to perform infiltration testing. The modified procedure included using the smaller 12-inch diameter inner ring without the 24-inch diameter outer ring, because doing so would require less water and be more efficient in terms of ease of setup and operation during testing.

A second phase of infiltration testing was conducted from October 11, 2022 through October 14, 2022. A combination of methods was used because testing at T-3R on October 11, 2022 (the first day of testing during the second phase) with a single-ring infiltrometer indicated that flow rates were low enough that subsequent "R" locations could be reasonably managed with the aid of the water truck using the ASTM D3385 (double-ring infiltrometer) method, which would result in less divergent flow below the test ring (**Figure 3-3**).

For an additional line of analysis, sieve analyses were performed in accordance with *Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis* (ASTM D6913) (ASTM International, 2009) on sediment samples collected at each test site to quantify the grain size distributions and provide information on soil texture. Finally, to more efficiently complete the work, the three planned tests at Transect T-5 and all other planned tests at left (L) locations at the other four transects were removed from the schedule. Thus, the center (C) and right (R) testing locations at Transects T-1 through T-4 were retained, resulting in eight testing sites along Santa Ysabel Creek rather than the originally planned 15 testing sites (**Figure 3-2**).

4.2.2 Infiltration Testing Results

Attachments II and III in Attachment A of this technical memorandum include the time-series data recorded during infiltration testing and grain size distribution charts that resulted from the October 2022 streambed investigation. **Table 4-1** summarizes the results from the streambed investigation. The analytical methods used to compute these results are described later in this section.

The steady flow rates and streambed vertical hydraulic conductivity values for the "C" locations were all greater than those rates and values for the "R" locations. This is consistent with the grain size analysis data. Sieve-tested sediments in the main Santa Ysabel Creek flow channel (corresponding to the "C" locations) are classified as poorly graded sand (SP). Poorly-graded (well-sorted) sediments have a narrower range of grain sizes, whereas well-graded (poorly-sorted) sediments have grains of many sizes. Tested sediments in the higher-flow portions of the Santa Ysabel Creek channel (corresponding to the "R" locations) have a greater percentage of finer-grained sediment as compared with the "C" locations and are classified as sandy silt (ML) or silty sand (SM) (**Table 4-1** and **Figure 3-2**).

Figure 4-2 shows the general relationships among different physical soil parameters. It is reasonable to expect the sediments in the Santa Ysabel Creek streambed to have a total porosity in the range of 35 to 40 percent (Freeze and Cherry, 1979; Vukovic and Soro, 1992). For a total porosity in the 35- to 40-percent range, the hydraulic conductivity values listed in **Table 4-1** for the "C" and "R" locations (**Figure 3-2**) plot in ranges of grain size and grading that are reasonable with respect to the grain size distributions presented in Attachment III within Attachment A of this technical memorandum. Thus, there is good consistency between the estimated parameter values from the infiltration tests and the grain size distributions from the sieve analyses.

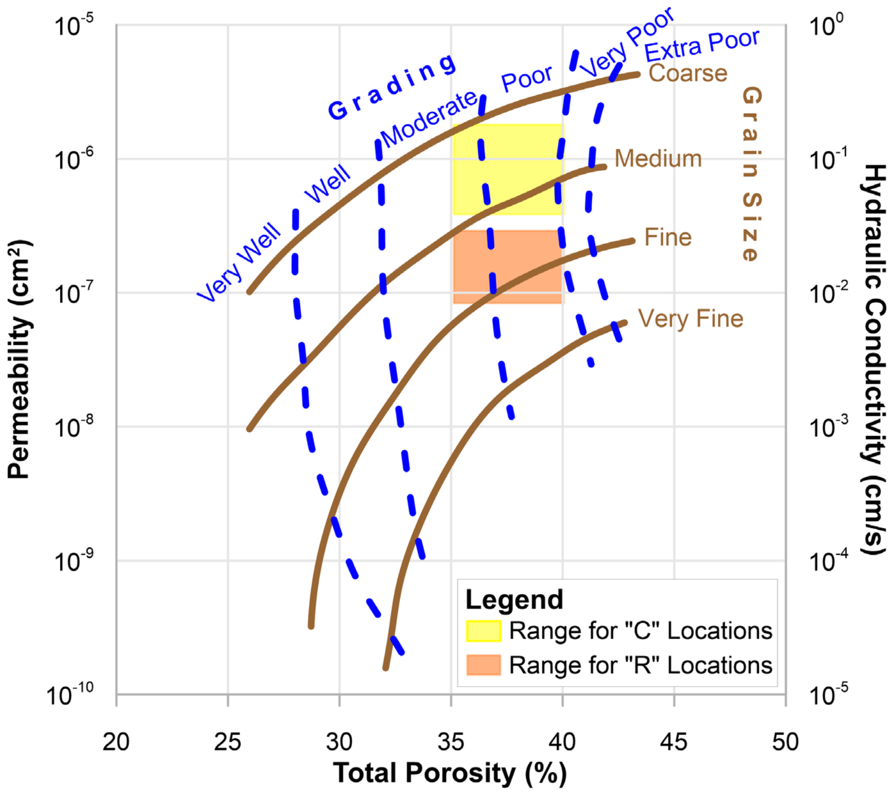

Image Modified from Selley and Sonnenberg (2015)

Figure 4-2. Relationships Among Different Physical Soil Parameters

Table 4-1. Summary of Infiltration Testing Results

Infiltration Testing Location	Test Date	Test Method	Soil Texture [a]	Water Temperature (°F)	Steady Flow Rate (gpm) [cm/s]	Flow Duration (min)	Streambed Vertical Hydraulic Conductivity (ft/d) [cm/s]
T-1C	10/13/2022	Single-ring infiltrometer	SP	72	10.6 [9.2E-01]	120	373 [1.3E-01]
T-2C	10/14/2022	Single-ring infiltrometer	SP	72	15.7 [1.4E+00]	135	552 [1.9E-01]
T-3C	10/11/2022	Single-ring infiltrometer	SP	NM	3.3 [2.9E-01]	180	116 [4.1E-02]
T-4C	10/12/2022	Single-ring infiltrometer	SP	NM	4.5 [3.9E-01]	150	158 [5.6E-02]
T-1R	10/13/2022	Double-ring infiltrometer	ML	78	0.4 [3.5E-02]	135	48 [1.7E-02]
T-2R	10/14/2022	Double-ring infiltrometer	SM	72	0.2 [1.7E-02]	125	24 [8.5E-03]
T-3R	10/11/2022	Single-ring infiltrometer	SM	NM	0.7 [6.1E-02]	136	25 [8.8E-03]
T-4R [e]	10/12/2022	Double-ring infiltrometer	SM	NM	0.7 [6.1E-02]	35	83 [2.9E-02]
Geomean-C [b]							*248 [8.7E-02]*
Geomean-R [c]							*39 [1.4E-02]*
Geomean-R,C [d]							*99 [3.5E-02]*

[a] Unified Soil Classification System: SP = poorly-graded sand, ML = sandy silt, and SM = silty sand

[b] Geometric mean of streambed vertical hydraulic conductivity values for the center (C) locations.

[c] Geometric mean of streambed vertical hydraulic conductivity values for the right (R) locations.

[d] Geometric mean of streambed vertical hydraulic conductivity values for both center (C) and right (R) locations

[fe] The test was stopped sooner than the other tests due to water truck availability constraints.

NM = Not measured | °F = degrees Fahrenheit | gpm = gallons per minute | min = minutes | ft/d = feet per day | cm/s = centimeters per second

Two analytical methods were used to account for divergent flow (**Figure 3-3**) that occurred below the test rings when computing the streambed vertical hydraulic conductivity (**Table 4-1**): the Reynolds and Elrick (1990) method (which was further evaluated by Nimmo et al., 2009) for the single-ring infiltrometer tests and the Fatehnia et al. (2016) method for the double-ring infiltrometer tests. Application of these methods results in the estimation of F (**Table 4-2**), which is a factor by which the infiltration rate exceeds the streambed vertical hydraulic conductivity, as follows:

$$I = \frac{Q}{\pi \cdot r^2} \quad (1)$$

$$K_{v-sb} = \frac{I}{F} \quad (2)$$

where

I = steady infiltration rate to maintain a constant head in the ring (L/T)
Q = steady volumetric flow rate to maintain a constant head in the ring (L^3/T)
r = radius of the infiltrometer ring (L)
K_{v-sb} = streambed vertical hydraulic conductivity (L/T)

Table 4-2. Equations to Compute Streambed Vertical Hydraulic Conductivity

Single-ring Infiltrometer (Reynolds and Elrick, 1990; Nimmo et al., 2009)	Double-ring Infiltrometer (Fatenhia et al., 2016)
$F = 1 + \frac{\lambda + H}{0.993D + 0.578r} \approx 7$ $K_{v-sb} = \frac{I}{F} = \frac{I}{7}$	$F = 1 + 1.10451\left(\frac{H \cdot \lambda}{\left[\frac{\theta - \theta_r}{\theta_s - \theta_r} + 1\right] \cdot d_i \cdot D}\right)^{0.53} \approx 2$ $K_{v-sb} = \frac{I}{F} = \frac{I}{2}$
where λ = macroscopic capillary length = 0.083 m [a] H = ponding height inside the ring = 18 in = 0.457 m [b] D = ring insertion depth = 0.1 in = 0.003 m [b,f] r = ring radius = 6 in = 0.152 m [b] Length units of meters (m) are required.	where λ = macroscopic capillary length = 8.3 cm [a] H = ponding height inside the ring = 14 in = 35.6 cm [b] D = ring insertion depth = 4 in = 10.2 cm [b] d_i = inner ring diameter = 12 in = 30.5 cm [b] θ = volumetric water content = 0.06 [c] θ_r = residual water content = 0.05 [d] θ_s = saturated water content = 0.36 [e] Length units of centimeters (cm) are required.

[a] Suggested value for sand (Elrick et al., 1989).
[b] Value based on infiltration testing in October 2022. See Attachment A for more details.
[c] Assumption based on dry initial conditions during October 2022 field effort.
[d] Value based on soil catalog value for sand (Carsel and Parrish, 1988).
[e] Assumed to be equivalent to total porosity; computed from grain size analysis (Vukovic and Soro, 1992).
[f] The single ring was inserted about one foot into the sediment and all but the bottom 0.1 inch of sediment from the inner portion of the single ring was removed to accommodate a deeper ponding height.

The F factors that pertain specifically to the setup used for infiltration testing along Santa Ysabel Creek in October 2022 are computed as shown in **Table 4-2**. Other setups could result in F factors that are different than those presented in **Table 4-2**. The F factor for the single-ring infiltrometer is approximately 3.5 times greater than the F factor for the double-ring infiltrometer. This is reasonable given that the double-ring approach is intended to minimize the divergent flow effect below the infiltration ring (**Figure 3-3**). In other words, the divergent flow effect below the single-ring infiltrometer is estimated to have been about 3.5 times greater than the divergent flow effect below the double-ring infiltrometer during testing in October 2022.

4.3 Photographic Surveys

A photographic survey was conducted in the eastern portion of the Basin on January 16, 2023. Jacobs staff selected this date based on the following information:

- Weather forecasts from the National Weather Service website[2] from the National Oceanic and Atmospheric Administration.
- Real-time hourly precipitation at California Irrigation Management Information System (CIMIS) station Escondido SPV #153 (**Figure 4-3**).
- United States Geological Survey (USGS) real-time streamflow data from the Santa Ysabel Creek (11025500), Guejito Creek (11027000), and Santa Maria Creek (11028500) stream gauges (**Figure 4-3**). These are the closest available stream gauges to the Basin.
- Real-time groundwater-level data from monitoring wells SDSY and SP073 (**Figure 4-3**)
- Text messages from a local resident confirming the presence of streamflow in the Basin.

Figure 4-4 shows cumulative hourly precipitation from the CIMIS Escondido SPV #153 station and cumulative 15-minute streamflow data in units of thousand acre-feet (TAF) from the aforementioned stream gauges along with depths to water at monitoring wells SDSY and SP073. As of the writing of this technical memorandum, data presented in **Figure 4-4** are classified as provisional (that is, subject to change after data are vetted by the agency responsible for the data collection). Displayed data start at the beginning of the 2023 water year (that is, October 1, 2022). The date labels on the horizontal axis are shown at 2-week intervals; vertical grid lines are shown at weekly intervals.

Although the SPV received nearly 2 inches of cumulative rainfall at the CIMIS Escondido SPV #153 station during the fourth quarter of 2022, this was not enough to generate streamflow at the Santa Ysabel Creek or Guejito Creek gauges. It was not until after receiving an additional 2 inches of rain at the CIMIS station during the 2-week period of storms that began on January 1, 2023 that streamflow at Santa Ysabel Creek occurred. Correspondence with a local resident indicated there was no streamflow in the Basin until around January 14th. When Jacobs field staff conducted the midday photographic survey two days later on January 16, 2023 after an additional 2.5 inches of rainfall accumulation at the CIMIS station, streamflow in Santa Ysabel Creek was continuous throughout the Basin, overtopping Ysabel Creek Road (**Figure 4-5**). According to a local resident, streamflows across Ysabel Creek Road are rare, occurring about once or twice per decade. Although streamflow along Santa Ysabel Creek in the eastern portion of the Basin began around

[2] https://forecast.weather.gov/MapClick.php?lon=-116.94628715515137&lat=33.091705590664475#.Y86wfXbMKUk

January 14th, groundwater levels at SDSY (approximately 100 feet from the stream) did not respond to this streamflow until a few days later around January 18th. Groundwater-level trends at SP073 (approximately 700 feet from the stream) do not show a similar response to streamflows (compare depths to water at SDSY and SP073 after January 16, 2023 in **Figure 4-4**). In summary, anecdotal information from local residents along with data presented in **Figure 4-4** indicate there may need to be a few inches of precipitation over a one- to two-week period before streamflow occurs in the Basin and it may take a few more days after that for groundwater levels next to the stream to respond.

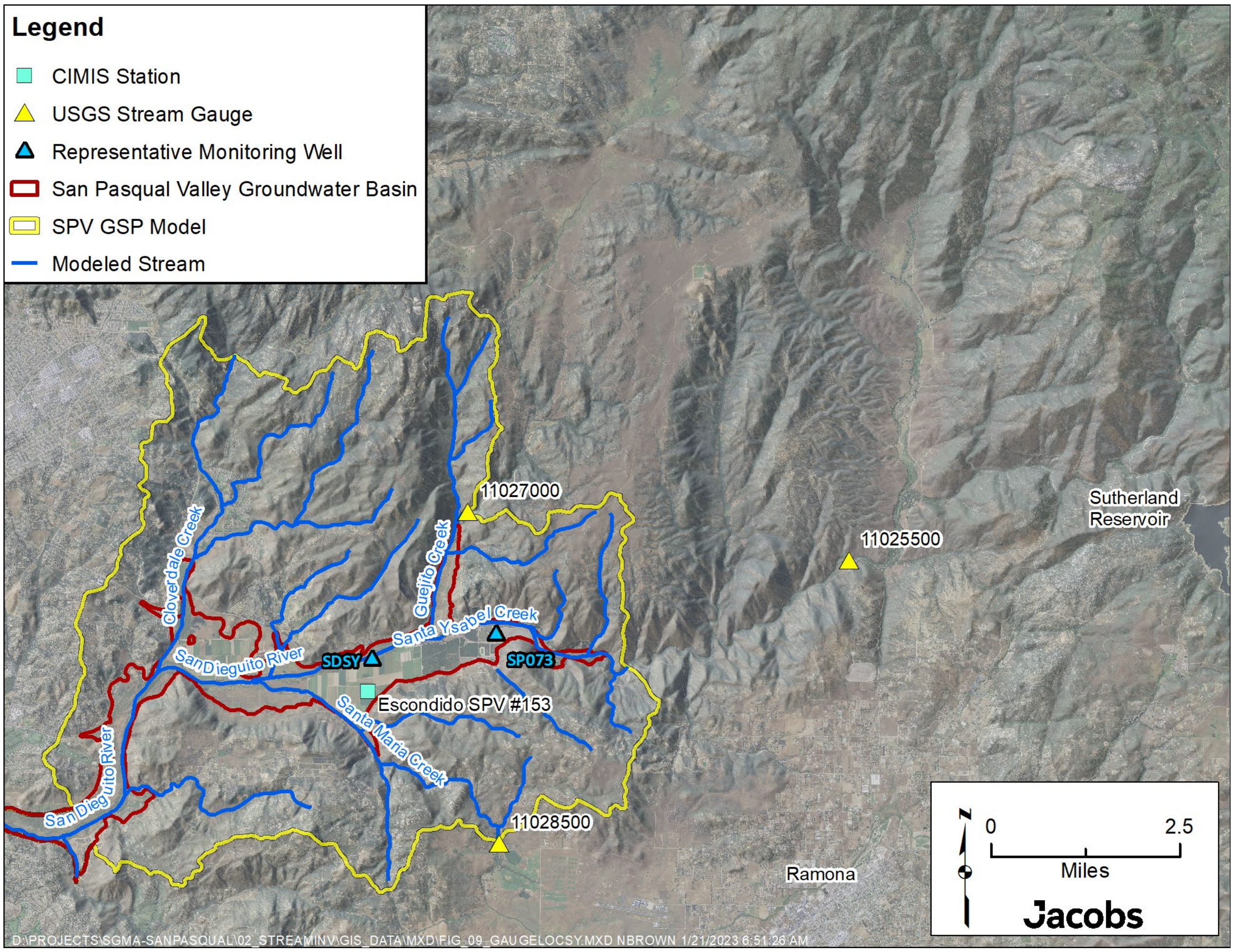

Figure 4-3. Stream and Precipitation Gauge Locations

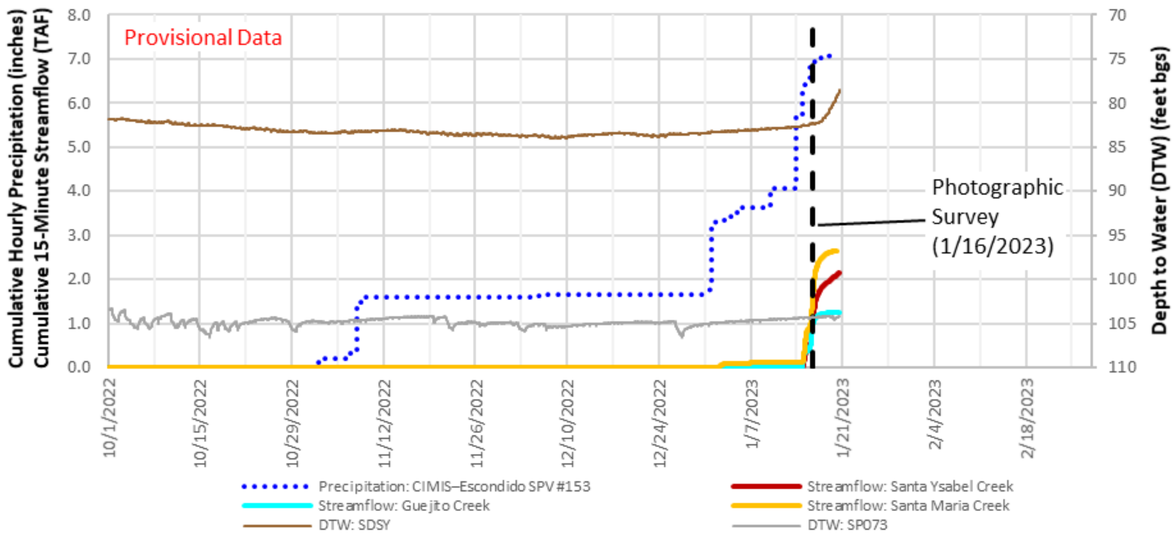

Figure 4-4. Hydrologic Conditions Before, During, and After the Photographic Survey

Figure 4-5. Photographs of Streamflow Conditions on January 16, 2023

5. RECOMMENDATIONS FOR UPDATING THE SPV GSP MODEL

The following subsections describe the recommendations for updating the SPV GSP Model with information acquired during execution of the streambed investigation to support the PMA No. 7 analysis. Consistent with Section 1.0, the version of the SPV GSP Model used during development of the GSP (City and County, 2021) and described in the following subsections is referred to as SPV GSP Model v1.0, whereas the updated version that will be used to support decisions associated with PMA No. 7 will be referred to as the SPV GSP Model v2.0. Model updates will include refining channel geometries that align more closely with actual channel shapes in the Basin, updating model parameters based on the streambed vertical hydraulic conductivity data listed in **Table 4-1**, and updating the streamflow calculation method to more accurately compute streamflow characteristics. Together, these changes will make the SPV GSP Model v2.0 more reliable with respect to streamflow and groundwater/surface-water interaction, particularly in the eastern portion of the Basin. It is anticipated that these changes will likely result in more stream infiltration in the SPV GSP Model v2.0, as compared with the SPV GSP Model v1.0. Details of how each of the recommendations will be implemented in the SPV GSP Model v2.0 are provided in the following subsections.

5.1 Stream Channel Definition and Calculation Method

The information acquired from the stream channel survey described in Section 4.1 will be used to refine the channel geometries incorporated into the SFR package in the SPV GSP Model v2.0. Currently, the SFR package in the SPV GSP Model v1.0 represents modeled stream channels with simple rectangular channel geometries (**Table 2-1**). A variable named "ICALC" in the SFR package controls the method used to compute stream depth. The SPV GSP Model v1.0 uses ICALC=1, whereby stream depth is calculated using Manning's equation assuming a fixed rectangular channel. This formulation of the SFR constrains the wetted widths of modeled streams to the assigned rectangular stream width, regardless of the magnitudes of different streamflow events. As shown in **Figure 4-1**, the stream channels in the SPV have irregular shapes that will result in variable flow depths and widths under varying streamflow conditions. The modeling team will switch to ICALC=2, whereby stream depth is calculated using Manning's equation assuming an eight-point channel profile for each stream segment (Attachment B). Stream depth, width, and wetted perimeter (perimeter of the cross-sectional area that is wet) are computed from the eight-point channel profile for a given flow using Manning's equation and by dividing the channel profile into three parts (**Figure 5-1**). A different value of Manning's roughness coefficient can be used in the calculations for Parts 1 and 3 (to represent overbank flow) from that used in Part 2 (Prudic et al., 2004; Niswonger and Prudic, 2005). The necessity for assigning different Manning's roughness coefficients in the Part 2 versus Parts 1 and 3 areas in the SPV GSP Model v2.0 will be evaluated when the model undergoes recalibration.

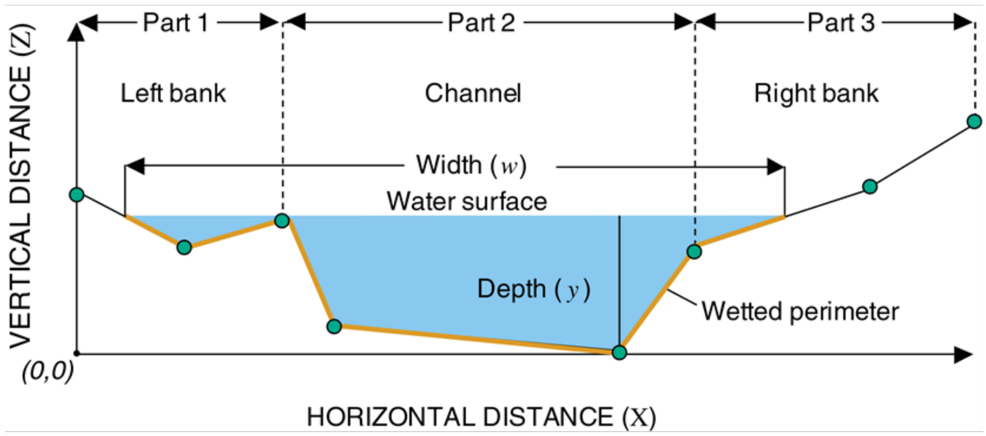

Image Source: Prudic et al. (2004)

Figure 5-1. Conceptual Eight-point Cross Section

Figure 5-2 illustrates the relationship between SFR stream segments and reaches. SFR segments are made up of smaller SFR reaches, which are the groundwater cells intersected by the SFR segments. Attachment B shows the eight-point stream channels that are planned for the SPV GSP Model v2.0. These eight-point channels were generated with the best available elevation data from a combination of surveyed stream data (**Figure 4-1**) and 3- and 10-meter resolution digital elevation models.

As modeled stream depths increase, the widths and wetted perimeters will automatically increase in the model based on the shapes of the stream channels, which are assigned for each SFR stream segment (**Figure 5-2**). This configuration of the SFR package will provide the opportunity for improved representation of transient wetted widths of the modeled streams and more accurate simulation of groundwater/surface-water interactions during streamflow events of different magnitudes. Incorporating these changes to the SFR package will likely result in more stream infiltration in the SPV GSP Model v2.0, as compared with the SPV GSP Model v1.0.

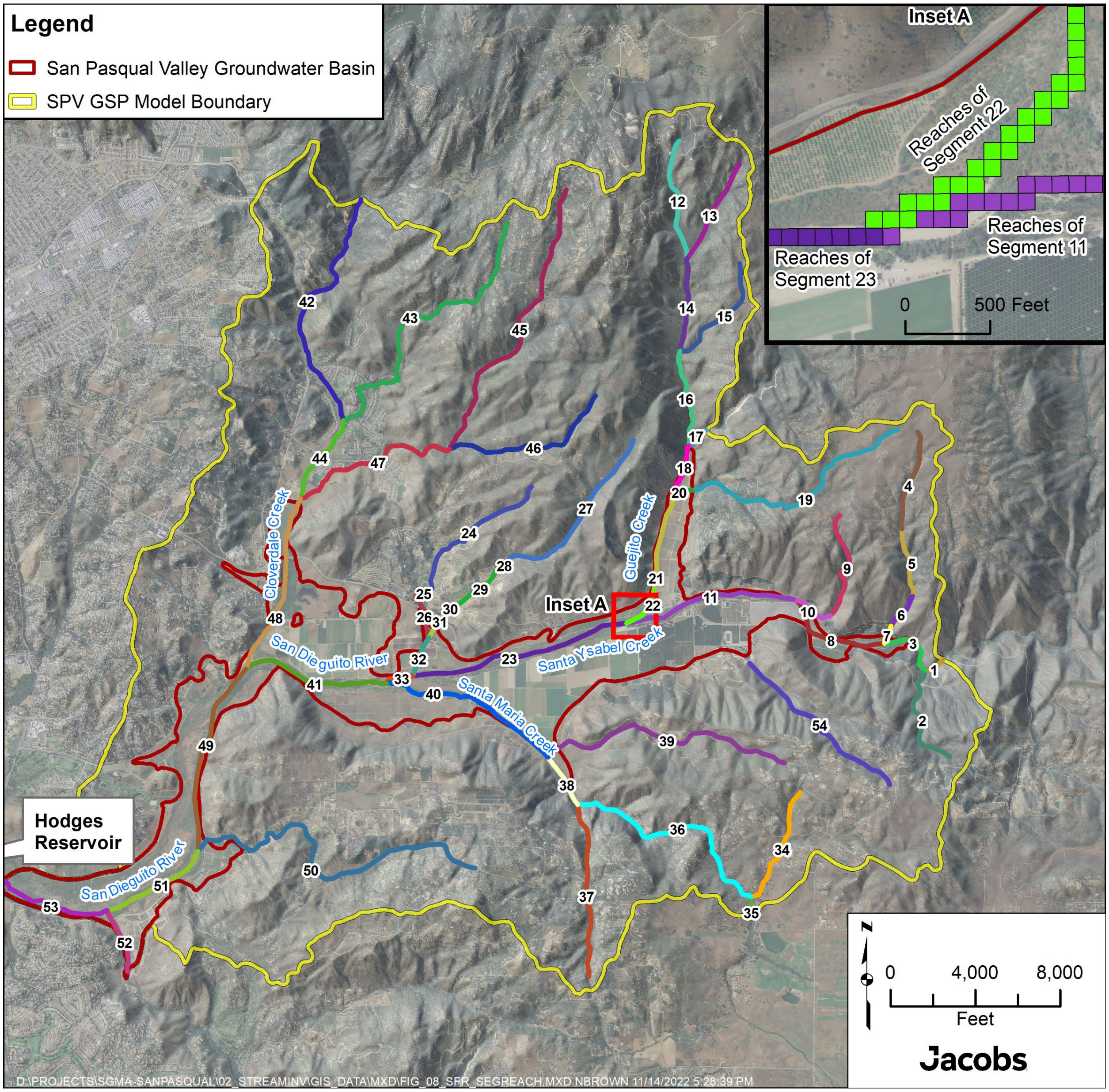

Figure 5-2. Map of Modeled Stream Segment Numbers and Stream Reaches

5.2 Approach for Updating Hydraulic Conductivity Assigned to Modeled Streams

The resulting estimates of streambed vertical hydraulic conductivity from the infiltration tests will help inform decisions related to the parameters in the SFR package of the model.

Due to a lack of groundwater monitoring wells in the Santa Ysabel Creek streambed, estimation of the vertical distribution of hydraulic conductivity in the depth interval between the bottom of the streambed and the water table cannot be estimated solely with the infiltration testing data. This limitation is especially relevant in the eastern portion of the Basin where the water table is decoupled from and typically dozens of feet below Santa Ysabel Creek. In this hydrologic setting, the least permeable sediment intervals between the streambed and water table are the intervals that control the rate of groundwater recharge from infiltration. Shorter-term infiltration tests only provide information on the vertical hydraulic conductivity of the shallower sediments rather than the effective vertical hydraulic conductivity of all the underlying materials above the deeper water table (Johnson, 1963). Therefore, vertical hydraulic conductivity estimates of shallower sediments from shorter-term infiltration tests in such hydrologic settings need to be processed as such when deciding how to incorporate the information into the SPV GSP Model v2.0. The following paragraph explains why.

It is important to understand the basic limitations of the SFR package as it has been configured in the SPV GSP Model v1.0, especially as it pertains to the eastern SPV where the water table is well below and decoupled from the stream bottom. When the modeled water table is below the stream bottom elevation, the magnitude of leakage from the stream to the underlying aquifer is independent of the water table elevation. Under this condition, leakage from the stream to the underlying aquifer is a function of the stream depth as the driving force with the vertical hydraulic conductivity, stream length, width, wetted perimeter, and streambed thickness collectively establishing the resistance of flow through the streambed. Further, flow across the streambed in the SFR package is translated directly to the underlying water table without delay and the leakage rate is not allowed to exceed the vertical hydraulic conductivity assigned to the SFR (Prudic et al., 2004). In other words, when the water table is decoupled from the modeled stream, the leakage rate from the stream is computed using the vertical hydraulic conductivity assigned in the SFR package as the effective vertical hydraulic conductivity of the entire vadose zone; thereby ignoring the vertical hydraulic conductivity assigned to the underlying groundwater cell in Model Layer 1 (that is, the model layer representing the unconfined alluvial aquifer below the modeled stream). As discussed above, the hydraulic conductivity value assigned in the SFR package should be based on not only the streambed hydraulic conductivity (that is, $K_{v\text{-}sb}$ in **Table 4-2**), but also the hydraulic conductivity of the vadose-zone sediments ($K_{v\text{-}vz}$) located between the streambed and water table. The plan for the SPV GSP Model v2.0 is to assign an effective vertical hydraulic conductivity in the SFR package ($K_{v\text{-}SFR}$) equal to the harmonic mean (Freeze and Cherry, 1979) of the $K_{v\text{-}sb}$ and the $K_{v\text{-}vz}$, according to Equation 3, as follows:

$$K_{v-SFR} = \frac{b_t}{\frac{b_{sb}}{K_{v-sb}} + \frac{b_{vz}}{K_{v-vz}}} \tag{3}$$

where

- b_{sb} = thickness of the modeled streambed [L]
- b_{vz} = thickness of the interval between the bottom of the streambed and average water table elevation [L]
- b_t = total porous medium thickness above the average water table elevation = b_{sb} + b_{vz} [L]

The $K_{v\text{-}SFR}$ value establishes the effective resistance to flow after water infiltrates the streambed and moves downward through the vadose zone to the underlying water table. The smaller the effective hydraulic conductivity value the greater the resistance to downward flow.

Model recalibration will begin by assigning the $K_{v\text{-}sb}$ for Santa Ysabel Creek the geometric mean of the center (C) infiltration testing results, which is approximately 250 ft/d (8.8E-02 cm/s) (**Table 4-1**). The range of $K_{v\text{-}sb}$ values listed in **Table 4-1** will be used to put approximate bounds on this parameter during the recalibration process. The K_{v-vz} will be based on the calibrated vertical hydraulic conductivity values assigned to groundwater model cells in Model Layer 1 that underlie SFR reaches (**Figure 5-2**). It is anticipated from early efforts of updating the SPV GSP Model v2.0 that the K_{v-vz} may be on the order of dozens of ft/d. Ultimately, the K_{v-SFR} will be assigned using Equation 3, which is the harmonic mean of the K_{v-sb} and K_{v-vz}.

5.3 Approach for Incorporating Results from the Photographic Survey

Information obtained from the photographic survey serves as visual evidence that will be kept in mind when updating the SPV GSP Model v2.0. For example, if there is a period of similar Basin inflow conditions in Santa Ysabel Creek, Guejito Creek, and Santa Maria Creek during the 15-year historical simulation period from October 1, 2004 through September 30, 2019, then the model could be assessed in terms of its ability to generate streamflow in Santa Ysabel Creek across Ysabel Creek Road. Such a comparison would help further inform whether additional refinements should be made with the parameters in the SFR package.

6. SUMMARY

Stream channel surveying at four transects across Santa Ysabel Creek and one transect across Guejito Creek was conducted from June 27, 2022 through June 29, 2022 to develop channel profiles and understand the shape of the channel at each of these transects (**Figure 3-1**). Surveying data were horizontally georeferenced to the NAD83 California State Plane Zone 6 system and vertically georeferenced to NAVD88 in units of U.S. survey feet. The stream channel profiles, along with other available topographic data, will be used to update modeled stream geometries in the SPV GSP Model v2.0, as described in Section 5.1.

Data from streambed constant-head infiltration testing that was conducted from October 11, 2022 through October 14, 2022 at eight locations (see "C" and "R" locations at T-1 through T-4 locations on **Figure 3-2**) were used to estimate K_{v-sb} and quantify sediment grain sizes. Both single-ring and double-ring infiltrometers were used for the infiltration tests. The late-time (steady) flow rates from these infiltration tests were processed to compute K_{v-sb} at each test location. The K_{v-sb} values range from 116 to 552 ft/d (4.1×10^{-2} to 1.9×10^{-1} cm/s) in the lower-flow channel ("C" locations) and from 24 to 83 ft/d (8.5×10^{-3} to 2.9×10^{-2} cm/s) on the higher-flow banks ("R" locations) (**Table 4-1**). These data indicate the streambed sediments in Santa Ysabel Creek are permeable (high K_{v-sb}). Sieve testing from sediment samples collected at these infiltration testing locations indicate poorly graded sand at the "C" locations and sandy silt to silty sand at the "R" locations, which is consistent with the ranges of K_{v-sb}. The K_{v-sb} values that will be used, along with estimates of the K_{v-vz} to update the SPV GSP Model v2.0 streambed properties, which will be used to help assess potential recharge strategies, as described in Section 5.2

A photographic survey along portions of Santa Ysabel Creek, Guejito Creek, and Santa Maria Creek was conducted on January 16, 2023 to document streamflow locations following a wet 2-week period. Anecdotal information from local residents along with data presented in **Figures 4-4 and 4-5** indicate there may need to be several inches of precipitation over a one- to two-week period before streamflow occurs in the Basin and it may take a few more days after that for groundwater levels next to the stream to respond. This information will be kept in mind when updating the SPV GSP Model v2.0.

7. REFERENCES

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ATTACHMENT A: INFILTRATION TESTING LETTER REPORT

6280 Riverdale Street
San Diego, CA 92120
(877) 215-4321 | oneatlas.com

November 9, 2022

Atlas No. 220083P6
Report No. 1896-1R

MS. SALLY JOHNSON
WOODARD & CURRAN
9665 CHESAPEAKE DRIVE, SUITE 320
SAN DIEGO, CALIFORNIA 92123

Subject: Infiltration Data Transmittal Letter
San Pasqual Valley Infiltration Testing
San Diego, California

Dear Ms. Johnson,

Atlas is pleased to present this infiltration data transmittal letter discussing the in-situ infiltration testing performed for the subject project. Atlas conducted the infiltration testing in general conformance with the scope of work presented in our amendment number 1R2 dated August 29, 2022. This letter presents the field and laboratory testing we performed at select locations along Santa Ysabel Creek in San Pasqual Valley of San Diego, California.

INTRODUCTION

This letter presents the results of field work performed by Atlas for the City of San Diego Groundwater Sustainability project. The purpose of our work was to perform in-situ infiltration testing and collect soil samples for laboratory testing in both high flow and low flow sections of the stream bed.

SITE DESCRIPTION

The project site is located in portions of Santa Ysabel Creek which runs westward along San Pasqual Valley toward Lake Hodges. The testing was performed at four transects – two tests at each transect – spreading along approximately 3 miles of the creek. The project team selected the test locations. The approximate location of the project site is presented in Figure 1, Site Vicinity Map.

SCOPE OF WORK

The geotechnical scope of work performed by Atlas consisted of:

- Performing infiltration testing at approximately the center of the inferred primary low-flow channel (i.e., C locations) and on the northern side of the center test in the inferred higher flow portions of the channel (i.e., R locations), at locations previously marked by others (Figure 2).
- Collecting soils samples from the test locations and performing particle-size distribution testing.
- Presenting the field and laboratory test results in this letter report.

INFILTRATION TESTING

Atlas attempted to perform double-ring infiltration testing and borehole percolation testing at the site in general accordance with ASTM D3385, Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer, and County of Riverside LID Design Handbook, respectively, in July of 2022. However, initial observation and percolation testing indicated a more continuous supply of water at higher flow rates should be considered to perform infiltration testing at the site. A modified constant head permeameter testing procedure was subsequently developed by Jacobs to assess the infiltration conditions at the site (Attachment I).

The modified test method included using an approximately 3,000-gallon water truck to provide a sufficient flow and volume of water to maintain a constant head during testing. Atlas performed the testing at the C locations in general accordance with procedures described in Attachment I and verbal directions provided by the client during the testing. As relatively lower permeability of near-surface materials was observed at T3-R on the first day of field work, it was decided to perform infiltration testing in general accordance with ASTM D3385 guidelines when materials of similar permeability were encountered elsewhere (i.e., at T1-R, T2-R, and T4-R).

The double-ring infiltration procedure included placing a 12-inch-diameter, 20-inch-tall metal ring approximately 4 inches into the ground and placing a 24-inch-diameter, 20-inch-tall ring approximately 6 inches into the ground, surrounding the inner ring. A graduated cylinder was used to assess the volume of water to maintain a constant head within the inner ring. Water was directed from a conveyance hose into the outer ring to maintain a constant head. The infiltration test was continued until either the infiltration rates stabilized, or the continuous flow of water from the water truck was no longer available (i.e., at T4-R). After the testing was completed, the soils below the test location were excavated to assess the wetted area. Field data collected during infiltration testing is presented in Attachment II. The wetted radii observations at each location are listed in Table 1. Our scope did not include post-processing the infiltration results to calculate the hydraulic conductivity of the riverbed sediments.

GEOTECHNICAL LABORATORY TESTING

Atlas representatives collected a disturbed bulk sample of the material at each testing location, which were then transported to our in-house geotechnical laboratory for testing. The samples obtained from the infiltration testing locations were tested for particle-size distribution per ASTM D6913 guidelines to evaluate pertinent classification and engineering properties of subsurface materials.

GEOLOGY AND SUBSURFACE CONDITIONS

Based on the materials encountered during our investigation and review of geologic maps (Figure 3), the site is generally underlain by alluvium. As encountered, the alluvium at the center of the inferred primary low-flow channel generally consisted of loose, fine to coarse grained, poorly graded sand. The alluvium on the northern side of the center test at the inferred higher flow portions of the channel generally consisted of a loose to medium dense, fine to medium grained, silty sand, poorly graded sand, and sandy silt. Groundwater or seepage was not observed at the test locations. Results of laboratory testing performed on collected samples are presented in Attachment III. Tested USCS classifications and the wetted radius measured at each location are summarized in Table 1.

Table 1: USCS Classifications of the Riverbed Materials

Test Location	Soil Type (USCS)	Approximate Wetted Radius (feet)
T1-C	Poorly Graded SAND (SP)	-
T2-C	Poorly Graded SAND (SP)	2½
T3-C	Poorly Graded SAND (SP)	3
T4-C	Poorly Graded SAND (SP)	5
T1-R	Poorly Graded SAND (SP)	-
T2-R	SANDY SILT (ML)	1½
T3-R	SILTY SAND (SM)	1
T4-R	SILTY SAND (SM)	2

Notes: (-) indicates not observed. Measurements are approximate.

CLOSURE

Atlas should be advised of changes in the project scope so that the recommendations contained in this report can be evaluated with respect to the revised plans. Changes in recommendations will be verified in writing. The findings in this report are valid as of the date of this report. Changes in the condition of the site can, however, occur with the passage of time, whether they are due to natural processes or work on this or adjacent areas. In addition, changes in the standards of practice and government regulations can occur. Thus, the findings in this report may be invalidated wholly or in part by changes beyond our control. This report should not be relied upon after a period of two years without a review by us verifying the suitability of the conclusions and recommendations to site conditions at that time.

In the performance of our professional services, we comply with that level of care and skill ordinarily exercised by members of our profession currently practicing under similar conditions and in the same locality. The client recognizes that subsurface conditions may vary from those encountered at the test hole locations, and that our data, interpretations, and recommendations are based solely on the information obtained by us. We will be responsible for those data, interpretations, and recommendations, but shall not be responsible for interpretations by others of the information developed. Our services consist of professional consultation and observation only, and no warranty of any kind whatsoever, expressed or implied, is made or intended in connection with the work performed or to be performed by us, or by our proposal for consulting or other services, or by our furnishing of oral or written reports or findings.

We appreciate the opportunity to provide our services. Should you have any questions, please contact the undersigned.

Respectfully submitted,
Atlas Technical Consultants LLC

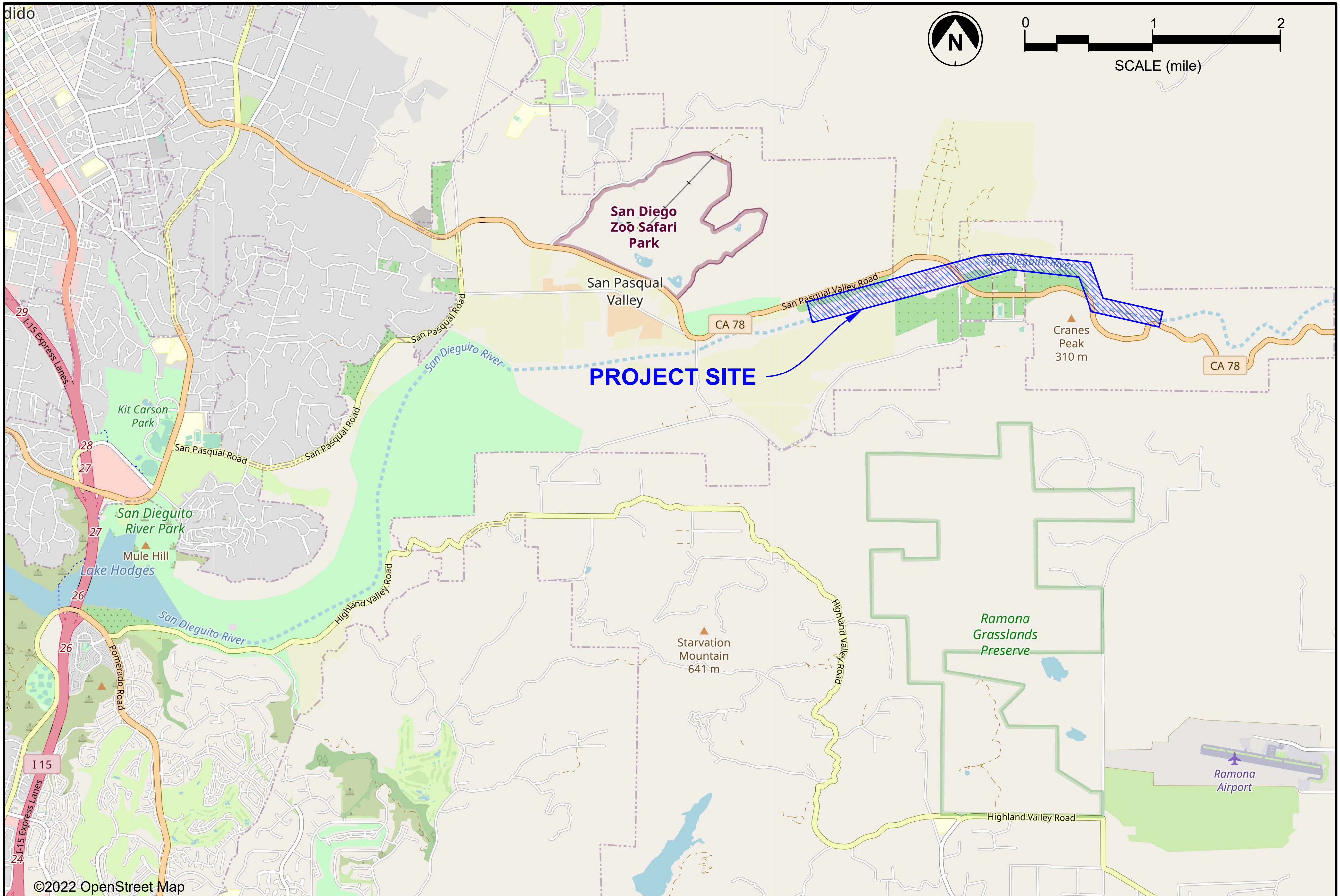
Douglas A. Skinner, CEG 2472
Senior Geologist

Morteza Mirshekari, PhD, PE C92374
Senior Engineer

JRD:JM:DAS:MM:ds

Attachments: Figure 1 – Site Vicnity Map
Figures 2A-2D – Subsurface Investigation Map
Figure 3 – Regional Geology Map
Attachment I – Well Permeameter Infiltrrtion Testing Procedure
Attachment II – Infiltration Test Data
Attachment III – Laboratory Testing

Distribution: sjohnson@woodardcurran.com



ATLAS

SITE VICINITY MAP

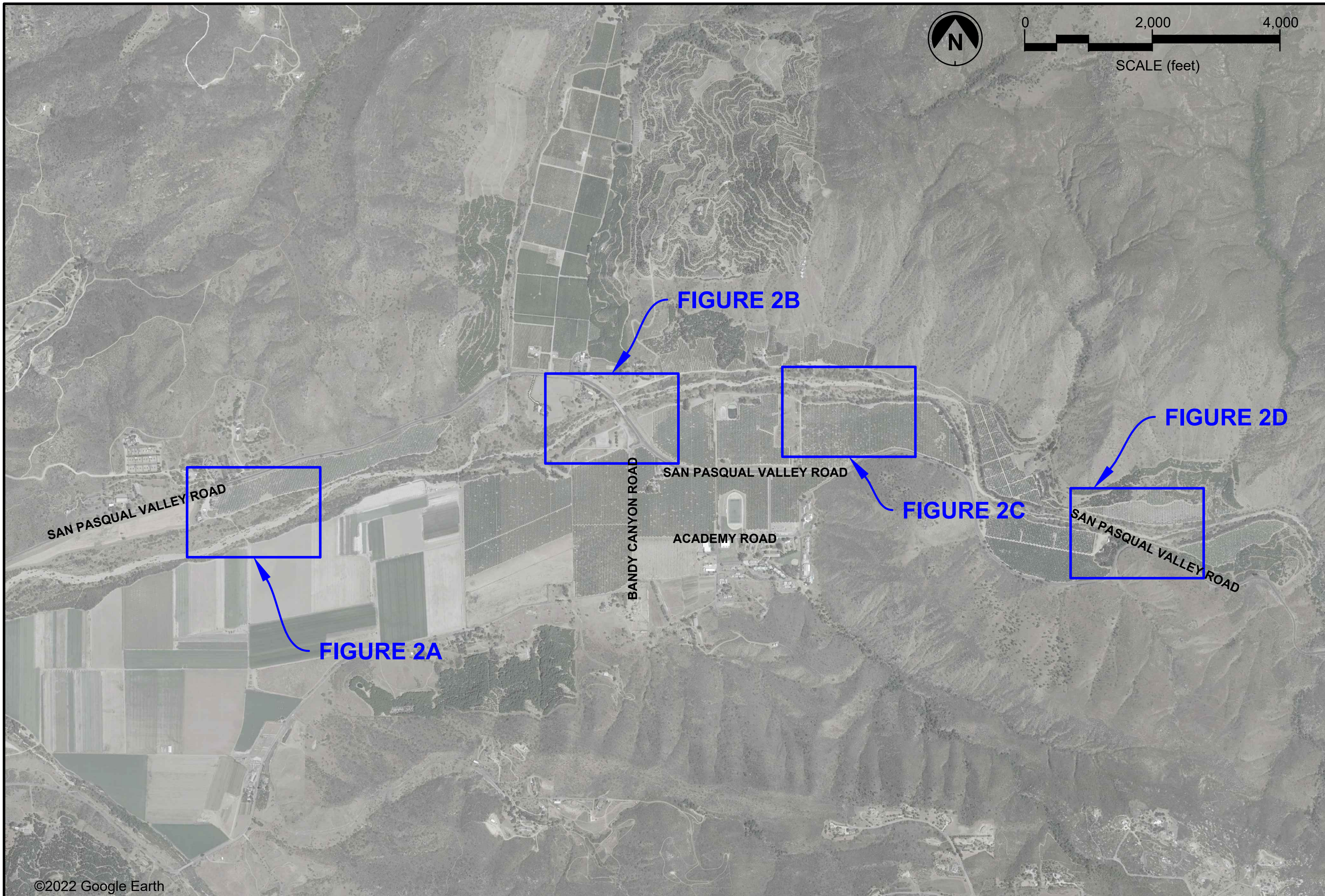
San Pasqual Valley Infiltration Testing

San Diego, California

Date:	November, 2022
By:	CGI
Job No.:	1896.000-1

Figure:

1



ATLAS	**SUBSURFACE EXPLORATION KEY MAP** San Pasqual Valley Infiltration Testing San Diego, California	Date: November, 2022 By: CGI Job No.: 1896.000-1	Figure: 2

NOTE: All locations are approximate.

LEGEND:

T4R Location of Infiltration Testing

ATLAS

SUBSURFACE EXPLORATION MAP
San Pasqual Valley Infiltration Testing
San Diego, California

Date: November, 2022
By: CGI
Job No.: 1896.000-1

Figure: 2A

LEGEND:

T3R Location of Infiltration Testing

ATLAS

SUBSURFACE EXPLORATION MAP
San Pasqual Valley Infiltration Testing
San Diego, California

Date:	November, 2022
By:	CGI
Job No.:	1896.000-1

Figure: 2B

LEGEND:

T2R Location of Infiltration Testing

ATLAS

SUBSURFACE EXPLORATION MAP
San Pasqual Valley Infiltration Testing
San Diego, California

Date:	November, 2022
By:	CGI
Job No.:	1896.000-1

Figure: 2C

LEGEND:

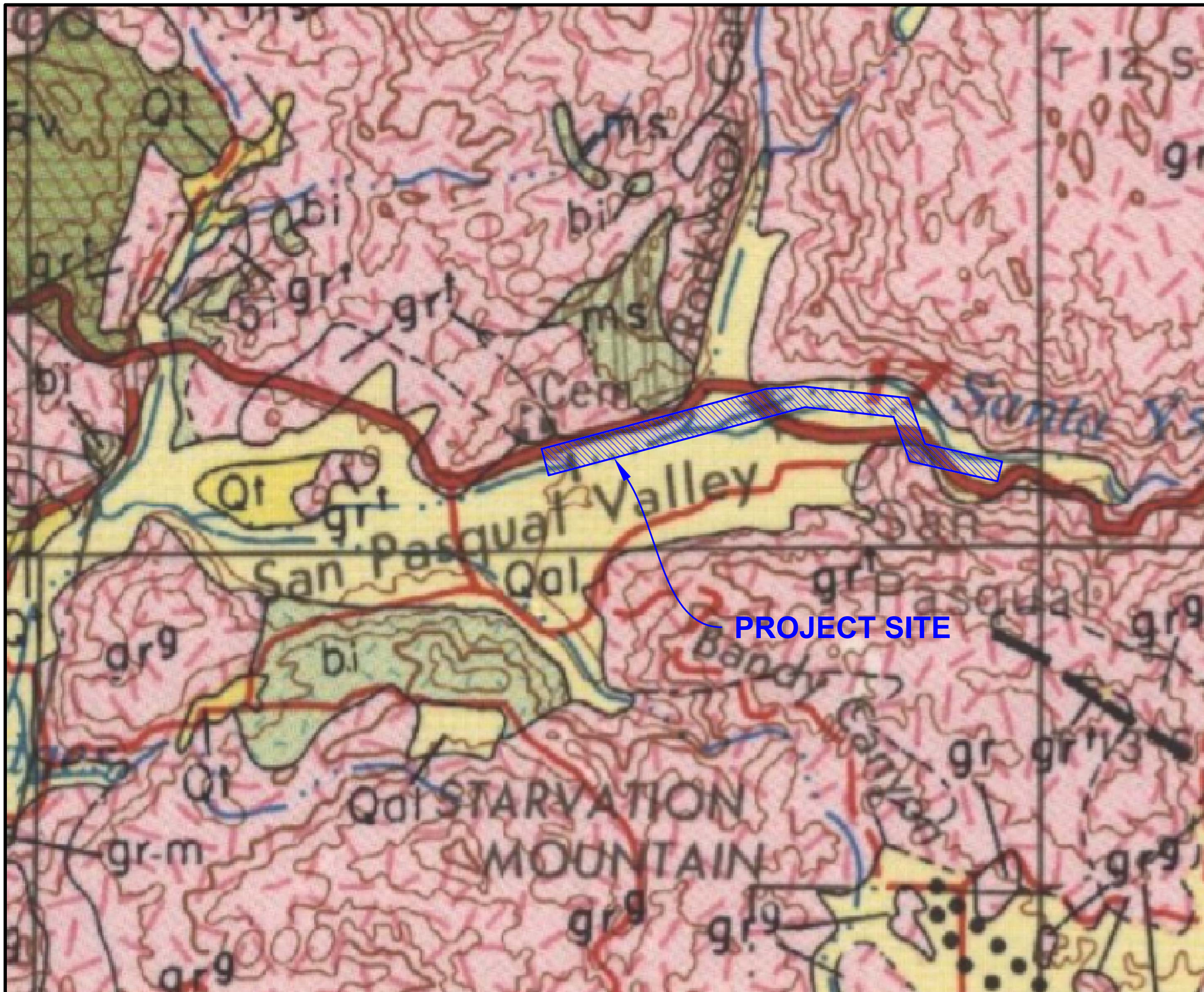
T1R Location of Infiltration Testing

ATLAS

SUBSURFACE EXPLORATION MAP
San Pasqual Valley Infiltration Testing
San Diego, California

Date:	November, 2022
By:	CGI
Job No.:	1896.000-1

Figure: 2D



EXPLANATION:

Qal	Alluvium
Qt	Quaternary nonmarine terrace deposits
gr	Mesozoic granitic rocks: gr^g-granodiorite; gr^t-tonalite and diorite
bi	Mesozoic basic intrusive rocks
Jrv	Jura-Trias metavolcanic rocks
ms	Pre-Cretaceous metasedimentary rocks

N

0 1 2

SCALE (mile)

NOTE: All locations are approximate.

Reference:
Rogers, T.H., 1965, Geologic map of California : Santa Ana sheet, California Division of Mines and Geology, series unknown, 1:250,000.

ATLAS

REGIONAL GEOLOGY MAP
San Pasqual Valley Infiltration Testing
San Diego, California

Date: November, 2022
By: CGI
Job No.: 1896.000-1

Figure: 3

ATTACHMENT I
WELL PERMEAMETER INFILTRATION TESTING PROCEDURE

Modified Constant Head Well Permeameter Test

Pre-test Procedure

1. Presoak test site and remove 12 inches of soil.
2. Install the 12-inch diameter metal infiltration ring (Figure 1).
3. Install 10- to 12-inch soil grate (Figure 2) at the ring bottom by pushing it down and twisting it in place until the grate is level and the soil is flush with the top of the soil grate. The soil grate is only intended to minimize movement of streambed material inside the ring during infiltration testing at greater flows. It must have enough open area to allow unimpeded flow into the underlying streambed.
4. Wet down the inside of the ring just enough to level/settle the soil and grate, if necessary.
5. Insert a removable 12-inch diameter flexible (e.g., rubber, poly-vinyl, or silicon) disc (Figures 1 and 3) on top of the soil grate at the ring bottom. Ideally this flexible disc would have handle or tether to allow rapid removal at the beginning of the infiltration test without damaging the disc.
6. Measure/Record the inner diameter of the ring (D) in units of inches and compute the inner area of the ring (A) in units of square inches; $A = \pi \cdot r^2$, where r equals the inner radius ($r=\frac{1}{2}D$).
7. Install a measuring rod/ruler inside the 12-inch diameter ring to allow accurate reading of the water level to within 0.1 inch.
8. Measure/Record the distance between the flexible disc and the target water-level mark inside the ring (h_0) in units of inches (Figure 1).
9. Establish the target water-level mark inside the ring. This will be based on an h_0/r ratio between 1 and 3 with an initial h_0/r ratio of 3.
10. Compute the volume (V_0) of the space between the flexible disc and the target water-level mark inside the ring; $V_0 = A \cdot h_0/231$ to get units of gallons.
11. Fill the ring with water to the target water-level mark.
12. Pull the flexible disc and immediately record with an accurate stopwatch the time it takes to drain the ring down to the top of the soil grate.
13. Compute the initial volumetric percolation rate (Q_0) by dividing the initial volume of water between the flexible disc and the target water-level mark in the ring (V_0) by the time to drain the ring down to the soil grate (t); $Q_0 = V_0/t$. Record Q_0 in units of gallons per minute (gpm).
14. To prepare for the infiltration test, open the valve and direct flow into a separate container, noting/marking the position of the valve to achieve Q_0. Close the valve.
15. Re-position the bottom soil grate (if necessary) and flexible disc at the ring bottom.
16. Assemble the ≥3-inch diameter conveyance piping from the water truck to the test site.
17. Install the most accurate flow meter for the anticipated flow range based on the Q_0 value, along with the appropriate length of upstream/downstream rigid 3-inch pipe per flow meter manufacturer specifications.

Test Procedure

1. With the flexible disc in place, fill the ring with water to the target water-level mark.
2. Open/Adjust the valve to direct the flow at the Q_0 rate into a separate container.
3. Record the initial totalizer and start time (t_0) and immediately pull the flexible disc, while redirecting the flow at the Q_0 rate from the separate container into the ring. Try to angle the discharge line to minimize movement of the water surface inside the ring to facilitate recording an accurate reading of the water level during the test.
4. While striving to maintain the water level inside the ring at h_0, record the time (t), water level (h_t), volumetric flow rate (Q_t), totalizer, and water temperature at the following frequency:
    - Strive for at least every 10 seconds from the 0-to-2 minute mark
    - Strive for at least every 30 seconds from the 2-to-5 minute mark
    - Strive for every 1 minute from the 5-to-10 minute mark
    - Strive for every 2 minutes from the 10-to-30 minute mark
    - Strive for every 5 to 10 minutes from the 30-to-60 minute mark
    - Strive for every 15 minutes thereafter.
5. Continue recording data until the 2,000-gallon water truck is drained unless approved by Nate Brown/Jacobs to stop the test before draining the water truck.

Post-test Procedure

1. Carefully remove the ring, while trying to minimize sediments sloughing into the hole.
2. Cutting the 12-inch ring footprint in half, dig down at least 12 inches below the position of the ring bottom during testing to expose the wetted width.
3. Measure/record the wetted diameter below the test ring. Given the loose materials, it might help to have a sheet of plexiglass or other transparent material to be able to view/measure the wetted profile while minimizing sloughing.
4. Photograph the wetted width with a tape measure to provide a sense of scale.
5. Collect and label a disturbed sediment sample from the wetted infiltration zone for sieve analysis.

Please take photographs of equipment used with something in the picture that provides a sense of scale (e.g., tape measure or ruler).

Miscellaneous Considerations

1. Confirm the water hauler will blow off sediments at the source water point (e.g., hydrant) before filling the truck.
2. Request the water hauler to have a filter at the outflow of the water truck to ensure we're not introducing foreign sediments into the test hole.
3. Conveyance piping should be threaded (avoid glues).

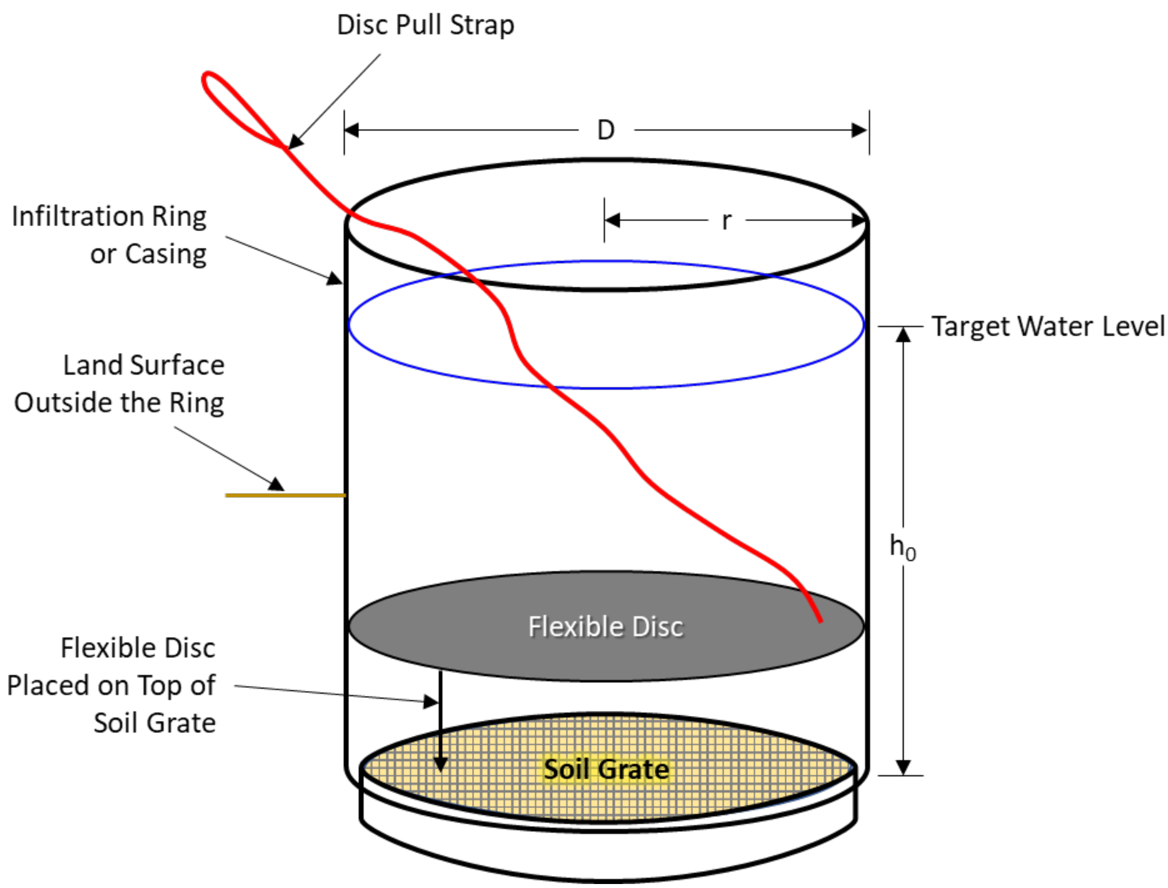


Figure 1. Conceptual Layout of infiltration Apparatus

Figure 2. Example Soil Grate

https://www.amazon.com/Polylok-10-Pipe-Grate-Black/dp/B0873CDVTJ

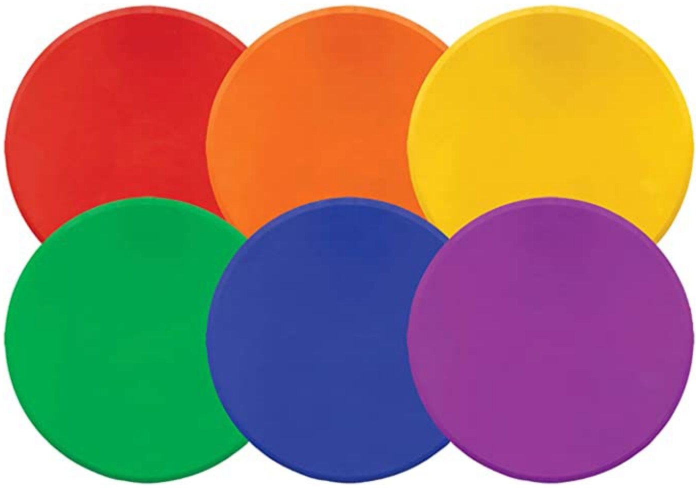


Figure 3. Example Flexible Disc

https://www.amazon.com/Champion-Sports-Poly-Markers-12-inch/dp/B002NR0742

ATTACHMENT II
INFILTRATION TEST DATA

Atlas performed in-situ infiltration testing utilizing both single and double-ring formats in general conformance with the procedures provided by Jacobs. The results of infiltration testing are provided in this attachment.

WEATHER DESCRIPTION: Partly cloudy.

Date: *10/13/2022*

TEST ID

T1-C

INFILTRATION TEST LOG

PROJECT: San Pasqual Valley Infiltration Testing — LOCATION: San Pasqual Valley, San Diego County, California

TEST CONTRACTOR: Atlas — INNER RADIUS OF RING/CASING, r (in): 6

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head

INNER DIAMETER OF RING/CASING, D (in): 12 — INNER RADIUS OF RING/CASING, r (in): 6

INNER AREA OF RING/CASING, A (in²): 113.1

TARGET WATER LEVEL INSIDE RING/CASING, h_0 (in): 18 — h_0/r RATIO:3

INITIAL TOTALIZER READING UPON ARRIVAL (gal): 0 — FINAL TOTALIZER READING AFTER TEST (gal): 1353.4

TARGET WATER VOLUME INSIDE RING/CASING, V_0 (gal): 8.8 — TIME TO DRAIN, t (min): 0.6

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 14.7

FIELD LEAD NAME: JD — FIELD SUPPORT STAFF NAME(S): HK

CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
-	0.17	-	0.5	18	-	(-) indicates not observed
-	0.33	-	3.7	18	-	
-	0.5	-	7.6	18	-	
-	0.66	-	11.2	18	-	
-	0.83	-	14	18	-	
-	1	-	16.7	18	-	
-	1.17	-	19.5	18	-	
-	1.33	-	22.4	18	-	
-	1.5	-	25.1	18	-	
-	1.66	-	27.7	18	-	
-	1.83	-	30.2	18	-	
-	2	-	32.9	18	-	
-	2.5	-	40.8	18	-	
-	3	-	48.5	18	-	
-	3.5	-	56.1	18	-	
-	4	-	63.3	18	-	
-	4.5	-	71.1	18	-	
-	5	-	78.6	18	-	
-	6	-	93	18	-	
-	7	-	107.9	18	-	
-	8	13.4	121.4	18	-	
-	9	14.1	135.1	18	-	
-	10	13.2	148.9	18	-	
-	12	13.3	176.1	18	-	
-	14	12.7	202.4	18	-	
-	16	12.3	228	18	-	
-	18	12.4	253	18	-	
-	20	11.9	278	18	-	
-	22	10.6	301.5	18	-	
-	24	11.1	324.9	18	-	
-	26	11.7	348.7	18	-	
-	28	11.4	371	18	-	
-	30	10.8	395.1	18	-	
-	35	11.4	450.9	18	-	
-	40	10.7	505.6	18	-	
-	45	10.7	563.1	18	-	
-	50	11.1	614.7	18	-	
-	55	10.5	668.4	18	-	
-	60	10.6	722.7	18	-	
-	75	11.9	880.6	18	-	
-	90	10.51	1039.2	18	72	
-	105	10.57	1196.6	18	68	
-	120	10.4	1353.4	18	72	

WEATHER DESCRIPTION: Partly cloudy.	**TEST ID** T1-R
Date: *10/13/2022*	# INFILTRATION TEST LOG

PROJECT: San Pasqual Valley Infiltration Testing LOCATION: San Pasqual Valley, San Diego County, California

TEST CONTRACTOR: Atlas INNER RADIUS OF RING/CASING, r (in): 6

TESTING METHOD AND EQUIPMENT USED: Double-Ring, Inner Ring Measurements

INNER DIAMETER OF RING/CASING, D (in): 12 INNER RADIUS OF RING/CASING, r (in): 6

INNER AREA OF RING/CASING, A (in²): 113.1

TARGET WATER LEVEL INSIDE RING/CASING, h_0 (in): 14 h_0/r RATIO: 2.3

INITIAL TOTALIZER READING UPON ARRIVAL (gal): 0 FINAL TOTALIZER READING AFTER TEST (gal): 62.8

TARGET WATER VOLUME INSIDE RING/CASING, V_0 (gal): 6.85 8.8 TIME TO DRAIN, t (min): 17

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 0.4

FIELD LEAD NAME: JD FIELD SUPPORT STAFF NAME(S): HK

CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
-	1	-	0.53	14	78	(-) indicates not observed
-	2	-	0.95	14	78	
-	3	-	1.45	14	78	
-	4	-	1.90	14	78	
-	5	-	2.43	14	78	
-	10	-	4.81	14	78	
-	15	-	7.32	14	78	
-	20	-	9.64	14	78	
-	25	-	12.02	14	78	
-	30	-	14.29	14	78	
-	35	-	16.67	14	78	
-	40	-	18.99	14	78	
-	50	-	23.54	14	78	
-	55	-	25.76	14	78	
-	60	-	28.08	14	78	
-	65	-	30.33	14	78	
-	70	-	32.63	14	78	
-	75	-	34.84	14	78	
-	80	-	37.14	14	78	
-	85	-	39.49	14	78	
-	95	-	44.12	14	78	
-	100	-	46.39	14	78	
-	105	-	48.63	14	78	
-	110	-	50.85	14	78	
-	115	-	53.23	14	78	
-	120	-	55.34	14	78	
-	125	-	57.62	14	78	
-	130	-	59.81	14	78	
-	135	-	62.08	14	78	

WEATHER DESCRIPTION: Partly cloudy.

Date: *10/14/2022*

TEST ID

T2-C

INFILTRATION TEST LOG

PROJECT: San Pasqual Valley Infiltration Testing LOCATION: San Pasqual Valley, San Diego County, California

TEST CONTRACTOR: Atlas INNER RADIUS OF RING/CASING, r (in): 6

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head

INNER DIAMETER OF RING/CASING, D (in): 12 INNER RADIUS OF RING/CASING, r (in): 6

INNER AREA OF RING/CASING, A (in²): 113.1

TARGET WATER LEVEL INSIDE RING/CASING, h_0 (in): 18 h_0/r RATIO:3

INITIAL TOTALIZER READING UPON ARRIVAL (gal): 0 FINAL TOTALIZER READING AFTER TEST (gal): 2149.1

TARGET WATER VOLUME INSIDE RING/CASING, V_0 (gal): 8.8 TIME TO DRAIN, t (min): 0.6

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 14.6

FIELD LEAD NAME: JRD FIELD SUPPORT STAFF NAME(S): HK

CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
-	0.17	-	3.8	18	-	(-) indicates not observed
-	0.33	-	7	18	-	
-	0.5	-	10.1	18	-	
-	0.66	-	12.8	18	-	
-	0.83	-	15.8	18	72	
-	1	-	18.9	18	-	
-	1.17	-	21.7	18	-	
-	1.33	-	24.5	18	-	
-	1.5	-	27.5	18	-	
-	1.66	-	30.2	18	-	
-	1.83	-	33.3	18	-	
-	2	17.7	36	18	-	
-	2.5	16.7	44.7	18	-	
-	3	17.2	53.6	18	-	
-	3.5	16.9	61.7	18	-	
-	4	16.9	70.3	18	-	
-	4.5	16.9	78.6	18	-	
-	5	16.9	87.2	18	-	
-	6	16.9	104	18	-	
-	7	18	121.1	18	-	
-	8	17.6	137.7	18	-	
-	9	16.6	154.6	18	-	
-	10	16.5	171.3	18	71	
-	12	16.9	204.1	18	-	
-	14	16.1	236.3	18	-	
-	16	16.1	268.3	18	-	
-	18	15.7	300.4	18	-	
-	20	16.1	331.6	18	-	
-	22	16	363.1	18	72	
-	24	16.3	395.6	18	-	
-	26	15.7	427.9	18	-	
-	28	16.2	460	18	-	
-	30	16.3	492.5	18	-	
-	35	15.7	574.1	18	-	
-	40	15.9	652.9	18	-	
-	45	15.9	732.1	18	-	
-	60	15.9	970.9	18	-	
-	75	15.8	1208.1	18	68	
-	90	15.7	1446.1	18	69	
-	105	15.9	1681.7	18	71	
-	120	15.4	1916.1	18	-	
-	135	15.4	2149.1	18	72	

WEATHER DESCRIPTION: Partly cloudy.

Date: *10/14/2022*

TEST ID

T2-R

INFILTRATION TEST LOG

PROJECT: San Pasqual Valley Infiltration Testing LOCATION: San Pasqual Valley, San Diego County, California

TEST CONTRACTOR: Atlas INNER RADIUS OF RING/CASING, r (in): 6

TESTING METHOD AND EQUIPMENT USED: Double-Ring, Inner Ring Measurements

INNER DIAMETER OF RING/CASING, D (in): 12 INNER RADIUS OF RING/CASING, r (in): 6

INNER AREA OF RING/CASING, A (in²): 113.1

TARGET WATER LEVEL INSIDE RING/CASING, h_0 (in): 14 h_0/r RATIO:2.3

INITIAL TOTALIZER READING UPON ARRIVAL (gal): 0 FINAL TOTALIZER READING AFTER TEST (gal): 24.36

TARGET WATER VOLUME INSIDE RING/CASING, V_0 (gal): 6.85 TIME TO DRAIN, t (min): 37

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 0.18

FIELD LEAD NAME: JD FIELD SUPPORT STAFF NAME(S): HK

CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
-	1	-	0.29	14	-	(-) indicates not observed
-	2	-	0.58	14	-	
-	3	-	0.88	14	-	
-	4	-	1.19	14	-	
-	5	-	1.48	14	-	
-	6	-	1.78	14	-	
-	7	-	2.05	14	-	
-	8	-	2.38	14	-	
-	9	-	2.69	14	-	
-	10	-	3.06	14	-	
-	12	-	3.43	14	-	
-	14	-	4.17	14	-	
-	16	-	4.49	14	-	
-	18	-	4.85	14	-	
-	20	-	5.30	14	-	
-	22	-	5.69	14	-	
-	24	-	6.12	14	-	
-	26	-	6.51	14	-	
-	28	-	6.96	14	-	
-	30	-	7.37	14	-	
-	35	-	8.37	14	-	
-	40	-	9.40	14	72	
-	45	-	10.38	14	-	
-	50	-	11.25	14	-	
-	55	-	12.13	14	-	
-	60	-	13.08	14	-	
-	65	-	14.05	14	72	
-	70	-	15.00	14	-	
-	75	-	15.90	14	-	
-	80	-	16.81	14	-	
-	85	-	17.73	14	-	
-	90	-	18.52	14	-	
-	95	-	19.39	14	-	
-	100	-	20.31	14	-	
-	105	-	21.11	14	-	
-	110	-	21.93	14	-	
-	115	-	22.75	14	-	
-	120	-	23.54	14	72	
-	125	-	24.36	14	-	

WEATHER DESCRIPTION: Morning clear, end of day light rain.	**TEST ID** T3-C
Date: *10/11/2022*	**INFILTRATION TEST LOG**

PROJECT: San Pasqual Valley Infiltration Testing LOCATION: San Pasqual Valley, San Diego County, California

TEST CONTRACTOR: Atlas INNER RADIUS OF RING/CASING, r (in): 6

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head

INNER DIAMETER OF RING/CASING, D (in): 12 INNER RADIUS OF RING/CASING, r (in): 6

INNER AREA OF RING/CASING, A (in²): 113.1

TARGET WATER LEVEL INSIDE RING/CASING, h_0 (in): 18 h_0/r RATIO:3

INITIAL TOTALIZER READING UPON ARRIVAL (gal): 0 FINAL TOTALIZER READING AFTER TEST (gal): 653.9

TARGET WATER VOLUME INSIDE RING/CASING, V_0 (gal): 8.8 TIME TO DRAIN, t (min): 2

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 4.4

FIELD LEAD NAME: MM FIELD SUPPORT STAFF NAME(S): JD/MM

CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
-	0.17	4.28	13.9	17.5	-	(-) indicates not observed
-	0.33	-	14.5	16	-	
-	0.5	-	15.2	15	-	
-	0.66	-	-	16	-	
-	0.83	-	-	17.1	-	
-	1	-	-	18	-	
-	1.17	-	-	18.25	-	
-	1.33	-	-	18	-	
-	1.5	-	-	18	-	
-	1.66	-	21.9	18	-	
-	1.83	-	22.6	18	-	
-	2	-	23.1	-	-	
-	2.5	4.95	25.6	18	-	
-	3	4.95	28	18	-	
-	3.5	4.95	30.1	18	-	
-	4	5.01	33.3	18.5	-	
-	4.5	3.91	35	17.8	-	
-	5	4.15	37.6	18	-	
-	6	5.32	43	18.4	-	
-	7	4.22	46.5	18	-	
-	8	5.25	51.9	19	-	
-	9	4.62	57	18	-	
-	10	4.64	60.3	18	-	
-	12	2.81	69.2	17.4	-	
-	14	6.5	77.3	17.5	-	
-	16	3.48	86.5	18	-	
-	18	4.34	94.3	18	-	
-	20	2.38	102.8	18	-	
-	22	3.85	111.1	17.9	-	
-	24	3.79	119	18	-	
-	26	3.91	126.6	18.1	-	
-	28	3.67	134.6	17.5	-	
-	30	4.64	142.6	18	-	
-	35	3.9	161	18	-	
-	40	3.79	179.4	18	-	
-	45	3.54	196.4	17.4	-	
-	50	3.73	214.7	17.8	-	
-	55	2.87	232.9	18	-	
-	60	3.24	250.9	18	-	
-	75	3.42	302.8	18	-	
-	90	3.36	354.1	18	-	
-	105	3.36	403.4	17.7	-	
-	120	3.36	453.9	18	-	
-	135	3.36	505.8	18	-	
-	150	3.36	554.9	18.1	-	
-	165	3.36	605.2	18.1	-	
-	180	3.36	653.9	18	-	

WEATHER DESCRIPTION: Morning clear,End of day light rain.

TEST ID

T3-R

Date: *10/11/2022*

INFILTRATION TEST LOG

PROJECT: San Pasqual Valley Infiltration Testing LOCATION: San Pasqual Valley, San Diego County, California

TEST CONTRACTOR: Atlas INNER RADIUS OF RING/CASING, r (in):6

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head, Manual Measurements

INNER DIAMETER OF RING/CASING, D (in): INNER RADIUS OF RING/CASING, r (in):6

INNER AREA OF RING/CASING, A (in²): 113.1

TARGET WATER LEVEL INSIDE RING/CASING, h_0 (in): 18 h_0/r RATIO:3

INITIAL TOTALIZER READING UPON ARRIVAL (gal): 0 FINAL TOTALIZER READING AFTER TEST (gal): 110

TARGET WATER VOLUME INSIDE RING/CASING, V_0 (gal): 8.8 TIME TO DRAIN, t (min): 8

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 1.1

FIELD LEAD NAME: MM FIELD SUPPORT STAFF NAME(S): JD/JM

CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
	4.52	-	5	19	-	(-) indicates not observed
	9.52	-	10	18	-	
	14.60	-	15	18	-	
	20.12	-	20	18	-	
	25.58	-	25	18	-	
	31.70	-	30	18	-	
	37.35	-	35	18	-	
	42.82	-	40	18	-	
	48.60	-	45	18	-	
	54.92	-	50	18	-	
	61.52	-	55	18	-	
	67.68	-	60	18	-	
	74.22	-	65	18	-	
	80.23	-	70	18	-	
	86.98	-	75	18	-	
	93.57	-	80	18	-	
	100.23	-	85	18	-	
	106.98	-	90	18	-	
	113.98	-	95	18	-	
	121.23	-	100	18	-	
	128.32	-	105	18	-	
	135.52	-	110	18	-	

WEATHER DESCRIPTION: Partly cloudy.

Date: *10/12/2022*

TEST ID

T4-C

INFILTRATION TEST LOG

PROJECT: San Pasqual Valley Infiltration Testing LOCATION: San Pasqual Valley, San Diego County, California

TEST CONTRACTOR: Atlas INNER RADIUS OF RING/CASING, r (in): 6

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head

INNER DIAMETER OF RING/CASING, D (in): 12 INNER RADIUS OF RING/CASING, r (in): 6

INNER AREA OF RING/CASING, A (in²): 113.1

TARGET WATER LEVEL INSIDE RING/CASING, h_0 (in): 18 h_0/r RATIO:3

INITIAL TOTALIZER READING UPON ARRIVAL (gal): 13 FINAL TOTALIZER READING AFTER TEST (gal): 713.4

TARGET WATER VOLUME INSIDE RING/CASING, V_0 (gal): 8.8 TIME TO DRAIN, t (min): 1.2

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 7.3

FIELD LEAD NAME: JM FIELD SUPPORT STAFF NAME(S): GT

CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
	0.17	-	-	-	-	(-) indicates not observed
	0.33	-	13.3	18	-	
	0.5	-	15.9	18	-	
	0.66	-	16.9	17	-	
	0.83	-	-	-	-	
	1	-	19.7	17.5	-	
	1.17	-	-	-	-	
	1.33	-	-	-	-	
	1.5	-	22	17.8	-	
	1.66	-	23	17.5	-	
	1.83	-	24.1	17	-	
	2	-	25.5	17.5	-	
	2.5	-	28.7	17	-	
	3	-	32.4	17	-	
	3.5	-	34.9	16	-	
	4	-	38.6	18	-	
	4.5	-	41.4	17.4	-	
	5	-	44.9	18	-	
	6	-	50.2	17.25	-	
	7	-	56	17.25	-	
	8	-	61.9	17.5	-	
	9	-	67.7	18	-	
	10	-	73	17	-	
	12	-	83	16.75	-	
	14	-	93.4	17.5	-	
	16	-	104.1	18	-	
	18	-	113.4	17.5	-	
	20	-	123.1	18	-	
	22	-	133.7	18	-	
	24	-	143.8	18	-	
	26	-	152.8	18	-	
	28	-	162.8	18	-	
	30	-	172.3	18	-	
	35	-	195.1	18	-	
	40	-	217.3	18	-	
	45	-	240.5	18	-	
	50	-	263.7	18	-	
	60	-	308.9	18	-	
	75	-	377.2	18	-	
	90	-	444.6	18	-	
	105	-	513.4	18	-	
	120	-	580	18	-	
	135	-	646.4	18	-	
	150	-	713.4	18	-	

WEATHER DESCRIPTION: Partly cloudy	**TEST ID** T4-R
Date: *10/12/2022*	# INFILTRATION TEST LOG

PROJECT: San Pasqual Valley Infiltration Testing LOCATION: San Pasqual Valley, San Diego County, California

TEST CONTRACTOR: Atlas INNER RADIUS OF RING/CASING, r (in): 6

TESTING METHOD AND EQUIPMENT USED: Double-Ring, Inner Ring Measurements

INNER DIAMETER OF RING/CASING, D (in): 12 INNER RADIUS OF RING/CASING, r (in): 6

INNER AREA OF RING/CASING, A (in²): 113.1

TARGET WATER LEVEL INSIDE RING/CASING, h_0 (in): 14 h_0/r RATIO:2.3

INITIAL TOTALIZER READING UPON ARRIVAL (gal): 0 FINAL TOTALIZER READING AFTER TEST (gal): 29.18

TARGET WATER VOLUME INSIDE RING/CASING, V_0 (gal): 6.85 TIME TO DRAIN, t (min): 7.5

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 0.91

FIELD LEAD NAME: JM FIELD SUPPORT STAFF NAME(S): GT

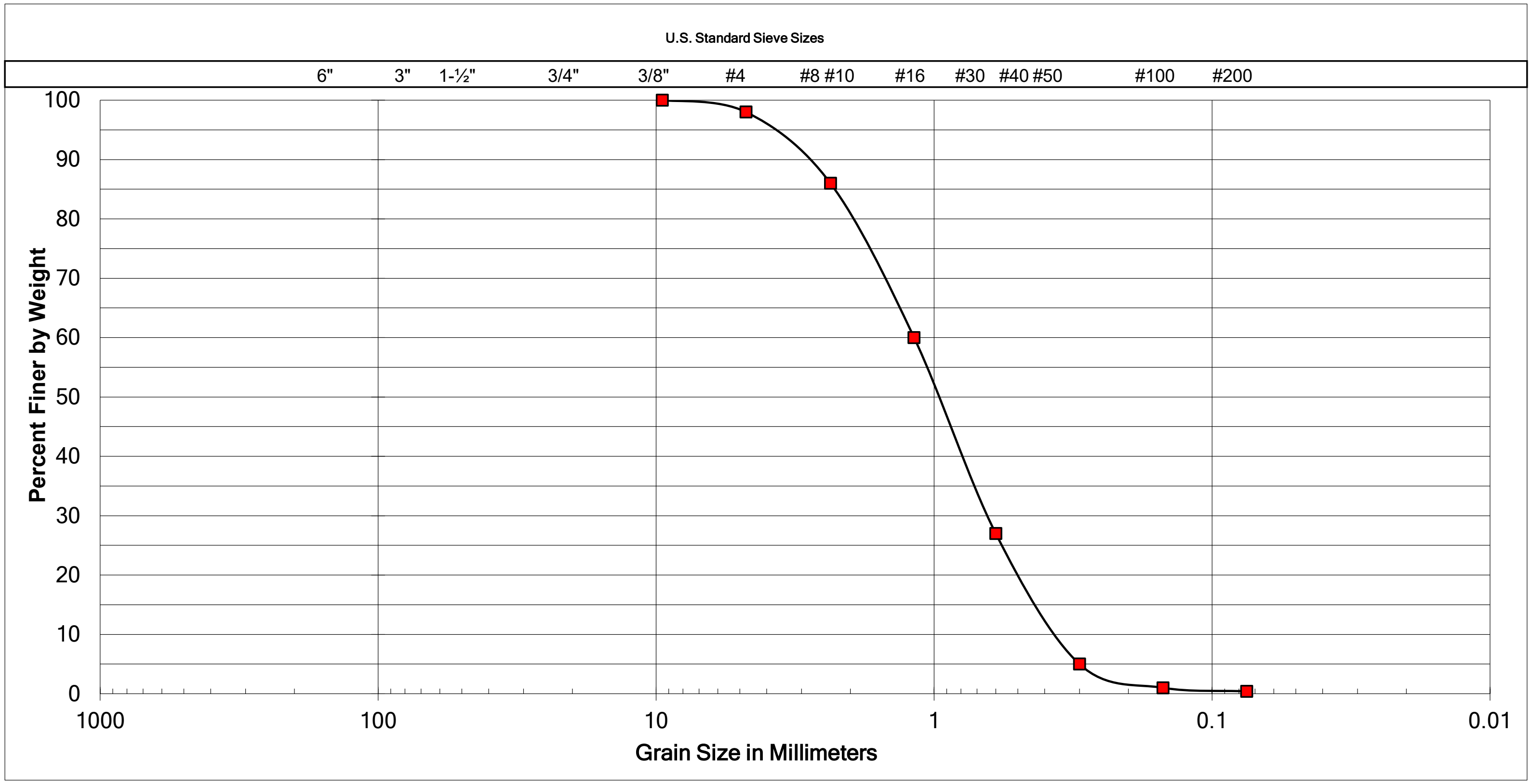
CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
	1	-	1.59	13.5	-	(-) indicates not observed
	2	-	2.87	14	-	
	3	-	4.06	14	-	
	4	-	5.12	14	-	
	5	-	6.17	14	-	
	6	-	7.12	14	-	
	7	-	8.04	14	-	
	8	-	8.97	14	-	
	9	-	9.87	14	-	
	10	-	10.73	14	-	
	12	-	12.47	14	-	
	14	-	14.16	14	-	
	16	-	15.85	14	-	
	18	-	17.38	14	-	
	20	-	18.89	14	-	
	25	-	22.35	14	-	
	30	-	25.80	14	-	
	35	-	29.18	14	-	

ATTACHMENT III
LABORATORY TESTING

The following laboratory test was performed to provide geotechnical parameters for the engineering analyses:

- **PARTICLE-SIZE DISTRIBUTION:** The particle-size distribution was determined on soil samples obtained from all infiltration testing locations in accordance with ASTM D6913.

Samples not tested are now stored in our laboratory for future reference and analysis, if needed. Unless notified to the contrary, all samples will be disposed of 30 days from the date of this document.



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

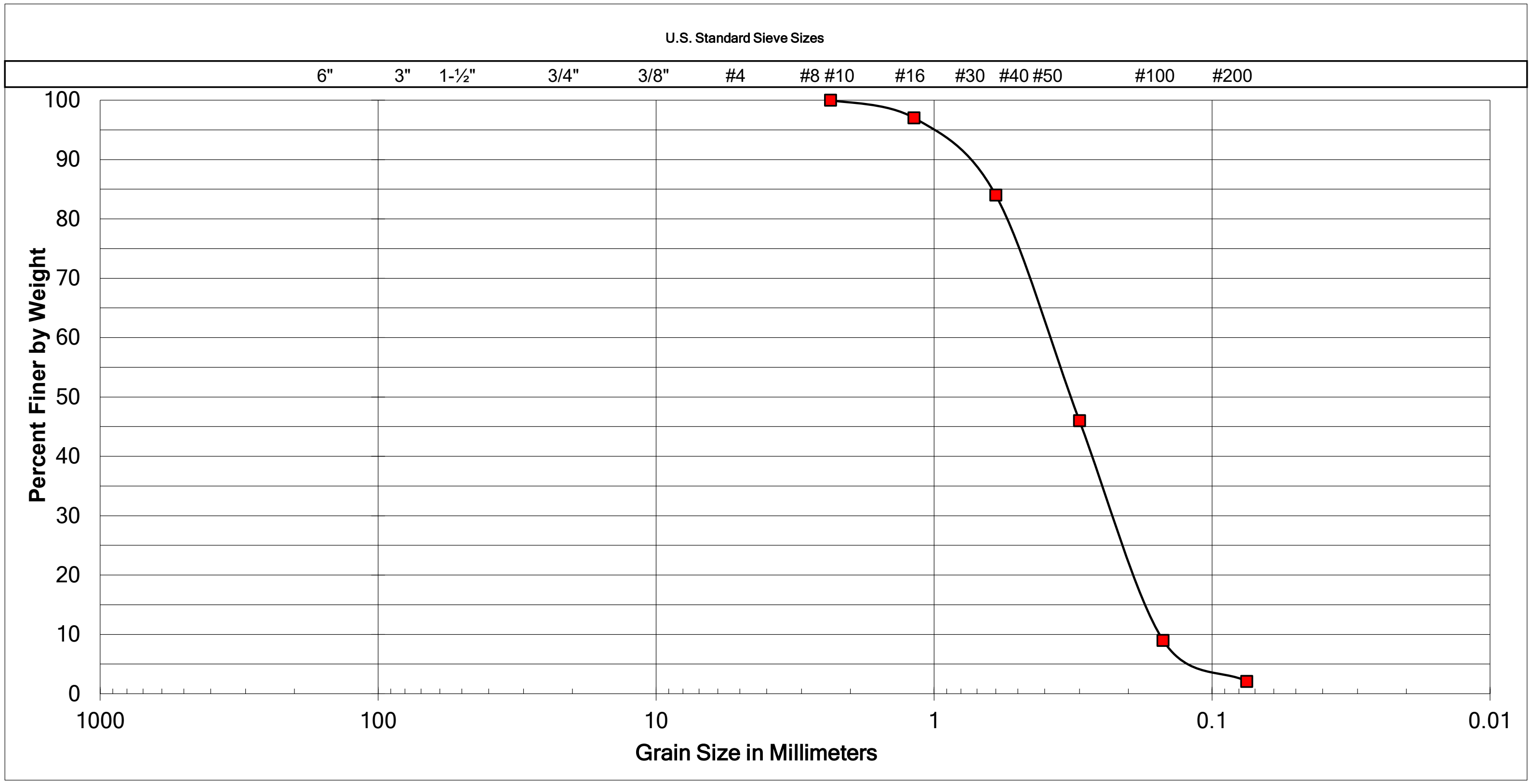
SAMPLE LOCATION
T1-C
SAMPLE NUMBER
78352

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing City of San Diego			
By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-1



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

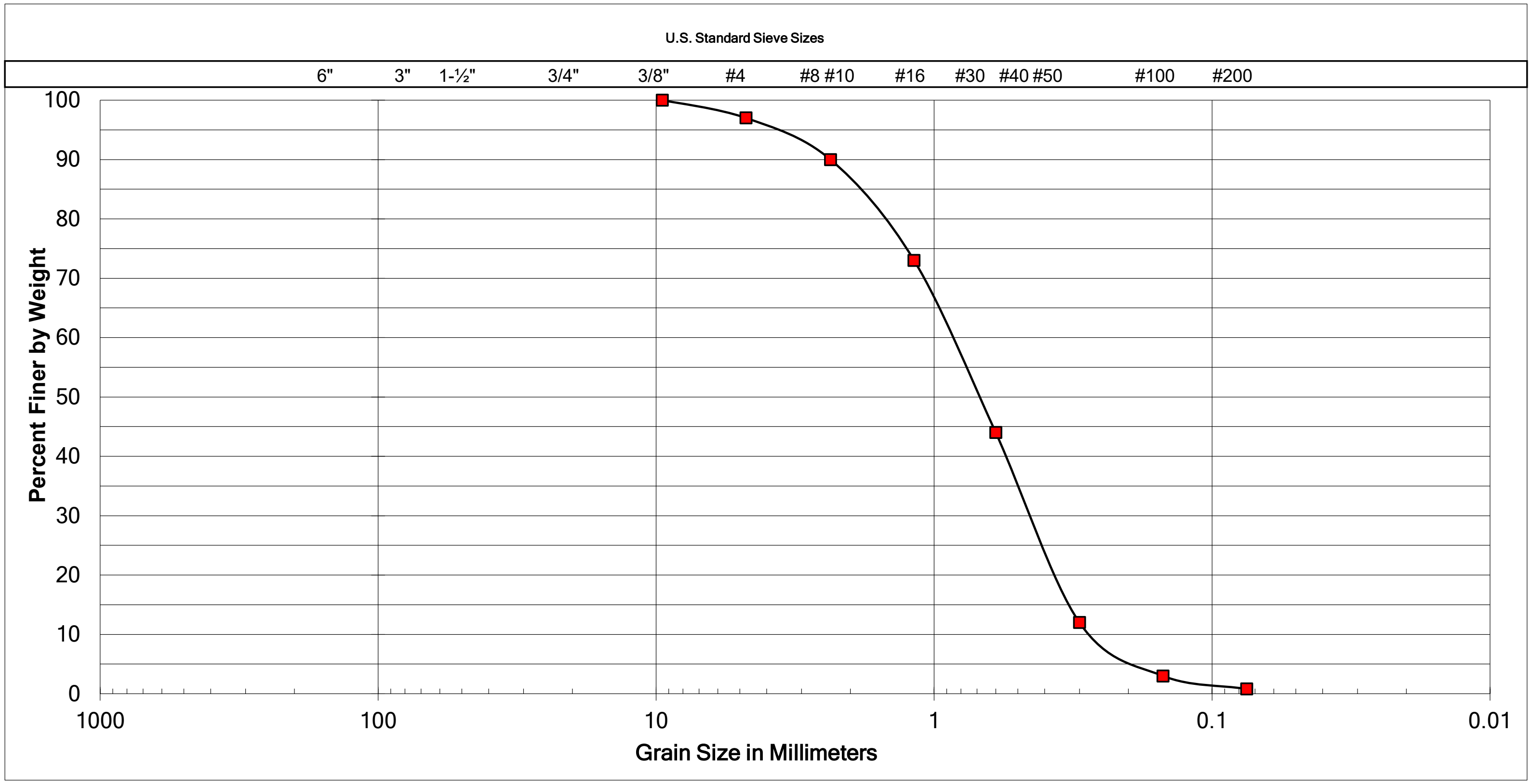
SAMPLE LOCATION
T1-R
SAMPLE NUMBER
78353

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing City of San Diego			
By: JRD		Date: November, 2022	
Job Number: 1896.000-1		Figure: I-2	



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

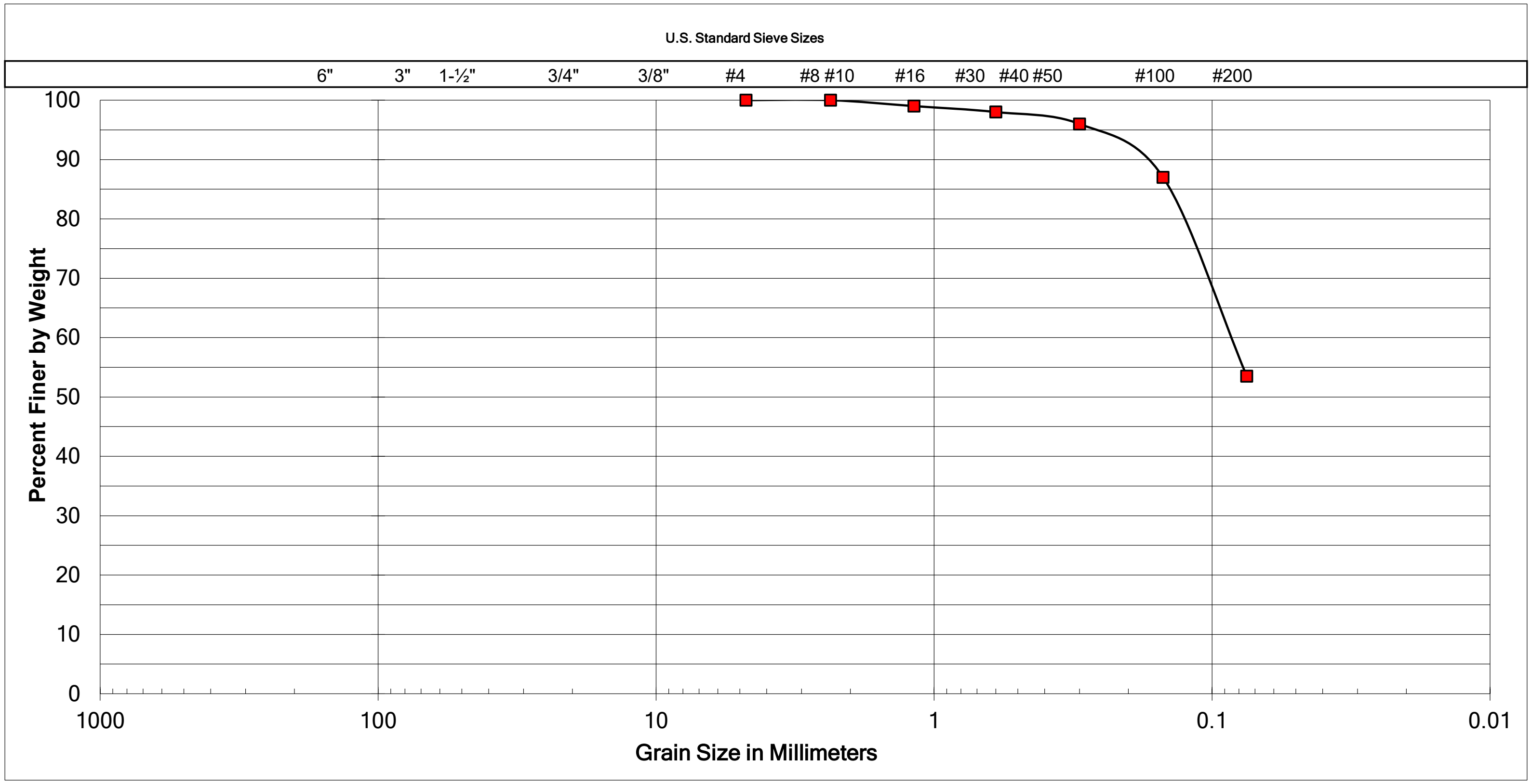
SAMPLE LOCATION
T2-C
SAMPLE NUMBER
78354

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing City of San Diego			
By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-3



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

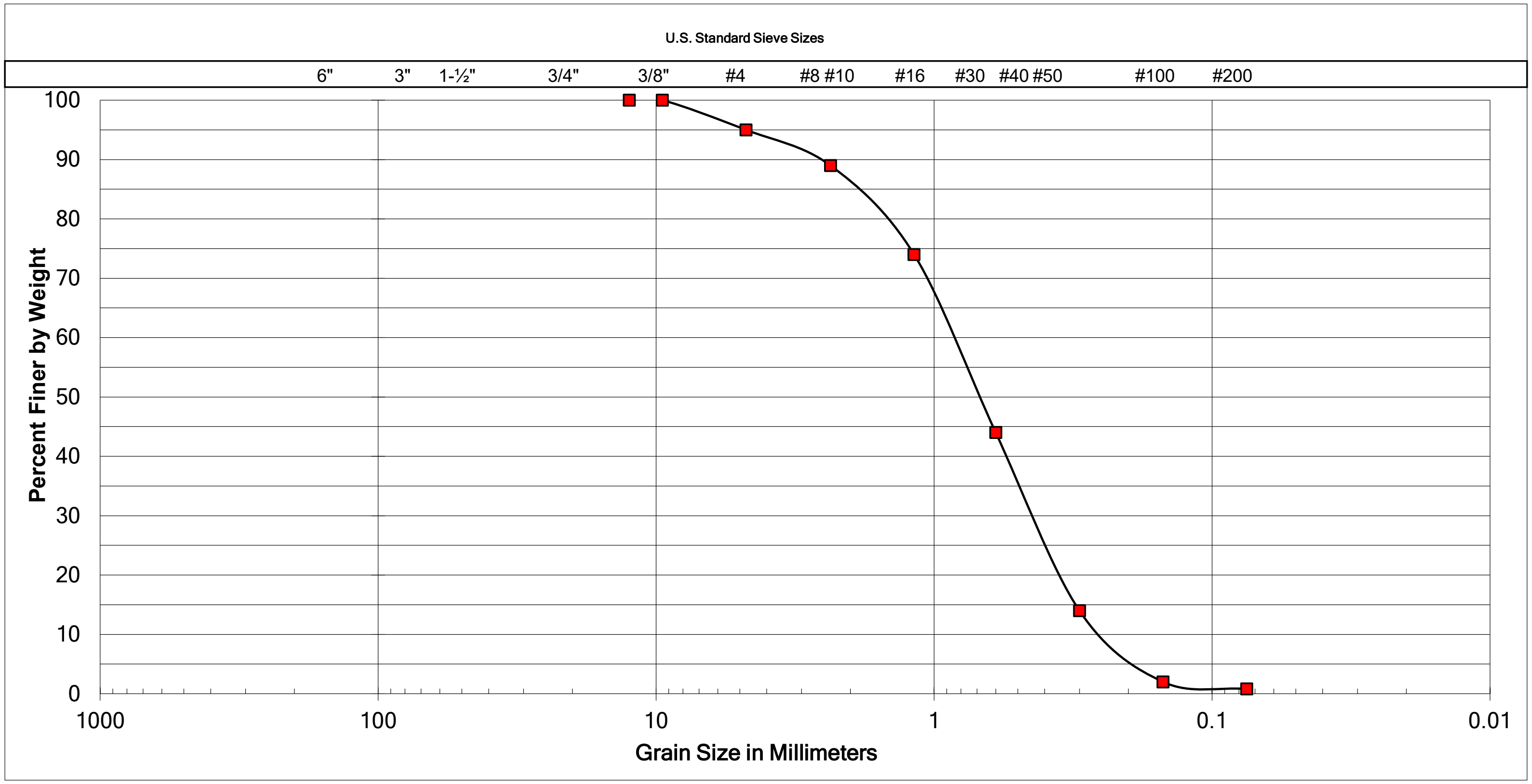
SAMPLE LOCATION
T2-R
SAMPLE NUMBER
78355

UNIFIED SOIL CLASSIFICATION:	ML
DESCRIPTION	SANDY SILT

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing City of San Diego			
By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-4



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

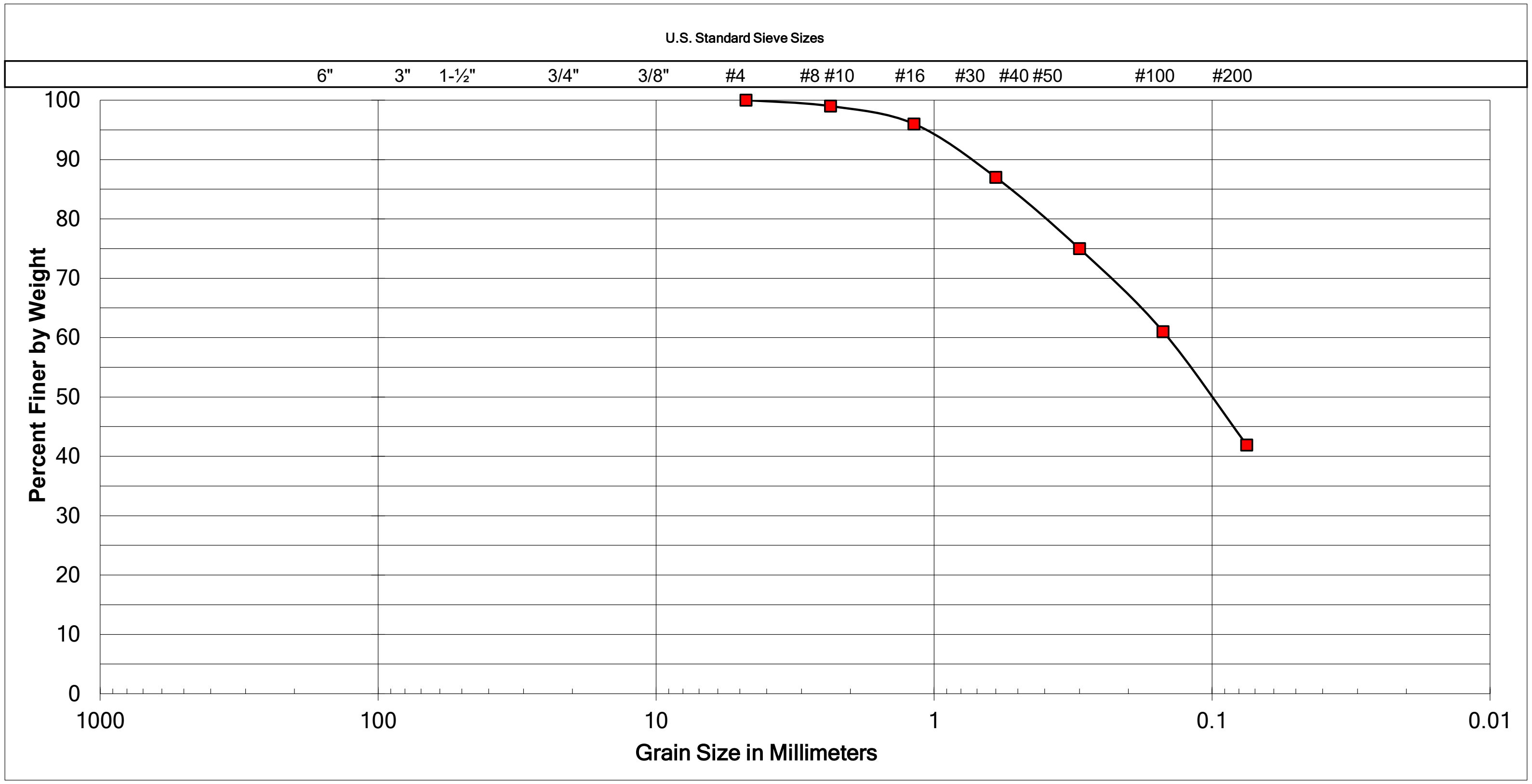
SAMPLE LOCATION
T3-C
SAMPLE NUMBER
78356

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing City of San Diego			
By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-5



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

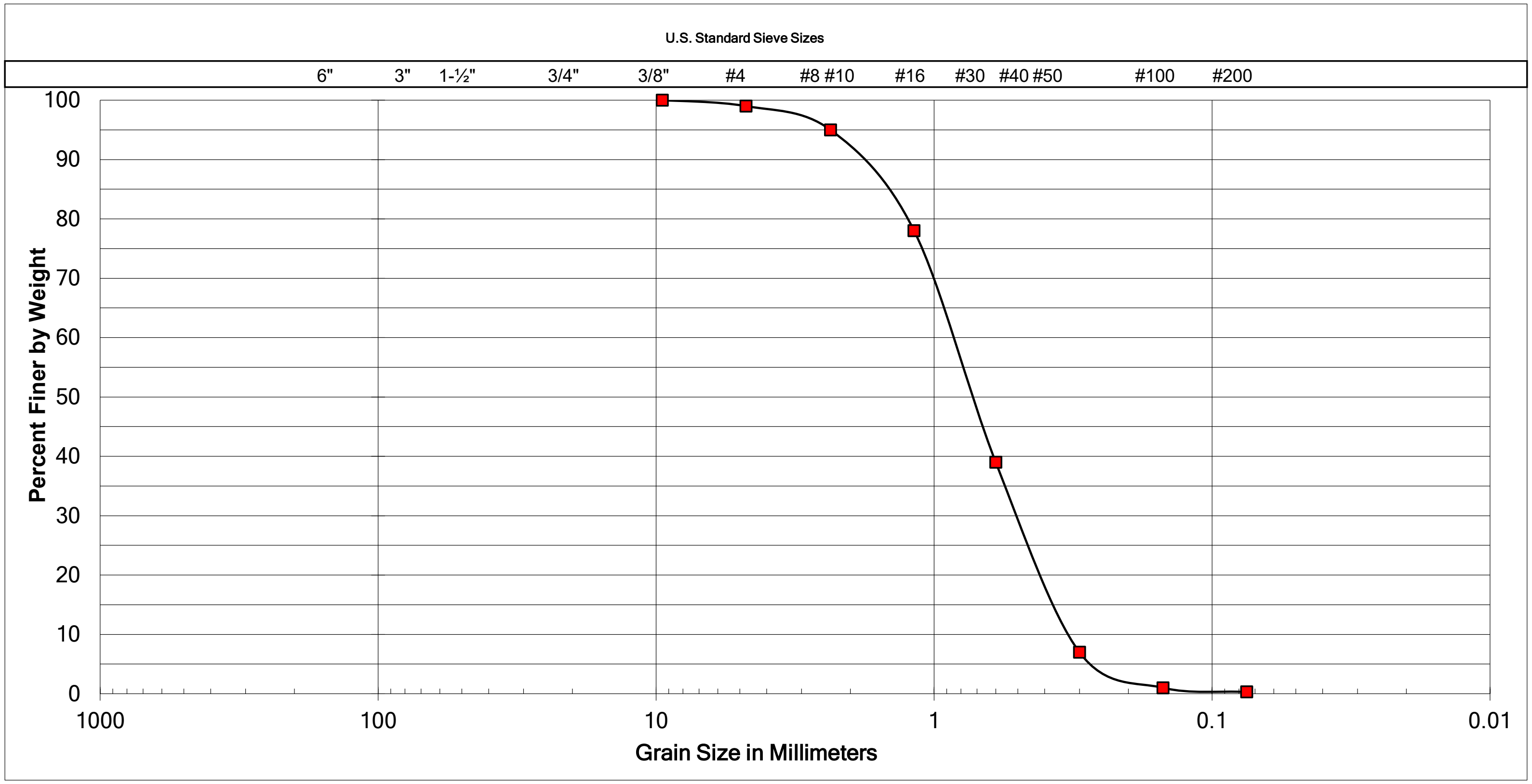
SAMPLE LOCATION
T3-R
SAMPLE NUMBER
78357

UNIFIED SOIL CLASSIFICATION:	SM
DESCRIPTION	SILTY SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing City of San Diego			
By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-6



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

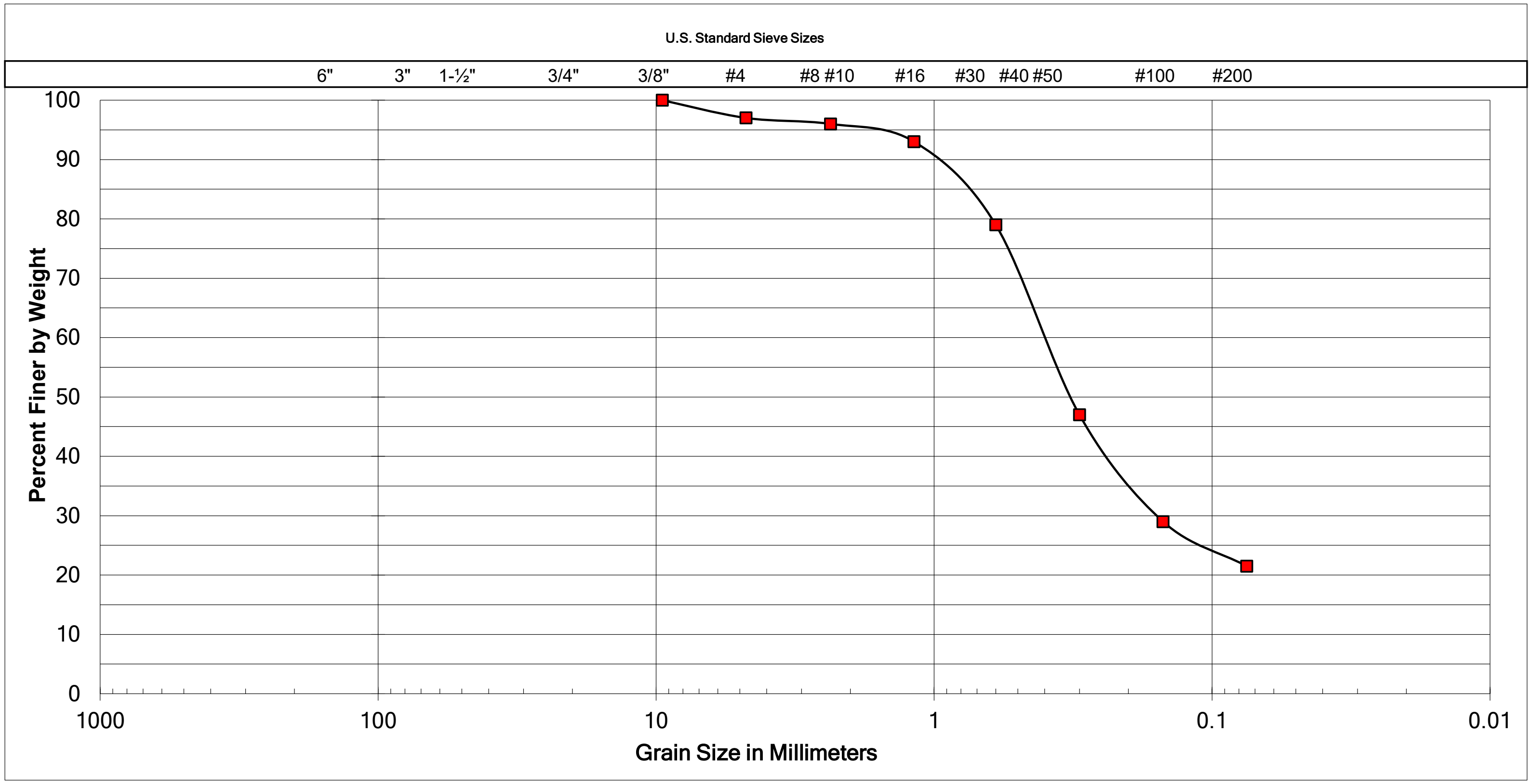
SAMPLE LOCATION
T4-C
SAMPLE NUMBER
78358

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing City of San Diego			
By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-7



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

SAMPLE LOCATION
T4-R
SAMPLE NUMBER
78359

UNIFIED SOIL CLASSIFICATION:	SM
DESCRIPTION	SILTY SAND

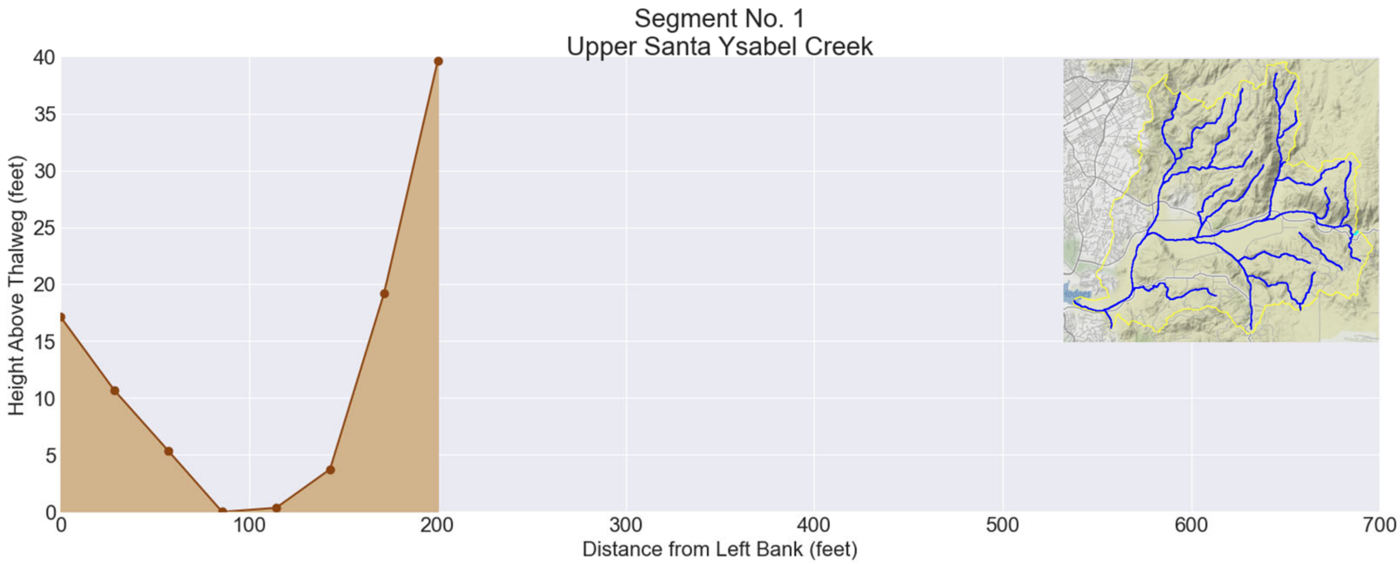
ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

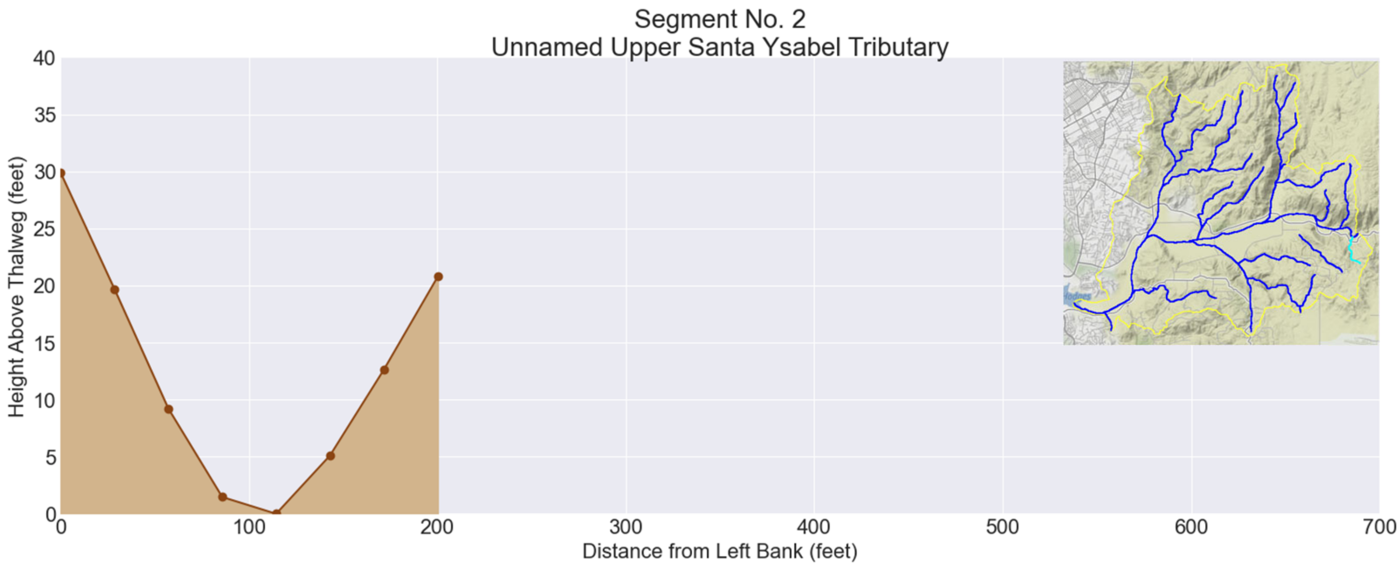
ATLAS

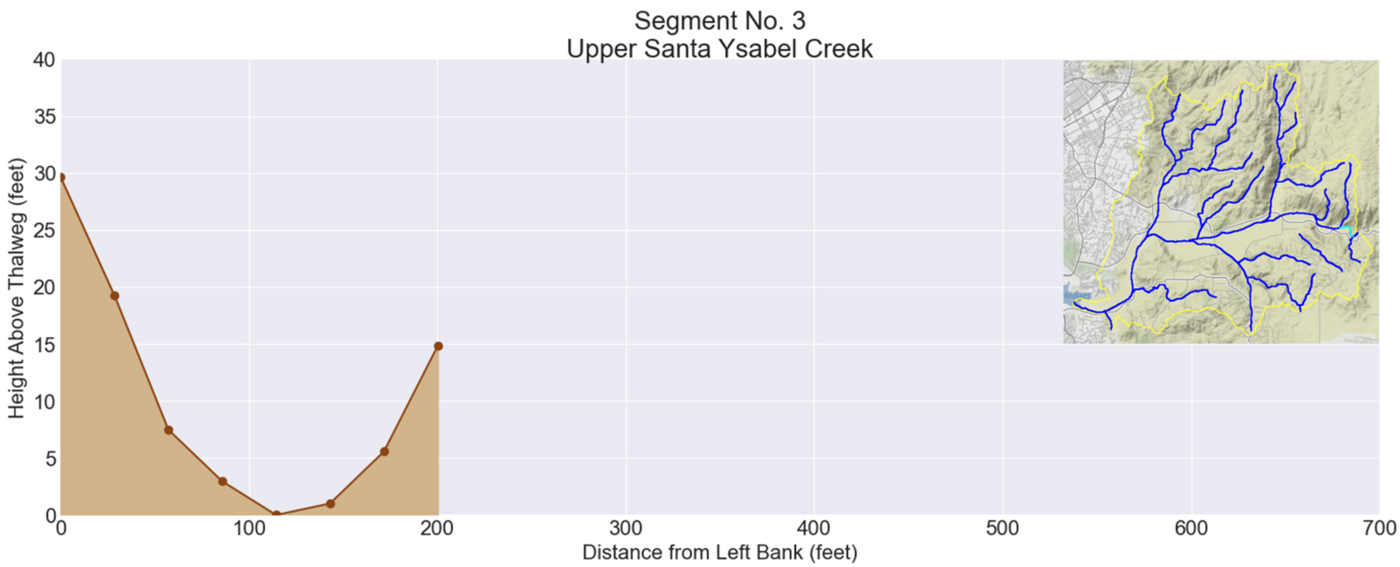
San Pasual Valley Infiltration Testing
City of San Diego

By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-8

ATTACHMENT B: PLANNED MODELED EIGHT-POINT STREAM CHANNELS







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-1

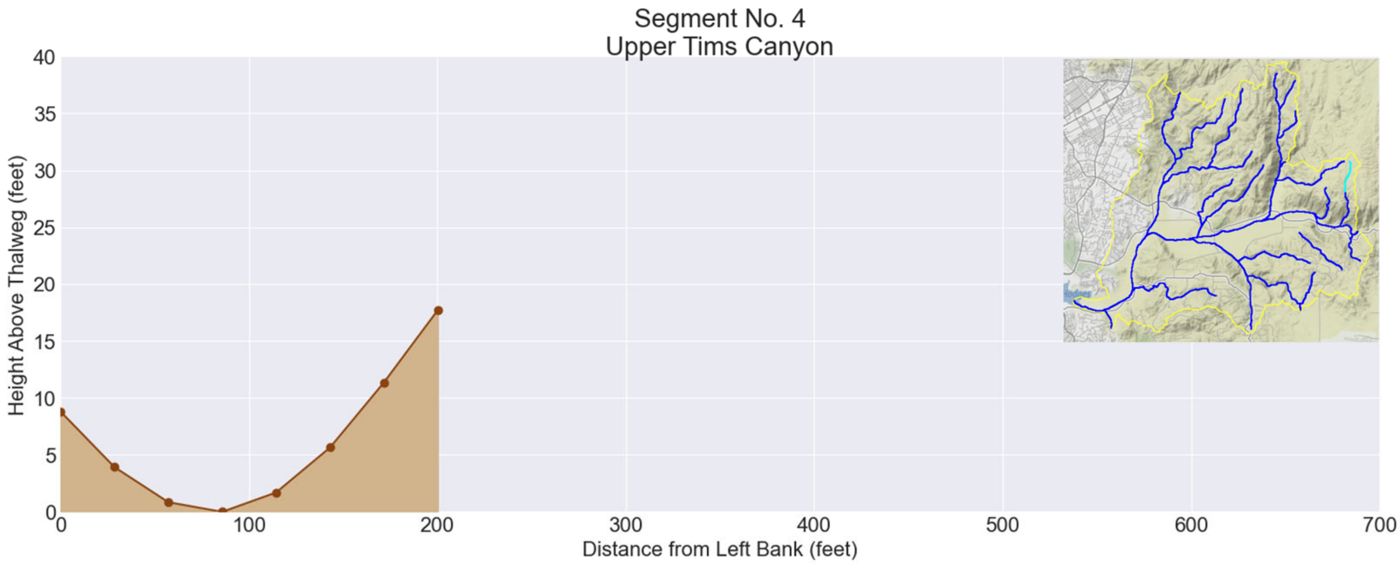
Modeled Eight-point Stream Channels by Segment Number

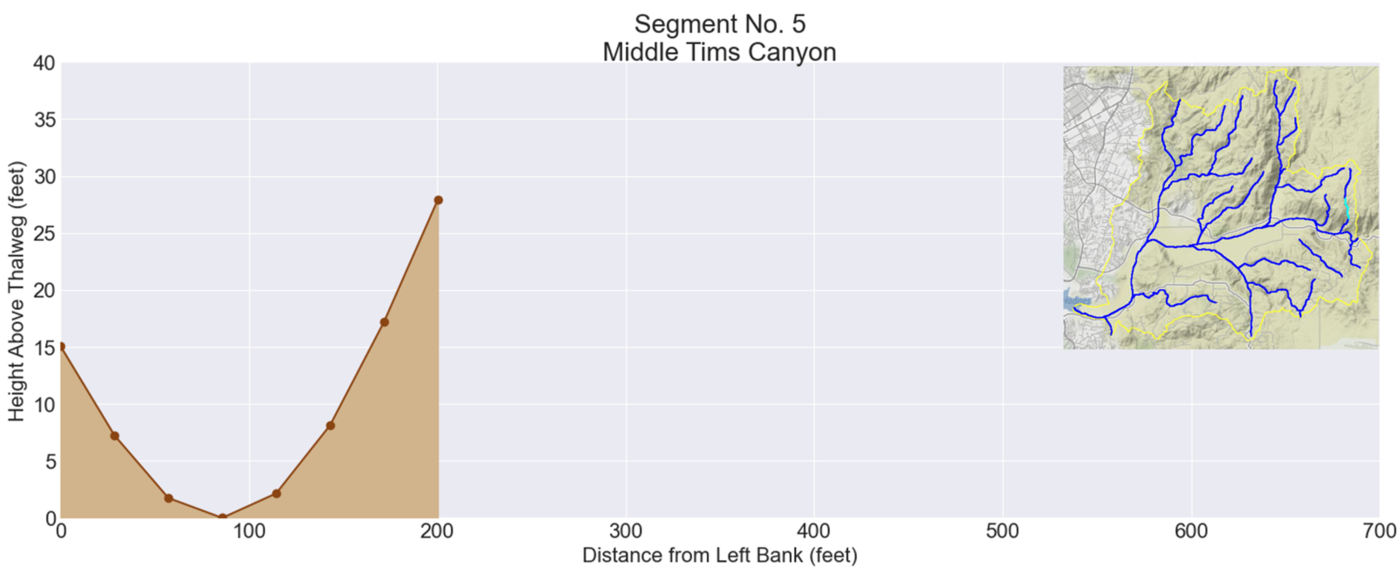
PMA7: Initial Surface Water Recharge Evaluation

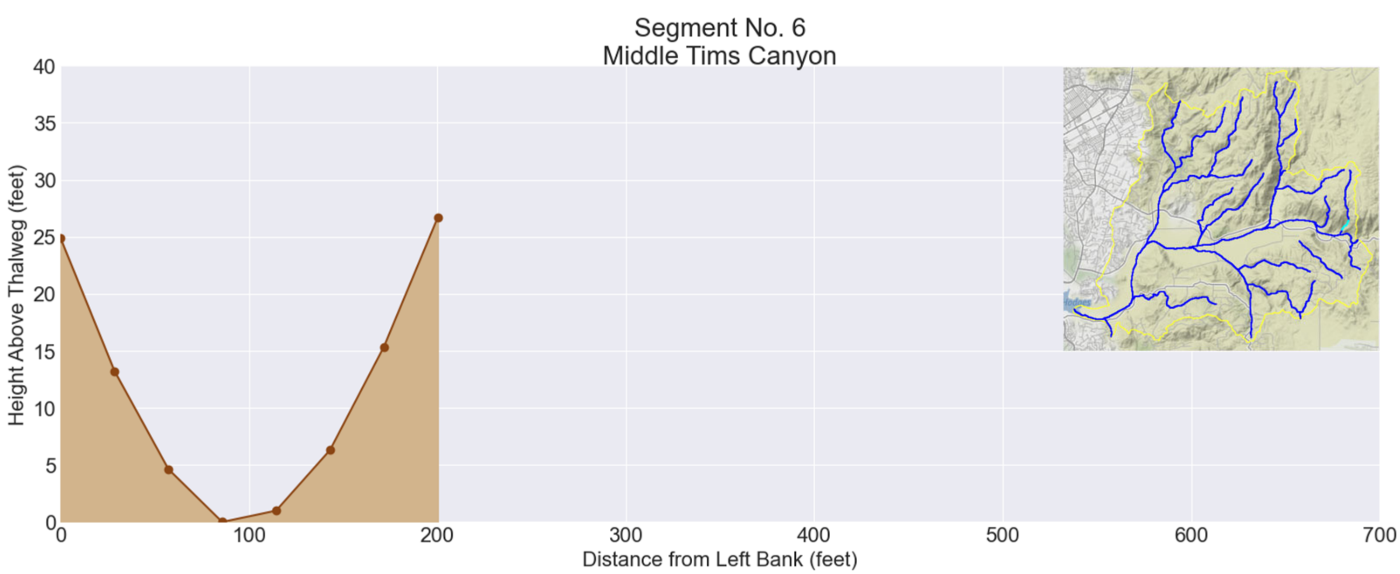
Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs







Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-2
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

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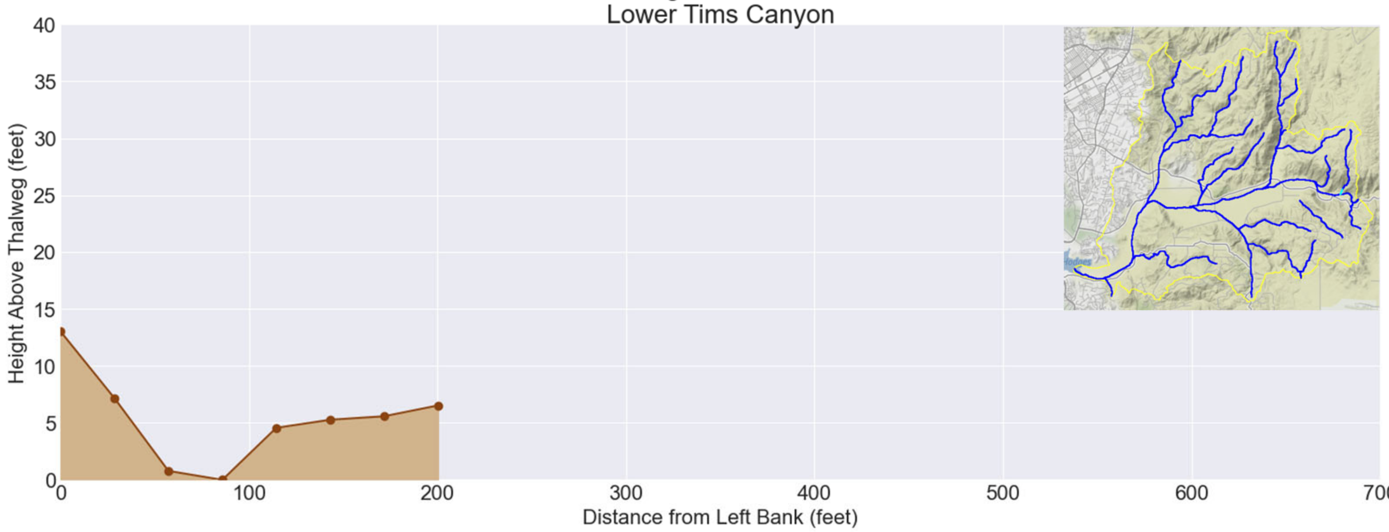
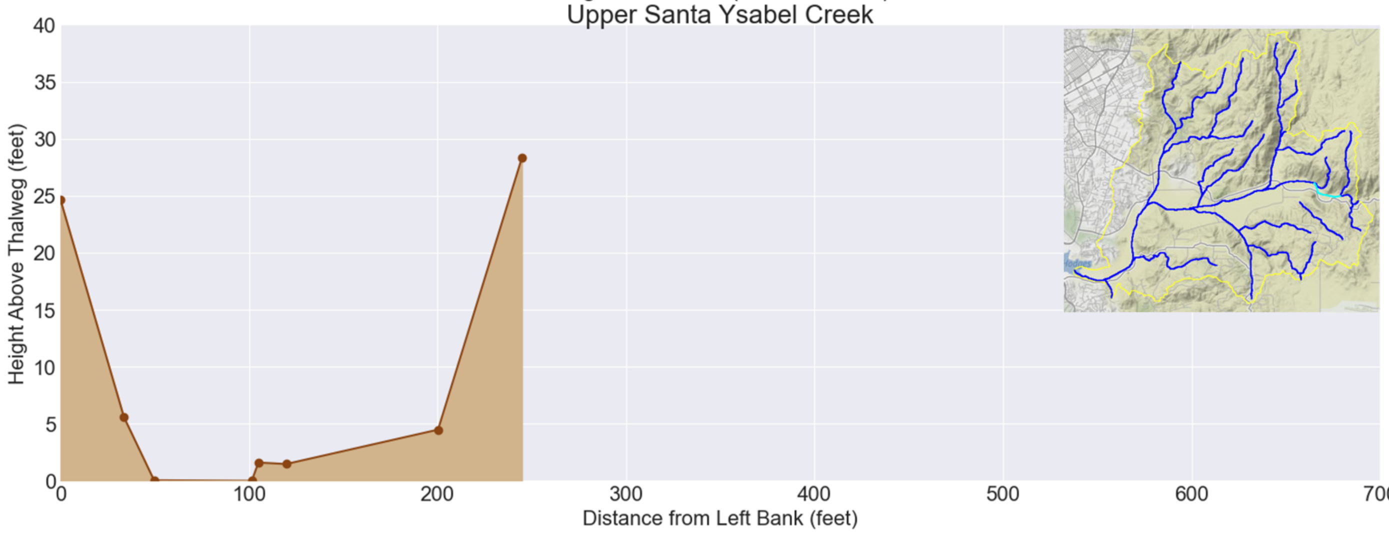
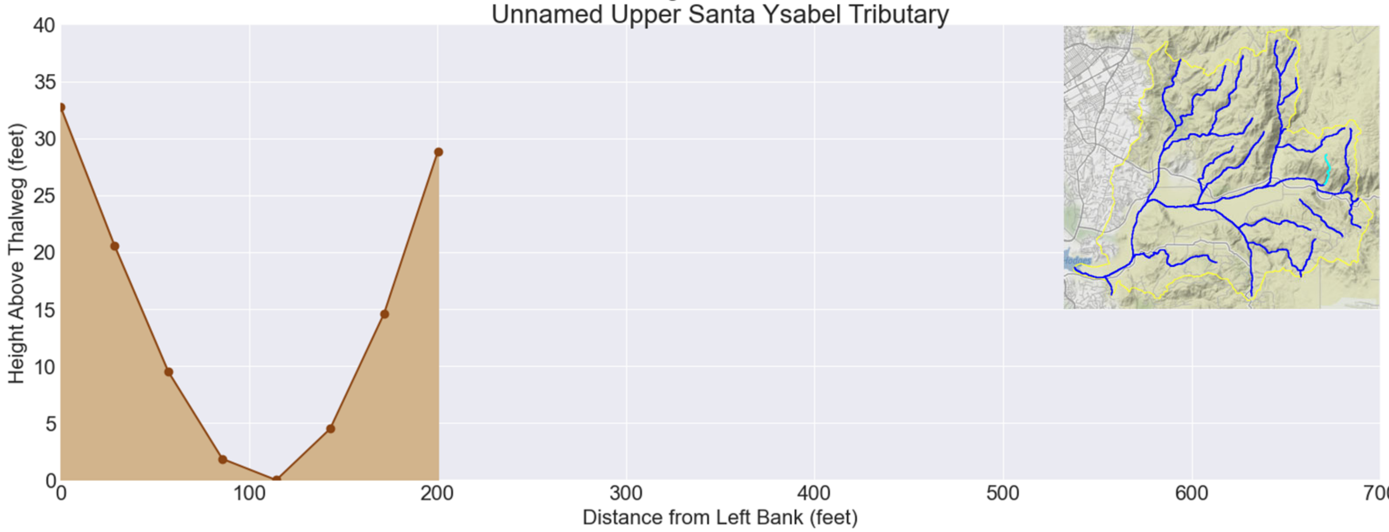
Segment No. 7
Lower Tims Canyon



Segment No. 8 (T-1 Transect)
Upper Santa Ysabel Creek



Segment No. 9
Unnamed Upper Santa Ysabel Tributary



Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-3

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

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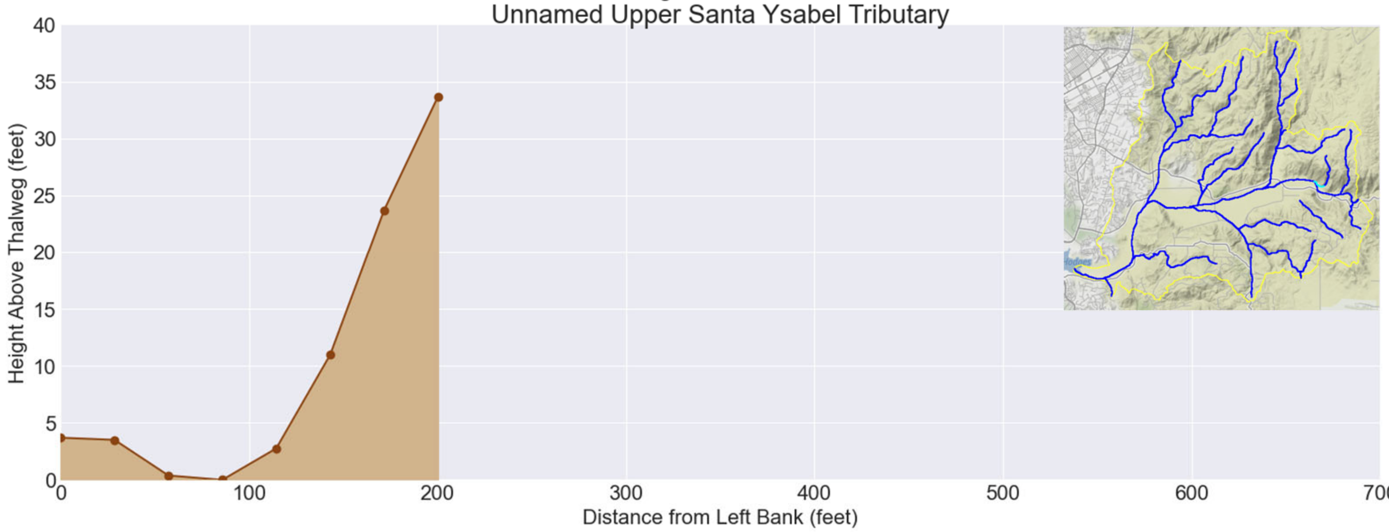
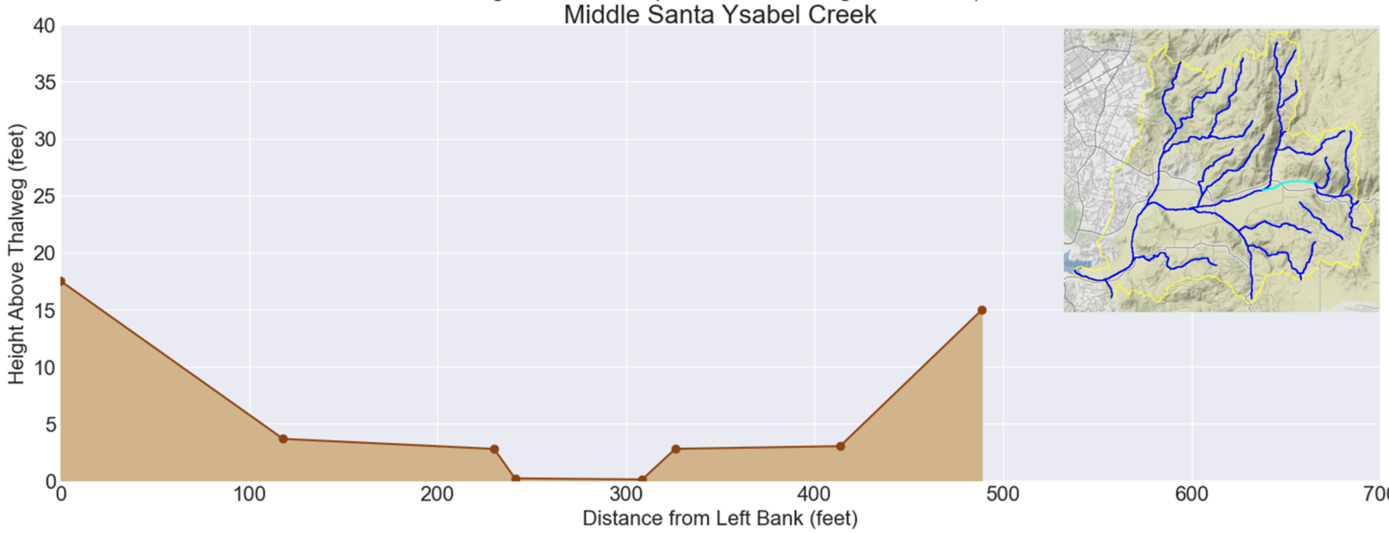
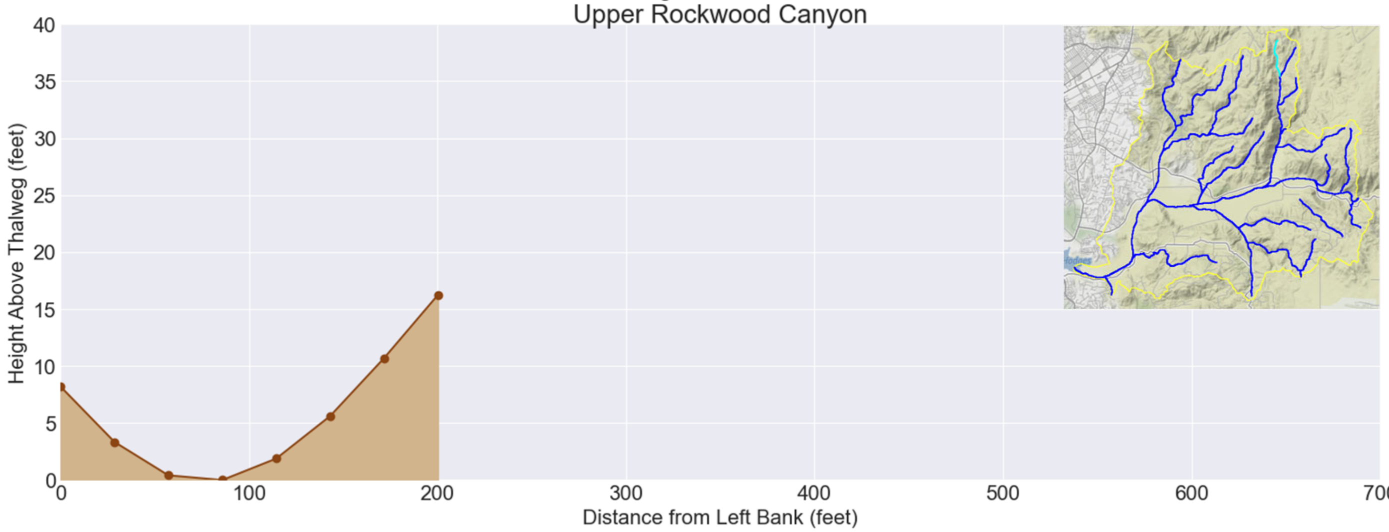
Segment No. 10
Unnamed Upper Santa Ysabel Tributary



Segment No. 11 (T-2 & T-3 Average Transect)
Middle Santa Ysabel Creek



Segment No. 12
Upper Rockwood Canyon



Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-4

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

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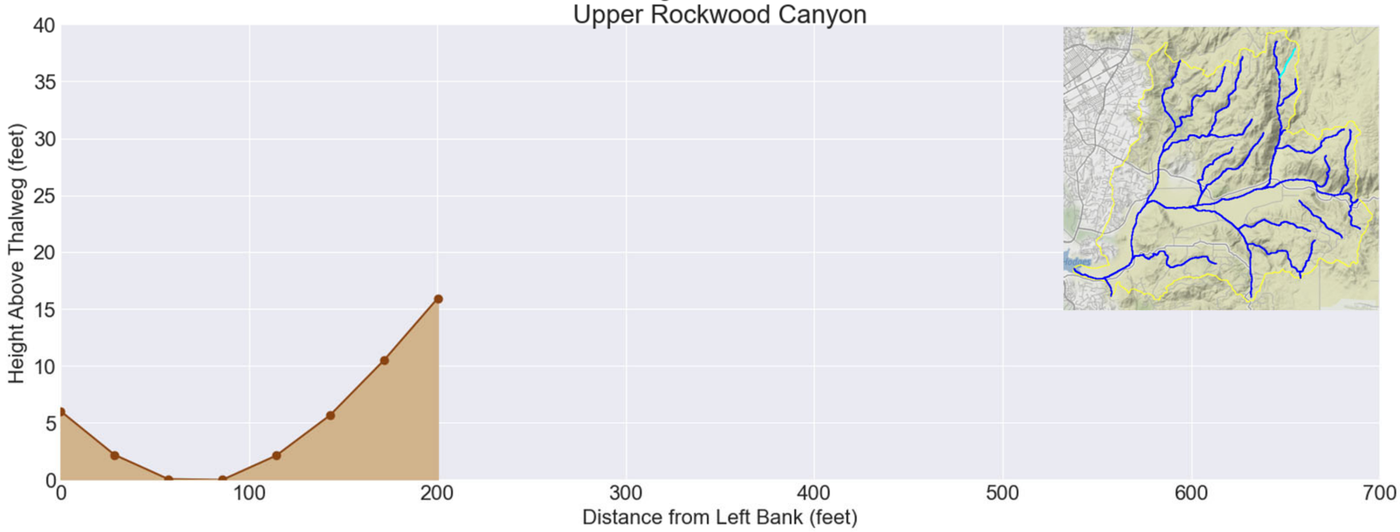
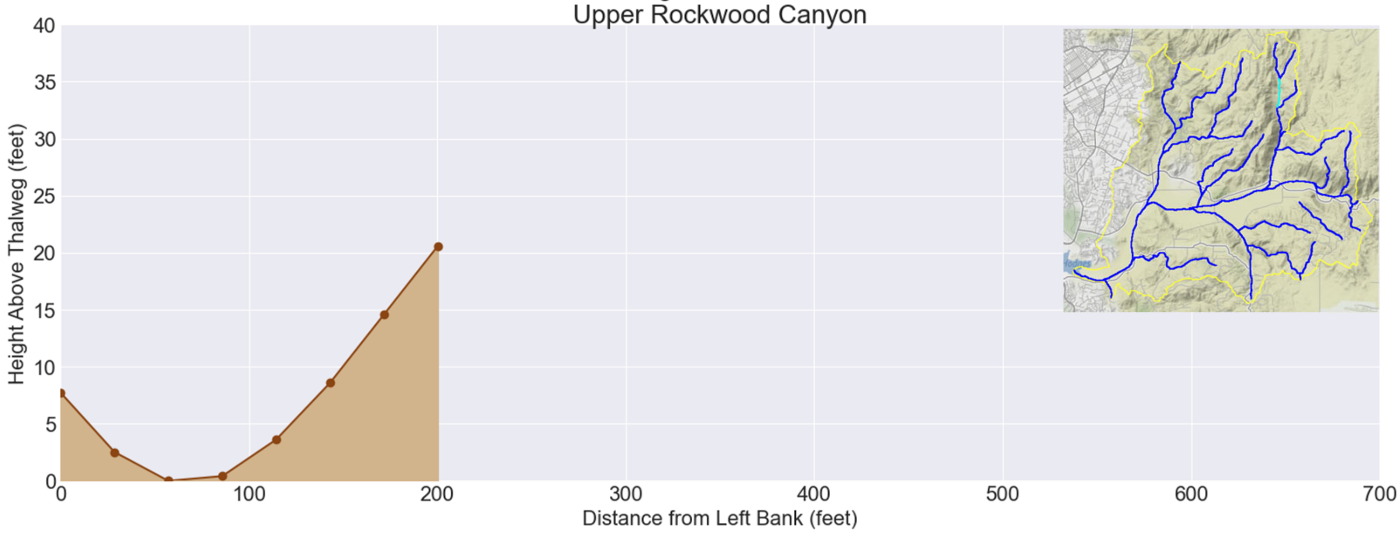
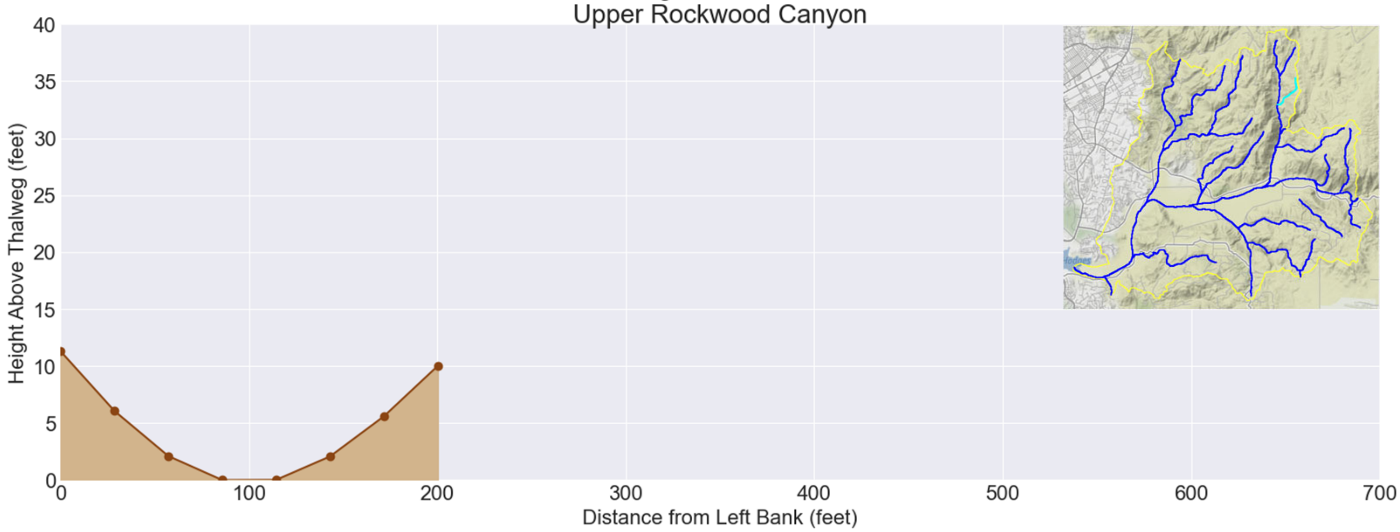
Segment No. 13
Upper Rockwood Canyon



Segment No. 14
Upper Rockwood Canyon



Segment No. 15
Upper Rockwood Canyon

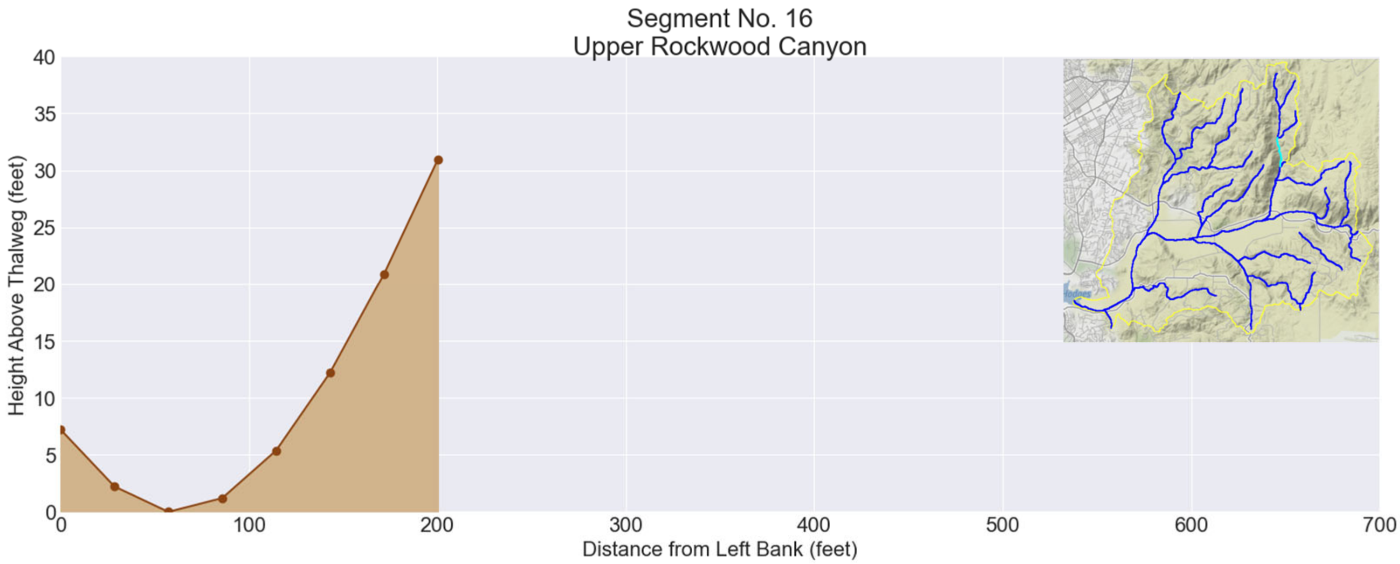


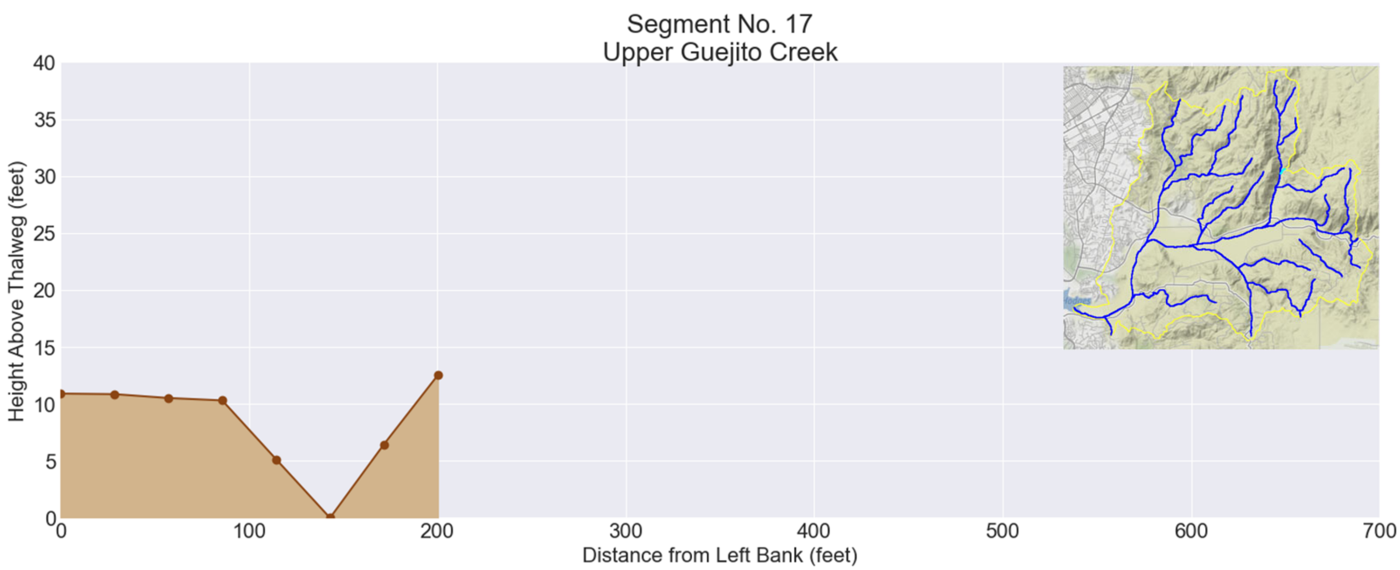
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

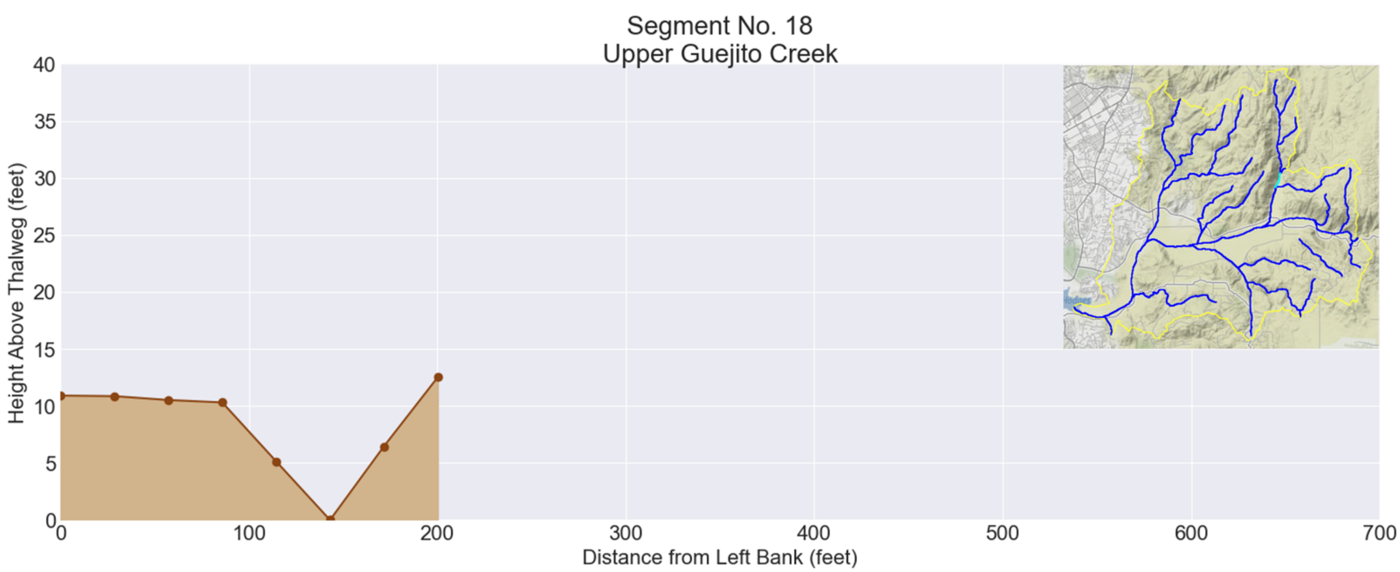
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-5
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs







Notes:

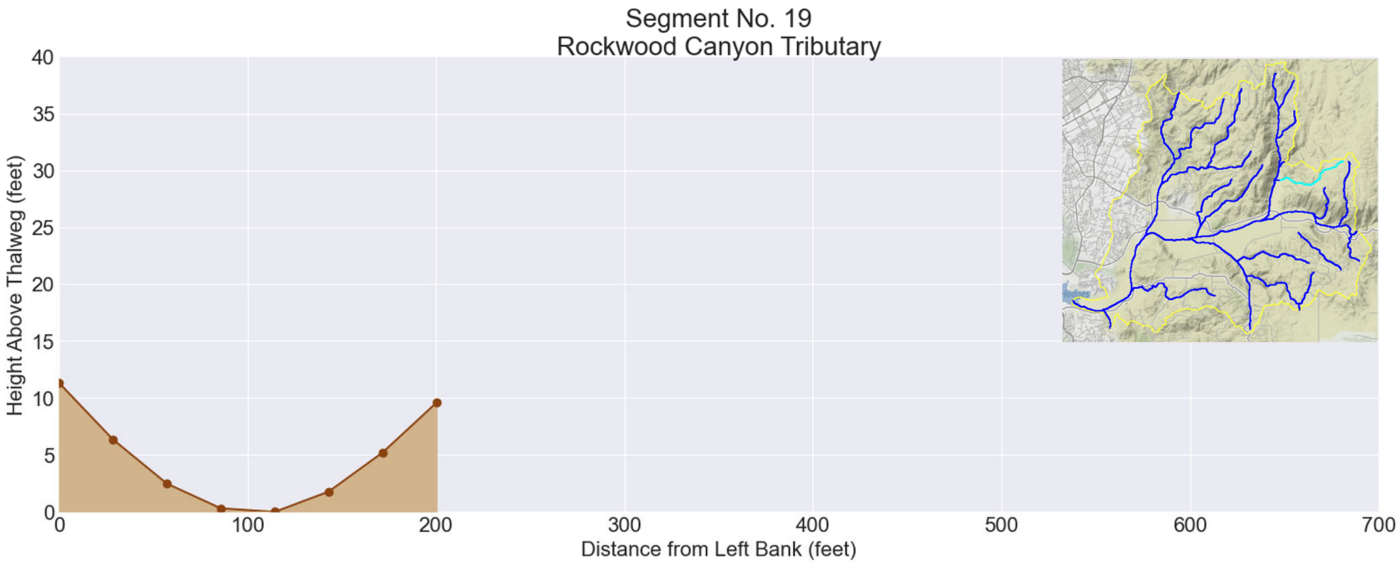
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

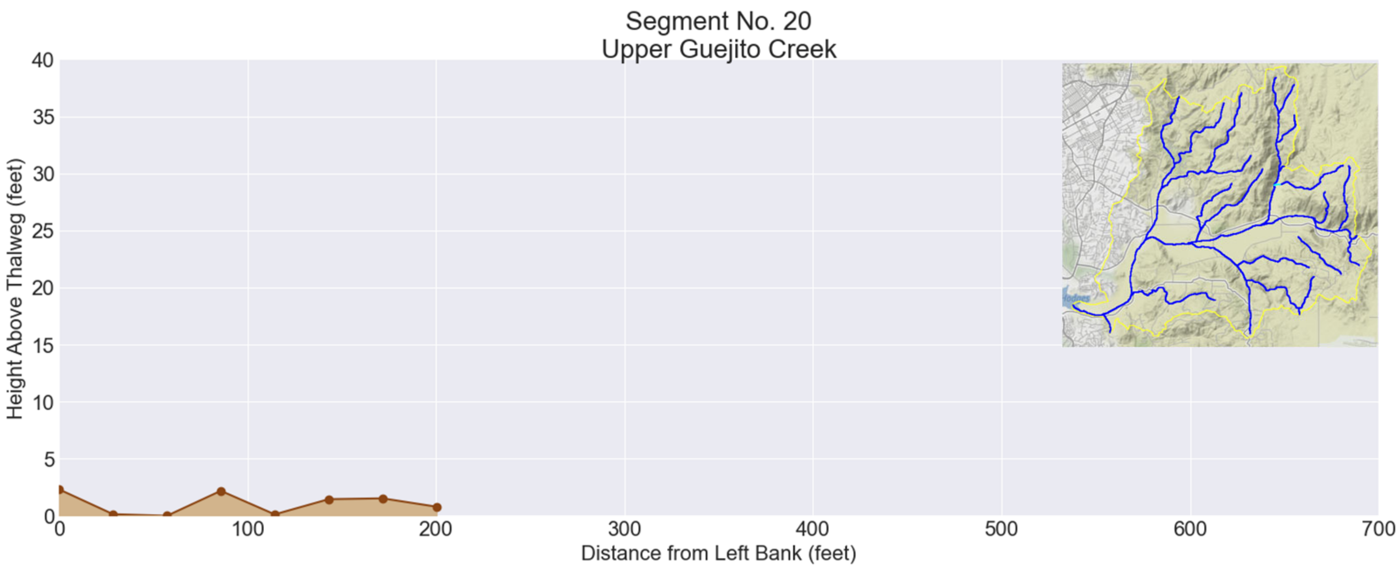
Map Legend

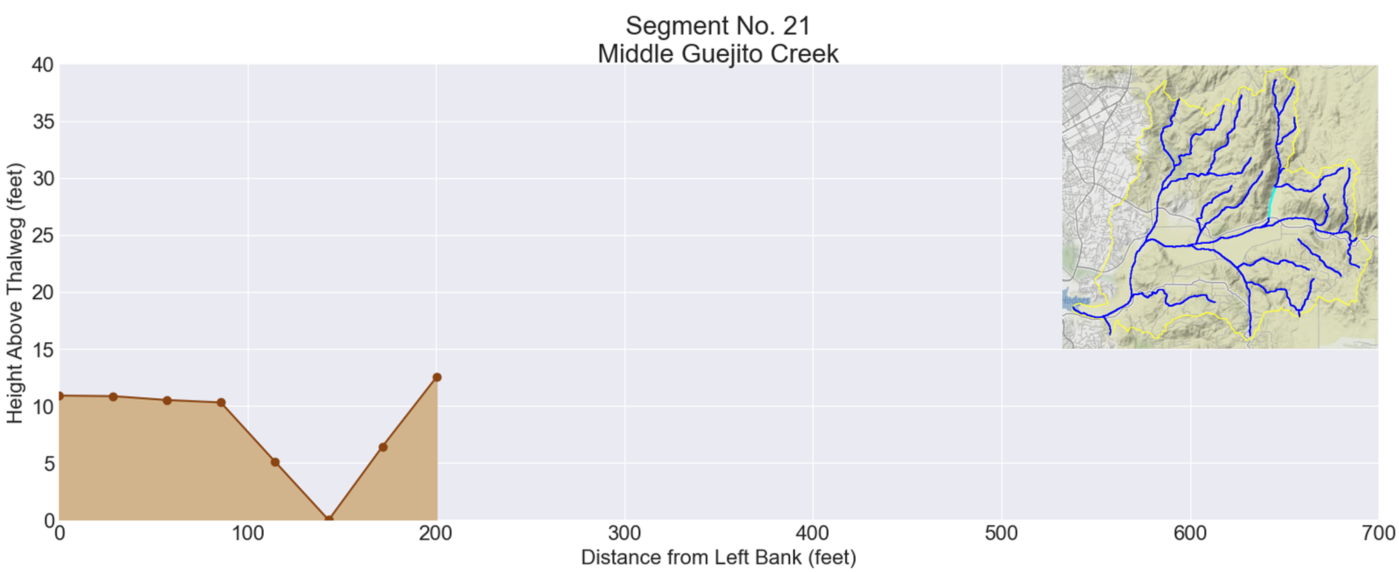
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-6
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend

Modeled Stream

Highlighted Segment of Modeled Stream

Figure B-7

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

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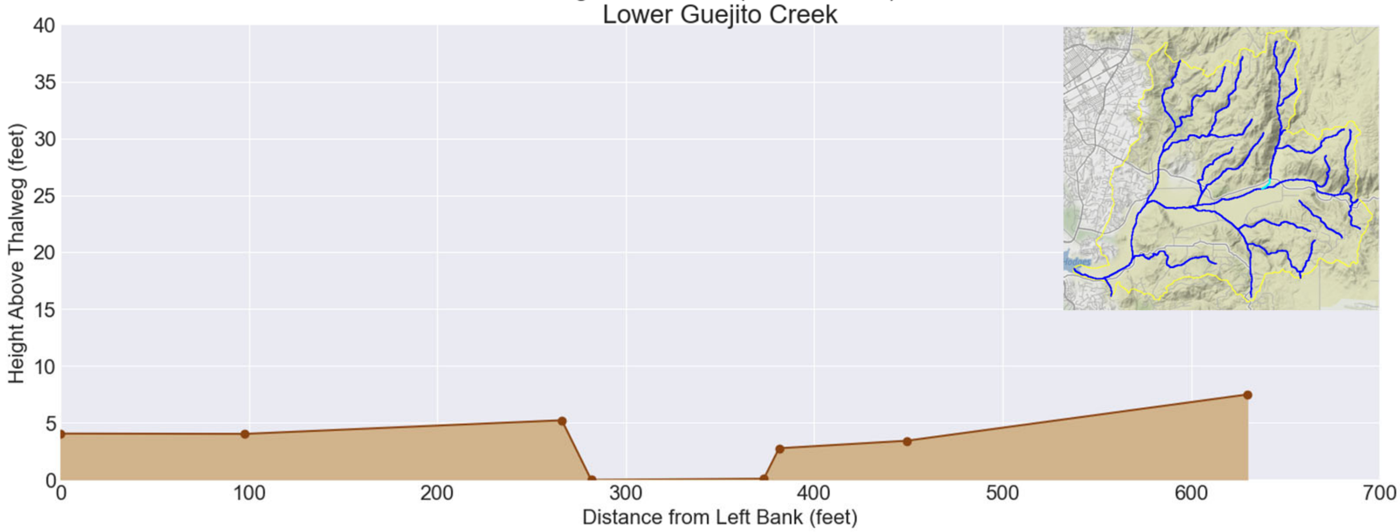
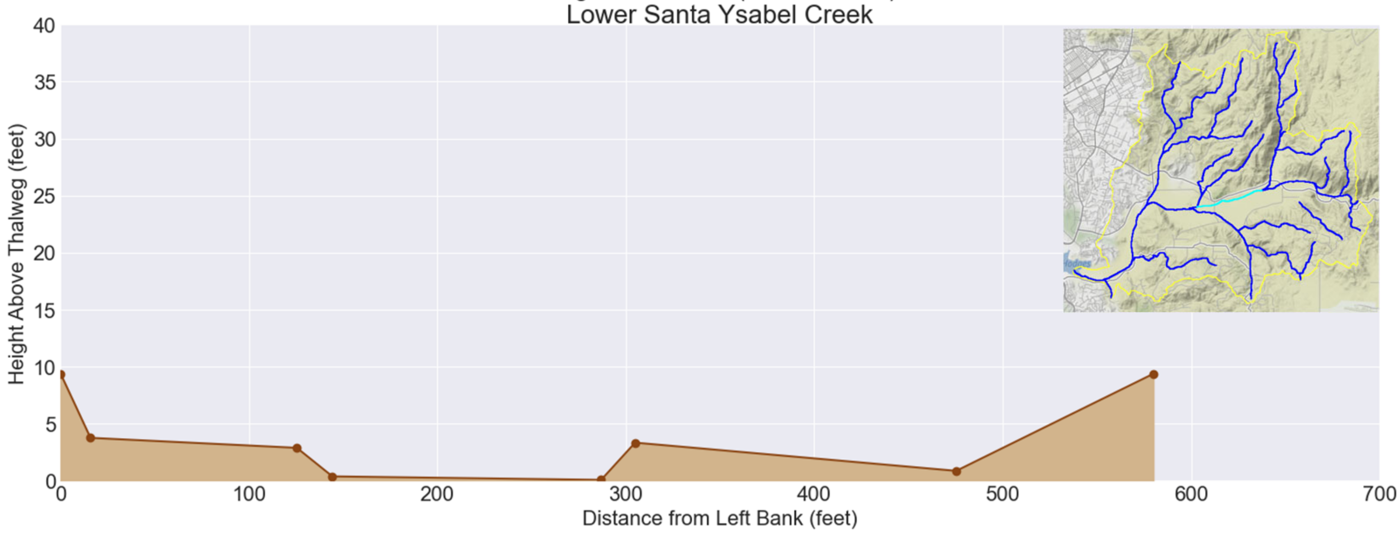
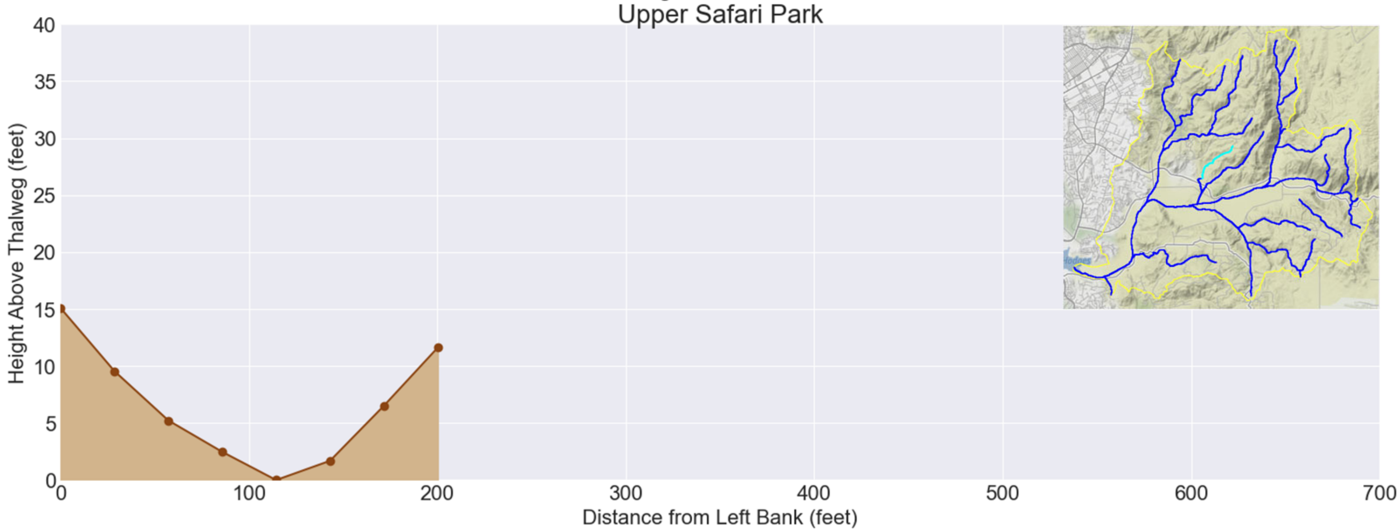
Segment No. 22 (T-5 Transect)
Lower Guejito Creek



Segment No. 23 (T-4 Transect)
Lower Santa Ysabel Creek



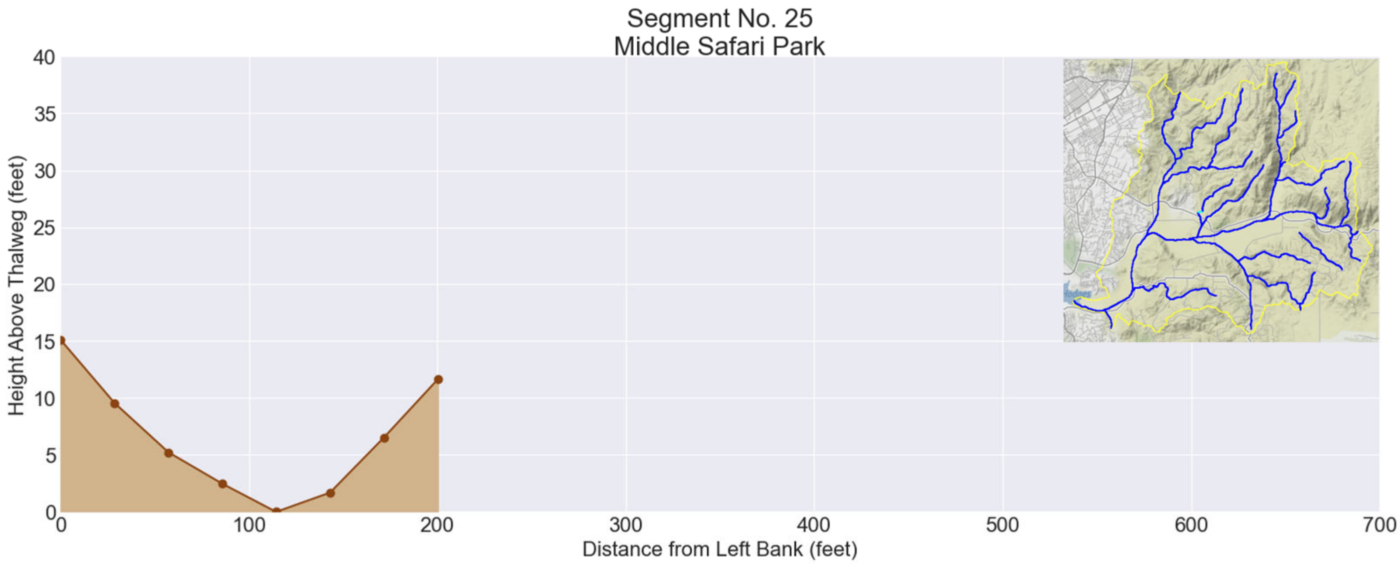
Segment No. 24
Upper Safari Park

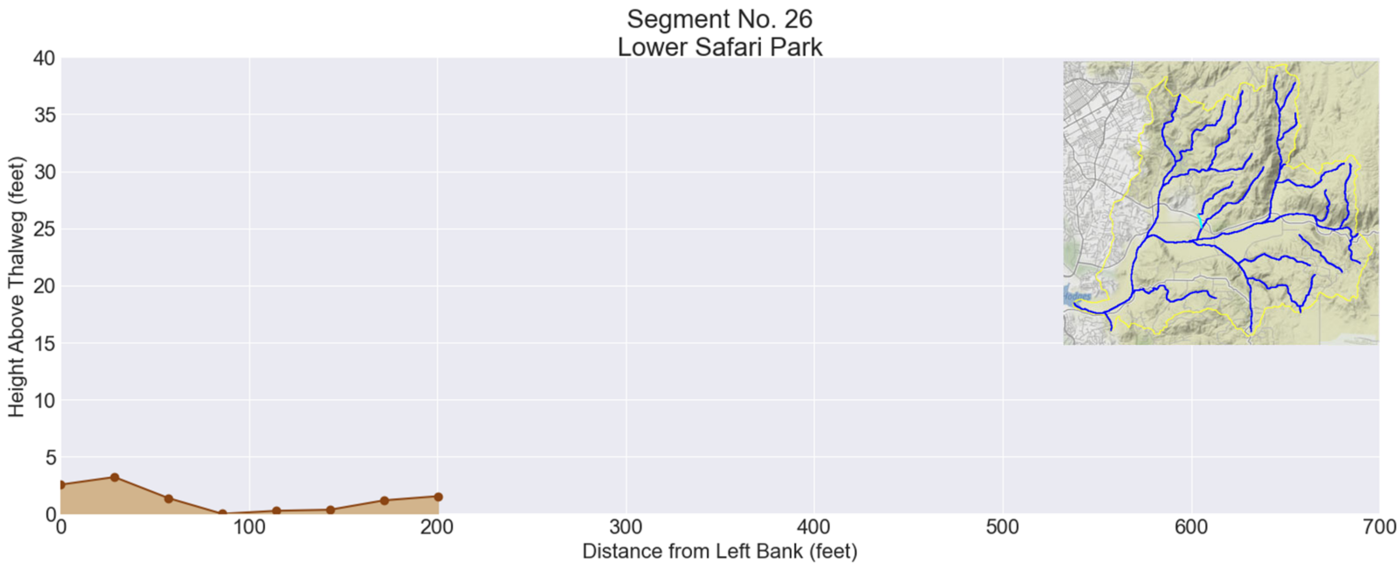


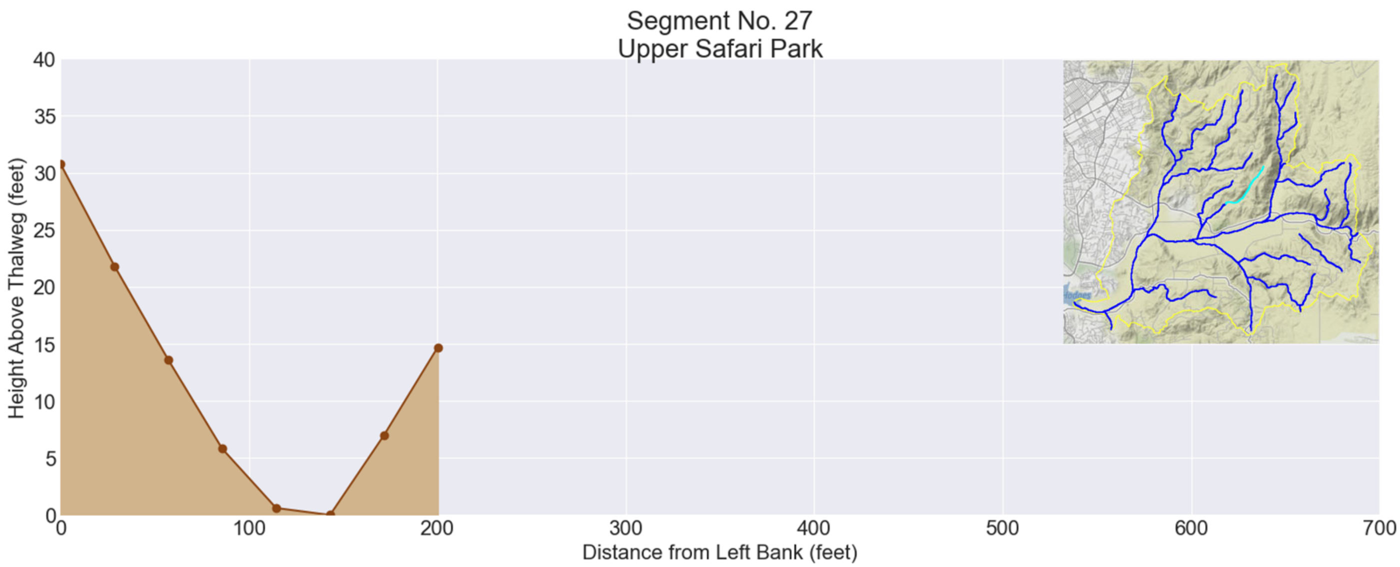
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-8
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California





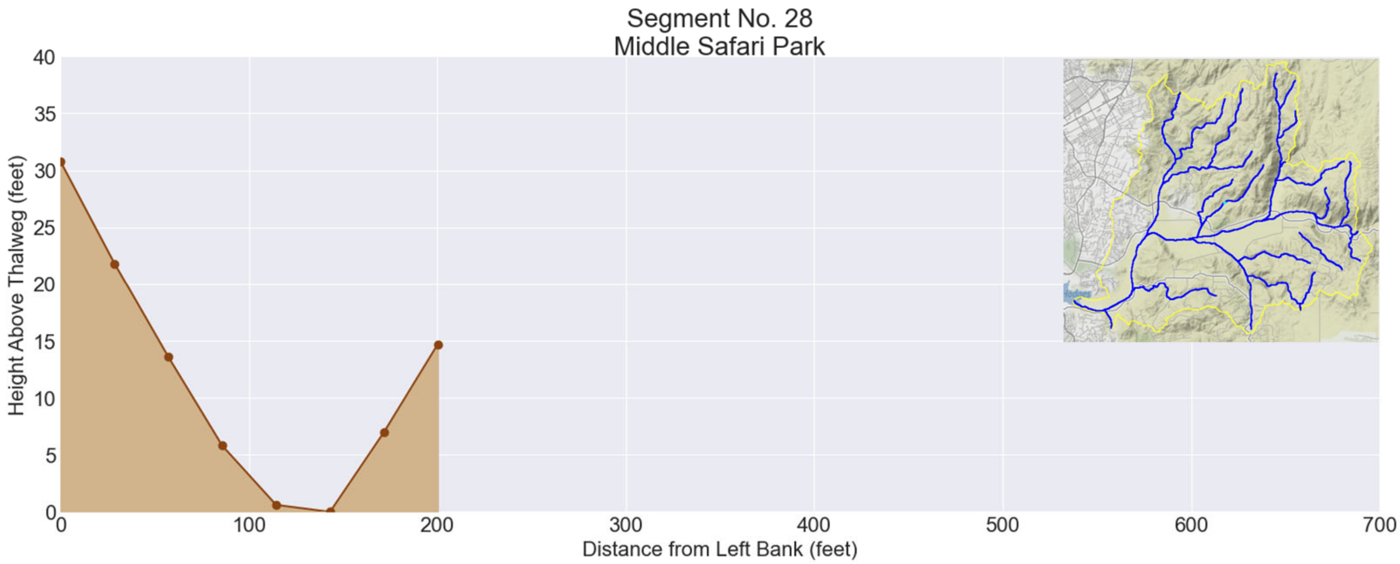


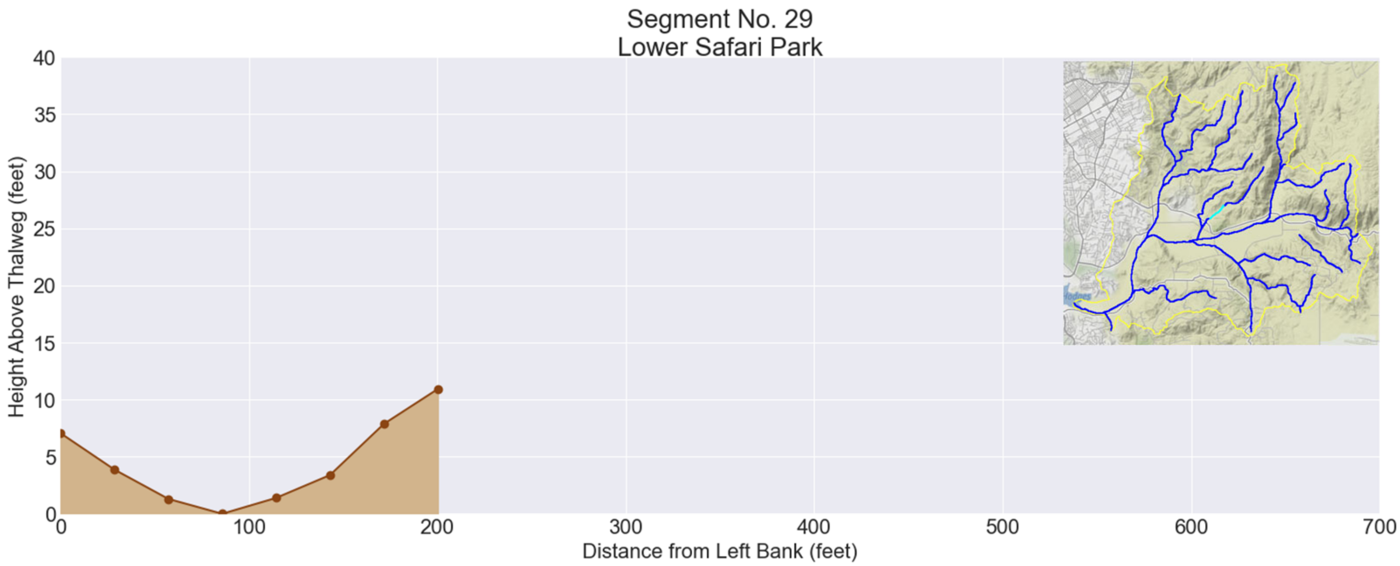
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

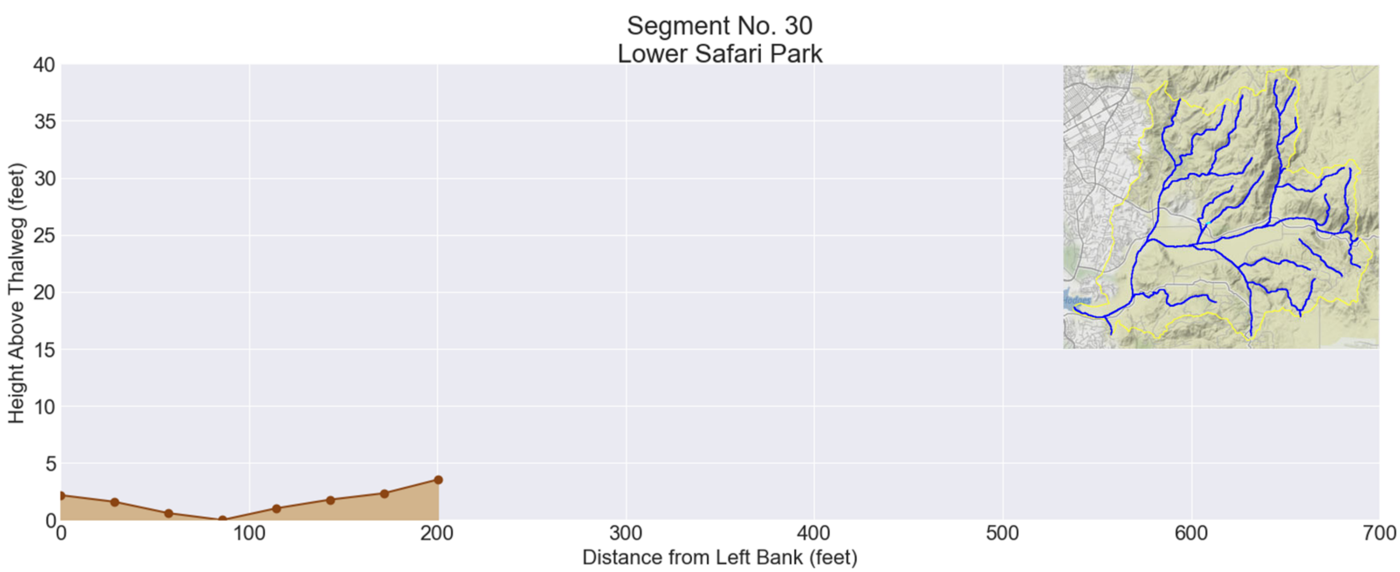
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-9
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs





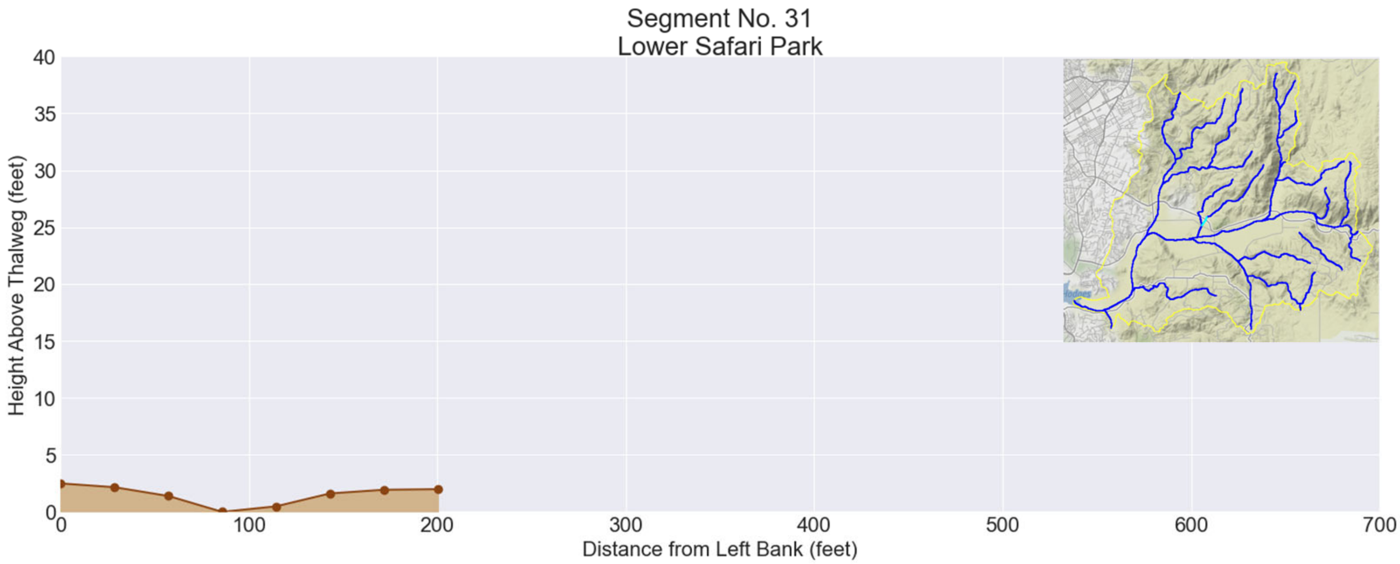


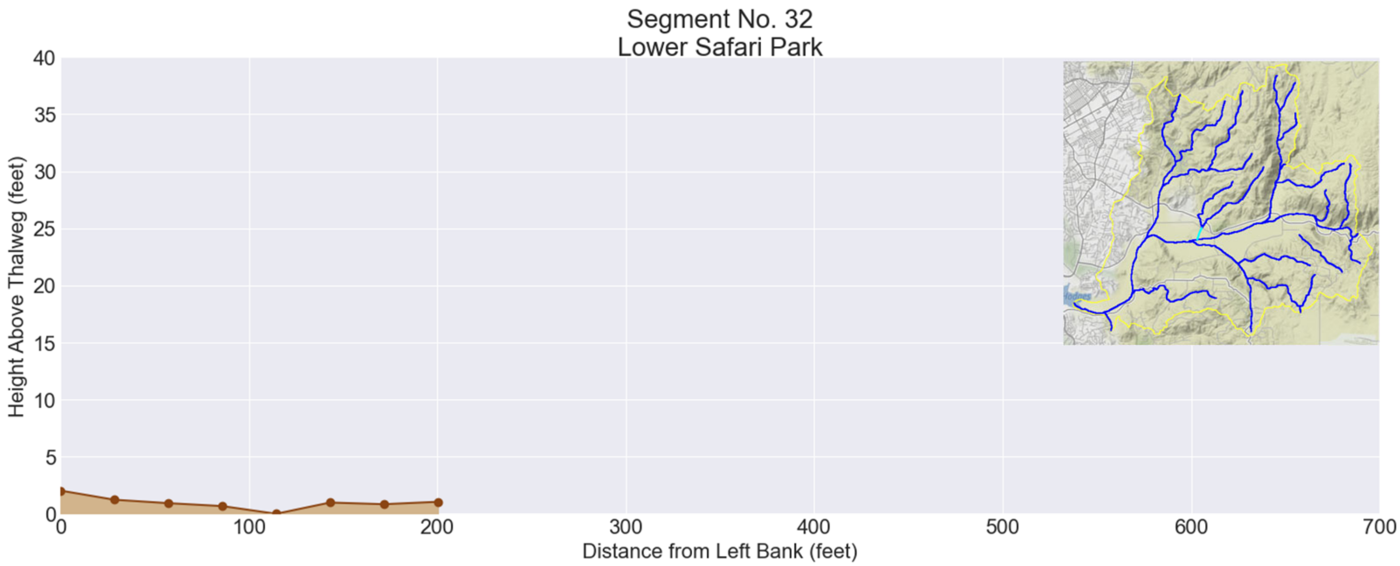
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

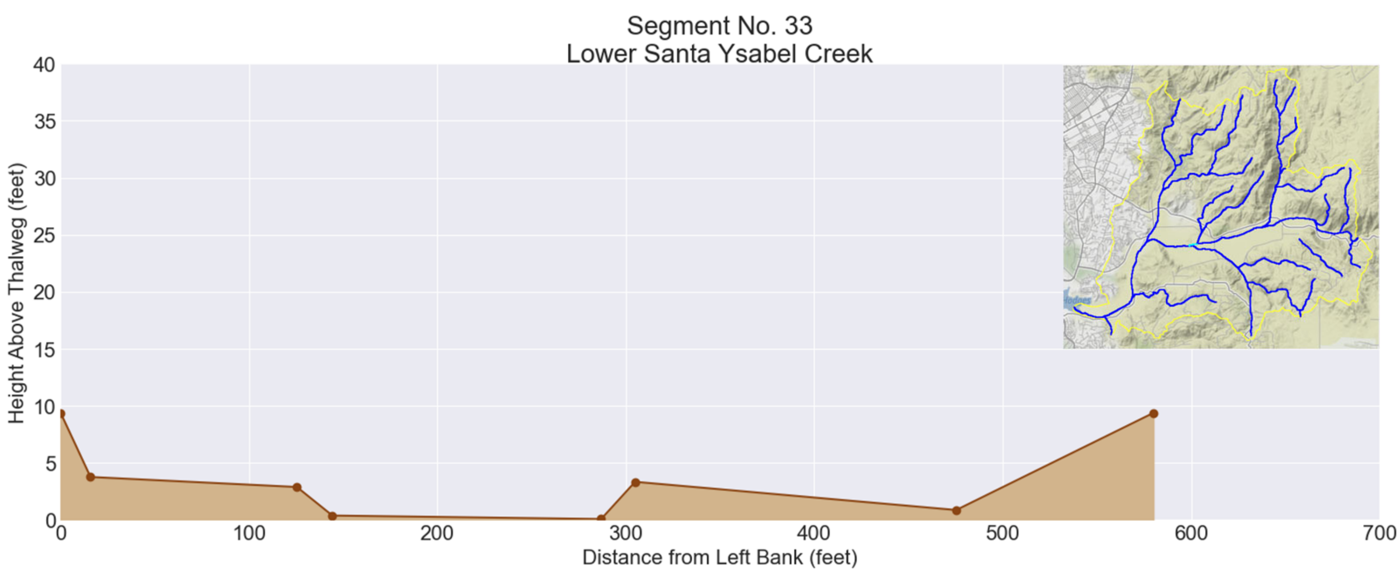
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-10
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend

Modeled Stream

Highlighted Segment of Modeled Stream

Figure B-11

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

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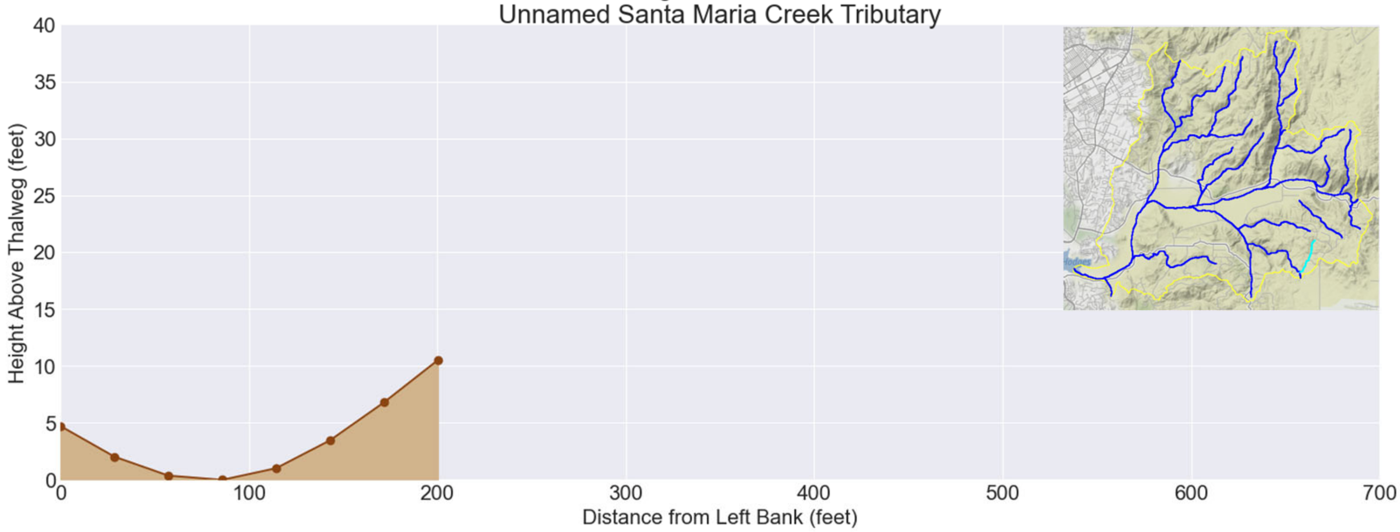
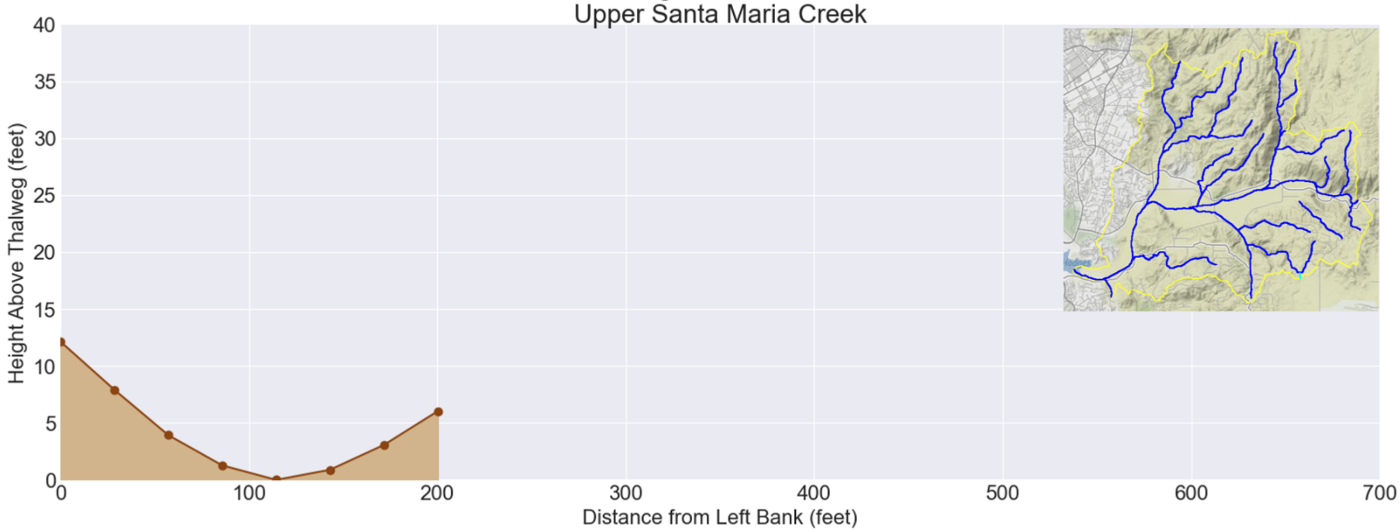
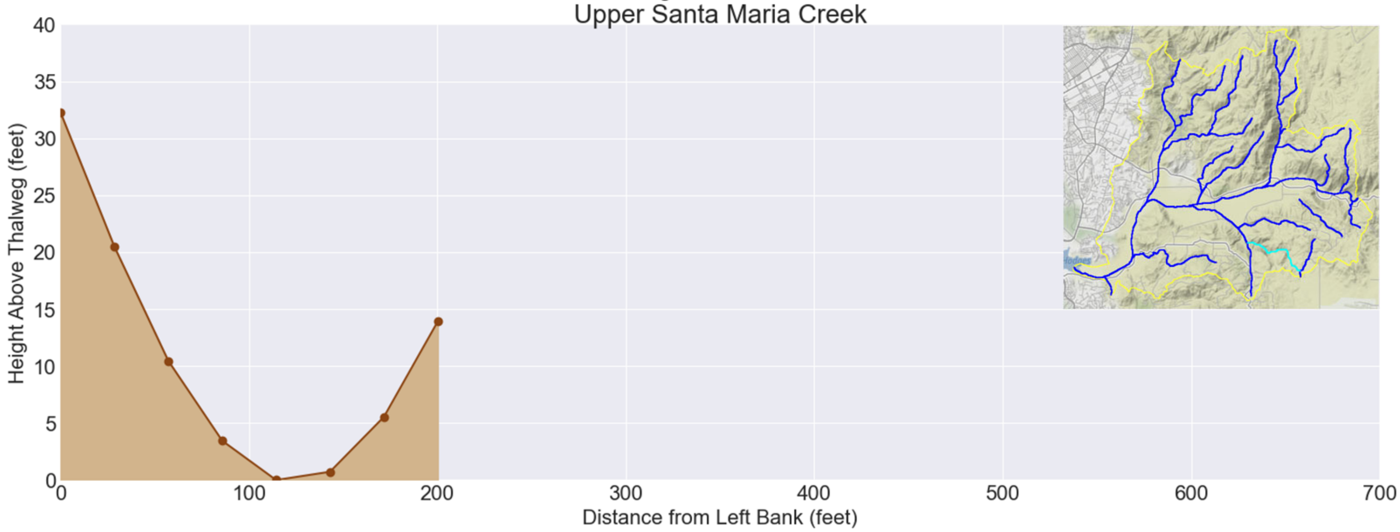
Segment No. 34
Unnamed Santa Maria Creek Tributary



Segment No. 35
Upper Santa Maria Creek



Segment No. 36
Upper Santa Maria Creek

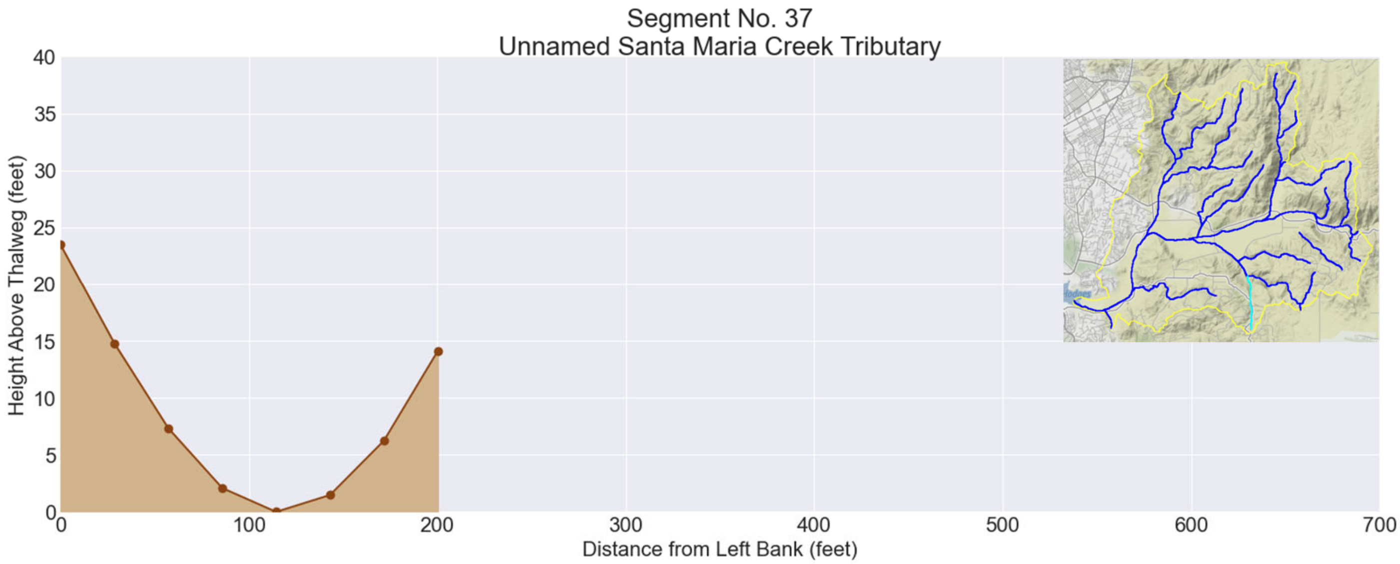


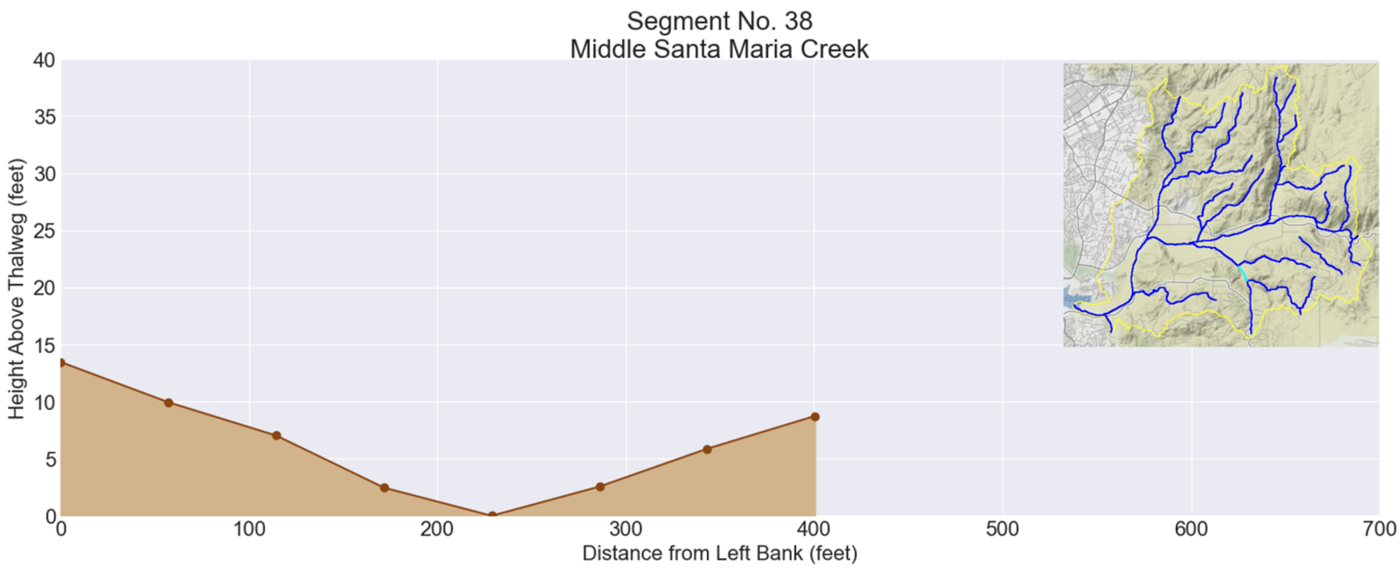
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

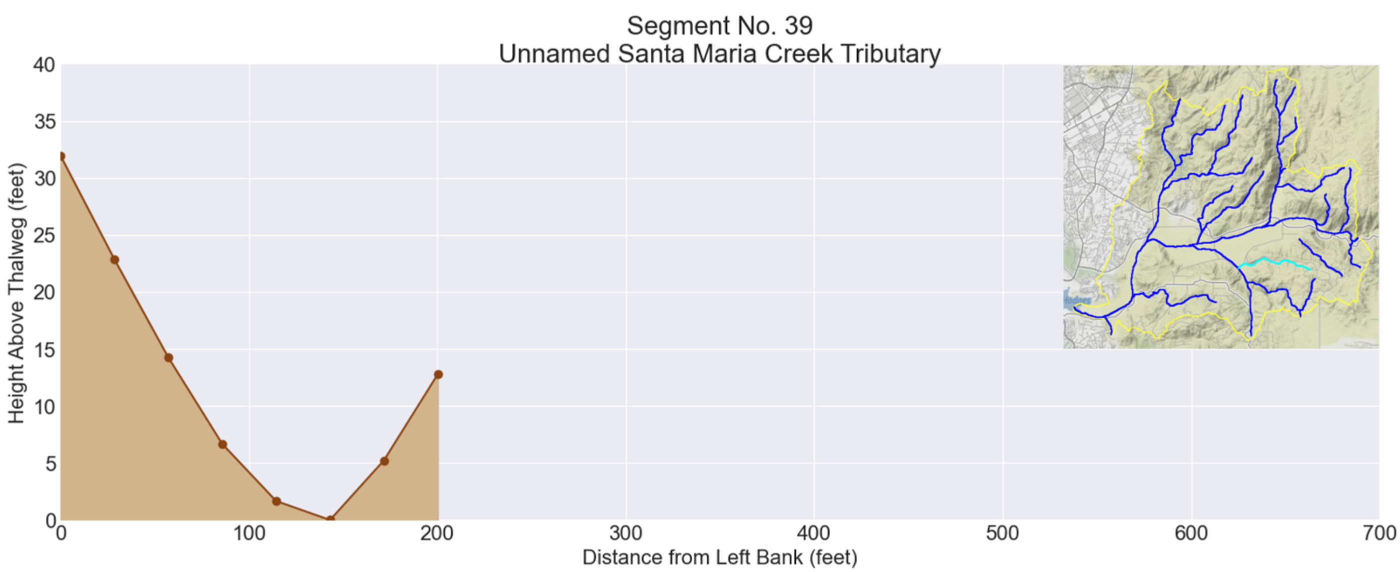
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-12
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend

Modeled Stream

Highlighted Segment of Modeled Stream

Figure B-13

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

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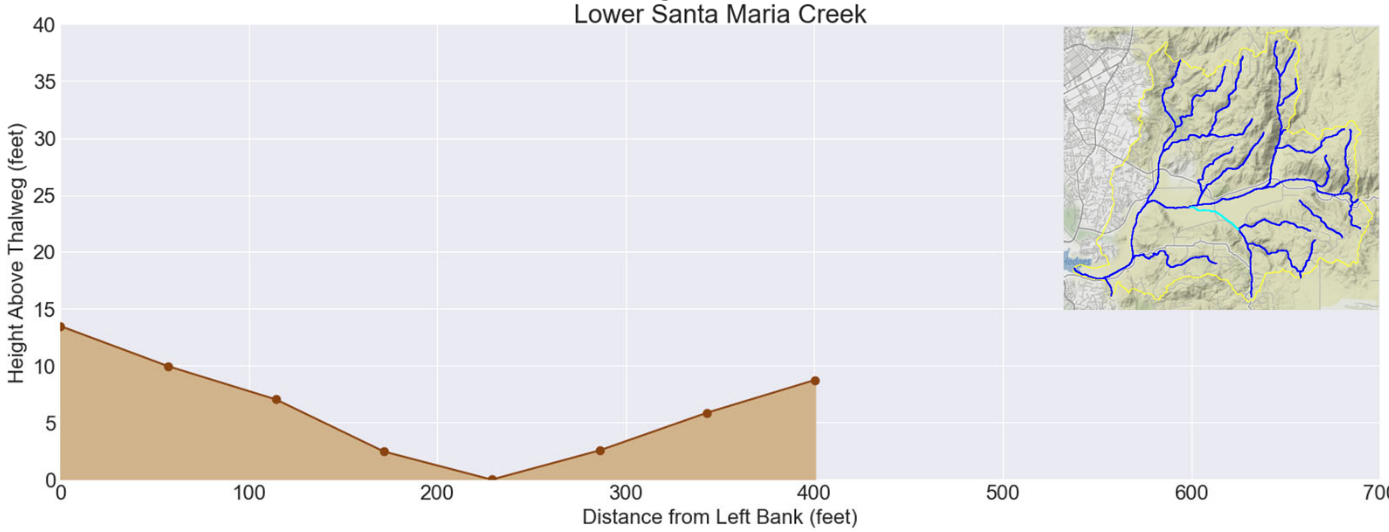
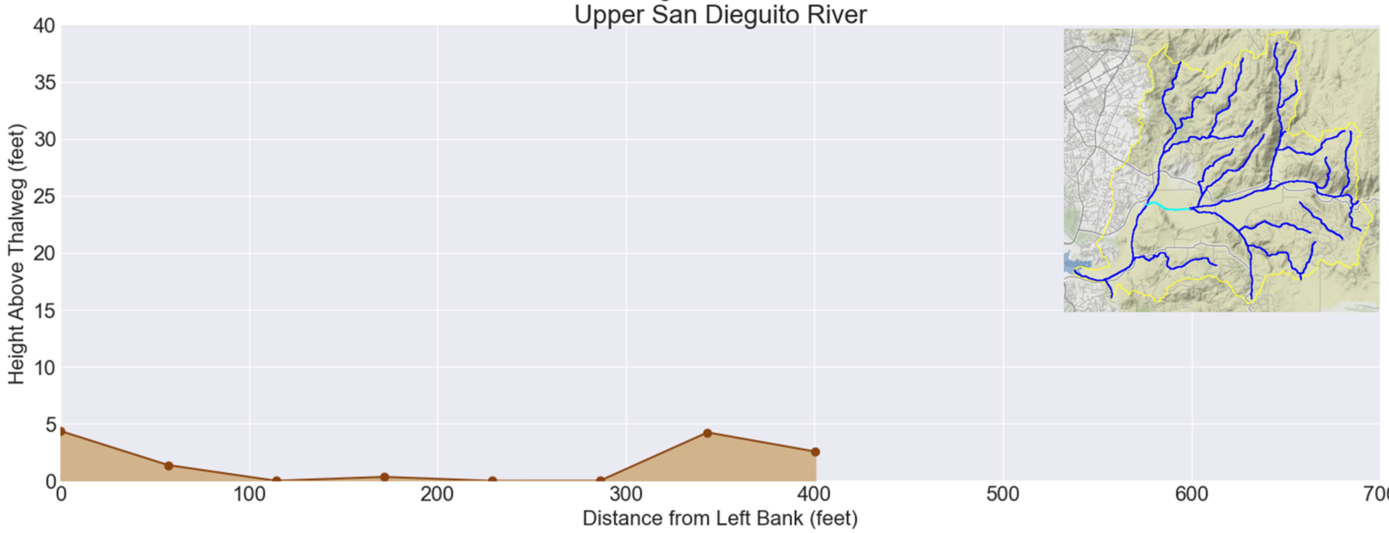
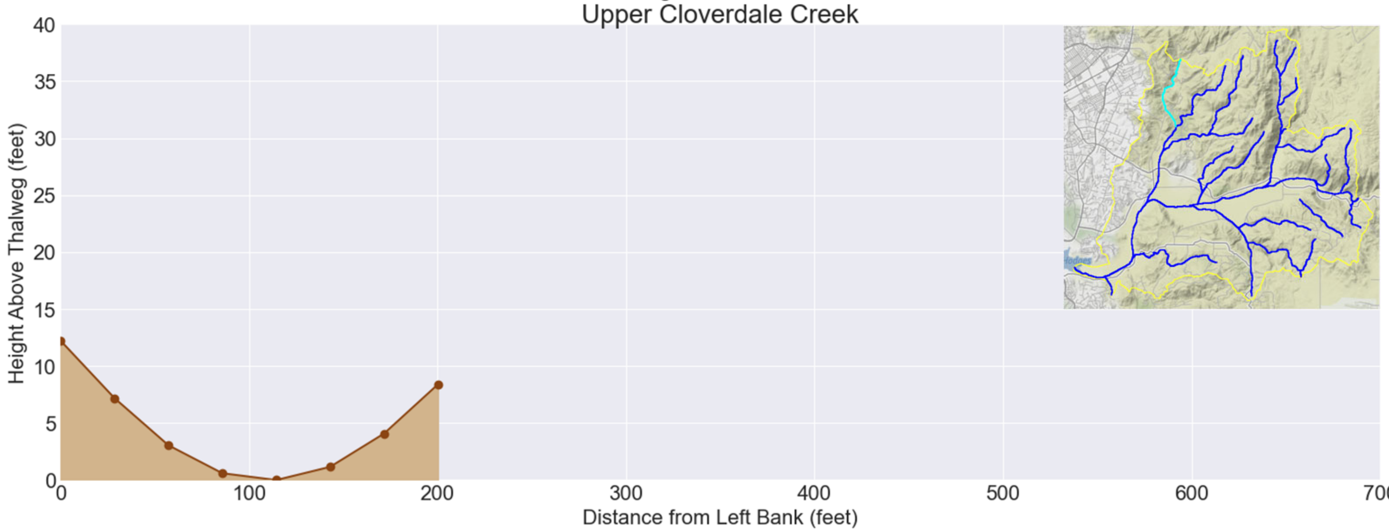
Segment No. 40
Lower Santa Maria Creek



Segment No. 41
Upper San Dieguito River



Segment No. 42
Upper Cloverdale Creek



Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend

Modeled Stream

Highlighted Segment of Modeled Stream

Figure B-14

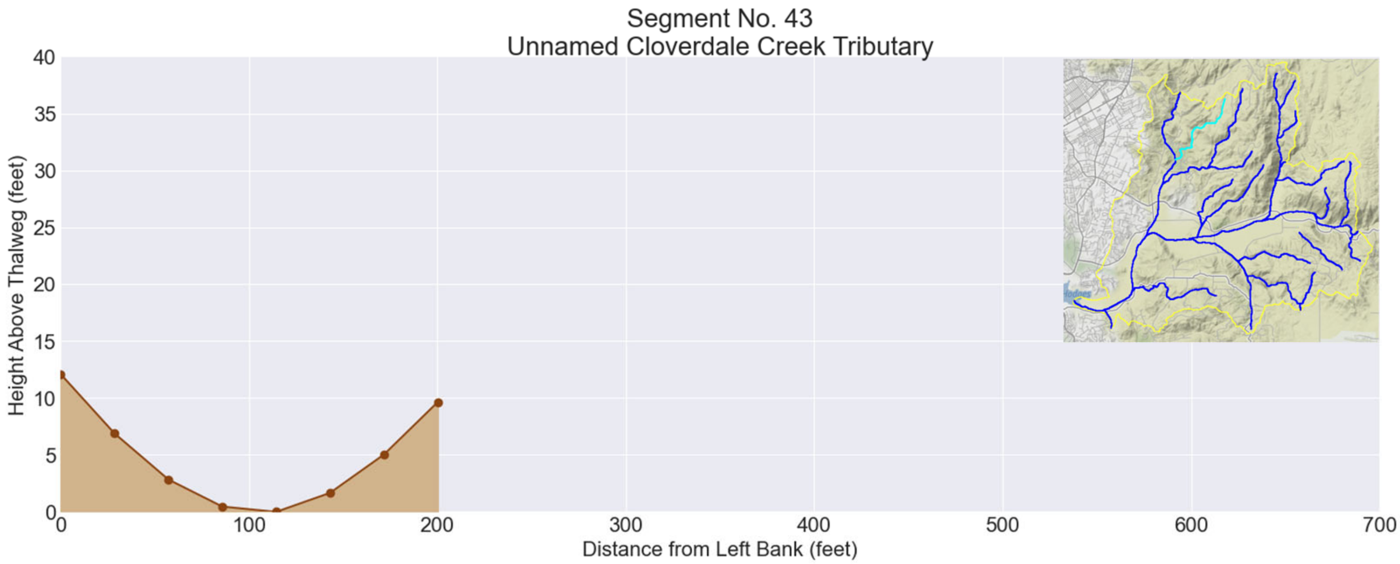
Modeled Eight-point Stream Channels by Segment Number

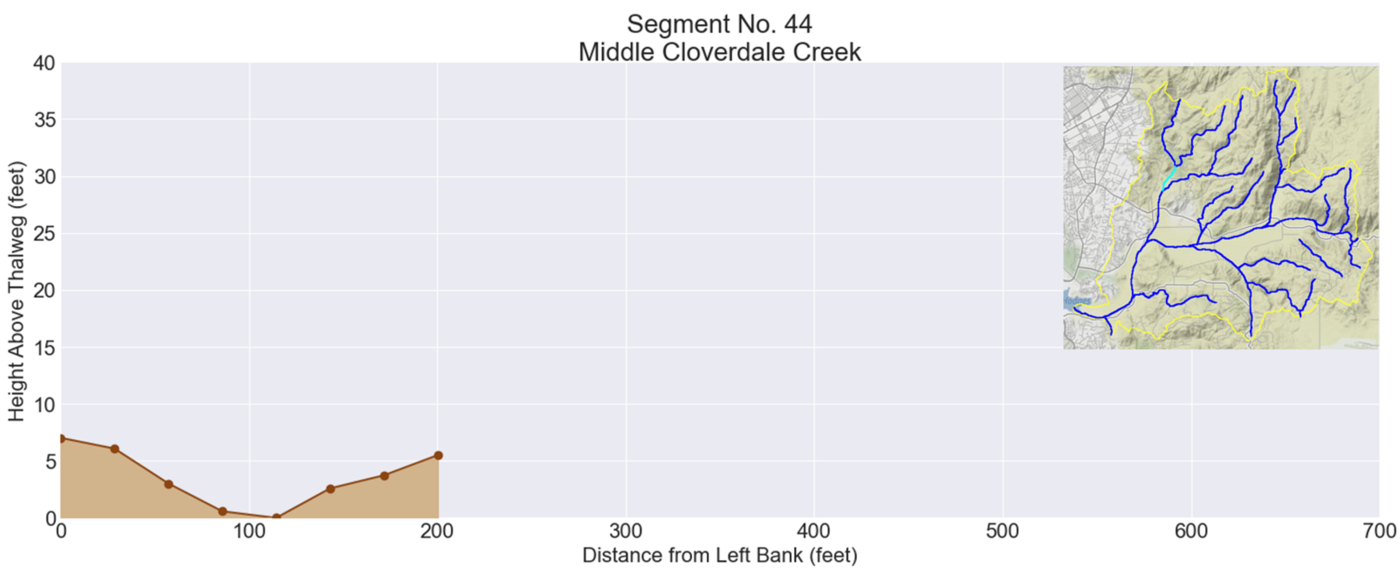
PMA7: Initial Surface Water Recharge Evaluation

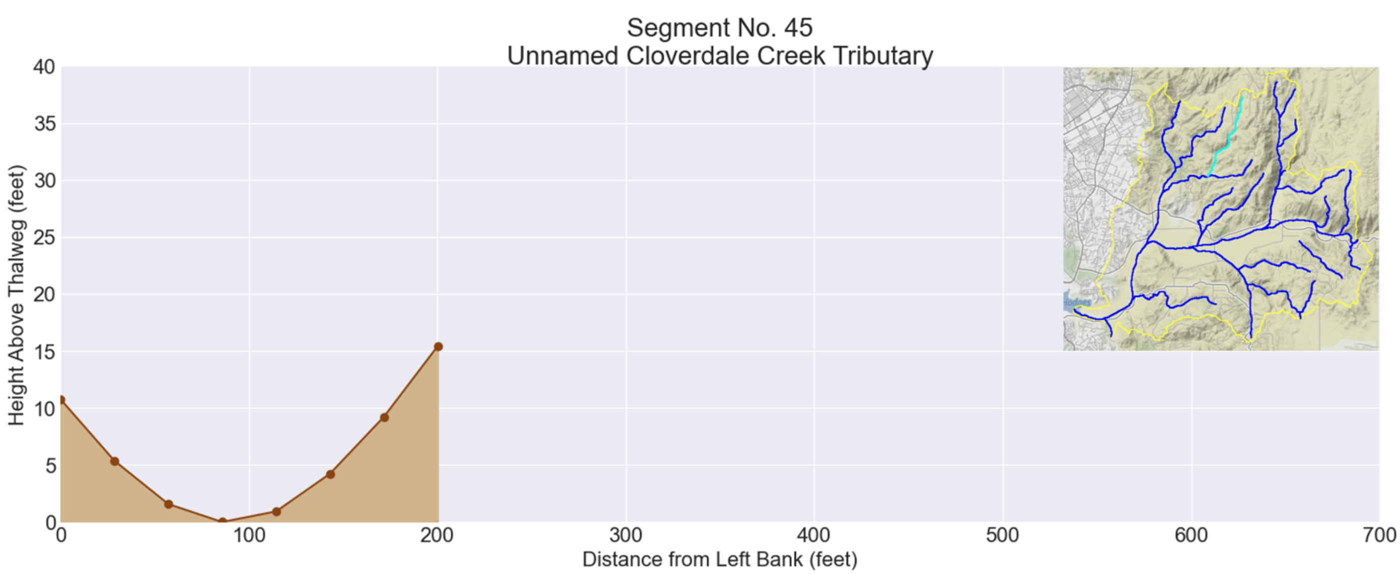
Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs





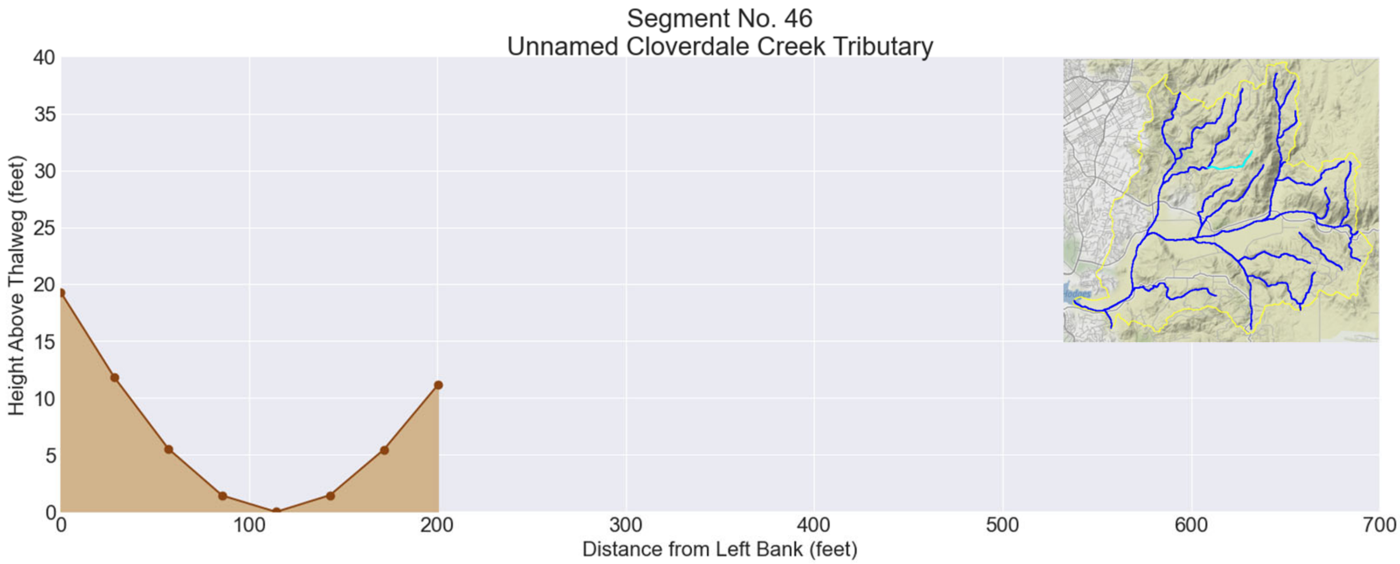


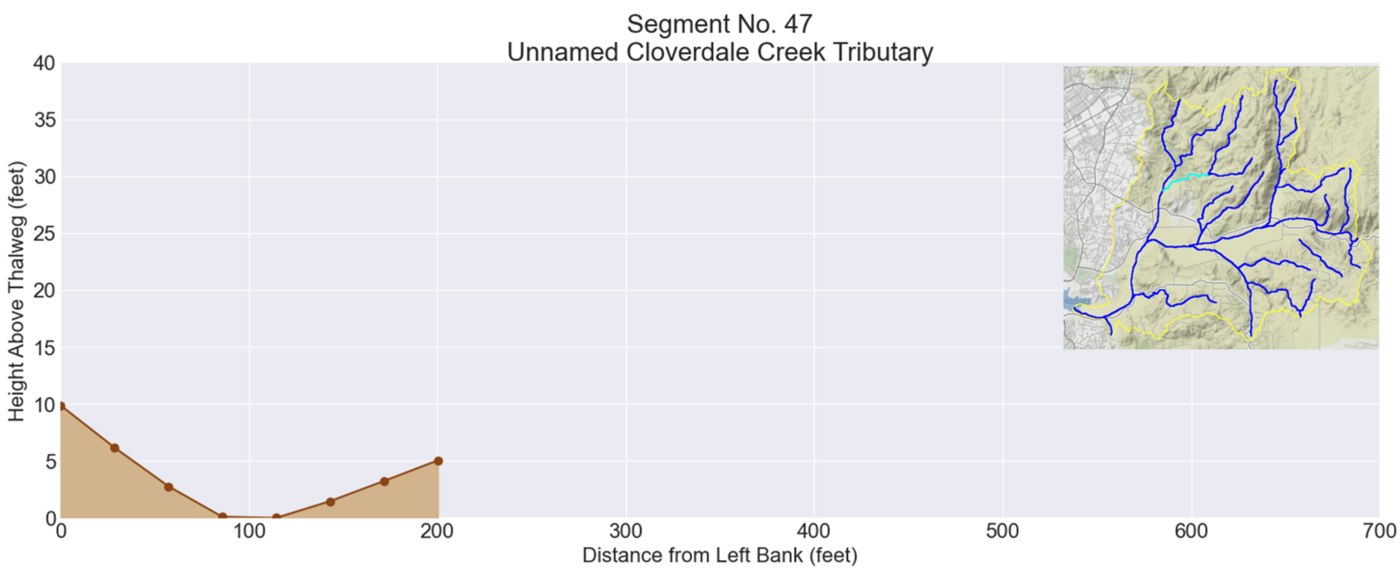
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

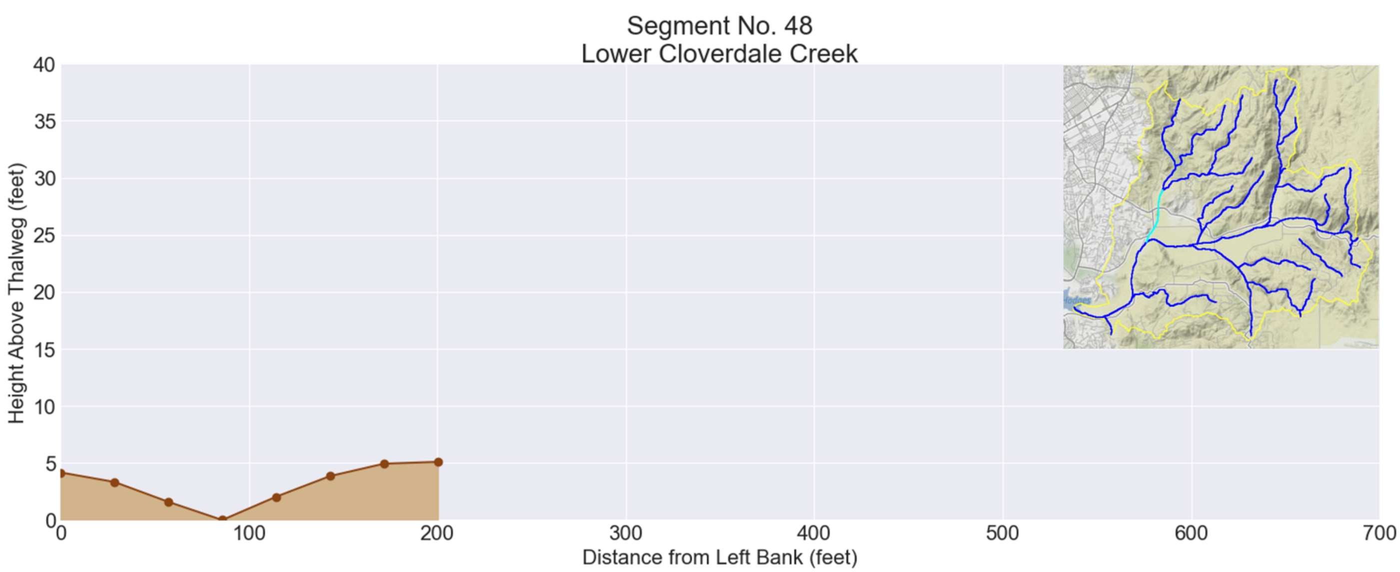
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-15
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-16

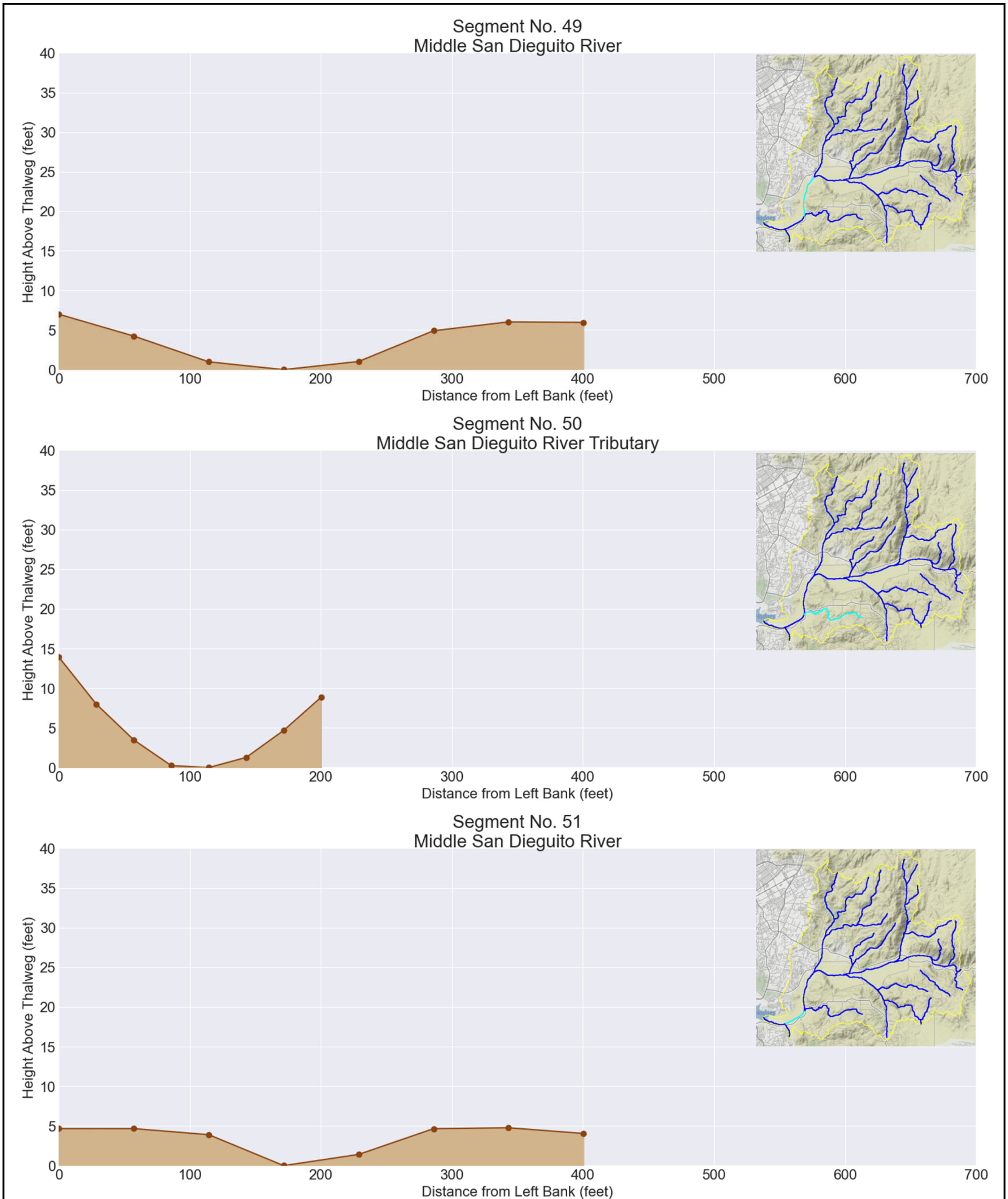
Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs

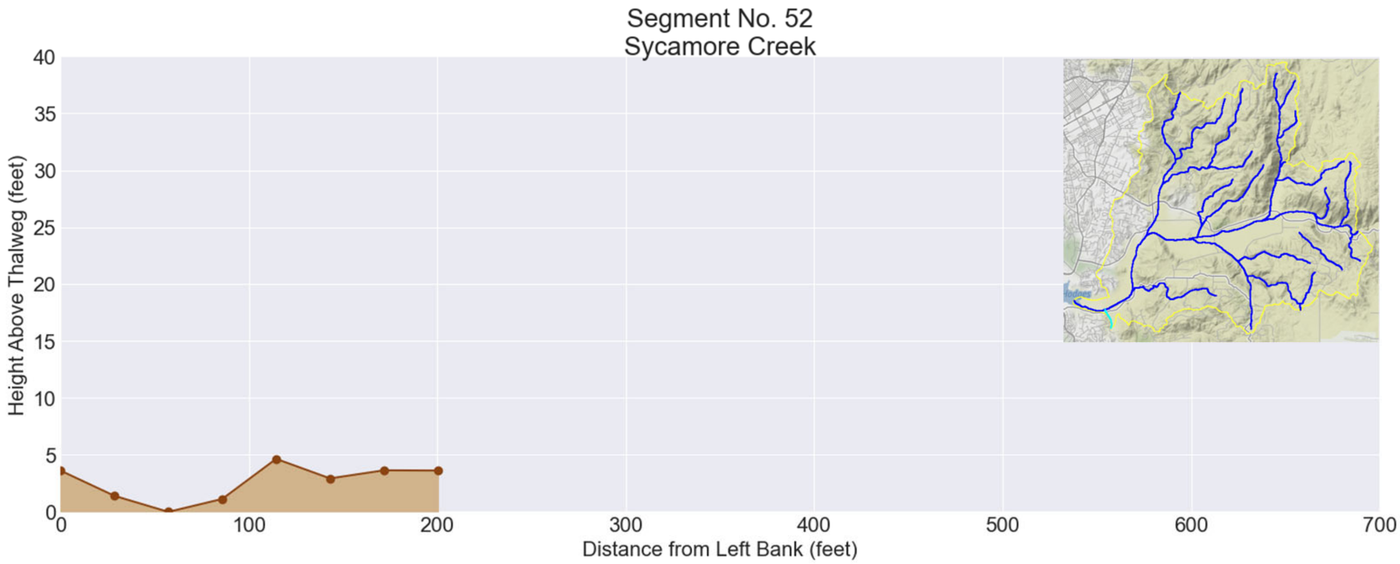


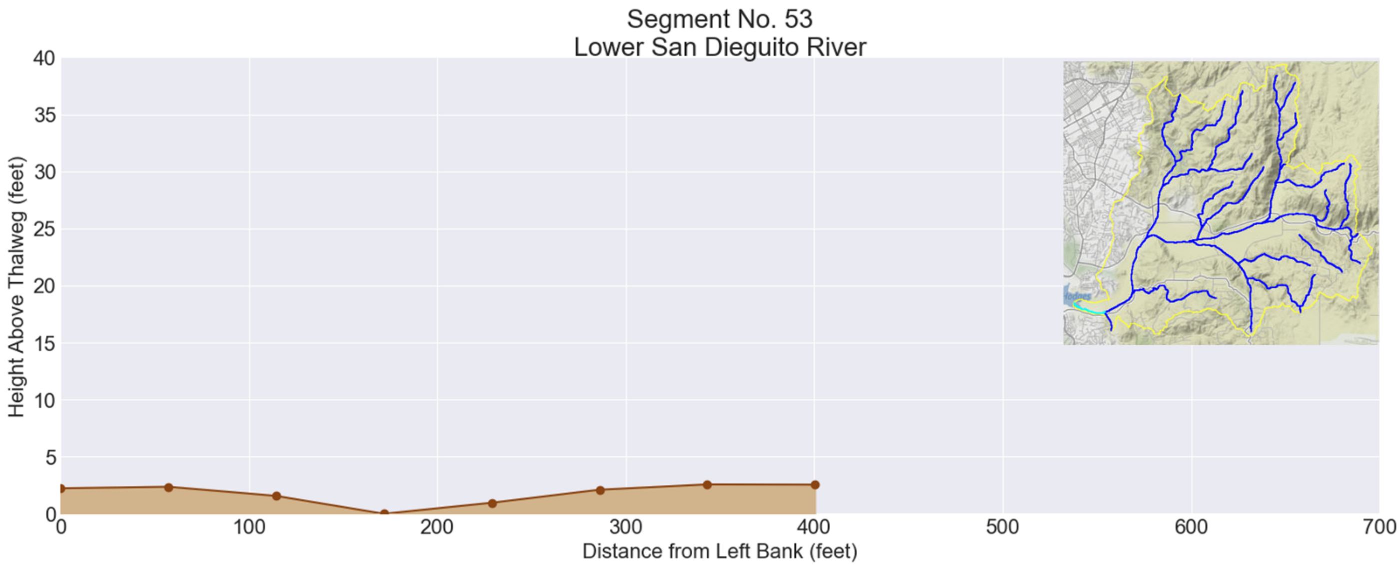
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

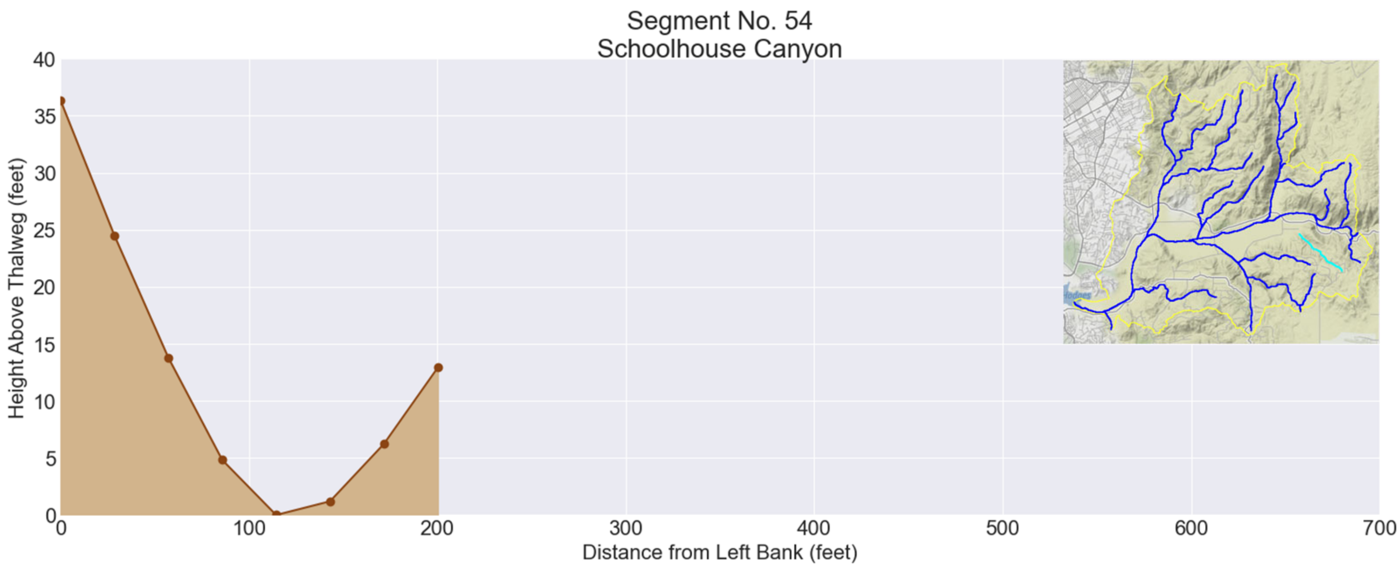
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-17
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs







Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-18
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs

APPENDIX C: TM 3: WATER SOURCES FOR POTENTIAL RECHARGE PROJECTS

TECHNICAL MEMORANDUM

TO: San Pasqual Valley Groundwater Sustainability Agency

PREPARED BY: Paula Silva/Jacobs, Nate Brown/Jacobs, Craig Cooledge/Jacobs, Jenny Callan/Jacobs, Sally Johnson/W&C, Martha De Maria y Campos/W&C

REVIEWED BY: Sally Johnson/W&C, Mark Elliott/Jacobs

DATE: January 27, 2023

RE: Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 3: Water Sources for Potential Recharge Projects

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ACRONYMS & ABBREVIATIONS

AF	Acre-foot	hp	horsepower
AFY	Acre-feet per year	M&I	Municipal and industrial
Basin	San Pasqual Valley Groundwater Basin	MGD	Million gallons per day
cfs	Cubic feet per second	NAD83	North American Datum of 1983
City	City of San Diego	NAVD88	North American Vertical Datum of 1998
County	County of San Diego	PMA	Project and Management Action
CWA	San Diego County Water Authority	psi	Pounds per square inch
DDWD	Division of Drinking Water	Ramona MWD	Ramona Municipal Water District
DSOD	Division of Safety of Dams	SPV	San Pasqual Valley
DWR	Department of Water Resources	SPV GSP Model	SPV GSP Integrated Groundwater/Surface Water Flow Model
GDE	Groundwater Dependent Ecosystem	USGS	United States Geological Survey
gpm	Gallons per minute	WY	Water Year
GSA	Groundwater Sustainability Agency	WYT	Water Year Type
GSP	Groundwater Sustainability Plan		

1. INTRODUCTION

The San Pasqual Valley Groundwater Sustainability Agency (GSA) – comprised of the City of San Diego (City) and the County of San Diego (County) – approved and submitted to the California Department of Water Resources (DWR) the San Pasqual Valley Groundwater Sustainability Plan (GSP) in January 2022 (City and County, 2021). The GSP provides guidance and quantifiable metrics to ensure the continued sustainable management of groundwater resources within the San Pasqual Valley Groundwater Basin (Basin) over the 20-year GSP implementation period (**Figure 1-1**). To accomplish this, the GSP includes a hydrogeological conceptual model, monitoring requirements, sustainability criteria, and several projects and management actions. The projects and management actions (PMAs) included in the GSP are intended to create opportunities for sustainable groundwater management in the Basin that respond to changing conditions and help prevent undesirable results. The Basin is currently sustainably managed, so no additional PMAs are needed to achieve sustainability. However, implementing PMAs could improve resilience against challenging future hydrologic conditions, such as extended droughts.

This technical memorandum is the third of several that focuses on PMA No. 7, which aims to complete an Initial Surface Water Recharge Evaluation. The first technical memorandum describes the evaluation criteria by which the best surface water recharge strategies for the Basin will be determined (City, 2022a). The second technical memorandum describes the approach and results of a streambed investigation along Santa Ysabel Creek in the eastern San Pasqual Valley (SPV) and provides recommendations for updating the SPV GSP Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) (City, 2022b).

This third technical memorandum includes the assessment of potential water sources that could be used for surface water recharge projects within the SPV Groundwater Basin (Basin). The recharge projects (or strategies) will be evaluated further in a future technical memorandum. In this technical memorandum, potential recharge locations and water sources to be used for recharge strategies are presented. Potential recharge areas have not been vetted by stakeholders or permitting agencies, so they should be viewed as conceptual for this stage of study. The potential source water analysis in this technical memorandum includes the following:

- **Streamflows:** The magnitude and frequency of streamflows in the eastern portion of the Basin are analyzed to assess the availability of this source of water for enhanced surface water recharge opportunities.

- **Sutherland Reservoir releases:** The existing infrastructure, agreements, and operations of Sutherland Reservoir are analyzed to provide context for the potential availability of stored water for controlled reservoir releases. The magnitude and frequency of inflows to the reservoir are analyzed to assess potential additional releases to be used to increase the Santa Ysabel Creek streamflow entering the Basin.

- **Untreated water from Ramona Municipal Water District (Ramona MWD):** The existing infrastructure, agreements with San Diego County Water Authority (CWA), and operations are reviewed to identify potential delivery quantities and conveyance needs for direct deliveries to Basin farmers and/or to designated Basin recharge locations.

Other potential sources of water for enhanced recharge in the Basin, such as recycled water, are not included in this study and not discussed in this technical memorandum.

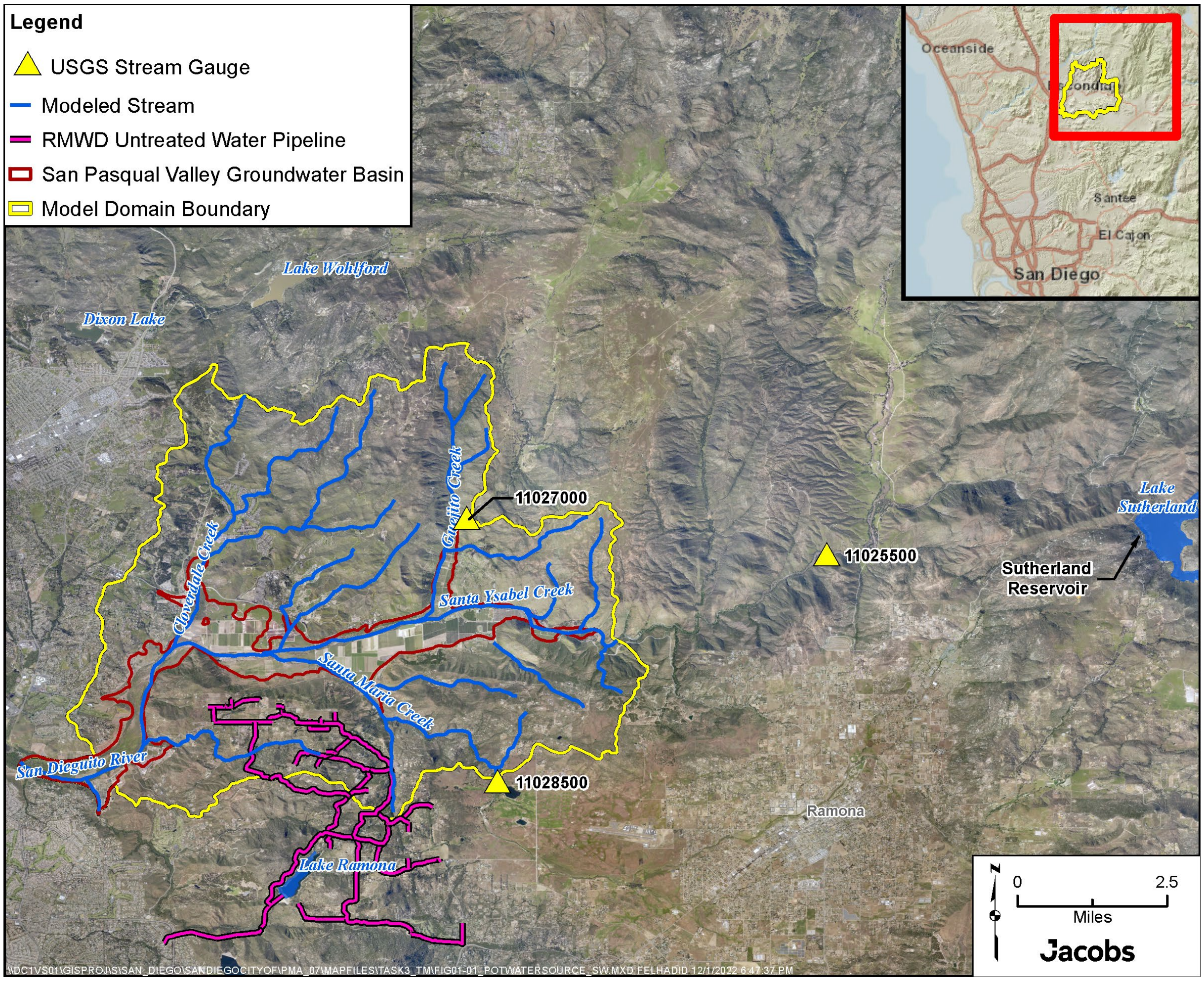

Figure 1-1. Regional Location Map

The GSA will use the Initial Surface Water Recharge Evaluation to help quantify potential benefits to the Basin and assess the feasibility of implementation of potential recharge projects. Ultimately, completing this Initial Surface Water Recharge Evaluation is estimated to take two years, and the resulting information will be provided in a Preliminary Feasibility Study. The Preliminary Feasibility Study will summarize the Initial Surface Water Recharge Evaluation technical memoranda developed during this process, and will include the following sections:

- Evaluation Criteria and Ranking Process (Task 1)
- Streambed Investigation (Task 2)
- Water Sources for Recharge (Task 3)
- Potential Recharge Strategies (Task 4)
- Modeling Approach and Results (Task 5)
- Potential Benefits to Groundwater Dependent Ecosystems (GDEs) (Task 6)

The following section provides a summary of potential source water quantities and describes conceptual-level recharge strategies.

2. HYPOTHETICAL SOURCE WATER QUANTITIES AND CONCEPTUAL RECHARGE STRATEGIES

Details around specific scenarios for additional water quantities and recharge strategies will be presented in the Task 4 technical memorandum, which will be completed in 2023. As previously mentioned, this technical memorandum includes an initial assessment to estimate hypothetical source water quantities and conceptual recharge strategies. In this section, a summary of preliminary results is presented to help frame the subsequent discussion of a more detailed analysis of the water sources in Sections 3 through 5. The conceptual-level strategies being considered (in no particular order) are listed here:

- Enhanced recharge via Santa Ysabel Creek and Santa Maria Creek
- Enhanced recharge via infiltration basins
- Enhanced recharge via injection wells
- In-lieu recharge via storing untreated water from Ramona MWD in storage ponds and growers in the Basin using this water to offset groundwater use for irrigation

Establishing these conceptual-level recharge strategies helps establish links between different recharge sources and recharge strategies. Ultimately, representatives from the City, the County, CWA, Ramona MWD, key local growers, and stakeholders will be convened in 2023 to gain consensus on recharge strategies and locations presented in this technical memorandum. Therefore, information presented in this technical memorandum should be viewed as a starting point for Task 4, recharge strategy development.

2.1 Hypothetical Quantities of Source Water for Recharge Strategies

Estimated monthly volumes of source water for recharge strategies are presented by source in **Figure 2-1.** These volumes provide an initial sense of the seasonal and multi-year availability of water supply that hypothetically could have been available during WYs 2005 through 2019 under the following operational conditions:

- If the excess streamflow passing by Ysabel Creek Road could have been retained and recharged east of Ysabel Creek Road,
- If surface water from Sutherland Reservoir could have been periodically released by the City to Santa Ysabel Creek, resulting in increased Santa Ysabel Creek flows to the Basin, while maintaining existing operations,
- If Ramona MWD could have delivered untreated water supply to the Basin during the summer using available system delivery capacity.

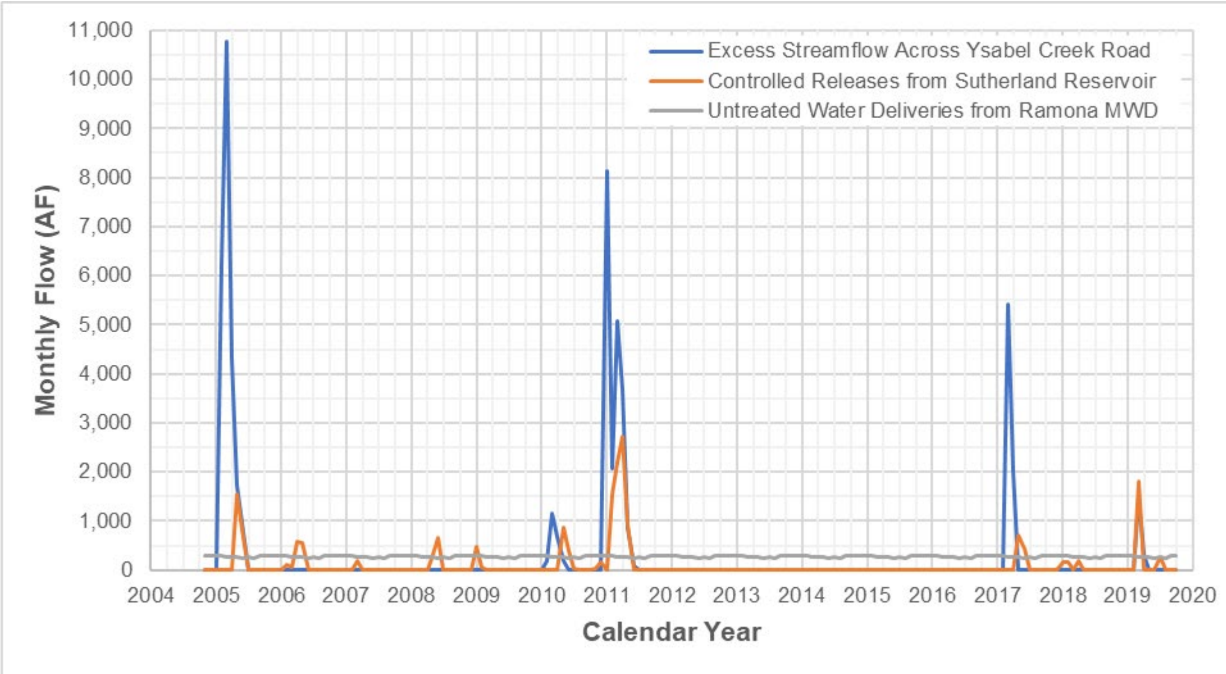

Figure 2-1. Hypothetical Monthly Quantities of Source Water for Enhanced Recharge Strategies

One of the primary sources of groundwater recharge in the Basin occurs through leakage of surface water along Santa Ysabel Creek in the eastern portion of the Basin. Because there were no stream gauges in the Basin during the 15-year historical period shown in **Figure 2-1**, estimates of streamflow from a preliminary version of SPV GSP Model v2.0 were used in this analysis. The version of the SPV GSP Model used during development of the GSP (City and County, 2021) will hereafter be referred to as SPV GSP Model v1.0, whereas the version that will be updated to support decisions associated with PMA No. 7 will be referred to as SPV GSP Model v2.0. Simulated streamflow information presented in this section and the following sections is based on a preliminary (non-calibrated) version of SPV GSP Model v2.0. Therefore, simulated streamflow information presented herein is subject to change as the model refinement and recalibration process continues to improve upon SPV GSP Model v1.0. The preliminary streamflow characteristics presented in this technical memorandum provide a reasonable starting point for bounding potential surface water recharge quantities that could be used to enhance groundwater recharge in the eastern SPV.

The permeable streambed of Santa Ysabel Creek naturally allows full infiltration of streamflow entering the Basin most of the time, leaving miles of a dry gap between the streamflow front and Ysabel Creek Road. Therefore, years when more frequent and larger streamflow events occur are the most likely years with periods of full transmission of streamflow in Santa Ysabel Creek through the eastern portion of the Basin. Thus, quantifying the frequency and magnitude of excess streamflow that crosses Ysabel Creek Road is a good step toward quantifying potential recharge opportunities with that excess water. As shown in **Figure 2-1**, the estimated monthly volume of excess streamflow across Santa Ysabel Road during the 15-year historical period ranged from 0 to nearly 11,000 acre-feet (AF), according to the preliminary version of SPV GSP Model v2.0. Section 3 provides additional details on the streamflow characteristics along various segments of Santa Ysabel Creek.

Given the limited streamflow entering the Basin in Santa Ysabel Creek, controlled releases from Sutherland Reservoir are being considered as a strategy to increase streamflows in the creek. Based on an initial assessment of historical data, some water from Sutherland Reservoir could be available for other uses, mostly during the January through May period, while maintaining the reservoir's existing operations, which include water releases to the San Vicente reservoir. Controlled releases are a more feasible way to provide additional flow to the creek than uncontrolled releases (spills) because the reservoir rarely reaches maximum storage capacity that would trigger such uncontrolled releases. Since the reservoir began operating in 1954, the estimated frequency of annual spills exceeding 5,000 AF has been less than 6 percent of the time. Because natural runoff is the only substantial inflow to the reservoir, water availability is sensitive to hydrology, and would most likely not be available during drought years as shown in **Figure 2-1** for years 2012 through 2016. Conveyance losses and operational feasibility are other key considerations that will be further evaluated using the CWASim tool to simulate operation scenarios as part of the future Task 4 technical memorandum that will further develop recharge strategies. Section 4 provides a detailed analysis of the Sutherland Reservoir water balance as well as a description of existing infrastructure, operation, and agreements.

The third water source analyzed is untreated water deliveries from Ramona MWD. This source is less subject to availability changes due to local climate because it is untreated water imported through the CWA's system. This water was formerly used for local irrigation by Ramona MWD customers and delivered to Ramona MWD's flow control facility RAM1 at the westerly boundary with the City of Poway. The Ramona MWD's untreated water demands have decreased from approximately 5,000 AFY to current demands of approximately 300 AFY to 400 AFY (Ramona MWD, 2022b). CWA's untreated supplies are a mix of water from the Colorado River Aqueduct and the State Water Project. **Figure 2-1** shows a hypothetical monthly delivery provided by Ramona MWD corresponding to an annual total delivery up to 3,350 AFY. Ramona MWD staff estimated 3,350 AFY could be delivered at two different locations from its untreated water system's Robb Zone using 80 percent of its conveyance capacity and assuming existing demand is within the 2019-2021 average. An alternative delivery point could be available for 850 AFY from its Snow Zone, assuming the same conveyance capacity of 80 percent and average future local demand. A monthly volume of approximately 280 AF could be delivered continuously throughout the year. One advantage of this water source is that some untreated water could be available during dry years, and only require minor modifications to the existing untreated water system infrastructure to deliver this additional water supply to the Basin. Discussions with CWA and Ramona MWD, including discussion around capacity and potential other constraints to receiving untreated water, will continue in future planning and design phases of the project. Operation of the First Aqueduct, through which untreated imported water is conveyed to Ramona MWD by CWA, would need to be aligned with and incorporate Ramona MWD's re-established new untreated water demand. It is possible that restrictions on water deliveries could be applied during droughts, given that this is not a municipal or industrial water use, the possibility of which will need to be considered in the future. Section 5 provides a description of existing Ramona MWD's water supply sources and operations.

2.2 Criteria for Selecting Surface Water Recharge Locations

The eastern portion of the Basin is the most suitable area for implementing enhanced surface water recharge strategies and was considered when evaluating these potential water sources. The focus on enhanced recharge strategies in the eastern portion of the Basin is consistent with past studies in the area (e.g., CDM, 2010; CH2M, 2016). Conceptual recharge locations have been identified based on the following criteria:

- Focus on the eastern portion of the Basin, where the deeper water table could accommodate additional recharge from enhanced recharge strategies.

- Prioritize recharge locations on City-owned parcels to avoid the need for land purchase or new easements.
- Prioritize enhancing retention of water supply within the eastern portion of the Basin. Therefore, improving outflows to Lake Hodges is not a priority for this study.
- Minimize distances between sources of recharge water and points of delivery to minimize lengths and cost of conveyance infrastructure.
- Prioritize recharge areas near existing roadways to facilitate routine maintenance.
- Prioritize recharge locations near representative monitoring wells that are used for ongoing GSP compliance to track effects of recharge on groundwater levels and quality.
- Minimize disturbance of existing active agricultural lands (e.g., orchards).

Figure 2-2 shows generalized areas that meet these criteria to varying degrees and **Table 2-1** describes these areas. Potential recharge areas have not been vetted by stakeholders or permitting agencies, so they should be viewed as conceptual for this stage of study.

The following sections summarize the estimated quantities of streamflow, controlled releases from Sutherland Reservoir, and Ramona MWD's untreated water system. These estimates represent quantities of source water that, hypothetically under certain assumptions, could have potentially been used for enhanced recharge strategies over a 15-year historical period including water years (WYs) 2005 through 2019.

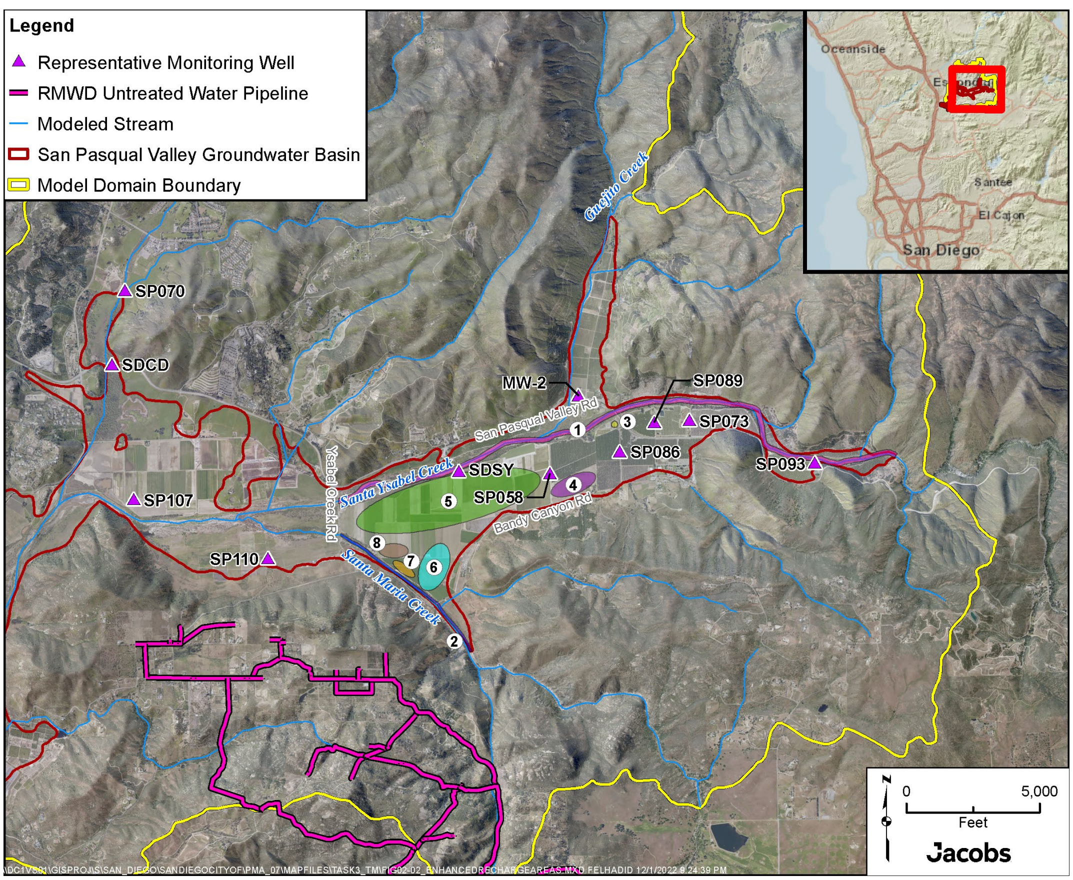

Figure 2-2. Six Hypothetical Areas for Enhanced Recharge Strategies

Table 2-1. *Summary of Initial Recharge Area Identification*

Area No.	Description and Initial Thoughts on Suitability for Enhanced Recharge Strategies
1	• Miles of permeable streambed along Santa Ysabel Creek east of Ysabel Creek Rd • Ideal for enhanced recharge strategies of excess streamflows via streambed infiltration • Excess streamflow would generally have better water quality than imported water sources
2	• More than a mile of streambed along Santa Maria Creek east of Ysabel Creek Rd • Good for enhanced recharge strategies via streambed infiltration
3	• In City-owned parcel near mouth of Rockwood Canyon along San Pasqual Valley Rd and Bandy Canyon Rd • Adjacent to San Pasqual Valley Staging Area • Located close to Santa Ysabel Creek; potentially short pipeline from creek as an occasional water source for recharge • Longer pipeline routes would be required from the untreated water distribution system • Limited space for recharge infrastructure; may be more suitable for injection strategies
4	• In City-owned parcel southwest of Area No. 3 along Bandy Canyon Rd • Area already cleared with sod crop; looks favorable for recharge infrastructure • Located between two representative monitoring wells for water levels • Longer pipeline routes would be required from the untreated water distribution system • Good for enhanced recharge strategies via infiltration basins and/or injection wells
5	• In large City-owned parcel west of Area No. 4 • Large areas of parcel are already cleared with sod and forage crops; looks favorable for recharge infrastructure • Santa Maria and Santa Ysabel Creeks both flow adjacent to area; potentially short pipeline from these creeks as an occasional water source for recharge • Shorter pipeline route from the untreated water distribution system • Some portions of area might be suitable for storage ponds and in-lieu recharge strategies • Reasonably good for enhanced recharge strategies via infiltration basins and/or injection wells, but some portions of area would likely be too far west to provide much additional supply benefits to eastern portion of the Basin
6	• In City-owned parcel south of Area No. 5 along Bandy Canyon Rd near mouth of Bandy Canyon • Shorter pipeline route from the untreated water distribution system • Some portions of parcel might be suitable for storage ponds and in-lieu recharge strategies • Possibly adequate for enhanced recharge strategies via infiltration basins and/or injection wells, but some portions of parcel may be too far south and west to provide much additional supply benefits to eastern portion of the Basin
7	• In City-owned parcel west of Area No. 6 along Bandy Canyon Rd next to Santa Maria Creek • Shorter pipeline route from the untreated water distribution system • Some portions of parcel might be suitable for storage ponds and in-lieu recharge strategies • Area is not ideal for enhanced recharge strategies via infiltration basins or injection wells • Some portions of parcel may be too far south and west to provide much additional supply benefits to eastern portion of the Basin
8	• In City-owned parcel between Area Nos. 5 and 7 along Bandy Canyon Rd • Shorter pipeline route from the untreated water distribution system • Some portions of parcel might be suitable for storage ponds and in-lieu recharge strategies • Area is not ideal for enhanced recharge strategies via infiltration basins or injection wells • Some portions of parcel may be too far south and west to provide much additional supply benefits to eastern portion of the Basin
*See **Figure 2-2** for locations of these areas.*	

3. HISTORICAL STREAMFLOW

One of the primary sources of groundwater recharge in the Basin occurs through leakage of surface water along Santa Ysabel Creek in the eastern portion of the Basin. To develop and implement surface water recharge projects within the Basin, it is important to understand the availability of naturally occurring streamflow and the groundwater/surface-water interactions that can occur throughout the Basin.

The Basin lies within the San Dieguito Drainage Basin, which is comprised of SPV and several canyons – most notably are Rockwood Canyon, Bandy Canyon, and Cloverdale Canyon. Within the Basin, the San Dieguito River is formed at the confluence of Santa Ysabel Creek and Santa Maria Creek and flows into Hodges Reservoir downgradient from the southwest boundary of the Basin (**Figure 1-1**). The eastern end of the Basin is generally a groundwater recharge area, where the aquifer receives water primarily from streambed infiltration of Santa Ysabel, Guejito, and Santa Maria Creeks. The western end of the Basin is generally a groundwater discharge area, where some groundwater discharges to the San Dieguito River or is consumed by vegetation. Groundwater that does not discharge to the river or is not consumed by vegetation leaves the Basin as subsurface outflow and flows toward Hodges Reservoir.

Upgradient from the San Dieguito River confluence, there are three U.S. Geological Survey (USGS) stream gauges along Santa Ysabel Creek (USGS 11025500), Guejito Creek (USGS 11027000), and Santa Maria Creek (USGS 11028500) with daily historical streamflow measurements. These stream gauges are all located upstream of the Basin (**Figure 1-1**). These stream gauge data were utilized in the development of SPV GSP Model v1.0 covering a 15-year historical period from water years (WYs) 2005 through 2019 (that is, October 2004 through September 2019) (City and County, 2021). No stream gauges existed within the Basin during this 15-year period.

Figure 3-1 presents annual volumes of streamflow measured at the Santa Ysabel Creek, Guejito Creek, and Santa Maria Creek gauges during the 15-year historical period. Water Year Types (WYTs)[1] established during the development of the GSP are also shown in **Figure 3-1** to provide context for the hydrology observed throughout the historical period. In general, Santa Ysabel Creek provides the largest source of streamflow to the eastern portion of the Basin, followed by Santa Maria Creek, and then Guejito Creek. As shown in **Figure 3-1**, these streams are ephemeral and typically only flow after precipitation events with sufficient intensity and duration. Therefore, without substantial precipitation events, the eastern portion of the Basin typically has dry streambeds.

[1] W = wet, AN = above normal, N = normal, D = dry, and C = critically dry.

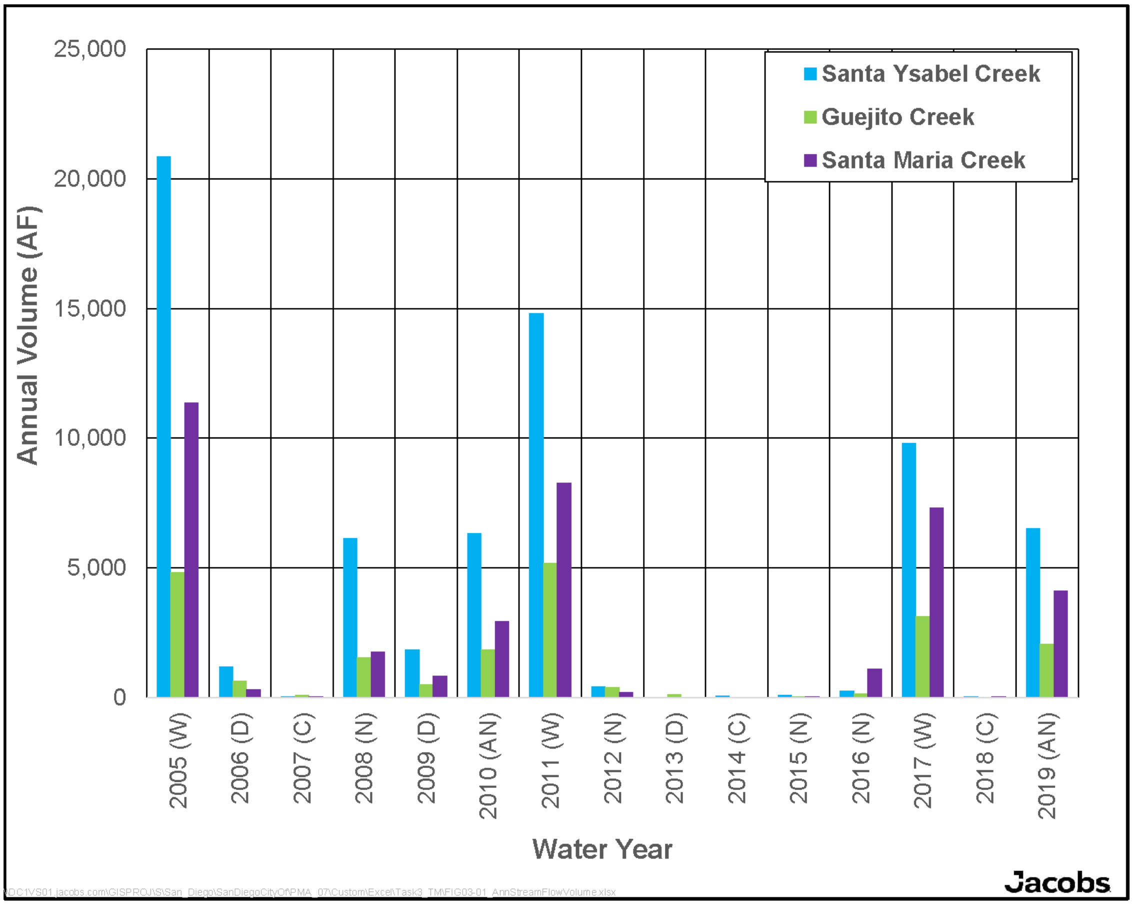

Figure 3-1. Annual Streamflow Volumes at Santa Ysabel, Guejito, and Santa Maria Creeks' Gauges

The permeable streambed of Santa Ysabel Creek naturally allows full infiltration of streamflow entering the Basin most of the time. Therefore, years when more frequent and larger streamflow events occur are the most likely years with periods of full transmission of streamflow in Santa Ysabel Creek through the eastern portion of the Basin. It is difficult to quantify the amount of excess streamflow (that is, streamflow leaving the eastern portion of the Basin) that would be available for recharge projects without a stream gauge within the eastern Basin. Given these complexities and the lack of measured streamflow data in this portion of the Basin, the best available tool to help quantify potential volumes of streamflow available for recharge projects is the SPV GSP Model. To better understand these groundwater/surface-water conditions, "virtual" stream gauges were incorporated into the modeling process and used to extract simulated streamflow data from a preliminary version of SPV GSP Model v2.0. This preliminary version of SPV GSP Model v2.0 is undergoing updates and recalibration with improved representation of stream channel conditions. Although this model update is not complete, it provides a reasonable starting point for estimates of streamflow at key locations where physical stream gauges are not present. **Figure 3-2** presents the locations of these virtual stream gauges. Virtual stream gauges were incorporated into the first five river miles of Santa Ysabel Creek, based on estimated distances from the intersection of Santa Ysabel Creek and the eastern SPV GSP Model boundary.

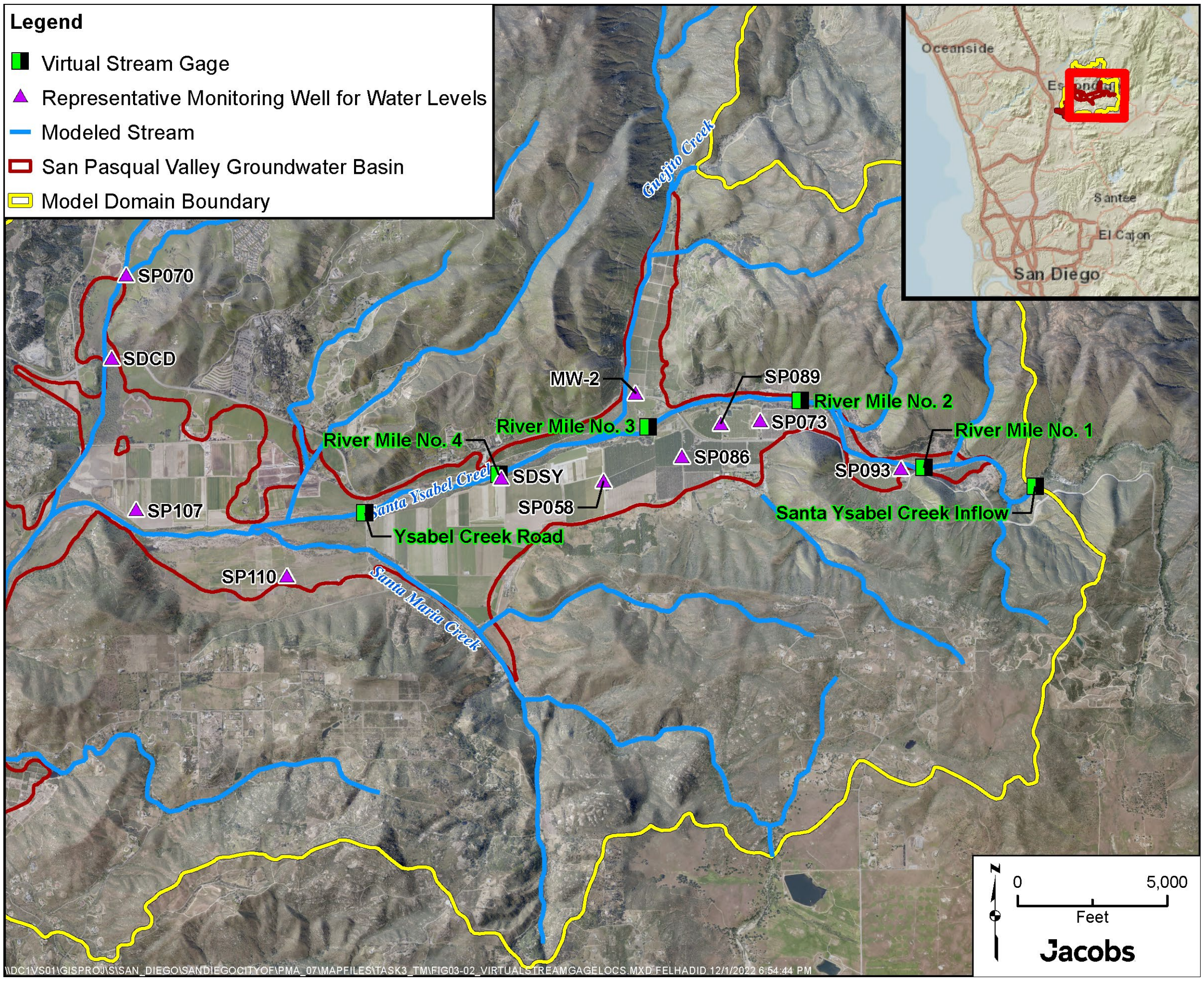

Figure 3-2. Virtual Stream Gauge Locations

Table 3-1 summarizes annual volumes of streamflow for each virtual streamflow gauge for the 15-year historical period. According to the preliminary version of the SPV GSP Model v2.0, there are 5 years out of the 15-year historical period when streamflow entering the eastern portion of the Basin flowed beyond the most downstream virtual streamflow gauge, which coincides with Ysabel Creek Road. Ysabel Creek Road was selected as the downstream virtual stream gauge location in Santa Ysabel Creek as a convenient geographic reference point for discussion and because it is west of any likely surface water recharge projects that may be developed in the Basin. In general, Santa Ysabel Creek streamflow volumes decrease from east to west across the eastern portion of the Basin, except between River Mile Nos. 3 and 4 because of streamflow additions from Guejito Creek at its confluence with Santa Ysabel Creek.

Table 3-1. ***Modeled Annual Streamflow Volumes at Virtual Stream Gauges***

Water Year[a]	Santa Ysabel Creek Inflow	River Mile No. 1	River Mile No. 2	River Mile No. 3	River Mile No. 4	Ysabel Creek Road
2005 (W)	24,062	24,135	23,181	20,340	24,526	23,826
2006 (D)	1,276	548	0	0	0	0
2007 (C)	29	0	0	0	0	0
2008 (N)	6,416	5,847	3,976	867	51	0
2009 (D)	1,982	1,492	397	0	0	0
2010 (AN)	6,625	6,494	5,674	2,785	3,059	2,230
2011 (W)	17,116	18,013	17,550	15,195	20,566	19,903
2012 (N)	487	0	0	0	0	0
2013 (D)	18	0	0	0	0	0
2014 (C)	67	0	0	0	0	0
2015 (N)	105	0	0	0	0	0
2016 (N)	301	0	0	0	0	0
2017 (W)	12,264	12,275	11,045	6,823	7,817	7,446
2018 (C)	548	491	0	0	0	0
2019 (AN)	7,073	6,742	5,358	2,345	2,463	1,816

[a] *Water year types are shown in parentheses and defined as follows: W=wet, AN=above normal, N=normal, D=dry, and C=critically dry.*

Values are expressed in units of annual acre-feet.

Not all water years with similar annual streamflow result in the same groundwater/surface-water characteristics. For example, there are two years, WYs 2008 and 2010, during which a similar volume of streamflow occurred at the Santa Ysabel Creek inflow gauge (6,416 AF and 6,625 AF, respectively). However, the excess streamflow passing beyond Ysabel Creek Road in the preliminary version of SPV GSP Model v2.0 was significantly different (0 AF and 2,230 AF, respectively). The two years leading up to WY 2008 were dry and critically dry, which likely resulted in groundwater-level declines in the eastern portion of the Basin in WY 2008, allowing for greater infiltration of streamflow in WY 2008 as compared to WY 2010. This means that streamflow in WY 2008 infiltrated before reaching Ysabel Creek Road, whereas in WY 2010, streamflow would have reached at least Ysabel Creek Road, despite both water years having similar volumes of water entering the Basin. A similar comparison can be made between WYs 2011 and 2017, both of which were wet WYs that followed very different sequences of hydrology in preceding years. As a result, the excess streamflow at Ysabel Creek Road was also significantly different between these two years (19,903 in WY 2011 and 7,446 in WY 2017).

Table 3-2. Modeled Monthly Streamflow Volumes in Santa Ysabel Creek at Ysabel Creek Road

Month	2005 (W)[a]	2010 (AN)[a]	2011 (W)[a]	2017 (W)[a]	2019(AN)[a]	Average
Oct	0	0	0	0	0	0
Nov	0	0	0	0	0	0
Dec	0	0	8,133	0	0	1,627
Jan	6,231	179	2,077	0	0	1,697
Feb	10,782	1,169	5,088	5,415	1,492	4,789
Mar	4,308	685	3,663	2,031	314	2,200
Apr	1,743	195	868	0	10	563
May	759	2	74	0	0	167
Jun	2	0	0	0	0	0
Jul	0	0	0	0	0	0
Aug	0	0	0	0	0	0
Sep	0	0	0	0	0	0
Annual	23,826	2,230	19,903	7,446	1,816	11,044

[a] Water year types are shown in parentheses and defined as follows: W=wet and AN=above normal.

Values are expressed in units of monthly acre-feet.

Although annual streamflow volumes are helpful in conceptualizing potential volumes of water available for surface water recharge projects, it is also important to consider the seasonal timing of streamflow. **Table 3-2** presents simulated monthly streamflow volumes at Ysabel Creek Road for the five above-normal and wet years of the historical period when streamflow is modeled to have occurred at this location (**Figure 2-1**). Based on the preliminary version of the SPV GSP Model v2.0, excess streamflow through the eastern portion of the Basin occurred between December and May with peak streamflow volumes occurring in the month of February on average. Aside from the timing and magnitude of streamflow volume, it is important to consider stream depths during these events to ensure that the enhanced recharge strategies could access and utilize excess streamflow along Santa Ysabel Creek.

Figure 3-3 presents a series of figures that show the percentage of days during the historical 15-year period where streamflow depths exceed depth thresholds of 0.5, 1, 2, and 4 feet along Santa Ysabel Creek, as simulated in the preliminary version of SPV GSP Model v2.0. The purpose of these graphics is to illustrate the infrequent nature of streamflows of different depths in the eastern portion of the Basin during the historical period. The cooler and warmer colors along the modeled streams indicate a larger and smaller percent of the 15-year historical period when the streamflow depth was at least 0.5, 1, 2, and 4 feet. **Figure 3-3** shows that the occurrence of deeper stream depths from WYs 2005 through 2019 was more prevalent at the eastern end of the Basin, according to the preliminary version of SPV GSP Model v2.0. These graphics further highlight the infrequent nature of large streamflow events providing full transmission of streamflow between Ysabel Creek Road and the east end of the Basin. The frequency of streamflow depth and the timing of surface water volumes will be further evaluated under Task 4 of PMA No. 7 during the development of recharge strategies to assess whether these strategies could take full advantage of the intermittent excess streamflow events that occur in the eastern portion of the Basin.

The availability of surface water during the historical 15-year period that hypothetically could have been utilized as a source for surface water recharge projects was intermittent and only available during certain above normal and wet years when the preceding hydrology was favorable (**Figure 2-1** and **Table 3-1** and **Table 3-2**). Streamflow entering the eastern portion of the Basin during most years already replenishes the aquifer through infiltration of the streambed. Thus, the recharge strategies devised under Task 4 of PMA No. 7 will focus on the times when streamflow would otherwise leave the eastern portion of the Basin. The development of these strategies will need to take advantage of locations along Santa Ysabel Creek where adequate streamflow volumes and depths occur to ensure any infrastructure put into place could access and convey the excess streamflow to recharge locations.

The SPV GSP Model v2.0 will be utilized as the primary tool for characterizing the availability of streamflow along Santa Ysabel Creek. As calibration of the SPV GSP Model v2.0 is finalized, refinements of the streamflow volumes presented herein will be refined to better reflect hydrologic conditions in the Basin.

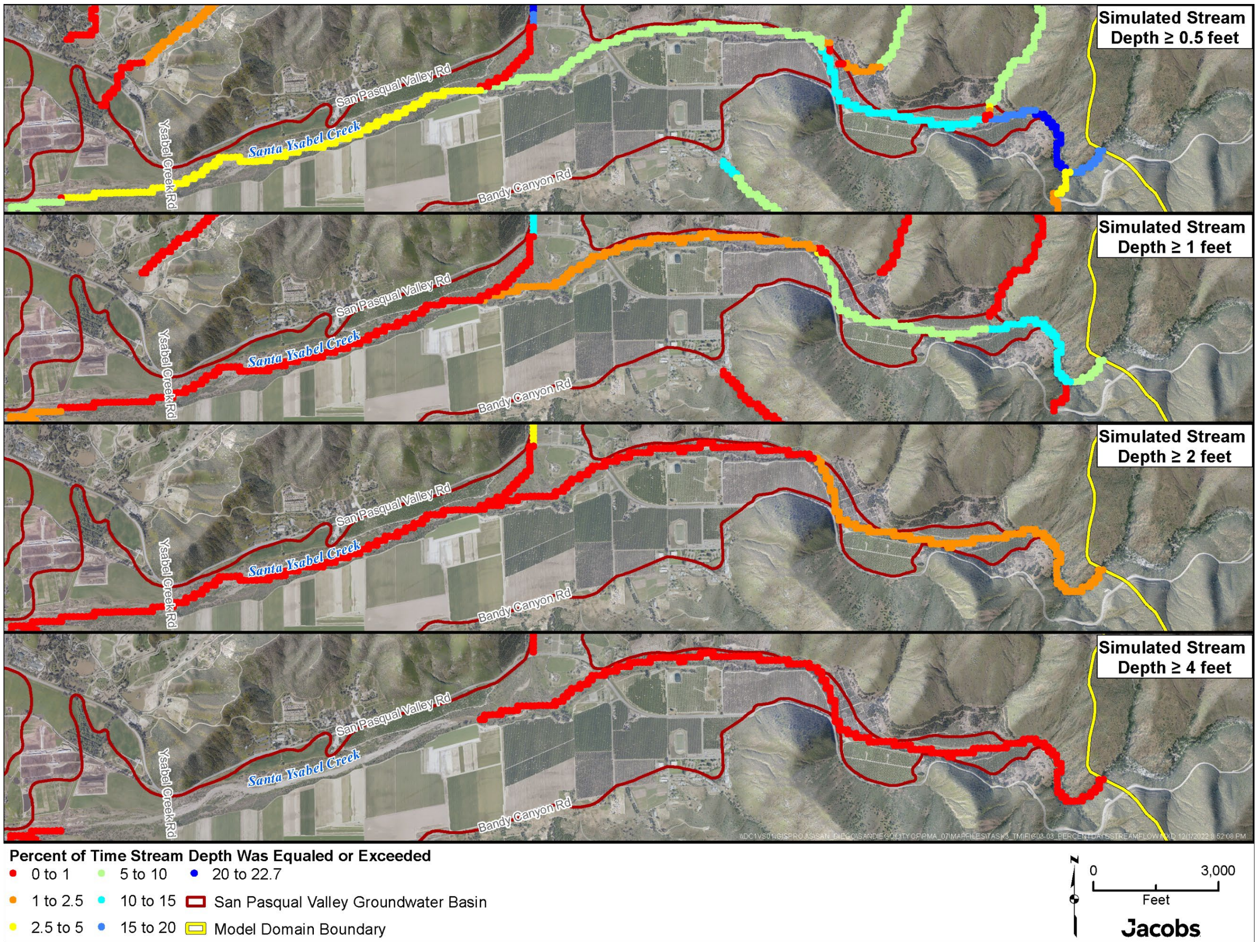

Figure 3-3. Percent of Days Streamflow Occurred During the 15-year Historical Period

4. SUTHERLAND RESERVOIR

Sutherland Reservoir is owned and operated by the City and is under the regulatory jurisdiction of the DWR, Division of Safety of Dams (DSOD) and SWRCB, Division of Drinking Water (DDW). This reservoir is located approximately nine miles northeast of the town of Ramona on Santa Ysabel Creek, a tributary system to the San Vicente Reservoir and a tributary stream to the Hodges Reservoir (City, 2020). Sutherland Reservoir is open to the public for recreational use, but functions primarily as a water impoundment.

In this section, the natural runoff stored in Sutherland Reservoir is assessed as a potential source for recharge projects in the Basin. In addition, the Sutherland Reservoir's existing infrastructure, agreements, and operations are analyzed to provide context for the potential availability of stored water to be released to augment streamflow in Santa Ysabel Creek entering the Basin. The magnitude and frequency of this additional source of water to the Basin are analyzed to assess its potential for use in enhance surface water recharge strategies. However, the actual future water availability from Sutherland Reservoir, in addition to hydrology variability affected by climate change, could be subject to future unknown regulation and restrictions. Recharge strategies will be explored as part of the next technical memorandum documenting Task 4, Potential Recharge Strategies.

4.1 Definitions

There are several technical terms associated with reservoir operations that are normally indicated as inflows to the reservoir and outflows from the reservoir. The following terms are used in this section:

- Inflows to the reservoir: water flowing into the reservoir to be stored. Inflows into the reservoir are defined based on the source from which they originate.
    - Runoff: draining of water flowing across the surface of an area. For each reservoir there is a specific drainage area that provides runoff that enters the reservoir as streamflow. Runoff is that part of the precipitation, snow melt, or irrigation water that appears in surface streams, rivers, drains, or sewers.
    - Rain on surface: the precipitation that falls directly onto the body of water (area) of the reservoir. This inflow volume is calculated as the precipitation depth times the water surface area, which varies depending on the storage level in the reservoir.
    - Other inflows: other reservoir inflows could come as imported water delivered through piped connections and as subsurface inflow from surrounding water-bearing zones.
- Outflows from the reservoir: stored water in the reservoir can leave the reservoir as a controlled release or uncontrolled release.
    - Controlled releases: also known as withdrawals, corresponds to stored water releases that require operation of outlet structures for routine maintenance and for compliance with dam safety. There are different purposes of controlled releases such as delivering water to downstream users to meet demands, transfer water to another reservoir, to allow empty space in reservoir in preparation of a flood event (flood releases or emergency operations).
    - Uncontrolled releases: these correspond to stored water that leaves the reservoir either through the spill crest, because the maximum storage capacity has been reached or due to leakages and other reservoir losses. Spillways typically represent structures at the top of the dam that allow water to go over the top of the dam in an uncontrolled manner releasing surplus flood water to ensure dam safety. The spill crest is the highest elevation of the floor of the spillway.

4.2 Historical Water Balance

Sutherland Reservoir captures runoff from the surrounding 53-square-mile drainage area, which is part of the San Dieguito Drainage Basin. Runoff and rain on the reservoir's surface are the only inflows to the reservoir. There are no additional inflows in the form of deliveries or piped connections into the reservoir and it is assumed that subsurface inflows to the reservoir are negligible. **Figure 4-1** presents Sutherland Reservoir's estimated annual runoff from the surrounding drainage area and the precipitation on the reservoir's surface. WYTs[1] established during the development of the GSP are shown to provide context for the hydrology observed during the 15-year historical period. Because there are no streamflow gauges upstream of the reservoir, the runoff is estimated by conducting a monthly water balance with information provided by the City comprising (City, 2022c) a monthly time series of inflows to Sutherland Reservoir and

[1] W = wet, AN = above normal, N = normal, D = dry, and C = critically dry.

outflows from the reservoir (see definitions in Section 4.1). The City Public Utilities Department produces this monthly time series with information from the National Oceanic and Atmospheric Association, and San Diego Geographical Information System.

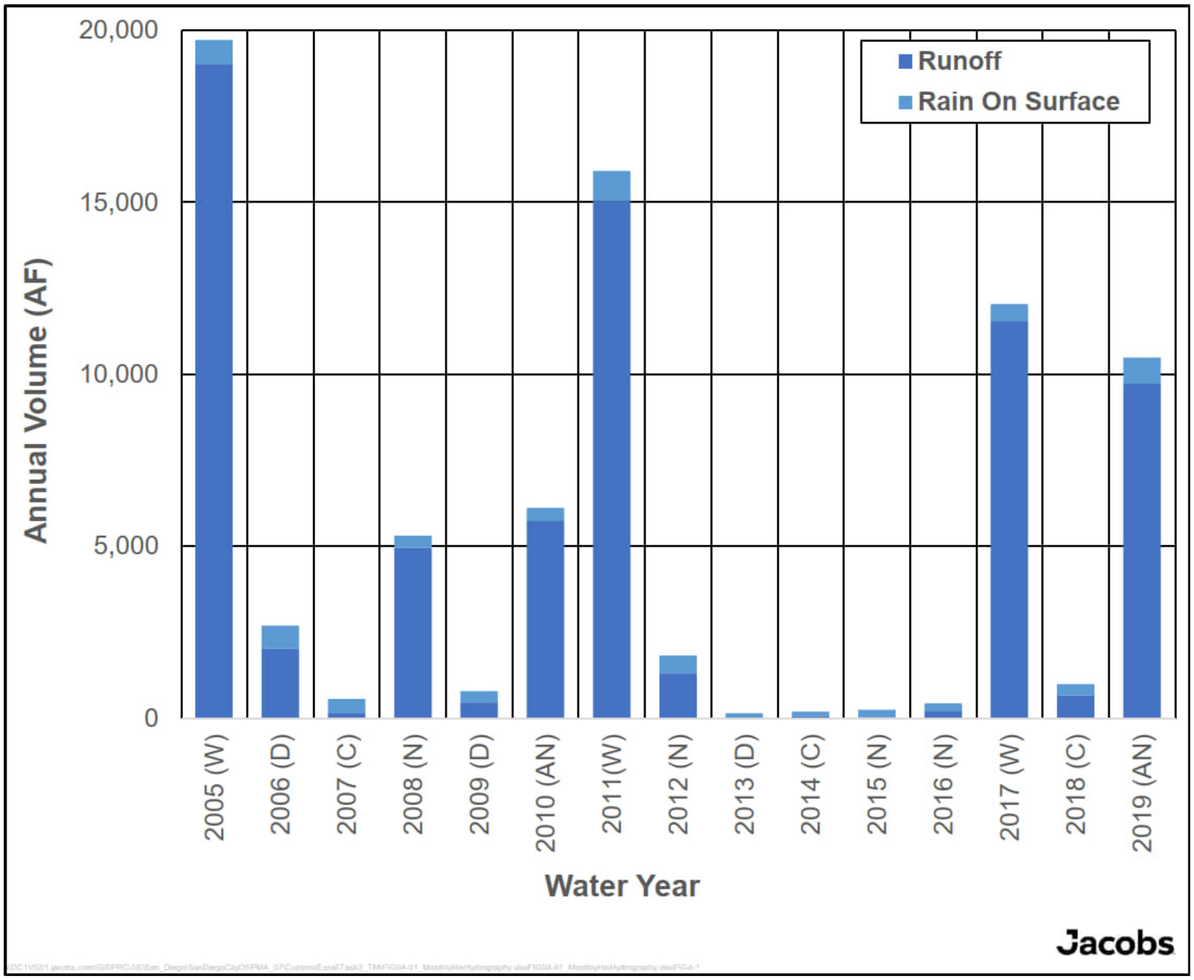

Figure 4-1. Estimated Annual Inflows to Sutherland Reservoir

Figure 4-2 presents the average annual inflows and outflows of Sutherland Reservoir during the 15-year historical period (WYs 2005 through 2019) that were used for the water balance (City, 2022c). The annual average inflow to the reservoir during this period was 5,166 AF, with a maximum annual inflow of 19,714 AF and a minimum annual inflow of 153 AF, showing significant variability (see **Figure 4-1**). The reservoir typically loses more than 4 feet of water every year due to evaporation (1,127 AFY), which represents approximately 22 percent of the average annual inflows. The remaining stored water was mostly transferred to San Vicente Reservoir (3,546 AFY). Other outflows were minor volumes: spills did not occur during this period and deliveries to Ramona only occurred during WYs 2005 through 2007 of around 500 AFY. More details on the existing operations are provided in the section below.

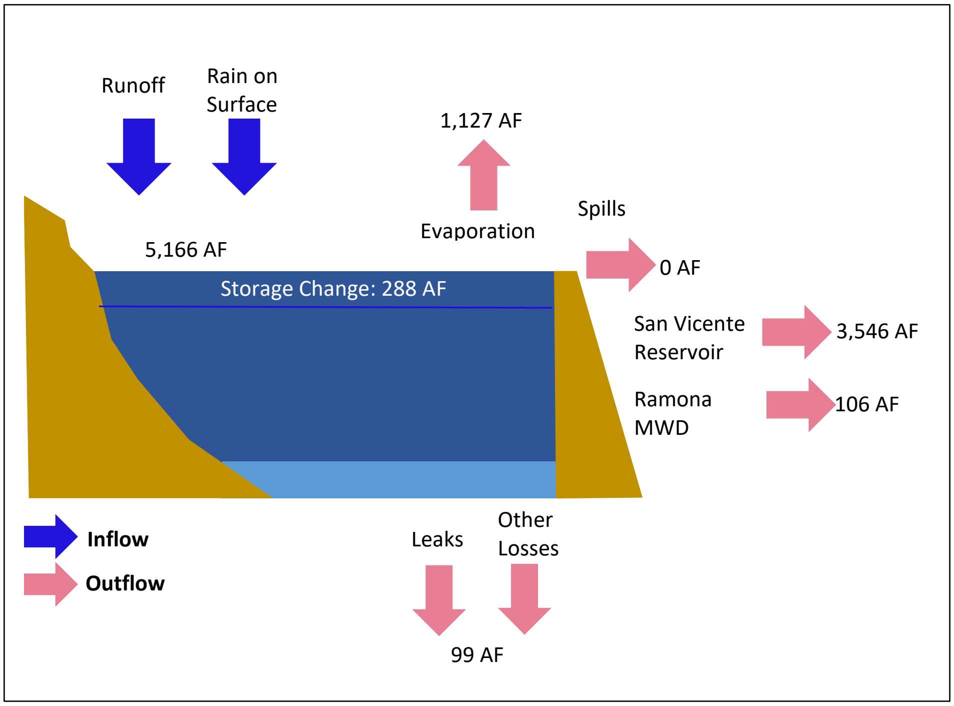

Figure 4-2. Sutherland Reservoir Average Annual Inflows and Outflows for Water Years 2005 through 2019

4.3 Existing Infrastructure, Operation and Agreements

In the following paragraphs, the key infrastructure, operations, and agreements are reviewed to understand limitations and existing operation conditions related to water spills (excess water above maximum capacity flowing to the Santa Ysabel Creek) and operational releases (water transfers downstream for other purposes).

4.3.1 Historical Reservoir Details and Spills

Sutherland Reservoir has a maximum storage capacity of 29,345 AF according to the latest bathymetry survey (City, 2021). When full, the water surface area is 557 acres at elevation 2,057 feet above the National Geodetic Vertical Datum of 1929 (NGVD29). The surface area versus volume curve is provided in **Attachment A**. Once the water level reaches this maximum elevation, water starts flowing through the spillway crest up to a maximum spill of 41,220 cubic feet per second (cfs) (City, 2022b).

During WYs 2005 through 2019 there were no recorded spills. In order to estimate the spill frequency outside of this 15-year historical period, the records between 1954 and 2021 were reviewed. During this longer-term period, spills occurred only during seven WYs: 1978, 1979, 1980, 1983, 1984, 1993, and 1995. The estimated frequency of annual spills exceeding 5,000 AF between 1954 and 2021 was less than 6 percent (see **Figure 4-3**).

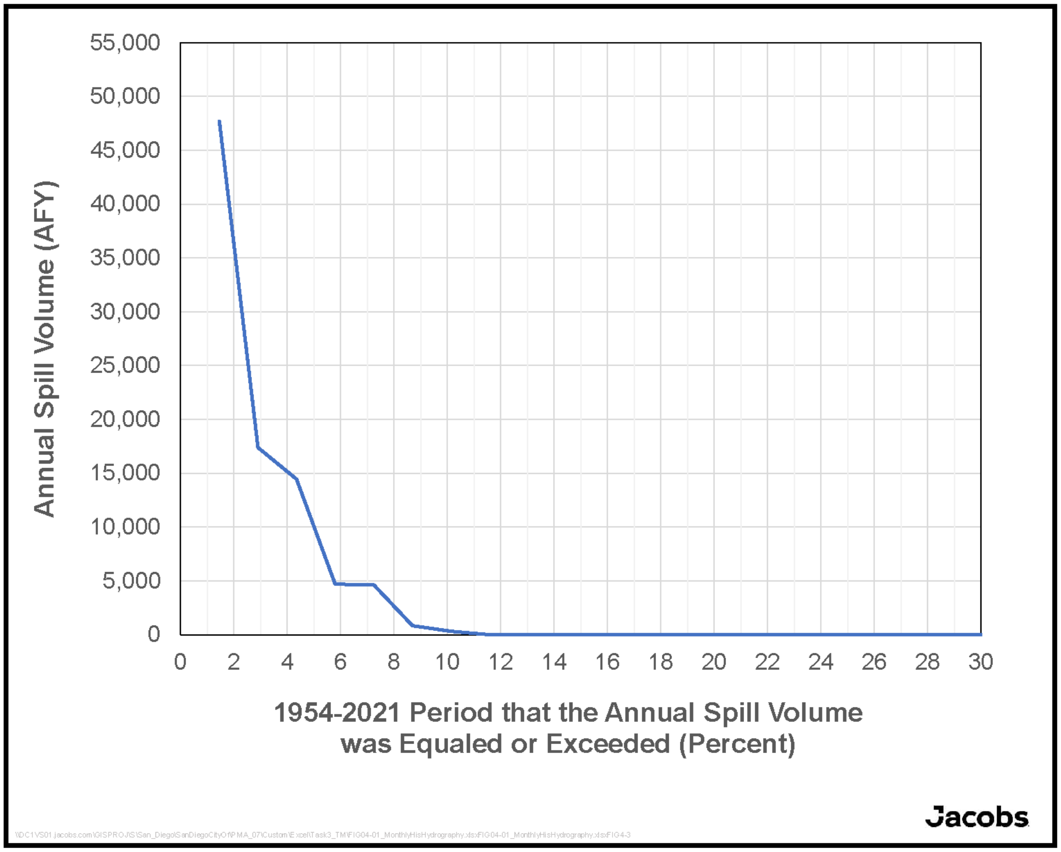

Figure 4-3. Historical Frequency of Sutherland Reservoir Spills

4.3.2 Reservoir Operational Releases

The Sutherland Dam outlet structure includes two 36-inch outlet pipes and a 30-inch gate valve which discharges to the 36-inch Sutherland Pipeline. One outlet pipe belongs to the City (west intake) and the other to Ramona MWD (east intake), though both are operated by the City. The east intake has a 24-inch bypass pipeline that can be used to control releases to Santa Ysabel Creek and has served as the main emergency valve. This intake is currently not functioning, and an interim plan is in place to use a combination of blow-offs along the west intake for emergency releases. If additional controlled releases are to be implemented, the same approach would need to be used to release flows to Santa Ysabel Creek. Currently, controlled releases to the Santa Ysabel creek are not taking place. The City is under no obligation per any agreements to release water to Santa Ysabel Creek.

Water released from the Sutherland Reservoir travels through the Sutherland-San Vicente mortar-coated steel mostly a 36-inch diameter pipeline for approximately 12 miles (see **Figure 4-4**). The pipeline runs southwest from Sutherland Reservoir through the town of Ramona and has a connection to Ramona MWD's Bargar WTP (currently out of commission and no longer used). The release capacity varies depending on the reservoir elevation and the valve operations, under the most current operation, the releases could reach up to 160 cfs as estimated for Alternative D in the 2020 Sutherland Outlet Works Status and Drawdown Alternatives (City of San Diego, 2020). Below are the descriptions of the current operation and agreements for these two controlled releases: to Ramona MWD and to San Vicente Reservoir.

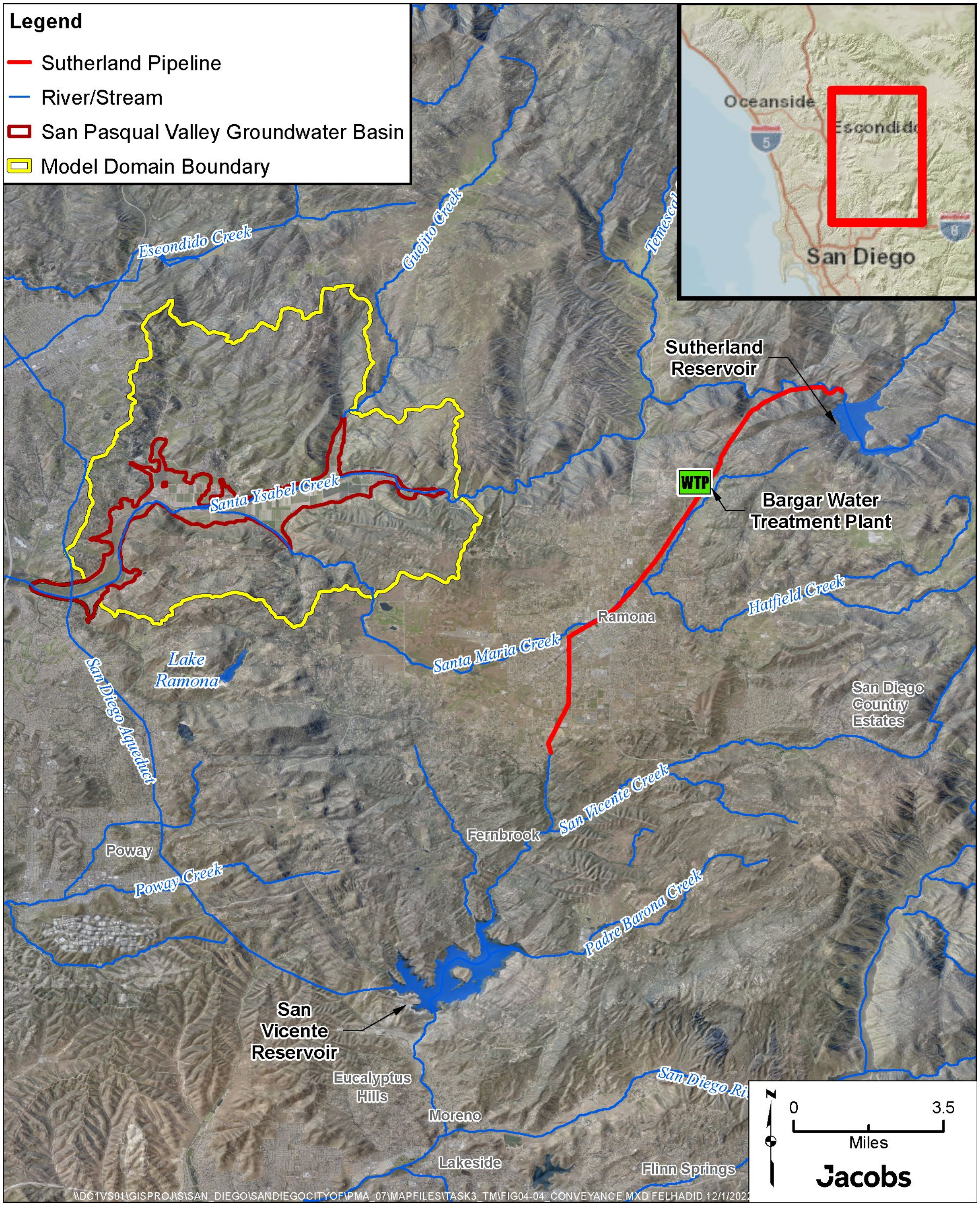

Figure 4-4. Conveyance Associated with Sutherland and San Vicente Reservoirs

The controlled releases to Ramona MWD are based on an agreement between Ramona MWD and the City signed on July 17, 2000 (Ramona MWD and City, 2000). This agreement is called the *Water Exchange and Transportation Agreement, and Water Exchange and Facility Utilization Agreement* and allows Ramona MWD to reserve or purchase stored water from Sutherland Reservoir available above the stage gauge of 65 feet (that is, above the minimum storage requirement of 112 AF). This volume was initially capped to 2,500 AF and then increased to 10,000 AF in an amendment (Ramona MWD and City, 2010) on August 27, 2010. The water to be delivered is subject to the City's approval on May 1st of each year. The delivered water plus Ramona MWD's share of evaporation, seepage and spill losses, is exchanged for delivery of an equal amount of Ramona MWD untreated water purchased from and delivered by CWA to the City at San Vicente Reservoir. Historic reservoir records and letters between the City and Ramona MWD indicate that only during year 2006, untreated water from Sutherland Reservoir was delivered to the Bargar WTP. As previously mentioned, the Barger WTP has been off-line since 2007 (CWA, 2021b). As seen in **Figure 4-5**, annual releases to Ramona MWD of approximately 500 AFY only took place during three years (WYs 2005 through 2007).

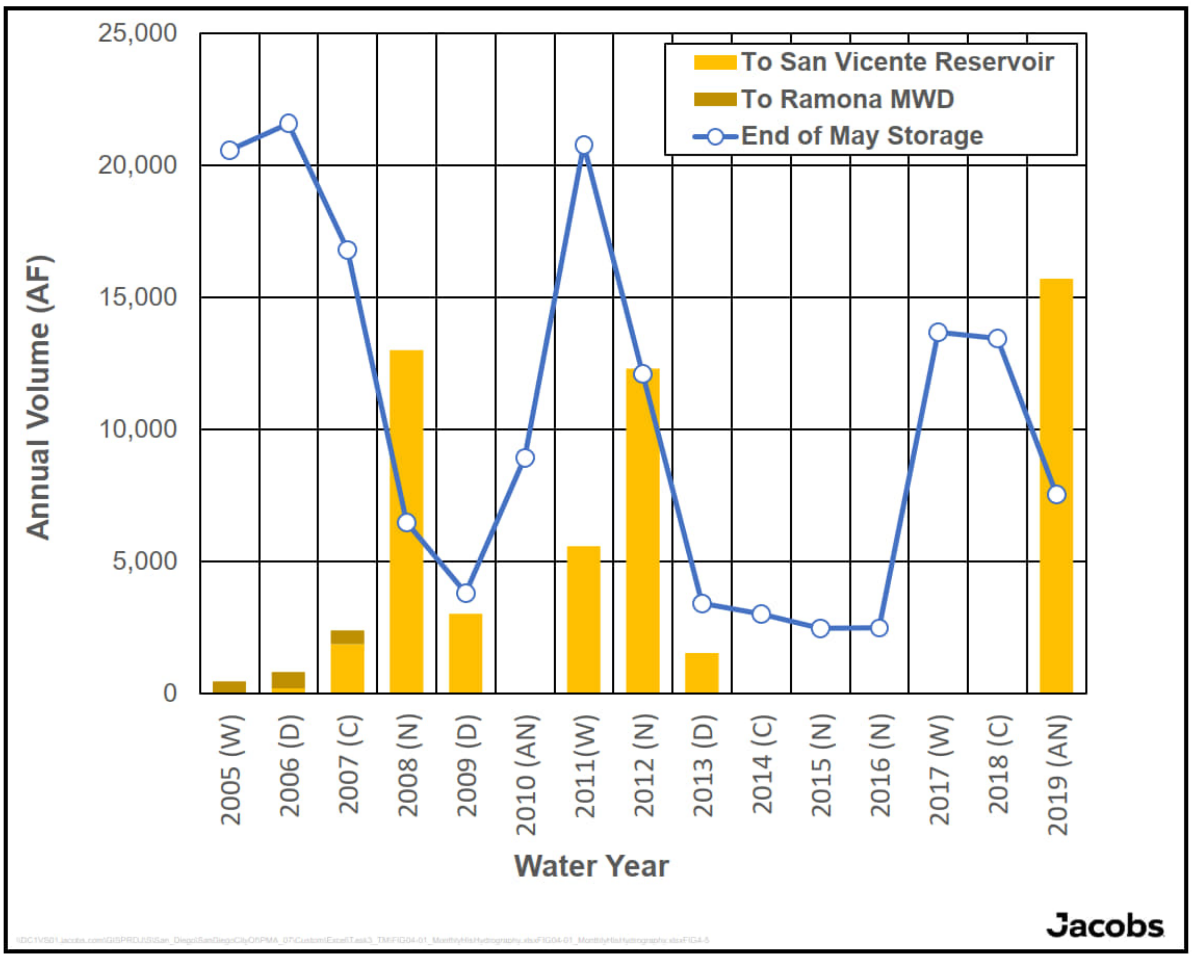

Figure 4-5. Historical Annual Releases from Sutherland Reservoir

The controlled releases to San Vicente Reservoir are based on water availability in Sutherland Reservoir, space available in San Vicente Reservoir to receive this water, and flow operation criteria. These controlled releases represent the majority of the reservoir's outflow; close to 70 percent of the water captured in

Sutherland Reservoir was ultimately transferred to San Vicente Reservoir during WYs 2005 through 2019, then to Alvarado WTP for treatment and delivery to City customers. The Sutherland-San Vicente Pipeline reduces its diameter to 27-inches and discharges into a San Vicente Creek tributary approximately two miles north of the San Vicente Reservoir. Based on the historical annual releases shown in **Figure 4-5**, there are no established volume and frequency releases to San Vicente Reservoir. In addition, the available yield and storage levels are not the only operation criteria. During WY 2010 and the period of WYs 2014 through 2018 there were no withdrawals from the reservoir. Annual releases to San Vicente above 10,000 AF only took place during three years (WYs 2008, 2012, and 2019). The controlled releases to San Vicente include operation criteria to minimize streambed erosion in San Vicente Creek, protect endangered species, and maximize conveyance efficiency. These operational criteria to determine the controlled release flows include the following:

- Release flow magnitude is determined based on Sutherland Reservoir storage level (that is, a higher storage level allows greater flow rate during releases). The range of flows can be between 50 and 95 cfs.
- Timing of releases follow these criteria:
  - February to April: minimize withdrawals during bass spawning season
  - March to September: during Arroyo Toad breeding season, the flow rates must be less than 10 million gallons per day (MGD)
  - March to April: maximize releases when the Santa Ysabel Creek streambed is saturated after the rainy season to reduce stream losses. The assumed stream conveyance loss between Sutherland and San Vicente reservoir is 22 percent (City, 2022d).
- Controlled releases only take place if there is available storage capacity in San Vicente Reservoir unless the releases bypass the reservoir and go directly to Alvarado WTP. San Vicente Reservoir is used to store water from other sources. Space to store water coming from Sutherland Reservoir needs to be available before starting the controlled releases. For instance, San Vicente Reservoir needs to have around 30 percent of available storage capacity before it can accept additional water from Sutherland Reservoir. This is below 200,000 AF of stored water with the possibility to store approximately another 70,000 AF until reaching its maximum capacity. Other criteria for evaluating the feasibility of the City to make releases from Sutherland or keep the water in the reservoir includes the need to use other local surface water resources like El Capitan reservoir.

Figure 4-5 shows the historical controlled releases to San Vicente Reservoir. During WY 2010 and the period of WY 2014 to WY 2018 there were no withdrawals from the reservoir even though stored water was available suggesting the above-mentioned operational criteria were implemented. Annual releases to San Vicente above 10,000 AF only took place during three years (WYs 2008, 2012, and 2019).

Figure 4-6 illustrates stored water at Sutherland Reservoir fluctuated between 7 to 70 percent of its full capacity and below the spillway level. The stored water volume did not decrease below 7 percent (around 2,000 AF) of its full capacity. The monthly releases from Sutherland Reservoir are below 4,000 AF and larger flow releases mostly took place from January through May.

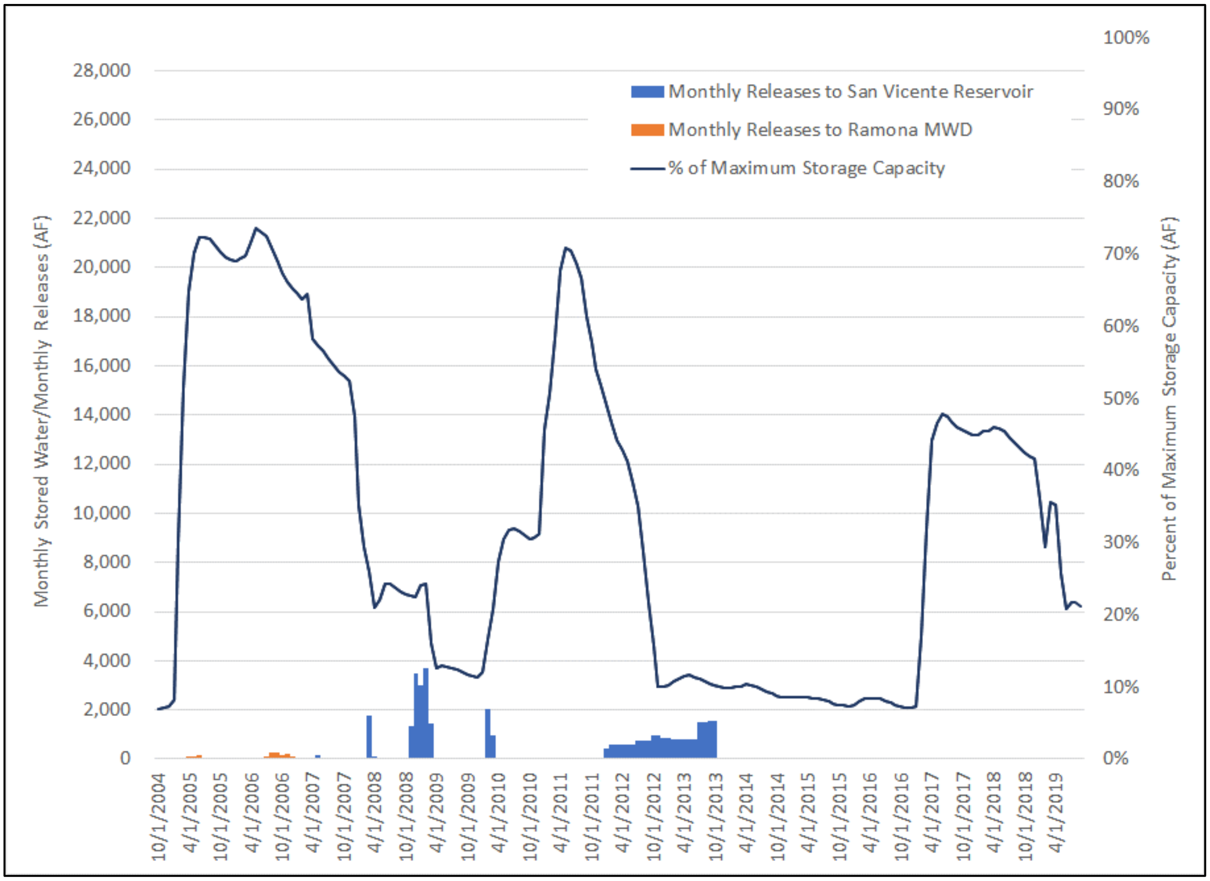

Figure 4-6. Historical Monthly Sutherland Reservoir Storage Volume and Releases

4.4 Considerations for Reservoir Releases to Santa Ysabel Creek

The availability of Sutherland Reservoir's stored water during the historical 15-year period that hypothetically could have been utilized as a source for releases to Santa Ysabel Creek is limited because most of the available runoff (around 70 percent) was transferred to the San Vicente reservoir and there were no spills. The feasibility of additional releases would depend on reservoir operational changes to increase releases during certain years preceding above normal and wet years when the stored water level is above normal operational levels. Sutherland Reservoir normal operating levels are less than 40 percent of maximum capacity (City, 2020). An initial estimate of range of this potential available water in historical years is presented in **Table 4-1**.

The recharge strategies that will be developed in future technical memorandum #4 for PMA No. 7 that include controlled releases from Sutherland Reservoir will focus on hypothetical operational changes to increase reservoir releases without dropping the storage level below normal operations or reducing releases to San Vicente and Ramona MWD below historic volumes. The outlet release capacity at the corresponding storage level would need to be taken into consideration to determine the release rate. For these initial hypothetical releases, it was assumed the releases would take place through the opening of the 20-inch blow-off near the dam and discharge into Santa Ysabel Creek with an average capacity of 74 cfs. Also, it was assumed the storage volume after the additional controlled releases would be at a minimum of 5,000 AF. The development of more refined operation scenarios will need to take advantage of optimization strategies as well as conveyance efficiency. Currently, 22 percent of the released volume to San Vicente reservoir is conveyance loss; mostly in the last 2-mile segment that is directly discharged into the San Vicente Creek prior to entering the San Vicente Reservoir (City, 2022). Similarly, the additional releases would be discharged into the Santa Ysabel creek with similar low efficiency challenges given direct discharges into the creek streambed. There are approximately 8 river miles of Santa Ysabel Creek between Sutherland Reservoir and the Basin boundary.

The CWASim model will be utilized as the primary tool for developing a set of operational scenarios to assess the potential daily magnitude of additional releases and the impact on storage levels. The output of these scenarios will be daily timeseries that will be processed to account for conveyance losses and represent additional stream inflows to the Basin via Santa Ysabel Creek to be used in SPV GSP Model v2.0.

Table 4-1. Estimated Historical Range of Water Resources Hypothetically Available from Sutherland Reservoir to Santa Ysabel Creek

Month	2005 (W)[a]	2006 (D)[a]	2007 (C)[a]	2008 (N)[a]	2009 (D)[a]	2010 (AN)[a]	2011 (W)[a]	2012 (C)[a]	2013 (C)[a]	2014 (C)[a]	2015 (C)[a]	2016 (C)[a]	2017 (W)[a]	2018 (C)[a]	2019 (AN)[a]
Oct	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	169	0	0	0	0	0	0	0	0
Dec	0	0	0	0	474	0	0	0	0	0	0	0	0	176	0
Jan	0	112	0	0	61	0	1,549	0	0	0	0	0	0	176	0
Feb	0	67	195	0	0	0	2,201	0	0	0	0	0	0	0	1,817
Mar	0	571	0	0	0	0	2,735	0	0	0	0	0	0	195	0
Apr	1,561	557	0	315	0	865	910	0	0	0	0	0	706	0	0
May	666	0	0	673	0	410	0	0	0	0	0	0	415	0	0
Jun	0	0	0	0	0	43	0	0	0	0	0	0	0	0	279
Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual	2,227	1,308	195	989	535	1,318	7,606	0	0	0	0	0	1,121	547	2,097

[a] Water year types are shown in parentheses and defined as follows: W=wet and AN=above normal, N=normal, D=dry, and C=critically dry. Values are expressed in units of monthly acre-feet.

5. RAMONA MUNICIPAL WATER DISTRICT

In this section, Ramona MWD's existing infrastructure, agreements with CWA, and operations are reviewed to identify potential delivery quantities and conveyance facilities needed for direct deliveries to Basin growers and/or to designated Basin recharge locations.

5.1 Existing Water District Sources and Operations

Ramona MWD provides water for urban and agricultural users servicing an area of 45,796 acres (72 square miles) (Ramona MWD, 2022). Of the service areas, Ramona MWD provides water to approximately 10,000 water meter connections on 7,000 urban parcels and 3,000 rural parcels. Ramona MWD purchases treated and untreated water from the CWA, which delivers water at three wholesale connections, two treated and one untreated. As previously mentioned, the Ramona MWD's Bargar WTP has been out of commission since 2007 and Ramona MWD is 100% reliant on CWA treated water deliveries for municipal and industrial (M&I) uses (Ramona MWD, 2022). The intakes with the CWA's and pump stations owned by Ramona MWD include:

- Intake RAM1 is for the delivery of untreated water with a capacity of 18.5 cfs. This connection can bring water to Lake Ramona using the Poway Pump Station (27-inch pipeline and 3 pumps, 13.36 cfs capacity flow). There is also the Lake Ramona pump station (4 pumps, 23.4 cfs) downstream the Ramona Lake connecting with Ramona MWD's untreated water system. See **Figure 5-2**.
- Intake RAM3 is for the delivery of treated water with a capacity of 32 cfs. This is the main CWA's delivery point currently used. A 30-inch diameter pipeline connecting to the Poway Forebay, where it is then pumped into the system via the Poway Treated Water Pump Station.
- Intake RAM2 is for the delivery of treated water from the Poway Treatment Plant in the neighboring City of Poway with a capacity of 10 cfs. This connection is only used during shutdowns from the Water Authority facilities to Connection 3.

Over the past 5 years (2018-2022), the total untreated water purchased from CWA for use throughout Ramona MWD has fluctuated resulting in an average of 405 AFY, and generally decreased over time.

Ramona MWD has access to two reservoirs (Sutherland Reservoir and Lake Ramona) (Ramona MWD, 2022). As previously mentioned, Sutherland Reservoir is owned and operated by the City. Although Ramona MWD has access to Sutherland Reservoir, it no longer has a surface water treatment plant and therefore cannot use water from Sutherland Reservoir. Lake Ramona is owned by Ramona MWD and is filled with untreated water from the CWA. There is essentially no runoff to the Lake. Lake Ramona has a capacity of 12,000 AF (CWA, 2021a) and its purpose is to supply untreated irrigation water to Ramona MWD's agricultural customers.

The GSA is considering using Ramona MWD's untreated water system to purchase additional supply from the CWA and deliver it to the Basin. CWA's untreated water supplies come from the Colorado River Aqueduct and the State Water Project, and is delivered to Ramona MWD's system via the San Diego Aqueduct. This untreated water can be a mix of the two sources, blended at the aqueduct, or one or the other, depending on supply availability and operational decisions. Lake Skinner, owned by Metropolitan Water District of Southern California, is the primary storage for the San Diego Aqueduct. Untreated water from Lake Skinner flows directly into Pipelines 3 and 5 (Second Aqueduct). Untreated water from the Second

Aqueduct is delivered through the Crossover Pipeline to the First Aqueduct to serve Escondido, Helix, Poway, Ramona, San Diego, and Vista. Ramona MWD has access to the First Aqueduct untreated water deliveries at the RAM1 flow control facility with a capacity of 18.5 cfs. From this CWA's delivery point, untreated water is pumped to Lake Ramona through the Poway Pump Station (2 pumps on duty and 1 pump on stand-by with a capacity of 13.36 cfs) and then from Lake Ramona to untreated water system through the Lake Ramona pump station (3 pumps on duty and 1 pump on stand-by with a capacity of 23.4 cfs) (see **Figure 5-1**).

Ramona MWD is planning to decommission the untreated water system as the agricultural demand has decreased to the point that it is no longer affordable to operate and maintain a dual water system. The Robb and Snow untreated water zones may be kept active because there are high-volume agricultural customers served from these zones. During the last three years (2019-2022), the average demand in these zones has been approximately 372 AFY. An initial assessment was conducted by Ramona MWD to estimate annual flows that could potentially be available to the Basin and indicated that 3,350 AFY from the Robb Zone or 850 AFY from the Snow Zone would be available from these areas of their untreated water system. During winter months, when there is less irrigation demand, there could be more flow available for delivery to the Basin compared to summer (July – October) when agricultural irrigation demands are higher. A monthly average of approximately 280 AF could be delivered constantly throughout the year with a maximum of 304 AF during March. Ramona MWD staff estimated an annual volume of 3,350 AFY could be delivered from its untreated water system's Robb Zone or 850 AFY from its Snow Zone using 80 percent of its conveyance capacity and assuming future untreated system local demand (2019-2021 average) continues to be delivered.

Minor modification would be required to the existing untreated water system infrastructure to deliver this additional source water to the Basin. A pressure-reducing station would need to be installed between the Woodson Untreated Zone and the Robb Untreated Zone along Highland Valley Road to feed the identified delivery points. Depending on the delivery volume and the need for interrupted deliveries, the untreated water could be stored in Lake Ramona, bypass the lake and pumped to the Kennedy tanks, or bypass the lake and pump directly to the Robb and/or Snow Untreated Zones for delivery. See **Figure 5-2**.

Ramona MWD would have to coordinate with CWA on the availability, timing, and delivery of additional imported untreated water for recharge to the Basin. Ramona MWD already coordinates on a daily basis with CWA to request flow changes for its treated and untreated water systems. Ramona MWD and the CWA have signed agreements to purchase and deliver untreated water for storage in Lake Ramona in such amounts that are practical, according to the parties' delivery and storage desires and capabilities. A 10,000 AF maximum stored volume at any one time and any one year was established. The CWA has not recently used Lake Ramona to store water.

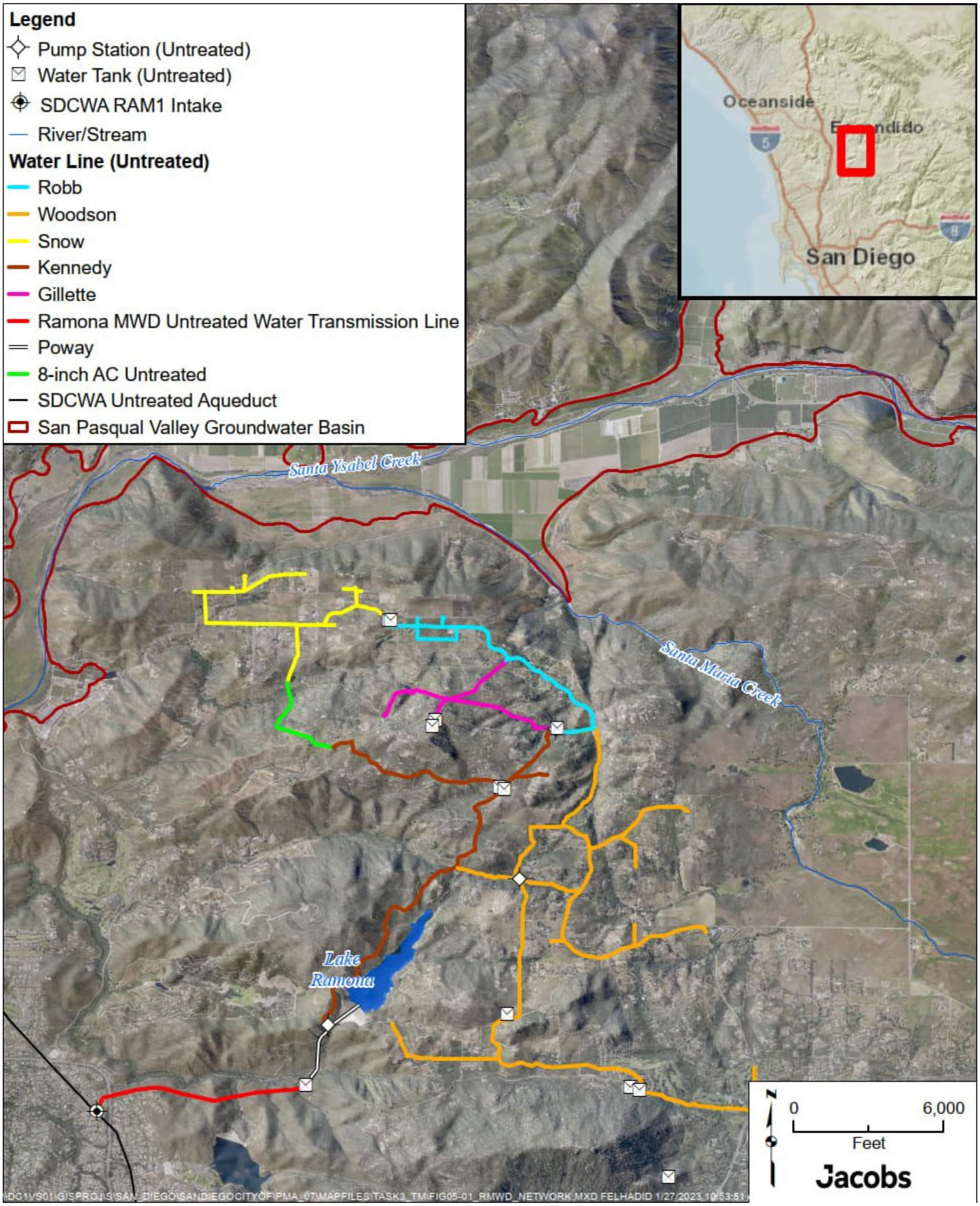

Figure 5-1. Ramona Municipal Water District's Untreated Water Network

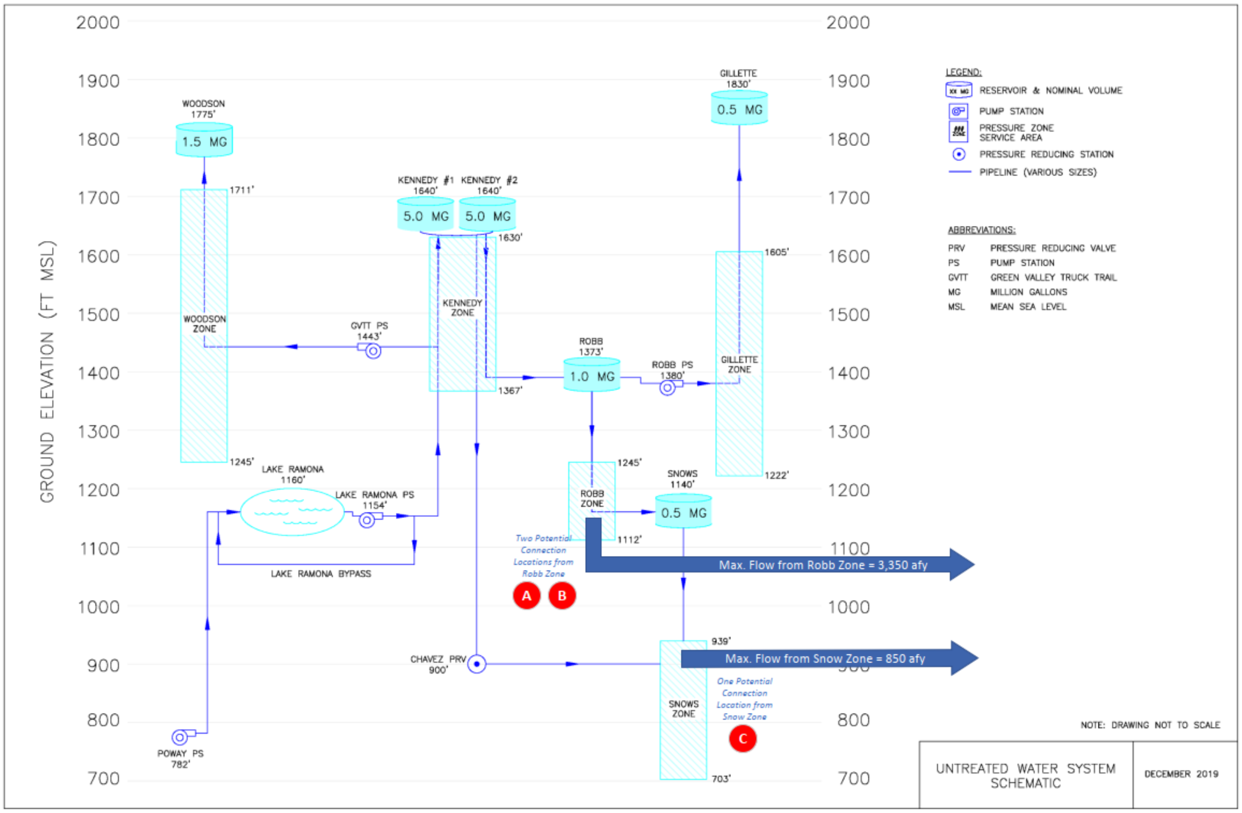

Figure 5-2. Ramona Municipal Water District's Untreated Water Network: Operation Zones

5.2 Potential Delivery Alternatives and Conveyance Requirements for Untreated Water

The volume of water available from Ramona MWD could be used in two ways that would benefit the Basin. The first is in-lieu recharge, using direct delivery to local growers to offset pumping demands, and would potentially require construction of conveyance pipelines from Ramona MWD's untreated water system to local growers' irrigation systems. The second approach is direct recharge, which would require construction of conveyance system from Ramona MWD's untreated water system to a recharge facility – either a groundwater recharge basin and/or injection wells. The need of water treatment prior to being used for basin recharge needs further evaluation, an initial water quality review is presented in Section 5.3. In the following subsections, the potential delivery alternatives and conveyance requirements are discussed.

5.2.1 Delivery to Local Growers

In-lieu recharge would involve direct delivery of untreated water to storage facilities such as ponds or tanks that would then be connected to existing local irrigation systems to help offset groundwater pumping. For this approach, water would be delivered directly to one or more growers within the areas identified for direct recharge (see Section 5.2.2). These growers are located near the diversion points from Ramona MWD and are within the portion of the Basin most suited to enhanced recharge. The imported irrigation water from Ramona MWD that is not consumed by plants or lost to evaporation would serve as an additional source of groundwater recharge. This approach would require voluntary participation by growers, need to be economically feasible, and result in a reliable water supply alternative to groundwater pumping.

The untreated water would be a reliable source of supplemental water and would help reduce the need for future conservation measures or restrictions. However, the price of untreated water from Ramona MWD would need to be determined to assess whether use of the untreated water system would represent a feasible cost-benefit alternative to growers and the Basin as a whole.

If this in-lieu recharge strategy is determined to be feasible, the location of pipeline alignments, potential growers to receive direct deliveries, location of storage facilities, and cost sharing/funding options would be developed in a future memorandum. In addition, existing programs currently being used in the region to deliver water to growers, such as the Permanent Special Agricultural Water Rate Program would be considered.

5.2.2 Delivery to Recharge Locations

Hypothetical potential recharge areas were identified in the Basin based on criteria identified in Section 2.2, and are shown in **Figure 2-2**. Ramona MWD identified three potential diversion points to its untreated water system, two in the Robb Zone and one in the Snow Zone. In this section, the required water delivery infrastructure is discussed for each of these potential diversion points.

5.2.2.1 Delivery from Robb Zone

The first diversion point in the Robb Zone was located along Highland Valley Road, approximately 500 feet west of Starvation Mountain Road (see **Figure 5-3)**. The second diversion point in the Robb Zone was also located along Highland Valley Road, approximately 800 feet north of Highland Trails Drive. Both diversion points would allow for delivery of up to 3,350 AFY untreated water to SPV as discussed in Section 5.1. The second diversion point in the Robb Zone was determined to be less desirable for potential recharge due to the longer pipelines that would be required to reach the recharge areas compared to the other Robb Zone diversion point. Therefore, this diversion point is not explored further in this technical memorandum.

From the Robb Zone preferred diversion point approximately 500 feet west of Starvation Mountain Road, the starting elevation is 757 feet, with the recharge areas having elevations of between 354 feet to 407 feet, which would allow water flow by gravity to aquifer recharge areas. It is estimated that no pumps would be required for conveyance and delivery based on preliminary assumptions to estimate the need for pumping, including calculated frictional head loss, an assumed delivery pressure of 10 pounds per square inch (psi) for the recharge basins. A 12-inch pipe would be sufficient to accommodate the flows to deliver the full volume of water per year of 3,350 AFY (that is, an average of about 3 million gallons per day [mgd] or about 4.62 cubic feet per second [cfs]). Maximum available flow from Ramona MWD at this diversion point is 6.6 cfs, based on seasonal demands and availability. Twelve-inch pipes with a maximum flow rate of 6.6 cfs results in flow velocity of 8.4 feet per second, within the City of San Diego’s design standards for maximum velocity of 15 feet per second, and a head loss of 18.9 feet per 1,000 feet of pipe. However, should the City determine a lower velocity and/or head loss is preferred, a larger diameter pipeline could be considered.

From this Robb Zone diversion point, potential pipeline alignments were identified that considered the minimum pipeline lengths needed to reach the distal portions of the recharge areas while still being able to utilize existing rights-of-way and minimizing creek crossings. These considerations were selected to reduce potential permitting needs, reduce impacts to growers, and potentially reduce costs. For Recharge Areas 1 and 2, which are instream recharge locations along Santa Ysabel Creek and Santa Maria Creek, respectively, the conveyance pipeline alignment also sought to be sufficiently upstream to allow for recharge of the full volume within the identified area, without creating excessive pipeline needs. Discharge points to Recharge Area 1 and Recharge Area 2 may shift during refinement of the alignments to best maximize recharge in these areas should additional analysis find that the preliminary locations would not allow for maximum recharge. For Recharge Area 1, the potential pipeline alignment to Santa Ysabel Creek would discharge at San Pasqual Valley Road, rather than at the easternmost portion of the creek identified, which would have required a substantial increase in pipeline length. For Santa Maria Creek, the potential pipeline would discharge near the Bandy Canyon Road creek crossing, to avoid the need to cross into private property upstream of this crossing.

The hypothetical pipelines to each of the eight recharge areas are shown in **Figure 5-1**. As seen in the figure, the pipelines would travel northeast from the diversion point to a private road at Bandy Canyon Ranch, where it turns northwest to Bandy Canyon Road. To reach Recharge Areas 7 and 8, the pipeline would follow Bandy Canyon Road until it turns north on Ysabel Creek Road, and back east to cross Santa Maria Creek and reach the two recharge areas. As noted, Recharge Area 2, Santa Maria Creek, would be reached at the point where Bandy Canyon Road crosses the creek, and represents the shortest of the hypothetical alignments. For Recharge Areas 1, 3, 4, 5, and 6, the hypothetical pipeline would cross Santa Maria Creek and continue east and northeast along Bandy Canyon Road, with a turnoff along a private road to reach Recharge Area 6, approximately 0.6 miles east of the creek crossing. Recharge Area 5 would be reached via a private road across from the intersection of Bandy Canyon Road and Burkhard Hill Road. Another 0.25 miles east along Bandy Canyon Road would be a turnout to reach Recharge Area 4, whereas Recharge Areas 1 and 3 would be reached by continuing to follow Bandy Canyon Road to where it crosses Santa Ysabel Creek.

These hypothetical pipelines would be refined based on further exploration of viable recharge locations within each recharge area, as well as potential access or permitting considerations that may arise. Additionally, pipes may need to be resized to accommodate pressure and flow requirements, or other design needs that might arise. As the potential recharge projects are refined, other infrastructure needs, such as a pump station or treatment facility should injection wells be used for recharge, would also be incorporated.

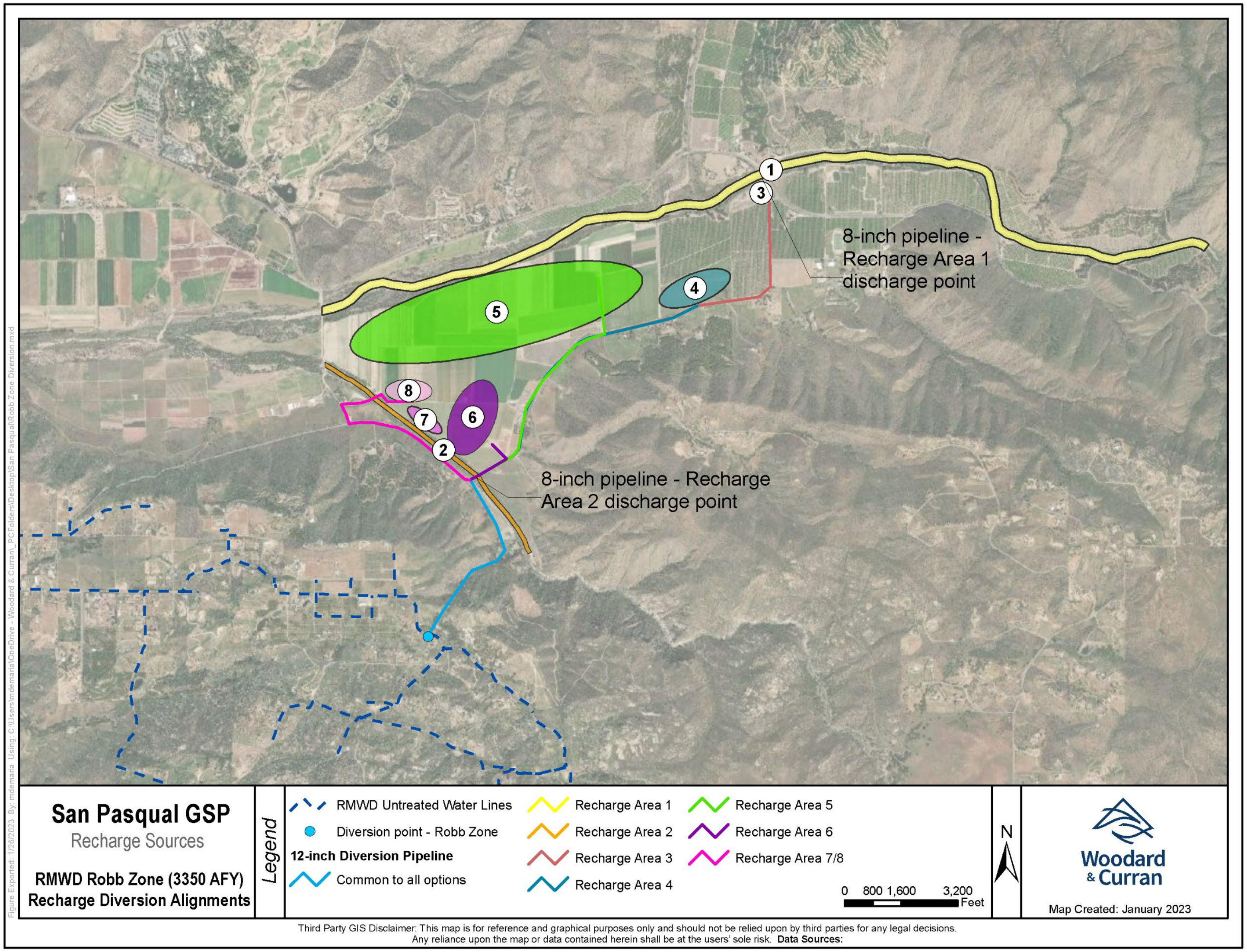

Figure 5-3: Hypothetical Pipelines from Robb Zone Diversion Point

5.2.2.2 Delivery from Snow Zone

The Snow Zone diversion point would be located approximately 200 feet north of the intersection of Bandy Canyon Road and Sky High Road, where Bandy Canyon Road turns northeast. From this diversion point, up to 850 AFY would be available for recharge. This diversion point has an elevation of 1,180 feet, and would deliver to the same potential recharge areas as above, which have elevations of between 354 and 407 feet. Similar to the hypothetical alignments from the Robb Zone, the Snow Zone alignments would be able to use gravity and would not require pumps to convey untreated water to the recharge areas. The smaller volume of available water would result in an average of 0.76 mgd of flows, or 1.17 cfs, with maximum flow rate of 2.3 cfs based on seasonal demand and availability. Supplies from this diversion point would only require 8-inch diameter pipes. At maximum flow, this would result in a head loss of 19.4 feet per 1,000 feet, and a velocity of 6.6 feet per second.

Using the same considerations for hypothetical alignments as the Robb Zone pipelines (that is, fewer creek crossings, less pipeline length, and using rights-of-way where possible), the Snow Zone pipelines are shown in **Figure 5-2**. As shown in **Figure 5-2**, this diversion point would have the pipelines follow Bandy Canyon Road from the diversion point to Ysabel Creek Road, where it would then follow the same alignments as described for the Robb Zone diversion point's pipelines to reach each of the recharge areas. As with the alignments described for the Robb Zone diversion alignments, these hypothetical alignments would be refined based on final recharge location and method and to accommodate final pressure and flow needs. Should injection wells be selected as the preferred recharge method, a pump station would be incorporated, with details explored in a future technical memorandum.

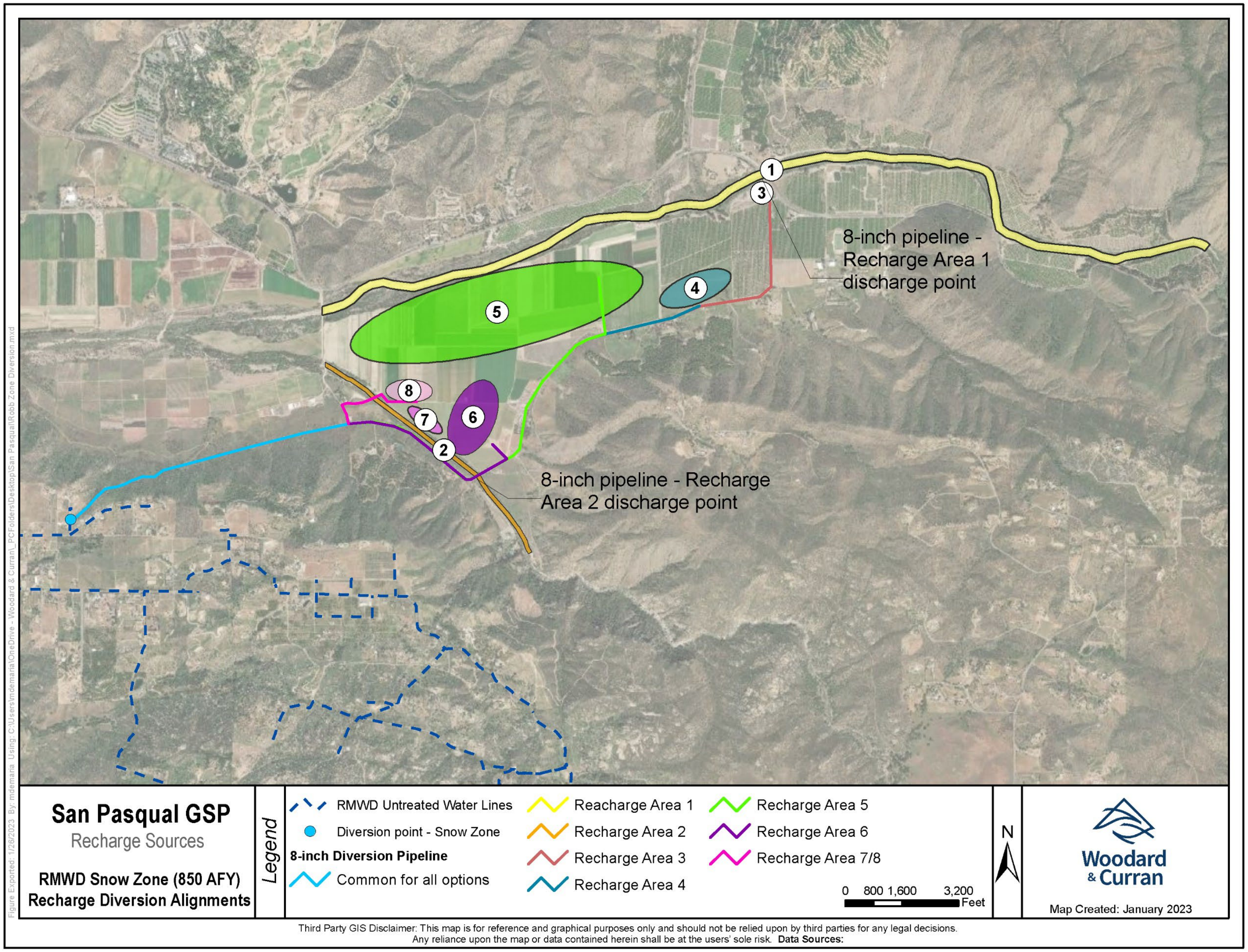

Figure 5-4: Hypothetical Pipelines from Snow Zone Diversion Point

5.3 Water Quality Review Relative to San Pasqual Academy's Existing Wells

The scope of work for this task requires a comparison of water quality of Ramona MWD's untreated water system with groundwater quality near the San Pasqual Academy to identify whether there is a need for further impact assessment of San Pasqual Academy water sources. San Pasqual Academy is located at 17701 San Pasqual Valley Road in the eastern portion of the Basin. (**Figure 5-5**). This facility is located outside the City-owned and -leased areas of the Basin, residing in the jurisdiction of San Diego County.

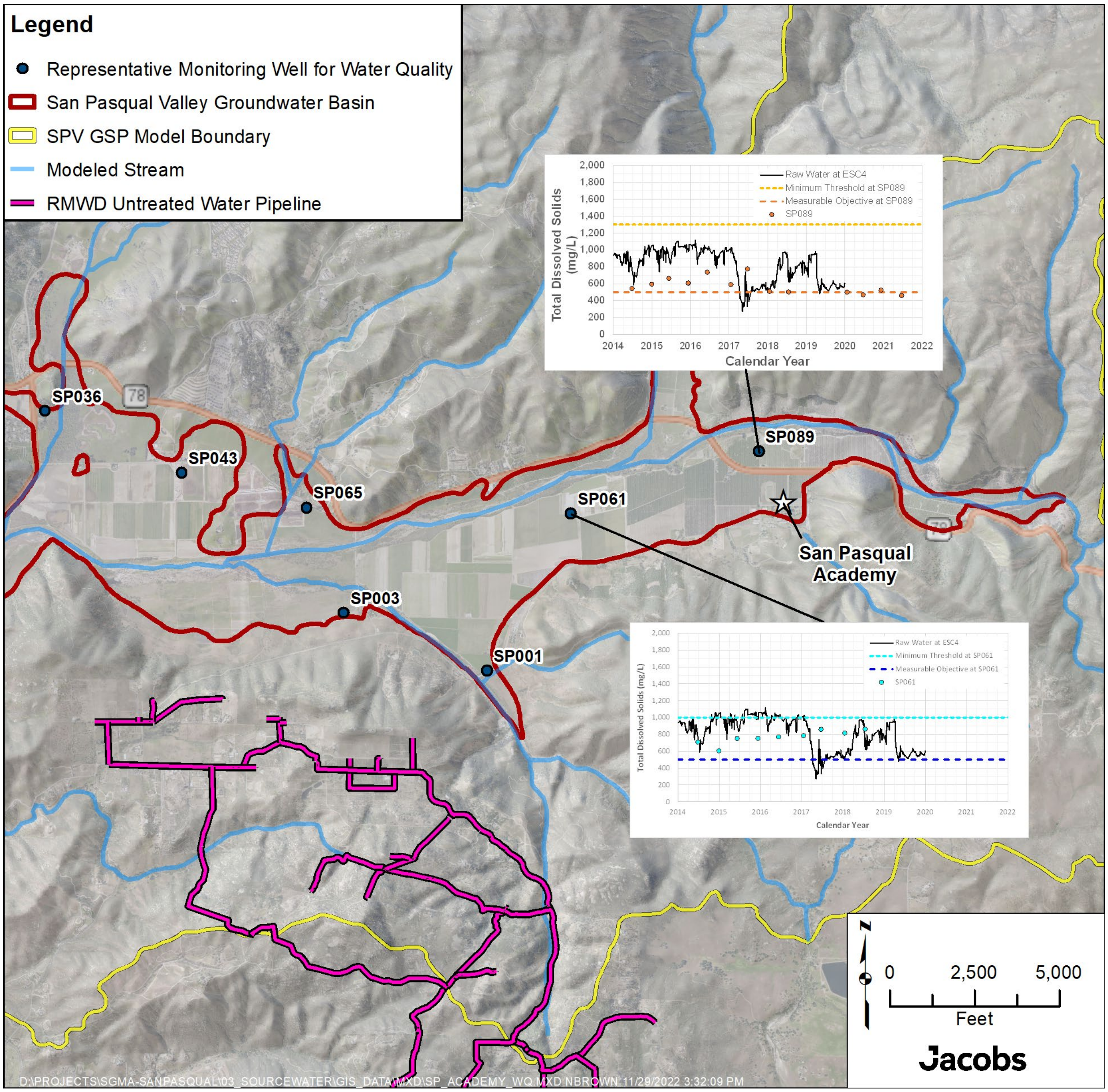

Figure 5-5. Comparison of TDS Concentrations Near San Pasqual Academy

The water quality comparison described herein focuses on total dissolved solids (TDS), because TDS is the only water quality parameter routinely monitored for the untreated water system (Personal Communication, 2022). If alternatives that include importation of water from the untreated water system are retained for further analysis after the Preliminary Feasibility Study, it may be necessary to perform additional sampling and expand the list of analytes. Expanding the list of analytes would be done to facilitate a more comprehensive assessment of how groundwater quality near San Pasqual Academy could potentially evolve in response to enhanced recharge activities in the eastern portion of the Basin. Further, water quality in the untreated water system is sensitive to the percentage that comes from the State Water Project (SWP) versus the Colorado River Aqueduct and this percentage varies from year to year. Generally, the greater the percentage of SWP water in the untreated water system, the lower the TDS concentrations.

Figure 5-5 shows TDS concentrations since 2014 for the untreated water system at the Escondido 4 (ESC4) monitoring location along with groundwater TDS concentrations at SP061 and SP089. These two monitoring wells (SP061 and SP089) are designated in the GSP as representative monitoring wells for water quality and are the most proximal representative monitoring wells to San Pasqual Academy (City and County, 2021). The TDS concentrations for the untreated water system and these two representative monitoring wells are presented along with two concentration thresholds established in the GSP: minimum threshold and measurable objective. A minimum threshold is defined in the SGMA regulations as a numeric value for each sustainability indicator used to define undesirable results. In this case, the TDS minimum threshold has been set at the historical high measured concentration for the representative monitoring well, or 1,000 milligrams per liter (mg/L), whichever is greater in concentration (City and County, 2021). A measurable objective is defined in the SGMA regulations as the specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted GSP to achieve a basin's sustainability goal. A measurable objective is used to help guide the GSA as it continues sustainable groundwater management over a GSP's planning and implementation horizon. In this case, the TDS measurable objective is 1,000 mg/L for representative monitoring wells that have historical TDS concentrations greater than 1,000 mg/L and 500 mg/L for representative monitoring wells that have historical TDS concentrations generally less than 1,000 mg/L (City and County, 2021). Therefore, because historical TDS concentrations at SP061 and SP089 have been less than 1,000 mg/L, the TDS measurable objective for these representative monitoring wells is set at 500 mg/L.

As shown in **Figure 5-5**, TDS concentrations of the untreated water system at ESC4 since 2014 have generally been greater than groundwater TDS concentrations at SP061 and SP089 and periodically greater than the minimum threshold of 1,000 mg/L at SP061. The latest available TDS concentrations of the untreated water system at ESC4 provided by CWA are from December 2019 and they are lower than the minimum thresholds and just above the measurable objective of 500 mg/L (City and County, 2021). Recent groundwater TDS concentrations at SP061 and SP089 have also been around the measurable objective of 500 mg/L. Therefore, more recent TDS concentrations in the untreated water system at ESC4 have been similar to groundwater TDS concentrations at SP061 and SP089. More recent TDS concentrations in the untreated water system would be needed to compare them with the groundwater TDS concentrations that have occurred since 2019. If 2019 TDS concentrations in the untreated water system are indicative of future TDS concentrations, then water quality impacts from the recharge project associated with deliveries from Ramona MWD in the areas near SP061 and SP089 should not result in triggering minimum thresholds, but they could prevent groundwater TDS concentrations from achieving measurable objectives at these two representative monitoring wells.

5.4 Considerations for Ramona MWD deliveries

The untreated water system conveyance capacity and the existing customers' demands are the main characteristics that would need to be considered when developing the delivery schedule for Ramona MWD's untreated water system. If the CWA's flow control facility is operated 75 percent of the time, it would be able to deliver approximately 10,000 AFY, which is the maximum storage capacity suggested in the agreements for storing CWA's untreated water. However, the existing agricultural customers' demands and the system conveyance capacity will determine the ability to deliver this annual volume. In addition, the CWA would need to confirm its untreated water availability and conveyance capacity.

Ramona MWD staff indicated that 3,350 AFY could be delivered from the Robb Zone or 850 AFY from the Snow zone. Depending on whether the Robb or Snow Zone location is chosen, a monthly volume of up to approximately 300 or 95 AF, respectively could be delivered throughout the year to the SPV Basin on an annual basis provided there has not been much fluctuation driven by hydrology and provided that CWA would agree to meet this additional demand.

One of the advantages of this water source is that untreated water could be available during dry years and minor modification would be required to the existing untreated water system infrastructure to deliver this additional water source to the Basin.

Discussions with CWA, based on capacity and potential other constraints to receiving untreated water, should continue in future planning and design phases of the project. First Aqueduct operation would need to be aligned and incorporate Ramona MWD's newly re-established untreated water demand into its operations. Also, restrictions on water deliveries might need to be applied during drought conditions because this is not an M&I water use.

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ATTACHMENT A: SUTHERLAND

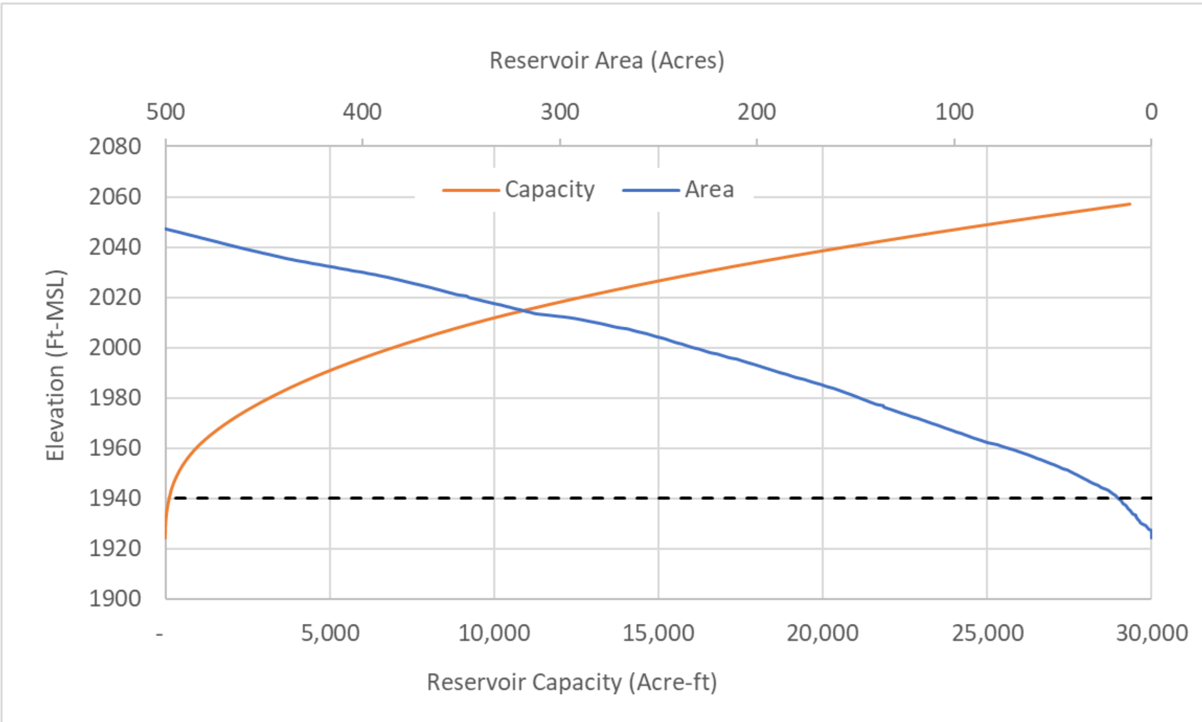
A.1 Sutherland design capacities

Design Element	Capacity/Length	Source
Capacity	29,345 AF	Sutherland Information Request
Spillway Crest Elevation	2,057 ft	Sutherland Information Request
Spillway Capacity	41,214 cf	Sutherland Information Request
Dead Pool	112 acre-feet	Sutherland Information Request
Maximum Release to San Vicente Reservoir through Sutherland Pipeline without blow-offs	95 cfs	Sutherland Information Request
Maximum Release to Santa Ysabel Creek through Sutherland Pipeline with blow-offs	110 cfs	Sutherland Information Request
San Vicente Pipeline	11-miles	City of San Diego, UWMP 2020
San Vicente Pumping Facilities	300 MGD	City of San Diego, UWMP 2020

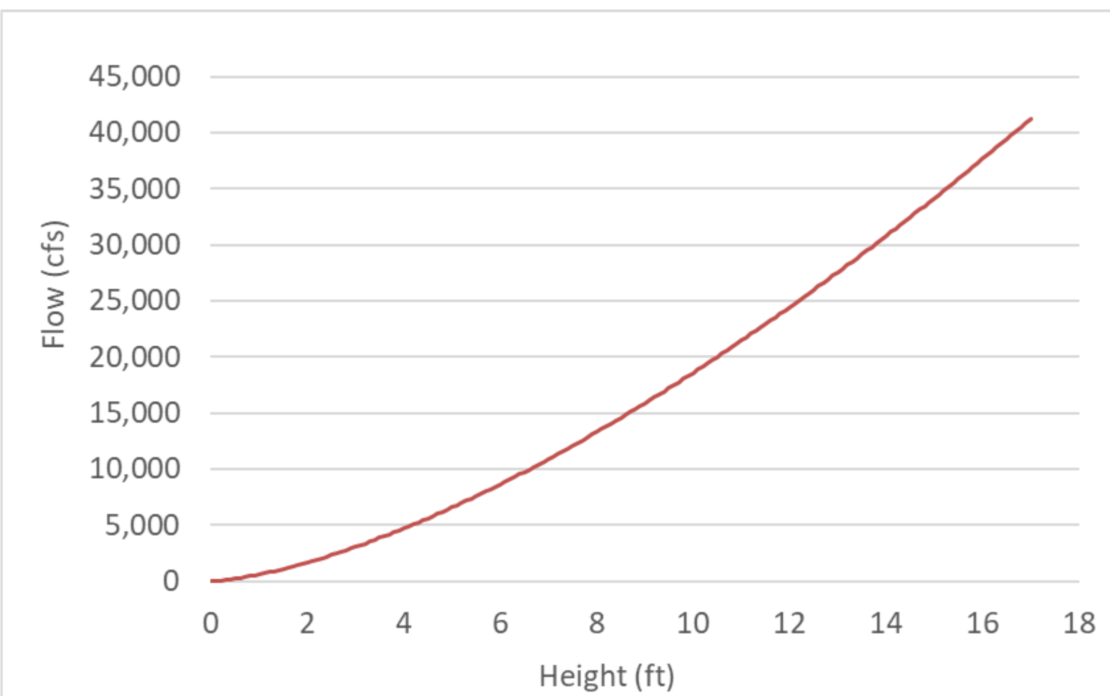
A.2 Sutherland operational rules

Operation Rules		Source
February to April: minimize withdrawals during bass spawning season		City of San Diego, 2022. Sutherland Information Request
March to April: maximize releases when the Santa Ysabel Creek streambed is saturated after the rainy season to reduce stream losses. The assumed stream conveyance loss between Sutherland and San Vicente reservoir is 22 percent		City of San Diego, 2022. Sutherland Information Request
San Vicente Reservoir needs to have around 30 percent of available storage capacity. This is below 200,000 AF of stored water with the possibility to store approximately another 70,000 AF until reaching its maximum capacity.		City of San Diego, 2022. Sutherland Information Request
March to September: during Arroyo Toad breeding season, the flow rates must be less than 10 million gallons per day (MGD)		City of San Diego, 2022. Sutherland Information Request
Releases flow rates: Based on Sutherland stored volume		City of San Diego, 2022. Sutherland Information Request
Sutherland stored volume	Release flow	
0-2,000 AF	55 cfs	
2,000-5,000 AF	67 cfs	
5,000-20,000 AF	90 fs	

A.3 Area vs Capacity Curve



A.4 Spill Crest Capacity



A.5 Agreements Summary

August 27, 2010. Ramona Amendment 1

- An amendment to the Water Exchange Agreement to increase the water exchange cap from the existing 2,500 Acre Feet ("AF") to a total of 10,000 AF, including all reserved water and owned water. Such cap raise will allow Ramona MWD to hold more water in Sutherland Reservoir, when available.

March 17, 2008. Subject: Water Available in Sutherland Reservoir

- In 2008, the current water level at Sutherland Reservoir was 81 feet with a storage of 5,500 acre feet. The City is currently drafting water from Sutherland and expects to be at approximately 5,200 AF by March 21, 2008. This represents about 2,500 AF above gauge 65 feet and available to Ramona MWD. The intent of the letter is to discuss the existing agreement for any Reserved Water should be drafted from the reservoir within the same year that is requested. Therefore, if RWMD does not have an operating plan to draft Reserved Water within the same year, the City recommends Ramona MWD purchase the required water as owned Water.

April 10, 2006. Subject: Water Exchange Report

- Letter in response to the requesting reservation of 2,500 acre feet of water in Sutherland Reservoir. States that Sutherland's reservoir water level is at gauge 128.7 feet with 21,368.8 AF of storage. This amounts to about 18,717 AF above gauge 65. Therefore, the City authorizes the reservation of2,500 AF for Ramona MWD in Sutherland Reservoir, beginning May I, 2006.

July 17, 2000. Agreement for Water Exchange and Transportation between the City of San Diego and the Ramona Municipal Water District.

- The reserved water will be transported by the city from Sutherland Reservoir through the Sutherland Reservoir/San Vicente Pipeline. The water delivered is subject to city approval on May 1st. The delivered water plus Ramona MWD's share of evaporation, seepage and spill losses, shall be exchanged for delivery of an equal amount of Ramona MWD untreated water purchased from and delivered by CWA to CITY at any other CITY facility.
- Owned Water shall be delivered by CITY to Ramona MWD as scheduled by Ramona MWD with 30 days written notice. Such delivery is subject to CITY approval and shall not significantly interfere, as determined by the CITY, with the CITY's ability to draft from Sutherland Reservoir.
- Term: 5 year term with 4 additional renewals

June 29, 1992. Subject: Lake Sutherland Water Exchange Agreement

- Construction: Ramona shall construct or modify to its sole expense metering and related devices;
- Water Storage and Releases: Ramona will tell the City how much water it needs before July that the city will hold in storage for Ramona for the following 12 month period. The maximum reserved in storage for Ramona shall not exceed 4,000 acre feet. If Ramona needs more than

4,000 acre feet, a written request will be needed before May 15. When the total storage in Sutherland Reservoir exceeds the requested amount, the city will decide which entity receives the water. If the city does not transfer water to the San Vicente Reservoir, Ramona is entitled to receive water from the surplus that is held in storage unless otherwise stated by the city.

- Reimbursements: commodity charge same the City pays to the CWA, operational charge 50$ per month; capital investment charge, $4 per AF
- Charges: evaporation and spillage: proportional; billing and payment, up to 1,000 AF only
- Water Quality: Ramona might elect not to use it
- Exchange of Water: Sutherland deliveries to Ramona exchanged for San Vicente deliveries to City less than 10% within 60 days after Ramona's deliveries have been completed
- Term and Termination: 20 years (2012)
- This agreement supersedes prior agreements

APPENDIX D: TM 4: POTENTIAL RECHARGE STRATEGIES

TECHNICAL MEMORANDUM

TO: San Pasqual Valley Groundwater Sustainability Agency

PREPARED BY: Paula Silva/Jacobs, Kate Dowsley/Jacobs, Lindsay Atkinson/Jacobs, Sally Johnson/W&C, Jim Blanke/W&C

REVIEWED BY: Nate Brown/Jacobs, Craig Cooledge/Jacobs, James Gorham/Jacobs, Mark Elliott/Jacobs, Christy Kennedy/W&C

DATE: May 22, 2023

RE: Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 4: Potential Recharge Strategies

TABLE OF CONTENTS

ACRONYMS & ABBREVIATIONS

AF	acre-foot	GSA	Groundwater Sustainability Agency
AFY	acre-feet per year	GSP	Groundwater Sustainability Plan
Basin	San Pasqual Valley Groundwater Basin	hp	horsepower
bgs	below ground surface	M&I	municipal and industrial
cfs	cubic feet per second	MGD	million gallons per day
City	City of San Diego	NAD83	North American Datum of 1983
County	County of San Diego	NAVD88	North American Vertical Datum of 1998
CWA	San Diego County Water Authority	O&M	operations and maintenance
DDWD	Division of Drinking Water	PMA	Project and Management Action
DSOD	Division of Safety of Dams	psi	pounds per square inch
DWR	Department of Water Resources	Ramona MWD	Ramona Municipal Water District
ft/d	feet per day	SPV	San Pasqual Valley
fbg	feet below grade	SPV GSP Model	SPV GSP Integrated Groundwater/Surface Water Flow Model
GDE	Groundwater Dependent Ecosystem	SWRCB	State Water Resources Control Board
gpm	gallons per minute	TM	technical memorandum
gpm/ft	gallons per minute per foot	USGS	United States Geological Survey

EXECUTIVE SUMMARY

This is the fourth technical memorandum (TM) in a series of six to evaluate recharge in the San Pasqual Valley Groundwater Basin (Basin). This TM focuses on identifying, assessing, and screening potential recharge strategies. A total of 15 recharge strategies for the Basin were developed (**Table E-1)** and analyzed based on the screening criteria in **Table E-2**.

Table E-1 Recharge Strategies Evaluated and Selected

Recharge Method → Water Source ↓	A Existing Streambed	B In-stream Modifications	C Infiltration Basins	D Injection Wells	E Managed Flood Irrigation	F In-Lieu Recharge
1. Stormwater in Santa Ysabel Creek	1A	1B	1C	1D	1E	1F
2. Controlled Releases from Sutherland Reservoir	2A	2B	2C	2D	2E	2F
3. Deliveries from Ramona MWD's Untreated Water System	3A	3B	3C	3D	3E	3F

Note: the code in cells indicates the source (number) and the recharge method (letter). Colored cells correspond to the selected strategies.

Table E-2 Screening Criteria for Recharge Strategies

Screening Criteria	Description
Yield	Potential annual average recharge volume
Cost	Estimate of capital and annual operation and maintenance costs
Recharge footprint	Loss of farmland
Timing	Estimate of time required before project could be implemented considering planning, design, permitting, and implementation
Energy	Estimated energy required to implement and operate
Reliability	Reliability of supply during dry periods
Flexibility	Degree to which the strategy could be turned off/on over a wide range of hydrologic conditions by having the ability to adjust operations according to hydrologic and infiltration or recharge conditions
Level of Complexity	Maturity of the technology required to implement the strategy
Pretreatment Requirements	Water supply pretreatment requirements and inferred risk of groundwater quality degradation because of implementing the recharge strategy
Operation & Maintenance (O&M) Frequency	O&M frequency required
Permitting	Anticipated permits required and status of whether the permitting process has begun for the strategy
Environmental	Anticipated positive or negative effects on the natural environment

A comparative numerical analysis of the 15 recharge strategies was completed to identify the benefits and constraints of the strategies that warranted further investigation.

Four strategies were selected for further investigation, based on comparative ranking, high potential for broad benefits, and preserving diversity in recharge methodology. The four strategies selected include:

- Strategy 1B: Enhance Streamflow Infiltration with In-stream Modifications
- Strategy 2A: Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases
- Strategy 3A: Augment Santa Ysabel Creek with Ramona MWD Untreated Water System Deliveries
- Strategy 3D: Injection Wells with Ramona MWD's Untreated Water System Deliveries

Each of the four strategies are described with planning-level design and preliminary cost information in Section 3 of this TM. More information on the technical design considerations and cost estimates are included in the TM attachments.

After this TM, the next step in evaluating surface water recharge within the Basin will be to simulate the four selected strategies with the updated SPV GSP Model to project potential benefits to groundwater levels and groundwater storage. After the four selected strategies are modeled, the benefits to groundwater dependent ecosystems (GDEs) will be assessed. Assessment work from these steps will then be summarized in a Preliminary Feasibility Study.

1. INTRODUCTION

The San Pasqual Valley Groundwater Sustainability Agency (GSA) – comprised of the City of San Diego (City) and the County of San Diego (County) – approved and submitted the San Pasqual Valley Groundwater Sustainability Plan (GSP) to the California Department of Water Resources (DWR) in January 2022 (City and County, 2021). The GSP provides guidance and quantifiable metrics to ensure the continued sustainable management of groundwater resources within the San Pasqual Valley Groundwater Basin (Basin; **Figure 1-1**) over the 20-year GSP implementation period.

The GSP concluded that the Basin is currently sustainably managed and that no additional projects and management actions (PMAs) are needed to achieve sustainability. However, implementing PMAs could improve resilience against challenging future hydrologic conditions, such as extended droughts, or can facilitate response to such conditions. The GSP groups the PMAs into three tiers. Tier 0 may be implemented after GSP adoption, Tier 1 may be implemented when planning thresholds are exceeded, and Tier 2 may be implemented when minimum thresholds are exceeded. Current implementation efforts have included Tier 0 PMAs, and monitoring is ongoing to inform the GSA on Basin conditions that would indicate whether Tier 1 PMAs are needed.

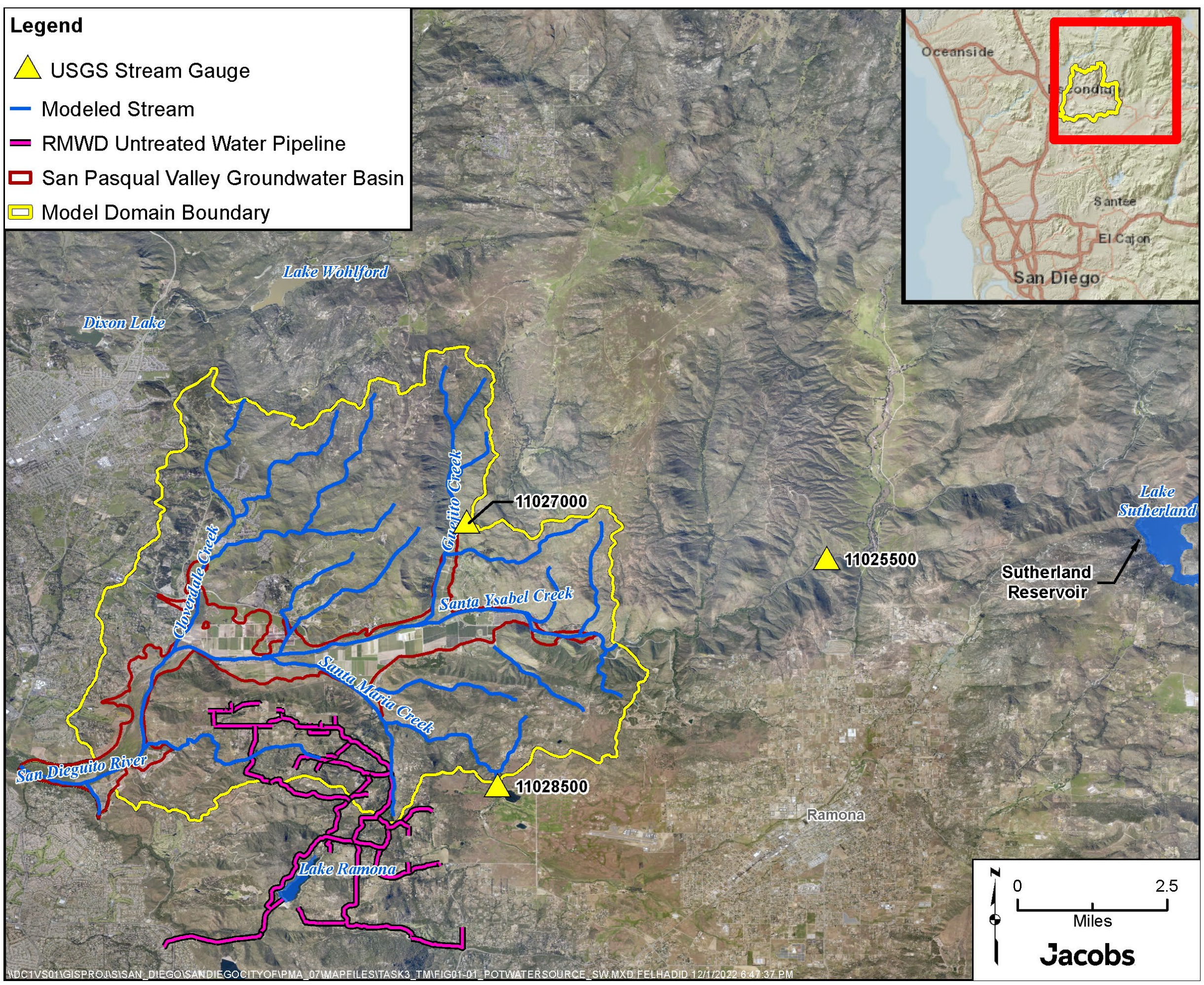


Figure 1-1 Regional Location Map

To improve the resilience of the Basin against extreme drought and unforeseen conditions, the GSA has begun implementation of the Initial Surface Water Recharge Evaluation, incorporated in the GSP as a Tier 0 activity labeled Management Action 7. The GSA will use the Initial Surface Water Recharge Evaluation, documented in a Preliminary Feasibility Study, to help estimate potential benefits to the Basin from implementing the potential recharge strategies. Such benefits may be seen in groundwater levels, groundwater storage, groundwater quality, and reduced depletions of interconnected surface water.

This TM is the fourth in a series of six, each covering an individual evaluation task. The six TMs will be summarized into the Preliminary Feasibility Study, each with its own section.

- Task 1 - Evaluation Criteria and Ranking Process: The first TM describes the evaluation criteria by which the best surface water recharge strategies for the Basin will be determined (City, 2022a).
- Task 2 - Streambed Investigation: The second TM describes the approach and results of a streambed investigation along Santa Ysabel Creek in the eastern San Pasqual Valley (SPV) and provides recommendations for updating the SPV GSP Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) (City, 2023a). The version of the SPV GSP Model used to support development of the GSP is referred to as SPV GSP v1.0 herein to differentiate it from the updated version of the model to be developed and used in Task 5. The updated version of the model is referred to as SPV GSP Model v2.0 herein.
- Task 3 - Water Sources for Recharge: The third TM describes the assessment of three types of water sources that could potentially be used for surface water recharge projects within the Basin, including stormwater flows in Santa Ysabel Creek in the eastern portion of the Basin, Sutherland Reservoir releases, and untreated water from Ramona Municipal Water District (Ramona MWD) (City, 2023b). Water sources and conveyance information is incorporated into the strategies described under Task 4.
- Task 4 - Potential Recharge Strategies: This fourth TM describes the assessment of potential recharge strategies that could be considered in the eastern portion of the Basin. Potential recharge areas and potential volume of water supplies presented in this TM have not been vetted by stakeholders or permitting agencies and should be viewed as conceptual for this stage of study.
- Task 5 - Modeling Simulations and Results: A fifth TM will be developed to describe how the strategies were incorporated into the SPV GSP Model and to provide the model's projections of benefits to groundwater levels and storage.
- Task 6 - Potential Benefits to Groundwater Dependent Ecosystems (GDEs): A sixth and final TM will be developed to describe potential benefits to GDEs resulting from the model-projected improvements in groundwater levels described in the fifth TM.

2. COMPONENTS OF RECHARGE STRATEGIES

The recharge strategies evaluated for this phase of the study (Task 4) have three components:

1. Water: Source of water that could be used for aquifer recharge as described as part of Task 3 (City, 2023b). These include stormflows, controlled releases from Sutherland Reservoir, and deliveries from Ramona MWD's untreated water system.
2. Conveyance: Infrastructure needed to transport the source water to the designated recharge area, as discussed as part of Task 3 [City, 2023b].
3. Method: Recharge or infiltration method to be used to increase groundwater recharge.

Several recharge methods are described below to provide context prior to discussing the selected recharge strategies in Section 0.

- Infiltration through existing streambed: Infiltration occurs naturally through streambeds. With this method, additional source water is introduced to the stream and allowed to infiltrate naturally into the aquifer system.
- Infiltration through existing streambed with in-stream modifications. This method modifies "infiltration through existing streambed" through modifications to the streambed to increase infiltration. These modifications can include weirs, berms, and rubber dams.
- Infiltration basins: Infiltration basins are typically shallow ponds constructed outside of the streambed. A water source would be conveyed to the basin to allow for infiltration.
- Injection wells: Injection wells operate the opposite of groundwater production wells, with source water pumped under pressure directly into the deeper aquifer system.
- Managed flood irrigation: Managed flood irrigation refers to the practice of inundating existing fields with water and allowing it to infiltrate.
- In-lieu recharge: The replacement of groundwater supplies with alternate supplies is known as in-lieu recharge. Reducing or eliminating groundwater pumping results in less water leaving the groundwater system, improving groundwater levels and storage conditions.

Additional detail is provided in **Attachment A**, including their potential benefits and challenges in the context of the Basin.

3. RECHARGE STRATEGIES

Based on the potential combinations of water source, conveyance system, and recharge method discussed above, 15 recharge strategies were identified for initial consideration, shown in **Table 3-1.**

Table 3-1 Recharge Strategies Evaluated

Recharge Method → Water Source ↓	A Existing Streambed	B In-stream Modifications	C Infiltration Basins	D Injection Wells	E Managed Flood Irrigation	F In-Lieu Recharge
1. Stormwater in Santa Ysabel Creek	1A	1B	1C	1D	1E	1F
2. Controlled Releases from Sutherland Reservoir	2A	2B	2C	2D	2E	2F
3. Deliveries from Ramona MWD's Untreated Water System	3A	3B	3C	3D	3E	3F

Note: the code in cells indicates the source (number) and the recharge method (letter). Colored cells correspond to the selected strategies.

In order to streamline this evaluation, four recharge strategies were chosen for further evaluation using a set of screening criteria shown in **Table 3-2**. Screening criteria were based on the evaluation criteria initially developed as part of Task 1 and further refined to include timing, energy demands, and source water reliability. While modeling outcomes are required to apply many of the evaluation criteria from Task 1, the screening criteria used in this Task 4 process aimed to capture factors that contribute to the Task 1 evaluation criteria without requiring modeling results or detailed project information.

Table 3-2 Screening Criteria for Recharge Strategies

Screening Criteria	Description
Yield	Potential annual average recharge volume
Cost	Estimate of capital and annual operation and maintenance costs
Recharge footprint	Loss of farmland
Timing	Estimate of time required before project could be implemented considering planning, design, permitting, and implementation
Energy	Estimated energy required to implement and operate
Reliability	Reliability of supply during dry periods
Flexibility	Degree to which the strategy could be turned off/on over a wide range of hydrologic conditions by having the ability to adjust operations according to hydrologic and infiltration or recharge conditions
Level of Complexity	Maturity of the technology required to implement the strategy
Pretreatment Requirements	Water supply pretreatment requirements and inferred risk of groundwater quality degradation because of implementing the recharge strategy
Operation & Maintenance (O&M) Frequency	O&M frequency required
Permitting	Anticipated permits required and status of whether the permitting process has begun for the strategy
Environmental	Anticipated positive or negative effects on the natural environment

The results of the screening analysis of the 15 recharge strategies are shown in **Table 3-3**. Scoring values, which range from 0 to 5, were arrived at by the Consulting Team. A value of 1 indicates an unfavorable score and 5 indicates it had a favorable score. Recharge strategies with overall scores above 35 were considered as having high suitability, between 30 and 35, middle ground suitability and less than 30, were considered to be strategies with low suitability.

Four recharge strategies were selected for further analysis based on the following rationale:

- Comparative score, used to identify benefits and constraints of the strategies
- High potential for providing broader benefits, including in the eastern portion of the Basin
- Provide diversity in recharge methodology.

Based on the evaluation rationale, Strategy 1B, 2A, 3A and 3D warrant further investigation. Strategies 1B, 2A and 3A involve recharge methods through infiltration and had high scores for each water supply. All of the strategies selected had high potential for providing broader benefits either through taking advantage of the high infiltration rate in Santa Ysabel Creek or by providing large volumes of water to be injected into the Basin. Strategy 3D, injection wells using Ramona MWD water, is carried forward to provide diversity in the strategies warranting further evaluation. By utilizing direct injection, it provides an excellent comparison against the three other selected alternatives that would rely on infiltration methods.

The following subsections provide additional details and planning level cost estimates for each of these selected recharge strategies. In addition, a general description and expected benefits and challenges of the four selected strategies are summarized in **Table 3-4.**

Capital cost estimates for the strategies included in this TM were based on similar projects and industry publications. As this study is for preliminary planning, the provided estimates are considered Class 5 estimates based on the International (AACEI) Recommended Practice No. 56R-08, Cost Estimate Classification System – As Applied for the Building and General Construction Industries (revised December 2012). Class 5 estimates are based on a level of project definition of 0 to 2 percent and are suitable for alternatives analysis. The typical accuracy ranges for a Class 5 estimate are -20 to -50 percent on the low end and +30 to +100 percent on the high end.

Table 3-3 Results of Screening Evaluation

Recharge Strategy	Total Score	Yield	Cost	Footprint	Timing	Energy	Reliability	Flexibility	Level of Complexity	Pretreatment Requirements	O&M Frequency	Permitting	Environmental
1A. Existing Streambed	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1B. Enhanced Stormwater Infiltration in Santa Ysabel Creek with In-stream Modifications	**42**	**1**	**5**	**5**	**4**	**5**	**1**	**2**	**4**	**5**	**4**	**2**	**4**
1C. Stormwater Infiltration Basin in Santa Ysabel Creek	33	1	3	3	3	4	1	2	3	4	3	3	3
1D. Stormwater Recharge via Injection Wells	26	1	2	4	2	3	1	2	2	1	2	2	4
1E. Managed Flood Irrigation with Stormwater	33	1	4	5	3	3	1	3	3	2	2	3	3
1F. In-lieu Recharge of Stormwater	31	1	4	5	2	3	1	3	2	1	2	4	3
2A. Sutherland Releases in Existing Santa Ysabel Creek Channel	**52**	**3**	**5**	**5**	**4**	**5**	**3**	**3**	**5**	**5**	**5**	**4**	**5**
2B. Sutherland Releases with Enhanced Stormwater Infiltration in SYC with In-stream Modifications	48	3	5	5	5	5	3	4	4	5	4	1	4
2C. Sutherland Releases with Infiltration Basin in Santa Ysabel Creek	39	4	3	3	3	4	3	4	3	4	3	2	3
2D. Sutherland Releases with Injection Wells	31	4	1	4	2	3	3	4	2	1	2	1	4
2E. Sutherland Releases with Managed Flood Irrigation	36	1	4	5	3	3	3	5	3	2	2	2	3
2F. Sutherland Releases with In-lieu Recharge	35	3	3	5	2	3	3	5	2	1	2	3	3
3A. Ramona MWD's Deliveries to Existing Santa Ysabel Creek Channel	**51**	**4**	**2**	**5**	**4**	**5**	**4**	**4**	**4**	**5**	**5**	**4**	**5**
3B. Ramona MWD's Deliveries to Santa Ysabel Creek with In-stream Modifications	47	4	2	5	5	5	4	5	3	5	4	1	4
3C. Ramona MWD's Deliveries to Infiltration Basin in Santa Ysabel Creek	44	5	1	3	3	5	4	5	4	5	4	2	3
3D. Ramona MWD's Deliveries to Injection Wells	**36**	**5**	**1**	**4**	**2**	**3**	**4**	**5**	**3**	**2**	**2**	**1**	**4**
3E. Ramona MWD's Deliveries for Managed Flood Irrigation	41	1	4	5	3	4	4	5	4	3	3	2	3
3F. Ramona MWD's Deliveries to In-lieu Recharge	43	3	3	5	2	5	4	5	4	3	3	3	3

NS = Not Scored. Higher scores indicate more favorable result. Bold entries shaded in blue indicate the selected recharge strategies

Table 3-4 Benefits and Challenges of the Four Selected Recharge Strategies

Recharge Strategy	Anticipated Benefits	Anticipated Challenges
Strategy 1B: Enhance streamflow infiltration in Santa Ysabel Creek with an in-channel detention structure	• Increase infiltration from existing conditions, partially capturing high storm event excess flows • Streambed used as the conveyance feature, requiring minimal additional infrastructure • Diverse solutions using different materials and designs: permanent versus semi-permanent versus temporary and in-channel only versus entire channel and floodplain • Potential location at the creek streambed where the highest infiltration rate is found • Rubber dam could deflate in certain storms or risk situations	• Soil management may be limited where riparian vegetation is established • Temporary inundation of the surrounding areas, such as the riverbank • Permitting is more stringent because impacts to stream and riparian vegetation would be more extensive • Some maintenance needed • Availability of supply dependent on variable hydrologic conditions
Strategy 2A: Augment Santa Ysabel Creek flows with controlled releases from Sutherland Reservoir	• No additional infrastructure required: existing infrastructure with required release capabilities and Santa Ysabel Creek used as the conveyance feature as well as using the streambed as the recharge method • Would provide access to a new regional water supply source in the Basin, using local surface water • Low O&M requirement	• Conveyance losses would occur prior to entering the Basin inlet • Operational adjustments and agreements would be needed • New water delivery agreement to be developed • Availability of supply dependent on variable hydrologic conditions
Strategy 3A: Augment Santa Ysabel Creek flows with Ramona MWD's untreated water treatment system deliveries	• Would provide a new, reliable, source of water to the Basin • Flexibility to time and manage volume to optimize infiltration rate in the streambed • Low O&M requirement	• New water delivery agreement would need to be developed • Conveyance infrastructure would require construction permitting

Recharge Strategy	Anticipated Benefits	Anticipated Challenges

Strategy 3D: Enhance groundwater recharge via injection wells with Ramona MWD's untreated water system deliveries	• Would provide a new, reliable, imported source of water to the Basin
	• Potentially provides more protection from tampering as compared to surface storage by securing access to wellheads, valves and controls through locked fences, gates and/or well houses
	• Ability to conduct remote monitoring
		• Source water would require filtration and disinfection under SWRCB Order 2012-0010 prior to injection. This would require a water treatment plant that occupies approximately 2 acres of land
		• Potential for high O&M frequency:
		  • Backflushing to avoid well clogging over time[a]
		  • Remote monitoring and control: instrumentation, controls (water level, injection rate, pressure, backflush cycles and rates, etc.) and security considerations
		• Specialized and dedicated staff for water treatment and O&M. Level of effort and total number of staff required will be dependent on total number of well sites and backflushing frequency.
		• Permitting and coordination with multiple regulatory agencies is anticipated, such as water resources, water quality and underground injection well (UIC) program
		• Conveyance infrastructure construction permitting

[a] Frequency of backflushing is determined during the pilot test phase and could be as frequent as daily to weekly		

3.1 Strategy 1B: Enhance Streamflow Infiltration with In-stream Modifications

The goal of Strategy 1B is to utilize the existing streambed as the recharge method, while incorporating a rubber dam to obstruct flow near Ysabel Creek Road to pool water in Santa Ysabel Creek and increase the opportunity for additional recharge to the underlying aquifer.

A general description of each recharge strategy component is provided in **Table 3-5**. For the water source, Task 3 described estimates of the frequency and magnitude of the excess streamflow of stormwater from water years 2005 through 2019 based on simulated streamflow estimates at multiple locations along Santa Ysabel Creek, including a location in the model representing the Ysabel Creek Road crossing (City, 2023b). No additional conveyance structure is needed, as Santa Ysabel Creek will be used to convey the stormflow. To improve the ability to recharge water beyond natural rates, a rubber dam installation would be installed to capture storm flows across the entire channel and floodplain. Modeling of this strategy in Task 5 will provide additional information in case an alternative type of in-stream modification, such as those discussed in **Recharge** Methods, should be recommended.

Table 3-5 Enhance Streamflow Infiltration with In-stream Modifications Description

Water Source	Conveyance	Recharge Method
"Excess streamflow" of stormwater in Santa Ysabel Creek at Ysabel Creek Road[a]	Existing Santa Ysabel Creek	Enhanced infiltration using in-stream modifications - Permanent rubber dam across entire channel and floodplain[b]

[a] Ysabel Creek Road represents a logical downstream extent of the eastern end of the Basin. The Task 3 analysis described estimates of the frequency and magnitude of this excess streamflow
[b] Project could potentially be limited to main channel rather than the full floodplain based on modeling results from Task 5.

3.1.1 Concept Design

The permanent rubber dam spanning the entire channel was selected as the design to be further evaluated (see **Figure 3-1**). Information on alternative designs is documented in **Attachment E.**

The permanent rubber dam will be modeled to coincide with the T4 transect location and span the entire channel with a height of 5 feet and a width of approximately 550 feet. Grading would be required to achieve those dimensions in this location. The estimated stream backup is roughly 1,550 feet forming a pool size of approximately 10.8 acres with a stream gradient of approximately 0.0033 ft/ft (0.33%). These estimates will be refined as part of Task 5.

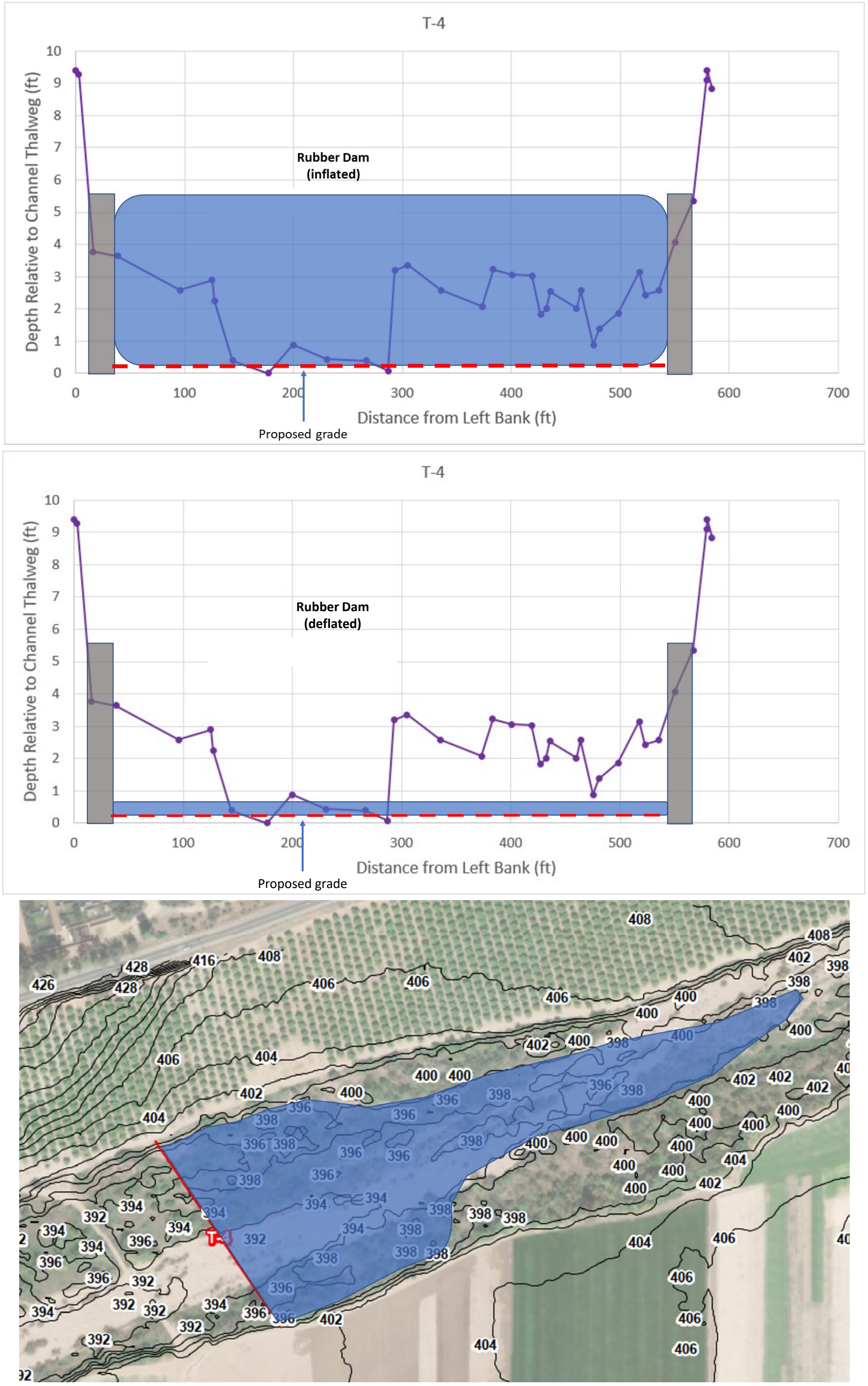


Figure 3-1 Concept Design for Permanent Rubber Dam Across Entire Santa Ysabel Creek Channel at Transect 4

Note: the map at the bottom of **Figure 3-1** shows a hypothetical water pool formed with inflated rubber dam. Considerations related to potential increased flooding risks and potential waterlogging issues would be analyzed if the concept moves forward. Not represented in **Figure 3-1** is the likely need for abutments located every 100 to 150 feet across the width of the rubber dam to provide structural stability during periods when the dam is inflated.

An alternative variation to Strategy 1B's infiltration method is shown in **Figure 3-2.** Instead of the permanent rubber dam spanning across the main channel and flood plain, in this alternative, the permanent rubber dam is only installed in the main channel to allow portions of flood flows to be detained outside the rubber dam with berms on remaining floodplain areas. In the case of peak stormflows, the indents depicted at the tops of the side berms would allow spills to reduce risks that can arise during higher streamflow events with a reduced cross-section that would increase flow velocity (e.g., flooding and erosion). This alternative to Strategy 1B could potentially require less environmental permitting and be easier to construct, but would require periodic maintenance for the berms.

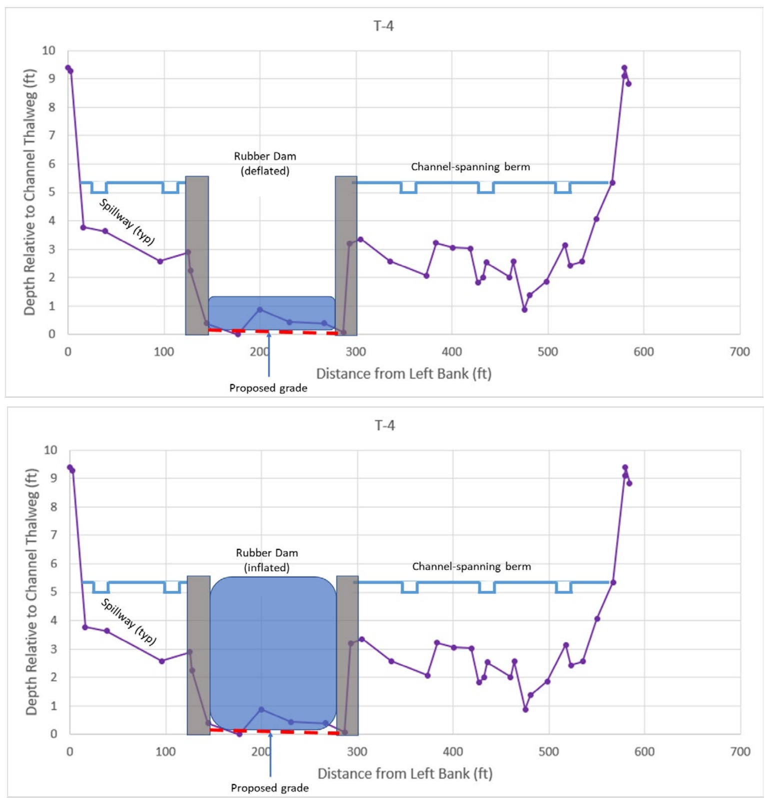


Figure 3-2 Permanent Rubber Dam in main channel with berms in remaining flood plain

3.1.2 Anticipated Benefits and Challenges

There are several benefits and challenges with the implementation of a permanent rubber dam in Santa Ysabel Creek. Benefits include the ability to increase capture and storage of water during and after storm events, and flexibility in design and location. By capturing more storm flows, Strategy 1B would reduce the volume of water "lost" to downstream flows, and would take advantage of natural hydrology and recharge capacity in the Basin. This strategy can be implemented in several ways, which allows for adjustments that can be made during future planning and design that can help address potential concerns or priorities. It can also be constructed at one of several locations in the creek, and can be sited to address concerns with location, capture water in areas that have highest infiltration potential, or provide highest benefit to the Basin. Challenges associated with this strategy include temporary inundation of surrounding areas, limited ability to manage soils where riparian areas are established, and on-going maintenance. Because this strategy relies on storm flows, which are unpredictable and irregular, there is uncertainty around timing and volumes available under this strategy. Additionally, because this strategy requires construction within the creekbed, permitting may be more challenging than alternatives that would not directly impact the creek or riparian areas.

3.1.3 Preliminary Cost Estimate

Construction of a permanent rubber dam is estimated to cost approximately $17,982,000, including grading, materials, design, and permitting. This includes approximately $8,880,000 in construction costs, a 50% construction contingency ($4,440,000), and 35% implementation costs ($4,662,000) that includes legal, design, environmental, and construction management.

3.2 Strategy 2A: Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases

Strategy 2A involves releasing water from Sutherland Reservoir into Santa Ysabel Creek to augment streamflow and infiltration through the streambed within the Basin. The intent of Strategy 2A is to utilize the existing streambed as the recharge method while introducing a new source of water to the Basin to support the sustainability goals in the SPV GSP.

A general description of each recharge strategy component is provided in **Table 3-6**. The water source is controlled releases from Sutherland Reservoir into Santa Ysabel Creek. In Task 3, the potential annual controlled release volume was estimated to be 1,200 AF, which represents the potential maximum water source supply for this supply. An analysis was performed as part of Task 4 using the SPV Model v2.0 to evaluate the maximum potential infiltration capacity of the streambed in the eastern portion of the Basin to determine the optimal magnitude and timing of Sutherland Reservoir releases. This step is important to avoid releasing more water than could be fully infiltrated in the eastern portion of the Basin. Exceeding the infiltration capacity in the streambed would result in created “excess streamflows” beyond Ysabel Creek Road that would not benefit the eastern portion of the Basin. Based on this analysis, the maximum monthly streambed infiltration rate was estimated to be approximately 900 AF, coinciding with periods when streamflow along the Santa Ysabel Creek would be minimal and when the channel would be expected to have capacity for additional infiltration. Details of this analysis are provided as **Attachment D**.

Table 3-6 Recharge Strategy Description: Augment Santa Ysabel Creek Streamflow with Controlled Releases from Sutherland Reservoir

Water Source	Conveyance	Recharge Method
Controlled releases[a] from Sutherland Reservoir into the Santa Ysabel Creek. Timing and magnitude dependent on maximum streambed infiltration rate volume[b]	Existing Santa Ysabel Creek used as the conveyance feature. Conveyance losses from Sutherland Reservoir to the eastern portion of Basin are expected.	Existing Santa Ysabel Creek streambed
[a] *Task 3 analysis described estimates of the frequency and magnitude of potential controlled releases. Additional analysis to be refined in Task 5* [b] *See **Attachment D** for analysis details.*		

3.2.1 Concept Design

The existing infrastructure of Sutherland Dam and the natural stream channel will be used for this recharge strategy. For the purpose of developing a concept design, a conveyance efficiency of 20% was used to estimate the maximum required Sutherland controlled releases to accommodate the 900 AF per month of infiltration capacity in the eastern portion of the Basin. A 20% conveyance efficiency means that only 80% of the volume released from Sutherland would be expected to reach the Basin for infiltration. To achieve 900 AF per month, approximately 1,100 AF per month would be needed from the controlled release.

During the 15-year historical period, the total maximum monthly Santa Ysabel Creek stream infiltration rate between Ysabel Creek Road and the eastern extent of the Basin was estimated at approximately 900 AF. This maximum stream infiltration rate will serve as a theoretical target maximum monthly release from Sutherland Reservoir to ensure that controlled releases are given optimal conditions for streambed infiltration to occur and to avoid Sutherland water flowing through and out of the Basin in Santa Ysabel Creek. With nearly 11 miles of stream channel between Sutherland Reservoir and the Basin inlet, the potential for conveyance losses is high and will be further analyzed under Task 5 to minimize potential losses of water prior to the controlled releases reaching the Basin. Additional strategies to help reduce overall conveyance losses between Sutherland Reservoir and the inlet of the Basin could be considered in the future, but were not analyzed as part of this evaluation.

Additionally, the timing of simulated stream infiltration was evaluated to determine months where augmented streamflow in the Basin could provide streambed infiltration benefits. Identified months generally cover times during the historical period where storm flows are minimal, the stream infiltration is less than the maximum rate, or during periods when Santa Ysabel Creek is dry. The target rate and timing of Sutherland Releases from the SPV GSP Model v2.0 will provide critical decision criteria for how to operate Sutherland Reservoir with the goal of allowing controlled releases to Santa Ysabel Creek without negatively impacting existing or planned reservoir operations.

As part of Task 5, the timing and magnitude of Sutherland controlled releases will be refined by simulating the operation of Sutherland reservoir and incorporating releases at optimal timing and volume for maximizing streambed infiltration benefits as well as minimizing conveyance losses. The modeling of Sutherland Reservoir will be performed using an operation model, developed as part of this effort, to simulate the monthly water balance of Sutherland Reservoir based on hydrologic conditions, reservoir operational criteria, and associated water demands of the system. The simulated scenarios using this model will be consistent with the historical and future hydrologic conditions simulated in the SPV GSP Model v2.0 and should maintain Sutherland Reservoir's historical average storage levels, historical deliveries to San Vicente Reservoir and environmental operation requirements. The operation model will be utilized to evaluate the scenario's magnitude and timing of controlled releases from Sutherland Reservoir that will be used to simulate stream infiltration benefits using the SPV GSP Model v2.0.

3.2.2 Anticipated Benefits and Challenges

Strategy 2A uses existing infrastructure to supply water to the Basin, and Santa Ysabel Creek to convey and recharge water. This provides benefits that include not needing additional physical infrastructure to increase recharge in the Basin. It would provide access to local surface water for Basin recharge that would not otherwise be available, and O&M may be lower than other strategies because it could be incorporated into existing O&M for Sutherland Reservoir. Challenges with this strategy include conveyance losses as water flows through Santa Ysabel Creek before it enters the Basin, with water lost to evaporation and infiltration before reaching the Basin. There would also need to be adjustments made to operation of Sutherland Reservoir and updates to existing agreements related to the reservoir would be needed. A new water delivery agreement would also need to be developed. Finally, because this strategy relies on surface water stored at Sutherland Reservoir, and would be operated to avoid negative impacts to existing operations, the availability of supply would vary depending on hydrologic conditions.

3.2.3 Preliminary Cost Estimate

Because this strategy utilizes existing infrastructure that may not require modification to achieve the goals of the strategy, no capital costs are expected for additional infrastructure construction. There may be costs associated with the water released as part of this strategy as well as costs associated with modifications to the dam to achieve the desired flow rate. Assuming that the water has a value equivalent to the wholesale cost of imported water (the alternative water supply for the region when local supplies are insufficient to meet demands), at a rate of $1,584 per AF, and an average release of 1,200 AF per year, this strategy could have a cost of approximately $1.9 million per year. An assumed "implementation cost" of 35% ($610,000), which includes legal costs, environmental, administration, and other soft costs would bring the overall cost of this strategy to $2.5 million for the first year. Annual costs would vary depending on the volume of water available for release in a given year. The annual cost of this strategy will be incorporated into a revised estimate in the Preliminary Feasibility Study once assumptions regarding available monthly volumes are determined in Task 5, any need for modifications to the dam are better understood, and unit costs for Sutherland Reservoir water are refined.

3.3 Strategy 3A: Augment Santa Ysabel Creek with Ramona MWD's Untreated Water System Deliveries

Strategy 3A utilizes untreated water from Ramona MWD to augment streamflow in Santa Ysabel Creek to increase streambed infiltration. Strategy 3A is focused on utilizing the streambed as the recharge method while bringing a new source of water to support the sustainability goals of the Basin. Untreated water from Ramona MWD will be conveyed through a pipeline to Santa Ysabel Creek where flows will be discharged directly into the stream channel.

Table 3-7 Recharge Strategy Description: Augment Santa Ysabel Creek with Ramona MWD's Untreated Water System Deliveries

Water Source	Conveyance	Recharge Method
Ramona MWD untreated water deliveries[a] from Robb Zone considering its system capacity availability and the maximum estimated infiltration rate[b]	New infrastructure required: pipeline to convey untreated water from the Robb Zone diversion location to Santa Ysabel Creek near the San Pasqual Valley Road bridge in the eastern portion of the Basin	Existing Santa Ysabel Creek streambed

[a] *Conservative capacity scenario using 80% capacity of one pump estimates a delivery capability of approximately 300 AF per month.*
[b] *Releases from Robb Zone diversion to occur at intervals that allow for full infiltration in the eastern portion of the Basin. The maximum estimated infiltration rate in this river reach is estimated to be 375 AF per month. See* ***Attachment D*** *for analysis details.*

The current proposed pipeline route would convey untreated water from the Robb Zone diversion location to Santa Ysabel Creek near the San Pasqual Valley Road bridge in the eastern portion of the Basin. Releases from the Robb Zone diversion point would occur at intervals that allow for full infiltration in the eastern portion of the Basin. The maximum estimated infiltration rate in this river reach is estimated to be 375 AF per month (see **Attachment D**).

The Robb Zone diversion point from Ramona MWD's untreated water system could supply an annual volume of 3,350 AF for use in the Basin (City, 2023b). The proposed pipeline route from the Robb Zone diversion point to the Santa Ysabel Creek discharge location is shown in **Figure 3-3**. The maximum monthly delivery capacity from Robb Zone, ranging from a minimum of 248 AF in August to a maximum of 304 AF in March is presented in **Table 3-8** (Ramona MWD, 2022c). These values were developed by the Ramona MWD as a conservative capacity availability scenario to be used as an initial reference for this recharge strategy assessment. The scenario assumes one pump is operated using 80% of its capacity[1], which would be adequate to deliver source water for this recharge strategy while still being able to provide water to the Ramona MWD's existing agricultural customers.

Table 3-8 Preliminary Maximum Monthly Delivery Capacity (AF) from Ramona MWD's Robb Zone

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
296	300	304	285	280	271	267	248	264	255	293	287	3,350

Similar to Strategy 2A, an analysis was conducted using stream infiltration rates from the SPV GSP Model v2.0 to determine the total maximum monthly Santa Ysabel Creek stream infiltration rate and the potential timing of deliveries to Santa Ysabel Creek. The maximum infiltration rate along Santa Ysabel Creek between the pipeline discharge location and Ysabel Creek Road during the 15-year historical period is approximately 375 AF per month. Details of the analysis to determine the magnitude and timing of untreated water deliveries to Santa Ysabel Creek are described in **Attachment D** and will be evaluated further under Task 5.

3.3.1 Concept Design

For this recharge strategy, the new infrastructure design includes the connection to the Ramona MWD diversion point in Robb Zone and the conveyance pipeline from this point to Area 1 (see **Figure 3-3**). To convey 3,350 AFY of raw water from the Robb Zone to Santa Ysabel Creek for recharge, 16,400 linear feet of 12-inch pipe is required. Due to the elevation of the Robb Zone in relation to Santa Ysabel Creek, water could be gravity-fed.

The conveyance pipeline would connect to the Robb Zone at a diversion point along Highland Valley Road, approximately 500 feet west of Starvation Mountain Road. The starting elevation is 757 feet, with the recharge areas having elevations of between 354 feet to 407 feet, which would allow water to flow by gravity to aquifer recharge areas. It is estimated that no pumps would be required for conveyance and delivery based on preliminary assumptions, including calculated frictional head loss and an assumed delivery pressure of 10 pounds per square inch (psi) for the recharge basins. A 12-inch pipe would be sufficient to

[1] According to Ramona MWD (2022c), intake RAM1 is the turnout for the delivery of untreated water from the San Diego County Water Authority (SDCWA) with a capacity of 18.5 cfs. This connection can bring water to Lake Ramona using the Poway Pump Station and there is also the Lake Ramona pump station downstream from the Ramona Lake connecting with Ramona MWD's untreated water system. The monthly capacity using one pump and its 80% capacity for Poway Pump Station is 376 AF and for Ramona Lake Pump Station is 323 AF. After delivering the existing monthly average demand of approximately 30 AF, the available capacity for additional deliveries is around 300 AF per month.

accommodate the flows to deliver the full volume of water, 3,350 AFY, or about 4.62 cfs. Maximum available flow from Ramona MWD at this diversion point is 6.6 cfs, based on seasonal demands and availability. Twelve-inch pipes with a maximum flow rate of 6.6 cfs results in flow velocity of 8.4 feet per second, which is within the City of San Diego's design standards for maximum velocity of 15 feet per second. This alignment would also experience a head loss of 18.9 feet per 1,000 feet of pipe.

From the diversion point, the pipeline would travel northeast from the diversion point to a private road at Bandy Canyon Ranch, where it turns northwest to Bandy Canyon Road. To reach Santa Ysabel Creek, the pipeline would cross Santa Maria Creek and continue east and northeast along Bandy Canyon Road and continue to follow Bandy Canyon Road to where it crosses Santa Ysabel Creek. In total, this route would require 16,400 linear feet of 12-inch pipeline.

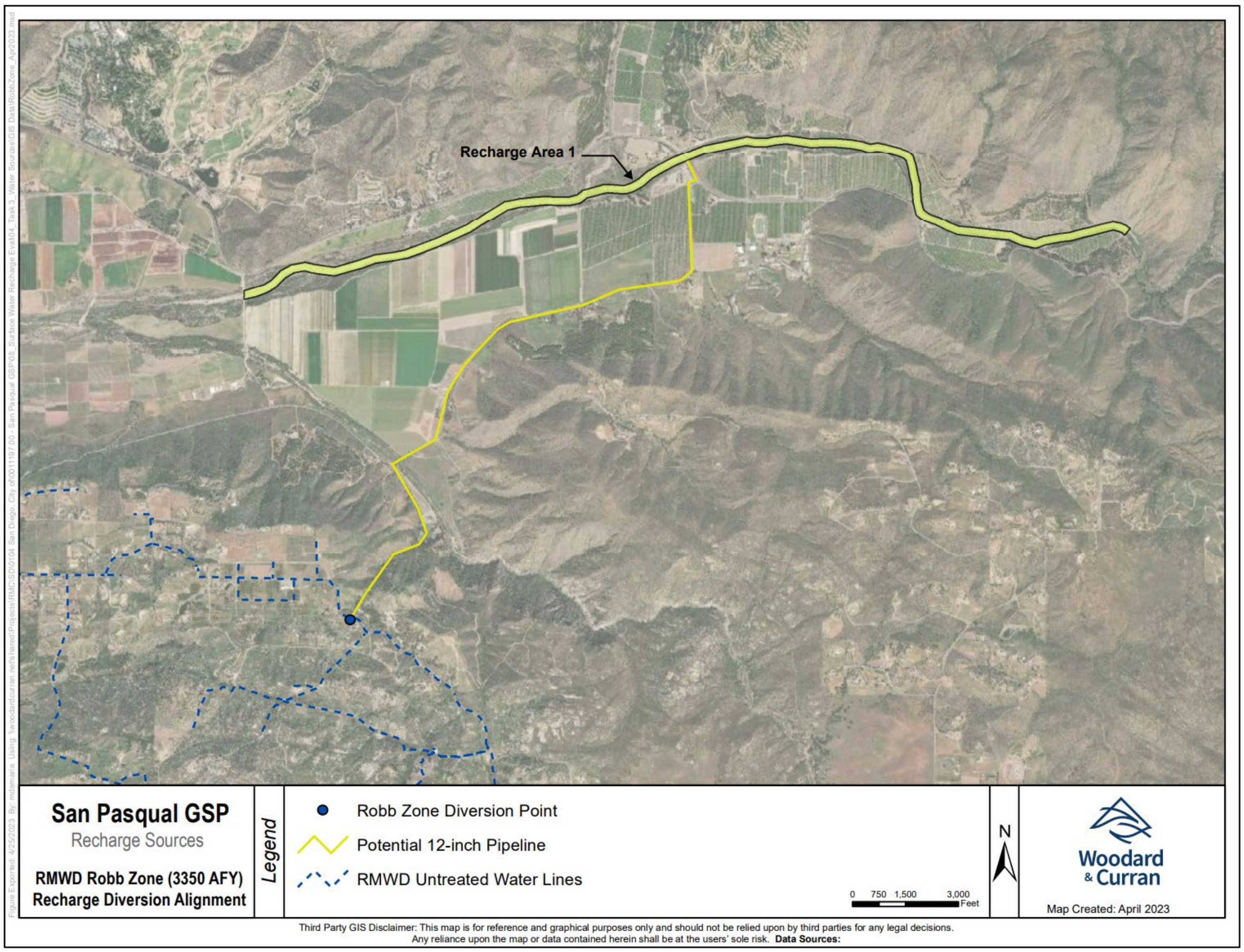


Figure 3-3 Potential Pipeline Route to Santa Ysabel Creek from Robb Zone Diversion Point

3.3.2 Anticipated Benefits and Challenges

Strategy 3A would convey raw water from Ramona MWD's system to Santa Ysabel Creek to recharge. Benefits of this strategy include accessing a large reliable source of new water for the Basin, that is not subject to hydrologic variability. This strategy also provides flexibility that provides the ability to time and manage volume of water delivered to Santa Ysabel Creek to optimize infiltration rates. Additionally, there are low O&M requirements because this strategy would install pipelines but not require additional complex infrastructure that require frequent maintenance. Some challenges associated with this strategy include the need to develop new water delivery agreements with Ramona MWD and permitting needed for pipeline construction, which would include a creek crossing.

3.3.3 Preliminary Cost Estimate

Pipeline construction costs were estimated based on a unit cost of $41 per inch-diameter per linear foot for 16,400 linear feet of 12-inch pipe, totaling $8,068,800. Water purchased from Ramona MWD is assumed at the wholesale rate for untreated imported water, which was $1,584 in 2023. With a total volume of 3,350 AFY, water costs are estimated at $5,306,400. Given a 50% construction contingency ($4,034,000) to account for this preliminary cost estimate and recent increases in construction costs, and a 35% "implementation cost" ($6,093,000) for design, legal, environmental, construction management, services during construction, and administration costs, the total preliminary cost estimate for this strategy is approximately $23.5 million. There would be wheeling costs paid to Ramona MWD for supplying water through its existing system to the diversion point at the start of this strategy's pipeline. Wheeling costs address the additional costs Ramona MWD would incur to deliver additional water including pumping and maintenance costs. Although wheeling costs are uncertain, pumping generally makes up the highest portion of the wheeling costs and are estimated to range from $436 to $566 per AF of water. Assuming the higher value in this range, wheeling costs would be a minimum of approximately $1.9 million for 3,350 AF of water per year. Wheeling costs do not include the cost of the water itself. The cost assumptions will be refined as part of the Preliminary Feasibility Study once monthly volumes are determined and more information about potential wheeling costs is available.

3.4 Strategy 3D: Recharge with Injection Wells Using Ramona MWD's Water System Deliveries

Strategy 3D utilizes injection wells to recharge water from Ramona MWD to increase groundwater levels in the underlying aquifer. Untreated water from Ramona MWD will be treated to meet injection standards and conveyed through a pipeline to injection wells located throughout the eastern portion of the Basin where water will be pumped into the aquifer to increase groundwater levels and storage. A conceptual design based on assumptions was developed as outlined below.

Table 3-9 Recharge Strategy Description: Recharge with Injection Wells Using Ramona MWD's Untreated Water System Deliveries

Water Source	Conveyance	Recharge Method[d]
Ramona MWD untreated water deliveries[a] from Robb Zone considering its system capacity availability and injection capacities[b]	New infrastructure required: pipeline to convey untreated water from the Robb Zone diversion to a treatment facility[c] and wellheads	Injection Wells – 16 needed to inject 300 AF per month.

[a] Conservative capacity scenario using 80% capacity of one pump estimates a delivery capability of approximately 300 AF per month.
[b] Releases from Robb Zone diversion based on the number of wells, their injection capacity, and planned layout
[c] Untreated water from Ramona MWD would need to be filtered and disinfected prior to injection to meet permitting requirements under SWRCB Order 2012-0010
[d] A total of 16 wells will be required to inject 300 AF per month at a continuous injection rate of 130 gpm

3.4.1 Concept Design

Due to the complexity of the infrastructure related to this strategy, the concept design is divided into the following subsections:

- Injection rate and total number of wells
- Well siting
- Conveyance of source to the wellheads
- Pretreatment system

3.4.1.1 Injection Rate and Total Number of Wells

A high-level analysis was performed to initially estimate the total number of injection wells and estimated injection rate per well required to recharge an estimated annual volume of 3,350 AF. The injection rate is used to size the well casing to accommodate the downhole equipment and above-grade piping and appurtenances.

The basis of design assumptions used to estimate the total number of injection wells and injection rate per well is summarized in **Table 3-10** Recharge Strategy Description: Injection Wells with Ramona MWD's Untreated Water System Deliveries. A conceptual well design was developed to provide a 30- to 40-year service life per well and is included in **Figure 3-4.** Materials for construction, casing diameter, screen interval, screen slot size and gravel pack size will be determined during future design phases and will require borings to confirm aquifer material and depth.

Table 3-10 Recharge Strategy Description: Injection Wells with Ramona MWD's Untreated Water System Deliveries

Design Criteria	Assumption
Total source water volume available for injection	3,350 AFY
Injection rate per well	130 gpm
Backflush rate per well	170 gpm[a]
Total number of wells	16 wells at injection rate of 130 gpm, 24/7 operations
Hydraulic conductivity	77 ft/d
Specific capacity	8.4 gpm/ft
Static water level	55 ft bgs
Depth of aquifer	200 feet (alluvial thickness)
Estimated draw-up (i.e., mounding of water levels)	16 feet
Injection water level	39 ft bgs
Backflush water level	76 ft bgs
[a] 2,078 gpm assuming 24/7 operation [b] Assumes 30% greater than injection rate to develop well	

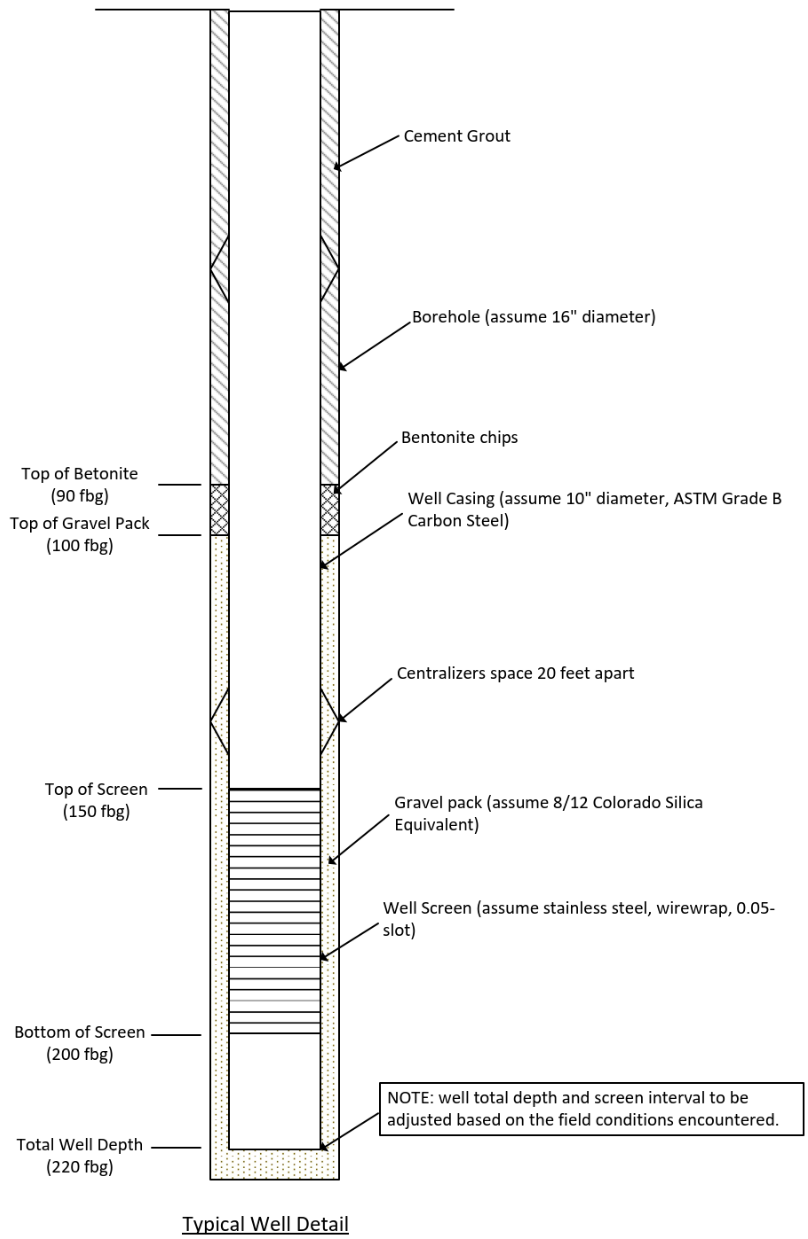


Figure 3-4 Typical Injection Well Concept Schematic

3.4.1.2 Well Siting

Once the total number of wells were determined, the following basis of design criteria was developed for siting of the wells within the Basin area:

- Provide sufficient area required to drill and construct the well (150 feet x 100 feet) on a City parcel. This footprint can be adjusted to accommodate individual site constraints.
- Located in available open space to minimize interference with existing structures, trees, or crops.
- Located adjacent to existing access roads to facilitate drill rig access and future maintenance access.
- Provide access for future maintenance equipment such as a pump rig, crane, and laydown area to accommodate well rehabilitation in the future.
- Provide concrete pad around the wellhead for discharge piping, flow meter and valves. Final size to be determined during final design; however, 24 feet by 9 feet is assumed. Optionally, the well and associated wellhead infrastructure can be located within a well house or potentially below grade vault (see further discussion on surface facilities below).
- Avoid conflicts with buried and above grade utilities; specific locations of which will be determined during final design phases.

Based on the above siting considerations, 16 areas were identified. Potential injection locations shown in **Figure 3-5** have not been vetted by stakeholders or permitting agencies, so they should be viewed as hypothetical for this stage of study. Furthermore, the number of injection wells and injection rates should be considered conceptual and subject to further refinement as part of modeling analysis in Task 5.

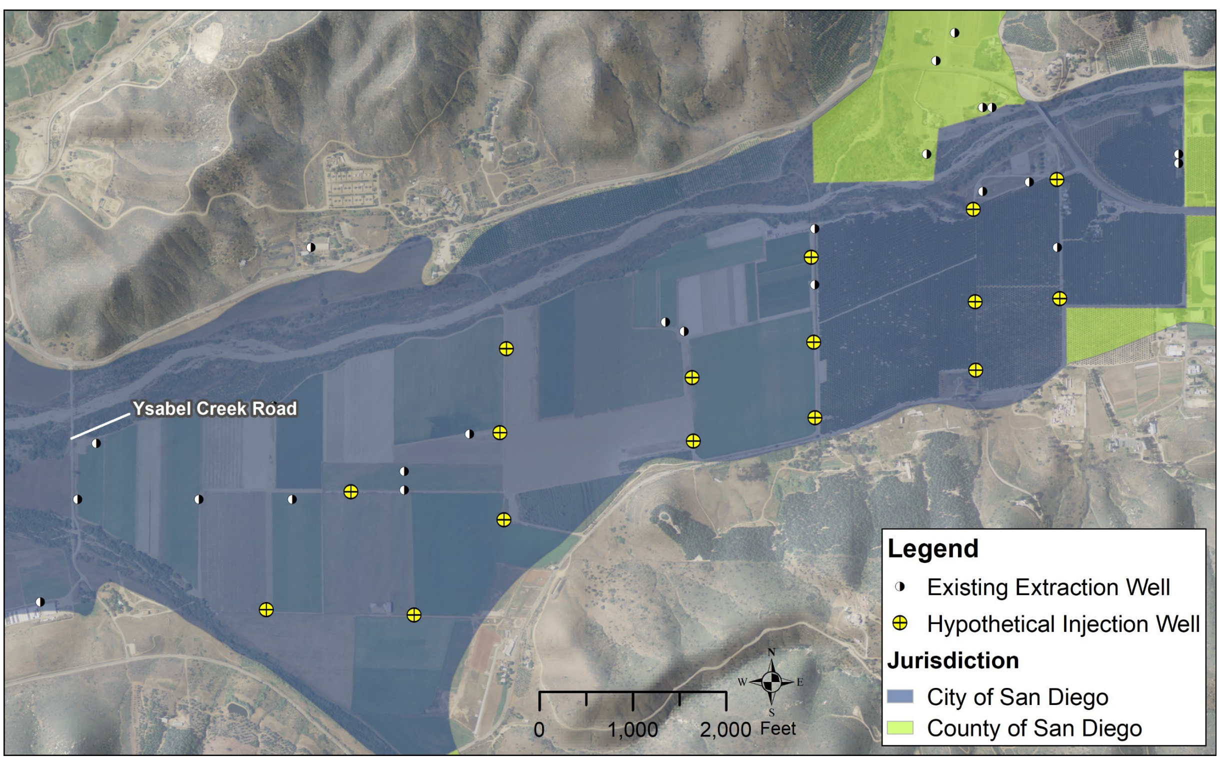


Figure 3-5 Conceptual Injection Well Locations (planning purposes only)

3.4.2 Conveyance Pipelines

As with Strategy 3A, this strategy would use imported water from Ramona MWD using a diversion point from the Robb Zone along Highland Valley Road, approximately 500 feet west of Starvation Mountain Road. The pipeline would generally follow the same route as the pipeline in Strategy 3A, with turnouts along existing roadways to reach the proposed well locations. These 12-inch pipelines are shown in **Figure 3-6,** and total approximately 28,000 linear feet.

3.4.3 Pretreatment System

A 3.0 MGD water treatment plant (WTP) would be needed to treat the full 3,350 AFY raw water to a level meeting SWRCB Order 2012-0010 prior to injection. This facility would include clarification, filtration, disinfection, and solids handling. It is estimated that the WTP would require a 2-acre footprint.

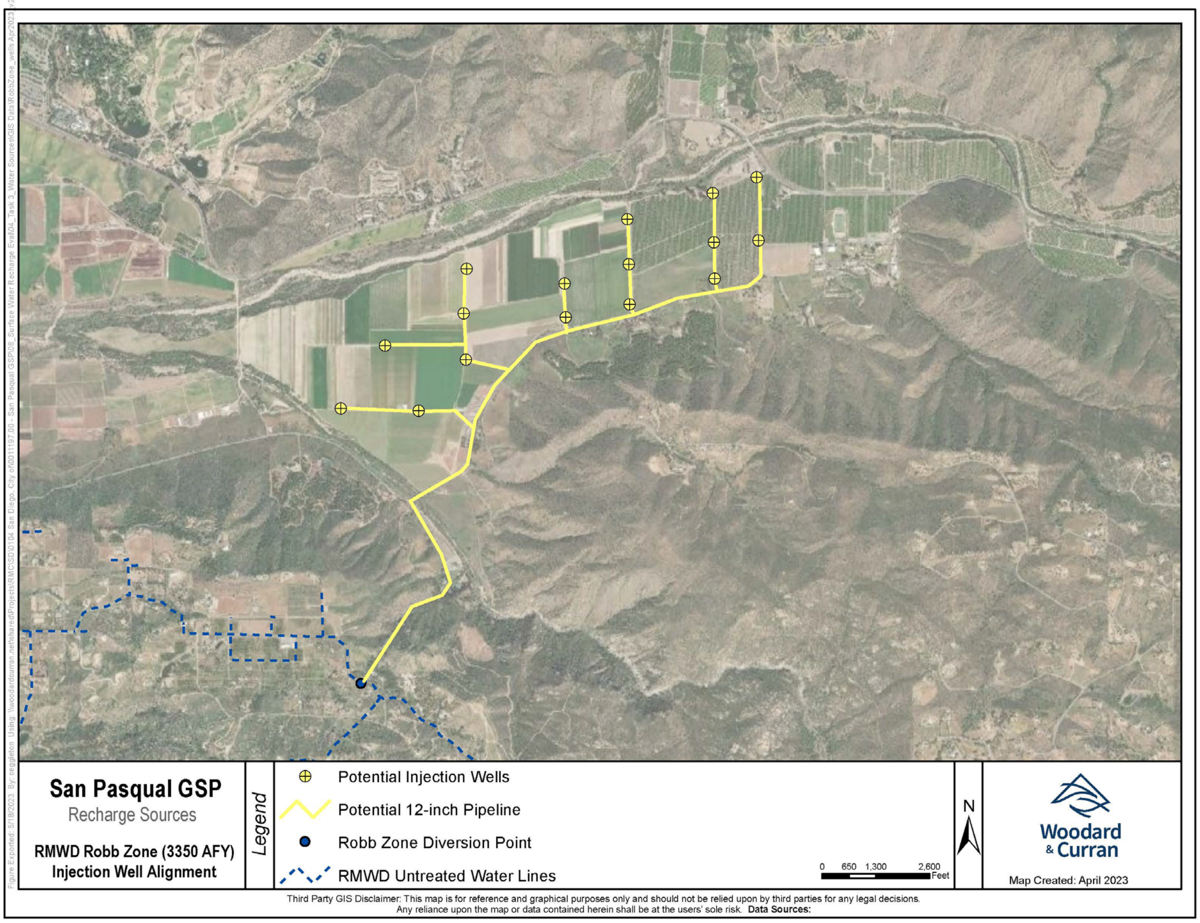


Figure 3-6 Potential Conveyance Pipelines for Strategy 3D

3.4.4 Anticipated Benefits and Challenges

Strategy 3D would have several benefits and challenges associated with construction of injection wells to recharge the Basin with water from Ramona MWD. This strategy would provide a reliable source of new water to the Basin that would be less sensitive to variability of local hydrologic conditions. It could also provide the ability to conduct remote monitoring of the Basin. Challenges with this strategy include the need for treatment prior to injection, which would require a treatment facility and approximately two acres of land. O&M for injection wells can be substantial, requiring backflushing to avoid well clogging over time, remote monitoring and controls, security considerations, and specialized staff to support water treatment and O&M activities for the injection wells. Additionally, this strategy would require permitting and coordination with several regulatory agencies for the injection wells and permitting for construction of both the injection wells and conveyance pipelines.

3.4.5 Preliminary Cost Estimate

Construction of the conveyance pipelines is estimated to cost $41 per inch-diameter per linear foot, for a total cost of $13,776,000. Water purchased from Ramona MWD is estimated to cost $1,584 per AF, consistent with the cost of untreated imported water from the Water Authority, for a supply cost of $5,306,400. The 3.0 MGD pretreatment facility is estimated to cost $32,000,000 to construct. Injection wells are estimated to cost $1,469,700 per well to construct, thus a total of $23,515,200 for 16 wells. As with Strategy 3A, a construction contingency of 50% (34,646,000) has been used to account for recent increase in construction costs and contingency, as well as 35% (38,235,000) for "implementation costs", which includes design, legal, environmental, construction management, services during construction, and administration costs. Strategy 3D is estimated to cost approximately $147.5 million to construct and for one year's worth of water. These costs reflect the use of 12-inch pipeline for the entire conveyance system, which may be adjusted as the strategy is further developed. Ongoing annual costs will vary, and will include the cost of water, Ramona MWD wheeling charges, and costs associated with operating the treatment facility. Although wheeling costs are uncertain, pumping generally makes up the highest portion of the wheeling costs and are estimated to range from $436 to $566 per AF of water. Assuming the higher value in this range, wheeling costs would be a minimum of approximately $1.9 million for 3,350 AFY of water. Wheeling cost do not include the cost of the water itself. Costs may additionally be refined as injection well strategy is refined and as more information about potential wheeling costs from Ramona MWD for delivery of raw water becomes known.

4. CONCLUSIONS AND NEXT STEPS

This analysis is the fourth task of GSP Management Action 7 to evaluate surface water recharge within Basin. Building off evaluation criteria and ranking, a field streambed investigation, and assessment of water sources and conveyance alternatives, this work assessed 15 recharge strategies considered within the Basin. Based on comparative ranking, high potential for broad benefits and preserving diversity in recharge methodology, four strategies were selected for further investigation. These four strategies include:

- Strategy 1B: Enhance Streamflow Infiltration with In-stream Modification
- Strategy 2A: Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases
- Strategy 3A: Augment Santa Ysabel Creek with Ramona MWD Untreated Water System Deliveries
- Strategy 3D: Injection Wells with Ramona MWD's Untreated Water System Deliveries

The next task in evaluating surface water recharge within the Basin will be to incorporate the four selected strategies into the SPV GSP Model v2.0 and estimate benefits to groundwater levels and groundwater storage. After the four selected strategies are modeled, the benefits to GDEs will be determined. These are potential strategies that could be implemented in case Basin monitoring indicates GSP thresholds were being exceeded and undesirable results would occur. Assessment work from these six steps will then be summarized in a Preliminary Feasibility Study.

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ATTACHMENT A. RECHARGE METHODS

Groundwater recharge methods considered for this phase of study are described in this section to identify their potential benefits and challenges in the context of the Basin. These recharge methods are as follows:

- Existing streambed
- In-stream modifications
- Infiltration basins
- Injection wells
- Managed flood irrigation
- In-lieu recharge

The above recharge methods, except in-lieu recharge, rely primarily on two processes including infiltration and injection. In-lieu recharge involves using an alternative water source for irrigation, so that less groundwater is pumped for irrigation, thereby reducing the depletion of groundwater from pumping.

- Infiltration is the process of introducing water at the land surface and allowing it to percolate downward under gravity into the subsurface in streambeds, infiltration basins, and/or on farmland through managed flood irrigation.

- Injection is the process of pumping water downward inside of an injection well directly into specific depth intervals of the aquifer. Thus, rather than relying on infiltration at the surface, the performance of injection wells relies more on hydraulic properties of the aquifer, such as hydraulic conductivity and saturated (that is, water-filled) thickness, and the injection infrastructure.

The following subsections provide an overview of each of these methods, followed by the identification of criteria that define the suitability of recharge methods to conditions in the eastern portion of the Basin. Analytical solutions have been used to estimate “order of magnitude” volumes that could potentially be recharged using each of the three basic recharge methods: weirs in streambeds, infiltration basins in the floodplain outside the main channel, and injection wells outside of the Santa Ysabel Creek floodplain. “Order of magnitude” volumes should be considered rough estimates intended primarily to provide an idea of the potential order of magnitude of how much water could be available under a given strategy, rather than as a guarantee of a specific volume of water. The specific volume of water available will depend on factors including, but not limited to, hydrologic conditions in a given year, agreements between involved parties, and final design of the selected strategy.

Infiltration using Existing Streambed

Infiltration of streamflow naturally occurs through the streambed. Streamflow is a key source of recharge to the aquifer in the eastern portion of the Basin and usually fully infiltrates east of Ysabel Creek Road (see **Figure 2-1**) around the middle of the Basin.

Additional source water volumes would be required to increase the infiltration through the Santa Ysabel Creek streambed. Local surface water supplies from Sutherland Reservoir or imported water supplied purchased from San Diego County Water Authority via Ramona MWD are potential additional water sources. Potential controlled releases from Sutherland Reservoir would be conveyed through the Santa Ysabel Creek in the eastern portion of the Basin. Water from Ramona MWD would be conveyed into a designated reach of the Santa Ysabel Creek streambed, requiring connections and pipeline infrastructure.

Due to the high permeability of the streambed in Santa Ysabel Creek in the eastern portion of the Basin (City, 2023a), enhanced groundwater recharge from Santa Ysabel Creek would largely depend on the available volume of source water that could be conveyed to the creek, rather than limitations on the ability of Santa Ysabel Creek streambed sediments to infiltrate the water.

Enhanced Infiltration using In-stream Modifications

A variety of in-stream modifications are possible to enhance infiltration in intermittent streams (that is, those that do not regularly flow). The key benefit of implementing in-stream modifications to enhance infiltration is that the stream itself serves as the conveyance feature and that infiltration of stormwater can be increased in place. In Santa Ysabel Creek, this would result in maximizing infiltration in place with less chance of excess streamflow passing downstream of Ysabel Creek Road. The stream channel in this approach serves as a temporary water storage system. When in-stream modifications are used in conjunction with natural streamflow or with supplemented streamflow (e.g., releases from Sutherland Reservoir), there would be no need for additional conveyance infrastructure to transfer the source water to the recharge location. In-stream modifications would be used to detain flow in the stream to promote infiltration through the streambed. Examples of instream modifications include, but are not limited to the following:

- Low-level weirs, temporary berms (e.g., 2- to 4-feet high) positioned across the streambed that would detain flow when it occurs. They are typically constructed of sand or gravel from the streambed and designed to detain low flows, wash out during flood events, and then be reconstructed after wash-out events.
- Low-level weirs, relatively permanent berms (e.g., 2- to 3-feet high) in the streambed that could be constructed with concrete or rock. These more robust structures are designed to overtop during flood events and may require spillway structures for high flow releases to avoid flood damage to the structure. An example of a low-level weir is shown in **Figure A-1**.
- Complex weir structures, such as "T and L" levees [1], where a series of chambers are constructed to spread and detain water in the stream channel and increase the opportunity for enhanced infiltration. **Figure A-2** shows sand "T and L" levees in the Santa Ana River in California that are routinely reconstructed in the streambed to spread the water in the channel.
- Rubber dams are permanently installed structures typically embedded in concrete anchor walls and base within the stream and are designed to inflate during detention periods and deflate when the stream channel is dry or to allow larger flood flow passage.

[1] https://www.calandtrusts.org/wp-content/uploads/2015/08/Recharging-the-OC-Basin-Hutchinson-OCWD.pdf

Figure A-1 Example of a Low-level Weir that Detains Streamflow in Northwestern Australia

Figure A-2 Example of T and L Levees in Santa Ana River

Stream characteristics, such as the sediment mobility, streamflow velocity, frequency of streamflow, and streambed infiltration rates would influence selection of the most appropriate in-stream modifications for a particular site.

The size of the pool that forms behind the weir is controlled by the slope of the streambed and its channel shape as well as the geometry of the stream-adjacent floodplain, both upstream and perpendicular to the stream into the floodplain.

Siting and Design Considerations

Optimal weir locations would be dependent on the following conditions:

- Streambed permeability – Higher streambed permeability would allow for more rapid infiltration rates and reduce the height of the weir needed to detain the desired volume of streamflow. Lower weirs are preferable due to their lower cost, greater stability, and shallower flooding impacts.
- Stream width – Stream width controls the length of the weir, the volume of materials needed for construction, and the installation cost.

- Depth to the water table – Deep water tables in the aquifer have space above them in the vadose (that is, unsaturated) zone for additional water storage beneath the streambed. If the water table is only a few feet below a streambed, then additional subsurface storage of water would be limited.

- Impacts from the weir pool – Even a low-level weir can create a weir pool that floods the surrounding land, particularly if the area is nearly flat. Although inundation of the surrounding land increases the opportunity for additional infiltration, inundation planning must consider potential impacts to existing land uses, transportation routes, access points, environmentally and/or culturally sensitive areas, and existing and planned infrastructure.

- Permitting and regulatory requirements are a consideration for any modification of existing streambeds, which are regulated under Section 404 and 401 of the federal Clean Water Act (administered by the U.S. Army Corps of Engineers) and Section 1600 of the California Fish and Game Code (administered by the California Department of Fish and Wildlife). Potential impacts to existing riparian and aquatic habitat are a key consideration from regulating agencies. The presence of sensitive, threatened, and endangered species could influence decisions regarding in-stream modification locations, regulated by state and federal endangered species acts.

Maintenance requirements would depend on streamflow and source water characteristics. For example, source water with a high sediment load could result in significant deposition of silt on the upstream side of the weir, which would reduce infiltration rates over time. In this example, routine removal of sediments and tilling of infiltration beds might be required to restore permeability and infiltration characteristics of the streambed. Weir pools are also subject to evaporative losses, especially if recharge rates are low. This could affect the feasibility of the recharge strategy in cases where source water availability is the limiting factor.

Infiltration Potential

A series of simple calculations were performed to approximate infiltration volumes that could potentially be achieved using a hypothetical weir across Santa Ysabel Creek in the vicinity of T-4 (**Figure A-3**). This location was selected considering the existing streambed infiltration capacity and the goal of enhancing the infiltration of remaining streamflow upstream from Ysabel Creek Road. Calculation assumptions are provided in **Attachment B**.

The shape of the streambed indicates that a weir at this location would need to be approximately 500-feet (ft) wide and 2-ft high. A full weir pool could hold around 82,500 cubic feet (ft^3). Based on the streambed permeability estimated during a 2022 streambed investigation in Santa Ysabel Creek (City, 2023a), daily infiltration could be approximately 42 acre-feet per day (AF/d). This is a high-level analysis that provides rough "order of magnitude" infiltration volumes for a weir at T-4, and therefore should be considered as a starting point for comparison rather than actual recharge volumes.

The recharge volumes could be increased if streamflow could be controlled with imported water supplies delivered to the weir or additional stormflows are detained. Delivering water to the weir when the water table is lowest would allow larger volumes to be recharged. This is because the water-table depth limits the volume of water that can be stored in the vadose (that is, unsaturated) zone, and because the water table can vary substantially between dry and wet periods in the eastern portion of the Basin. For example, managing a weir pool when the water-table depth is 80 ft below ground surface (bgs) could double the recharge volumes, as compared to a water-table depth of 40 ft bgs. A deeper water table could also be achieved operationally by extracting groundwater beneath the weir pool.

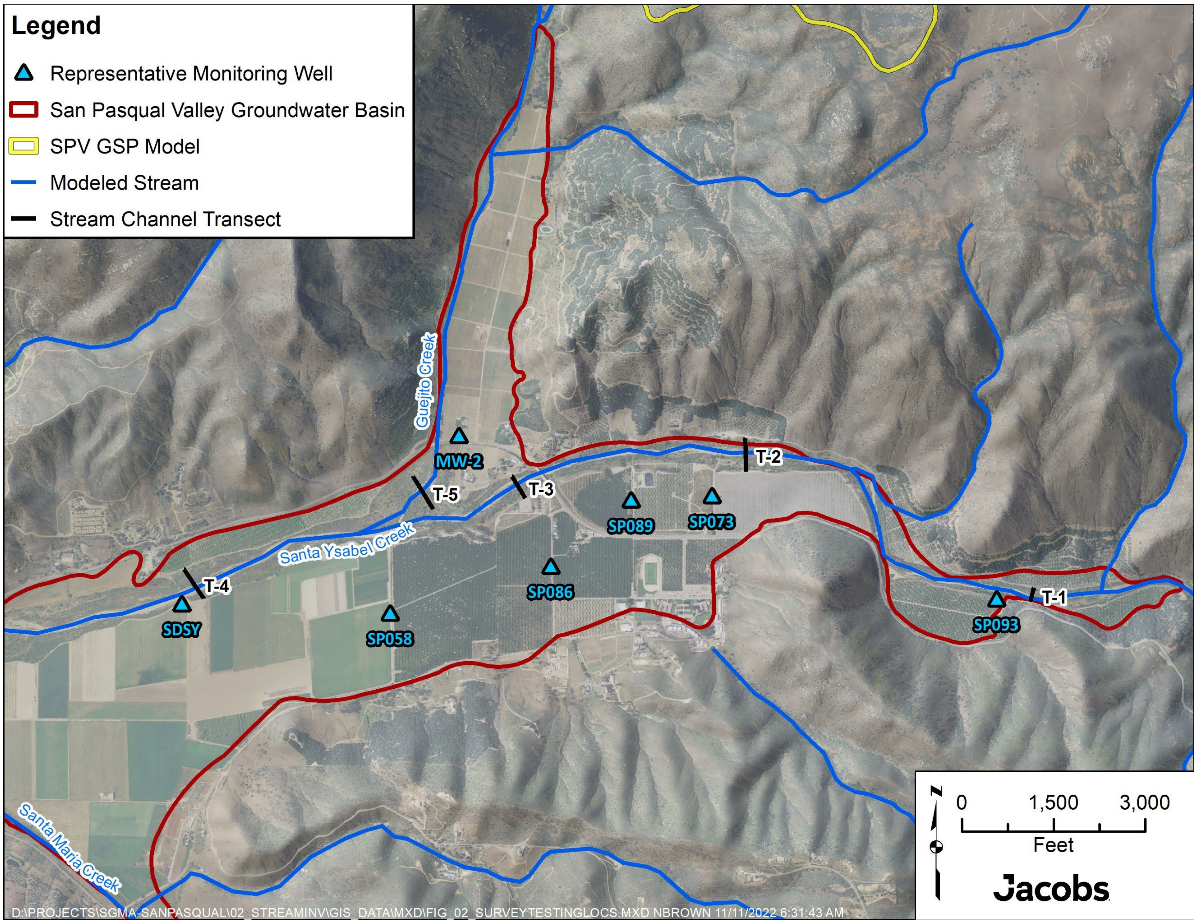

Figure A-3 Stream Channel Transect Locations

Constructing additional weirs upstream from T-4 in Santa Ysabel Creek would be another way to increase recharge volumes, assuming there is sufficient source water available and a reliable means for conveyance. Upstream weirs would also enable water to be temporarily stored in different parts of the aquifer beneath the eastern portion of the Basin. Similar calculations could be done for the upstream transects to determine approximate recharge volumes.

Strategy optimization could be evaluated in the future to maximize recharge volumes by delivering the water source periodically. This would allow time for water recharged into the subsurface to flow both vertically and horizontally away from the infiltration location, which would deepen groundwater levels beneath the weir as the recharged volume of water dissipates, thereby creating more storage space for subsequent recharge volumes. Groundwater modeling conducted in Task 5 could be used to help assess the timing of water delivery to maximize recharge and improve efficiency.

Infiltration Basins

Infiltration basins are typically shallow ponds constructed outside of the streambed. A water source would be conveyed to the basin via gravity or pumped and released into the infiltration basin to allow for infiltration. Ideally infiltration basins would be located where surface sediments are highly permeable, because this would allow for smaller infiltration basins, which would limit the land requirements and reduce the volume of evaporative losses.

Outside the primary Santa Ysabel Creek stream channel on the banks and on elevated "benches" in the stream channel, the permeability of shallow sediments is generally lower than the permeability of sediments in the main flow channel due to deposition of finer-grained sediments at the slower-flowing edges of the stream (City, 2023). Thus, infiltration basins outside of the main flow channel would generally have lower infiltration rates than in-stream approaches. This method is therefore best suited where large areas are available for inundation. Because of the potential for high evaporative losses, infiltration basins are also suited to climates with lower evapotranspiration (ET) or where the water source is available in winter.

Infiltration rates in infiltration basins tend to reduce over time due to processes such as chemical precipitation, biological growth, and siltation, depending on the composition of the source water. Maintenance of infiltration basins includes the need for scraping the base of the basin to restore permeability. Depending on the composition of the source water, pretreatment might be needed prior to infiltration.

Siting and Design Considerations

Infiltration basins would more likely be constructed outside the main Santa Ysabel Creek channel, because recharge in the main Santa Ysabel Creek channel is already effective under natural conditions. A larger infiltration basin would create the opportunity for greater recharge volumes; however, suitable land would be limited in the eastern portion of the Basin. The potential recharge areas are shown in **Figure A-4** (City, 2023a) and were prioritized according to the following criteria:

- Enhance retention of water within the eastern portion of the Basin
- Manage recharge locations on City parcels
- Have shorter pipelines between sources of recharge water and points of delivery
- Site recharge areas near existing roadways for ease of access
- Site recharge locations near representative monitoring wells to support groundwater sustainability evaluations
- Minimize disturbance to existing active agricultural lands

Infiltration Potential

A simple analysis was used to approximate infiltration volumes for a range of infiltration basin sizes, loosely based on the potential areas identified in **Figure A-4.** Vertical hydraulic conductivity of 17 ft/d was adopted for the infiltration scenarios, similar to the lower-end values measured on the edges of the river (City 2023a). This analysis assumes that infiltration basins would be 2-ft deep, filled instantaneously, and drained at a constant flow rate. The assumed water-table depth for this calculation is 30 ft bgs, which is an approximate depth in the area near Ysabel Creek Road. A porosity of 35% was assumed, consistent with analysis in Task 2 (City, 2023a).

To infiltrate 42 AF/d, a 3.6-acre infiltration basin would be required. Hypothetical infiltration basin recharge volumes are summarized in **Table A-1**. These estimates are approximate and should be considered as a starting point for comparing recharge methods, rather than absolute volumes. Infiltration would occur rapidly due to the high infiltration capacities, as long as the water table remains deep enough to not intersect the bottom of the infiltration basin.

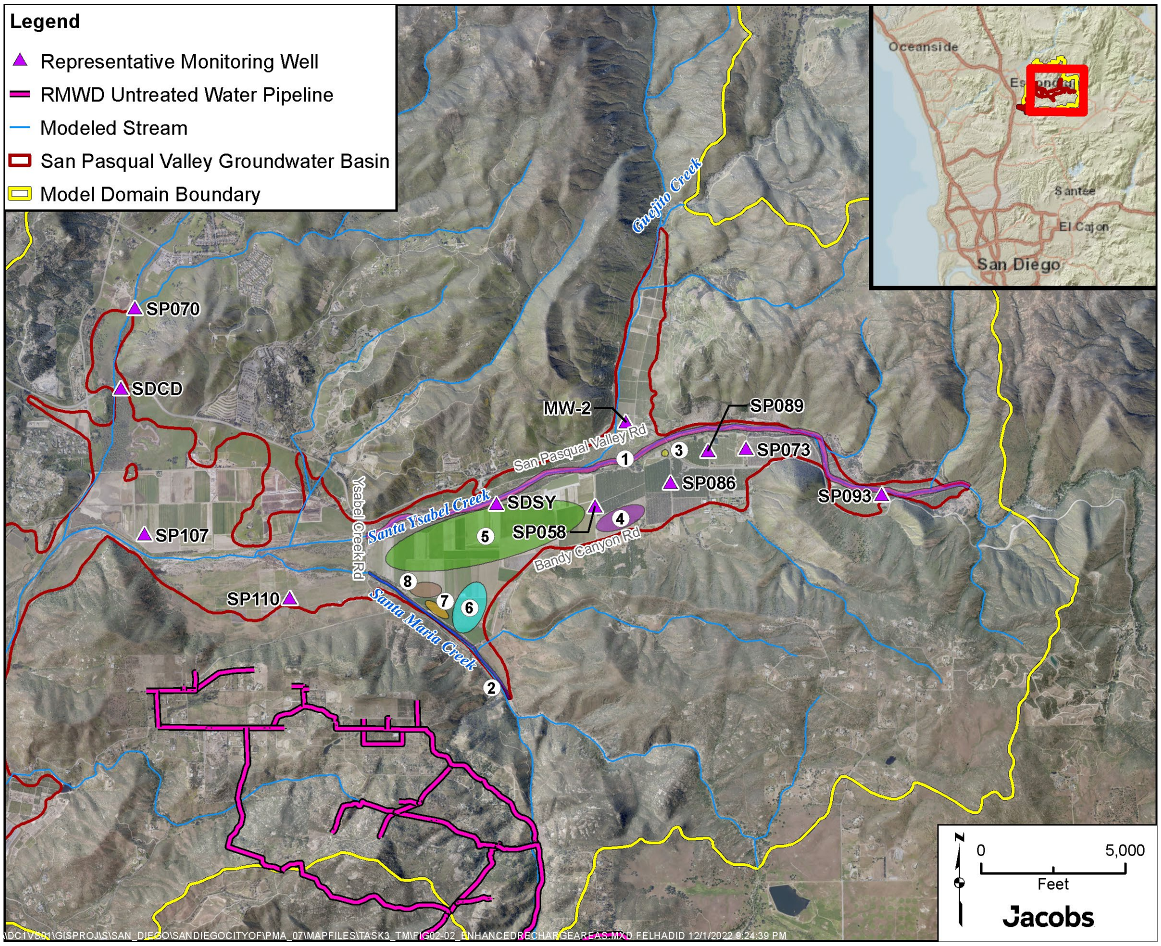

Figure A-4 Hypothetical Areas for Recharge (Areas 1 through 8) (City, 2023a)

Table A-1 Hypothetical Infiltration Basin Recharge Volumes

Characteristic	Areas 4 and 6[a]	Area 5[a]	Area 7[a]	Area 8[a]	2-ft Weir Equivalent Basin[b]
Surface Area (acres)	28	181	1	10	3.6
Basin Volume (AF)	56	356	1.9	19	7.2
Recharge Volume (AF)	324	2,079	11	111	42

[a] *See **Figure A-4** for mapped locations of areas presented in this table.*
[b] *For comparison purposes, this column has been included to highlight the surface area needed to recharge the equivalent volume of a 2 ft weir located at T-4 in Santa Ysabel Creek.*

Injection Wells

The aquifer in the eastern portion of the Basin could also be recharged using injection wells that could inject source water into a specific depth interval within the aquifer. A comprehensive understanding of the hydrogeology is required to ensure that injected water is available at the intended recovery wells. In this case, the intended recovery wells would be irrigation wells in the vicinity of the injection wells.

Recharge volumes that could be achieved with injection wells would depend on aquifer characteristics (e.g., horizontal and vertical hydraulic conductivity and aquifer storage capacity), injection well design, and source water quality. Large recharge volumes would typically require multiple injection wells.

An advantage of this recharge method is the ability to target specific depth intervals in the aquifer. Injection well performance would not be dependent on high near-surface permeability and could be used where the presence of shallow silts or clays makes surface infiltration unfeasible. Injection wells also have a relatively small surface footprint for recharge infrastructure, so they would not require redevelopment of large areas of land. All water from Ramona MWD's untreated water system that would be used as source water for injection wells would need to be routed through a future water treatment plant with an estimated footprint of approximately two acres. Source water would need to undergo filtration and disinfection prior to injection per State Water Resources Control Board (SWRCB) Order 2012-0010 [1].

Physical and geochemical challenges can emerge while recharging even highly purified water into aquifers containing reactive, metal-bearing, or unstable clay minerals. Such challenges could include potentially damaging the borehole environment (that is, the well screen, filter pack, and near-well formation) by clogging pore spaces with solids, reducing permeability near the well, and eventually reducing the injection capacity of the well. Other issues could potentially arise when recharge water interacts with minerals in the aquifer. Some reactions could release naturally occurring metals from the aquifer that degrade groundwater quality (e.g., iron and manganese), or release toxins to the aquifer environment (e.g., arsenic, if it is present in the aquifer). Although not strictly related to chemical reactions, treatment residuals in the form of particulates can also represent a source of clogging in the injection well. To mitigate these challenges, a geochemical evaluation is required to determine the compatibility of the source water to the native groundwater at the injection well. This could be conducted in phases with the first phase being a desktop evaluation and the second phase involving constructing a pilot test facility with a series of cycle tests to characterize the quality of the source water and recovered groundwater by collecting samples and analyzing them for a comprehensive list of chemical constituents. **Table A-2** lists the constituents that should be analyzed in both the source water and native groundwater as part of the injection well evaluation if injection wells are retained as a potentially feasible recharge strategy.

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1 https://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/2012/wqo2012_0010_with%20signed%20mrp.pdf

Table A-2 List of Constituents of Interest for Injection Wells

Constituent	Analysis Method	Purpose or Note
Sodium, Na	E200.7	General chemistry
Potassium, K	E200.7	General chemistry
Calcium, Ca	E200.7	General chemistry
Magnesium, Mg	E200.7	General chemistry
Chloride, Cl	E300.0	General chemistry
Total Alkalinity	SM2320B	General chemistry
Sulfate, SO_4	E300.0	General chemistry
Total Dissolved Solids, TDS	SM2540C	General chemistry
Silica, SiO_2	SM4500-SiO2-D	General chemistry
pH	Not applicable	Field parameters
Water Temperature	Not applicable	Field parameters
Specific Conductance	Not applicable	Field parameters
Oxidation-Reduction Potential, ORP	Not applicable	Field parameters
Dissolved Oxygen	Not applicable	Field parameters
Turbidity	Not applicable	Field parameters
Dissolved Iron, Fe	E200.7	Redox indicators
Dissolved Manganese, Mn	E200.7	Redox indicators
Nitrate, NO_3	E300.0	Redox indicators
Ammonia, NH_3	E350.1	Redox indicators
Total Organic Carbon, TOC	SM5310B or C	Redox indicators
Dissolved Aluminum, Al	E200.7	Clay swelling potential
Orthophosphate as P	SM4500-PE	Competitive desorption
Total Phosphorus, P	SM4500-PE	Competitive desorption
Total Kjeldahl Nitrogen, TKN	SM4500-N_{org}B or C	Oxidation of organic material
Total Arsenic, As	E200.7	If already analyzed in native groundwater
Dissolved Arsenic, As	E200.7	If already analyzed in native groundwater

Backflushing represents an important activity during injection operations to maintain hydraulic characteristics (injectivity) of the injection well. Backflushing entails stopping injection operations for a brief period and pumping or airlifting the injection well to remove solids that have accumulated inside the injection well screen and filter pack and then resuming injection operations.

Source water would need to be delivered to the wellhead, which would require conveyance infrastructure and a source of electricity for pumping water to the wellhead. Conveyance infrastructure would include a connection to the water source, a pumping station, and pipelines to each wellhead. If the source water is streamflow, the conveyance infrastructure would be likely to include construction of a retention structure in the stream, or a storage feature in the floodplain, which could provide an additional recharge location.

Although simple analytical calculations indicate injection rates as high as 350 gallons per minute (gpm) could potentially be achievable with properly designed injection wells, the Consultant Team assumed 130 gpm per well. This lower injection rate considers existing yields of water supply wells in the area and the tendency for injection well capacity to reduce over time. Another consideration is to inject at lower rates, but over longer injection durations. Injecting smaller volumes over a longer period has the added benefit of minimizing the size of conveyance infrastructure (e.g., pipes and pumps). However, extending injection periods could necessitate temporary above-ground storage (e.g., ponds or tanks) to balance water supply and injection rates. Additional assumptions associated with injection wells are provided in **Attachment B**.

Managed Flood Irrigation

Managed flood irrigation refers to the practice of inundating active agriculture lands with water and allowing it to infiltrate. This practice could also be applied in fallowed land, working landscapes, or open spaces within the Basin. This method could be implemented during storm events or with imported water supplies delivered directly to the fields. Recharge water is anticipated to be applied during the non-irrigation season, using existing or additional irrigation equipment. In the Basin, conveyance infrastructure would be required to convey water from the source to the irrigation fields.

Flood-MAR (Managed Aquifer Recharged) is an integrated and voluntary resource management strategy that uses flood water resulting from, or in anticipation of, rainfall or snowmelt for groundwater recharge on agricultural lands and working landscapes, including but not limited to refuges, floodplains, and flood bypasses (DWR, 2018). **Figure A-5** shows a picture of a flooded orchard as a way to recharge depleted aquifers. In the case of the SPV, flooding events are infrequent, and this practice could still be implemented with water delivered from other sources. The California Department of Water Resources (DWR) has an ongoing Flood-MAR program [1] to build on the knowledge and lessons from past and ongoing studies and programs, pursue expanded implementation of Flood-MAR, and make Flood-MAR an integral part of California's water portfolio.

The opportunity for infiltration would be greatest on flat land where runoff would be limited. Some retaining walls might be necessary to protect surrounding areas from unplanned inundation. Land availability for flooding would need to be confirmed to understand the feasibility of this method based on crop type and existing soil-flushing practices. Nutrient runoff and soil flushing characteristics would need to be carefully controlled to manage water quality effects.

Potential benefits and impacts of Flood-MAR are project specific. In the SPV, the primary benefit would be the aquifer replenishment, potential reduction of pumping costs, and ecosystem enhancement. There could be a potential impact to terrestrial habitat at flood sites, which would need to be carefully considered prior to project implementation. According to Flood-Map White Paper (DWR, 2018), agencies that have implemented this type of recharge strategy, have encountered the following challenges: understanding crop suitability, willingness of local landowners to participate, accounting and reporting of replenished water, developing explicit agreements for operation and use of water.

[1] Flood-Managed Aquifer Recharge (Flood-MAR) (ca.gov)

Figure A-5. Flooded orchard as a method to recharge aquifers.

Reference: taken from DWR, 2018

In-lieu Recharge

Replenishment methods can be generally divided into two main categories: direct replenishment and indirect or in-lieu replenishment. The previously described methods fall into the direct replenish category. In some areas, recharge may be accomplished by providing an alternative source of water to users who would normally use groundwater, leaving groundwater in place and increasing the potential to improve the groundwater levels, or for later use. The in-lieu recharge method would provide an alternative water source to irrigators to reduce the demand for groundwater. This would result in increasing groundwater levels and a greater groundwater storage volume. Benefits would include reduced electricity consumption due to less groundwater pumping, assuming the alternative water source could be provided using a less energy-intensive method. Additional groundwater storage may also be considered as emergency storage, providing drought resilience when other water sources are less available. Higher groundwater levels may also have environmental benefits for vegetation.

Source water would need to be conveyed to a point of interconnection with existing irrigation delivery systems on individual parcels. The volume of groundwater that would remain in the aquifer because of reduced groundwater pumping would be similar to the volume of source water available that would be conveyed to irrigators, depending on the elapsed time between injection and extraction.

One of the challenges for the in-lieu recharge method is coupling available water supply seasonality (in case the source is stormwater), rate and water volume available, and the water cost. Another challenge is the assessment of the effect on sustainable management of the Basin. In-lieu recharge may result in replenishment on a one-for-one basis in some groundwater basins where a unit of water delivered in-lieu of groundwater pumping is a unit of water remaining in the aquifer (DWR, 2016).

ATTACHMENT B. ANALYSIS OF POTENTIAL RECHARGE VOLUMES

Weirs

Stream-channel surveys were conducted during a streambed investigation in June 2022 at five transect locations in the eastern portion of the Basin, as described in City (2023a). A "transect" represents a line perpendicular to and cutting across the stream channel along which streambed elevations were measured using surveying equipment. Four transects across Santa Ysabel Creek (designated T-1 through T-4) and one transect across Guejito Creek (T-5) are shown in **Figure A-3**.

Potential recharge volumes behind a low-level weir near San Pasqual Valley Road (T-4 location) were assessed by calculating the approximate size of the weir pool and estimating infiltration using a Darcy flow solution, as follows:

- The Santa Ysabel Creek channel at T-4 is approximately 500-ft wide and 2-feet (ft) high, which would be the dimensions of a weir at this location.
- The average slope of the streambed in Santa Ysabel Creek between T-4 and T-3 upstream is approximately 30 ft over 5000 ft, or 0.006 ft/ft. If this slope were truly uniform, the weir pool would be approximately 330-ft long behind the 2-ft weir, with an approximate volume of 82,500 cubic feet (ft^3).
- The center of Santa Ysabel Creek has a higher hydraulic conductivity than the banks and elevated "benches", so the weir pool was split into three equal parts, with the central channel assigned a vertical hydraulic conductivity (Kv) of 170 feet per day (ft/d), and the edges were assigned a Kv of 24 ft/d (City, 2023a).
- The water-table depth averages about 50 ft bgs in the general vicinity of T-4 since monitoring began in 2011 in the nearest monitoring well, SDSY, which is approximately 100 ft from the edge of the Santa Ysabel Creek channel. Santa Ysabel Creek is at a lower elevation, and so the water table was assumed to be 40 ft bgs beneath Santa Ysabel Creek for the initial calculations described herein. The thickness of the unsaturated zone together with an assumed porosity of 0.35 are the key constraints on the volume of water that could be temporarily stored beneath the creek.
- The central part of Santa Ysabel Creek could recharge around 14 acre-feet per day (AF/d) and each edge could recharge 14 AF/d, resulting in a total potential recharge of 42 AF/d.

This is a high-level analysis that provides rough "order of magnitude" infiltration volumes for a weir at T-4, and therefore should be considered as a starting point for comparison rather than actual recharge volumes.

Injection Wells

As part of the *San Pasqual Groundwater Conjunctive Use Study* (2010 Conjunctive Use Study) (CDM, 2010), aquifer properties were estimated by measuring the changes in water levels in well SPMW-1 during cyclic pumping at an adjacent irrigation well. Estimates from that test indicate a transmissivity of 11,000 to 13,500 square feet per day (ft^2/d) with corresponding horizontal hydraulic conductivity ranging from 77 to 95 ft/d.

A simplified analysis was used to get an initial sense of possible extraction volumes from the aquifer. The analysis used the following assumptions:

- Horizontal hydraulic conductivity of 77 ft/day (low value from SPMW-1 aquifer testing)

- Aquifer thickness of 145 ft, assuming an alluvial thickness of 200 ft with an average water-table depth of 55 ft bgs
- Groundwater levels outside the injection wells in the aquifer during injection should not be within 6 ft of land surface.
- The reduced efficiency of injection compared to extraction was accounted for by assuming a low well efficiency of 20%.

These parameters along with information on existing water-supply wells suggest that extraction and injection wells, if properly designed to maximize their capacities, could potentially yield hundreds of gpm. For example, theoretically 350 gpm could be injected without mounding the water table to depths within 6 feet of the land surface. However, given the tendency for injection well capacities to diminish over time, as well as the hydraulic interference that would occur between neighboring injection wells, the Consultant Team assumed a maximum injection rate of 130 gpm per well. Total injection volumes and redundancy could be improved by installing additional injection wells. Pilot testing would ultimately be needed to reduce uncertainty associated with recharge strategies that rely on injection wells.

ATTACHMENT C. RECHARGE STRATEGY SCREENING ANALYSIS

Table C-1 Description of Recharge Strategies

Code	Name	Description
1.	**Stormwater in Santa Ysabel Creek**	
1A	Existing Conditions	Stormwater infiltrates in the existing streambed, there is excess streamflow after Ysabel Creek Road that could be considered for enhanced infiltration in the eastern portion of the Basin
1B	Enhancement of streamflow infiltration	Streamflow infiltration is enhanced with in-stream modifications in Santa Ysabel Creek (e.g., semi-permanent or permanent weir or berm) at T-4 (see **Figure A-3**). Excess streamflow after Ysabel Creek Road is reduced. Santa Ysabel Creek would serve as the conveyance feature and infiltration in the streambed in Area 1 would be the recharge method.
1C	Infiltration basin – Stormwater	Streamflow is diverted at an offtake from a pool formed with a water detention infrastructure (e.g. weir) at creek streambed and conveyed to a basin via pump and pipe. Infiltration basin located in City-owned parcel southwest of Area No. 3 along Bandy Canyon Rd (Area No. 4) or in large City-owned parcel west of Area No. 4 (Area No. 5)
1D	Injection wells with Stormwater	Streamflow is diverted at an offtake from a pool formed with a water detention infrastructure (e.g. weir) at creek streambed and conveyed to wellheads via pump and pipe. Pre-treatment would be required per SWRCB Order 2012-0010 (filtration and disinfection), with additional infrastructure for these processes. Injection wells located at potential locations are shown in **Figure 3-5.** Number of injection wells will depend on the water source, land access, and injection capacity of wells.
1E	Managed Flood Irrigation with stormwater	Streamflow is diverted at an offtake from a pool formed with a water detention infrastructure (e.g. weir) at creek streambed and conveyed to wellheads via pump and pipe. Existing irrigation system is used, and water pre-treatment is required (i.e. settling).
1F	In-lieu Recharge with stormwater	Streamflow is diverted with water capture (e.g. weir) & offtake structure from creek streambed, stored in tank and conveyed to farmland via pump and pipe when farmer needs to irrigate. Existing irrigation system is used, and water pre-treatment is required (i.e. settling).

Code	Name	Description
	2. Controlled releases from Sutherland Reservoir: initial potential annual release estimated approximately around 1,000 AF	
2A	Increase of streamflow with Sutherland controlled releases	Sutherland Reservoir conducts controlled releases to the Santa Ysabel Creek, some flow is lost during conveyance (~20%) from Sutherland Reservoir to the eastern portion of Basin, the rest infiltrates in the existing streambed (Area 1). Releases from reservoir timed to occur at intervals that allow for full infiltration in the eastern portion of the Basin. The maximum estimated infiltration rate in this river reach is estimated to be 900 AF per month (see **Attachment D)**
2B	Sutherland releases with enhancement of streamflow infiltration	Infiltration of controlled releases from Sutherland Reservoir are enhanced with in-stream modifications in Santa Ysabel Creek (e.g. a weir) at T-4 (see **Figure A-3**)
2C	Sutherland releases with off-stream infiltration basin	Controlled releases from Sutherland Reservoir into Santa Ysabel Creek are diverted from creek streambed with detention structure to form a pool (i.e. weir) and an offtake structure. Water is conveyed to basin via pump and pipe. Infiltration basin located in City-owned parcel southwest of Area No. 3 along Bandy Canyon Rd (Area No. 4) or in large City-owned parcel west of Area No. 4 (Area No. 5)
2D	Sutherland releases with injection wells	Controlled releases from Sutherland Reservoir into Santa Ysabel Creek are diverted from creek streambed with detention structure to form a pool (i.e. weir) and an offtake structure. Water is conveyed to each wellhead via pump and pipe. Pre-treatment is required (filtration and disinfection). Injection wells located at proposed locations as shown in **Figure 3-5.** Number of wells will depend on the water source.
2E	Sutherland releases used for managed Flood Irrigation	Controlled releases from Sutherland Reservoir into Santa Ysabel Creek are diverted with water capture (i.e. weir) & offtake structure from creek streambed and conveyed to farm land via pump and pipe. Existing irrigation system is used, and water pre-treatment is required (i.e. settling).
2F	Sutherland releases used for In-lieu Recharge	Controlled releases from Sutherland Reservoir into Santa Ysabel Creek are diverted from pool formed with water detention structure (weir) & offtake structure from creek streambed, stored in tank and convey to farmland via pump and pipe when farmer needs to irrigate. Existing irrigation system is used and water pre-treatment is required (i.e. settling).

Code	Name	Description
	3. Deliveries from Ramona MWD's Untreated Water System: 850 AFY to 3,350 AF could be delivered from Snow and Robb Zone respectively	
3A	Increase of streamflow with Ramona MWD deliveries	Ramona MWD deliveries of untreated water. The current proposed pipeline route would convey untreated water from the Robb Zone diversion location to Santa Ysabel Creek near the San Pasqual Valley Road bridge in the eastern portion of the Basin. Releases from Robb Zone diversion to occur at intervals that allow for full infiltration in the eastern portion of the Basin. The maximum estimated infiltration rate in this river reach is estimated to be 375 AF per month (see **Attachment D**)
3B	Increase of streamflow with Ramona MWD deliveries and streambed modification	Ramona MWD deliveries of untreated water through conveyance pipeline to Santa Ysabel creek, with modified streambed (i.e. weir) at T-4 (see **Figure A-3**) enhancing infiltration (Area 1 in **Figure A-4**)
3C	Infiltration basin - Ramona RWD deliveries	Ramona deliveries of untreated water conveyed to basin via pipes under gravity. Infiltration basin located in City-owned parcel southwest of Area No. 3 along Bandy Canyon Rd (Area No. 4) or In large City-owned parcel west of Area No. 4 (Area No. 5) (see **Figure A-4**)
3D	Injection wells with Ramona RWD deliveries	Ramona deliveries of untreated water conveyed to balancing tank/wells via pipes under gravity. Pre-treatment is required (filtration and disinfection per SWRCB Order 2012-0010) at a future water treatment plant. Injection wells located same areas as infiltration basin (Area No. 4 and Area No. 5). A estimated total of 16 total would be required to recharge the 300 AF per month. **Figure 3-5** shows the location of 16 hypothetical injection well locations. Potential injection well locations will be further assessed under Task 5.
3E	Managed Flood Irrigation with Ramona RWD deliveries	Ramona deliveries of untreated water conveyed to farmland via pipes under gravity. Existing irrigation system is used and water pre-treatment is required (i.e., settling).
3F	In-lieu Recharge with Ramona RWD deliveries	Ramona deliveries of untreated water conveyed to farmland via pipes under gravity when farmer needs to irrigate. Existing irrigation system is used and may require onsite filtration for operation of irrigation equipment.

ATTACHMENT D. MAGNITUDE AND TIMING OF STREAMBED INFILTRATION ANALYSIS

The SPV GSP Model v2.0 (that is, the updated version of the SPV GSP Model) was utilized to analyze the potential for increasing streambed infiltration along Santa Ysabel Creek during the 15-year historical period. To support development of controlled releases from Sutherland Reservoir, monthly streambed infiltration rates along Santa Ysabel Creek between the Basin inlet and Ysabel Creek Road were aggregated. This extent of Santa Ysabel Creek will serve as the primary recharge area for Strategy 2A; thus, it is important to characterize the magnitude and timing of historical streambed infiltration along this portion of Santa Ysabel Creek. The estimated total Santa Ysabel Creek stream leakage that occurred during the 15-year historical period between the Basin inlet and Ysabel Creek Road is presented in **Figure D-1**. During this period, the maximum monthly streambed infiltration rate was approximately 900 AF. This maximum monthly streambed infiltration rate served as the target maximum additional Santa Ysabel Creek inflow that should not be exceeded at the inlet of the Basin to maximize streambed infiltration of these additional flows.

To evaluate the timing of additional Santa Ysabel Creek inflow that could infiltrate the streambed, monthly simulated streamflow at River Mile No. 3 was analyzed to identify periods where streamflow transmission along the Santa Ysabel Creek is minimal (**Figure D-1**). River Mile No. 3 is located upstream from the Guejito Creek confluence with Santa Ysabel Creek, just downstream from the San Pasqual Valley Road bridge crossing over Santa Ysabel Creek. River Mile No. 3 was chosen due to the proximity of the Guejito Creek confluence which could introduce additional streamflow to Santa Ysabel Creek that may limit streambed infiltration of flow passing beyond River Mile No. 3. Thus, when flows at River Mile No.3 are minimal, there should be plenty of capacity for increasing streambed infiltration if controlled releases from Sutherland Reservoir were provided to the Basin. These periods would minimize the potential for additional streamflows from leaving the eastern portion of the Basin. Therefore, the months to target controlled releases from Sutherland Reservoir were determined to be times when streamflow at River Mile No. 3 were estimated to be zero. Based on this timing, the maximum additional Santa Ysabel Creek inflow was calculated as the maximum streambed infiltration rate minus the total Santa Ysabel Creek streambed infiltration. The maximum additional Santa Ysabel Creek inflow will serve as a target for further analysis of the availability of water for controlled releases from Sutherland Reservoir to Santa Ysabel Creek. This approach will be refined with the aid of the SPV GSP Model v2.0 under Task 5.

A similar analysis was performed to support the timing of deliveries from Ramona MWD's untreated water system. The current proposed pipeline route would convey untreated water from the Robb Zone diversion location through a water treatment plant for filtration and disinfection to Santa Ysabel Creek near the San Pasqual Valley Road bridge in the eastern portion of the Basin. The analysis for maximum streambed infiltration rate was evaluated between the point of discharge to Santa Ysabel Creek and Ysabel Creek Road, rather than between the Basin inlet and Ysabel Creek Road as was analyzed for the controlled releases from Sutherland Reservoir. The total monthly streambed infiltration for this extent of Santa Ysabel Creek, is shown in **Figure D-2**, and is approximately 375 AF. Like the controlled Sutherland Releases strategy, it is important to evaluate the transmission of streamflow at River Mile No. 3 to determine the appropriate timing of Ramona MWD deliveries to Santa Ysabel Creek. Months to target Ramona MWD deliveries were identified to occur when streamflow at River Mile No. 3 was zero to maximize streambed infiltration between the delivery point and Ysabel Creek Road. Further evaluation of this analysis will occur during the development of Task 5 TM, which is scheduled for delivery in Summer 2023.

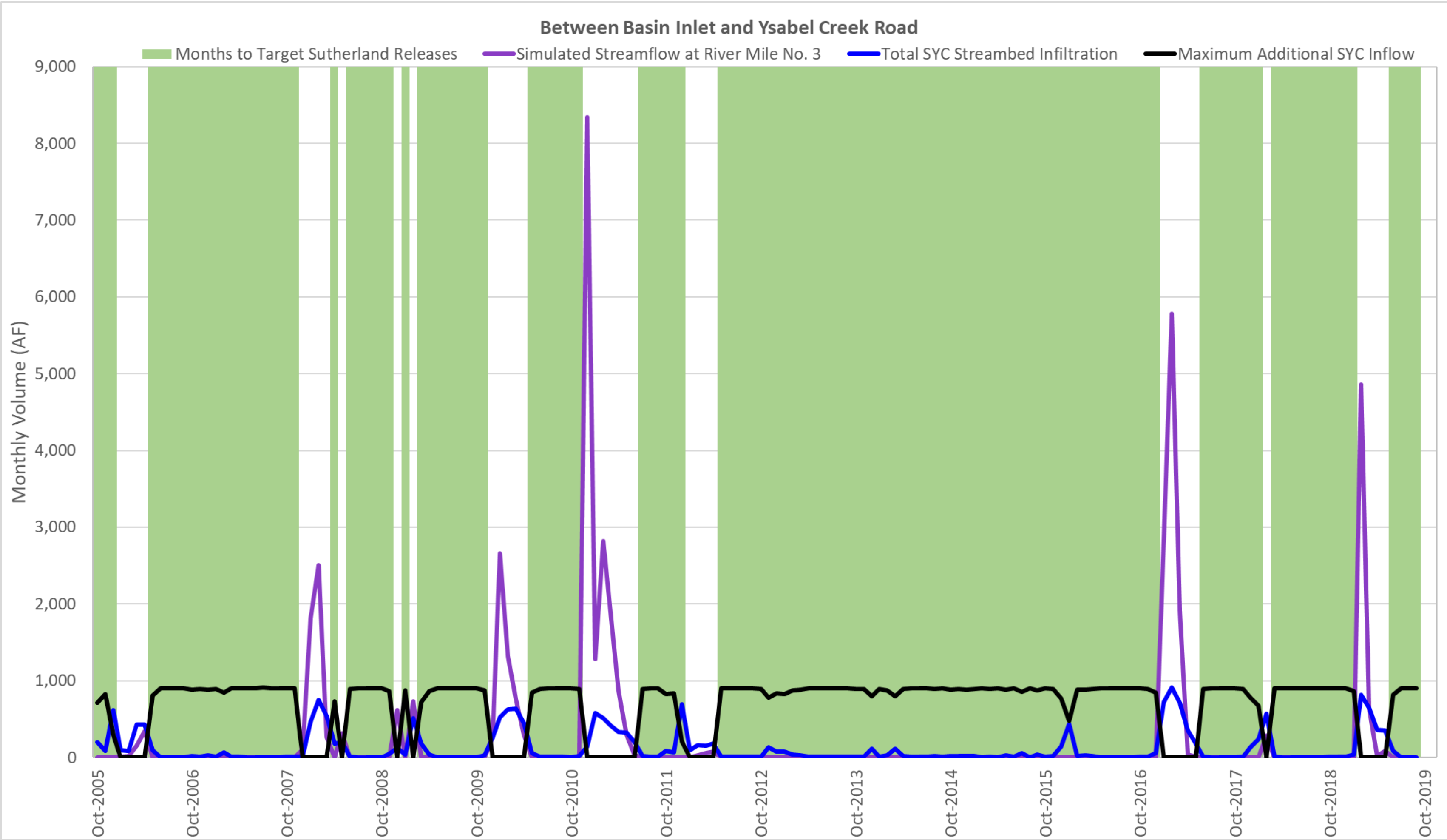


Figure D-1 Santa Ysabel Creek Streambed Infiltration Analysis to Support Development of Controlled Sutherland Releases

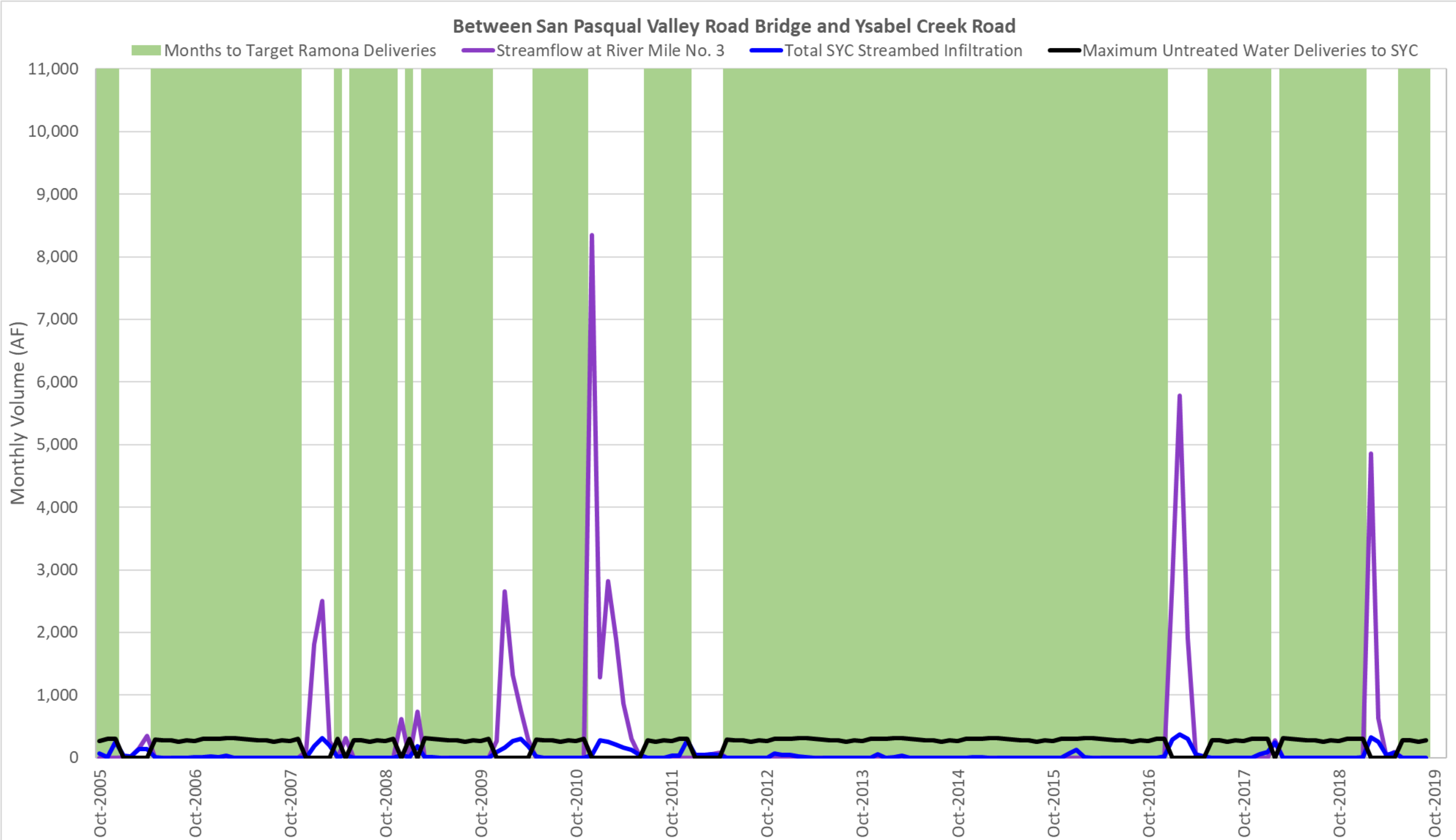


Figure D-2 Santa Ysabel Creek Streambed Infiltration Analysis to Support Development of Deliveries from Ramona MWD

ATTACHMENT E. ENHANCE STREAMFLOW INFILTRATION WITH IN-STREAM MODIFICATIONS

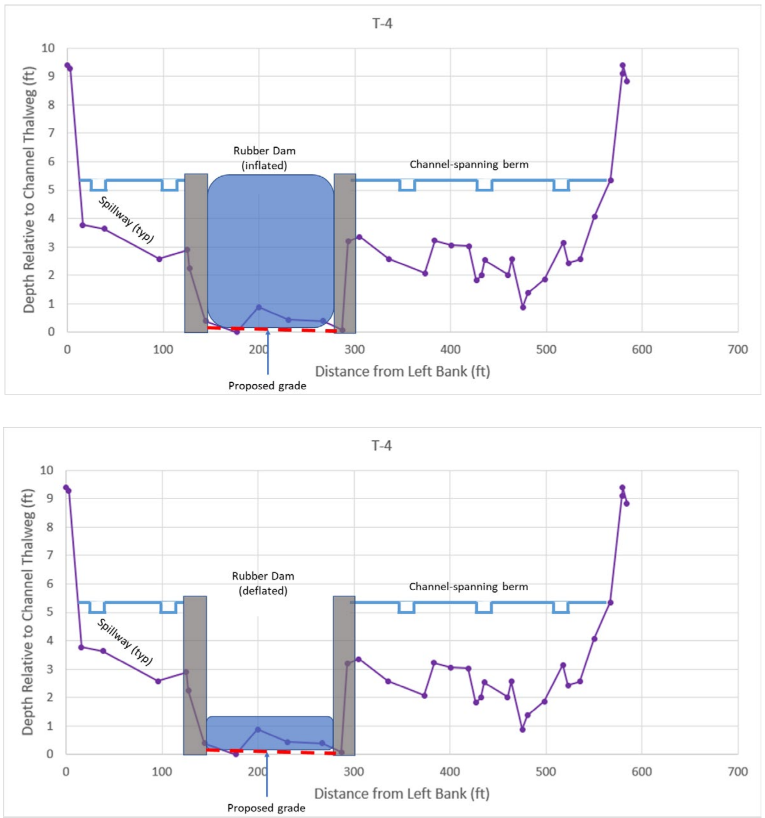


Figure E-1 Permanent Rubber Dam in main channel with berms in remaining flood plain

An alternative to Strategy 1B's infiltration method is shown in **Figure E-1**. Instead of the permanent rubber dam spanning across the main channel and flood plain, in this alternative, the permanent rubber dam is only installed in the main channel to allow flow through floods with berms on remaining floodplain areas. The grading required will be less but the volume that could potentially be captured would be similar to the full-channel alternative.

APPENDIX E: TM 5: GROUNDWATER AND SURFACE WATER MODEL SIMULATIONS

TECHNICAL MEMORANDUM

TO: San Pasqual Valley Groundwater Sustainability Agency

PREPARED BY: Nate Brown/Jacobs, Craig Cooledge/Jacobs, Paula Silva/Jacobs

REVIEWED BY: Sally Johnson/W&C, Christy Kennedy/W&C, Jim Blanke/W&C

DATE: August 22, 2023

RE: Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 5: Groundwater and Surface Water Model Simulations

TABLE OF CONTENTS

ACRONYMS & ABBREVIATIONS

AF	acre-feet
AFY	acre-feet per year
Basin	San Pasqual Valley Groundwater Basin
bgs	below ground surface
b_{sb}	thickness of streambed
b_t	total alluvium thickness above the water table
b_{vz}	thickness of vadose zone beneath the streambed
cfs	cubic feet per second
City	City of San Diego
cm/s	centimeter(s) per second
County	County of San Diego
DWR	Department of Water Resources
ft	foot/feet
ft/d	foot/feet per day
GCM	global circulation model
GDE	Groundwater Dependent Ecosystem
gpm	gallons per minute
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HadGEM2-ES	Hadley Centre Global Environment Model v2-ES
K	hydraulic conductivity
$K_{v\text{-}sb}$	streambed vertical hydraulic conductivity
$K_{v\text{-}SFR}$	effective vertical hydraulic conductivity assigned to SFR package
$K_{v\text{-}vz}$	vertical hydraulic conductivity of vadose zone below the stream channel
MR	mean residual
NAVD88	North American Vertical Datum of 1988
NHDPlus	National Hydrography Dataset Plus
PMA	Project and Management Action
PT	Planning Threshold
R^2	coefficient of determination
Ramona MWD	Ramona Municipal Water District
Range	range of measured head values
RMSR	root mean squared residual
RMW	representative monitoring well
RSD	residual standard deviation
SFR	Streamflow Routing
SPV	San Pasqual Valley
SPV GSP Model	SPV GSP Integrated Groundwater/Surface Water Flow Model
TDS	total dissolved solids
TM	technical memorandum
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WY	water year

EXECUTIVE SUMMARY

This technical memorandum (TM) describes the update of the San Pasqual Valley Groundwater Sustainability Plan Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) and the application of the model to evaluate four potential recharge strategies. This TM is part of a broader effort to develop a Preliminary Feasibility Study, which will contain the following components, each developed under a separate task:

- Evaluation Criteria and Ranking Process (Task 1)
- Streambed Investigation (Task 2)
- Water Sources for Recharge (Task 3)
- Potential Recharge Strategies (Task 4)
- Modeling Approach and Results (Task 5)
- Possible Benefits to Potential Groundwater Dependent Ecosystems (GDEs) (Task 6)

The SPV GSP Model was updated from the version used to support the development of the GSP to improve its representation of streams and aquifer characteristics in the SPV Groundwater Basin (Basin). This updated model incorporates more permeable stream channels, a more permeable alluvial aquifer, and more realistic streamflow behavior as compared with the previous version used to support GSP development. The SPV GSP Model updates were conducted using information obtained during the Task 2 streambed investigation and recalibrated using a combination of daily and monthly stress periods. A stress period is an interval of time during which different values of precipitation, stream inflows at the perimeter of the model, and groundwater pumping are used in the model.

This updated SPV GSP Model was used to evaluate the four recharge strategies retained from the Task 4 assessment of potential recharge strategies. The intent of the evaluation is to better understand potential benefits of the recharge strategies, should they require implementation as part of adaptive management to avoid undesirable results in the Basin. These recharge strategies are as follows:

- Strategy 1B: Enhance Streamflow Infiltration with In-stream Modifications
- Strategy 2A: Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases
- Strategy 3A: Augment Santa Ysabel Creek Streamflow with Ramona MWD Deliveries
- Strategy 3D: Injection Wells with Ramona MWD Deliveries

Model output from these simulations was processed to establish numerical values for six of the eight criteria developed as part of Task 1. The eight evaluation criteria from Task 1 are as follows:

- Criterion 1: Reduction of Modeled Deficit in Groundwater Storage
- Criterion 2: Average Reduction of Depth to Water
- Criterion 3: Fewer Exceedances of Minimum Thresholds
- Criterion 4: Efficiency of Recharge Strategy
- Criterion 5: Average Reduction of Groundwater Total Dissolved Solids Concentration

- Criterion 6: Fewer Consecutive Days Groundwater Levels are Below 30 Feet Below Ground Surface
- Criterion 7: Costs and Monetary Benefits of Implementation and Maintenance
- Criterion 8: Feasibility of Implementation and Maintenance

Numerical values for Criteria 6 through 8 for each recharge strategy are listed in **Table ES-1**. Additional details for the modeling results are provided in Section 3.3.

Table ES-1: Summary of Results for Evaluation Criteria

Recharge Strategy	Criterion 1 Reduction of Modeled Deficit in Groundwater Storage (AF)	Criterion 2 Average Reduction of Depth to Water (feet bgs)	Criterion 3 Fewer Exceedances of Minimum Thresholds (count)	Criterion 4 Efficiency of Recharge Strategy (percent)	Criterion 5 Average Reduction of Groundwater TDS Concentration (mg/L)	Criterion 6 Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs
1B–Enhance Streamflow Infiltration with In-stream Modifications	-1	0	4	110	-0.3	0
2A–Augment Streamflow with Sutherland Controlled Releases	0	1	41	84	3.1	1
3A–Augment Streamflow with Ramona MWD Deliveries	17	4	208	93	3.1	2
3D–Injection Wells with Ramona MWD Deliveries	80	10	476	97	6.7	10
Evaluation Criteria 7 (cost) and 8 (feasibility) will be presented in the draft Preliminary Feasibility Study, which will be completed in 2023. Larger positive values indicate larger benefits from implementing the recharge strategy.						

Although the simulations of recharge strategies show positive benefits toward enhancing resilience against undesirable results, the simulations also show some limitations of the recharge strategies. The maintenance of sustainable groundwater levels in the eastern portion of the Basin during extended drought periods may require implementation of more than one recharge strategy. With reduced natural aquifer replenishment due to extended droughts, recharge strategies (or demand reduction) would need to be implemented to avoid exceeding minimum thresholds and possible undesirable results. Depending on the availability of water from sources outside of the Basin and the frequency and duration of dry years, implementing more than one recharge strategy at a time, or combining a strategy with other options may be necessary to achieve sustainability. Doing so would provide the most operational flexibility to conjunctively manage the Basin's water resources. Further, modeling results suggest that the individual strategies might not be adequate to meet long-term sustainability goals.

Results from this effort will be used to help develop two additional documents: the Task 6 TM, which will use the simulation outcomes described herein to assess possible benefits to potential GDEs from implementing each of the four individual recharge strategies and the Preliminary Feasibility Study. The draft Preliminary Feasibility Study will be completed in 2023.

The following studies are recommended as part of adaptive management to provide resilience against undesirable results:

- Follow-on study of potential losses due to conveyance from Sutherland Reservoir to the Santa Ysabel Creek inflow point to the Basin, if the GSA chooses to further assess Strategy 1B
- Follow-on modeling of Sutherland Reservoir operations linked to regional system to further optimize water resources
- System-wide reservoir water supply analysis to determine alternative conjunctive-use strategies
- Pilot study to assess the viability of injection well operation, if the GSA chooses to further assess Strategy 3D
- Assessment of potential ecosystem impacts from addition of supplemental water into Santa Ysabel Creek
- Assess and update water-use agreements with water purveyors in the region to support future flexibility of recharge strategies in the Basin

1. INTRODUCTION

The San Pasqual Valley Groundwater Sustainability Agency (GSA) – composed of the City of San Diego (City) and the County of San Diego (County) – adopted the San Pasqual Valley Groundwater Sustainability Plan (GSP) and submitted it to the California Department of Water Resources (DWR) in January 2022 (City and County, 2021). The GSP provides guidance and quantifiable metrics to provide for the continued sustainable management of groundwater resources within the San Pasqual Valley Groundwater Basin (Basin) over the 20-year GSP implementation period **(Figure 1-1**). To accomplish this, the GSP includes a hydrogeological conceptual model, monitoring requirements, sustainable management criteria, and several projects and management actions (PMAs). The PMAs included in the GSP provide opportunities to enhance water supply, reduce demands, and otherwise support sustainable groundwater management in the Basin, allowing the GSA to respond to changing conditions and help prevent undesirable results, as defined in the GSP. The Basin is currently sustainably managed, so no additional PMAs are needed to achieve sustainability. However, implementing PMAs could improve resilience against challenging future hydrologic conditions, such as extended droughts.

This technical memorandum (TM) is the fifth of six that focuses on PMA No. 7, which is an Initial Surface Water Recharge Evaluation.

- The first TM describes the evaluation criteria by which the best surface water recharge strategies for the Basin will be determined (City, 2022a).
- The second TM describes the approach and results of a streambed investigation along Santa Ysabel Creek in the eastern San Pasqual Valley (SPV) and provides recommendations for updating the SPV GSP Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) (City, 2023a).
- The third TM describes the assessment of three types of water sources that could potentially be used for surface water recharge projects within the Basin, including stormwater flows in Santa Ysabel Creek in the eastern portion of the Basin, controlled releases from Sutherland Reservoir, and untreated water from Ramona Municipal Water District (Ramona MWD) (City, 2023b).
- The fourth TM describes a screening assessment of different recharge strategies, the basis for selecting the four following strategies for further assessment, and additional details about the four following strategies:
    - Strategy 1B–Enhance Streamflow Infiltration with In-stream Modifications
    - Strategy 2A–Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases
    - Strategy 3A–Augment Santa Ysabel Creek Streamflow with Ramona MWD Deliveries
    - Strategy 3D–Injection Wells with Ramona MWD Deliveries
- This fifth TM documents the work performed as part of Task 5 of PMA No. 7, which included the following two activities: SPV GSP Model update and simulation and assessment of the four strategies retained for further assessment from Task 4 (City, 2023c).

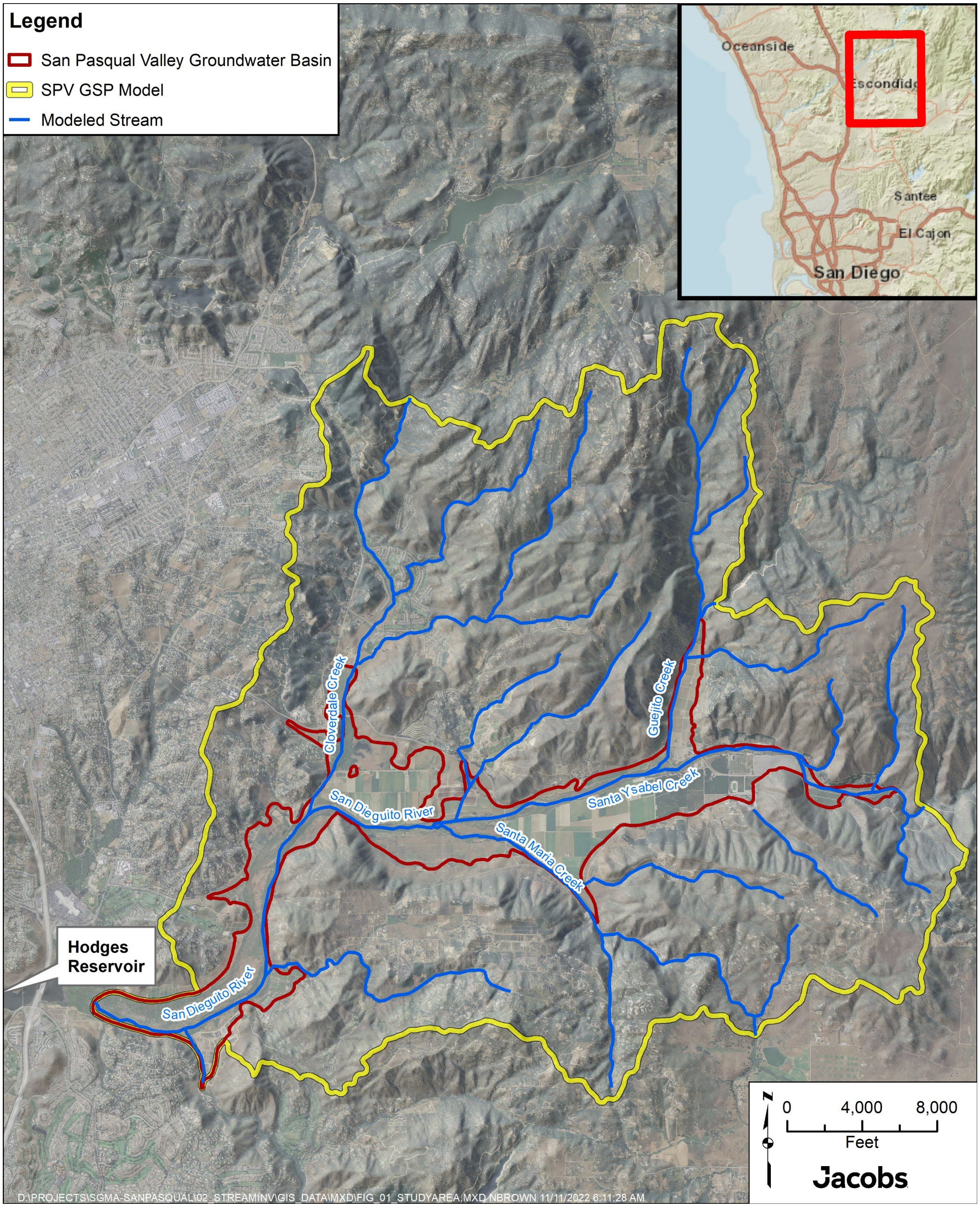


Figure 1-1: San Pasqual Valley Groundwater Basin and Model Area

The SPV GSP Model updates were conducted following the recommendations from the Task 2 streambed investigation (City, 2023a). The Task 2 streambed investigation was performed to provide site-specific data that could be used to improve the understanding of stream channel characteristics in Santa Ysabel Creek in the eastern portion of the Basin. From this point forward in this TM, the version of the SPV GSP Model used during development of the GSP (City and County, 2021) is referred to as SPV GSP Model v1.0, whereas the updated version that was used in Task 5 to evaluate the four selected recharge strategies is referred to as SPV GSP Model v2.0. The ultimate modeling objective for this Task 5 effort is to quantify potential groundwater benefits from implementing these four recharge strategies, using SPV GSP Model v2.0.

The GSA will use the Initial Surface Water Recharge Evaluation to better understand the recharge strategies, should they require implementation as part of adaptive management to avoid undesirable results, as defined in the GSP. Potential recharge areas presented in this TM have not been vetted by stakeholders or permitting agencies, so they should be viewed as conceptual for this stage of study. The Initial Surface Water Recharge Evaluation will be completed in 2023, and the resulting information will be provided in a Preliminary Feasibility Study. The Preliminary Feasibility Study will include the following sections:

- Evaluation Criteria and Ranking Process (Task 1)
- Streambed Investigation (Task 2)
- Water Sources for Recharge (Task 3)
- Potential Recharge Strategies (Task 4)
- Modeling Approach and Results (Task 5)
- Possible Benefits to Potential Groundwater Dependent Ecosystems (GDEs) (Task 6)

2. MODEL UPDATES

Updates to the SPV GSP Model v1.0 in this TM are divided into three categories: (1) Modeled streams, (2) Time discretization (how time is handled in the model), and (3) Recalibration, each of which is described here.

2.1 Modeled Streams

Streamflow and groundwater-surface water interaction along the modeled streams are simulated using the Streamflow Routing (SFR) package of the MODFLOW-OWHM software code (Boyce et al., 2020). The following subsections describe how modeled stream and runoff characteristics have been updated for the Initial Surface Water Recharge Evaluation.

2.1.1 Stream Channel Definition and Calculation Method

Cross sections used to describe the shape of the streambed in the model were updated to more closely reflect actual channel shapes in the Basin, rather than the simplified rectangular channel shapes used in the SPV GSP Model v1.0. Instead of using simple rectangular shapes to describe the stream channel, irregularly shaped cross sections were incorporated into the SPV GSP Model v2.0 using information acquired from the stream channel survey described in the Task 2 TM (City, 2023a), along with 3-meter to 10-meter digital elevation model data from the United States Geological Survey (USGS).

The SFR package in SPV GSP Model v1.0 represented modeled stream channels with simple rectangular channel shapes (City and County, 2021; City 2023a); therefore, whenever streamflow occurred in the model, the wetted width of the stream equaled the assigned rectangular stream width, regardless of the magnitudes of different streamflow events. As a result, the variations in streamflow width that occurred from storms with different intensities and durations were not as well represented in the SPV GSP Model v1.0 as they could be. Conceptually, an increase in streamflow width with higher flows would allow greater surface area for the stream to recharge the groundwater system. Because of the interest of the Initial Surface Water Recharge Evaluation in infiltration characteristics in the eastern portion of the Basin, the SPV GSP Model v2.0 was modified to use an eight-point cross section of the stream channel for each stream segment, rather than the fixed rectangular channels (**Figure 2-1**). The shapes of the different stream segments now included in the SPV GSP Model v2.0 are provided in Attachment A.

With this updated setup, stream depth and wetted perimeter (the perimeter of the cross-sectional area that is wet at a given time) are computed internally by the software code during a simulation based on the shape of the eight-point cross section, allowing the SPV GSP Model v2.0 to automatically account for wider streams that cover more of the stream channel during larger streamflow events and narrower streams that cover less of the stream channel during smaller streamflow events. This configuration of the SFR package provides the opportunity for improved representation of wetted widths of modeled streams that change through time and more accurate simulation of groundwater-surface water interactions during streamflow events of different magnitudes.

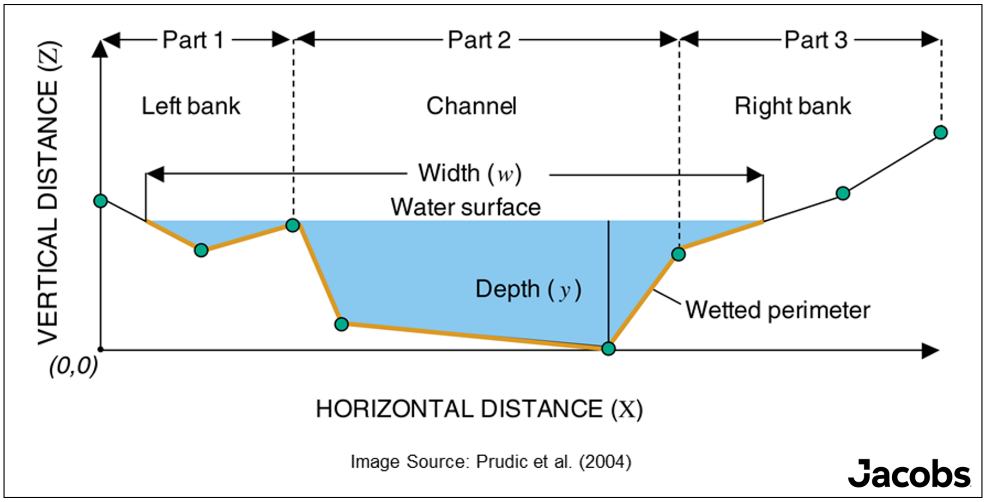


Figure 2-1: Conceptual Eight-point Cross Section

The eight-point cross section is split into the three parts shown on **Figure 2-1**, including the left bank, channel, and right bank also named Part 1, Part 2, and Part 3 correspondingly. One variable that is required with the SFR package is the Manning's roughness coefficient, which is a measure of the resistance of the stream channel to streamflow (Chow, 1959). This coefficient affects the velocity of streamflow in the modeled channel. Larger roughness coefficients have the effect of impeding modeled stream velocities, because larger values correspond to stream channels with greater resistance to streamflow. Although it is possible to assign different values of the Manning's roughness coefficient to the stream channel (Part 2) and to the stream banks (Parts 1 and 3) of the stream cross section (Prudic et al., 2004; Niswonger and Prudic, 2005), the modeling team assigned uniform roughness coefficient values in Parts 1 through 3 (**Figure 2-1**). This was done because there are no stream gauges within the Basin with long enough recording histories to calibrate the model to streamflow. Additionally, actual stream channel characteristics are quite complex and change over time. Thus, the modeling team did not want to overcomplicate the assignment of roughness coefficients to stream features in an ever-changing stream channel environment when the model simulations span multiple decades. The roughness coefficients assigned to the SFR package in the SPV GSP Model v2.0 are summarized in **Table 2-1** and are reasonable considering the types and conditions of stream channels included in the model (e.g., main channels and mountain streams) (Chow, 1959).

Table 2-1: Summary of Manning's Roughness Coefficients in SPV GSP Model v2.0

Stream	Manning's Roughness Coefficient
Santa Ysabel Creek	0.035 to 0.05
Guejito Creek	0.05 to 0.08
Santa Maria Creek	0.035 to 0.08
Cloverdale Creek	0.05 to 0.08
Sycamore Creek	0.08
Other Creeks	0.03 to 0.08
San Dieguito River	0.08

After modifying the shapes of the modeled stream channels and changing the SFR package to compute transient wetted widths of the streams during the simulations, the effective vertical hydraulic conductivity values assigned to the SFR package in the SPV GSP Model v1.0 were also updated, as is described in the following subsection.

2.1.2 Hydraulic Conductivity of Modeled Streams

Hydraulic conductivity (K) is one of the most important input parameters in a numerical groundwater flow model. It is a measure of the physical capacity of porous materials (e.g., clay, silt, sand, gravel, and rock) to allow fluids to move through them. It is a function of the interconnected pore space within the materials and the characteristics of the fluid (specifically the fluid density and viscosity) flowing through the materials. In this case, the fluid of interest is water. Porous materials can resist water flow differently in different directions. Typically, alluvial sediments like those in the Basin are deposited in such a way that the horizontal K is larger than the vertical K. In other words, water flowing vertically through the sediments is typically met with more resistance than water flowing horizontally. However, this is not necessarily true for fractured bedrock systems, where the direction of fractures and other imperfections in the rock affects the directional resistance to water flow. Regardless of the directional characteristics of K, K values are larger for sand and gravel and smaller for silt, clay, and rock. A larger K value means that water moves more easily through the material than a material with a smaller K value, which has an increased resistance to flow. Conceptual images of water flowing through materials with different vertical K characteristics are presented in **Figure 2-2**. Hypothetical water flowpaths are shown in this figure as blue flowlines moving through and around the materials presented. Note how these flowlines become less straight as the flowlines are met with more resistance along the flowpath in the lower-K materials. The blue flowlines shown for the clay in **Figure 2-2** are intended to imply that water would move very slowly through the clay and would mostly flow around it. When considering groundwater recharge strategies in a stream channel, the K value is an important parameter that limits how much streamflow can infiltrate the streambed material and recharge the underlying aquifer.

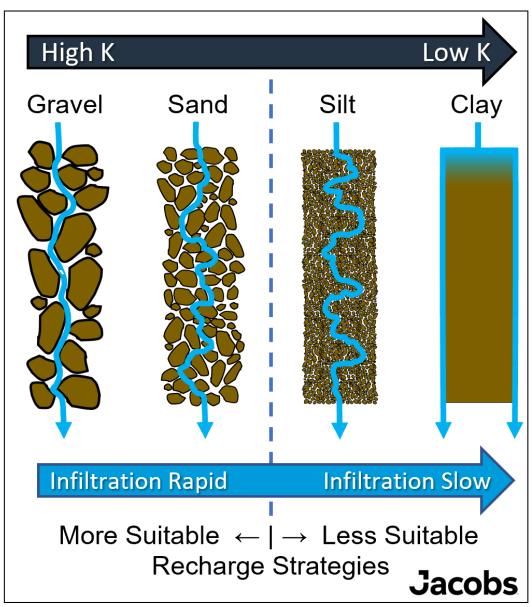


Figure 2-2: Role of Hydraulic Conductivity with Infiltration

To help put the role of streambed K values into perspective, it is important to have a general understanding of how streams and aquifers are simulated in the SPV GSP Model. With numerical groundwater models, the three-dimensional surface and subsurface region being modeled is subdivided into "mathematical boxes" known as cells. All versions of the SPV GSP Model are subdivided into 100-foot by 100-foot model cells in each model layer. The software code solves the groundwater flow equations for each model cell at each simulation time step. The result of these calculations is cell-by-cell values at a given simulation time for groundwater elevation, groundwater flow between each cell with its neighboring cells, and groundwater storage. Portions of modeled streams that are located within a model cell are known as stream reaches. Stream reaches "sit on top" of the underlying groundwater cells (**Figure 2-3**). Portions of groundwater cells above and below the water table represent the vadose zone and aquifer, respectively. The water table is depicted in **Figure 2-3** as the horizontal blue dashed line with the blue inverted triangle. The vadose zone is the subsurface interval that is only partially saturated with water above the water table, whereas the aquifer is fully saturated with water.

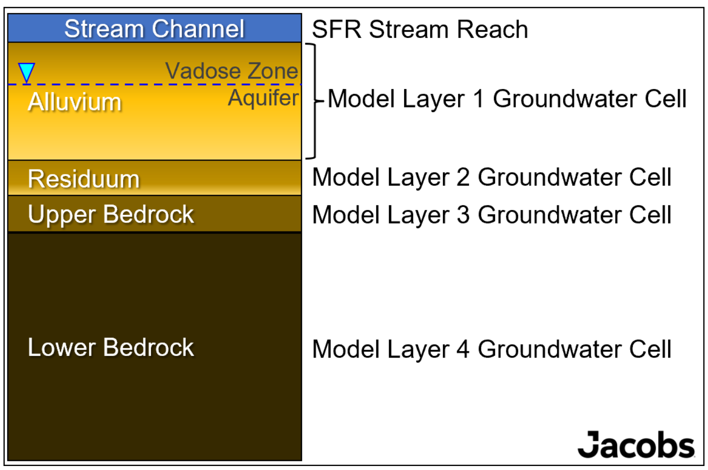


Figure 2-3: Stream Reaches and Groundwater Cells

Values for the vertical K of the streambed material derived from the Task 2 streambed investigation are representative of sediments in the stream channel and some upper portion of the vadose zone below the stream channel (**Figure 2-3**). Water that infiltrates the stream channel, moves through the vadose zone, and enters the aquifer is referred to as groundwater recharge from streams. The rate at which water infiltrates the stream channel at the surface is not necessarily the rate at which the infiltrated water enters the aquifer as groundwater recharge from the stream. This is because the vertical K of the vadose zone materials below the stream channel affects the rate of groundwater recharge from the stream.

The influence of vertical K of the vadose zone on groundwater recharge from streams must be accounted for by the modeler. The K values of the streambed materials that were derived in Task 2 (City, 2023a) are not appropriate to directly assign to the SFR package as they only account for the vertical K of the stream. To account for the K of both the streambed and underlying vadose zone, the modeling team developed a mathematical formulation as described in Attachments B and C, respectively.

2.1.3 Improved Runoff Routing

Understanding how runoff flows across a watershed is important for understanding the overall water balance. In the model, this translates into understanding how runoff flows between model cells. Runoff is examined at the subwatershed level, where a subwatershed is any of several parts of a larger watershed that drains to a specific location. Although runoff is not a major component of the water balance during most months in the model area, there are times when some runoff is generated in the model.

With the SPV GSP Model v1.0, runoff from groups of model cells called "water balance subareas" was distributed evenly across the SFR reaches that were within each water balance subarea (City and County, 2021). However, some water balance subareas spanned more than one subwatershed, so the routing of runoff in the SPV GSP Model v1.0 was not as physically realistic as it could be.

Runoff routing assignments were therefore reconfigured in the SPV GSP Model v2.0 to better account for how subwatersheds within the modeled area collect and convey runoff to streams. Subwatershed boundaries from the United States Environmental Protection Agency (US EPA) National Hydrography Dataset Plus (NHDPlus) (US EPA, 2019) repository were used to relate SFR reaches (**Figure 2-3**) to subwatersheds within the model area, rather than only to the water balance subareas. The distribution of NHDPlus subwatersheds and water balance subareas within the model area is shown in **Figure 2-4**. The runoff component of the SPV GSP Model v2.0 was reconfigured so that each SFR reach receives an equal amount of runoff generated within its subwatershed. This setup allows the runoff to flow downstream through the SFR as streamflow originating within its subwatershed.

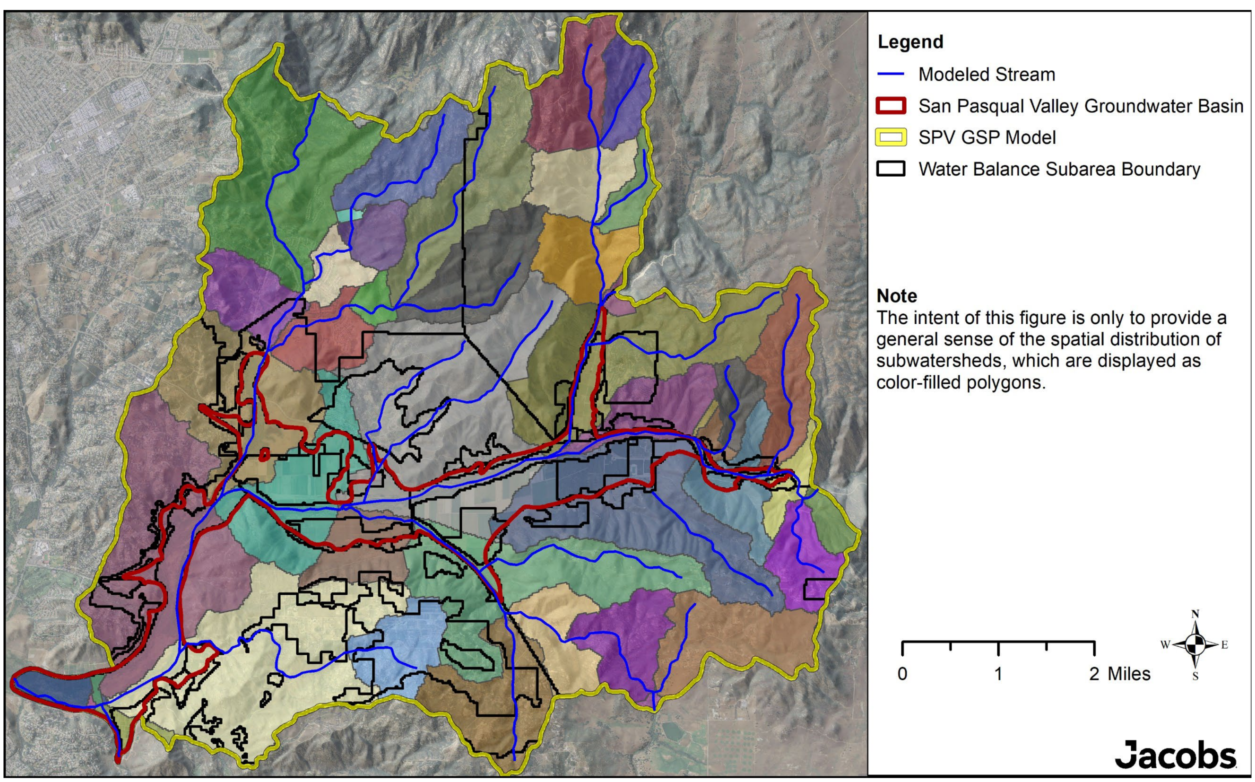


Figure 2-4: National Hydrography Dataset Plus Subwatersheds within the Model Area

2.2 Time Discretization

A computer simulation of flow that varies in time must be set up with discrete time intervals known as stress periods. A stress period is an interval of time at which different values of precipitation, stream inflows at the perimeter of the model, and groundwater pumping are used in the model (e.g., daily or monthly). The SPV GSP Model v1.0 was set up to simulate hydrologic conditions with monthly stress periods. The monthly stress periods in the SPV GSP Model v1.0 were adequate for establishing long-term water budgets and supporting the development of the GSP (City and County, 2021). However, for the current effort, the modeling team wanted to improve the ability of the model to simulate selected streamflow events that occur for durations of less than one month. Doing so provides the opportunity to better simulate selected recharge strategies that utilize the existing streambed to infiltrate intermittent Santa Ysabel Creek streamflow in the eastern portion of the Basin.

A 24-hour day is the finest practical stress period duration for a numerical integrated flow model as large as the SPV GSP Model with a simulation period that spans multiple years to decades. This is due to the practical constraints of computing resources and the need to perform multiple simulations to complete the work. If one were to replace all monthly stress periods with daily stress periods in the SPV GSP Model v2.0, runtimes would range from several days to weeks to complete a single simulation of a recharge strategy, which would substantially slow the modeling progress. Therefore, the modeling team implemented an approach of embedding daily stress periods selectively throughout the 15-year historical simulation period. The basis for selecting timeframes within the 15-year historical simulation period to embed daily stress periods is as follows. Daily streamflow measured at the USGS Santa Ysabel Creek stream gauge near Ramona (gauge number 11025500) from the 15-year historical record were processed to identify periods when continuous streamflow occurred. The modeling team evaluated different numbers of days within a month when streamflow occurred and selected seven days as the basis for embedding daily stress periods. If streamflow at the Santa Ysabel Creek stream gauge occurred for at least seven days within a given month during the 15-year historical period, then that monthly stress period was subdivided into daily stress periods. Selection of seven streamflow days per month as the basis for embedding daily stress periods provided a reasonable balance between being able to simulate more storm events at finer time scales while avoiding excessively long model runtimes. A graph illustrating the timing of the daily stress periods (blue bars) along with monthly streamflow at the Santa Ysabel Creek stream gauge are shown in **Figure 2-5**. Thus, the SPV GSP Model v2.0 incorporates a combination of daily and monthly stress periods.

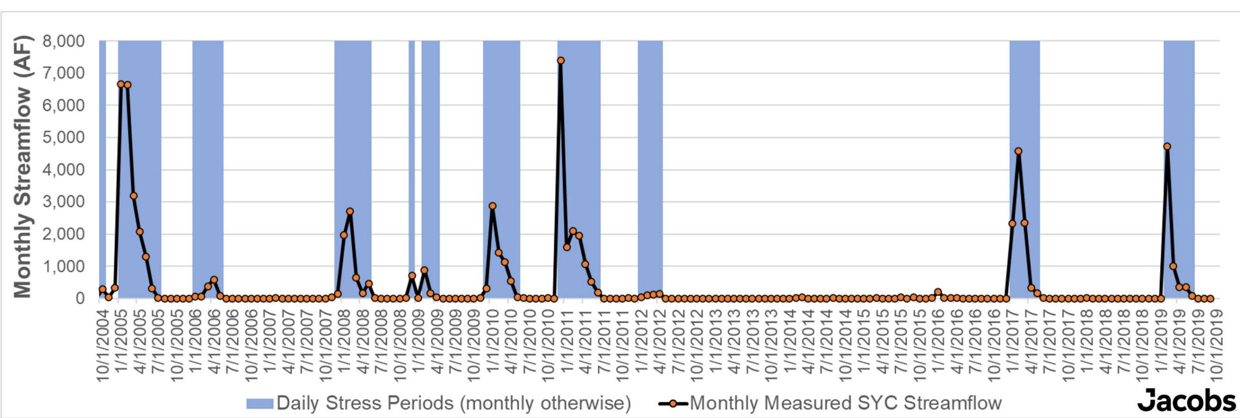


Figure 2-5: Portions of Historical Simulation with Daily Stress Periods

2.3 Recalibration

After updating the modeled stream and runoff characteristics and stress period configuration, as described in Sections 2.1 and 2.2, the 15-year historical simulation from water year (WY) 2005 through WY 2019 was run to allow for a calibration check. Model calibration is a process of adjusting selected model input parameter values within realistic ranges until modeled groundwater levels are reasonably consistent with groundwater levels measured in monitoring wells. This calibration check was done to assess whether the SPV GSP Model v2.0 could adequately replicate measured groundwater levels after the updates described above were incorporated. The outcome of that calibration check indicated that recalibration was necessary. The updates described above resulted in more permeable stream channels, a more permeable alluvial aquifer, and more realistic transient streamflow behavior, which resulted in modeled groundwater elevations being too high across the Basin as compared with measured groundwater levels.

The recalibration approach initially included reviewing the updated groundwater budget of the Basin to note the largest sources of water to the Basin relative to the groundwater outflow processes and rates. This step was done to provide guidance for how to better match groundwater levels by adjusting parameters that affect rates of groundwater inflows and outflows. Additionally, the assigned K values and groundwater storage values of the alluvial aquifer, residuum, and surrounding rock were also varied to gain insight into how modifications to these parameters could improve the fit to measured groundwater levels. The recalibration effort resulted in the SPV GSP Model v2.0, which was sufficiently recalibrated for use on this Initial Surface Water Recharge Evaluation. Additional details regarding the recalibration of the SPV GSP Model v2.0 are provided in Attachments C and D.

3. SIMULATIONS OF RECHARGE STRATEGIES

Once the SPV GSP Model v2.0 was recalibrated, it was used to simulate the four retained recharge strategies discussed in the Task 4 TM (City, 2023c). The following subsection describes the approach and assumptions for setting up and simulating the recharge strategies.

3.1 Approach for Simulating Recharge Strategies

As discussed above, the intent of this study is to better understand the recharge strategies, should they require implementation as part of adaptive management to avoid undesirable results, as defined in the GSP. The four recharge strategies retained from the Task 4 TM (City, 2023c) are described as follows:

- **Strategy 1B**–Enhance streamflow infiltration with in-stream modifications. The in-stream modification in this case is a hypothetical inflatable rubber dam constructed across the channel of Santa Ysabel Creek (white line across Santa Ysabel Creek east of Ysabel Creek Road in **Figure 3-1**).
- **Strategy 2A**–Augment streamflow where Santa Ysabel Creek flows into the model area with controlled releases from Sutherland Reservoir (light blue triangle in **Figure 3-1**).
- **Strategy 3A**–Augment streamflow at and downstream from a hypothetical outfall location in Santa Ysabel Creek with Ramona MWD deliveries (green triangle in **Figure 3-1**).
- **Strategy 3D**-Injection of Ramona MWD deliveries at three hypothetical injection wells in the eastern portion of the Basin (yellow circles in **Figure 3-1).**

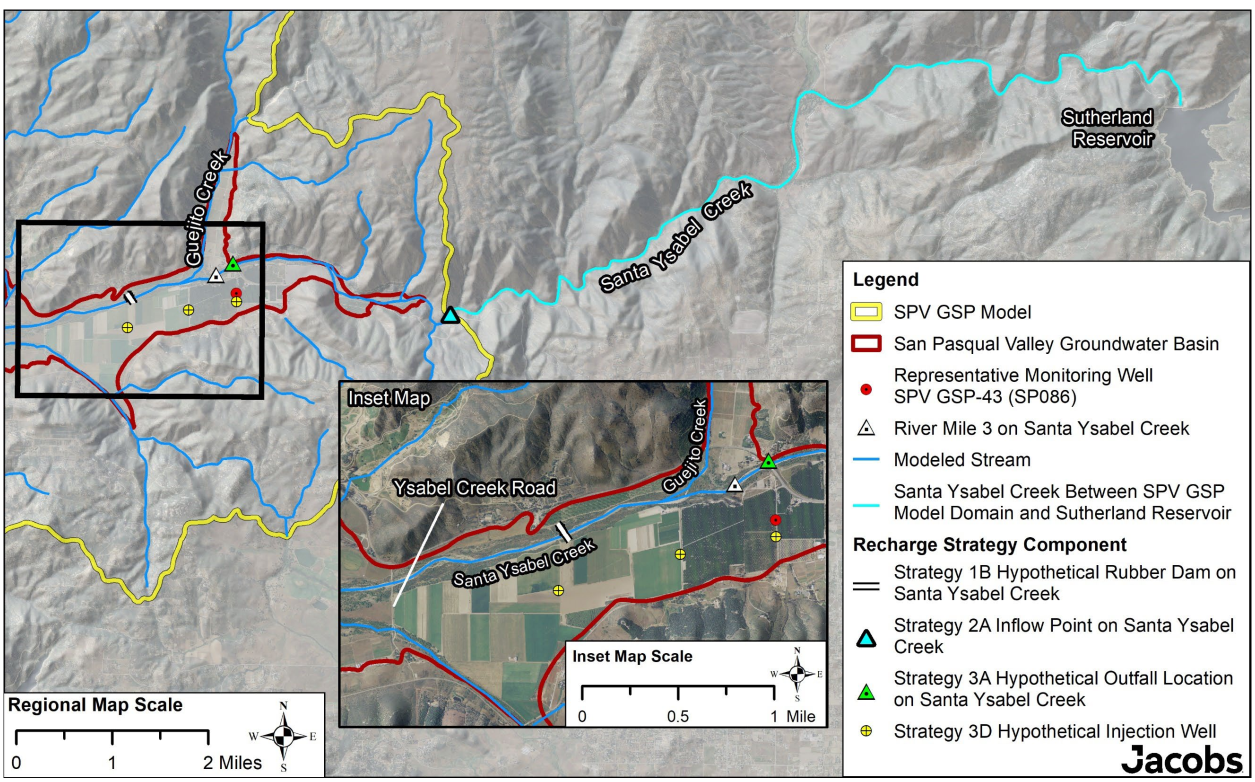


Figure 3-1: Conceptual Layout for Recharge Strategies

For this evaluation, it was assumed that the intent of implementing a recharge strategy would be to enhance resilience against undesirable results, as defined in the GSP (City and County, 2021), rather than to keep the Basin full of groundwater year after year. Therefore, determining when and how much source water is needed was critical in determining the modeling approach for simulating recharge strategies that would rely on controlled releases and deliveries from Sutherland Reservoir and Ramona MWD, respectively (Strategies 2A, 3A and 3D). For Strategy 1B, the source water would be naturally occurring stormwater in the form of streamflow in Santa Ysabel Creek (**Figure 3-1**). Thus, Strategy 1B would only be implemented under specific streamflow conditions in Santa Ysabel Creek, as described in Section 3.1.1.

The modeling approach first required establishing a simulation that did not incorporate any of the recharge strategies described above. This simulation is hereafter in this TM referred to as the Baseline simulation. The Baseline simulation was created by using the SPV GSP Model v2.0 to simulate the same hydrology, land-use, and climate conditions described in the GSP (City and County, 2021). The 15-year historical simulation period includes WYs 2005 through 2019 and the 52-year projection period includes WYs 2020 through 2071. The projection period incorporates projected changes in climate based on the Hadley Centre Global Environment Model v2-ES (HadGEM2-ES) global circulation model (GCM) with the Representative Concentration Pathway 8.5 emissions scenario. This GCM was selected during the development of the GSP for its warmer and drier tendencies. Full details regarding the assumptions associated with the projection period can be found in Section 5 of Appendix I of the GSP (City and County, 2021). Land use and the associated agricultural demand within the Basin were held constant at 2018 conditions for the entirety of the projection period. Thus, the Baseline simulation and recharge strategy simulations do not consider changes in land use that could occur in the future in response to droughts or other factors.

Preliminary SPV GSP Model v2.0 recharge simulations were conducted and compared to the Baseline simulation to get an initial sense for how streamflow in Santa Ysabel Creek and Basin groundwater levels might respond to implementation of the recharge strategies. This comparative assessment helped the modeling team consider possible operational rules or "Conditions" that would help establish the timing for when to implement Strategies 2A, 3A, and 3D in the simulations. Because the water from Sutherland Reservoir and Ramona MWD's untreated water system would have associated costs, the goal of incorporating these Conditions in the modeling process is to simulate recharge strategies that would strive for maximizing recharge benefits while minimizing excess streamflow across Ysabel Creek Road[1]. Based on these preliminary modeling simulations, the decision process shown in **Figure 3-2** was developed for Strategies 2A, 3A, and 3D.

[1] Excess streamflow across Ysabel Creek Road is defined in this TM as the streamflow across Ysabel Creek Road in a recharge strategy simulation minus the streamflow across this road in the Baseline simulation. This flow volume is considered excess in that it would occur because of implementing a recharge strategy, as opposed to what would have naturally occurred. Because this evaluation only focuses on recharge benefits to the Basin, any water flowing in Santa Ysabel Creek that, because of implementing a recharge strategy, ultimately leaves the Basin in San Dieguito River is considered a loss. (**Figure 1-1**).

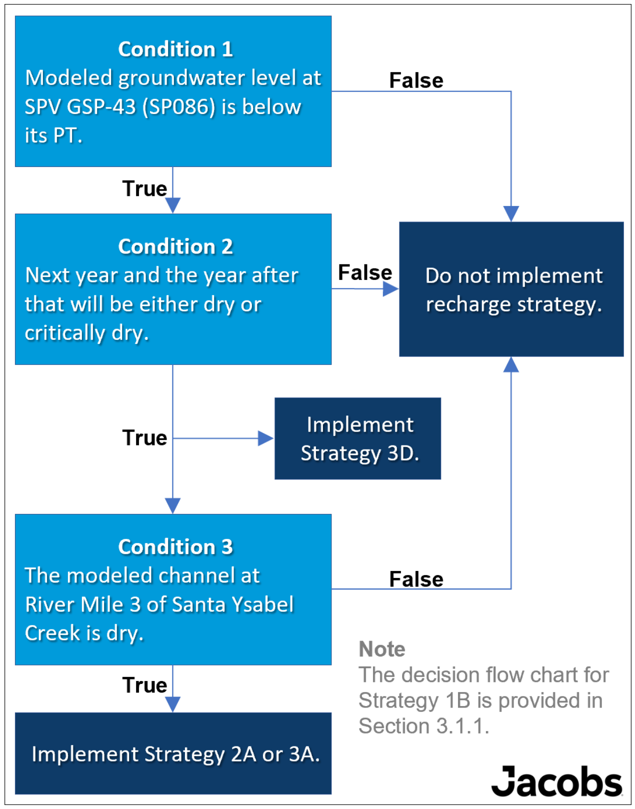


Figure 3-2: Decision Flow Chart for Recharge Strategies 2A, 3A, and 3D

The Conditions were developed to establish initial sets of rules for when to implement the recharge strategies in the model simulations. These rules would likely be modified if the GSA were to choose to implement the recharge strategies described herein. Additional details for the strategy timing are provided as follows:

- **Condition 1**: During development of the GSP, a planning threshold (PT) was established for representative monitoring wells. The intent of these PTs is to provide an early warning for planning purposes before groundwater levels at a representative monitoring well (RMW) drop below minimum thresholds. Condition 1 uses the PT elevation of 347.4 feet[2] at RMW SPV GSP-43 (SP086), which was established during the development of the GSP (City and County, 2021). This particular well is used for Condition 1 due to its location in the eastern portion of the Basin (**Figure 3-1**) and the tendency for modeled groundwater levels at this well to drop below its PT more frequently than at other RMWs in the eastern portion of the Basin. The modeled groundwater-level hydrograph for SPV GSP-43 (SP086) is shown in **Figure 3-3** along with the timing for when Condition 1 is met (see the vertical yellow bars, which coincide with times when the black line drops below the horizontal dashed yellow line). The modeled “head” in the figure legend is synonymous with the modeled “groundwater elevation”. If modeled groundwater levels at SPV GSP-43 (SP086) at the end of a given month in the Baseline

[2] All elevations in this TM are presented in reference to the North American Vertical Datum of 1988 (NAVD88)

simulation are not below the PT, then additional flows associated with Strategy 2A, 3A, or 3D are not simulated. If Condition 1 is met for a given month, then Condition 2 is assessed, as described below.

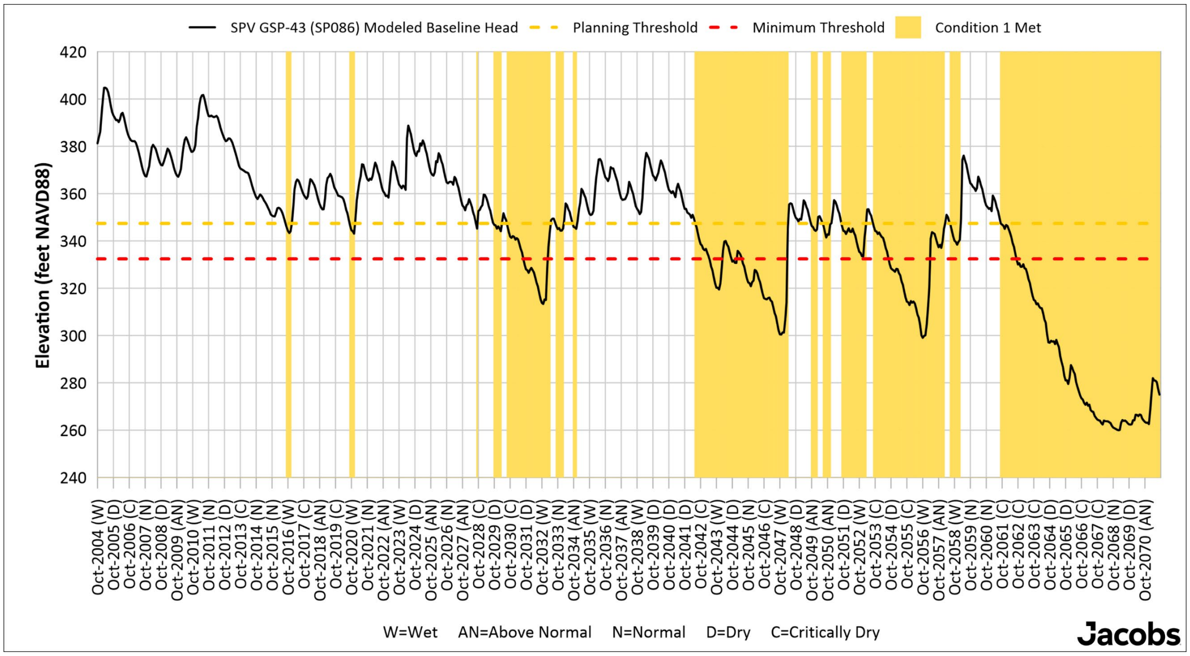


Figure 3-3. Timing for When Condition 1 is Met at SPV GSP-43 (SP086)

- **Condition 2**: A water year classification scheme was developed during GSP development to establish WY types based on annual precipitation including wet, above normal, normal, dry, and critically dry classifications. These classifications are defined for the historical and projection periods. Condition 2 is assessed if Condition 1 is met. Condition 2 incorporates a 2-year look-ahead at WY type with the Baseline simulation for the months during which Condition 1 is met. If this look-ahead indicates that two consecutive dry or critically dry years occur, then the additional flows from Sutherland Reservoir or Ramona MWD would be implemented in the recharge simulation. The timing for when Conditions 1 and 2 are met during the 67-year simulation period is illustrated in **Figure 3-4**. Condition 2 is intended to avoid controlled releases and deliveries if, after Condition 1 is met, either of the two following years has a WY type of wet, above normal, or normal. This Condition was chosen because past groundwater monitoring has demonstrated that Basin groundwater levels are able to rebound naturally to some degree during years with these WY types. For example, modeled groundwater levels in October 2020 in **Figure 3-4** drop below the PT established for SPV GSP-43 (SP086), so Condition 1 is met at that time. However, modeled groundwater levels rebounded naturally by nearly 30 feet after October 2020 during normal and above normal water years without the need to implement a recharge strategy. If Condition 2 is met, then that would mean drier conditions will occur over the two years after Condition 1 is met, which would limit the natural rebound of Basin groundwater levels. For example, Condition 2 is met in October 2029, because the two years after that are designated as critically dry and dry. If Condition 1 is met for a given month, and Condition 2 is also met, then Strategy 3D is implemented (see the timing that coincides with the vertical gray bars in **Figure 3-4**). However, the decision for implementing Strategy 2A or 3A also depends on the assessment of Condition 3, as shown in **Figure 3-2** and below.

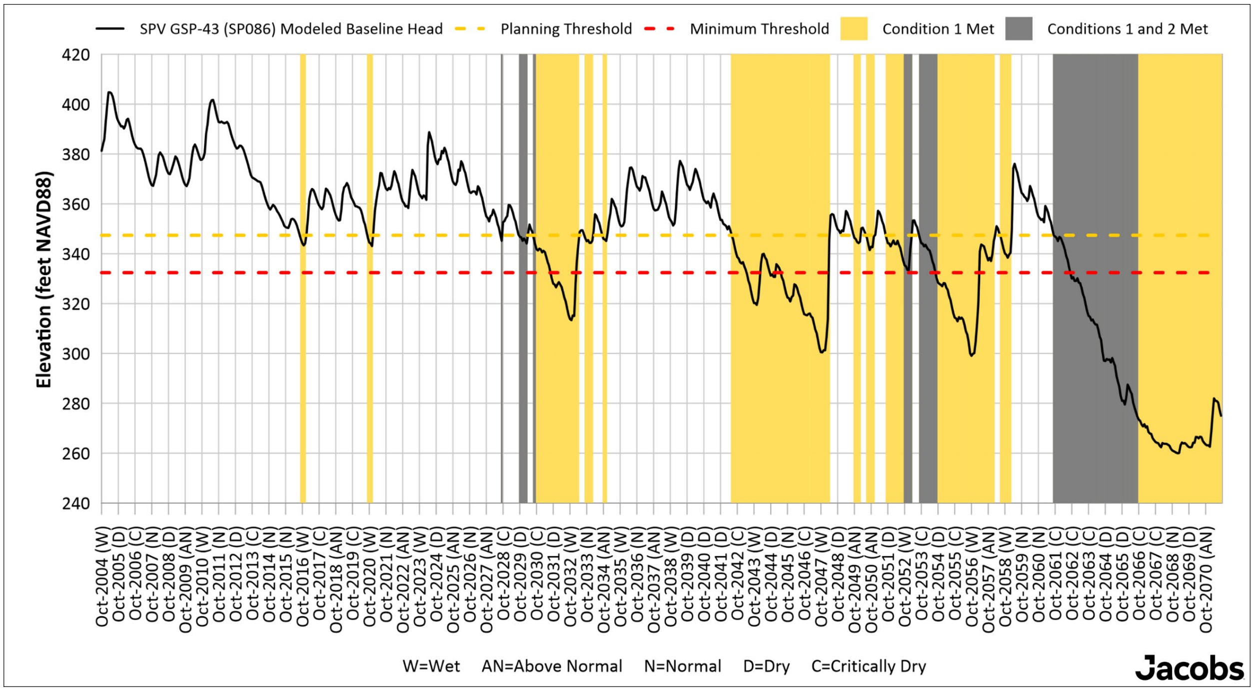


Figure 3-4: Implementation Timing for Strategy 3D (When Conditions 1 and 2 are Met)

- **Condition 3**. If modeled streamflow in Santa Ysabel Creek occurs when Conditions 1 and 2 are met, then releases or deliveries of water to the Santa Ysabel Creek at that time would have a greater chance of creating excess flows across Ysabel Creek Road in the model. Excess flow across Ysabel Creek Road is considered a loss for this study because it that water would not recharge the eastern portion of the Basin. River Mile 3 shown in **Figure 3-1** was used to assess whether modeled streamflow in the Baseline simulation occurs in Santa Ysabel Creek when Conditions 1 and 2 were met. Therefore, Strategy 2A or 3A, the two recharge strategies that rely on streambed infiltration, is implemented in the recharge simulation only if streamflow does not occur in the Baseline simulation at River Mile 3 during a month when Conditions 1 and 2 are met. The timing for when all three Conditions are met and Strategy 2A or 3A is implemented is illustrated in **Figure 3-5**. Comparison of the vertical gray bars in **Figure 3-4** and **Figure 3-5** shows that inclusion of Condition 3 results in fewer months when Strategy 2A or 3A is implemented (**Figure 3-5**), as compared with Strategy 3D (**Figure 3-4**).

  Condition 3 is not assessed for Strategy 3D because injection well performance would depend on aquifer parameters rather than infiltration conditions in Santa Ysabel Creek. Thus, all three Conditions must be met for a given month in the Baseline simulation for Strategy 2A or 3A to be implemented in the recharge simulation, whereas only Conditions 1 and 2 need to be met for Strategy 3D to be implemented in the recharge simulation (**Figure 3-2** and **Figure 3-4**).

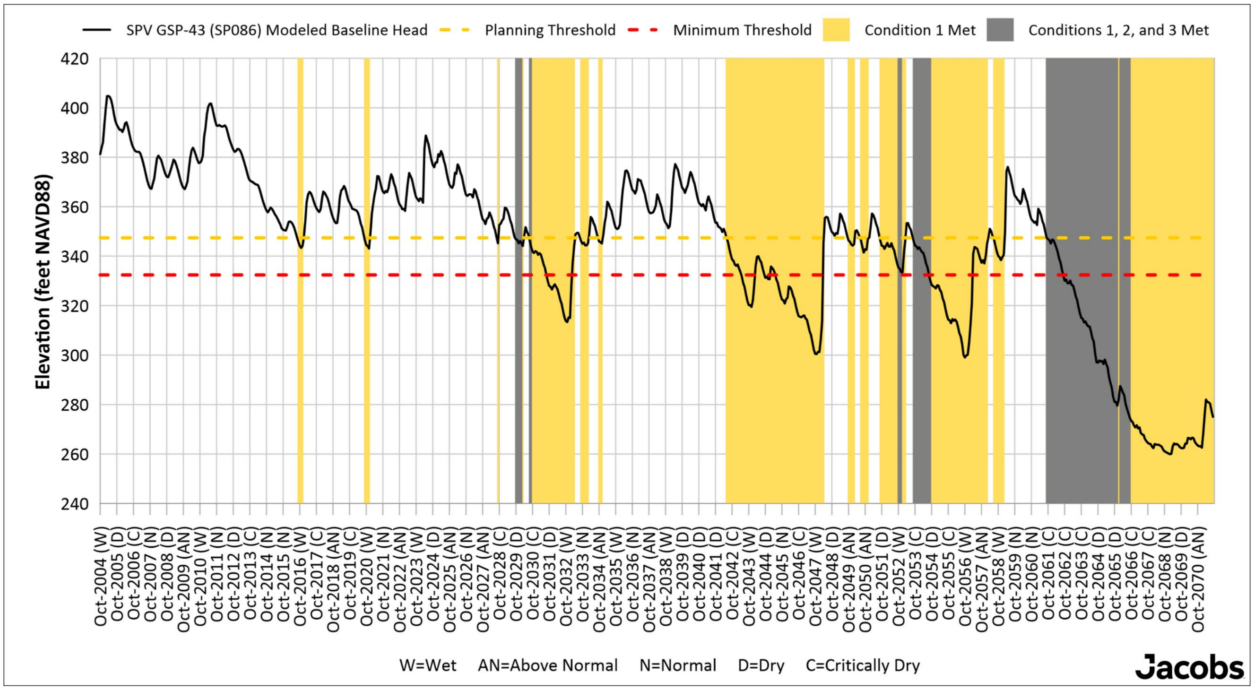


Figure 3-5: Implementation Timing for Strategy 2A or 3A (When Conditions 1, 2, and 3 are Met)

The three Conditions described above were used to decide on the timing for when to implement additional flows associated with Strategy 2A, 3A, or 3D in the recharge simulations. Implementation of these strategies in reality could require other real-time operations considerations not included herein. For example, additional time would be needed before the initial releases or deliveries to develop an agreement with the parties involved. Regardless, the types of observations and forecasts described in the three Conditions are important factors that should be incorporated into adaptive management planning.

Although the decision flow chart shown in **Figure 3-2** helps establish the timing for when to implement Strategy 2A, 3A, or 3D, flow constraints were also needed to determine the volume of source water needed during those times. These flow constraints, as well as other additional details and assumptions, are provided for each recharge strategy in the following subsections.

3.1.1 Strategy 1B–Enhance Streamflow Infiltration with In-stream Modifications

The goal of Strategy 1B is to enhance streambed infiltration along Santa Ysabel Creek through in-stream modifications (City, 2023c). A permanent, channel-spanning, inflatable rubber dam across Santa Ysabel Creek (**Figure 3-6**) was selected for further evaluation using the SPV GSP Model v2.0. Strategy 1B is the only recharge strategy considered in this TM that does not rely on controlled releases from Sutherland Reservoir or deliveries from Ramona MWD. Instead, it relies on stormwater in the form of streamflow in Santa Ysabel Creek at the location shown in **Figure 3-1**. Therefore, the decision flow chart shown in **Figure 3-2** does not apply to Strategy 1B; instead, the decision flow chart shown in **Figure 3-7** applies to Strategy 1B.

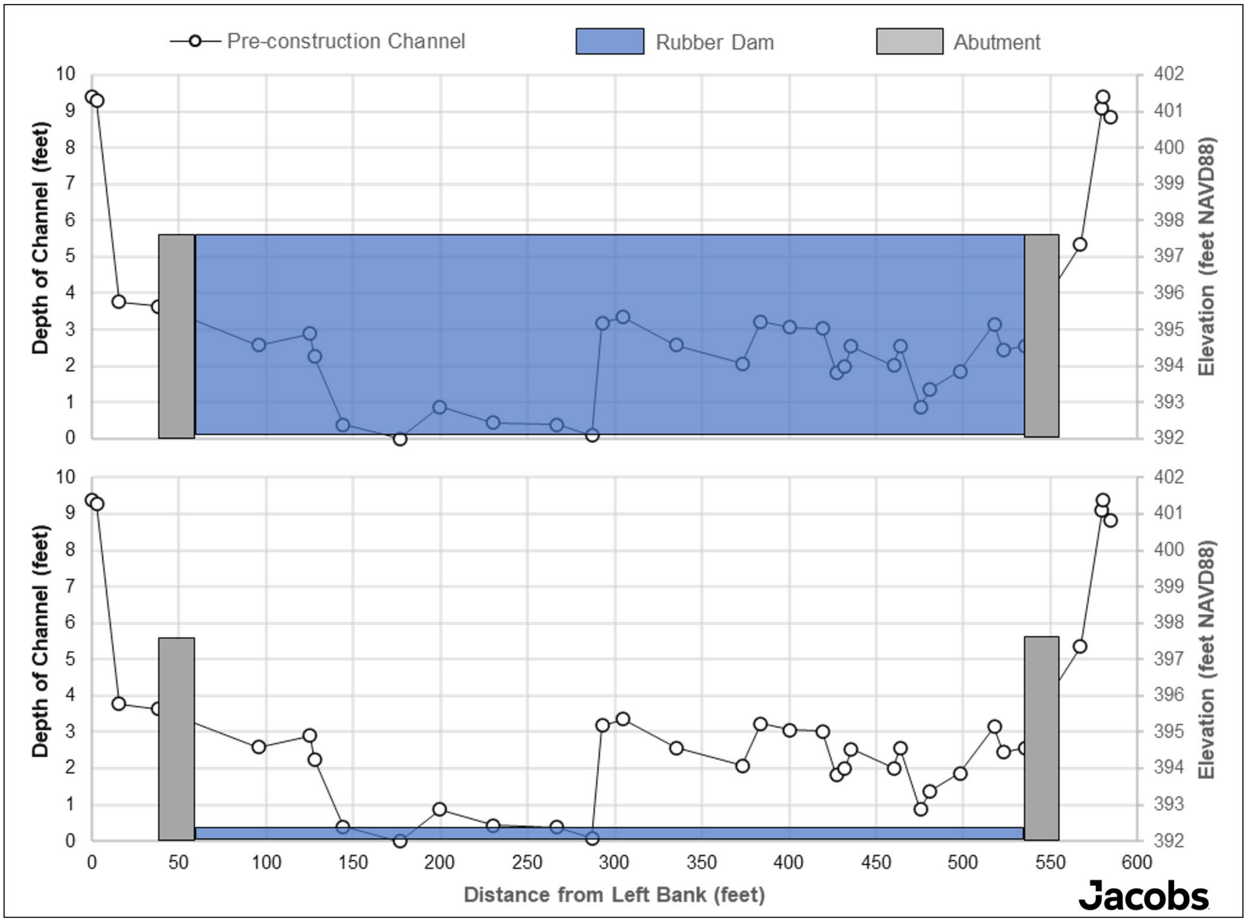


Figure 3-6: Concept for Inflatable Rubber Dam Across Santa Ysabel Creek Channel at Transect 4

Conceptually, the rubber dam would be inflated during selected periods to detain stormwater and increase the opportunity for additional infiltration and groundwater recharge behind the dam (when both Conditions A and B are met; see **Figure 3-5**) and deflated when Santa Ysabel Creek is dry or during higher-streamflow periods to allow stormwater in the creek to flow past the dam (when either Condition A or B is not met; see **Figure 3-5**). Therefore, determining the timing for inflating and deflating the dam was the first step in developing the approach for simulating Strategy 1B. The following discussion in this subsection describes the approach and assumptions for determining when to inflate the rubber dam (**Figure 3-7**).

As with the other recharge strategies, Strategy 1B is based on Baseline simulation outputs. Modeled streamflow at the hypothetical rubber dam location shown in **Figure 3-1** and **Figure 3-8** in the Baseline simulation was processed for WYs 2005 through 2071 to establish the timing for when the rubber dam would be inflated and deflated.

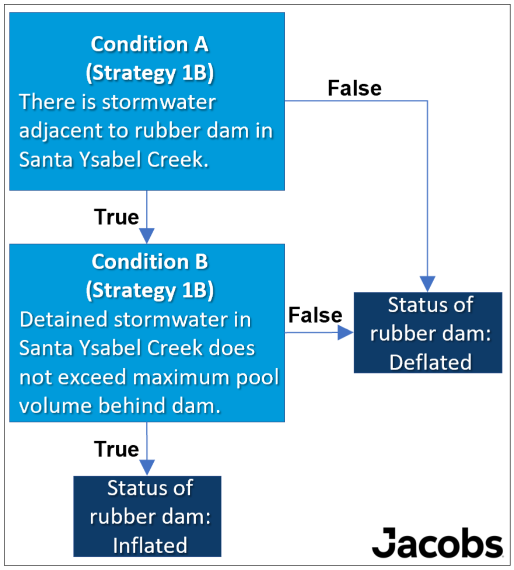


Figure 3-7: Decision Flow Chart for Strategy 1B

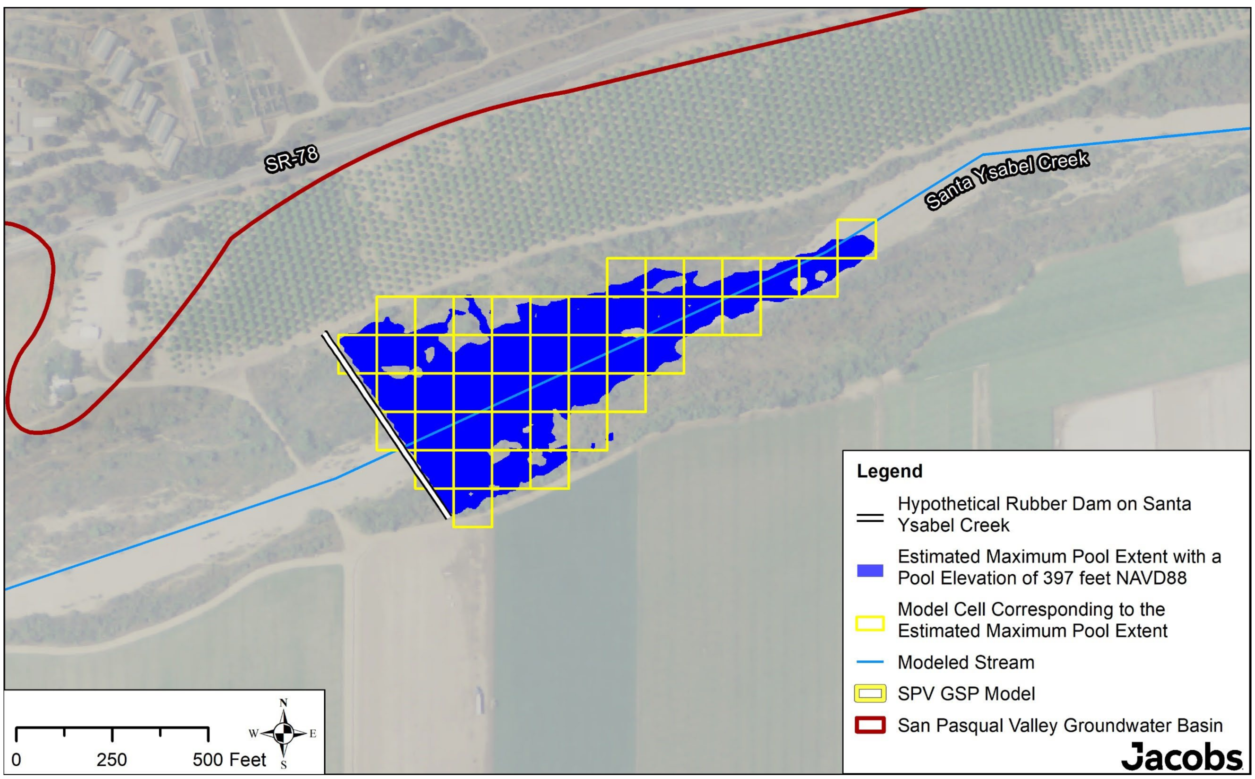


Figure 3-8: Estimated Maximum Pool Extent Behind the Hypothetical Inflatable Rubber Dam

Operation of the dam should ensure that a maximum pool volume is not exceeded, to minimize the potential for adverse flooding in upstream areas and to ensure that the pool does not overtop the dam and create erosional hazards around and downstream of the dam. Using the best available topographic data[3], a maximum pool surface elevation and extent behind the dam was estimated. This extent is shown in blue in **Figure 3-8** and is based on an assumed maximum pool depth of 5 feet behind the dam, which would be 6 inches below the top of the dam shown in **Figure 3-6**. The pool surface elevation corresponding to this 5-foot depth behind the dam is approximately 397 feet NAVD88. Once the maximum pool extent was estimated, an equation that defines the relationship between the pool volume and pool depth was established with the aid of Surfer® v23 and Excel software. The maximum pool volume of 11.3 acre-feet (AF) for a pool depth of 5 feet behind the dam was calculated using Surfer. The output data from Surfer were plotted in Excel and fit with the equation shown in **Figure 3-9**.

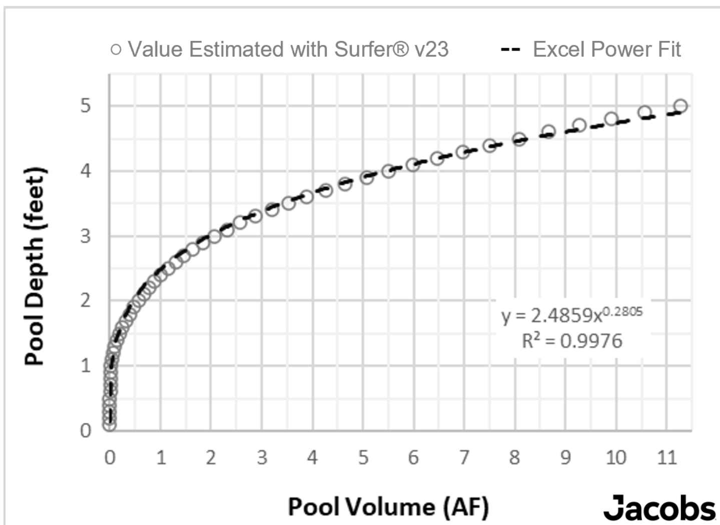


Figure 3-9: Estimated Pool Depth Versus Pool Volume

Once the maximum pool volume and the equation shown in **Figure 3-9** were developed, the modeled streamflow from the Baseline simulation at the SFR reach representing the location of the rubber dam was tabulated in an Excel spreadsheet. A daily pool-water-balance was then developed in this spreadsheet based on the tabulated streamflow from the Baseline simulation to compute time-series groundwater recharge values for the pool that reflect operation of the inflatable rubber dam. This pool-water-balance equation is provided as Equation 3-1:

$$S_t = S_{t-1} + Qin_t - Qout_t \quad (3\text{-}1)$$

[3] The best available topographic data that are continuous across Santa Ysabel Creek and the areas surrounding the modeled location of the rubber dam (**Figure 3-1** and **Figure 3-6**) are 3-meter digital elevation model data from the USGS.

where

S_t = pool storage for current daily time step (AF)
S_{t-1} = pool storage from previous daily time step (AF)
Qin_t = detained stormwater volume for current daily time step (AF)
$Qout_t = \frac{Dp_t}{\left({}^{b_{sb}}/_{K_{v-SFR}}\right)}$ = groundwater recharge from pool for current daily time step (AF)
Dp_t = pool depth for current daily time step (feet)

Equation 3-1 uses the Baseline-simulated streamflow corresponding to the location of the rubber dam to track the daily pool volume that would be detained each day behind the dam. It also accounts for the groundwater recharge from the pool each day. With this pool mass balance, the rubber dam is assumed to be inflated when the stormwater volume behind the dam plus the previous day's pool storage volume is less than the maximum pool volume of 11.3 AF. The daily pool volume is tracked to determine whether there is still available room behind the rubber dam on a particular day during the simulation to detain additional stormwater without exceeding the maximum pool volume. While the dam is inflated, the only modeled outflow from the pool is groundwater recharge from the pool (**Figure 3-10)**. Groundwater recharge from the pool is calculated based on the pool depth during the current time step, the modeled streambed thickness, and the $K_{v\text{-}SFR}$. If the detained pool volume exceeds the maximum pool volume on a given day, then the dam is deflated, and any water currently stored behind the dam is released and allowed to flow downstream (**Figure 3-10**).

The daily groundwater recharge from the pool, as estimated using Equation 3-1, was incorporated into the Strategy 1B simulation using a "boundary condition". Boundary conditions are mathematical rules coded into the modeling software that specify head (groundwater elevation) or water flux (water flow) at selected locations within the model area. The boundary condition that represents groundwater recharge from the pool is referred to as a specified-flux boundary. With this type of boundary condition, time-series groundwater recharge values associated with the detained pool are input to the software by the modeler before the simulation. During the simulation, the software incorporates the provided flow values at the intended boundary-condition cells. In this case, the intended boundary-condition cells are the 44 yellow model cells shown in **Figure 3-8** and **Figure 3-10**. The groundwater recharge values associated with the detained pool (Qout) are divided evenly across these 44 model cells through time during the simulation. The detained stormwater volume is also removed from the Santa Ysabel Creek reach representing the rubber dam to establish the Qin values for Equation 3-1 (**Figure 3-10**). When the dam is deflated due to maximum pool conditions, the detained water that is released is simulated as a stream inflow in the Santa Ysabel Creek reach immediately downstream from the rubber dam location to account for the stormwater released downstream.

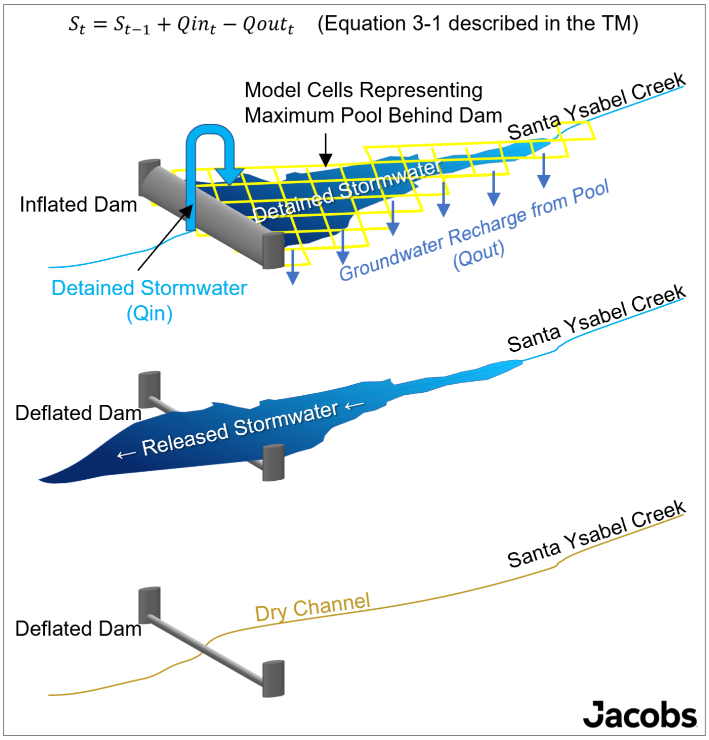


Figure 3-10: Conceptual Dam Operations and Location of Groundwater Recharge Cells for Detained Pool

Figure 3-11 shows the cumulative groundwater recharge from the pool using the daily pool mass balance approach (Equation 3-1). Over the 67-year historical and projection period, including WYs 2005 through 2071, the Strategy 1B simulation incorporated approximately 720 AF of groundwater recharge from the 44 model cells representing the detained stormwater pool (**Figure 3-8** and **Figure 3-10**), at an average of approximately 11 AFY.

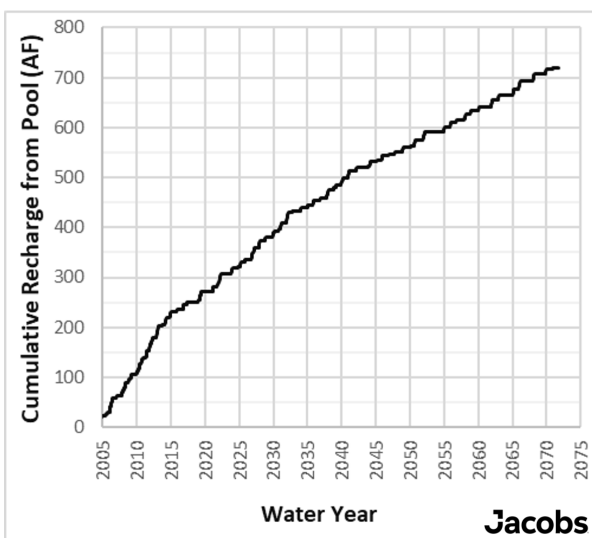


Figure 3-11: Cumulative Groundwater Recharge from Pool

Additional considerations not addressed herein would be needed if Strategy 1B were to be implemented in the Basin. Examples of such considerations include, but are not limited to, the following:

- Deposition of silt and other materials behind the dam could affect infiltration rates through time or would require removal
- Whether stormwater pooled over time could affect the stability of the banks adjacent to the nearby farm roads
- Maintenance activities could affect the timing for when Strategy 1B would be implemented
- Releases of stormwater from the dam could create problems at or downstream from the dam
- The dam should be deflated when pooled water reaches some depth greater than 5 feet

3.1.2 Strategy 2A–Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases

The simulation of Strategy 2A included two steps:

- First, the estimation of maximum controlled releases that Santa Ysabel Creek can infiltrate in the Basin through time from Sutherland Reservoir and
- Second, the estimation of how much of these maximum controlled releases were available at the reservoir throughout the simulation period.

The following sections describe the assumptions and approach for these steps.

Estimation of Maximum Controlled Releases from Sutherland Reservoir

As discussed in the Task 4 TM (City, 2023c), the primary goal of Strategy 2A is to augment streamflow in Santa Ysabel Creek with controlled releases from Sutherland Reservoir. Strategy 2A takes advantage of infiltration in Santa Ysabel Creek as the mechanism for additional groundwater recharge but introduces a "new" source of water to the Basin. The timing of recharge strategy implementation shown in **Figure 3-4** would occur based on Conditions 1 and 2 in the decision flow chart provided in **Figure 3-2**. However, an additional consideration was made beyond these two conditions to establish the Strategy 2A implementation periods. If Conditions 1 and 2 are both met, then Condition 3 addresses whether streamflow is already occurring in Santa Ysabel Creek at River Mile 3 (**Figure 3-1** and **Figure 3-2**). To implement Strategy 2A at a given simulation time, streamflow must also be zero at River Mile 3 at that simulation time. Thus, all three Conditions shown in **Figure 3-2** must be met before Strategy 2A is implemented.

In addition to these three Conditions, limits on the controlled release volume from Sutherland were imposed. A monthly maximum streambed infiltration volume between the inflow point of Santa Ysabel Creek into the model area and Ysabel Creek Road (**Figure 3-1**) was estimated to be approximately 900 AF from the historical (WYs 2005 through 2019) Baseline simulation period. The analysis conducted to estimate this monthly maximum volume is presented in Attachment D of the Task 4 TM (City, 2023c). Additionally, an annual maximum streambed infiltration volume between the inflow point of Santa Ysabel Creek into the model area and Ysabel Creek Road (**Figure 3-1**) was estimated to be 3,000 AF based on a December through May period of the Baseline simulation.

Using the three Conditions presented in **Figure 3-2,** and the monthly and annual maximum streambed infiltration rates, monthly maximum controlled releases from Sutherland Reservoir were developed for the 67-year simulation period, including WYs 2005 through 2071. Maximum controlled releases from Sutherland Reservoir were estimated as the monthly maximum streambed infiltration volume of 900 AF minus the current month's streambed infiltration volume in the Baseline simulation. These monthly values were then uniformly reduced such that the total annual infiltration volume did not exceed the annual maximum streambed infiltration volume of 3,000 AF. The result of this calculation is an estimate of the maximum controlled release target from Sutherland Reservoir (**Figure 3-1**) and does not directly account for when water is available as a controlled release from Sutherland Reservoir. The purpose of these calculations and the monthly and annual maximum constraints was to evaluate periods when the streambed infiltration capacity along Santa Ysabel Creek is the greatest to maximize recharge benefits to the Basin, while minimizing excess streamflow[1] at Ysabel Creek Road. Excess streamflow across Ysabel Creek Road due to implementation of a recharge strategy is considered a negative outcome. However, some excess flows might be unavoidable due to the complex nature of how the Basin streams and aquifer respond to increases in streambed infiltration.

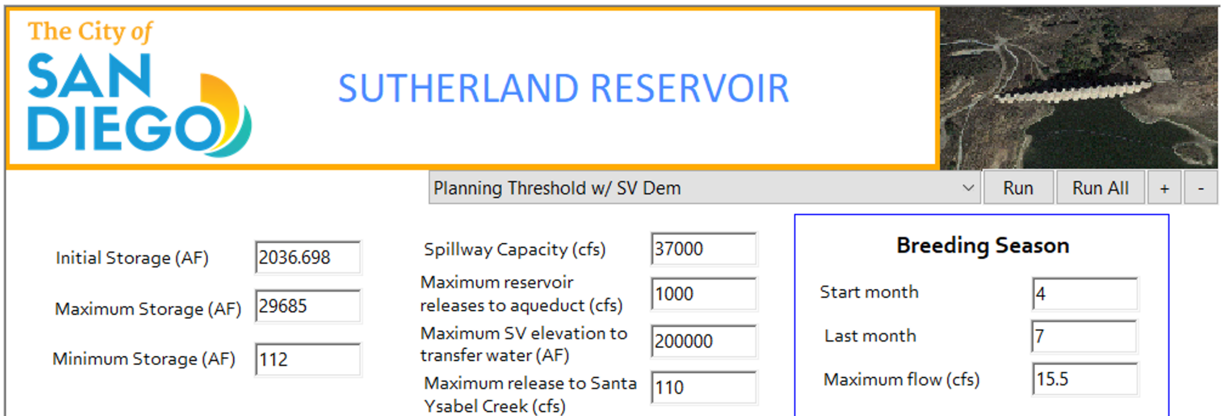
Estimation of Available Controlled Releases Using Sutherland Reservoir Operations Model

A reservoir operation model was needed to provide an estimate of the water available from Sutherland Reservoir up to the target maximum controlled releases discussed above. A reservoir operation model was developed for this effort using the GoldSim platform (**Figure 3-12**) to estimate the monthly available controlled releases to Santa Ysabel Creek for the 67-year simulation period. This GoldSim model uses a reservoir water balance approach based on the assumptions listed in **Table 3-1**. These assumptions and the reservoir operation characteristics, as described in Attachment A in the Task 3 TM (City, 2023b), are based on information provided by City staff (City, 2022b, 2022c and 2022d). A water balance is conducted at the monthly timescale to estimate the available stored water in the reservoir for controlled releases. The stored water available for release is estimated as the water stored above a minimum operation storage level and below the maximum operation level. Monthly operational targets were defined using historical records, where the operational minimum and maximum storage levels are approximately 2,350 AF and 27,300 AF respectively. For example, if the current monthly reservoir storage is 10,000 AF after evaporation and other uncontrolled releases (spills) have been accounted for, then the estimated available volume for controlled releases from the reservoir is approximately 7,650 AF to maintain a minimum storage of 2,350 AF (10,000 minus 2,350 equals 7,650). The GoldSim model allocates the available volume for releases according to the following priorities, first the existing controlled releases of San Vicente Reservoir and Ramona MWD and then the controlled releases associated with the Strategy 2A:

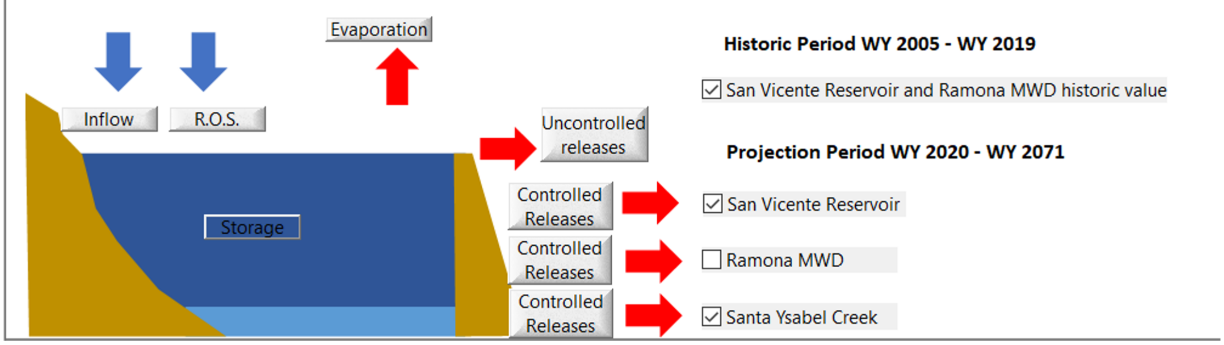
1. **Releases to San Vicente Reservoir.** The flow volume and timing to San Vicente are determined by conveyance constraints, such as maximum capacity releases (5 cubic feet per second [cfs] to 95 cfs, which varies depending on the storage level) and environmental restrictions like the toad breeding season. Modeled releases to San Vicente Reservoir are assumed for the projection period (WYs 2020 through 2071) to follow the assumptions indicated in Table 3-1.
2. **Releases to Ramona MWD.** Although the agreement between the City and Ramona MWD to send water to Ramona MWD's Bargar Water Treatment Plant is still in effect, the Water Treatment Plant has been offline since 2007. Historically, releases to Ramona MWD only took place in 2005, 2006 and 2007. Ramona MWD does not currently have plans for placing this water treatment plant back into service as

a source of potable water (Ramona MWD, 2021). Therefore, releases from Sutherland Reservoir to Ramona MWD are not considered for the projection period.

3. **Releases to Santa Ysabel Creek.** The flow volume and timing to Santa Ysabel Creek are determined based on the monthly maximum controlled releases estimated as described above, water in storage after San Vicente releases, and a release maximum capacity of 110 cfs of the reservoir outlet to Santa Ysabel Creek.



	January	February	March	April	May	June	July	August	September	October	November	December
Flood_Zone	1	1	1	1	1	1	1	1	1	1	1	1
Seasonal_Zone	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.93	0.93	0.93
Carriover_Zone	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07
Emergency_Zone	0	0	0	0	0	0	0	0	0	0	0	0



Note: The Sutherland GoldSim model allows one to turn on and off controlled releases. During the historical period, Santa Ysabel Creek controlled releases are turned off and San Vicente Reservoir and Ramona MWD controlled releases are turned on and use historical values as indicated in Table 3-1. For the projection period, only San Vicente Reservoir and Santa Ysabel Creek controlled releases are turned on.

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Figure 3-12: Sutherland Reservoir Operation Model Dashboard

Table 3-1: Water Balance Assumptions in GoldSim Model

Water Balance Component		Historical Period Assumptions WYs 2005 though 2019	Projection Period Assumptions WYs 2020 though 2071
Inflows	Runoff	Monthly runoff estimates from the USGS Basin Characterization Model (Flint et al., 2013; Flint and Flint, 2014) were aggregated over the contributing watershed area of Sutherland Reservoir for the 67-year simulation period. A bias-correction process was implemented to modify the simulated runoff response from the Basin Characterization Model to be consistent with the City's historical water balance information (City, 2022c). The bias-correction process was then applied to the runoff for the projection period.	
	Rain on surface	Monthly volume estimated based on an area versus storage relationship (to determine the surface area) and monthly historical precipitation data provided by the City.	Monthly volume estimated based on an area versus storage relationship and monthly projected precipitation developed based on projected WY type (see Section 3.1). Average precipitation by WY type were developed based on historic precipitation data.
Outflows	Evaporation	Monthly volume estimated based on an area versus storage relationship and evaporation data provided by the City.	Same approach as projected Rain on Surface but used average evaporation by WY type.
	Uncontrolled Releases and Controlled Flood Releases	Uncontrolled flood releases (or spills) are monthly flows estimated based on volume exceeding the maximum storage level of 29,685 AF and up to the spillway capacity of 37,000 cfs. Controlled flood releases can take place when reaching maximum operation volume of 27,000 to 27,300 AF (depending on the month).	
	Controlled Releases to San Vicente Reservoir	Historical releases	• Release up to the maximum outlet capacity determined by storage level (5 cfs to 95 cfs) • During toad breeding season (April through July), releases were conservatively constrained to a maximum flow of 15.5 cfs • Assumes San Vicente Storage has available space in the City's account to store releases from Sutherland
	Controlled Releases to Ramona MWD	Historical releases	No future release
	Controlled Releases to Santa Ysabel Creek	No releases	Estimated based on target maximum controlled releases and stored water availability (after San Vicente controlled releases). The maximum controlled releases to Santa Ysabel Creek are limited by an assumed maximum capacity of 110 cfs

The GoldSim model provides an estimate of the water available for controlled releases from Sutherland Reservoir based on the Strategy 2A implementation period and the target maximum controlled releases (see light-blue line in **Figure 3-13**). However, as shown by the orange line in **Figure 3-13**, particularly in the 2061 to 2068 time frame, no water is available for release to Santa Ysabel Creek due to limited water availability from Sutherland Reservoir during dry and critical years. Based on the conditions under which this recharge strategy was modeled, the cumulative water available for controlled releases to meet the monthly target releases is approximately 2,400 AF over the 67-year simulation period (see black line in **Figure 3-13**), or about 36 AFY. For this initial assessment, it was assumed all the water released from Sutherland as controlled releases would be available as additional inflow to the Basin. Additional considerations would need to be made to ensure that losses between Sutherland Reservoir and the Basin are minimized and that controlled Sutherland Releases would be conveyed at a time when efficient streamflow transmission to the Basin could be achieved.

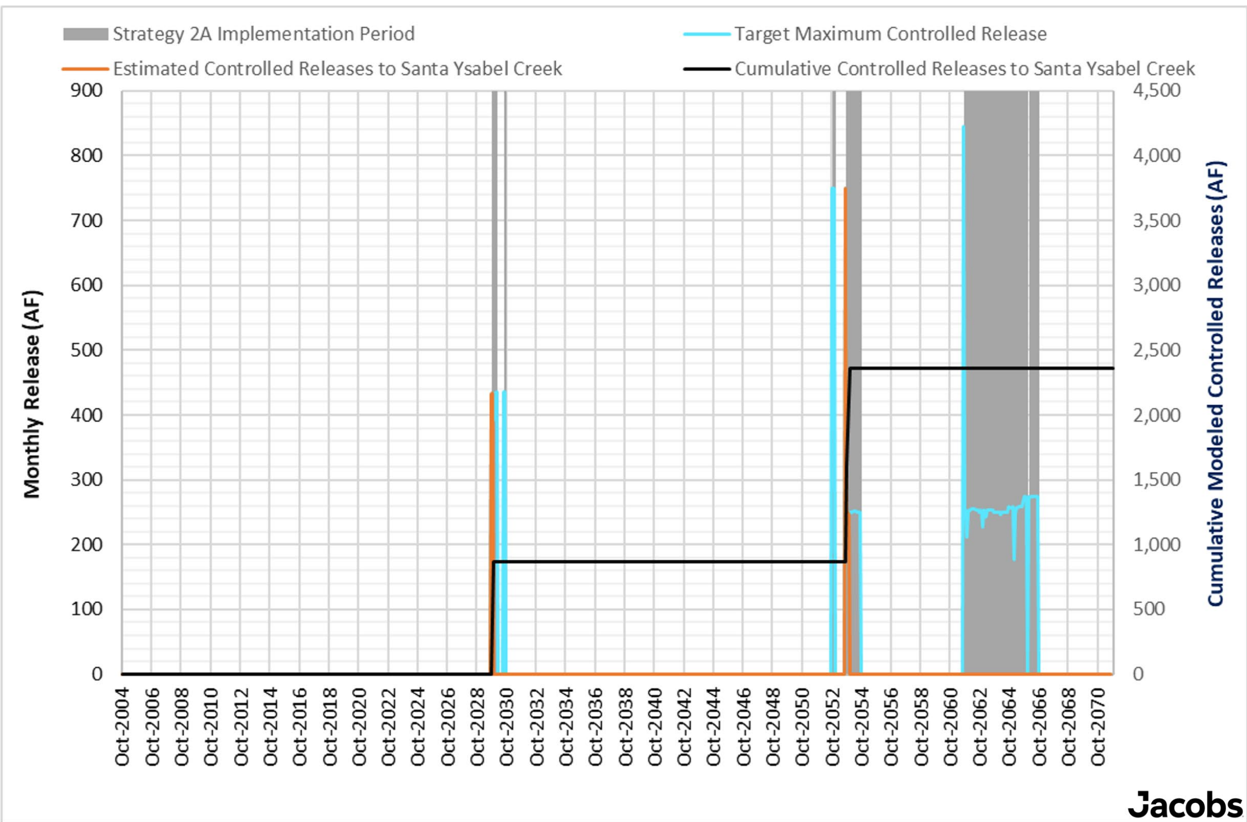

Figure 3-13: Target and Available Controlled Releases from Sutherland Reservoir

The available controlled releases from Sutherland Reservoir were incorporated into the SPV GSP Model v2.0 as additional inflow at the Santa Ysabel Creek inflow location (see blue triangle in **Figure 3-1**). Additional factors not addressed herein would need to be considered if Strategy 2A were to be implemented in the Basin. Examples of such factors include, but are not limited to, the following:

- Whether conveyance losses from the outlet of Sutherland Reservoir to the Basin inflow location could be estimated and refined to better inform the GoldSim model

- Whether the timing and volume of San Vicente Reservoir releases could be modified to make more water available during dry and critical years for controlled releases to Santa Ysabel Creek
- Whether the maximum release capacity to Santa Ysabel Creek with other operational rules not considered herein could result in greater daily controlled releases
- Whether the additional flows in Santa Ysabel Creek may hinder biological function due to the presence of flows during times when the creek would naturally be dry

3.1.3 Strategy 3A–Augment Santa Ysabel Creek Streamflow with Ramona MWD Deliveries

As discussed in the Task 4 TM (City 2023c), the primary objective of Strategy 3A is to augment Santa Ysabel Creek streamflow with deliveries from Ramona MWD. Deliveries of Ramona MWD would occur upstream of River Mile 3 near the San Pasqual Valley Road bridge (see the green triangle in **Figure 3-1**). This location was ultimately determined to maximize the potential for streambed infiltration by conveying water along a realistic hypothetical pipeline route from Ramona MWD's conveyance system to Santa Ysabel Creek and delivering the water in the eastern portion of the Basin. Deliveries from Ramona MWD district would occur based on Conditions 1 and 2 in the decision flow chart of **Figure 3-2**. However, an additional consideration was made beyond these two conditions to establish the Strategy 3A implementation periods. If Conditions 1 and 2 are both met, then Condition 3 addresses whether streamflow is already occurring in Santa Ysabel Creek at River Mile 3 (**Figure 3-1** and **Figure 3-2**). To implement Strategy 3A, streamflow must also be zero at River Mile 3 in Santa Ysabel Creek. Thus, all three conditions must be met before Strategy 3A is implemented (**Figure 3-14)**.

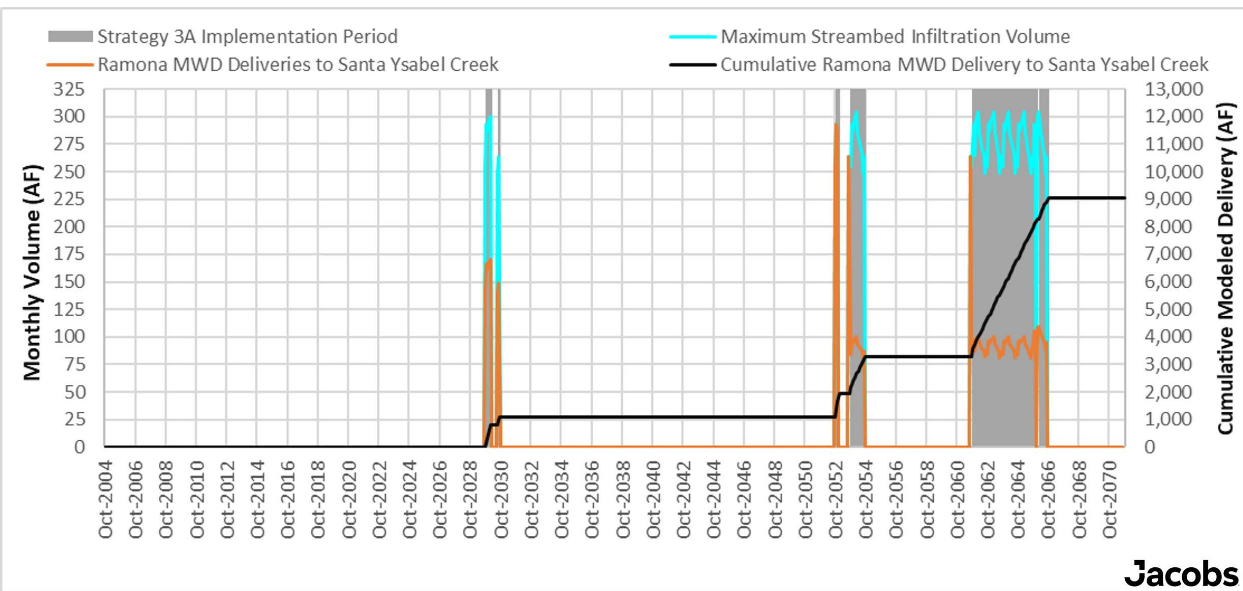

Figure 3-14: Ramona MWD Deliveries to Santa Ysabel Creek

In addition to the three conditions shown in **Figure 3-2**, limits on the deliveries to Santa Ysabel Creek from Ramona MWD were imposed. From the historical Baseline simulation, a monthly maximum streambed infiltration volume of 375 AF was determined for Santa Ysabel Creek between the proposed delivery location and Ysabel Creek Road. Additionally, an annual maximum streambed infiltration volume was determined based on the maximum December through May streambed infiltration volume of 1,100 AF for the same portion of Santa Ysabel Creek. An initial estimate of the maximum Ramona MWD deliveries that the streambed could infiltrate was calculated as the monthly maximum streambed infiltration volume (375 AF) minus the current month's streambed infiltration volume, as modeled in the Baseline simulation (see Maximum Streambed Infiltration Volume as the blue line in **Figure 3-14**). Monthly water available from Ramona MWD (**Table 3-2**) was then accounted for by taking the full amount of water available from Ramona MWD up to the determined monthly maximum streambed infiltration volume. These monthly volumes were then uniformly reduced such that the total annual volume did not exceed the annual maximum streambed infiltration volume (1,100 AF) to establish the Ramona MWD deliveries to Santa Ysabel Creek (**Figure 3-14**). The monthly and annual streambed infiltration volumes were applied to maximize recharge benefits to the Basin while minimizing excess flows across Ysabel Creek Road.

Table 3-2: Monthly Water Volume Available from Ramona Municipal Water District

Month	Available Flow Volume (acre-feet)	Available Flow Volume (gpm)
Jan	296	2,161
Feb[a]	300	2,424
March	304	2,219
April	285	2,150
May	280	2,044
Jun	271	2,044
Jul	267	1,949
Aug	248	1,810
Sep	264	1,991
Oct	255	1,861
Nov	293	2,210
Dec	287	2,095
Total	3,350	2,080[b]

[a] Value assumes a 28-day month.
[b] Value is the average of the monthly values.

The Ramona MWD deliveries developed from this analysis were included in the SPV GSP Model v2.0 as additional inflow to the SFR package at the Ramona MWD delivery location on Santa Ysabel Creek (the green triangle on **Figure 3-1**). The cumulative volume of water made available for recharge from Ramona MWD deliveries was approximately 9,000 AF (see the black line in **Figure 3-14**), or about 134 AFY.

Additional factors not addressed herein would need to be considered if Strategy 3A were to be implemented in the Basin. Examples of such factors include, but are not limited to, the following:

- Whether the conveyance capacity of the pipeline and outfall to Santa Ysabel Creek could be operated to convey the simulated Ramona MWD deliveries
- Whether permitting constraints would constrain operations of this strategy
- Whether concentrations of other constituents in Ramona MWD deliveries not evaluated herein could result in degradation of groundwater quality
- Whether the additional flows in Santa Ysabel Creek may hinder biological function due to the presence of flows during times when the creek would naturally be dry

3.1.4 Strategy 3D–Injection Wells with Ramona MWD Deliveries

As discussed in the Task 4 TM (City, 2023c), the primary goal of Strategy 3D is to recharge water from Ramona MWD directly into the Basin aquifer through injection wells. For the implementation of Strategy 3D, three hypothetical injection well locations were identified (see the yellow circles in **Figure 3-1**). These locations were ultimately determined based on the thickness of aquifer material in this area, proximity to existing agricultural pumping wells, and proximity to proposed pipeline routes from Ramona MWD's conveyance system to the eastern portion of the Basin. Deliveries to the injection wells would occur based on Conditions 1 and 2 in the decision flow chart of **Figure 3-2**. During the Strategy 3D implementation periods, the monthly water available from Ramona MWD (**Table 3-2**) would be conveyed and evenly distributed across each of the three injection wells (**Figure 3-15**).

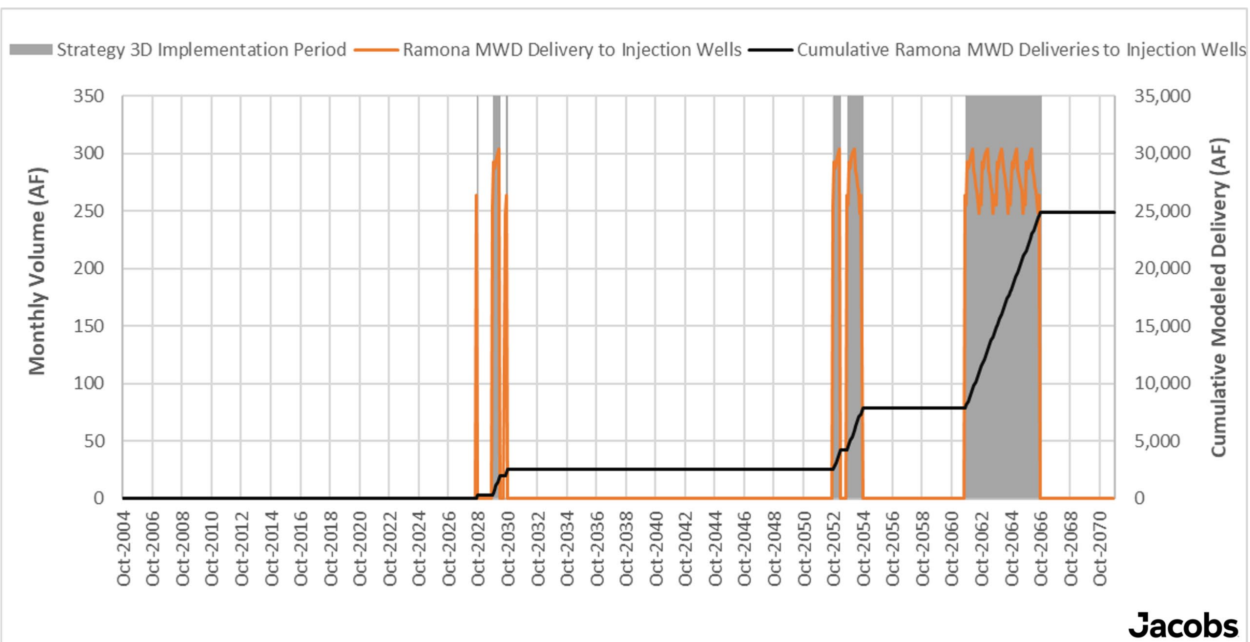

Figure 3-15: Ramona MWD Deliveries to Injection Wells

Injection wells were incorporated into the SPV GSP Model v2.0 using the Multi-Node Well package. Each injection well was assumed to be 12-inch diameter wells with a 50-foot screened interval. The bottom of the screened interval was set to coincide with the bottom of the alluvial aquifer. The Multi-Node Well package allows for constraints that limit how much water can be injected by the wells. For Strategy 3D, the injected water level inside the well was not allowed to go above the land surface. This constraint can reduce the assigned injection rate dynamically during the simulation to prevent water inside the injection well from rising above the land surface. The total surface water made available from Ramona MWD for delivery to injection wells over the 67-year simulation period is 24,874 AF (see the black line in **Figure 3-15**), or about 371 AFY.

Additional factors not addressed herein would need to be considered if Strategy 3D were to be implemented in the Basin. Examples of such factors include, but are not limited to, the following:

- Whether water treatment requirements would affect the rate at which water could be delivered to the injection wells
- Whether injection of water could negatively affect groundwater quality
- Whether injection of water with the modeled rates and locations might cause localized mounding into rooting zone depths that could hinder agricultural operations
- Whether operational considerations would cause downtime of the injection wells that may reduce the overall time that wells could be operated, reducing the volume of water that could be injected into the Basin

3.2 Approach for Evaluating Recharge Strategies

As described in Section 3.1, the modeling approach first required establishing the Baseline simulation, in which the SPV GSP Model v2.0 simulates the same hydrology, land-use, and climate conditions described in the GSP (City and County, 2021). The simulation period for all simulations described in this and later sections of this TM cover the historical period (WYs 2005 through 2019) and the projection period (WYs 2020 through 2071). This Baseline simulation does not incorporate any of the recharge strategies described above. Each recharge strategy simulation is built upon the Baseline simulation, so the effects from implementing the recharge strategy can be isolated by comparing outputs from the recharge strategy simulation against those from the Baseline simulation.

It is important to acknowledge that the western and eastern portions of the Basin have distinctly different depths to water and potential GDE characteristics (refer to Section 8 of the GSP [City and County, 2021] for more details). Therefore, to facilitate processing simulation results in a meaningful and consistent manner, the Basin was subdivided near the western edge of the confluence of Santa Ysabel Creek and Santa Maria Creek into the Western Subarea and Eastern Subarea (**Figure 3-15**). Processed outputs include groundwater budget summaries for the Eastern Subarea, groundwater-level hydrographs at RMWs, streamflow in modeled streams, and groundwater recharge from streams in the Eastern Subarea. Computing groundwater budgets for the Eastern Subarea for this Initial Surface Water Recharge Evaluation is appropriate because most stream recharge in the Basin occurs in the Eastern Subarea. Furthermore, groundwater levels at domestic and irrigation wells in the Eastern Subarea are more vulnerable to dropping below minimum thresholds during drought conditions, as compared with groundwater levels in the Western Subarea. Processing groundwater budgets for the Eastern Subarea allows for a better understanding of each strategy's benefit without inadvertently "averaging out" the modeled benefits over the entire Basin.

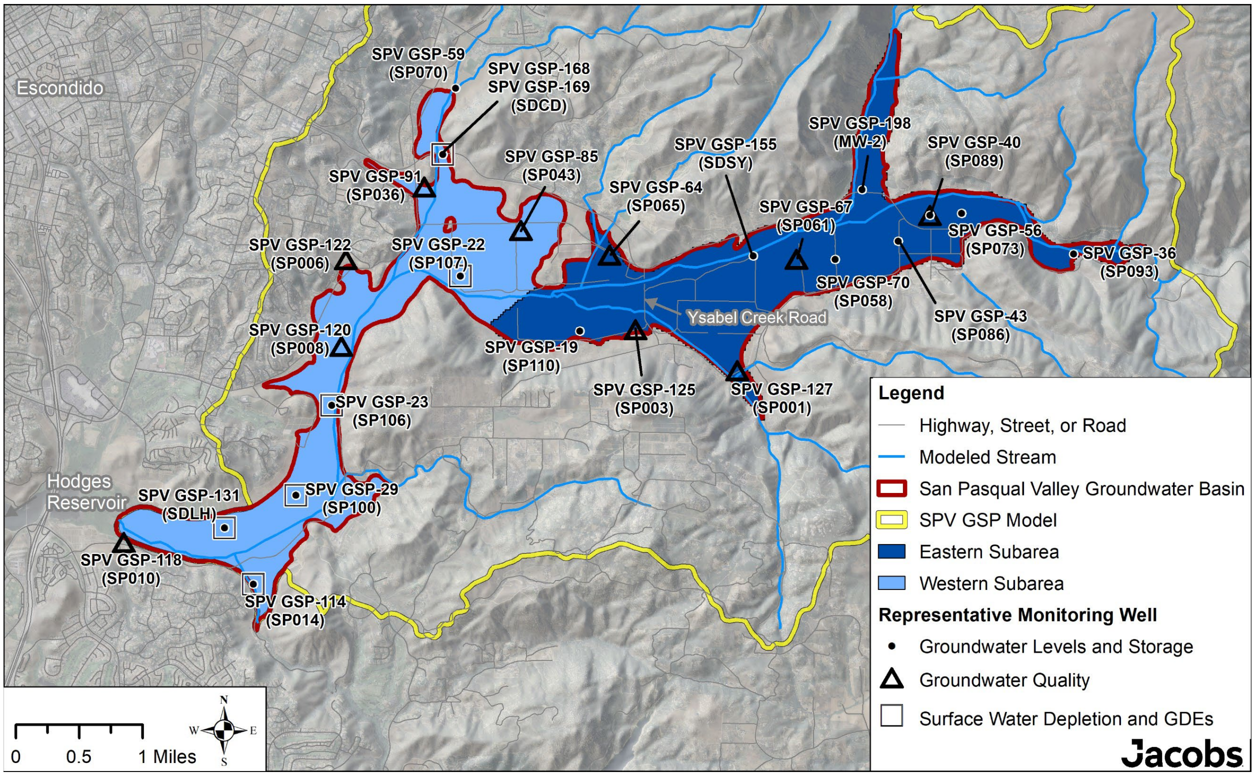

Figure 3-16: Representative Monitoring Well Locations and Basin Subareas

Model outputs were used to provide values for the metrics associated with six of the eight evaluation criteria established in the Task 1 TM (City, 2022a). Because Evaluation Criteria 7 and 8 are not individually based on simulation output, the findings for these two criteria will be presented in the draft Preliminary Feasibility Study, which will be completed in late 2023. The metrics and evaluation approach associated with the first six evaluation criteria are summarized in **Table 3-3**, along with the weighting values that were developed collaboratively with Basin stakeholders during preparation of the Task 1 TM (City, 2022a). Thus, the weighting values shown in **Table 3-3** reflect the priorities of the City and Basin stakeholders. The following subsections provide additional details for the criterion-specific evaluation approach.

Table 3-3: Evaluation Criteria Metrics and Evaluation Approach Summary

Criterion[a]	Metric	Evaluation Approach	Weighting (%)
Criterion 1: Reduction of Modeled Deficit in Groundwater Storage	Average change in modeled groundwater storage in Eastern Subarea for WYs 2005 through 2071	Average change in modeled groundwater storage in a recharge strategy simulation minus that in the Baseline simulation over the 67-year simulation period	13
Criterion 2: Average Reduction of Depth to Water	Modeled depths to water at groundwater-level RMWs[b] during extended drought periods[c]	Sum of modeled depths to water at RMWs in the Baseline simulation minus those in a recharge strategy simulation divided by the number of simulation days, divided by the number of groundwater-level RMWs	7
Criterion 3: Fewer Exceedances of Minimum Thresholds	Modeled groundwater levels at groundwater-level RMWs[b]	Number of occurrences when modeled groundwater levels at RMWs are below Minimum Thresholds in the Baseline simulation minus that in a recharge strategy simulation over the 67-year simulation period	18
Criterion 4: Efficiency of Recharge Strategy	Percentage of water made available with the recharge strategy that recharges the aquifer in Eastern Subarea for WYs 2005 through 2071	Calculated as 1 minus the loss. The loss is computed as the modeled streamflow across Ysabel Creek Road in a recharge strategy simulation minus that in the Baseline simulation divided by the total volume of surface water made available with the recharge strategy over the 67-year simulation period.	18
Criterion 5: Average Reduction of Groundwater TDS Concentration	Estimated groundwater TDS concentrations at selected RMWs[b] in Eastern Subarea for WYs 2005 through 2071	Estimated average groundwater TDS concentration in the Baseline simulation minus that in a recharge strategy simulation over the 67-year simulation period	7
Criterion 6: Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs	Modeled groundwater levels at GDE RMWs[b]	Average number of consecutive days modeled depths to water occur below 30-feet below ground surface in the Baseline Simulation minus that from a recharge strategy simulation over the 67-year period	7

[a] Because Criteria 7 and 8 are not individually based on model output and are not shown in this table, the weights do not add up to 100%. The findings for these two criteria will be presented in the draft Preliminary Feasibility Study, which will be completed in late 2023.
[b] RMW locations are shown in **Figure 3-15**.
[c] Extended drought periods are defined as having three or more consecutive dry or critically dry years. Extended drought periods during the projected period include WYs 2029 through 2032, 2040 through 2043, 2054 through 2056, and 2061 through 2068.

3.2.1 Evaluation Approach for Criterion 1

The evaluation approach for Criterion 1 focuses on quantifying the reduction of the modeled deficit in groundwater storage by implementing a recharge strategy. Groundwater inflows and outflows were summarized for the Eastern Subarea and used to compute changes in groundwater storage (groundwater inflows minus groundwater outflows) for each WY. An average change in groundwater storage value was calculated for the Baseline simulation and each recharge strategy simulation over the 67-year period for use in the evaluation approach for Criterion 1.

3.2.2 Evaluation Approach for Criteria 2, 3, and 6

Criteria 2, 3, and 6 all focus on modeled groundwater levels from the recharge strategy simulations as compared with those from the Baseline simulation (**Table 3-3**). As such, modeled groundwater-level hydrographs were prepared and include modeled groundwater levels for the Baseline simulation and each of the four recharge strategy simulations over the 67-year simulation period. These groundwater-level hydrographs are discussed in Section 3.3. Groundwater-level data associated with these hydrographs were processed to obtain depth-to-water values and to evaluate groundwater levels relative to groundwater-level thresholds including Minimum Thresholds for Criterion 3 and a GDE threshold of 30-feet below ground surface (bgs) for Criterion 6.

3.2.3 Evaluation Approach for Criterion 4

Criterion 4 evaluates the efficiency of recharge associated with each recharge strategy as defined by the goal of maximizing recharge benefits to the Basin while minimizing excess streamflow at Ysabel Creek Road. The cumulative volume of surface water made available for recharge was determined during the approach for simulating recharge strategies (Section 3.1). As this volume of water is introduced to the Basin, the unintended consequence of excess streamflow leaving the eastern portion of the Basin could occur. This excess streamflow is compared to the volume of water made available for recharge as a means of determining how efficient the recharge strategy is at benefiting the Basin.

3.2.4 Evaluation Approach for Criterion 5

Criterion 5 seeks to estimate how total dissolved solids (TDS) concentrations in groundwater might change in response to implementing a recharge strategy. Other constituents such as nitrate could be assessed as part of a future evaluation, if necessary. Measured TDS concentrations at groundwater-quality RMWs east of Ysabel Creek Road and raw water TDS concentrations from Ramona MWD's untreated water system and Sutherland Reservoir were evaluated to estimate how the mixing of these source waters with Basin groundwater could affect groundwater TDS concentrations east of Ysabel Creek Road. Measured TDS concentrations for these wells and source waters are provided in **Figure 3-17**.

Groundwater TDS concentrations east of Ysabel Creek Road depend on the following:

- Volumes of surface waters and groundwater and the associated TDS concentrations in those waters entering the eastern portion of the Basin
- Volume of groundwater and the associated TDS concentrations exiting the eastern portion of the Basin across Ysabel Creek Road

Because the SPV GSP Model v2.0 is a flow model and not a transport model, it cannot be directly used to compute TDS concentrations. However, the volumes of flow computed by the SPV GSP Model v2.0 can be used along with measured TDS concentrations shown in **Figure 3-17** to perform mixing calculations in a spreadsheet. The result of these mixing calculations approximates groundwater TDS concentrations in the eastern portion of the Basin through time for the Baseline simulation and each recharge strategy simulation.

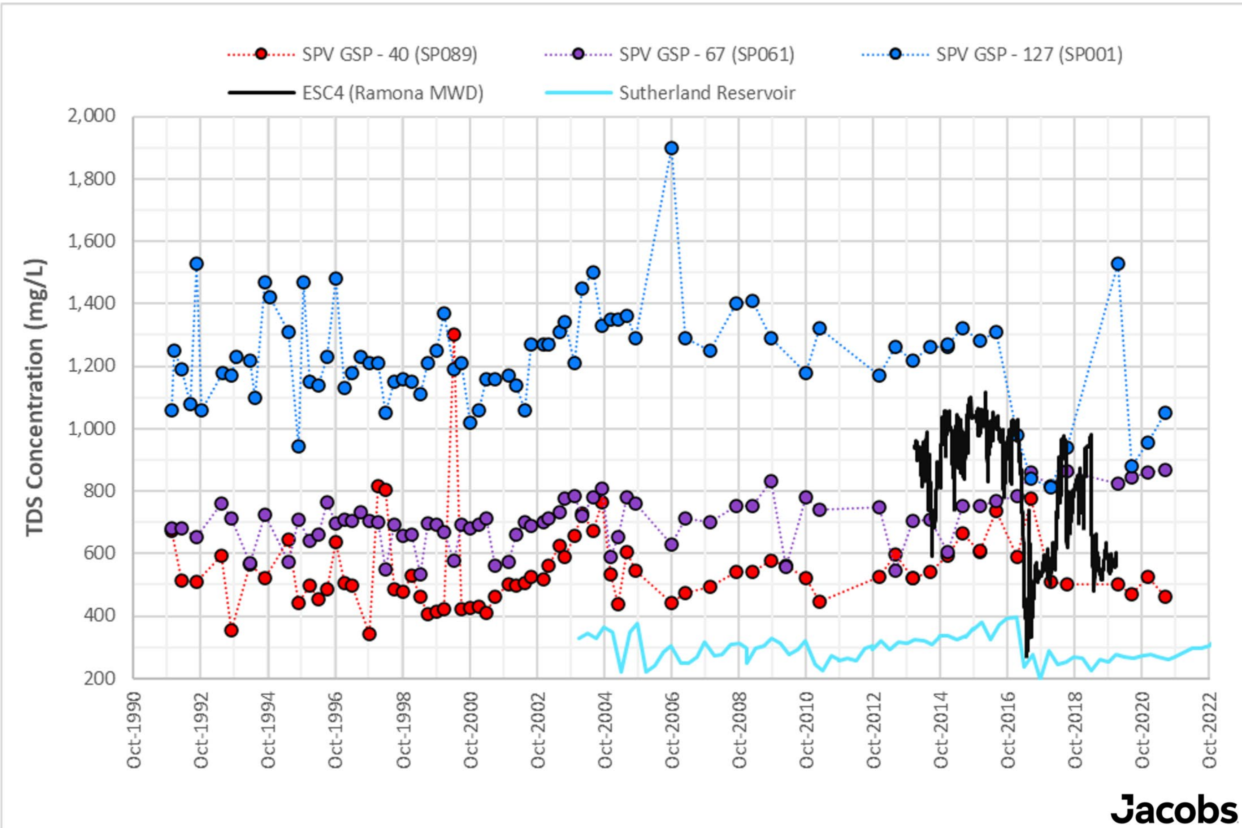

Figure 3-17: Historical TDS Concentrations in Surface Water and Groundwater

3.3 Results for Recharge Strategy Simulations

Using the approach described in Section 3.2, modeled outputs from the Baseline and recharge strategy simulations were processed to support the evaluation of the recharge strategies. Results for each criterion's metric are shown in **Table 3-4**. The larger positive values in **Table 3-4** indicate larger benefits from implementing the recharge strategy, based on simulation results. Criterion-specific details are further discussed below.

Table 3-4: Summary of Results for Evaluation Criteria

Recharge Strategy	Criterion 1 Reduction of Modeled Deficit in Groundwater Storage (AF)	Criterion 2 Average Reduction of Depth to Water (feet bgs)	Criterion 3 Fewer Exceedances of Minimum Thresholds (count)	Criterion 4 Efficiency of Recharge Strategy (percent)	Criterion 5 Average Reduction of Groundwater TDS Concentration (mg/L)	Criterion 6 Fewer Consecutive Days Groundwater Levels are Below 30-feet bgs
1B–Enhance Streamflow Infiltration with In-stream Modifications	-1	0	4	110	-0.3	0
2A–Augment Streamflow with Sutherland Controlled Releases	0	1	41	84	3.1	1
3A–Augment Streamflow with Ramona MWD Deliveries	17	4	208	93	3.1	2
3D–Injection Wells with Ramona MWD Deliveries	80	10	476	97	6.7	10
Evaluation Criteria 7 (cost) and 8 (feasibility) will be presented in the draft Preliminary Feasibility Study, which will be completed in 2023. Larger positive values indicate larger benefits from implementing the recharge strategy.						

3.3.1 Reduction of Modeled Deficit in Groundwater Storage

Criterion 1 evaluates the change in groundwater storage in the Eastern Subarea over the 67-year simulation period. The cumulative change in groundwater storage was processed for each model simulation and plotted for comparative purposes. The chart in **Figure 3-18** shows that the cumulative changes in groundwater storage for all simulations are very similar for most of the simulation period. This is supported by the small values listed in **Table 3-4** under Criterion 1. Periods in which there are larger deviations in the cumulative change in groundwater storage coincide with droughts and periods following droughts, which is consistent with the general timing for when Strategies 2A, 3A, and 3D are implemented. Note that none of the strategies stabilize long-term groundwater levels, which would appear as a line that trends horizontally as opposed to the lines in **Figure 3-18** that have long-term downward trends.

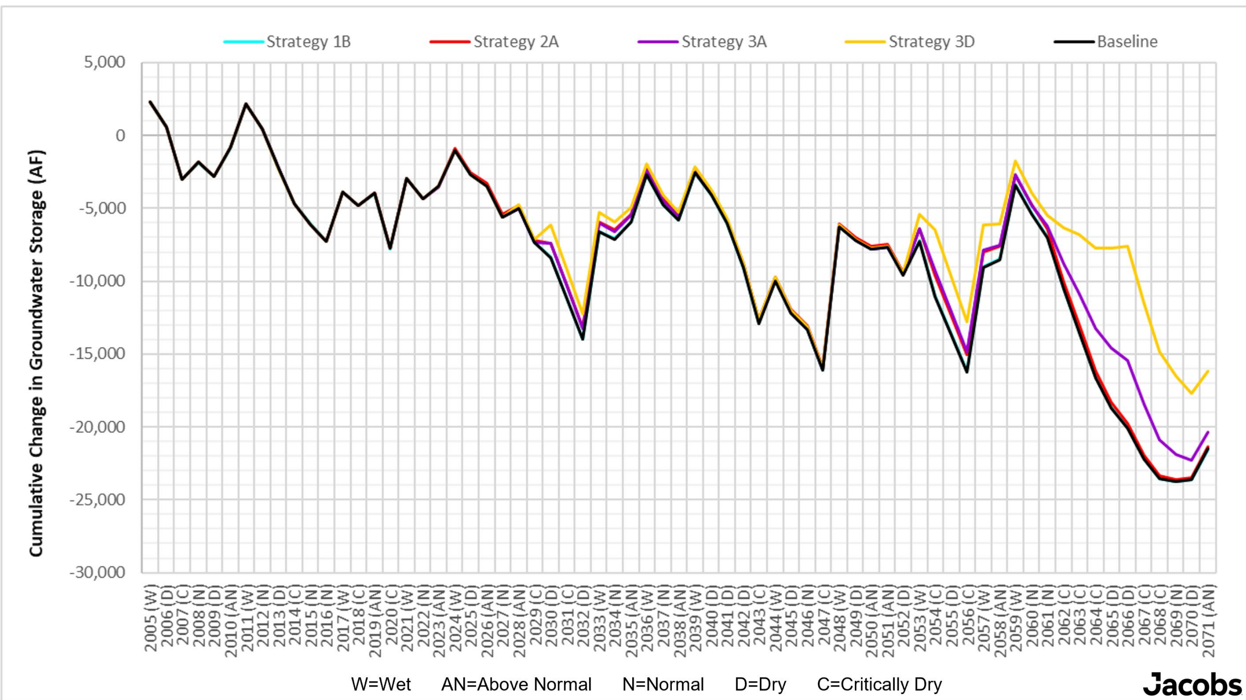

Figure 3-18: Modeled Cumulative Change in Groundwater Storage

Overall, Strategy 3D provides the greatest improvement in groundwater storage (represented as the largest reduction in the modeled deficit in groundwater storage), as compared with the Baseline simulation, followed by Strategy 3A, Strategy 2A, and then Strategy 1B (**Table 3-4**). Note that the yellow line associated with Strategy 3D in **Figure 3-18** does not drop as low during extended drought periods as the Baseline or other strategies. Because Strategy 3D would involve directly recharging the aquifer in the Eastern Subarea, it has the greatest effect on groundwater storage of the four recharge strategies. The light blue line associated with Strategy 1B is not visible in **Figure 3-18** because it is very similar to and obscured by the black line of the Baseline simulation. Overall, Strategies 3A and 3D tend to simulate the greatest reduction in the modeled deficit in cumulative groundwater storage, representing the largest benefit in groundwater storage. This is because source water availability is greatest from Ramona MWD as compared with Sutherland Reservoir under Strategy 2A.

3.3.2 Average Reduction of Depth to Water

Criterion 2 evaluates the change in depth to water at groundwater-level RMWs during four extended droughts that occur in the projection period. Groundwater-level hydrographs for the Baseline simulation and each recharge strategy simulation at all RMWs are included in Attachment E for the 67-year simulation period. These groundwater-level hydrographs were processed for use in the evaluation of Criterion 2. For Criterion 2, extended drought periods were focused on for this criterion's metric to better evaluate how the recharge strategies influence depth to water during stressed conditions in the Basin. The evaluation approach looks at the average change in depth to water across all groundwater-level RMWs as compared with Baseline conditions. As with Criterion 1, implementation of Strategy 3D would have the greatest average reduction of depths to water, representing the greatest benefit to modeled groundwater levels, and Strategy 1B would have no discernible effect on depths to water, according to the model. Note that the yellow line associated with Strategy 3D in the hydrographs in Attachment E is higher in elevation during drier conditions. Because Strategy 3D would involve directly recharging the aquifer in the Eastern Subarea, it has the greatest effect on groundwater levels of the four recharge strategies.

3.3.3 Fewer Exceedances of Minimum Thresholds

Criterion 3 evaluates the number of exceedances of minimum thresholds at groundwater-level RMWs for the Baseline simulation and each recharge strategy simulation. Although exceedances of minimum thresholds can occur without triggering undesirable results, having fewer exceedances can be viewed as having greater resilience against undesirable results. Like Criteria 1 and 2, Strategy 3D has the largest reduction in exceedances of minimum thresholds followed by Strategy 3A, Strategy 2A, and Strategy 1B (same order as Criteria 1 and 2). Strategy 3D includes twice the reduction of exceedances in minimum thresholds as compared to Strategy 3A due to the proximity of injection wells to RMWs where the response of the groundwater levels to nearby injection of water is greatest in the model (**Table 3-4**).

3.3.4 Efficiency of Recharge Strategy

Criterion 4 quantifies the efficiency of the recharge strategy based on the goal of maximizing benefits to the Basin, while minimizing excess streamflow across Ysabel Creek Road. For this criterion, the cumulative volume of surface water made available for recharge was quantified based on the implementation of each recharge strategy, as discussed in Sections 3.1.1 through 3.1.4. The modeled flows used to compute the efficiencies listed in **Table 3-4** under Criterion 4 are listed in **Table 3-5**. The initial volume of surface water made available for recharge for Strategy 3D was 24,874 AF over the 67-year simulation period. During the model simulation injection rates were automatically reduced at specific wells to avoid having water levels inside the injection wells rise above land surface, reducing the total volume of surface water made available to 23,264 AF (**Table 3-5**). The cumulative streamflow volume across Ysabel Creek Road was quantified for the Baseline simulation and each recharge strategy simulation. Each recharge strategy, except for Strategy 1B, caused an increase in streamflow across Ysabel Creek Road, as compared with the Baseline simulation. Strategy 1B simulates a reduction in streamflow across Ysabel Creek Road, as compared with the Baseline simulation, by detaining stormwater that would have otherwise crossed Ysabel Creek Road. This is why the efficiency listed in **Table 3-4** under Criterion 4 for Strategy 1B is greater than 100%. All recharge strategies achieved efficiencies greater than 80%.

Table 3-5: Summary of Modeled Flow for Criterion 4

Strategy	Cumulative Volume of Surface Water Made Available (AF)	Cumulative Streamflow Across Ysabel Creek Road (AF)	Difference in Cumulative Streamflow Across Ysabel Creek Road as Compared with Baseline Simulation (AF)
Baseline	0	587,938	-
Strategy 1B	720	587,863	-75
Strategy 2A	2,363	588,306	368
Strategy 3A	9,063	588,581	643
Strategy 3D	23,264	588,572	634

3.3.5 Average Reduction of Groundwater TDS Concentration

Criterion 5 addresses potential changes in groundwater quality conditions in the Eastern Subarea due to implementation of recharge strategies. The water quality constituent evaluated for this criterion is TDS. Using the mixing-calculation approach described in Section 3.2.4, groundwater TDS concentrations throughout the 67-year simulation period were approximated for the Baseline simulation and each recharge strategy simulation (**Figure 3-19**). Overall, groundwater TDS concentrations from each recharge strategy show minor deviations from the Baseline simulation. Improvements to groundwater TDS concentrations occur for Strategies 2A, 3A, and 3D during the periods when water is imported to the Basin for these strategies from Sutherland Reservoir and Ramona MWD's untreated water system. Strategy 2A tends to show greater improvements in TDS concentrations as compared with Strategies 3A and 3D when controlled releases from Sutherland Reservoir occur (see periods when the red line is below all other lines in **Figure 3-19**). This is a result of Sutherland Reservoir having a lower TDS concentration as compared with water from Ramona MWD (**Figure 3-17**).

3.3.6 Fewer Consecutive Days Groundwater Levels are Below 30 Feet Below Ground Surface

Criterion 6 quantifies possible benefits to potential GDEs by evaluating the number of consecutive days that modeled groundwater levels are below a 30-foot bgs threshold at GDE RMWs (locations of GDE RMWs are symbolized as open squares in **Figure 3-15**). GDE RMWs tend to be in the Western Subarea of the Basin where groundwater levels are shallower than groundwater levels in the Eastern Subarea. As a result, the implementation of recharge strategies in the Eastern Subarea has minimal influence on groundwater levels at GDE RMWs. The largest change in the number of consecutive days that groundwater levels were below 30-feet bgs occurred with Strategy 3D with 10 fewer consecutive days. Strategy 3A, followed by Strategy 2A produced the next largest change in consecutive days with Strategy 1B having no influence on water levels relative to 30-feet bgs at GDE RMWs (**Table 3-4**).

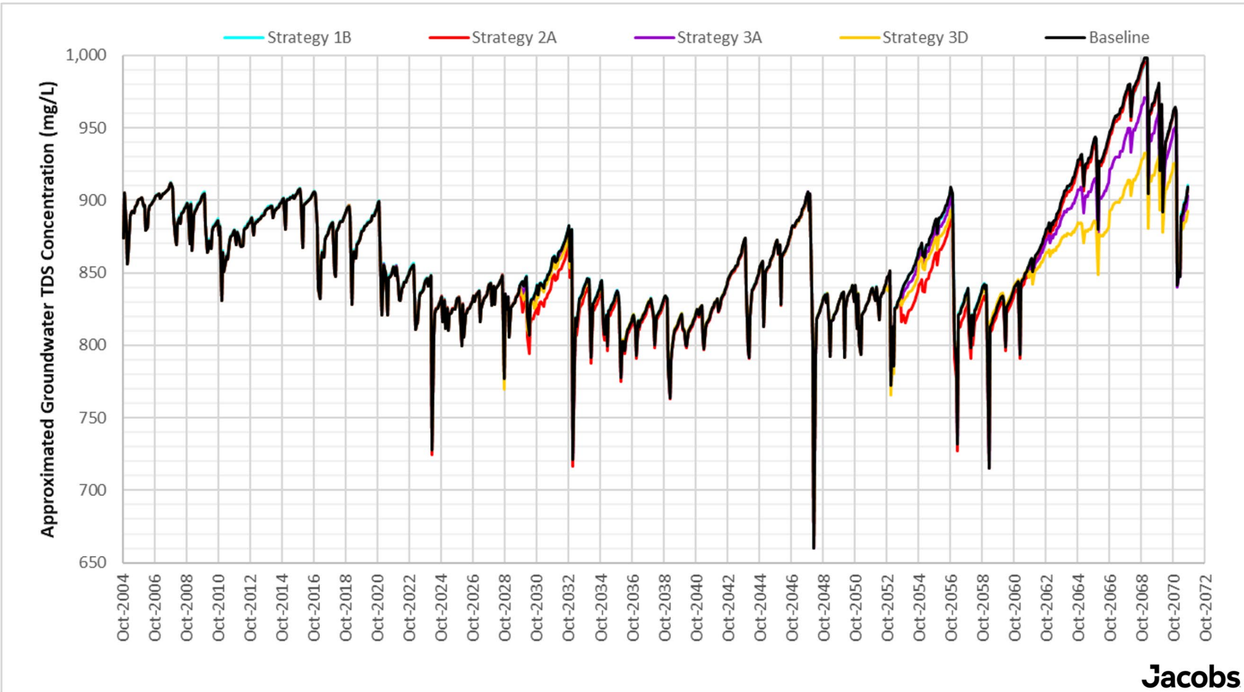

Figure 3-19: Approximated Average Groundwater TDS Concentrations

3.4 Sensitivity Analysis

According to the discussion in Section 3.3, Strategy 1B performed the worst of all four strategies because the height of the dam limits the volume of stormwater that can be detained and the area over which additional infiltration can occur, relative to the Baseline simulation. The simulation results highlight the fact that Santa Ysabel Creek has a high infiltration capacity on its own without implementing an inflatable rubber dam as an in-stream modification. The additional groundwater recharge from the detained water in the Strategy 1B simulation was small enough that considering variations of Strategy 1B any further would provide little value. However, to gain additional insights into the performances of Strategies 2A, 3A, and 3D, different operational variations were considered as part of a sensitivity analysis. The sensitivity analysis was set up to address the following question:

If Strategies 2A, 3A, and 3D had been implemented more frequently than the simulations described in Sections 3.1 through 3.3, how might that have affected the number of exceedances of minimum thresholds (Criterion 3) and the efficiency of recharge (Criterion 4)?

These two criteria were selected to summarize the results of the sensitivity analysis because they received the highest evaluation criteria weighting values (City, 2022a) (**Table 3-3**). The most efficient way to change the timing for when Strategies 2A, 3A, and 3D were implemented in the sensitivity analysis simulations was to consider a more stringent Condition 1 (**Figure 3-2**). The operational variations incorporated into the sensitivity analysis consider a change in the SPV GSP-43 (SP086) water-level trigger to include an offset of 10 feet above the PT. The PT at this well is elevation 347.4 feet. Thus, for this sensitivity analysis, Condition 1 was met when modeled groundwater levels dropped below a level that is 10 feet above the PT at well SPV GSP-43 (SP086), which equates to an elevation of 357.4 feet. This operational variation should in no way be interpreted to mean that the PT for well SPV GSP-43 (SP086) is inadequate or that the modeling team is proposing a different PT for this RMW. Implementing a vertical offset of 10 feet from the PT at this well was done purely out of mathematical convenience to incorporate the desired effect in the sensitivity analysis simulations to answer the question posed above in this section.

Sensitivity results for Criteria 3 and 4 for Strategies 2A, 3A, and 3D are presented in **Figure 3-20**. All three sensitivity analysis simulations achieved fewer exceedances of minimum thresholds (note the difference between the blue bars and orange bars in the left chart of **Figure 3-20**). For example, the sensitivity analysis simulation for Strategy 2A has 109 fewer exceedances (orange bar) than the Baseline simulation, as compared with the original Strategy 2A simulation, which had only 41 fewer exceedances (blue bar) than the Baseline simulation. Thus, as action is taken sooner and more often, more recharge water is made available to the Basin in the simulation, resulting in greater benefit to the Basin in terms of having fewer exceedances of minimum thresholds.

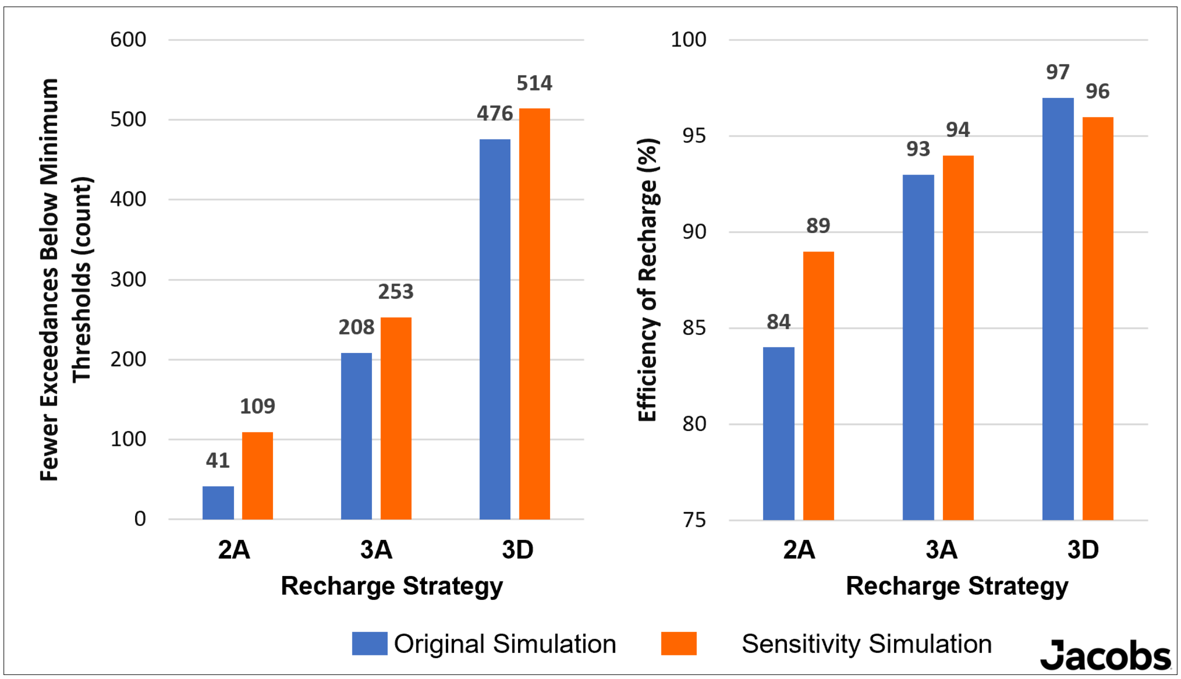

Figure 3-20: Sensitivity Analysis Results for Criteria 3 and 4

For Criterion 4, Strategies 2A and 3A both simulate an increase in the efficiency of recharge with the sensitivity analysis simulations (note the orange bars are taller than the blue bars in the right chart of **Figure 3-20** for Strategies 2A and 3A). This indicates that the additional water introduced to the Basin did not proportionally increase excess streamflow across Ysabel Creek Road. Thus, the timing and volume of releases and deliveries occurred at times when benefits to the Basin could be maximized. Strategy 3D, however, simulated a small reduction in efficiency (orange bar) as compared with the original Strategy 3D simulation (blue bar), which is a result of increasing groundwater levels enough to induce greater streamflow across Ysabel Creek Road.

3.5 Results Summary

The updated SPV Model v2.0 provided an improved understanding of groundwater changes in the Basin under Baseline conditions and if each of the four recharge strategies were implemented under the conditions described in this TM. The approach of utilizing the PT exceedance at SPV GSP-43 (SP086) and a 2-year look-ahead at WY type to determine the timing of recharge strategies helped to ensure that the recharge strategies were implemented during the most challenging periods and assessed using the similar implementation conditions. Additional considerations were made depending on the recharge strategy that aimed to maximize benefits to the Basin while minimizing excess flow across Ysabel Creek Road. Overall, each recharge strategy maintained an efficiency greater than 80% based on the recharge implementation approaches. The operational variation for recharge strategy implementation explored in the sensitivity analysis (Section 3.4) highlights that the timing of implementation of a recharge strategy is an important consideration to maximize benefits to the Basin while minimizing excess streamflow across Ysabel Creek Road.

Although the simulations of recharge strategies show positive benefits toward enhancing resilience against undesirable results, the simulations also highlight the limitations of the recharge strategies. The maintenance of modeled groundwater levels in the eastern portion of the Basin during extended drought periods will be challenging, as modeled groundwater levels under each recharge strategy show long-term declines in groundwater levels. With reduced natural aquifer replenishment due to extended droughts, recharge strategies (or demand reduction) would need to be implemented to avoid exceeding minimum thresholds and possible undesirable results. Depending on the availability of water from sources outside of the Basin and the frequency and duration of dry years, implementing more than one recharge strategy at a time, or combining a strategy with other options may be necessary to achieve sustainability. Doing so would provide the most operational flexibility to conjunctively manage the Basin's water resources. It may also be possible that selecting different conditions under which a recharge strategy is implemented could also provide additional benefits to the Basin not modeled as part of this study. As modeled, results suggest that the individual strategies alone might not be adequate to meet long-term sustainability goals.

Overall, the recharge strategies implemented in the Eastern Subarea had minimal influence on modeled groundwater levels in the Western Subarea.

Results from this effort will be used to help develop two additional documents: the Task 6 TM, which will use the simulation results described herein to assess possible benefits to potential GDEs from implementing the four recharge strategies and the Preliminary Feasibility Study. The draft Preliminary Feasibility Study will be completed in 2023.

4. NEXT STEPS

Evaluation criteria results described in Section 3.3 for each of the four recharge strategies will be used to help develop two additional documents: the Task 6 TM, which will use the simulation results described in this TM to assess possible benefits to potential GDEs from implementing the four recharge strategies and the draft Preliminary Feasibility Study, which will be completed in 2023. During the development of the Preliminary Feasibility Study the results shown in **Table 3-4** will be further evaluated and ranked. Additionally, Criteria 7 (cost) and 8 (feasibility) will also be evaluated during the ranking process.

Because long-term groundwater level trends for Baseline conditions and for each of the recharge strategies show long-term declines in groundwater levels, the following studies are recommended to better understand the recharge strategies, should they require implementation as part of adaptive management to avoid undesirable results:

- Follow-on study of potential losses due to conveyance from Sutherland Reservoir to the Santa Ysabel Creek inflow point to the Basin
- Follow-on modeling of Sutherland Reservoir operations linked to regional system to further optimize water resources.
- System-wide reservoir water supply analysis to determine alternative conjunctive-use strategies
- Pilot study to assess the viability of injection well operation, if the GSA chooses to further assess Strategy 3D
- Assessment of potential for ecosystem impacts from addition of supplemental water into Santa Ysabel Creek
- Assess and update water-use agreements with water purveyors in the region to support future flexibility of recharge strategies in the Basin

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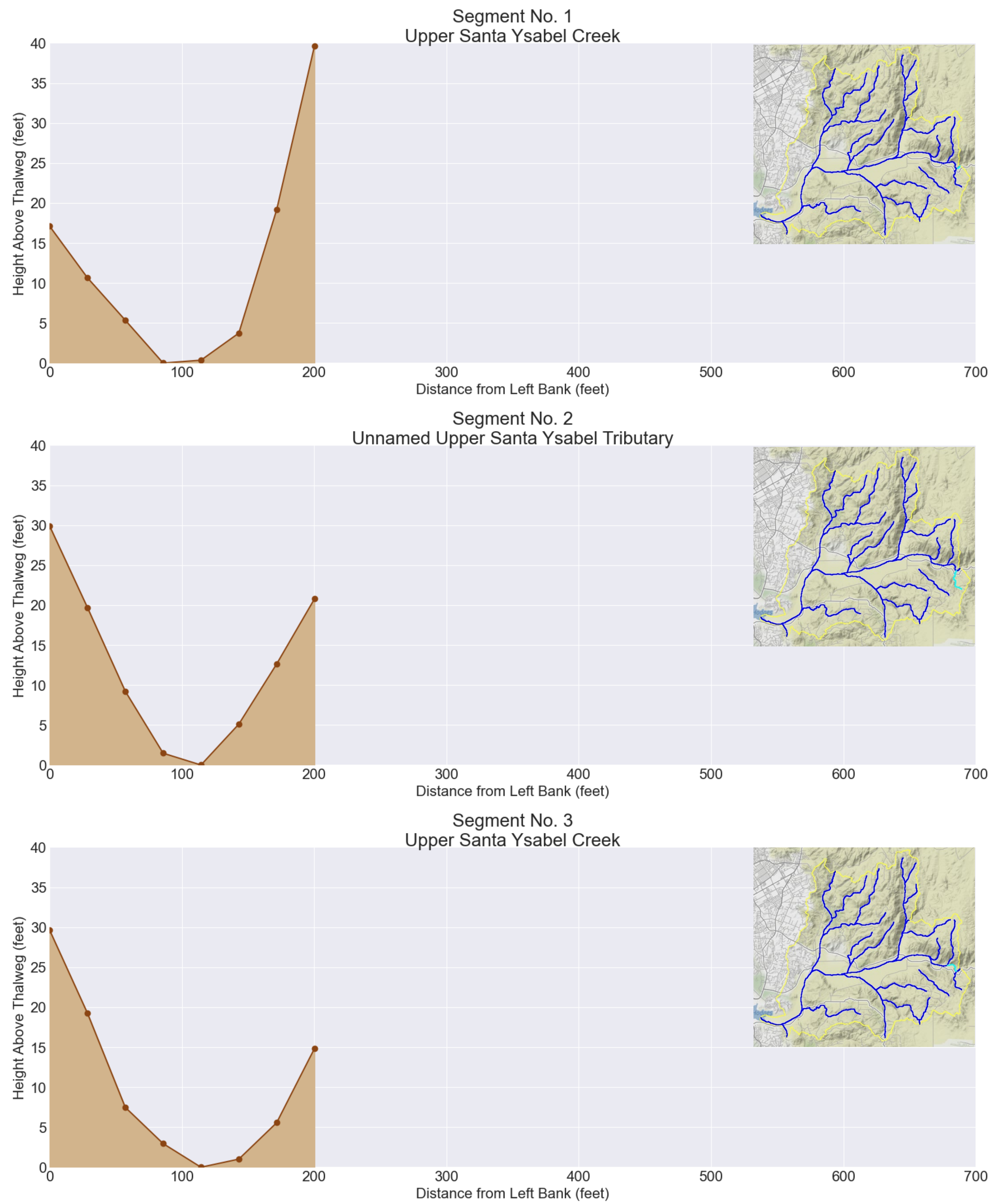
ATTACHMENT A: MODELED EIGHT-POINT STREAM CHANNELS



Notes:

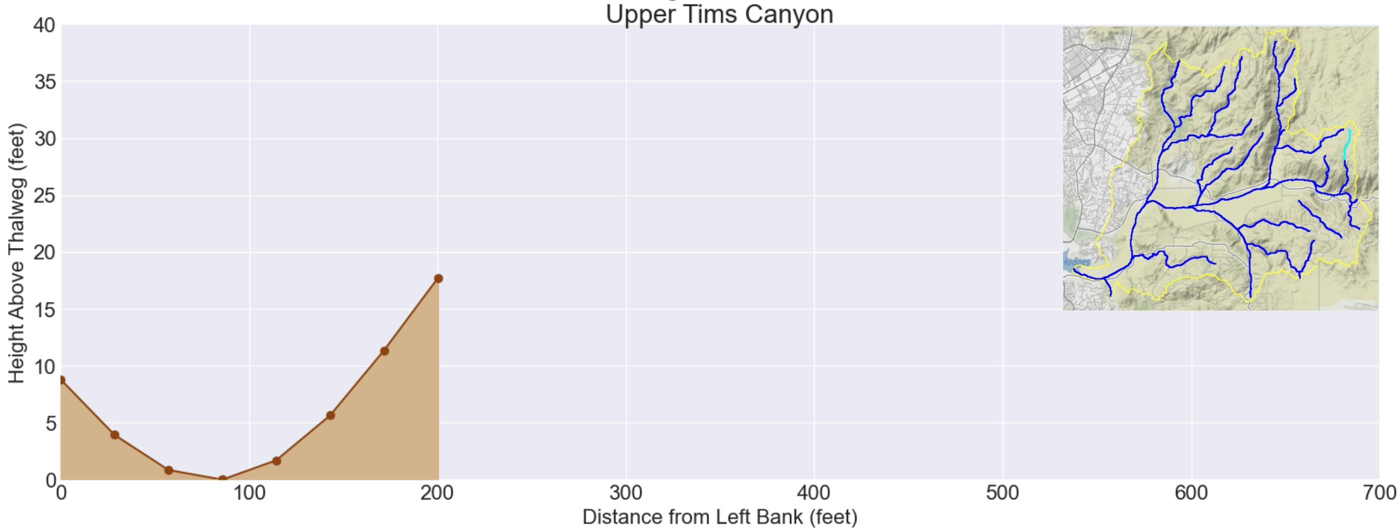
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend

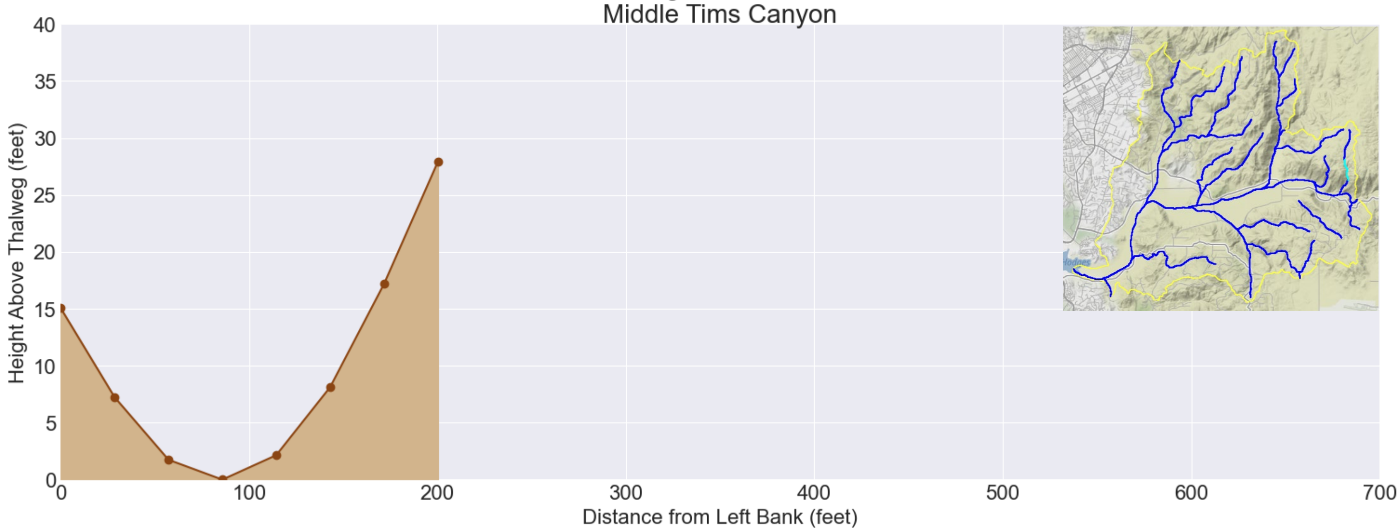
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-1
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

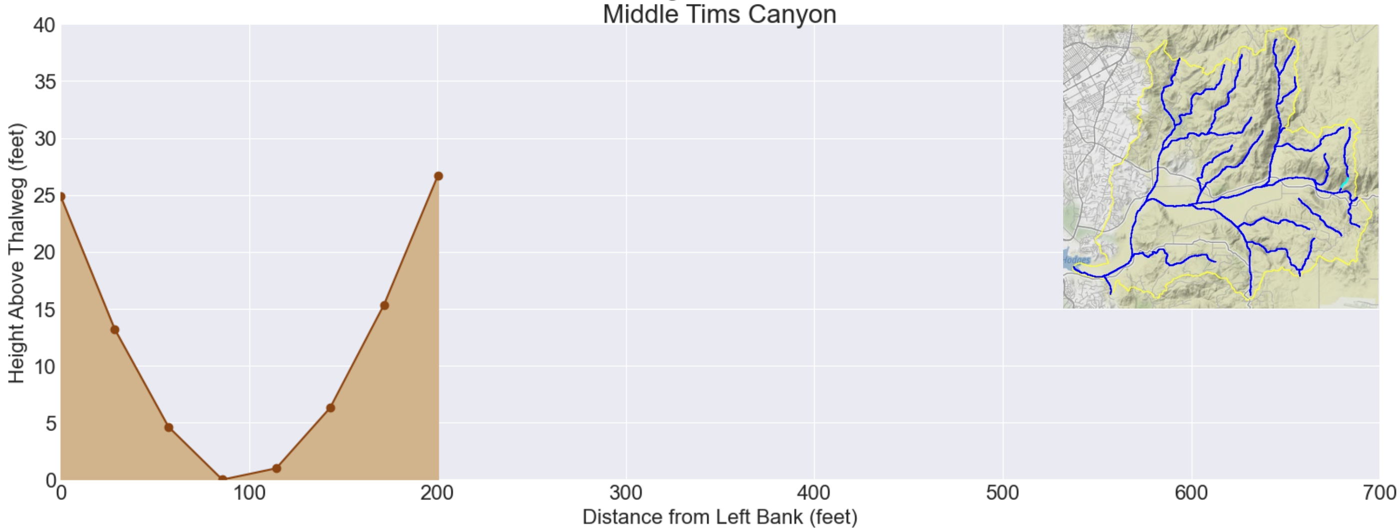
Segment No. 4
Upper Tims Canyon



Segment No. 5
Middle Tims Canyon



Segment No. 6
Middle Tims Canyon



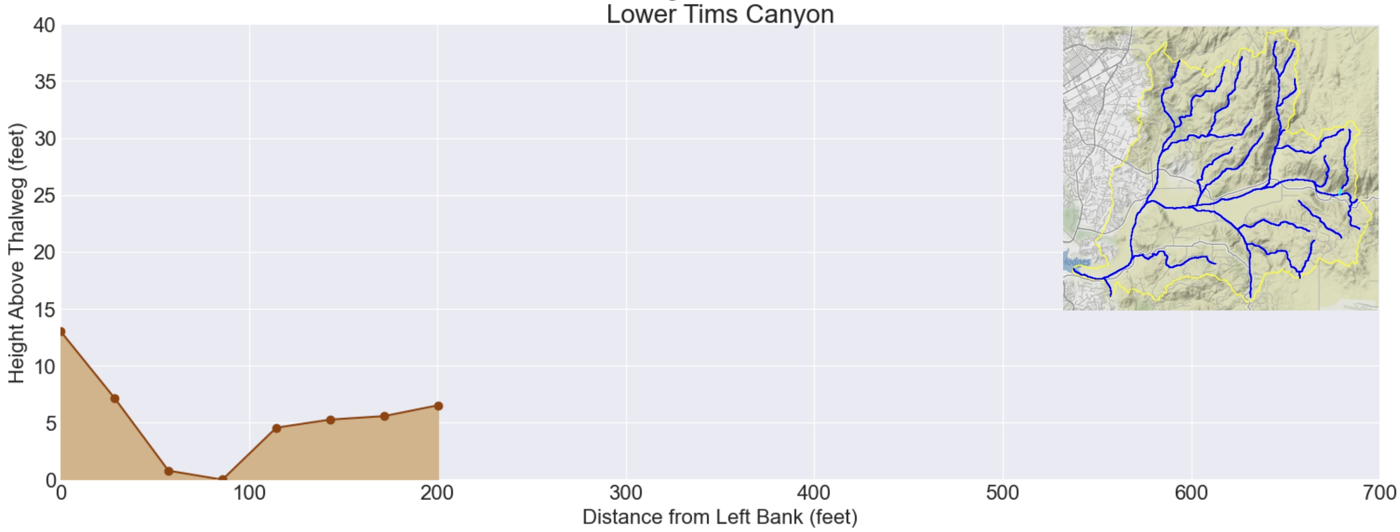
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend
Modeled Stream
Highlighted Segment of Modeled Stream

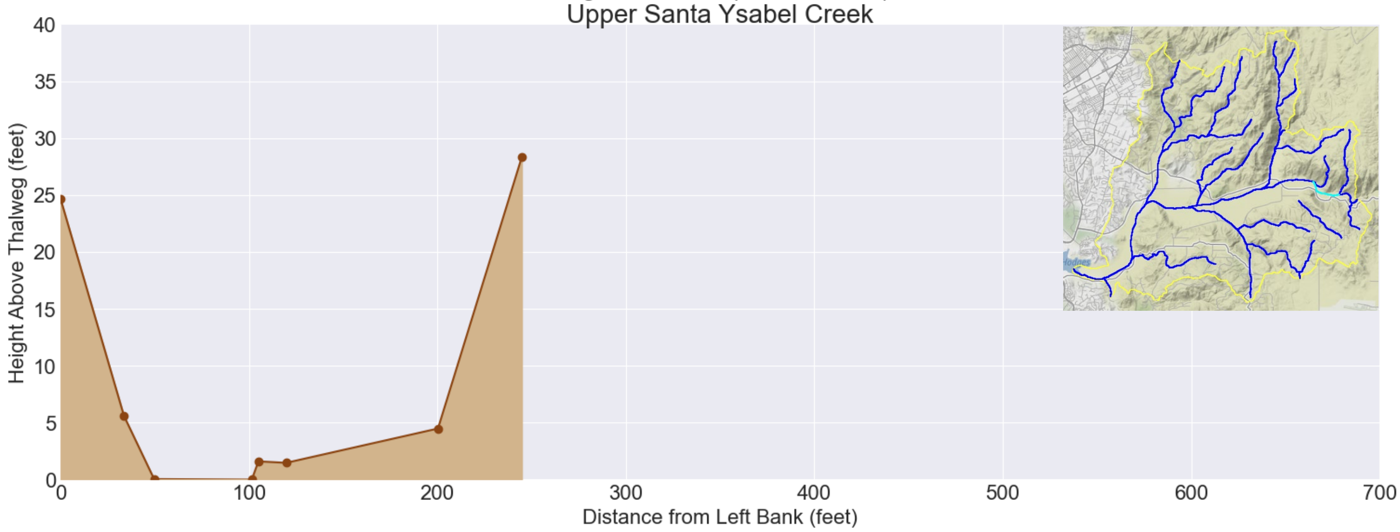
Figure A-2
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

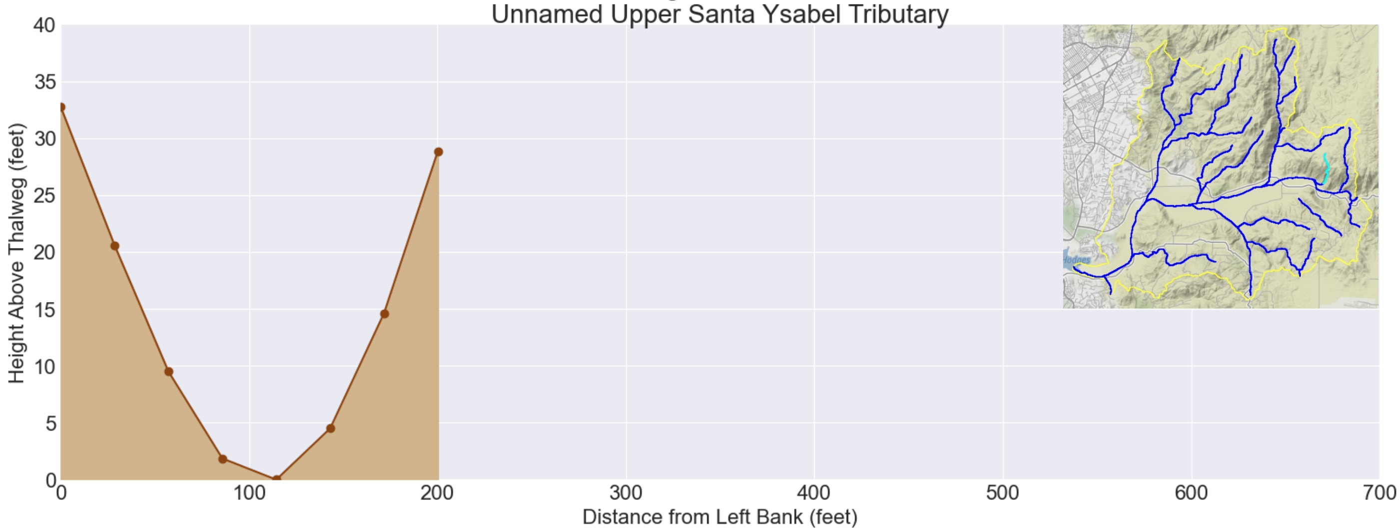
Segment No. 7
Lower Tims Canyon



Segment No. 8 (T-1 Transect)
Upper Santa Ysabel Creek



Segment No. 9
Unnamed Upper Santa Ysabel Tributary



Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

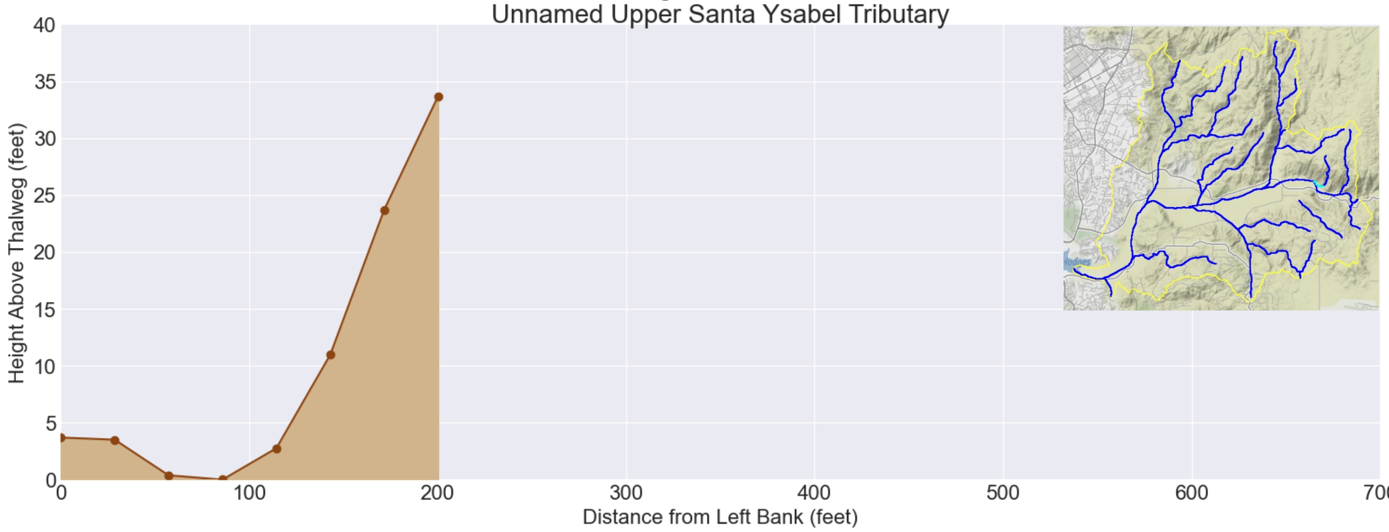
Map Legend

Modeled Stream
Highlighted Segment of Modeled Stream

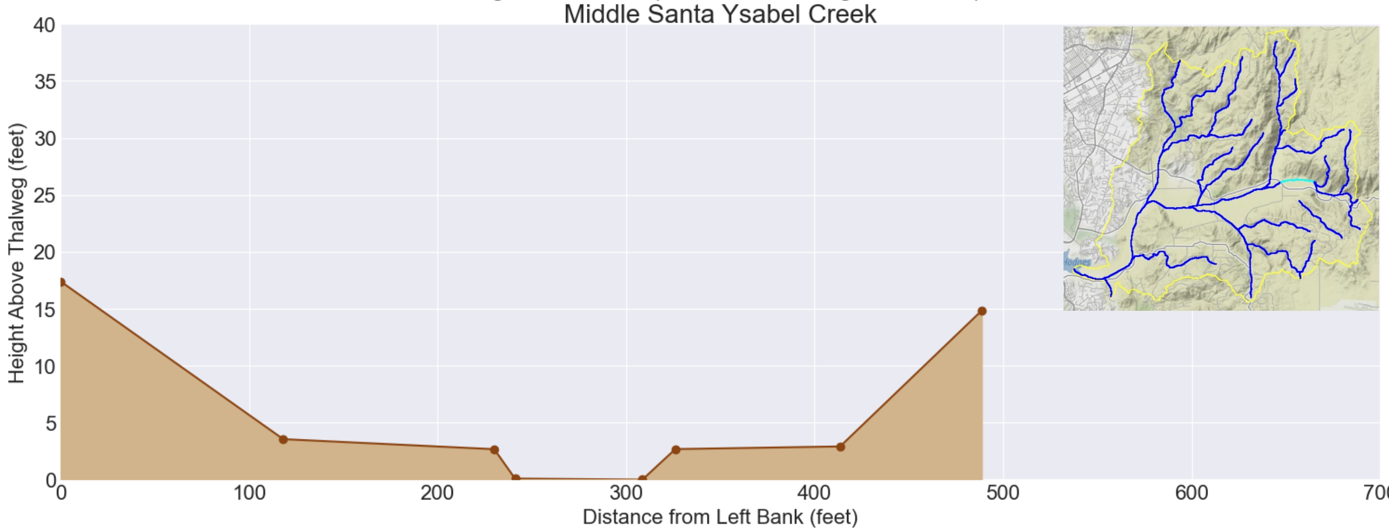
Figure A-3
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

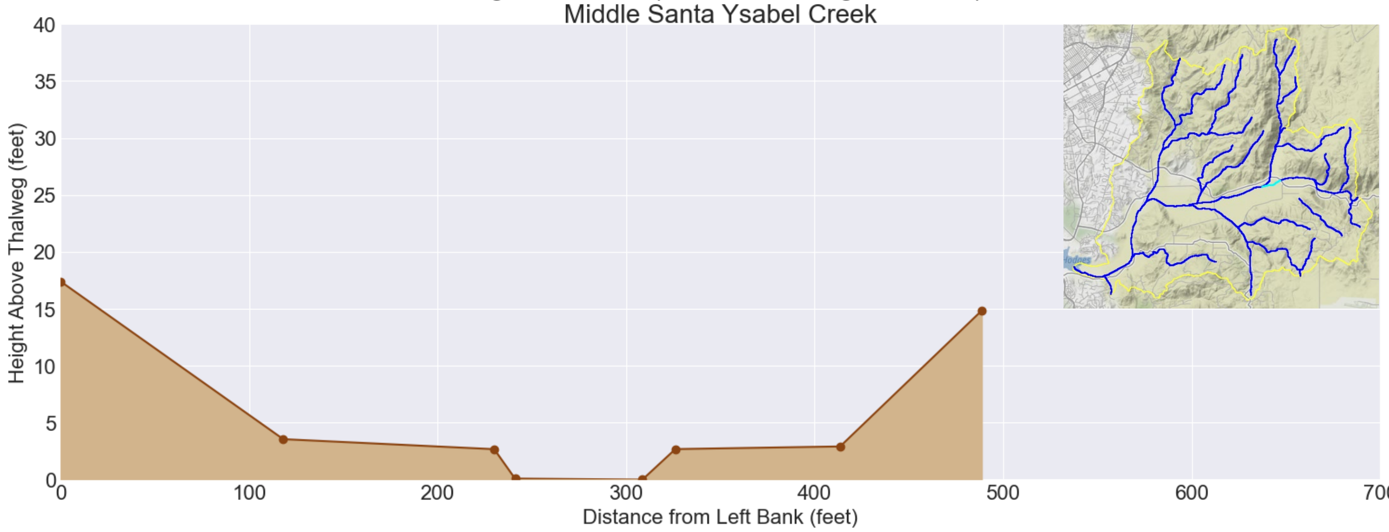
Segment No. 10
Unnamed Upper Santa Ysabel Tributary



Segment No. 11 (T-2 & T-3 Average Transect)
Middle Santa Ysabel Creek



Segment No. 12 (T-2 & T-3 Average Transect)
Middle Santa Ysabel Creek

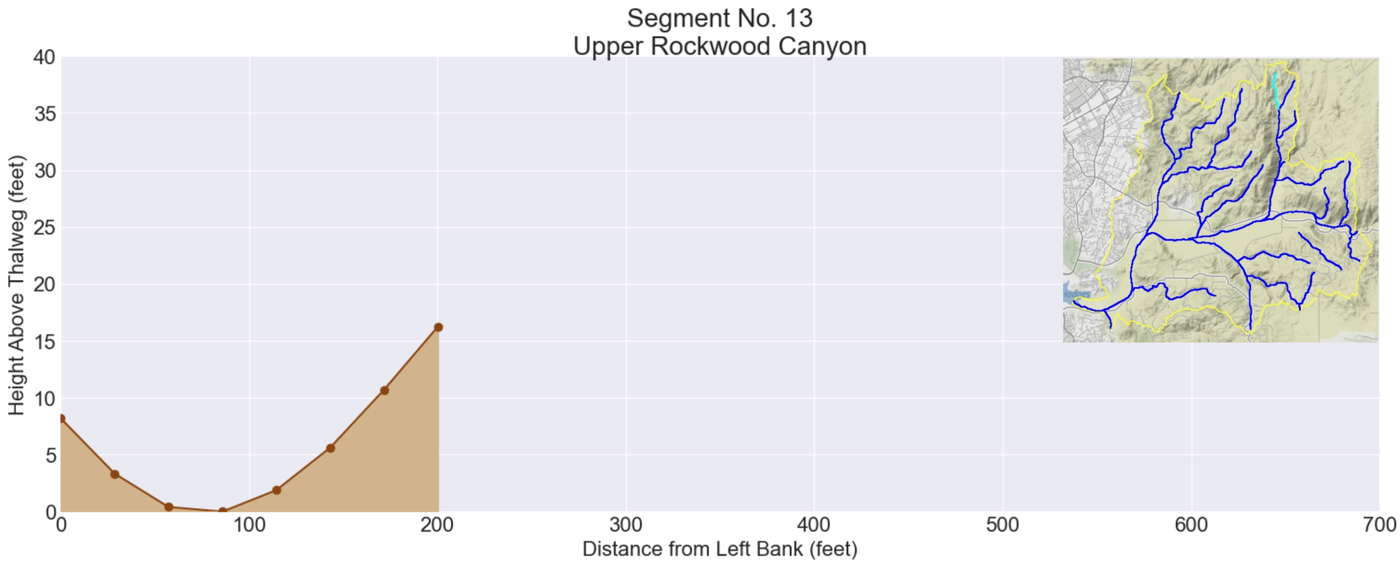


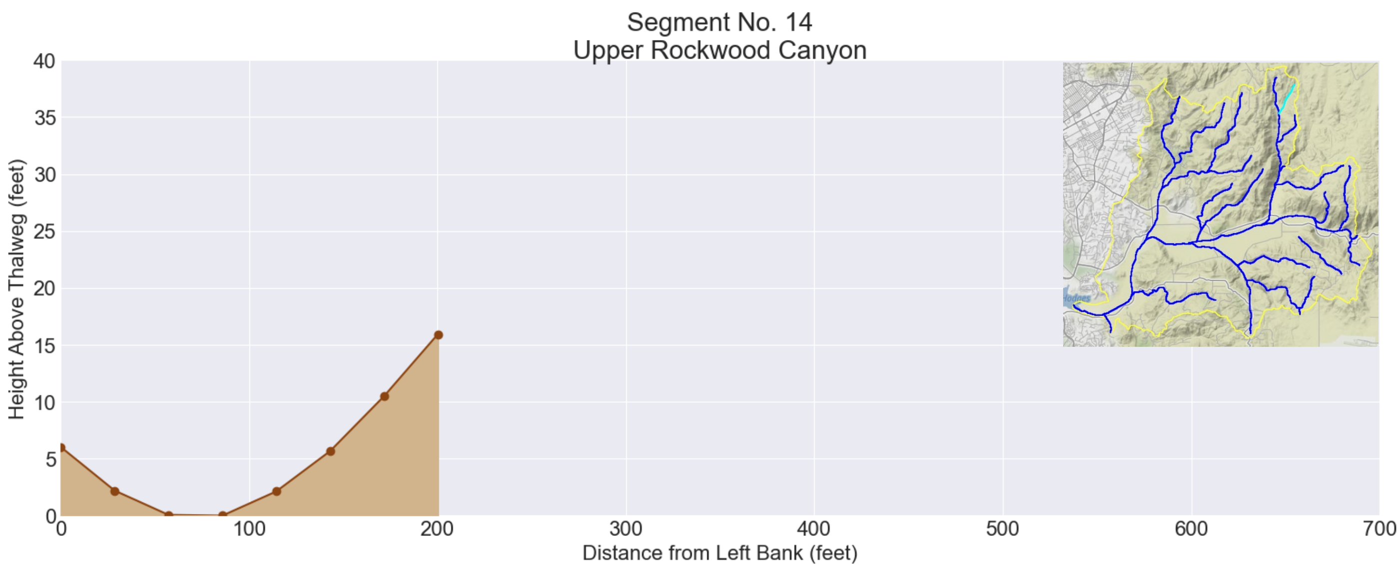
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

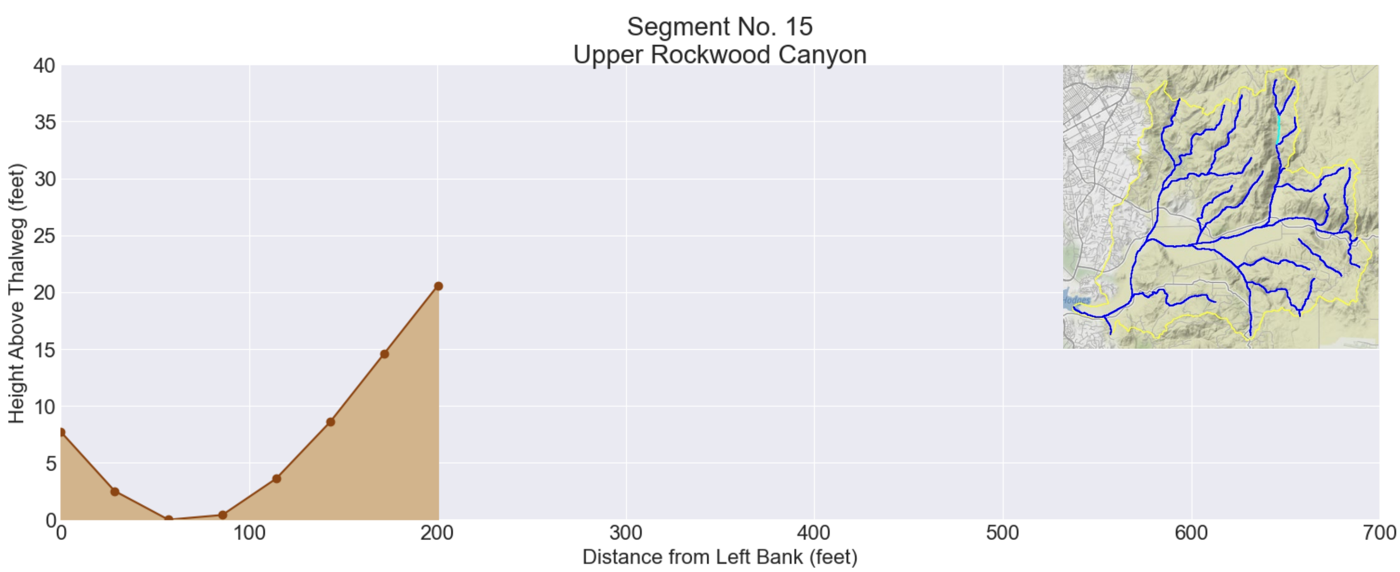
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-4
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend

Modeled Stream

Highlighted Segment of Modeled Stream

Figure A-5

Modeled Eight-point Stream Channels

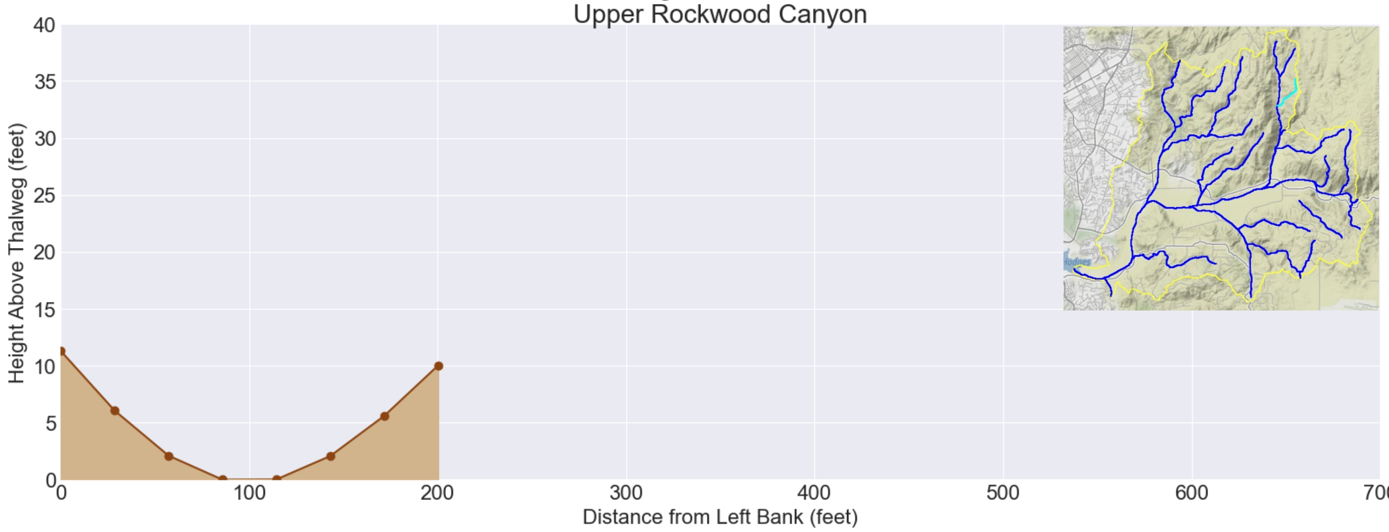
PMA7: Initial Surface Water Recharge Evaluation

Task 5 Groundwater and Surface Water Simulations

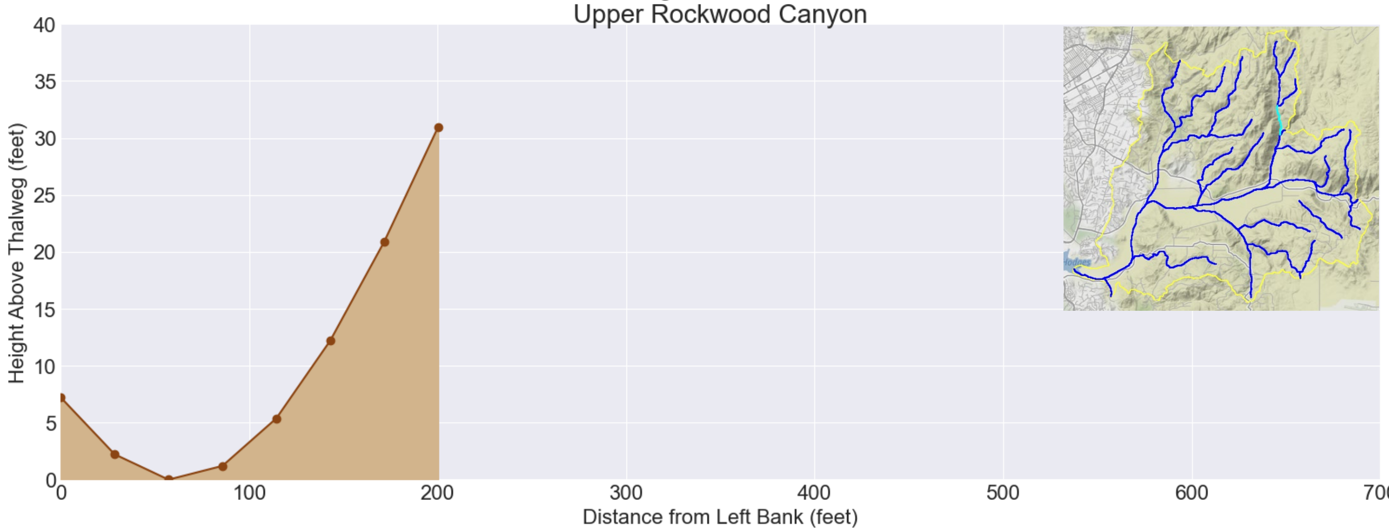
San Pasqual Valley, California

Jacobs

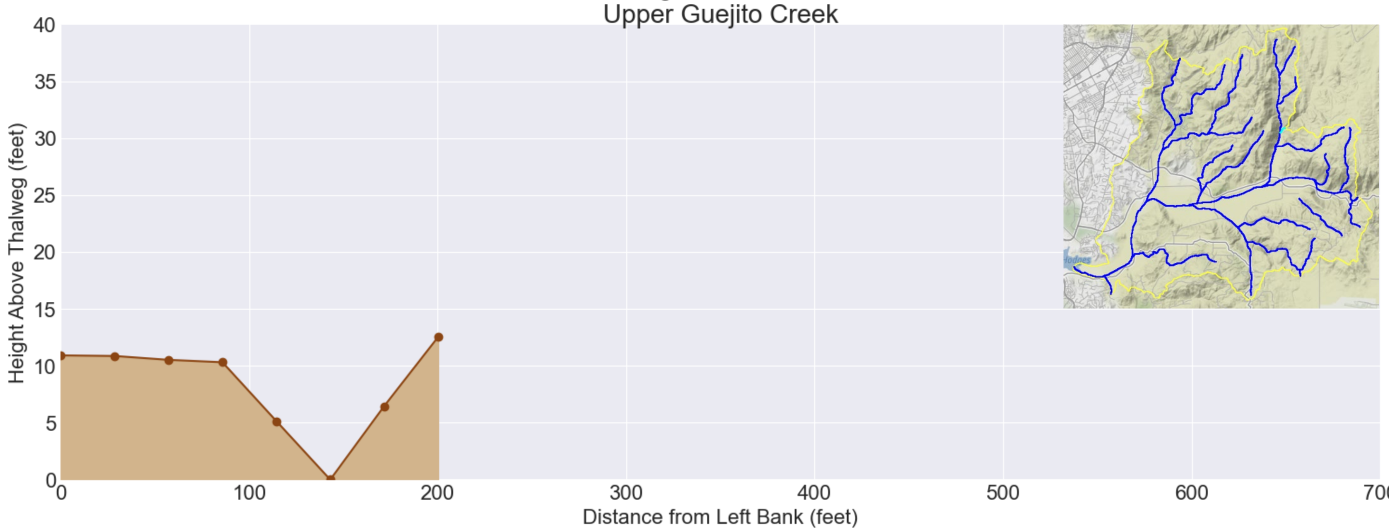
Segment No. 16
Upper Rockwood Canyon



Segment No. 17
Upper Rockwood Canyon



Segment No. 18
Upper Guejito Creek



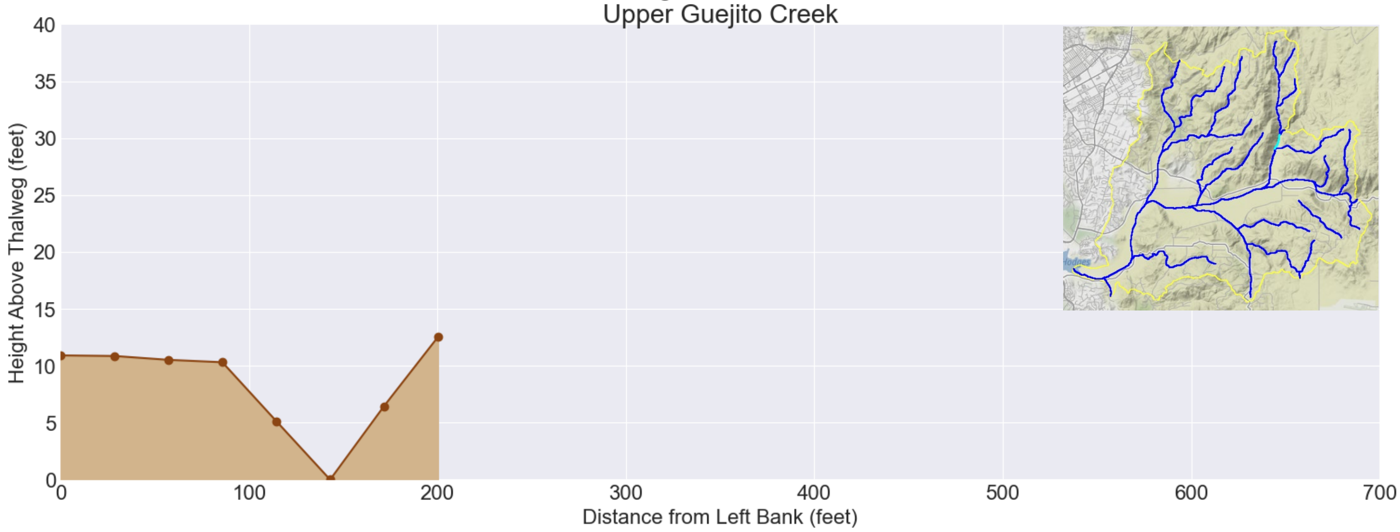
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

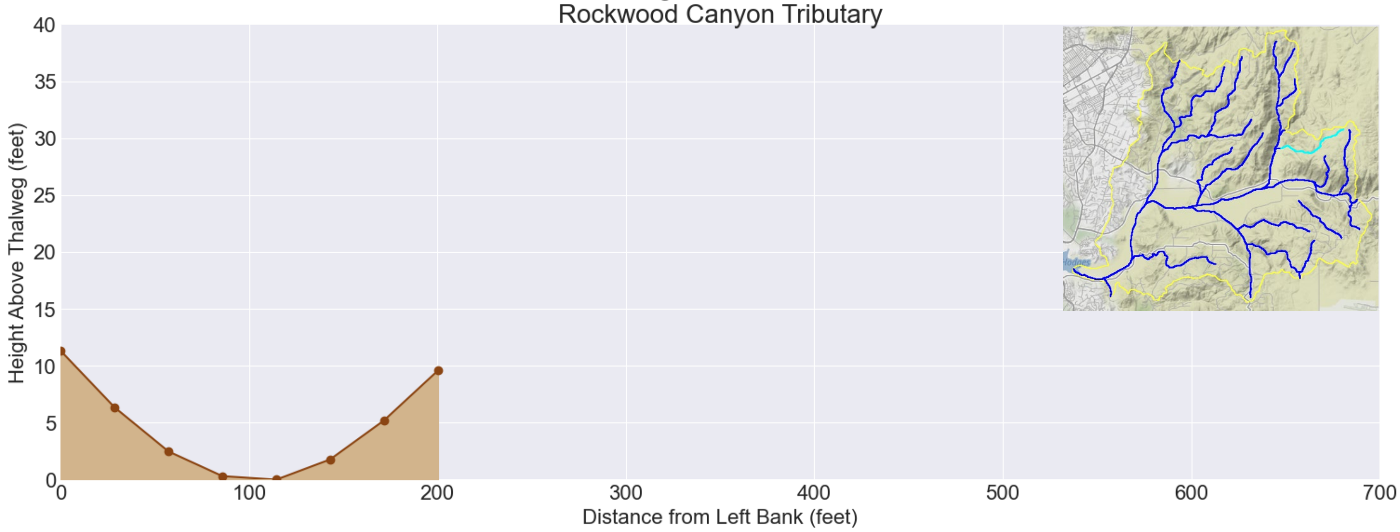
Figure A-6
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

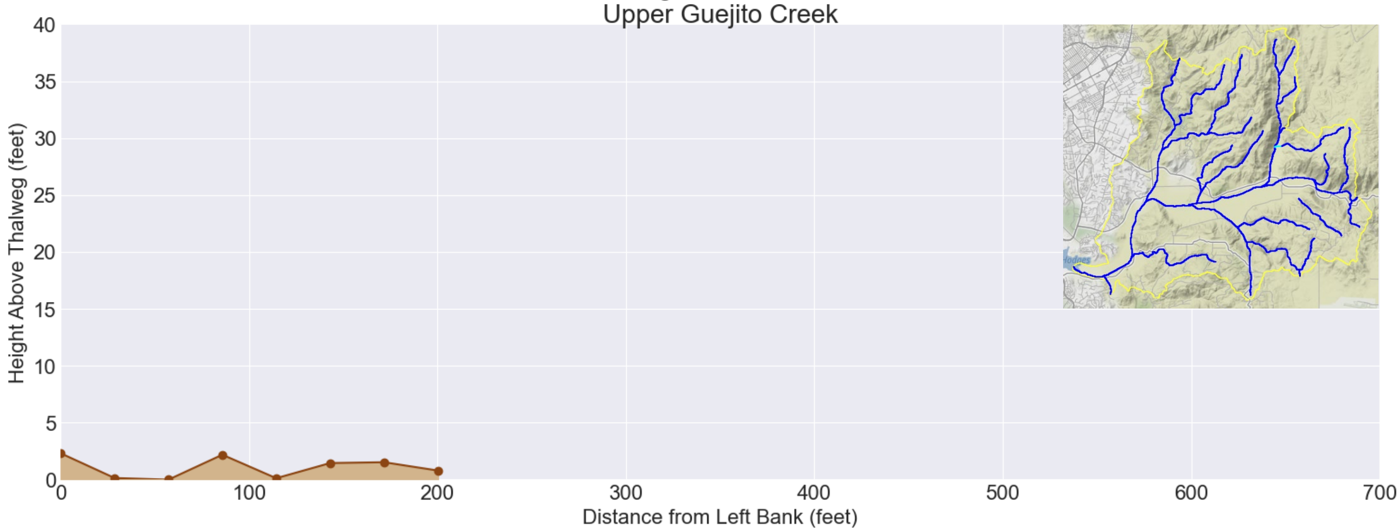
Segment No. 19
Upper Guejito Creek



Segment No. 20
Rockwood Canyon Tributary



Segment No. 21
Upper Guejito Creek

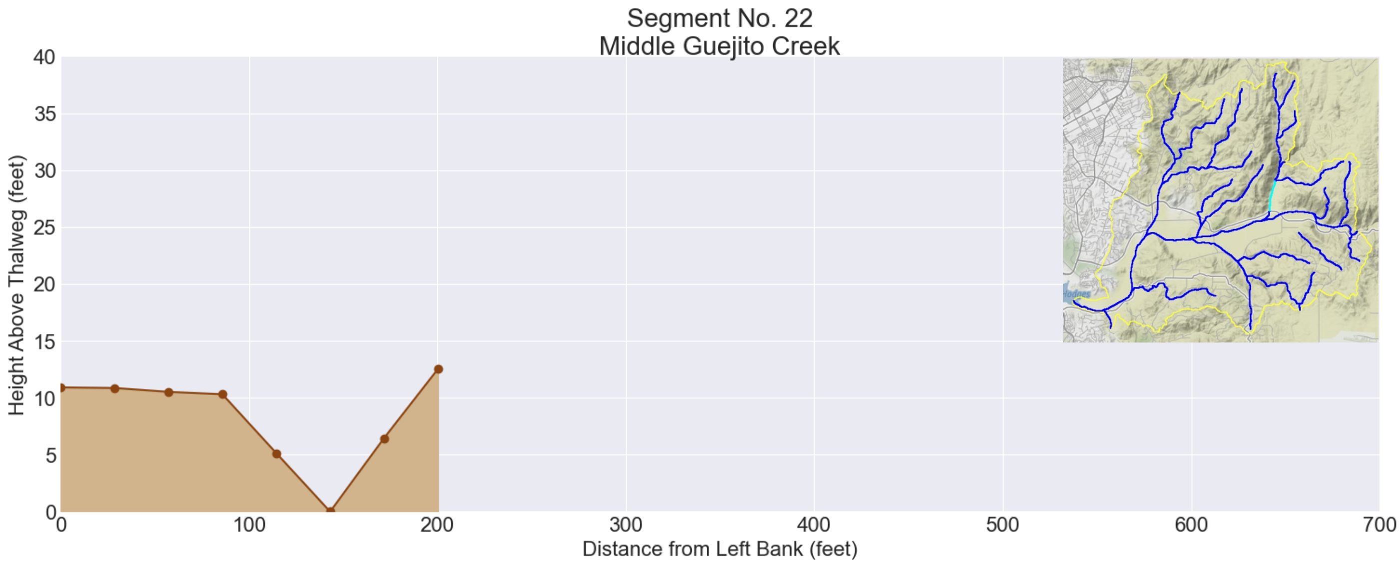


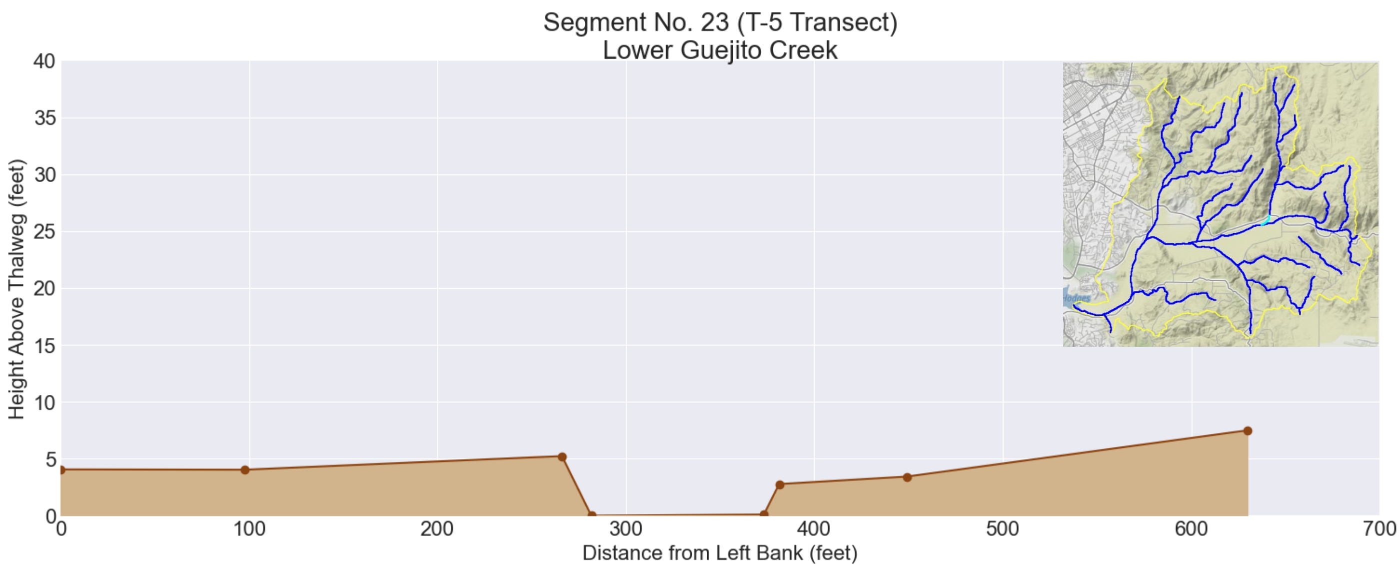
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.

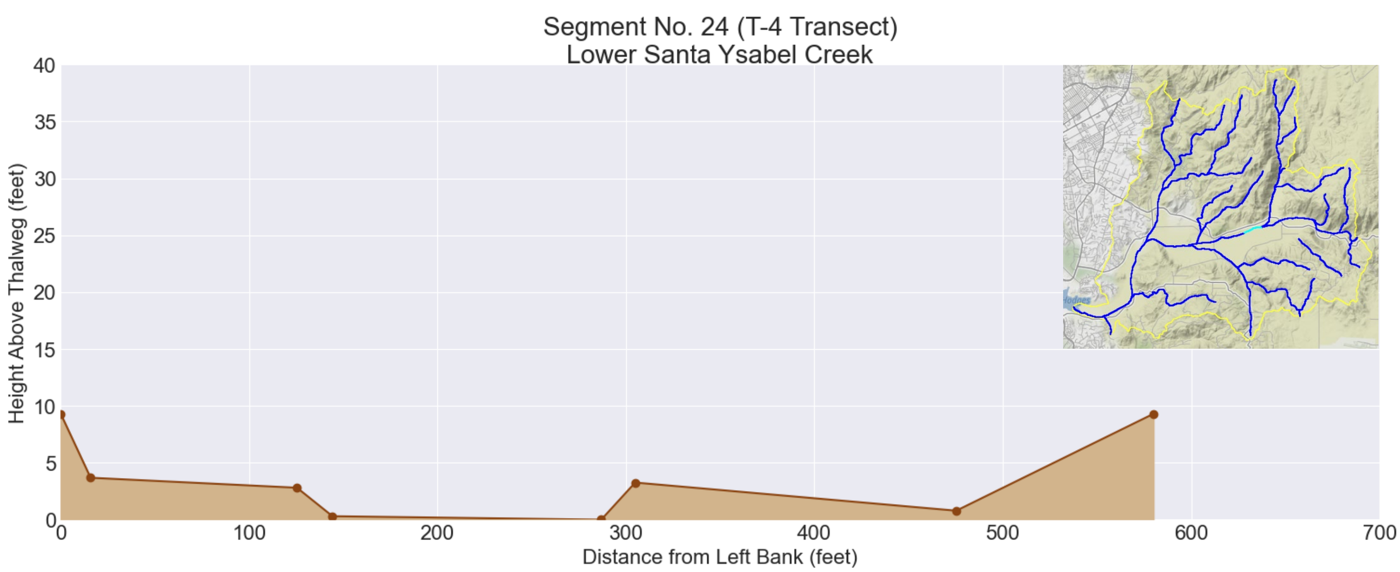
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-7
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs







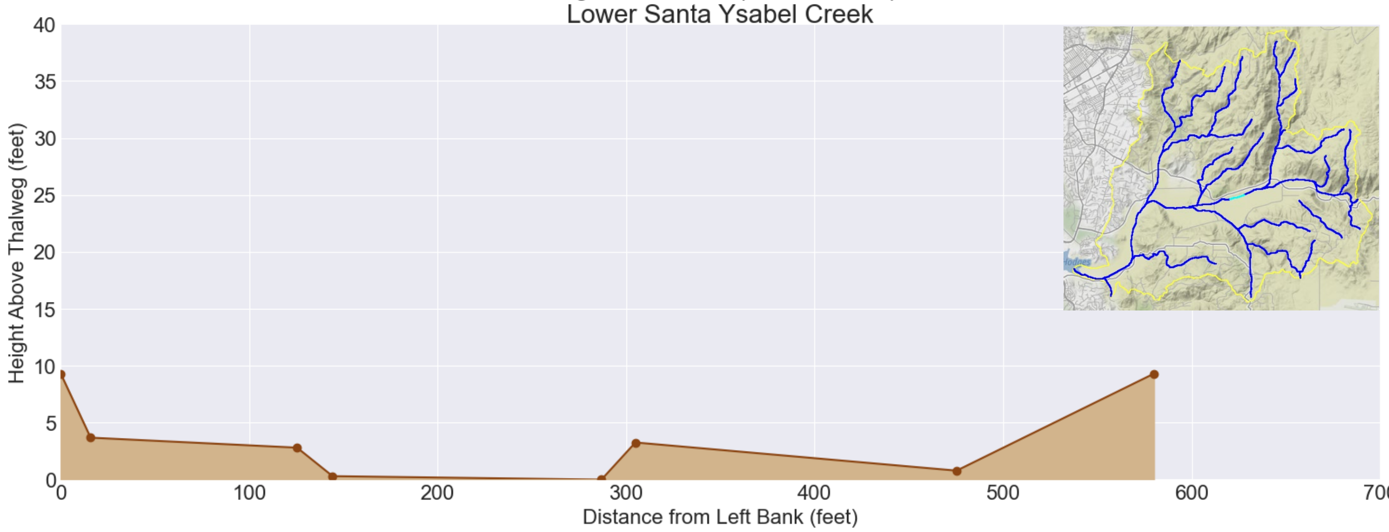
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

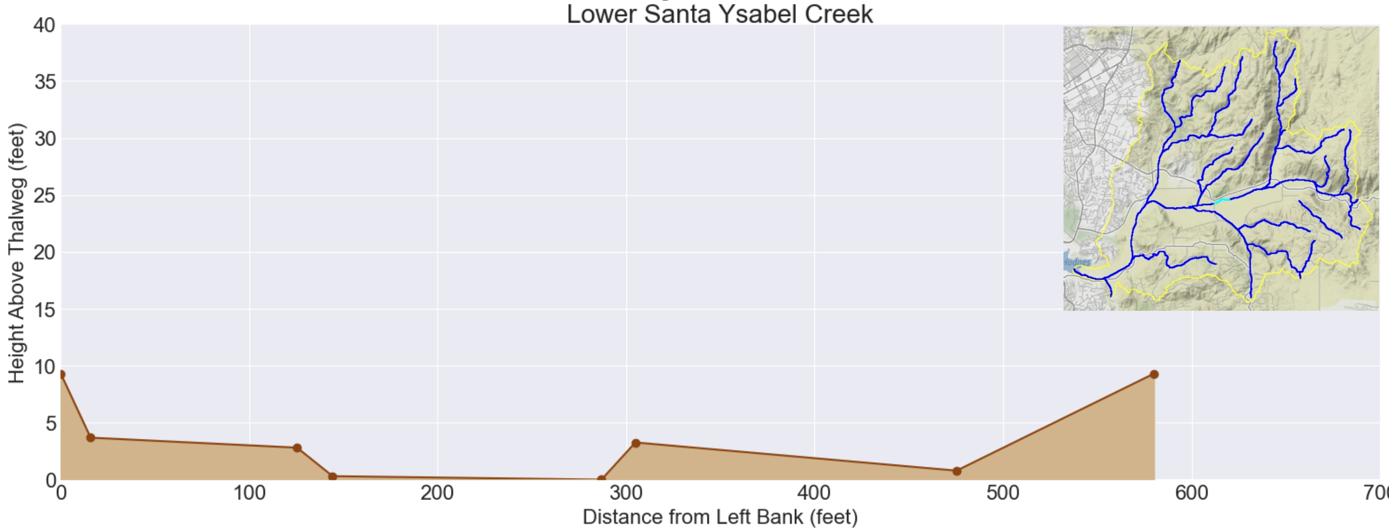
Figure A-8
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

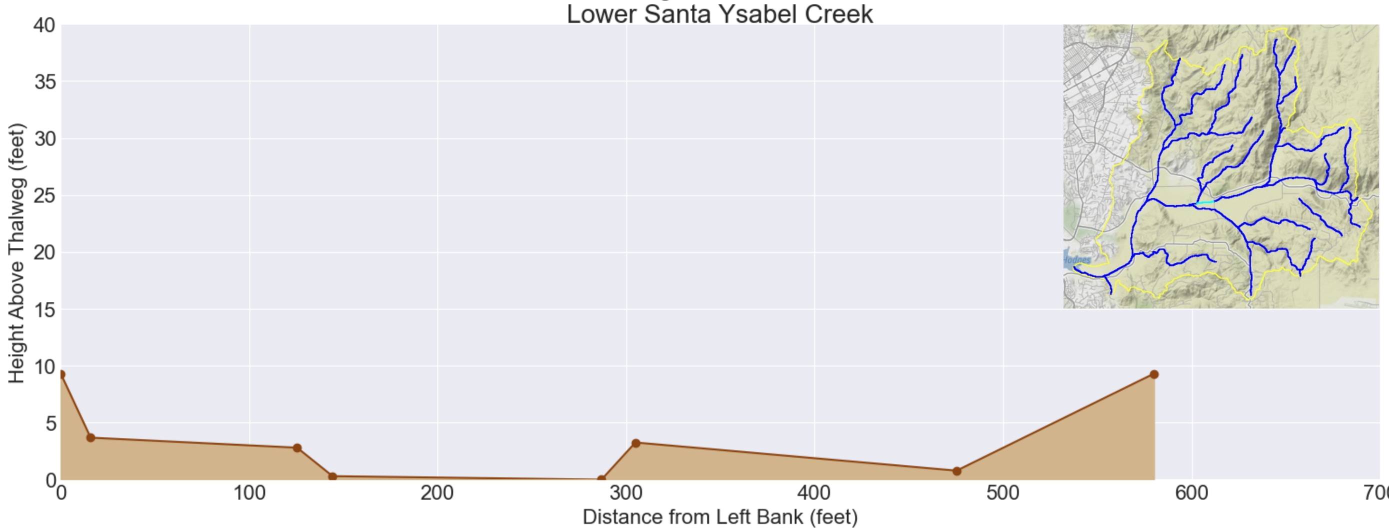
Segment No. 25 (T-4 Transect)
Lower Santa Ysabel Creek



Segment No. 26
Lower Santa Ysabel Creek



Segment No. 27
Lower Santa Ysabel Creek

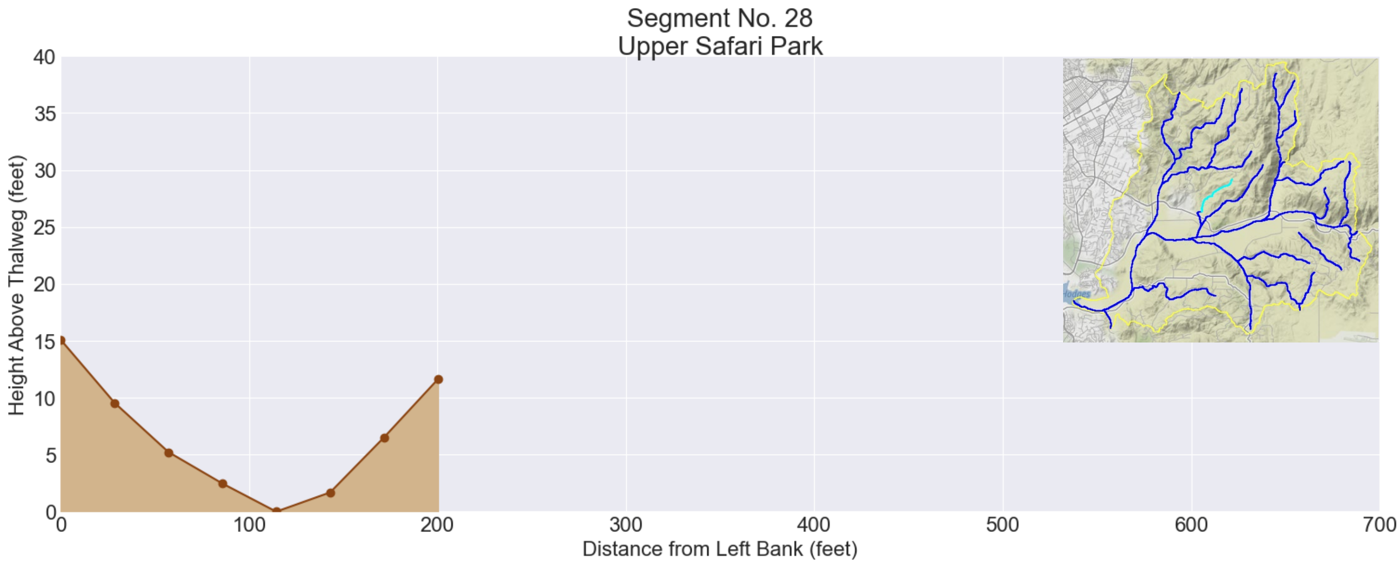


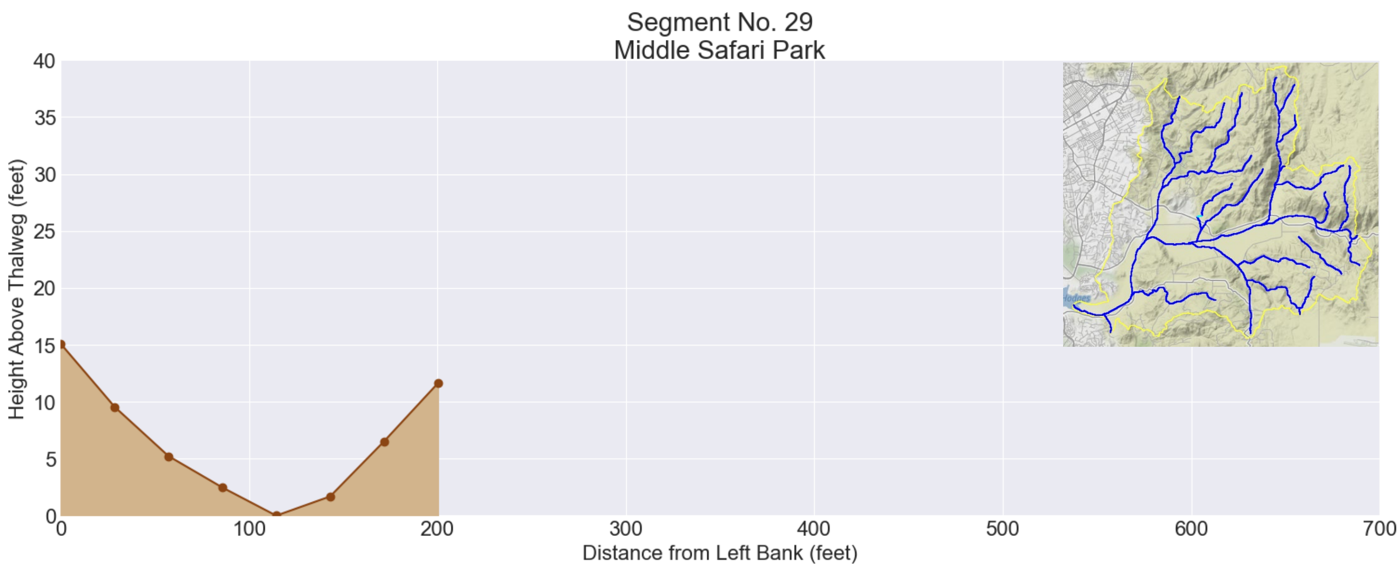
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

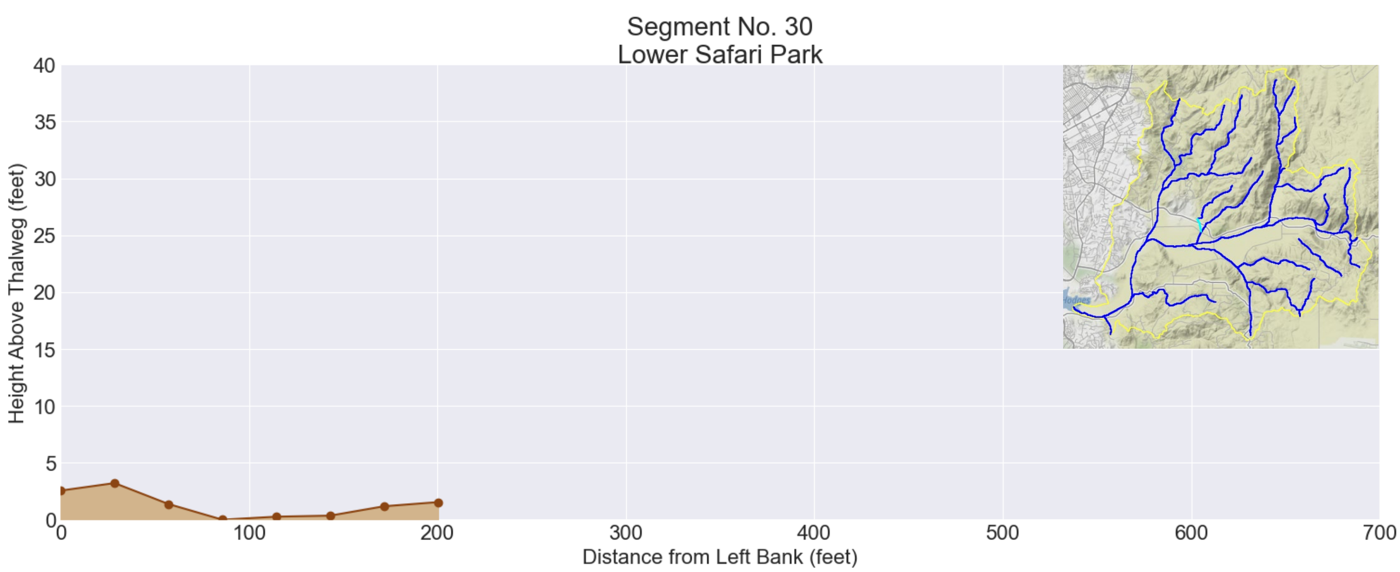
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-9
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-10

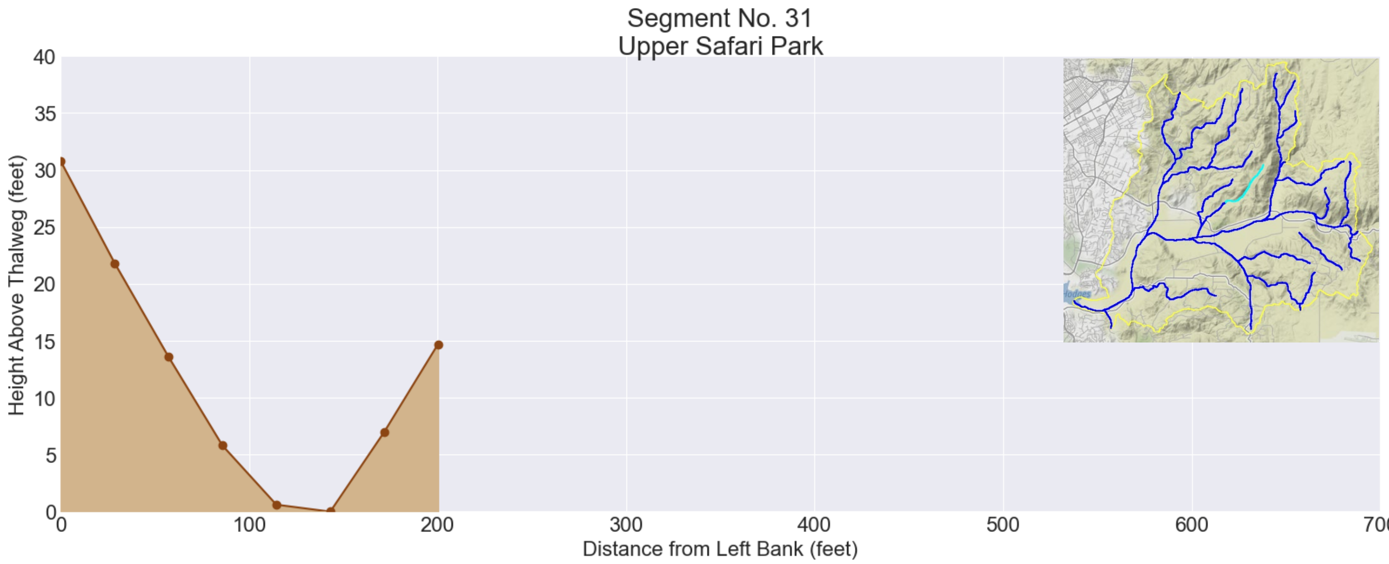
Modeled Eight-point Stream Channels

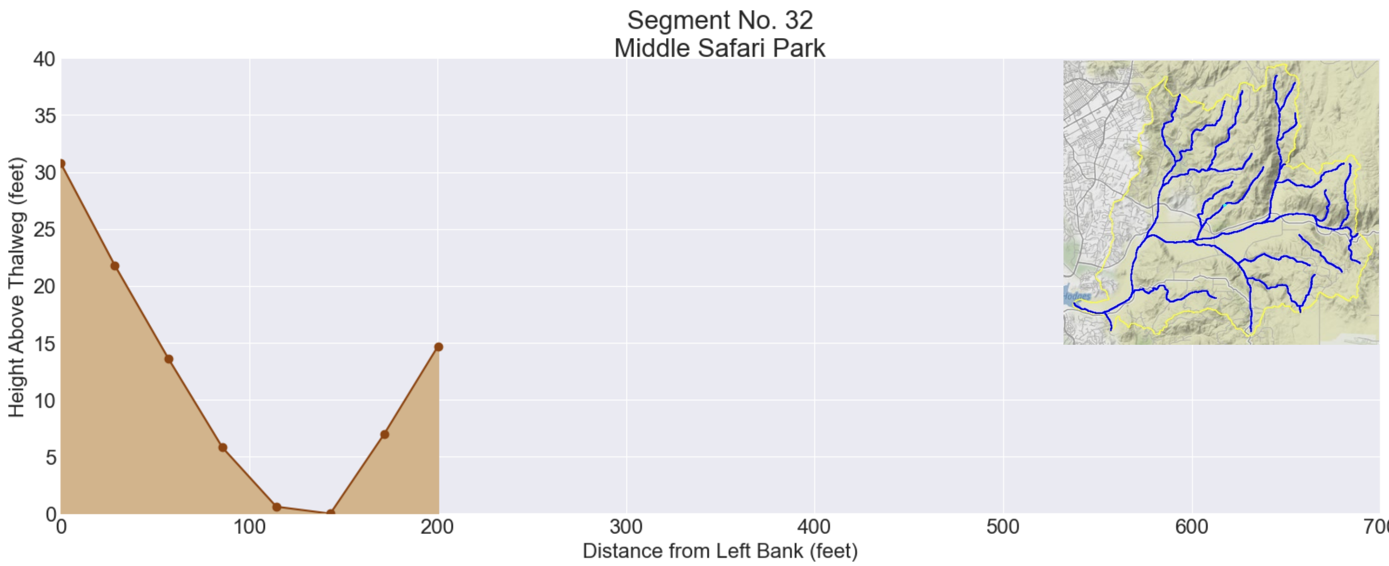
PMA7: Initial Surface Water Recharge Evaluation

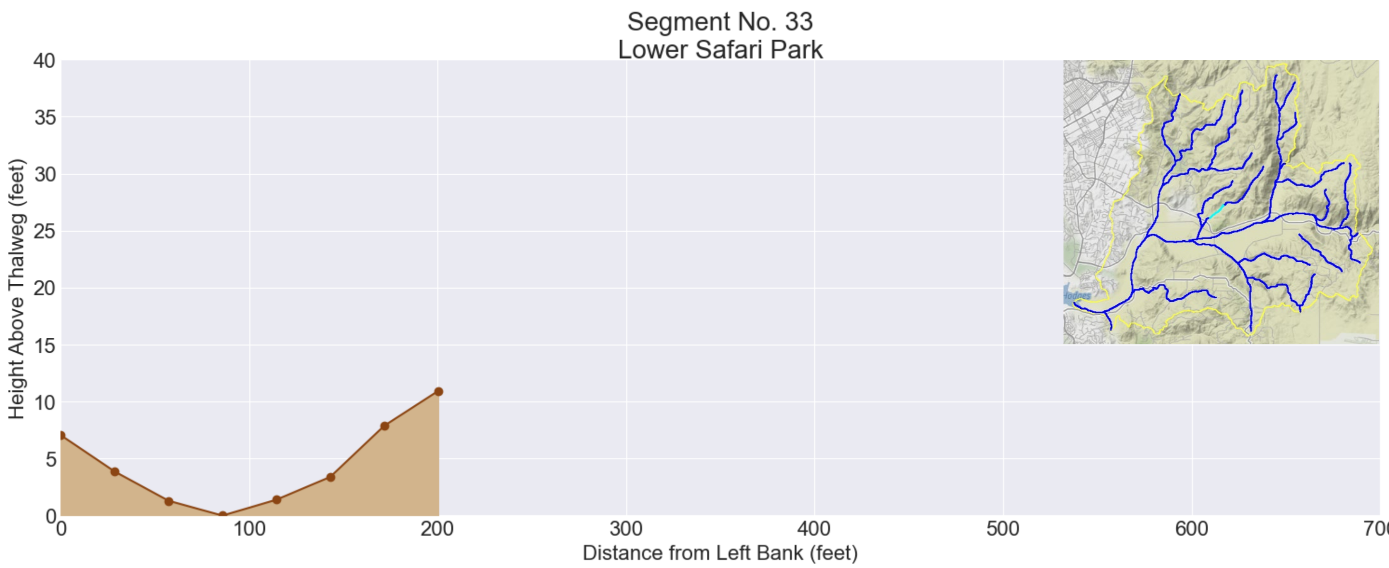
Task 5 Groundwater and Surface Water Simulations

San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend

Modeled Stream

Highlighted Segment of Modeled Stream

Figure A-11

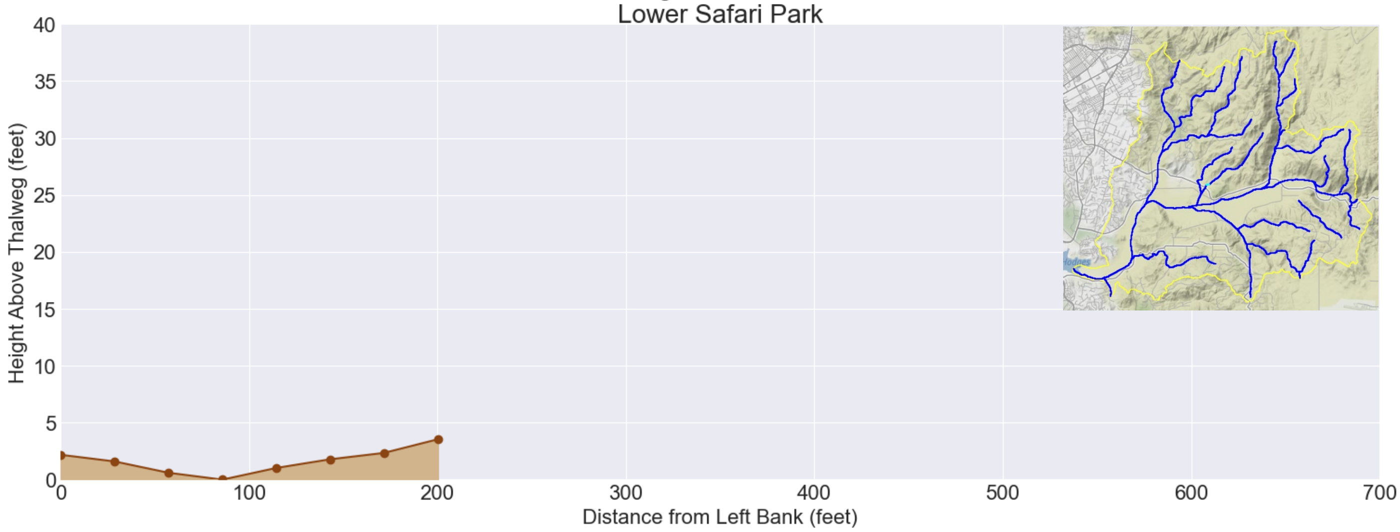
Modeled Eight-point Stream Channels

PMA7: Initial Surface Water Recharge Evaluation Task 5 Groundwater and Surface Water Simulations

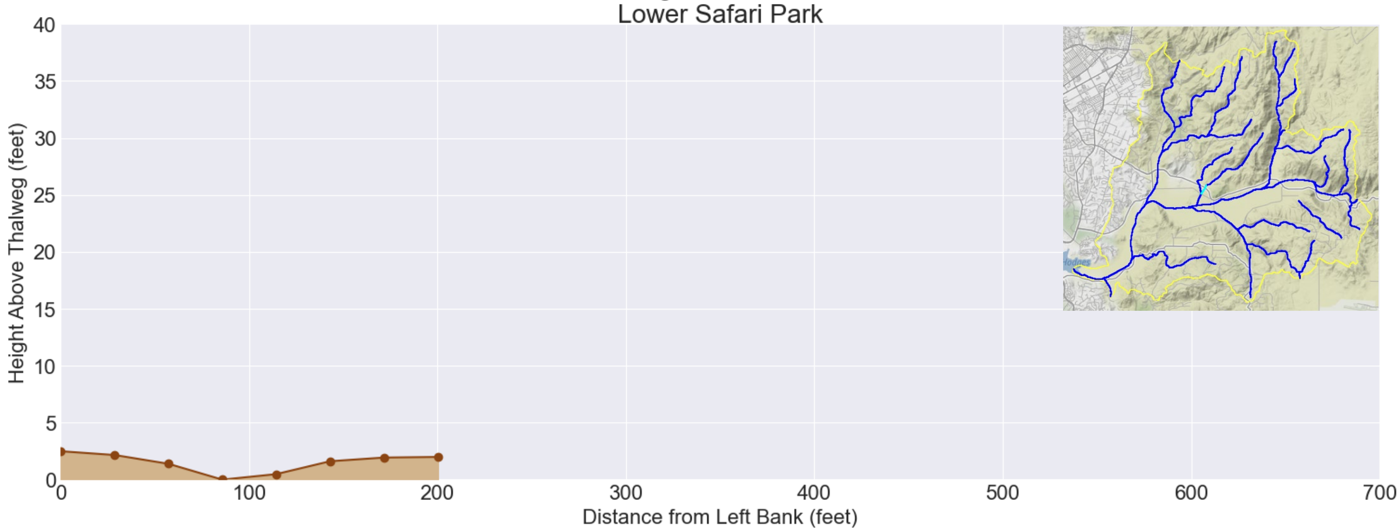
San Pasqual Valley, California

Jacobs

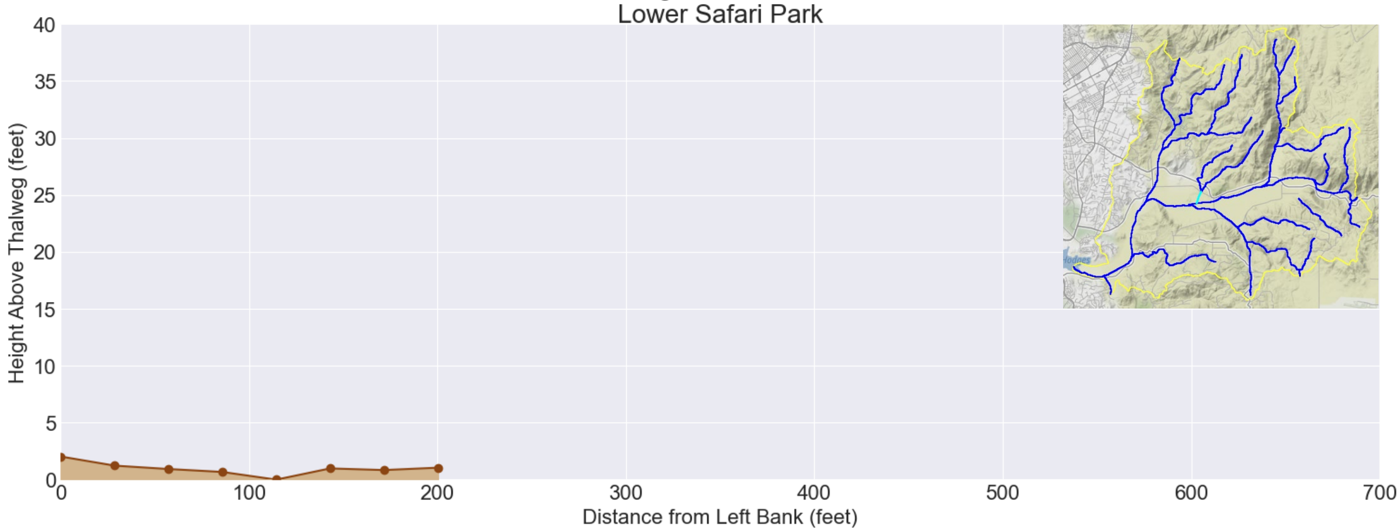
Segment No. 34
Lower Safari Park



Segment No. 35
Lower Safari Park



Segment No. 36
Lower Safari Park

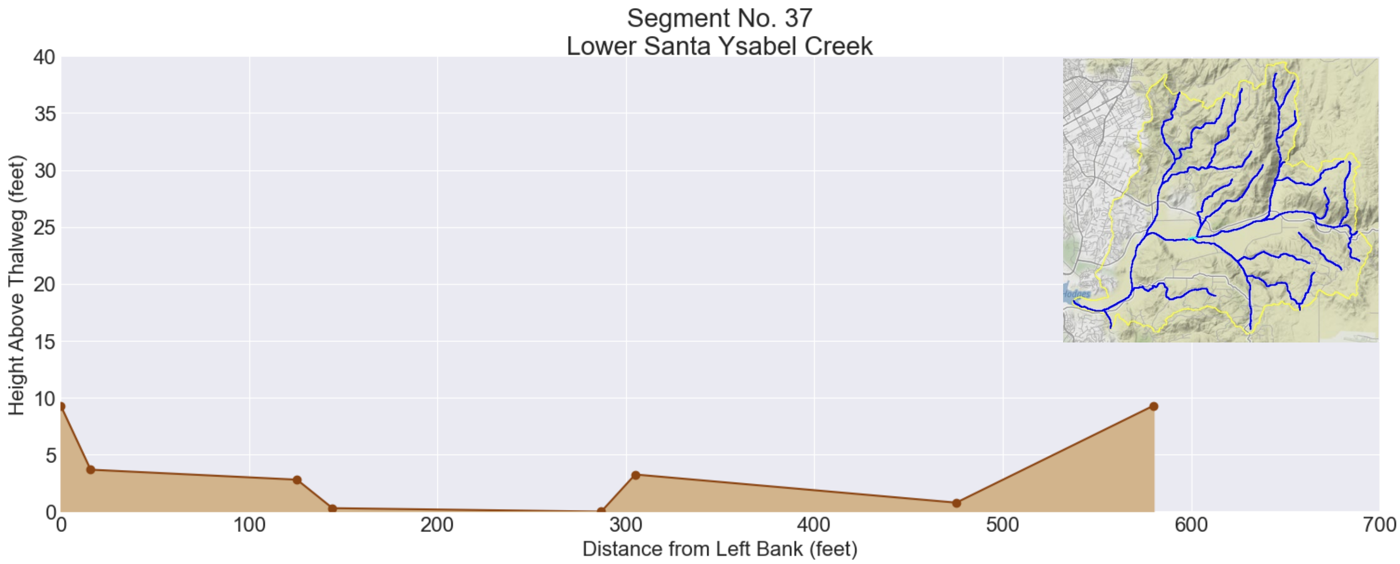


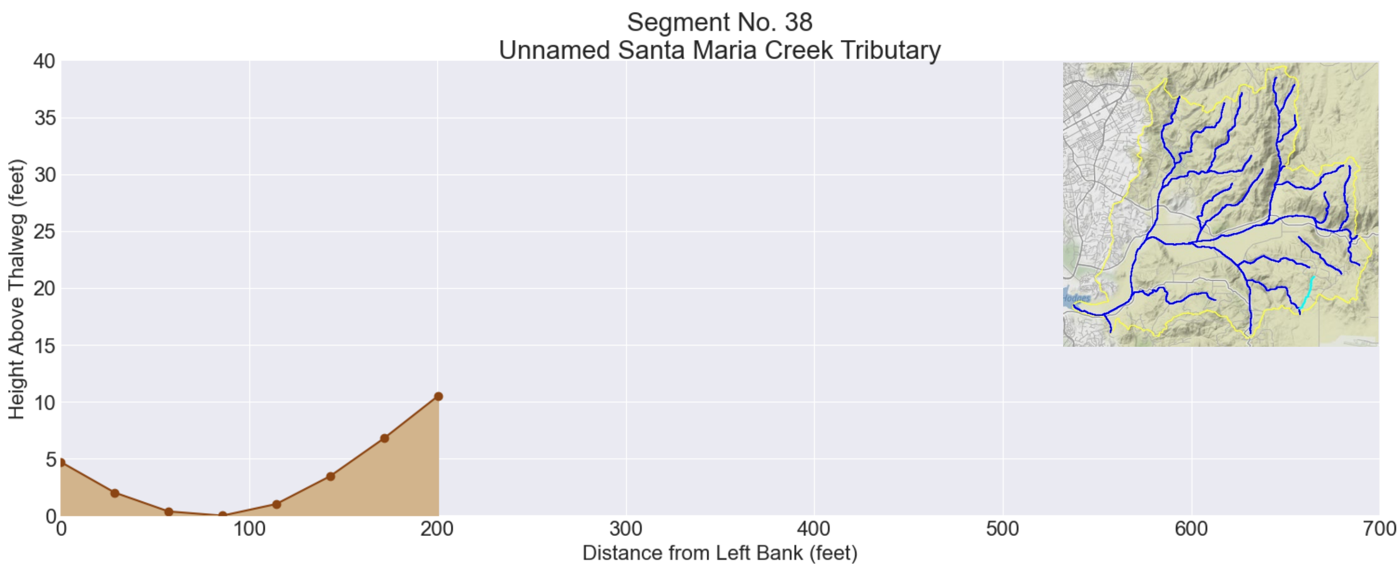
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.

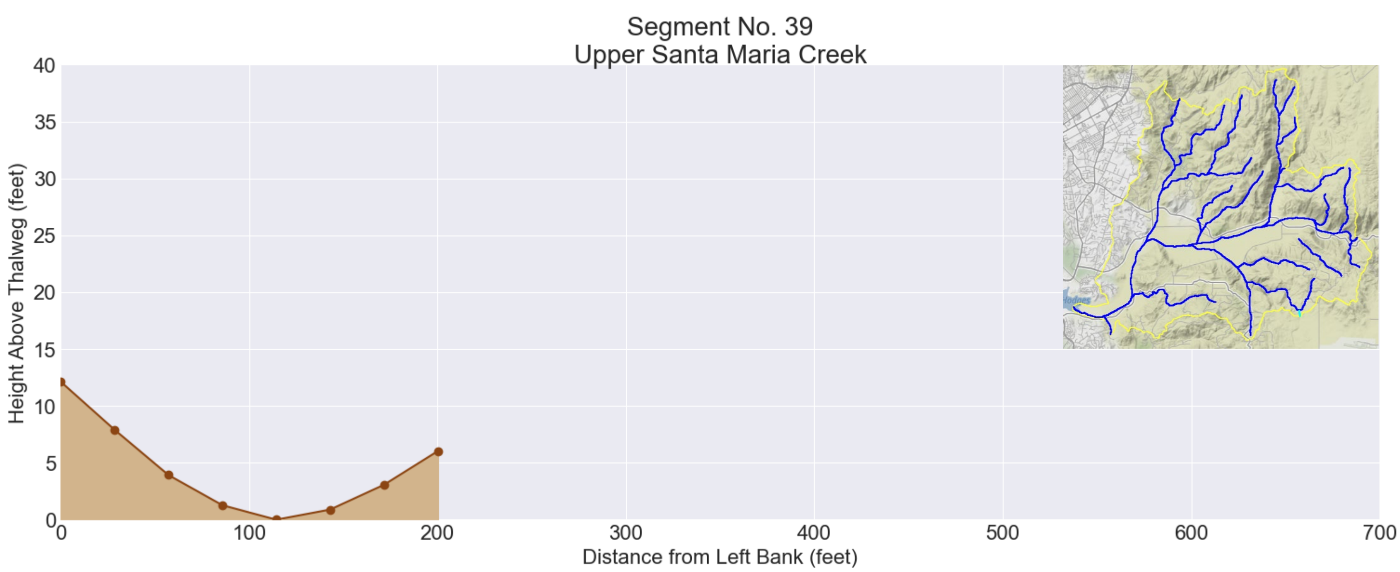
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-12
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-13

Modeled Eight-point Stream Channels

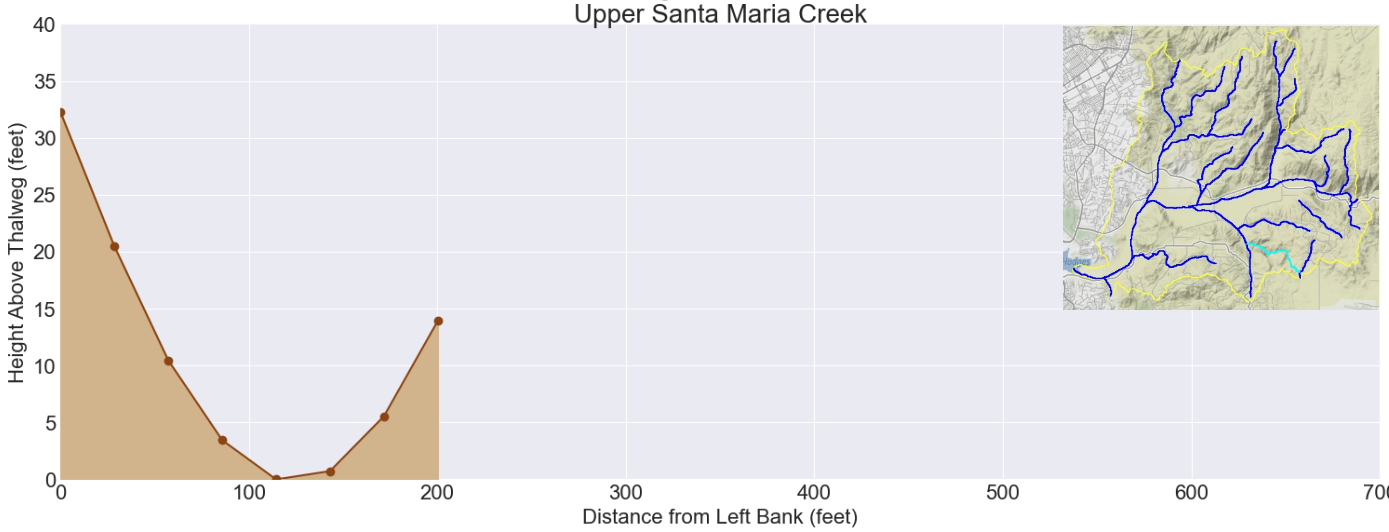
PMA7: Initial Surface Water Recharge Evaluation

Task 5 Groundwater and Surface Water Simulations

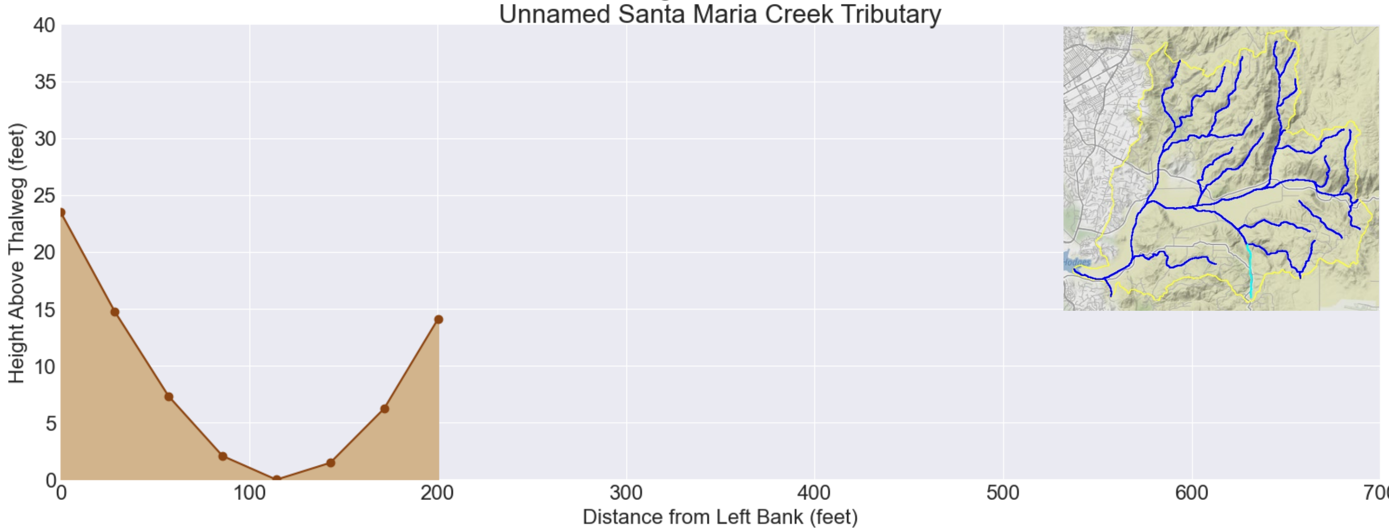
San Pasqual Valley, California

Jacobs

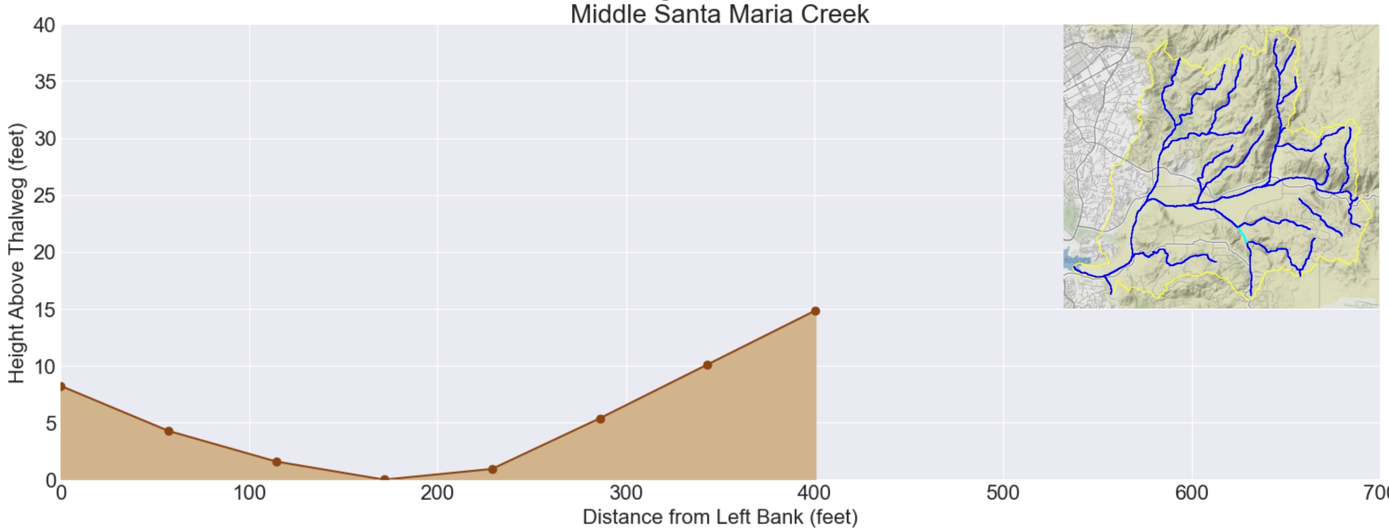
Segment No. 40
Upper Santa Maria Creek



Segment No. 41
Unnamed Santa Maria Creek Tributary



Segment No. 42
Middle Santa Maria Creek



Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

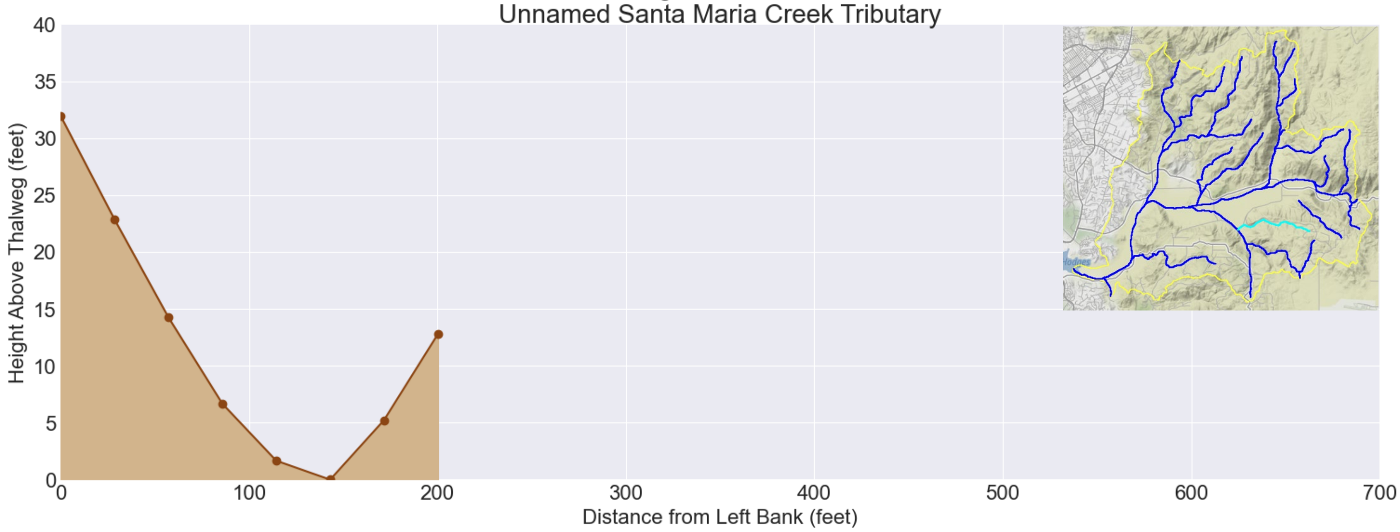
Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

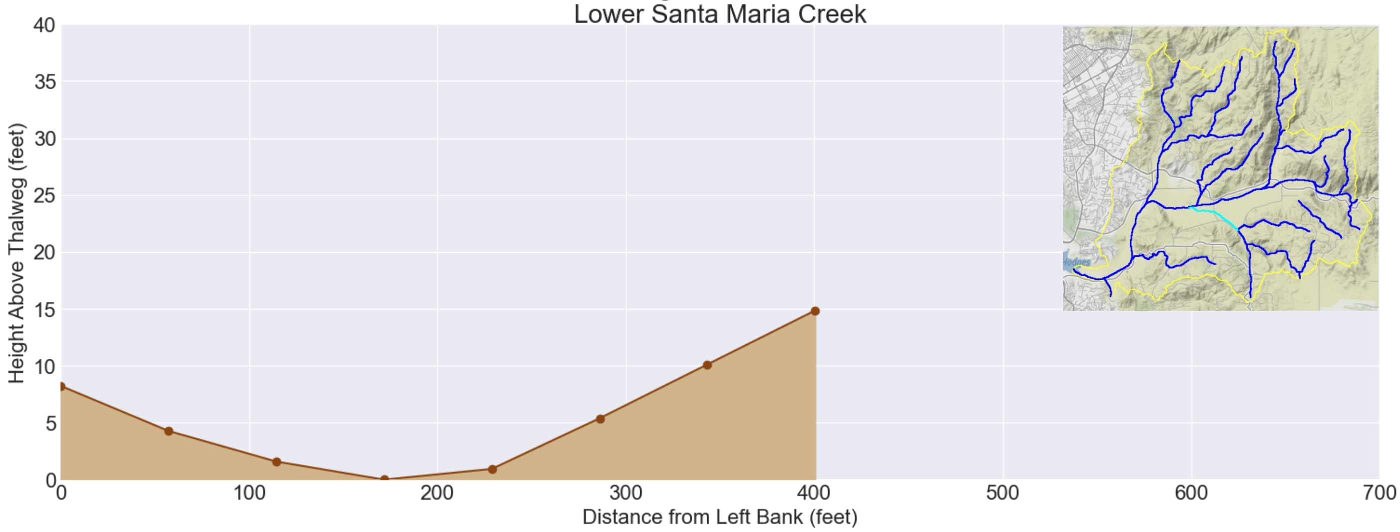
Figure A-14
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\PMA7\Task5\TM\Attachments\Attachment_A\Attachment_A_Modeled_8Pt_StreamChannels.pptm

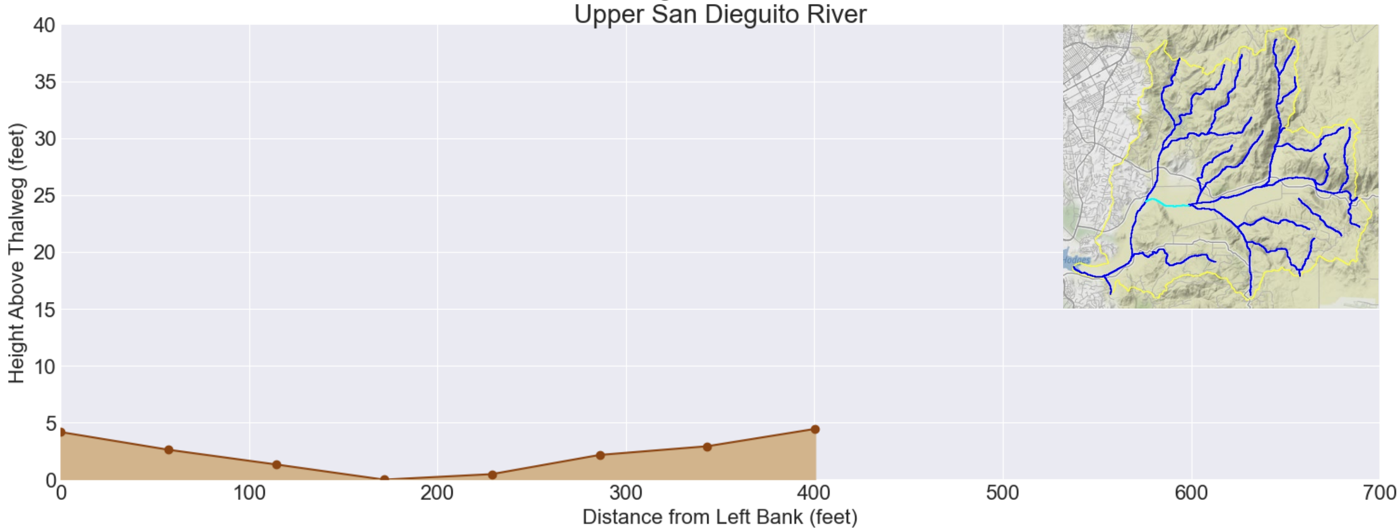
Segment No. 43
Unnamed Santa Maria Creek Tributary



Segment No. 44
Lower Santa Maria Creek



Segment No. 45
Upper San Dieguito River



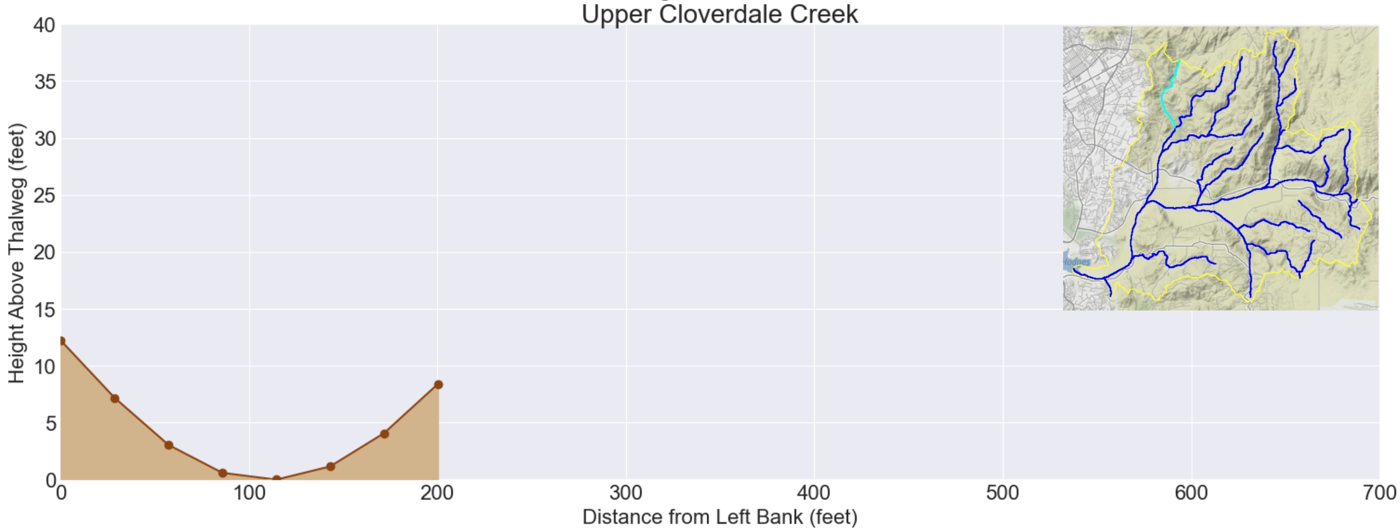
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

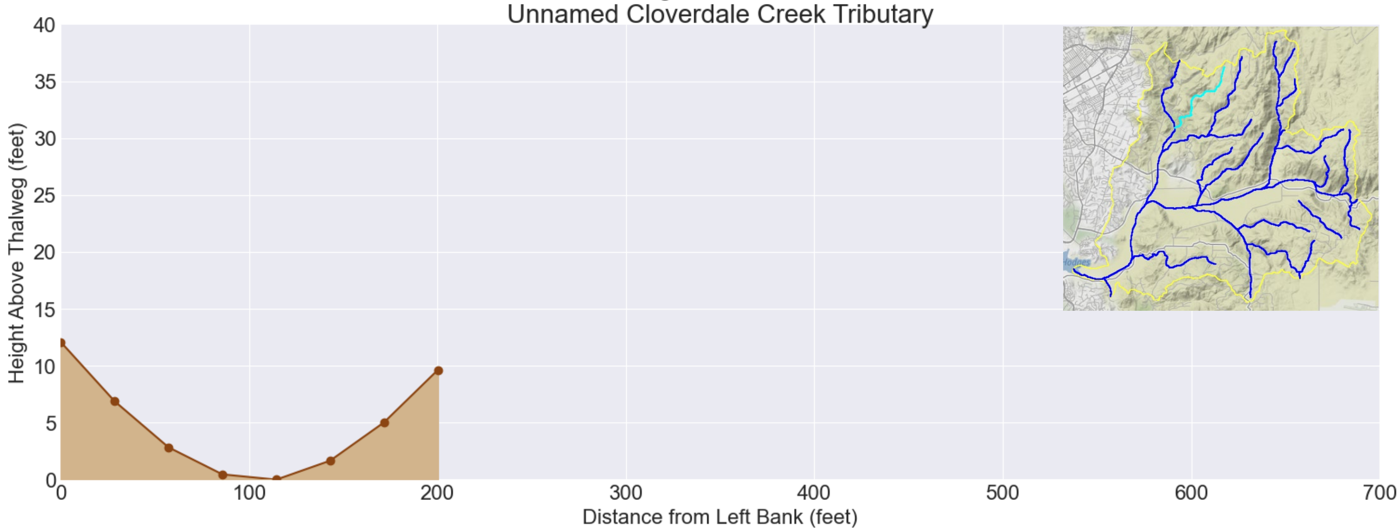
Figure A-15
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

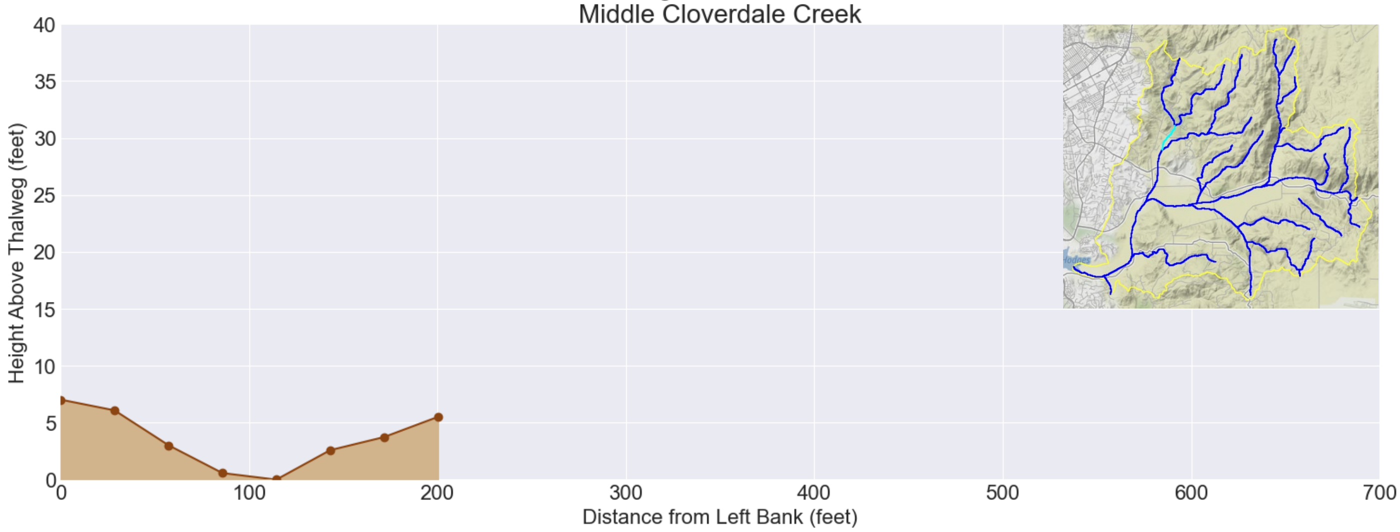
Segment No. 46
Upper Cloverdale Creek



Segment No. 47
Unnamed Cloverdale Creek Tributary



Segment No. 48
Middle Cloverdale Creek



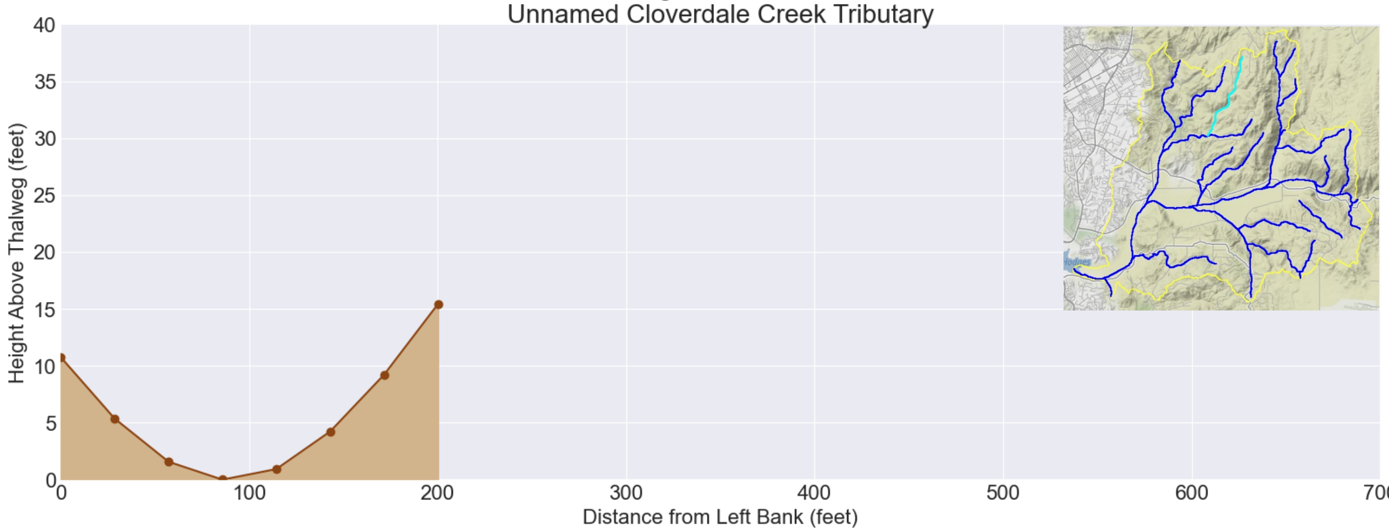
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

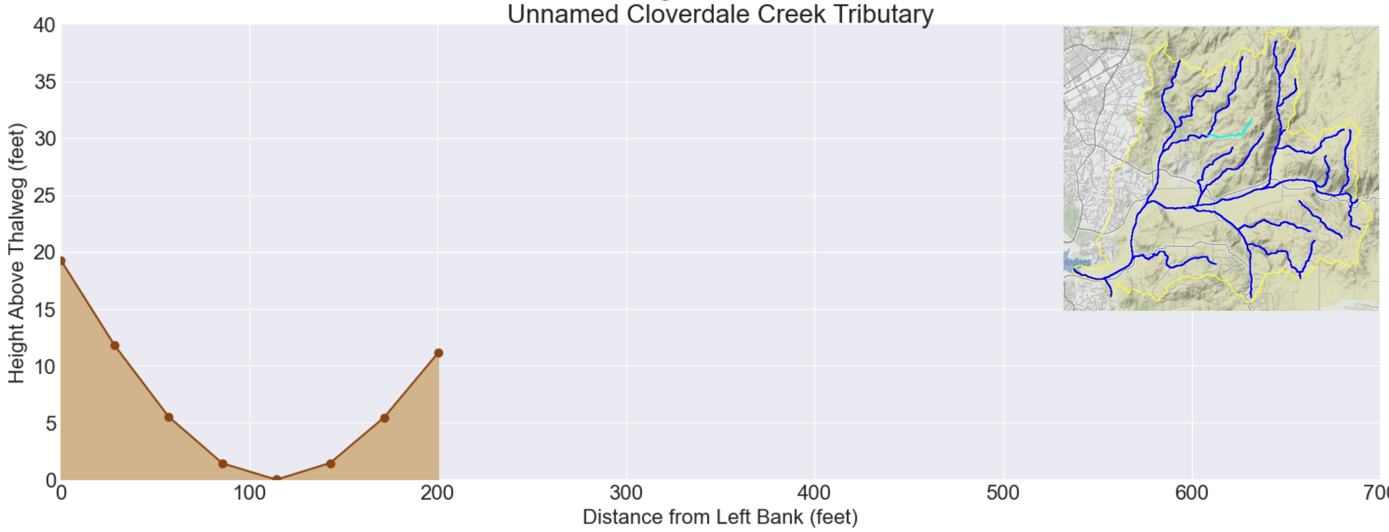
Figure A-16
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

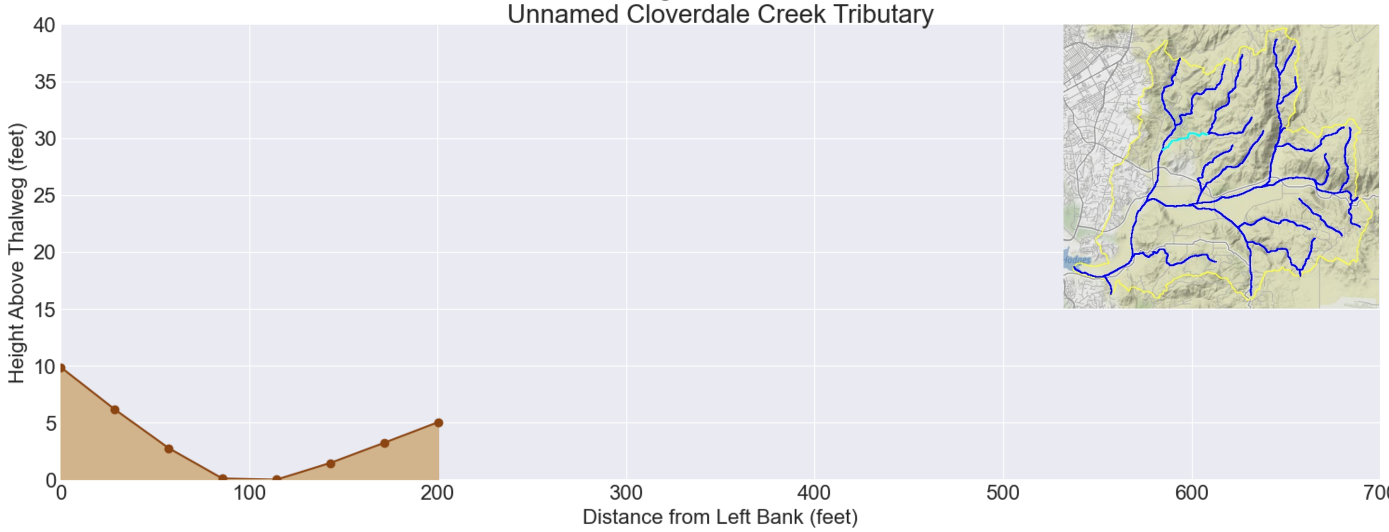
Segment No. 49
Unnamed Cloverdale Creek Tributary



Segment No. 50
Unnamed Cloverdale Creek Tributary



Segment No. 51
Unnamed Cloverdale Creek Tributary

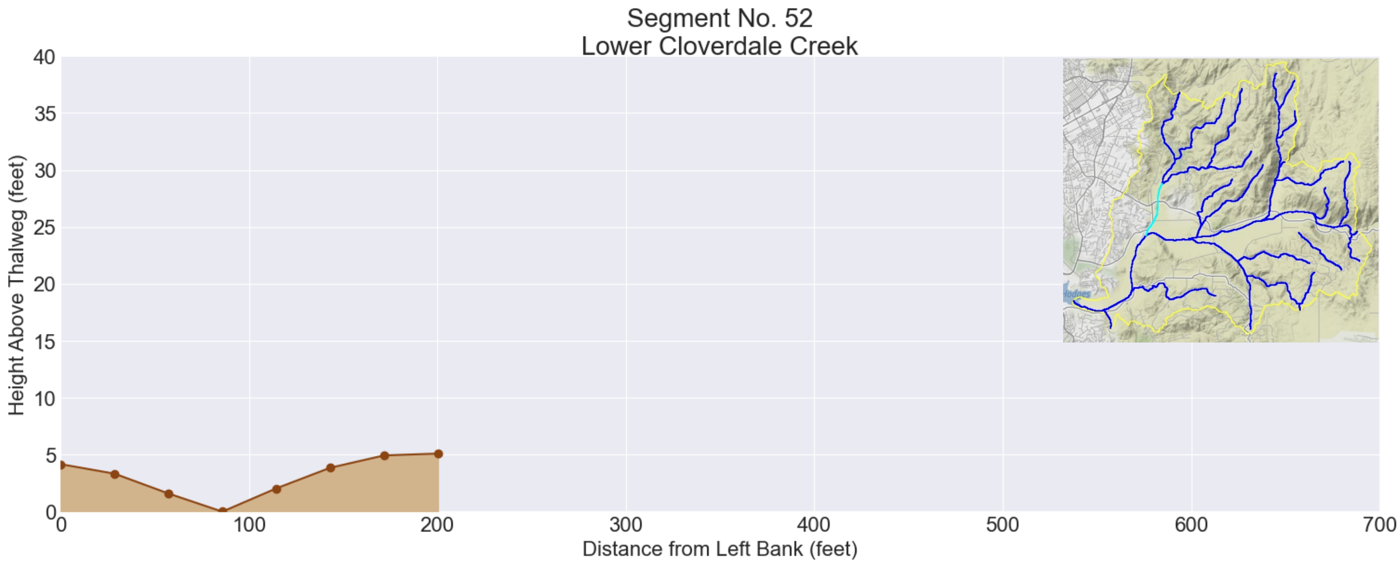


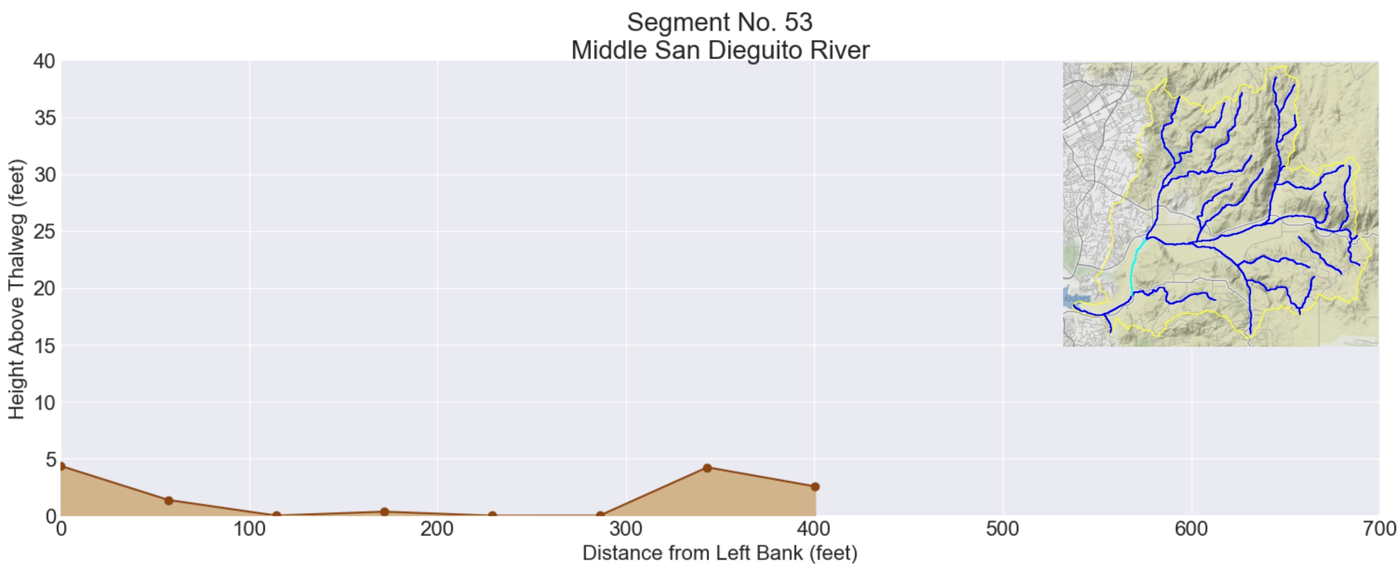
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.

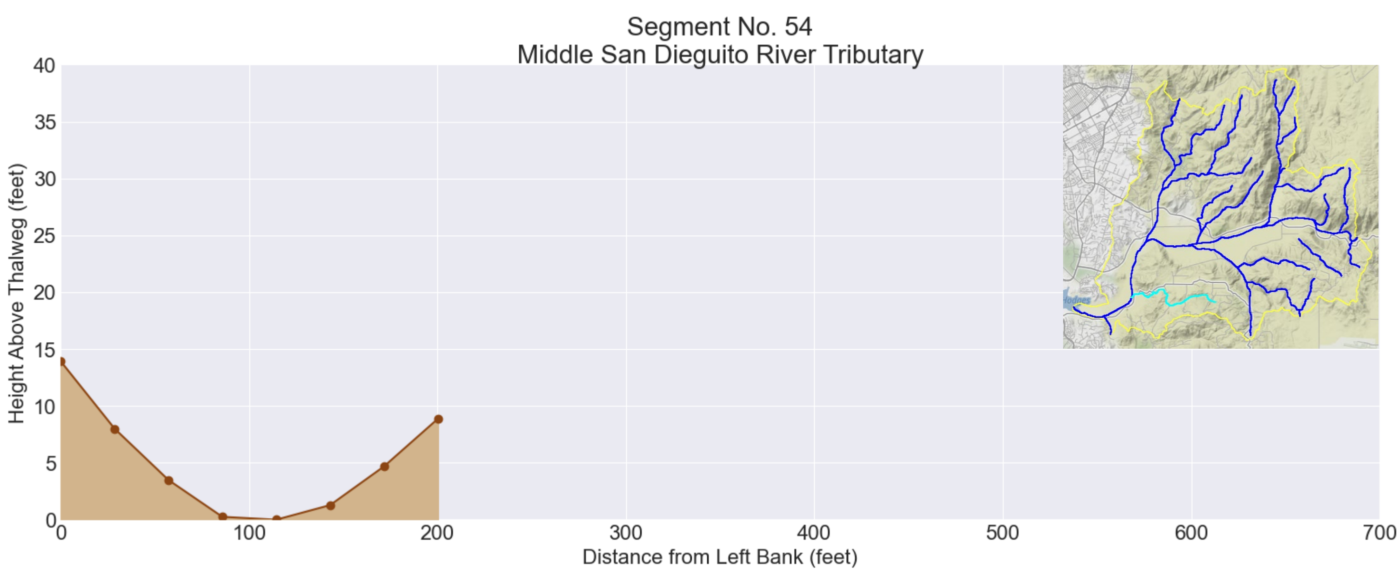
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-17
Modeled Eight-point Stream Channels
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs







Notes:

1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure A-18

Modeled Eight-point Stream Channels

PMA7: Initial Surface Water Recharge Evaluation

Task 5 Groundwater and Surface Water Simulations

San Pasqual Valley, California

Jacobs

ATTACHMENT B: MATHEMATICAL FORMULATION FOR HYDRAULIC CONDUCTIVITY OF MODELED STREAMS

This attachment describes the mathematical formulation used to compute effective vertical K values assigned to the SFR package in the SPV GSP Model v2.0. This mathematical formulation is needed because the SFR package requires input of K values that represent the effective vertical K of the streambed and underlying materials above the water table. The K values of the streambed materials that were derived in Task 2 (City, 2023a) are not appropriate to directly assign to the SFR package as they only account for the vertical K of the stream. The following background subsection describes the basis for why the approach for assignment of vertical K in the SFR package was needed.

Background

The SPV GSP Model v1.0 was originally calibrated to groundwater levels measured over the 15-year historical period including WYs 2005 through 2019. The calibration process involves varying selected input parameter (e.g., K) values within realistic ranges until there is a reasonable match between modeled and measured groundwater levels through time, while also achieving acceptable numerical mass balances. A numerical mass balance discrepancy is computed and reported by the model for each stress period and is a measure for how well the software code[1] was able to solve the flow equations during each stress period. A stress period is an interval of time during which different values of precipitation, stream inflows at the perimeter of the model, and groundwater pumping are used in the model.

It was discovered during the calibration process of the SPV GSP Model v1.0 that the numerical mass balance discrepancy was sensitive to the effective vertical K values assigned to the SFR package ($K_{v\text{-}SFR}$). Generally, the higher the assigned $K_{v\text{-}SFR}$ values, the worse the numerical mass balance discrepancies. The modeling team corresponded with one of the software code developers on this topic and confirmed that higher $K_{v\text{-}SFR}$ values can result in higher mass balance discrepancies. Because the key model output of interest for the GSP (City and County, 2021) was the groundwater budget, achieving adequate numerical mass balances was of utmost importance. Therefore, during the development of the GSP, a compromise was made by assigning a $K_{v\text{-}SFR}$ value of 0.1 feet per day (ft/d) (3.5×10^{-5} centimeters per second [cm/s]) to achieve sufficient numerical mass balances, even though it was understood at that time that actual K values of the streambed could be greater. This compromise was deemed reasonable and appropriate during development of the GSP, especially given that streambeds in the SPV were dry most of the time during the 15-year historical calibration period and because no site-specific K data for the streambed or underlying sediments above the water table were available to confirm or refute the assigned value.

The uncertainty in site-specific K values for the Santa Ysabel Creek streambed provided the motivation for the Task 2 streambed investigation (City, 2023a). One of the key findings from this streambed investigation was a range of streambed vertical hydraulic conductivity ($K_{v\text{-}sb}$) values at eight locations along the Santa Ysabel Creek channel. The $K_{v\text{-}sb}$ values were estimated to range from 116 to 552 ft/d (4.1×10^{-2} to 1.9×10^{-1}

[1] The USGS code MODFLOW-OWHM: One Water Hydrologic Flow Model version 2 (Boyce et al., 2020) was selected for this modeling effort. Additional details on this software code can be found in Section 3.1 of Appendix I of the GSP (City and County, 2021).

cm/s) for the main Santa Ysabel Creek channel (e.g., Part 2 in **Figure 2-1**) and from 24 to 83 ft/d (8.5×10^{-3} to 2.9×10^{-2} cm/s) for the right bank (e.g., Part 3 in **Figure 2-1**). However, the software code developer indicated that the $K_{v\text{-}SFR}$ should consider not only the $K_{v\text{-}sb}$, but also the vertical K of the vadose zone below the stream channel ($K_{v\text{-}vz}$). This is because the SFR package ignores the vertical K assigned to the groundwater cell in Model Layer 1 directly beneath the SFR channel and instead uses the $K_{v\text{-}SFR}$ when computing the groundwater recharge from the stream (**Figure 2-3**). Therefore, a mathematical formulation was needed to compute $K_{v\text{-}SFR}$ values that account for both the $K_{v\text{-}sb}$ estimates from the Task 2 streambed investigation (City, 2023a) as well as the $K_{v\text{-}vz}$, because (as indicated in Section 2.1.2) the rate at which water infiltrates the stream channel at the surface is not necessarily the rate at which the infiltrated water enters the aquifer as groundwater recharge from the stream. This is because the vertical K of the vadose zone materials below the stream channel affects the rate of groundwater recharge from the stream. For this reason, it would not be appropriate to directly assign to the SFR package the K values of the streambed materials that were derived in Task 2 (City, 2023a).

Mathematical Formulation

Groundwater monitoring wells in the Santa Ysabel Creek streambed could provide information on the rate of groundwater recharge from the stream. However, none of the existing groundwater monitoring wells are located in the streambed and estimation of the vertical distribution of K in the vadose zone below the stream channel cannot be estimated solely with the infiltration testing data from the Task 2 streambed investigation (City, 2023a). This limitation is especially relevant in the eastern portion of the Basin where the water table is disconnected from and typically dozens of feet below Santa Ysabel Creek. In this hydrologic setting, the lower-K sediment intervals between the stream channel and water table are the intervals that limit the rate of groundwater recharge from streams. For example, if zone K_5 in **Figure B-1** were to have a much lower K value than the other zones below the infiltration test ring, then it would be the zone that limits the groundwater recharge from infiltration in the test ring. In other words, the zone with the lowest K value above the water table would be the limiting factor for how easily water moves through the vadose zone and enters the aquifer as groundwater recharge from streams. Shorter-term infiltration tests only provide information on the $K_{v\text{-}sb}$ and the vertical K of shallower sediments beneath the streambed, rather than the effective vertical K of all the materials (e.g., $K_{v\text{-}sb}$ and K_1 through K_7 zones in **Figure B-1**) above the water table under the stream (Johnson, 1963).

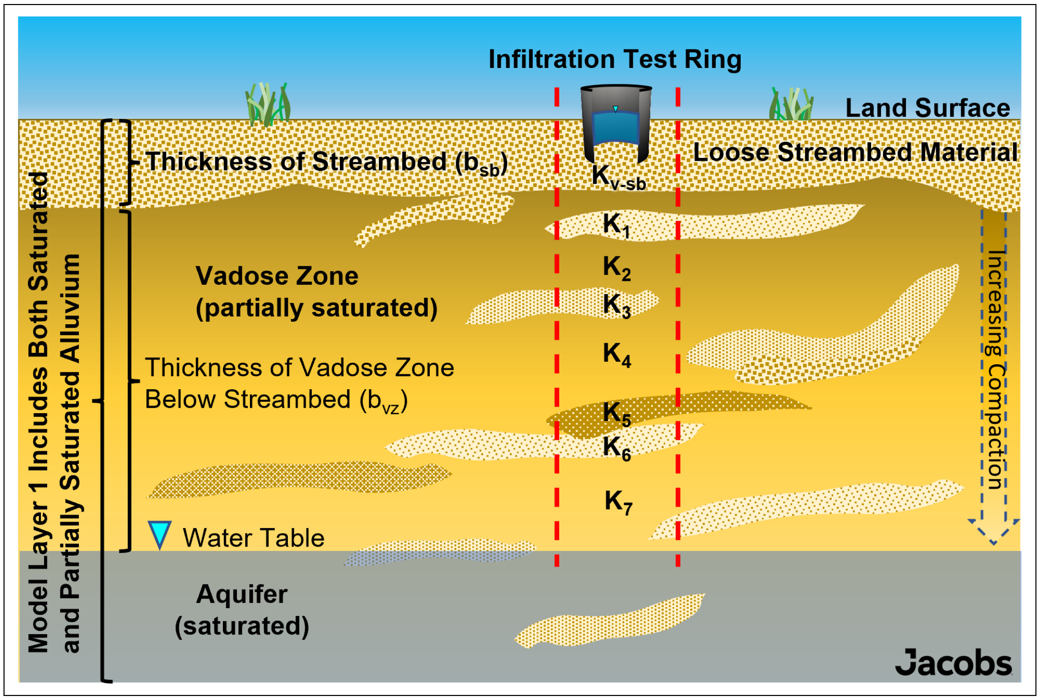


Figure B-1: Hypothetical K Zones Below a Stream Channel

As indicated above, when the water table is some distance below the modeled stream channel, the groundwater recharge rate from the stream is computed using the $K_{v\text{-}SFR}$ as the effective vertical K of the entire vadose zone below the stream; thereby ignoring the vertical K value assigned to the underlying groundwater cell in Model Layer 1 (**Figure 2-3** and **Figure B-1**). In recognition of this aspect of the SFR package, the modeling team assigned $K_{v\text{-}SFR}$ values to SFR stream reaches in the SPV GSP Model v2.0 based on the harmonic mean (Freeze and Cherry, 1979) of the $K_{v\text{-}sb}$ and vertical K assigned in the underlying groundwater cell in Model Layer 1, according to Equation B-1, as follows:

$$K_{v-SFR} = \frac{b_t}{\frac{b_{sb}}{K_{v-sb}} + \frac{b_{vz}}{K_{v-vz}}} \qquad \text{(B-1)}$$

where (see **Figure B-1)**

$K_{v\text{-}SFR}$ = effective vertical hydraulic conductivity assigned to SFR package
$K_{v\text{-}sb}$ = streambed vertical hydraulic conductivity
$K_{v\text{-}vz}$ = vertical hydraulic conductivity of vadose zone below the stream channel
b_{sb} = thickness of the modeled streambed
b_{vz} = thickness of the interval between the bottom of the streambed and average water table elevation
b_t = total alluvium thickness above the average water table elevation = b_{sb} + b_{vz}

The $K_{v\text{-}SFR}$ value establishes the effective resistance to flow after water infiltrates the streambed and moves downward through the vadose zone to the underlying water table (**Figure B-1**). The smaller the $K_{v\text{-}SFR}$ the greater the resistance to downward flow between the stream and underlying aquifer. The $K_{v\text{-}vz}$ values in

Equation B-1 were based on the vertical K values assigned to groundwater model cells in Model Layer 1 that underlie SFR reaches (**Figure 2-3** and **Figure B-1**). The $K_{v\text{-}vz}$ values were arrived at through the recalibration process discussed in Section 2.3 and Attachment C.

ATTACHMENT C: RECALIBRATION DETAILS

As indicated in Section 2.3, recalibration of the SPV GSP Model v2.0 was necessary after incorporating updates because modeled groundwater elevations were too high across the Basin as compared with measured groundwater levels. This attachment describes the modifications made to recalibrate the SPV GSP Model v2.0 for use on this Initial Surface Water Recharge Evaluation.

Input Parameter Modifications

In addition to the stream channel configuration update (see Section 2.1.1 and Attachment A) and the improved runoff routing (see Section 2.1.3), the following modifications were made:

- Updated $K_{v\text{-}SFR}$ values using vertical K values from Model Layer 1 and $K_{v\text{-}sb}$ values from the Task 2 streambed investigation (City, 2023a), and Equation B-1 (see Attachment B)
- Removed specified subsurface inflow along the northern, eastern, and southern boundaries of the model area
- Updated the depth to bedrock near the mouth of Rockwood Canyon
- Modified the boundary condition at the western end of the Basin to better match groundwater-level responses in the western portion of the Basin to water-level changes in Hodges Reservoir

The following subsections provide additional details regarding each of these bulleted items.

Effective Hydraulic Conductivity of Modeled Streambeds

As described in Section 2.1.2 and Attachment B, a mathematical approach was formulated to assign $K_{v\text{-}SFR}$ values to the SFR package in the SPV GSP Model v2.0. A summary of the streambed thickness (b_{sb}), streambed vertical K ($K_{v\text{-}sb}$), vadose zone thickness (b_{vz}), and effective vertical K assigned to the SFR package ($K_{v\text{-}SFR}$) by stream systems is listed in **Table C-1**.

The $K_{v\text{-}SFR}$ values shown in **Table C-1** were calculated using Equation B-1 from Attachment B, based on the assigned $K_{v\text{-}sb}$, b_{sb}, $K_{v\text{-}vz}$, and b_{vz}. SFR reaches representing stream channels located near the Task 2 streambed infiltration testing locations were assigned $K_{v\text{-}sb}$ values based on the channel-center K estimates derived during the Task 2 streambed investigation (City, 2023a) (**Table C-2)**. The rest of the SFR reaches within the Basin were assigned a $K_{v\text{-}sb}$ value of 50 ft/d (1.8×10^{-2} cm/s), whereas the SFR reaches outside of the Basin were assigned a $K_{v\text{-}sb}$ value of 0.01 ft/d (3.5×10^{-6} cm/s) **(Figure C-1**). Having lower $K_{v\text{-}sb}$ values assigned to stream reaches located outside the Basin is reasonable because these narrow reaches exist over rock and likely have stream channel material that is either very thin or nonexistent. SFR reaches within the Basin were assigned a streambed thickness value of 5 feet, whereas SFR reaches outside of the Basin were assigned a value of 1 foot. The spatial distributions of $K_{v\text{-}sb}$ and $K_{v\text{-}SFR}$ are shown in **Figure C-1** and **Figure C-2**.

Table C-1: Summary of Parameters Used to Compute Effective Hydraulic Conductivity of Modeled Streams

Stream	Streambed Thickness, b_{sb} (feet)	Streambed Vertical Hydraulic Conductivity, $K_{v\text{-}sb}$ (ft/d)[a,b]	Vadose Zone Thickness, b_{vz} (feet)	Effective Vertical Hydraulic Conductivity Assigned to Modeled Stream, $K_{v\text{-}SFR}$ (ft/d)[b,c]
Santa Ysabel Creek	1 or 5	0.01 to 552 (3.5×10^{-6} to 1.9×10^{-1})	0 to 57	0.01 to 0.71 (3.5×10^{-6} to 2.5×10^{-4})
Guejito Creek	1 or 5	0.01 to 116 (3.5×10^{-6} to 4.1×10^{-2})	0 to 50	0.01 to 0.31 (3.5×10^{-6} to 1.1×10^{-4})
Santa Maria Creek	1 or 5	0.01 to 50 (3.5×10^{-6} to 1.8×10^{-2})	0 to 50	0.01 to 0.48 (3.5×10^{-6} to 1.7×10^{-4})
Cloverdale Creek	1 or 5	0.01 to 50 (3.5×10^{-6} to 1.8×10^{-2})	0	0.01 to 0.60 (3.5×10^{-6} to 2.1×10^{-4})
Sycamore Creek	5	50 (1.8×10^{-2})	0	0.30 (1.1×10^{-4})
Other Creeks	1 or 5	0.01 to 373 (3.5×10^{-6} to 1.3×10^{-1})	0 to 46	0.01 to 0.69 (3.5×10^{-6} to 2.4×10^{-4})
San Dieguito River	1 or 5	0.01 to 50 (3.5×10^{-6} to 1.8×10^{-2})	0	0.01 to 0.60 (3.5×10^{-6} to 2.1×10^{-4})

[a] Values are from City (2023a).
[b] Values in parenthesis are expressed in units of cm/s.
[c] Values were computed using Equation B-1 (see Attachment B).

Table C-2: Summary of Task 2 Streambed Investigation Vertical Hydraulic Conductivity

Location[a]	Channel-center Vertical Hydraulic Conductivity (ft/d)[b,c]
Transect 1, T-1	373 (1.3×10^{-1})
Transect 2, T-2	552 (1.9×10^{-1})
Transect 3, T-3	116 (4.1×10^{-2})
Transect 4, T-4	158 (5.6×10^{-2})

[a] Transect locations are shown in **Figure C-1.**
[b] Values are from City (2023a).
[c] Values in parenthesis are expressed in units of cm/s.

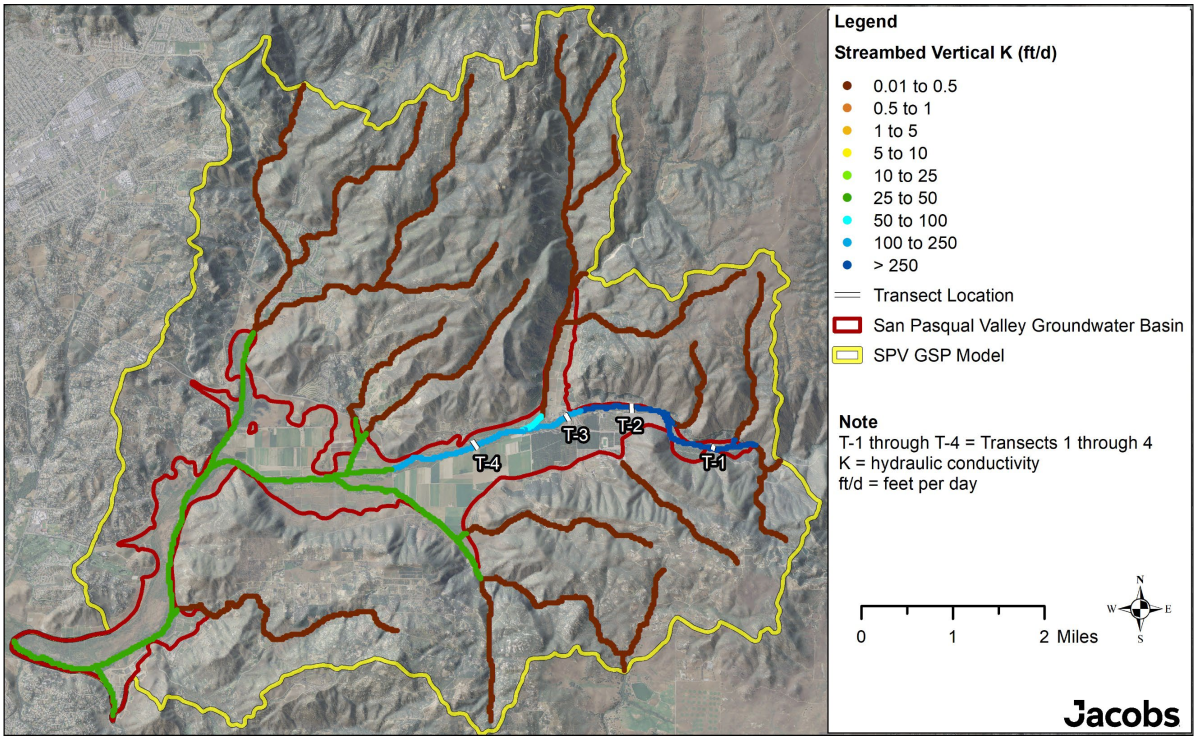


Figure C-1: Assigned Streambed Vertical Hydraulic Conductivity

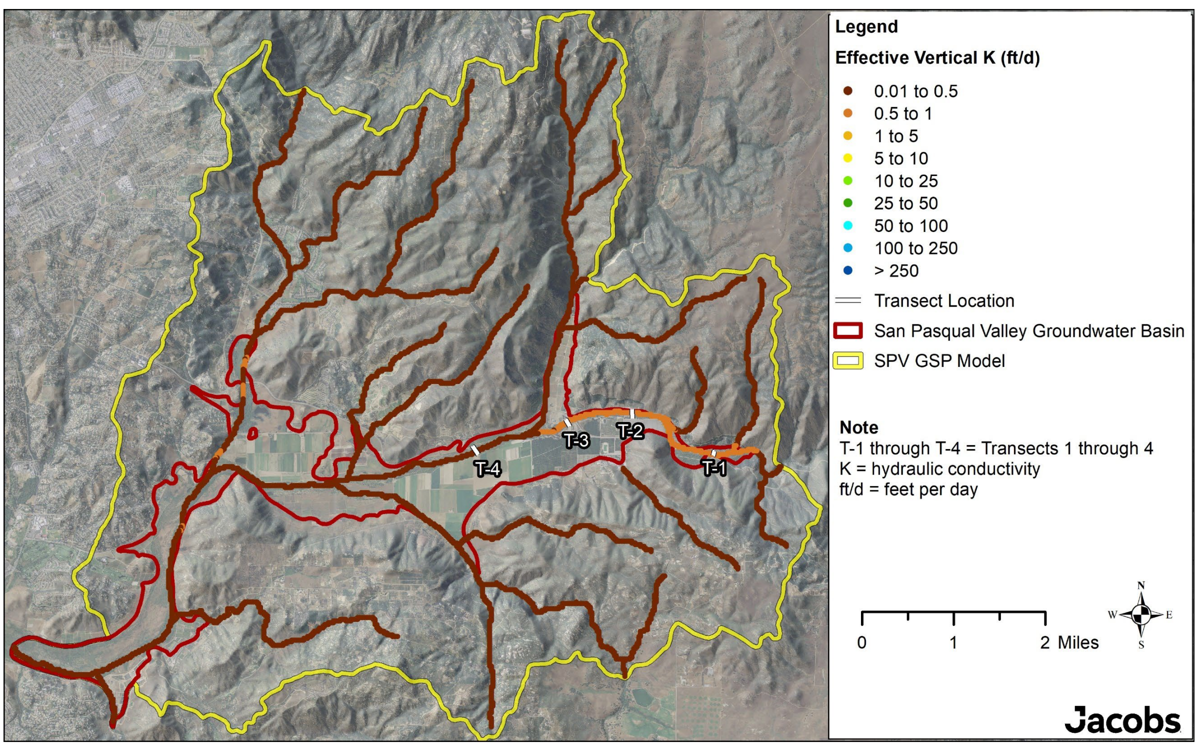


Figure C-2: Calibrated Effective Vertical Hydraulic Conductivity

Removal of Specified Subsurface Inflow

Groundwater flow entering the model area at its northern, eastern, and southern boundaries from areas adjacent to the model area was simulated in the SPV GSP Model v1.0. This term was called "subsurface inflow from contributing catchments" in the GSP (City and County, 2021). This groundwater inflow into the model area was simulated in the SPV GSP Model v1.0 using a boundary condition. Boundary conditions are mathematical rules coded into the modeling software that specify head (groundwater elevation) or water flux at selected locations within the model area. The boundary condition that represents subsurface inflow from contributing catchments is referred to as a specified-flux boundary. With this type of boundary condition, time-series subsurface inflow values are input to the software by the modeler before the simulation. During the simulation the software incorporates the provided flow values at the intended boundary-condition cells.

Throughout the recalibration process, modeled groundwater levels within the Basin were generally higher than the measured groundwater levels because of higher $K_{v\text{-}SFR}$ values allowing for greater groundwater recharge from the streams. As a result, other sources of groundwater recharge to the Basin needed to be reduced within reasonable ranges to help achieve better fits to the measured groundwater levels. Additionally, the increase in groundwater recharge from streams was causing water at the inflow point of the Basin in Santa Ysabel Creek to pond above ground surface, which is not consistent with the hydrogeologic conceptual model, suggesting that this boundary condition overestimated the subsurface contribution of water from adjacent catchments. With these considerations in mind, the specified-flux boundary condition values that represent subsurface inflow from contributing catchments in the SPV GSP Model v2.0 were reduced to a value of zero in the relevant boundary-condition cells. This change helped avoid water ponding along the eastern perimeter of the model and helped play a small part in lowering modeled groundwater levels in the Basin. Removal of these subsurface inflows does not limit the ability of the SPV GSP Model v2.0 to achieve its purpose to help quantify potential benefits from implementing the four recharge strategies described in Section 1.

Updated Depth to Bedrock

Throughout the recalibration process, modeled groundwater levels near the mouth of Rockwood Canyon were consistently too high as compared with measured groundwater levels. Inspection of detailed subarea groundwater budgets between Rockwood Canyon and the SPV revealed that groundwater was moving too easily into the mouth of Rockwood Canyon from the south. In other words, groundwater depressions that would in reality exist around the irrigation wells in the mouth of Rockwood Canyon were being replenished with some of the groundwater that was mostly flowing west down the SPV. This observation compelled the modeling team to examine the model layering within this subarea.

Cross-section D-D′ is shown in **Figure C-3** and extends along the center of Rockwood Canyon to where it meets A-A′ along the center of SPV. According to Cross-section D-D′, which was prepared by Snyder Geologic during development of the GSP (City and County, 2021), the bedrock surface rises in elevation at LWELL16379. This higher bedrock surface means that near this well there is less thickness of alluvium, which could create a barrier effect to groundwater flow between the Rockwood Canyon and SPV (**Figure C-3**). Although the SPV GSP Model v1.0 included this bedrock high along Cross-section D-D′, the modeled bedrock surface decreased in elevation east of this bedrock high creating a "saddle" or low-point in the bedrock surface between the bedrock high at LWELL16379 and the southeast corner of Rockwood Canyon, where the Basin meets the surrounding bedrock (**Figure C-4**).

Bottom elevations of Model Layers 1 and 2 were raised by a range of 2 to 60 feet at selected model cells in the vicinity of LWELL16379 to create a smoother transitional surface between the bedrock high at LWELL16379 and the Basin margin to the east (**Figure C-4**). The layer modifications in this subarea improved the fits between the measured and modeled groundwater levels at calibration wells within Rockwood Canyon by reducing the amount of groundwater flow from the south into the lower end of Rockwood Canyon.

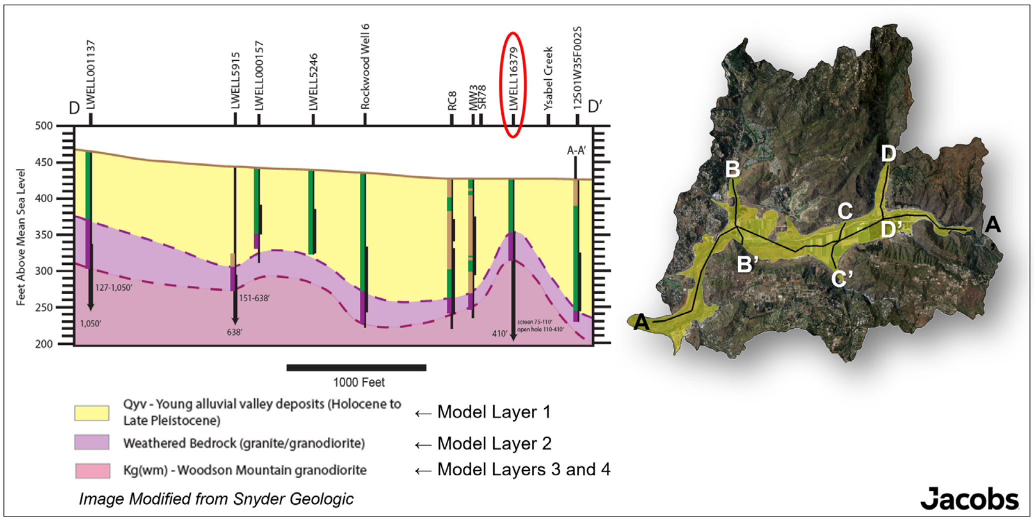


Figure C- 3: Geologic Cross Section Along Rockwood Canyon

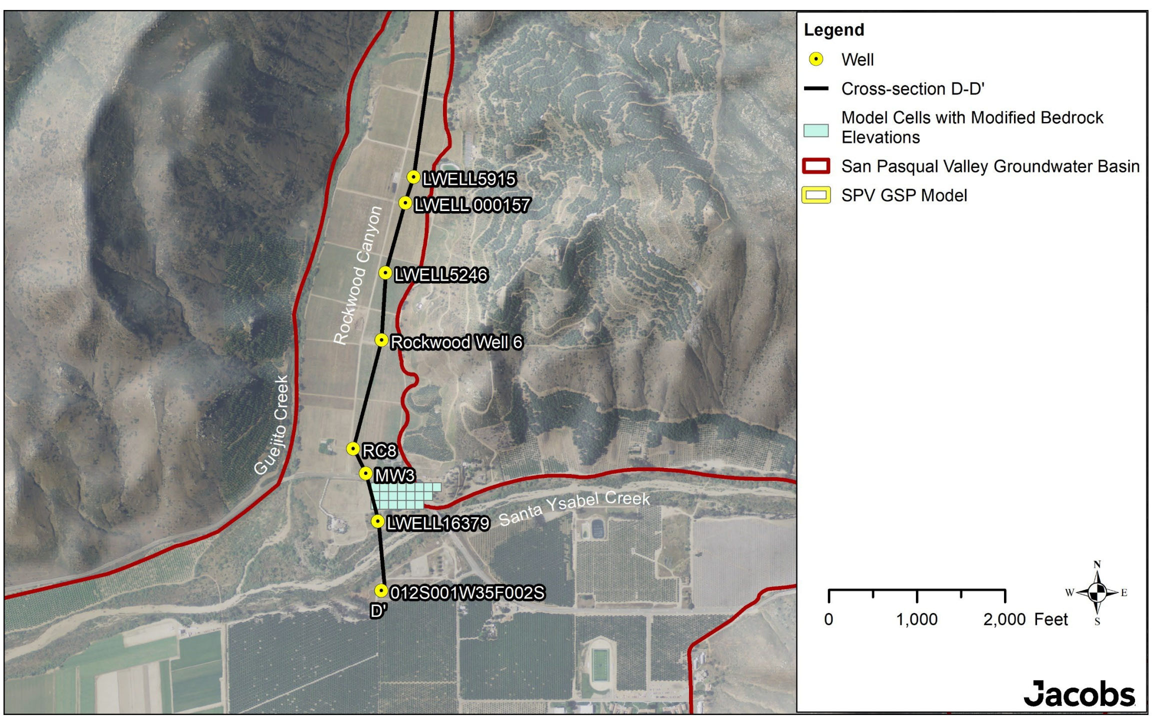


Figure C- 4 Model Cells with Modified Bedrock Elevations

Modified Flow Boundary at Basin Outlet

Groundwater flow across the western end of the Basin near Hodges Reservoir is simulated using a boundary condition (**Figure C-5**). The boundary condition assigned at the western end of the Basin is referred to as a head-dependent flux boundary. With this type of boundary condition, the head (groundwater elevation) and hydraulic-conductance values are assigned to selected model cells, and water fluxes across the boundary cells are computed automatically by the model code during a simulation. This type of boundary condition is a two-way boundary condition, meaning that groundwater can move across the boundary-condition cells into and out of the Basin. Groundwater is simulated to move from the Basin toward Hodges Reservoir when modeled heads in the western end of the Basin are higher than the head value assigned to the boundary condition cell. Groundwater is simulated to move into the Basin from the area between Hodges Reservoir and the western end of the Basin when modeled heads in the western end of the Basin are lower than the head value assigned to the boundary-condition cell. The time-series head values assigned to these boundary-condition cells is the measured surface elevation or "stage" of Hodges Reservoir through time during the simulation.

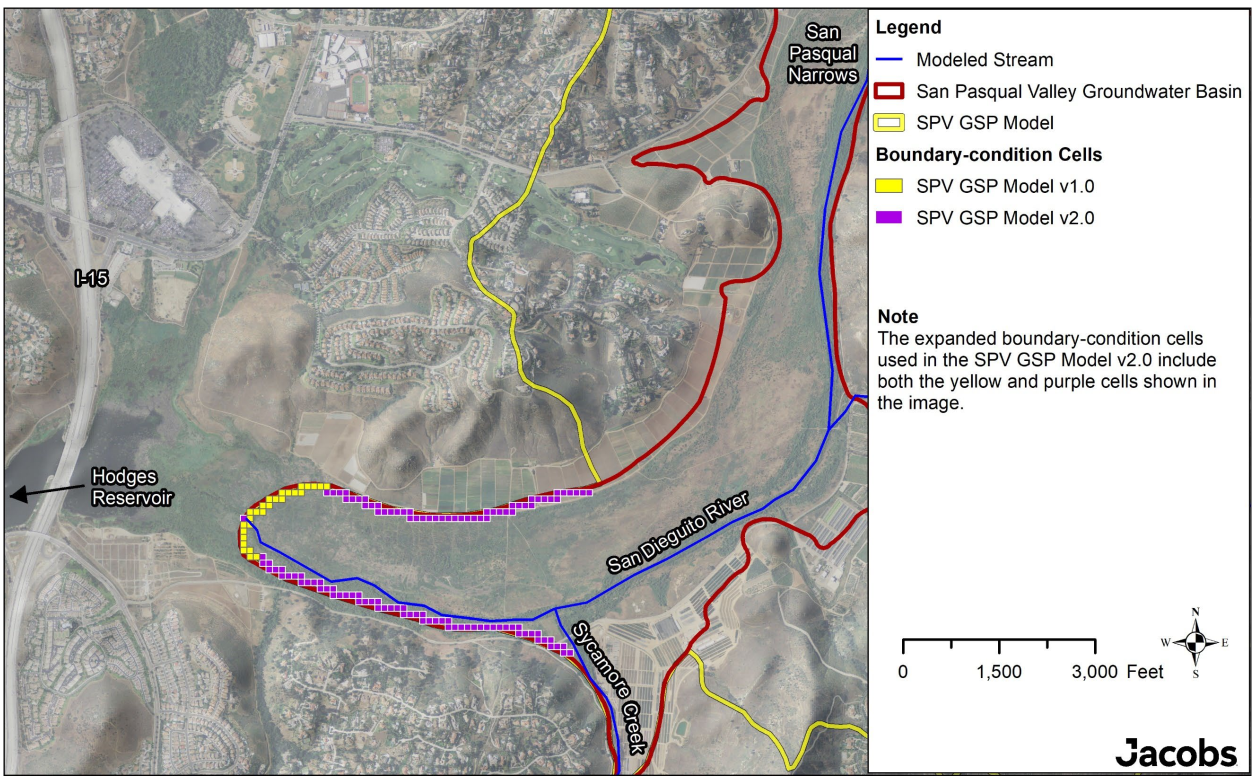


Figure C-5: Boundary-condition Cells Along Western Basin Boundary

During early stages of recalibration, it was evident that modeled groundwater levels along San Dieguito River through San Pasqual Narrows in the western end of the Basin were too high as compared with measured groundwater levels (**Figure C-5**). To help lower modeled groundwater levels, the assignment of boundary-condition cells described above was expanded eastward, thereby allowing the opportunity for greater groundwater flow exchange across the western boundary of the Basin. The conductance term assigned to each of these boundary-condition cells incorporates the distance of the cell to the Interstate-15 bridge to scale the influence of the Hodges Reservoir stages. In other words, the boundary condition cells at the western tip of the Basin are closer to Hodges Reservoir than those boundary-condition cells located farther east; therefore, groundwater flow from this location should respond more easily to stage changes in Hodges Reservoir, as compared with those boundary-condition cells farther from Hodges Reservoir. These modifications resulted in an overall better match between modeled and measured groundwater levels in the western end of the Basin.

Recalibration Results

This subsection presents the recalibration results from the modifications described in Section 2 and in the above attachments.

Calibration Statistics and Goals

The following definitions of terms are provided to support the technical discussion provided in this subsection.

- Head: Synonymous with "groundwater elevation" in this TM
- Residual: Computed as the modeled-head value minus the measured-head value that serves as the calibration target
- Mean residual (MR): Computed as the sum of all residuals divided by the number of observations.
- Residual standard deviation (RSD): Computed as the square root of the average of all squared differences of each residual from the MR. This provides a measure of the spread of the residuals around the MR.
- Root mean squared residual (RMSR): Computed as the square root of the average of all squared residuals.
- Range of measured-head values (Range): Computed as the maximum measured-head value minus the minimum measured-head value.
- RMSR/Range: A summary statistic provided to demonstrate the overall quality of the calibration. A value of less than 10% would indicate an adequately calibrated groundwater model.
- Coefficient of determination (R^2): Computed as the square of the correlation coefficient, which is a statistical measure of the strength of the linear relationship between two variables. In this case the two variables are the modeled and measured heads.

During the recalibration effort, the modeling team executed work with the following general goals:

- Minimize spatial bias of residuals in key areas of the model area.
- Minimize residuals, MR, RMSR, and RMSR/Range values.
- Strive for R^2 values as close to one as possible.

During model recalibration, it is helpful to be aware of model tendencies or inclinations referred to as bias. The modeling team evaluated two types of bias during the recalibration effort: global bias and spatial bias.

Global bias would be evident if the residual values were either all large positive or large negative values. Plotting the modeled versus measured groundwater elevations, as is presented in **Figure C-6**, is a good way to evaluate the degree to which a model exhibits global bias. It also facilitates assessing the overall ability of a model to replicate historical groundwater levels. Overall, the SPV GSP Model v2.0 does not exhibit global bias. Global bias would be evident if all the points in **Figure C-6** were either above or below the "1:1 correlation line". Most points in this figure plot along the 1:1 correlation line with some points falling above and below the line. Calibration statistics for the modeled groundwater elevations are also listed in **Figure C-6** (see definitions and acronyms of statistical terms above). The MR is small, the RMSR/Range is less than 10%, and R^2 is greater than 0.7, which indicates the modeled and measured heads are well correlated. All of the points shown in **Figure C-6** are also provided in Attachment D in the form of groundwater-level hydrographs for each of calibration target location. These hydrographs include modeled groundwater elevations from the SPV GSP Model v1.0 and the SPV GSP Model v2.0 to show how the historical simulation results differ between the two versions of the model.

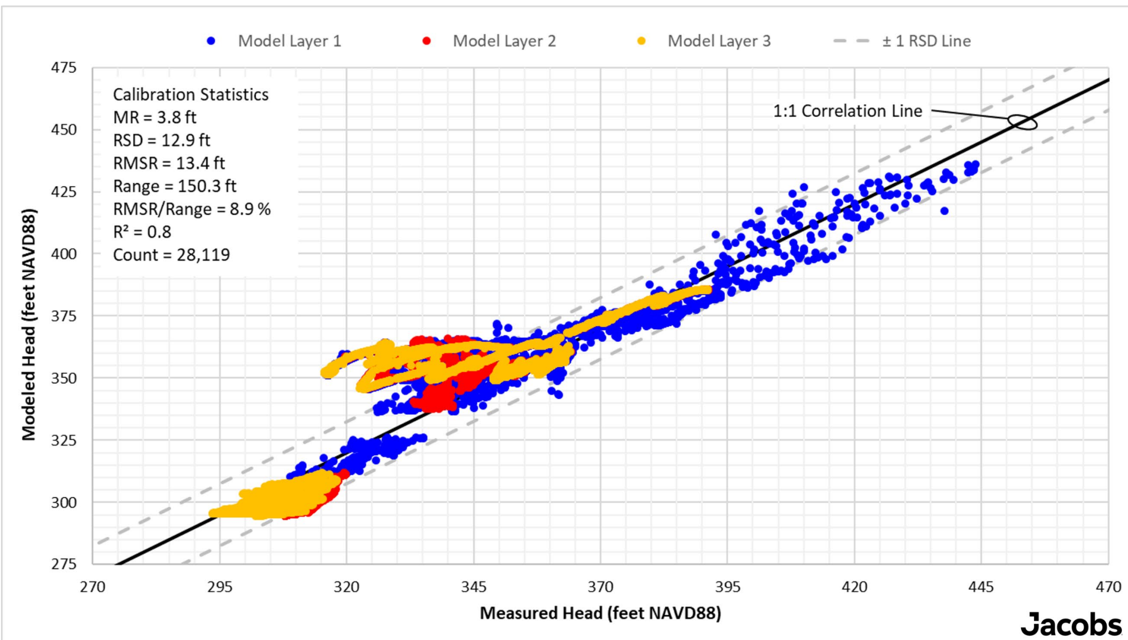


Figure C-6: Modeled Versus Target Groundwater Elevations

Although the modeled heads in the SPV GSP Model v2.0 do not exhibit global bias, it is important to also assess whether the model exhibits spatial bias. Spatial bias would be evident if there are groups of wells in specific subareas of the model with large positive or large negative residuals. A map of the MRs for each calibration well is provided in **Figure C-7.** This type of map is useful for assessing whether spatial biases are evident. Throughout most of the model area there are both positive and negative MRs at nearby wells. The exception to this is in the southern portion of the San Pasqual Narrows near the western outlet of the Basin. Although the fit to measured groundwater levels was generally improved in the SPV GSP Model v2.0 in this western end of the Basin (see **Figure D-7** and **Figure D-8** in Attachment D), as compared with the SPV GSP Model v1.0, it tends to underestimate groundwater levels in that subarea. All the calibration wells in that subarea have negative MRs, indicating some degree of spatial bias in modeled heads in that subarea. However, because the recharge strategies are focused on the eastern portion of the Basin, the spatial bias in heads in the western portion of the Basin is not of concern for this effort. Furthermore, because the simulation of each recharge strategy will be based on the same underlying "baseline model", the spatial bias would be "washed out" when making comparisons among the simulations of recharge strategies. Overall, the degree of calibration looks sufficient for the intended purpose of the SPV GSP Model v2.0 for the Initial Surface Water Recharge Evaluation.

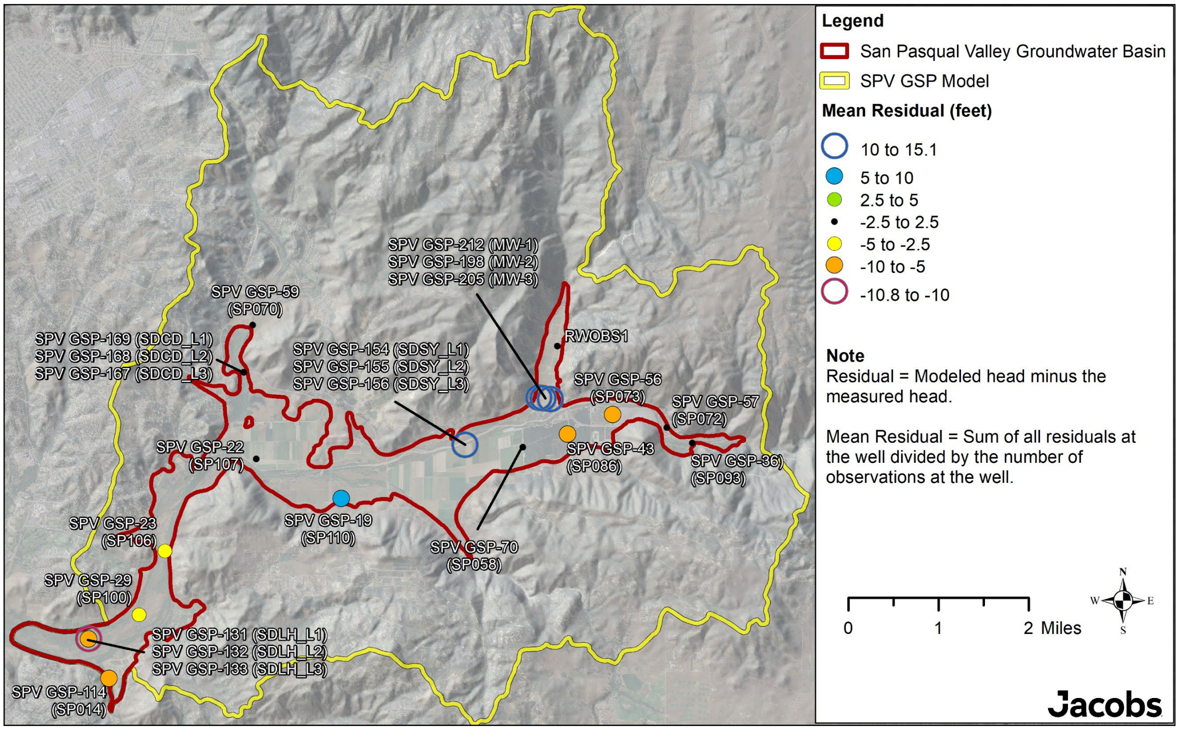


Figure C-7: Map of Mean Residuals

Recalibrated Parameters

The recalibrated horizontal and vertical K values for the subsurface materials are presented in **Figure C-8** and **Figure C-9,** respectively. Hydraulic conductivity zones in Model Layers 1 and 2 were defined to differentiate between the hydrostratigraphic units within the Basin boundary (e.g., alluvium in Model Layer 1 and residuum in Model Layer 2) and the bedrock material surrounding the Basin. Calibrated horizontal and vertical K values for the subsurface materials are summarized by hydrostratigraphic unit and model layer in **Table C-3**.

Overall, the SPV GSP Model v2.0 included multiple refinements to better reflect the dynamics of surface water dynamics and their interaction with groundwater to develop a tool that will be better suited for analyzing the recharge strategies outlined in the Task 4 TM (City, 2023c).

Table C-3: Model Calibrated Horizontal and Vertical Hydraulic Conductivity for Subsurface Materials

Hydrostratigraphic Unit	Model Layer(s)	Horizontal Hydraulic Conductivity (ft/d)[b]	Vertical Hydraulic Conductivity (ft/d)[b]
Alluvium	1	100 (3.5×10^{-2})	0.20 to 0.63 (7.1×10^{-5} to 2.2×10^{-4})
Residuum	2	2.0 to 9.0 (7.1×10^{-4} to 3.2×10^{-3})	0.04 to 0.95 (1.4×10^{-5} to 3.4×10^{-4})
Bedrock	1 through 4[a]	0.004 (1.4×10^{-6})	0.4 (1.4×10^{-4})

[a] Bedrock is represented in all four layers outside the Basin.
[b] Values in parenthesis are expressed in units of cm/s.

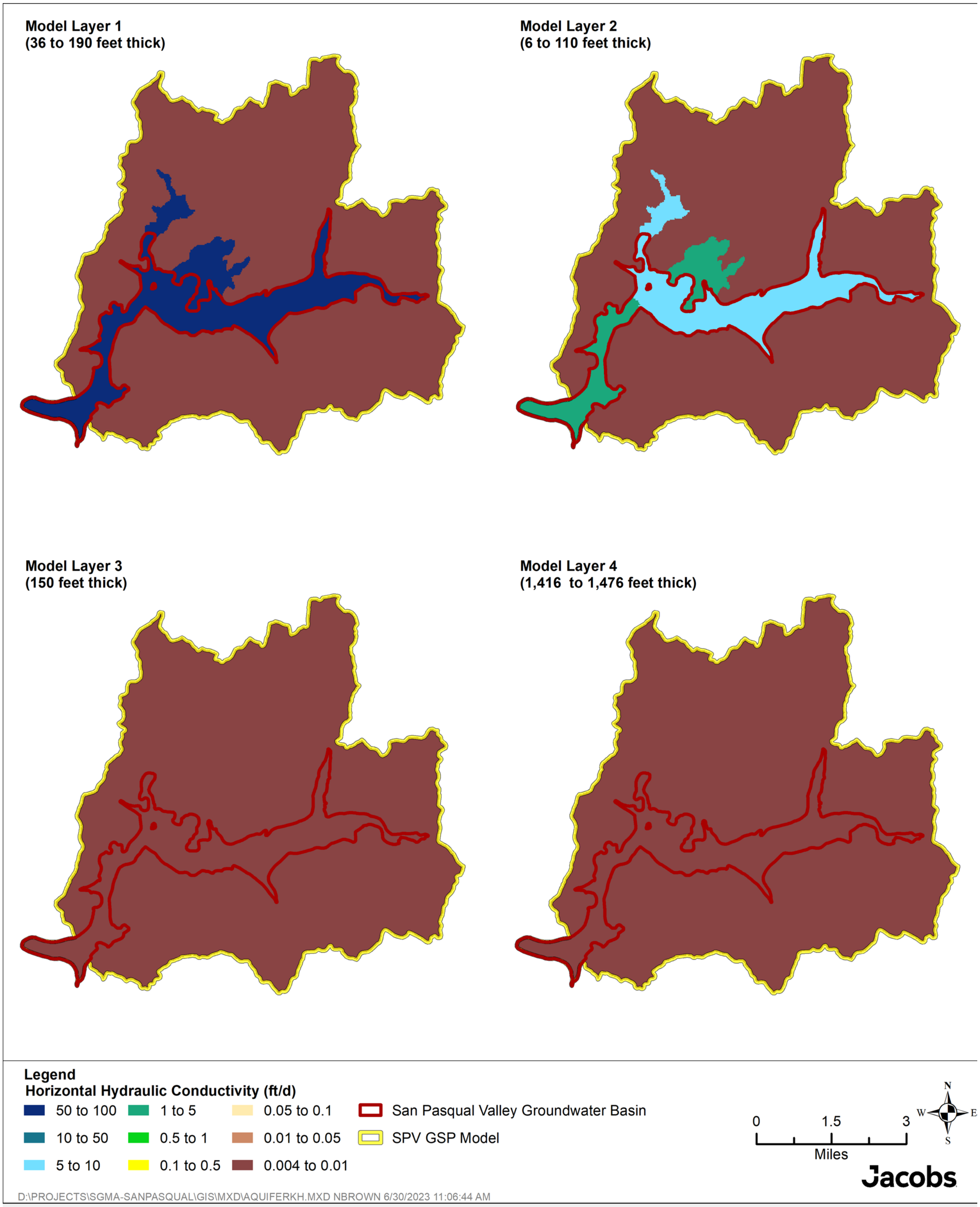


Figure C-8: Calibrated Horizontal Hydraulic Conductivity

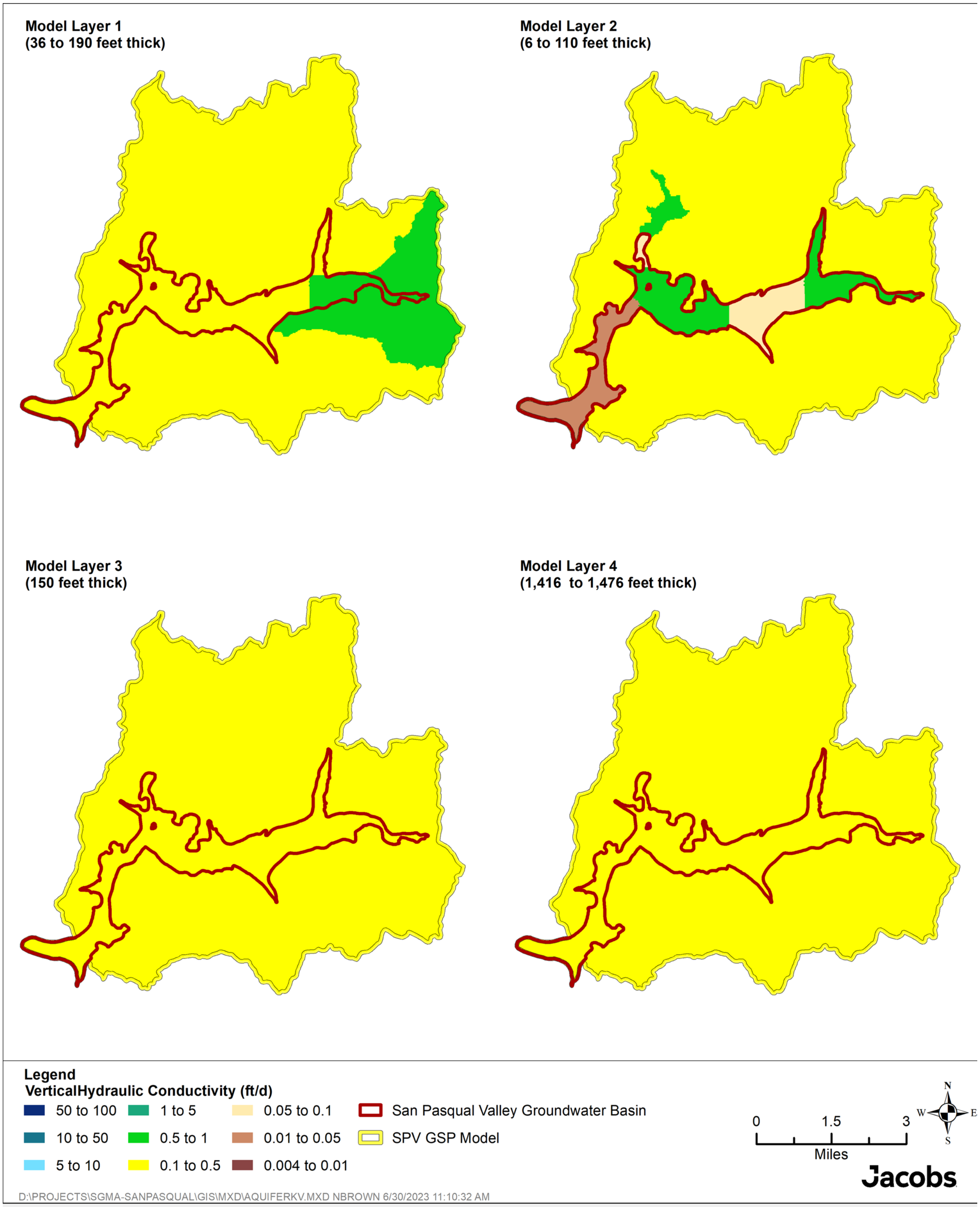


Figure C-9: Calibrated Vertical Hydraulic Conductivity

ATTACHMENT D: HISTORICAL GROUNDWATER HYDROGRAPHS

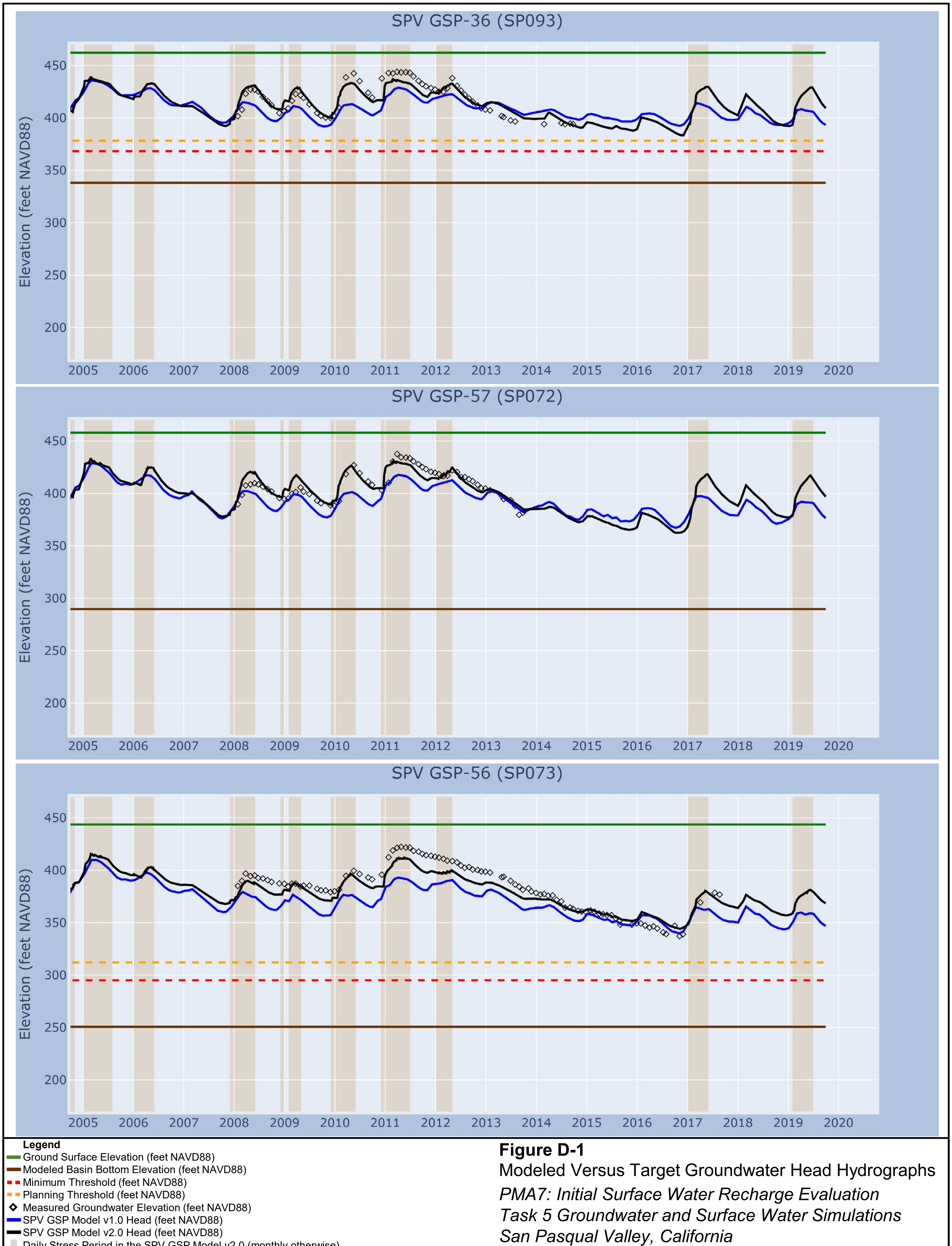
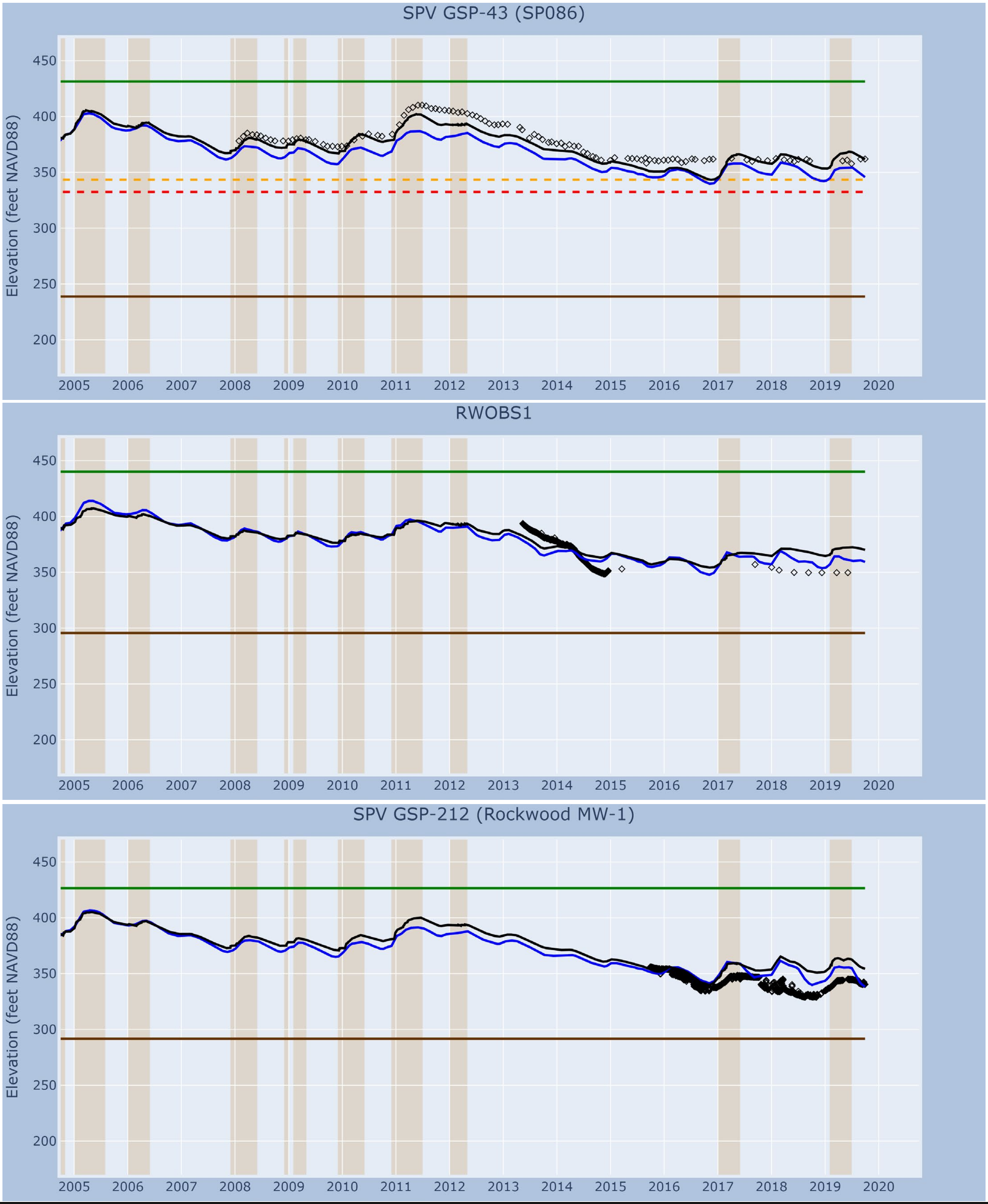


Figure D-1
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California



Legend

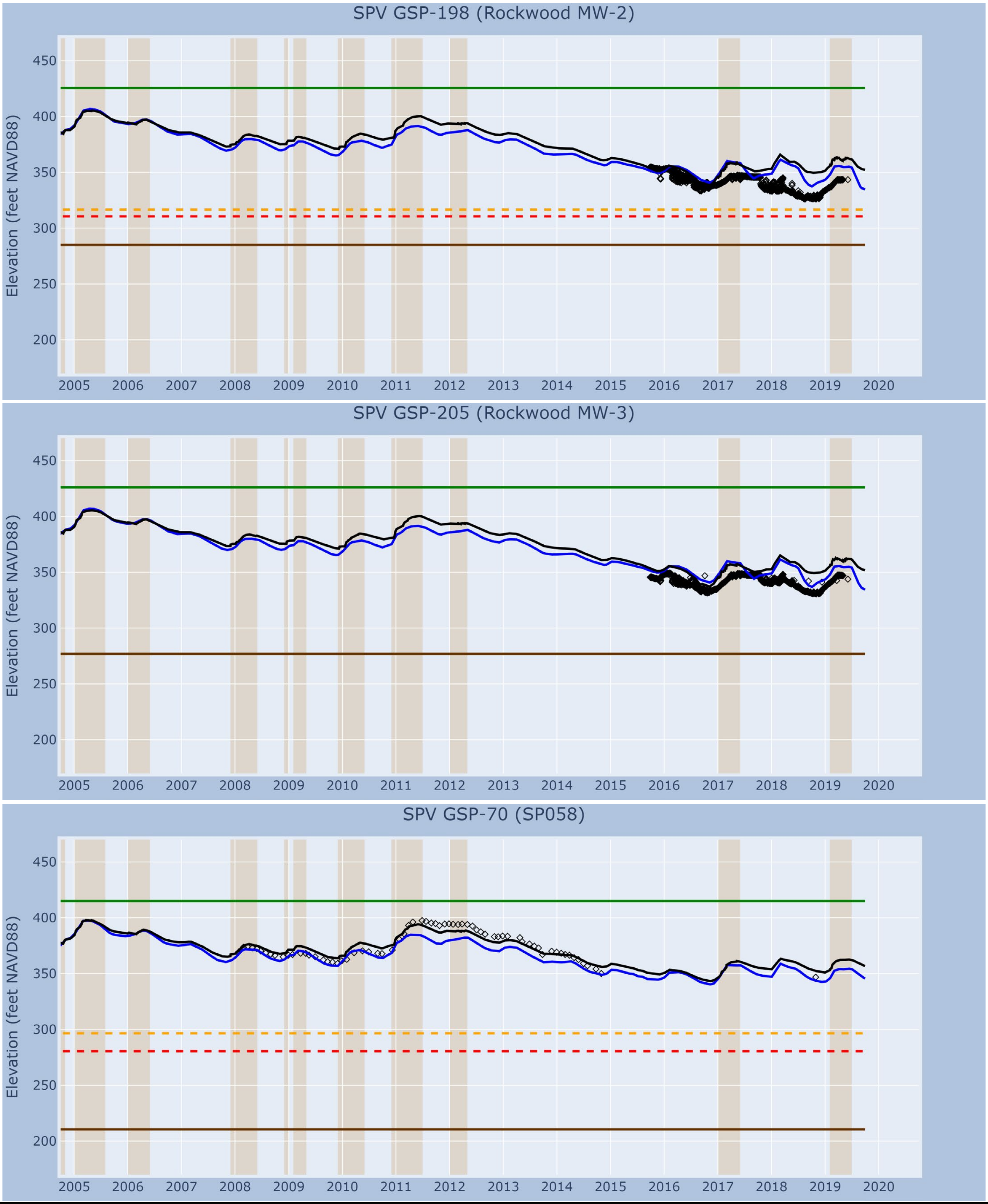
- Ground Surface Elevation (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measured Groundwater Elevation (feet NAVD88)
- SPV GSP Model v1.0 Head (feet NAVD88)
- SPV GSP Model v2.0 Head (feet NAVD88)
- Daily Stress Period in the SPV GSP Model v2.0 (monthly otherwise)

Figure D-2

Modeled Versus Target Groundwater Head Hydrographs

PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs



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- Daily Stress Period in the SPV GSP Model v2.0 (monthly otherwise)

Figure D-3
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

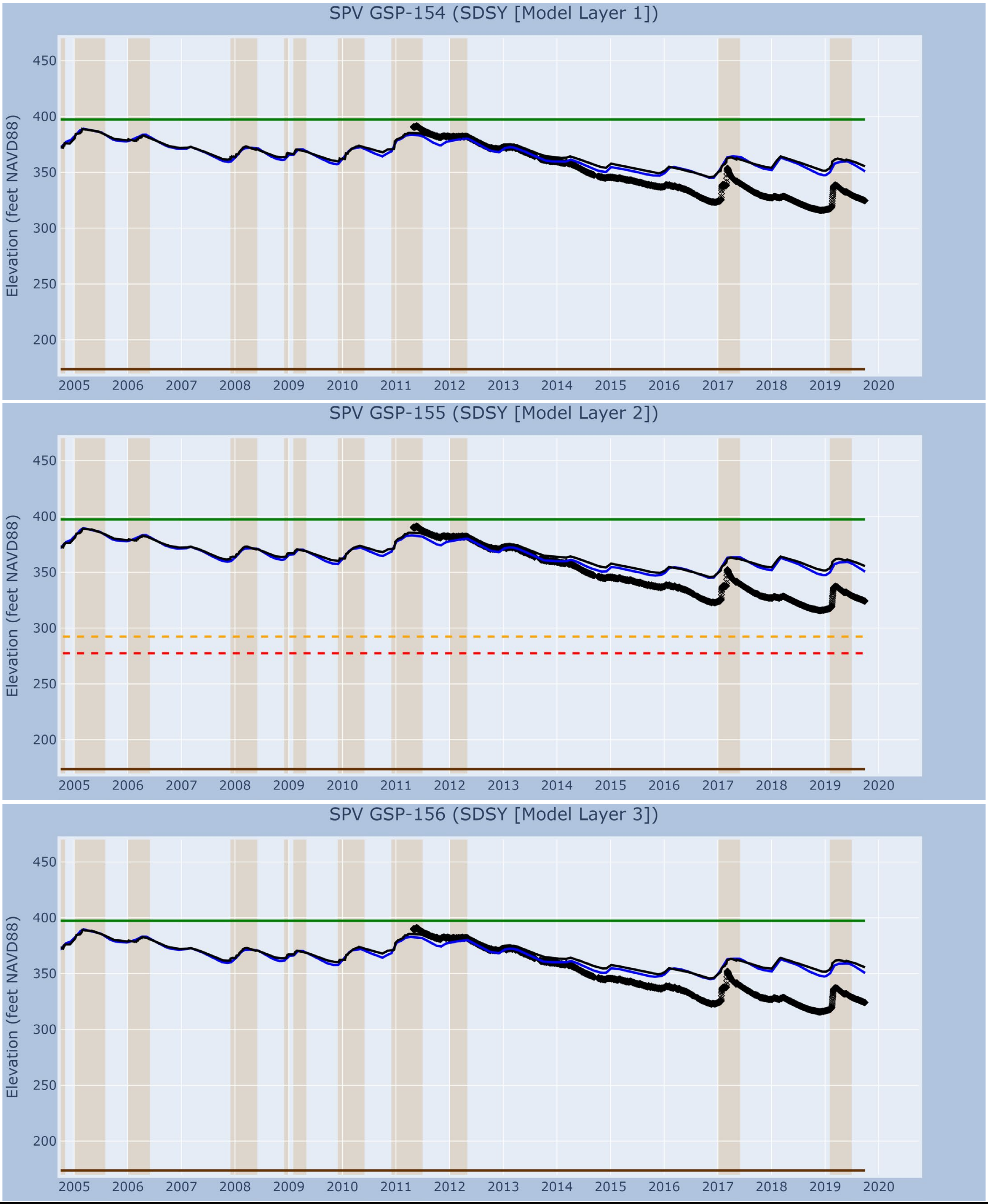

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Figure D-4
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
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San Pasqual Valley, California

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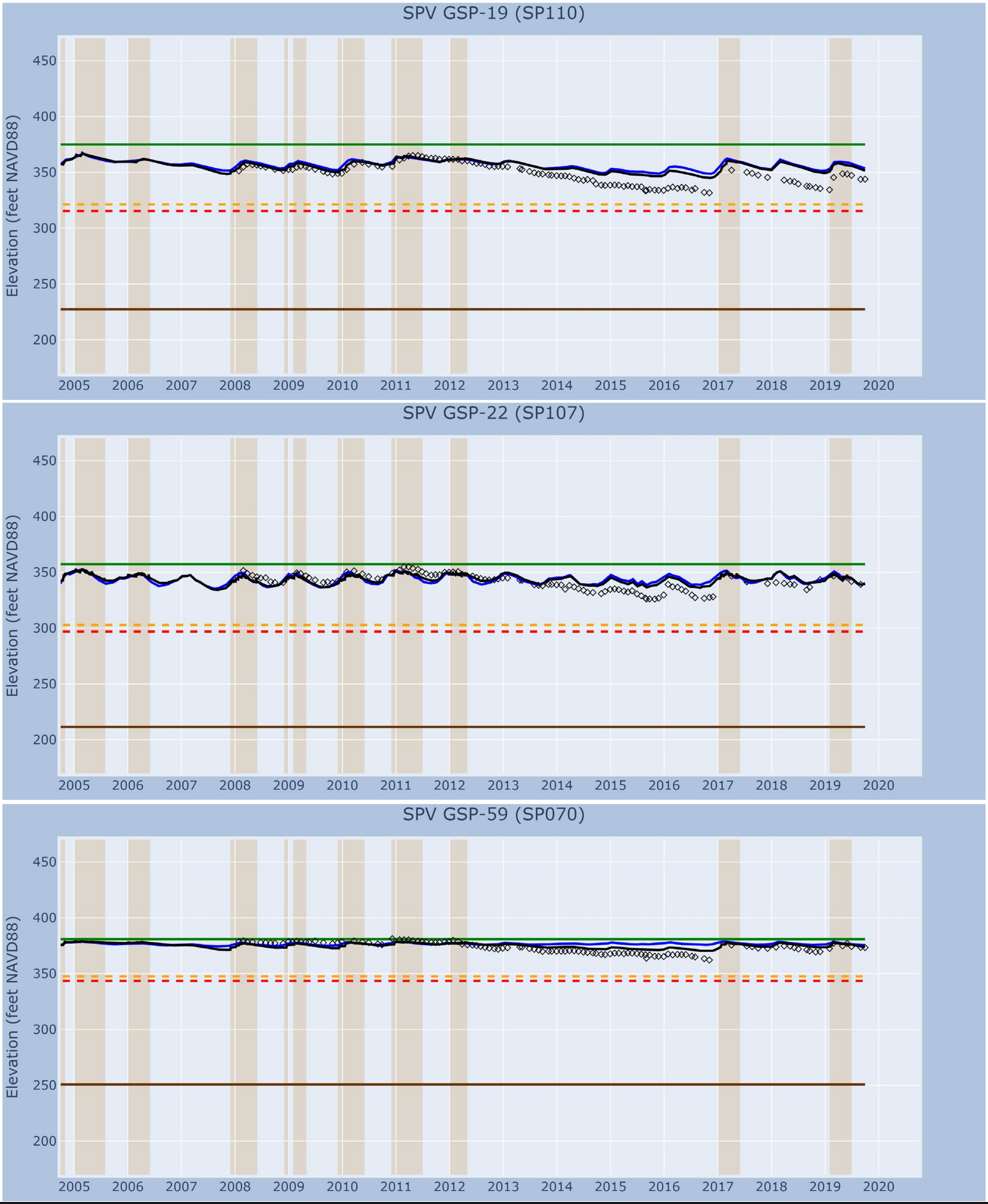

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Figure D-5
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

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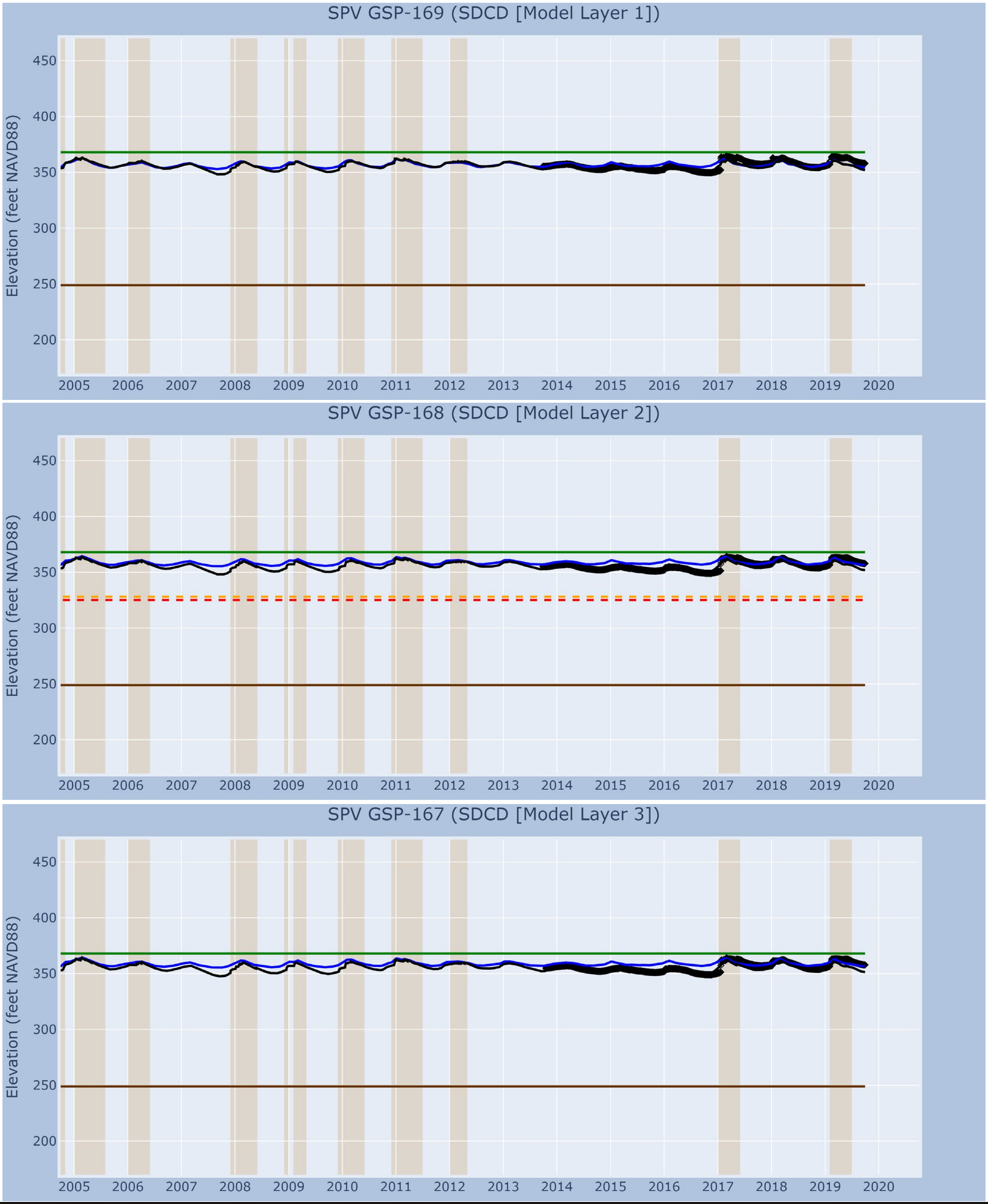

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Figure D-6
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

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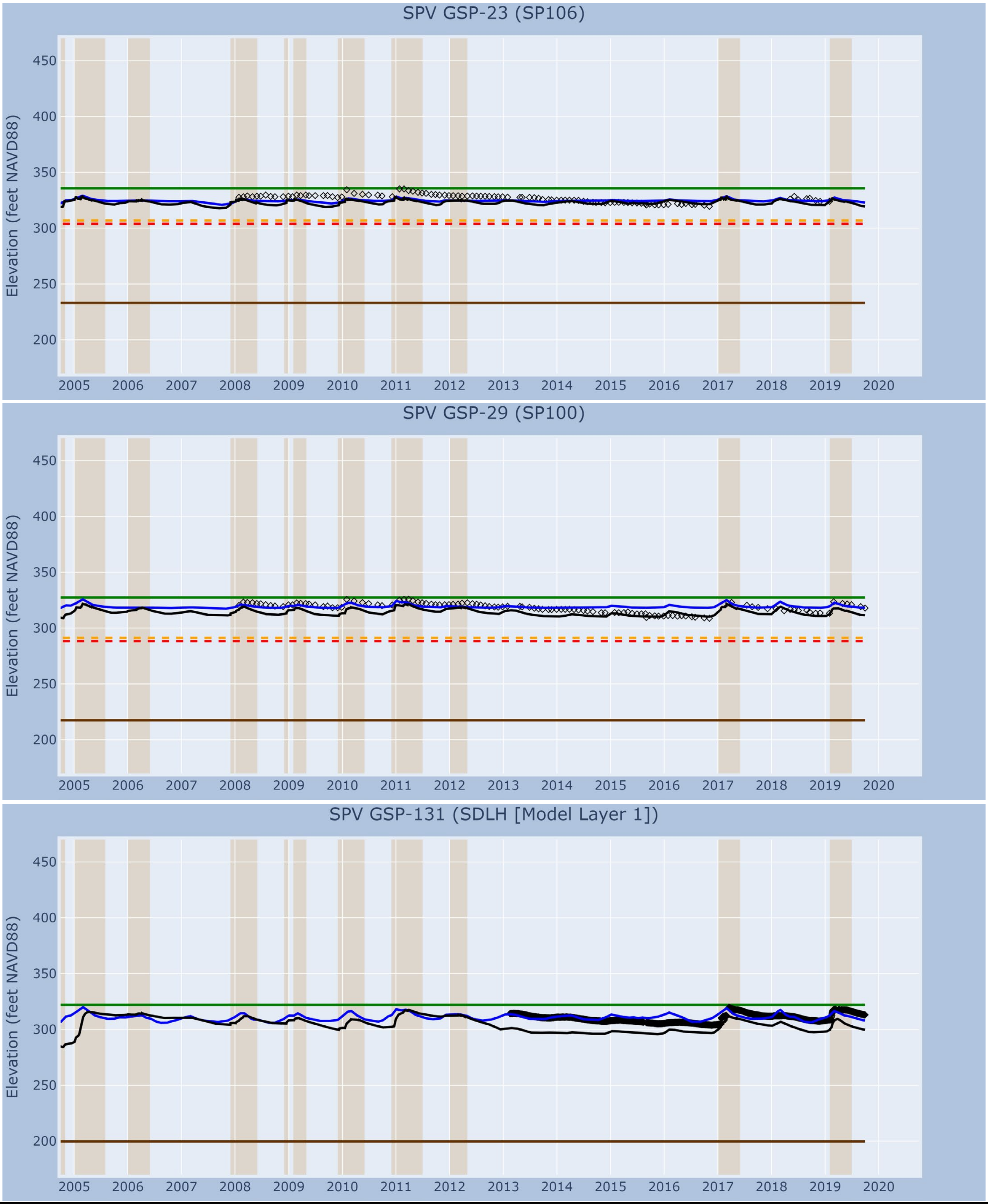

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Figure D-7
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

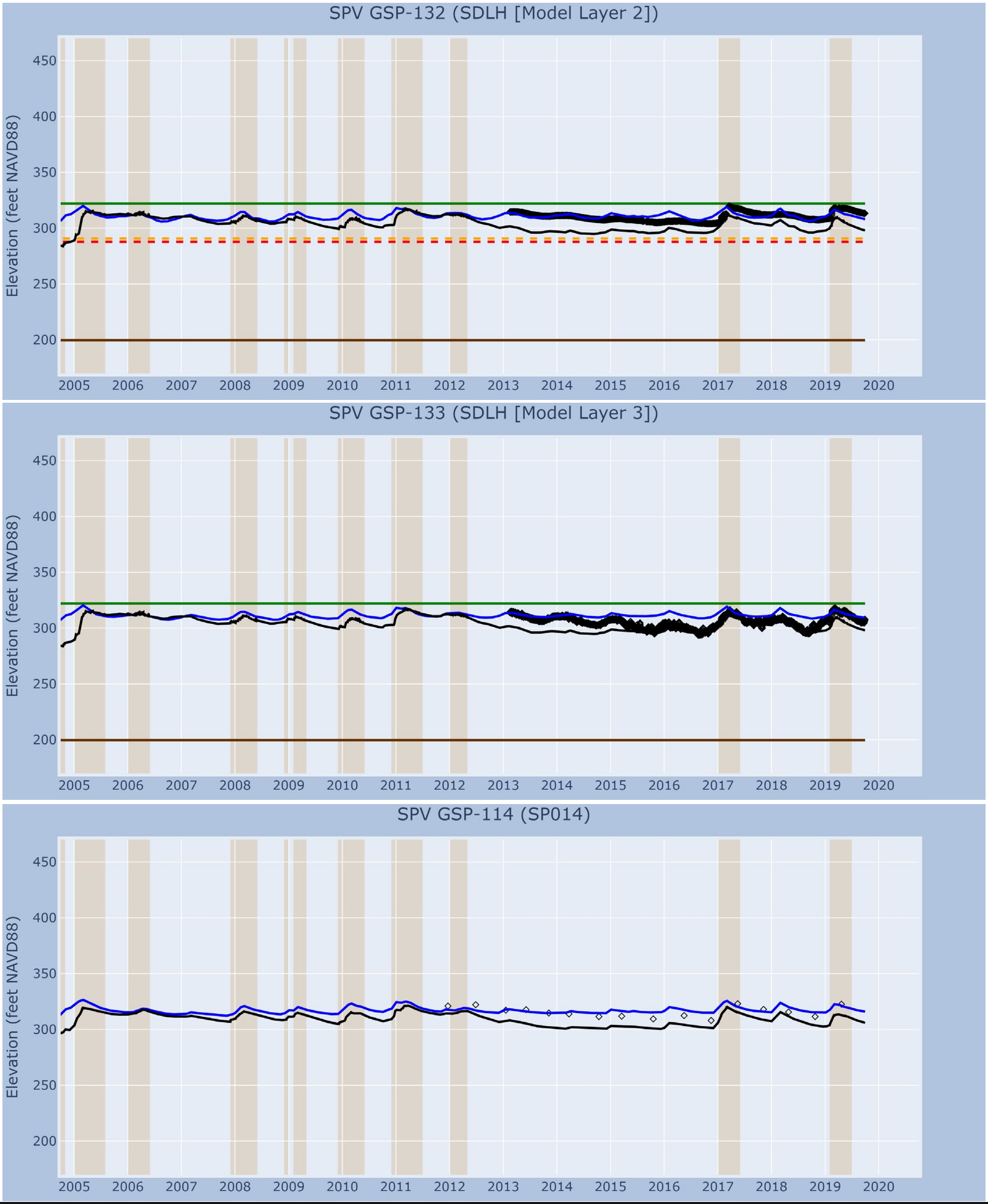

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Figure D-8
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

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ATTACHMENT E: RECHARGE STRATEGY GROUNDWATER-LEVEL HYDROGRAPHS

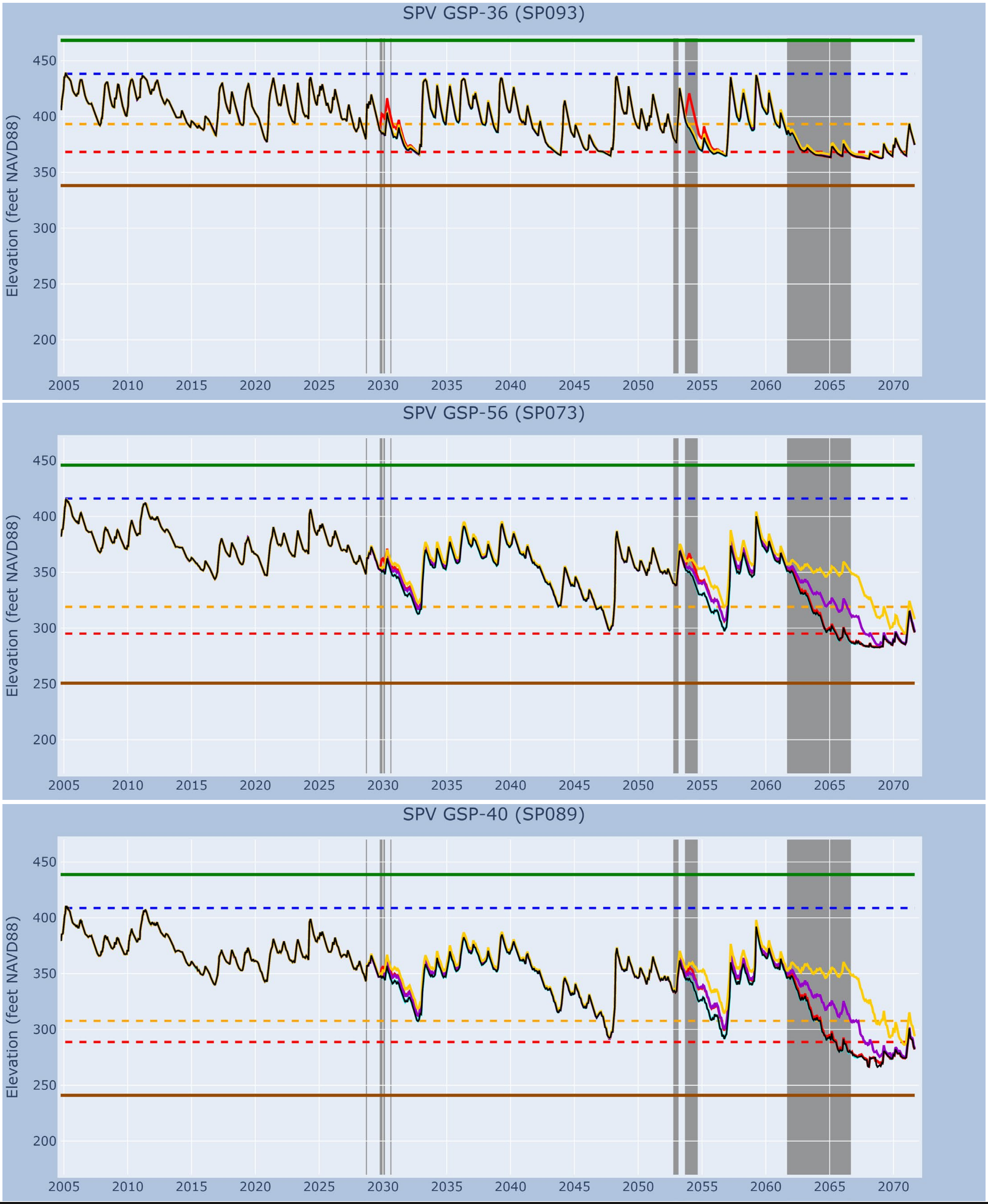

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Figure E-1
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

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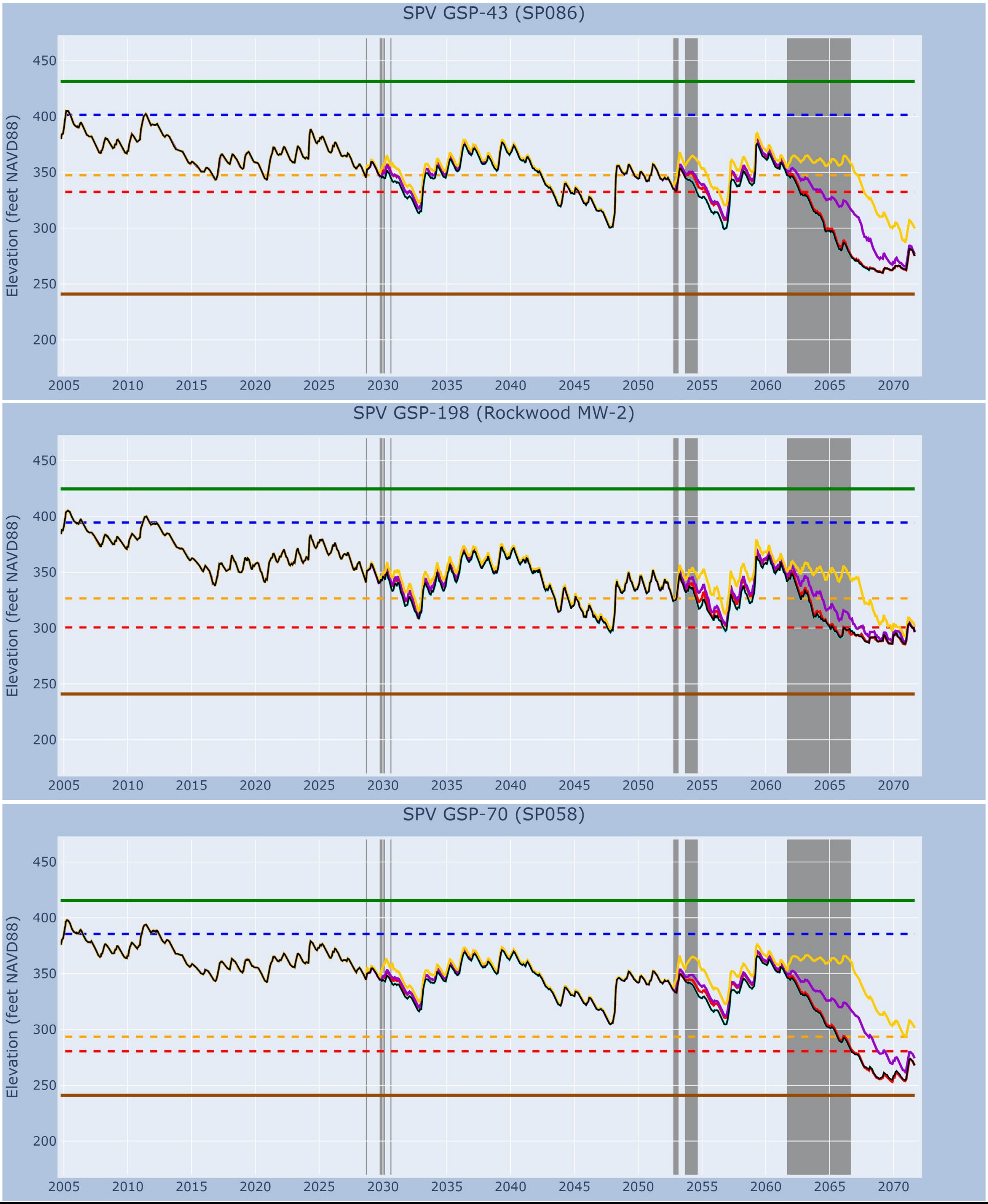

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Figure E-2
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

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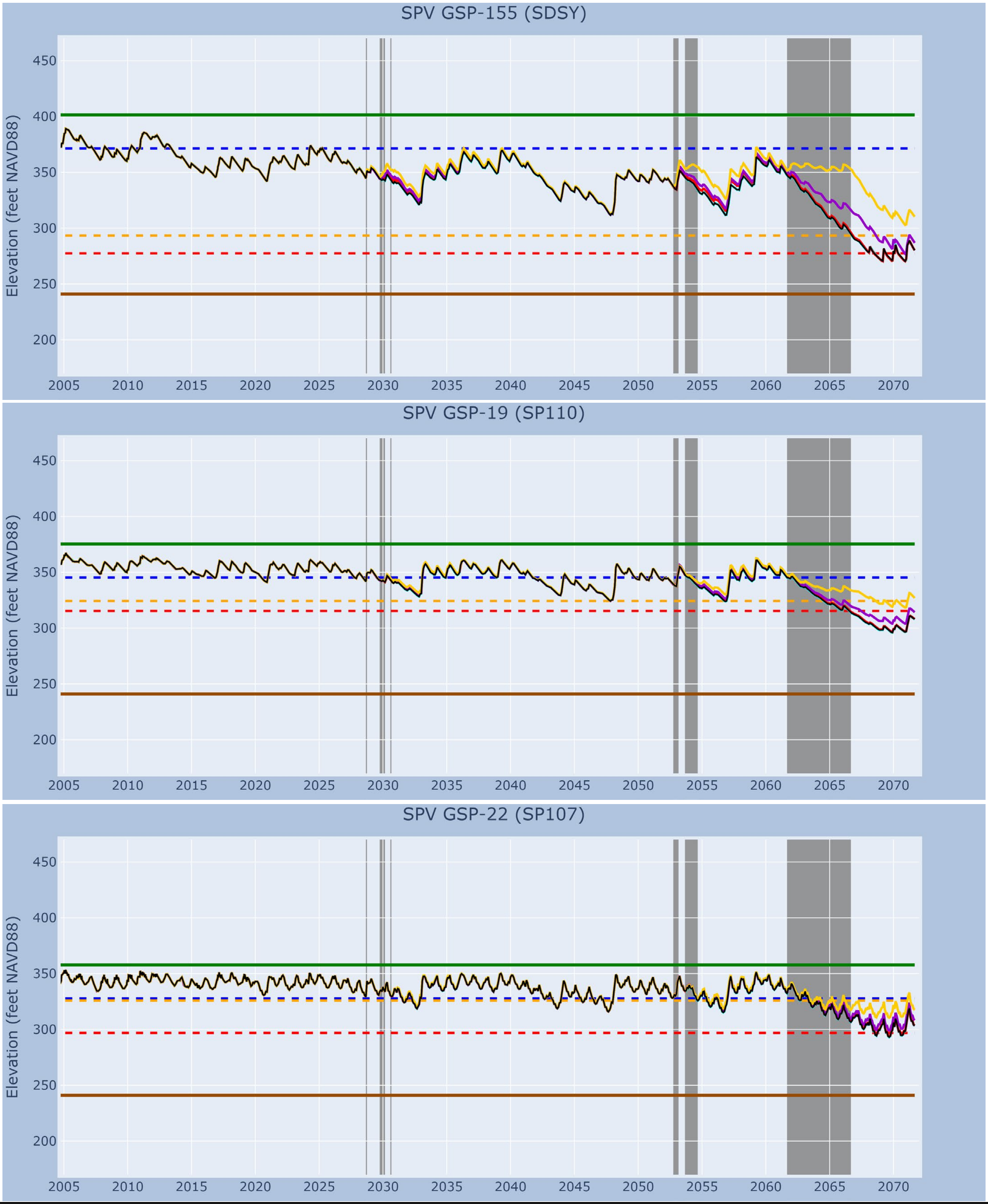

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Figure E-3
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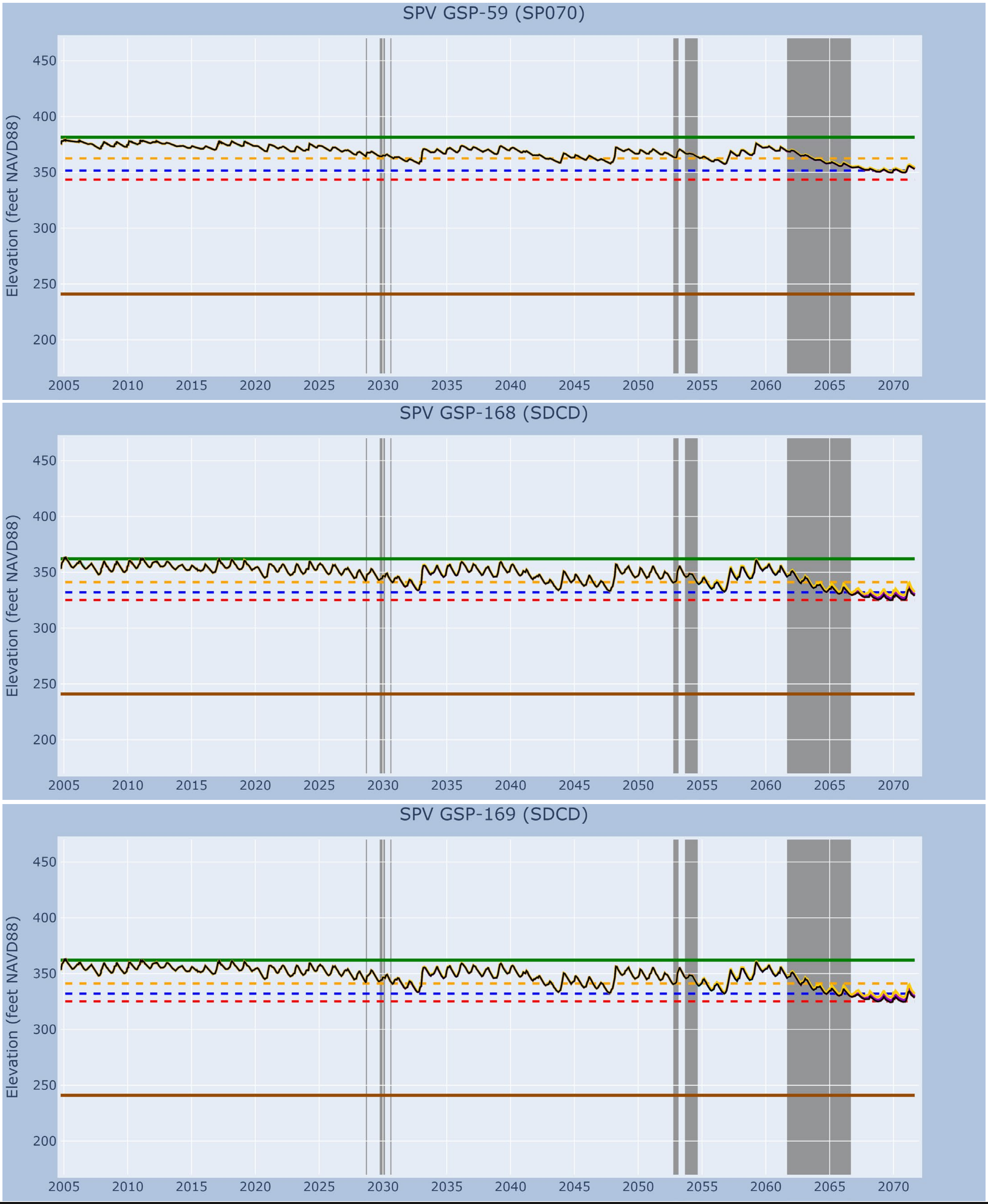

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Figure E-4
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PMA7: Initial Surface Water Recharge Evaluation
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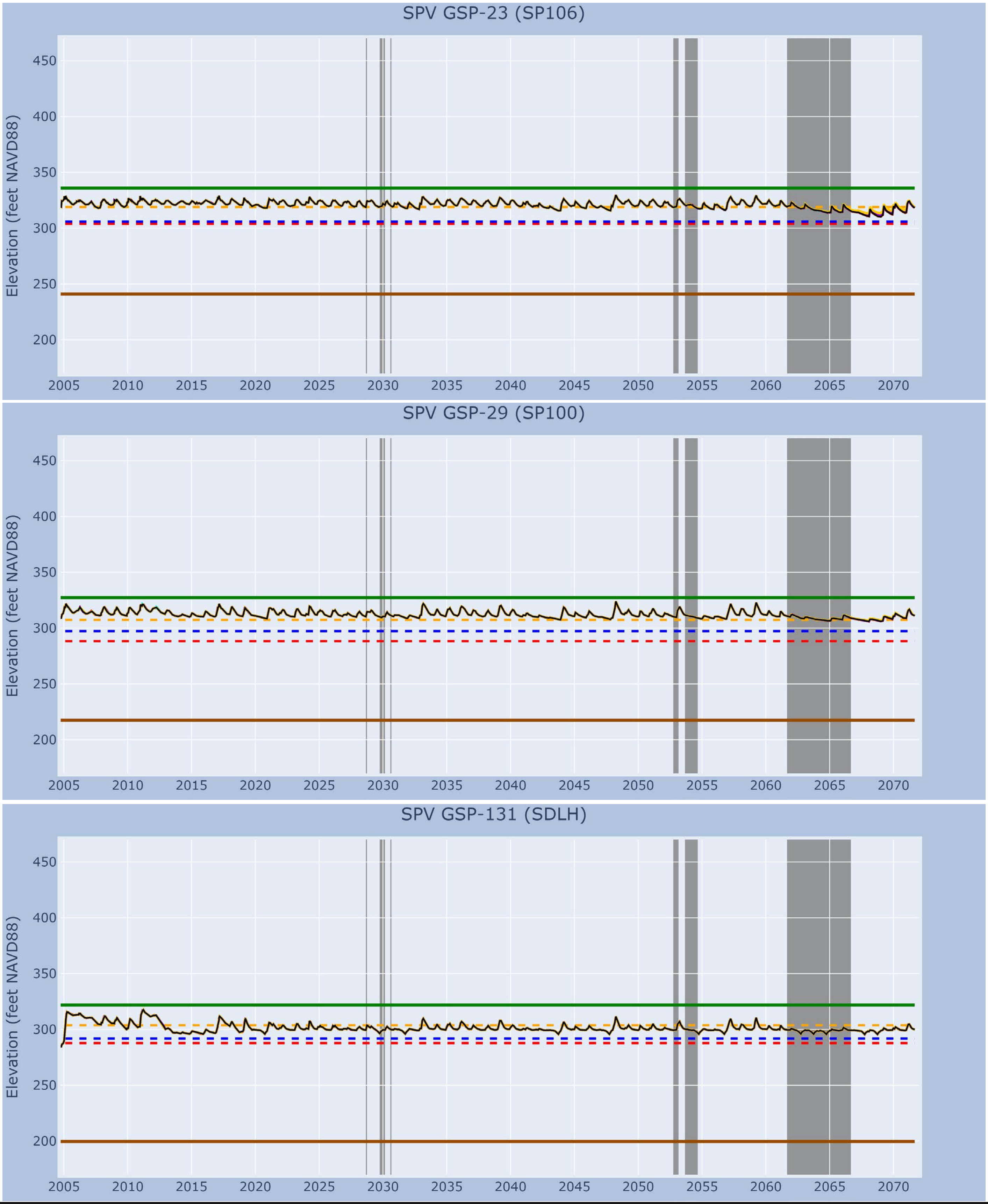

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Figure E-5
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
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San Pasqual Valley, California

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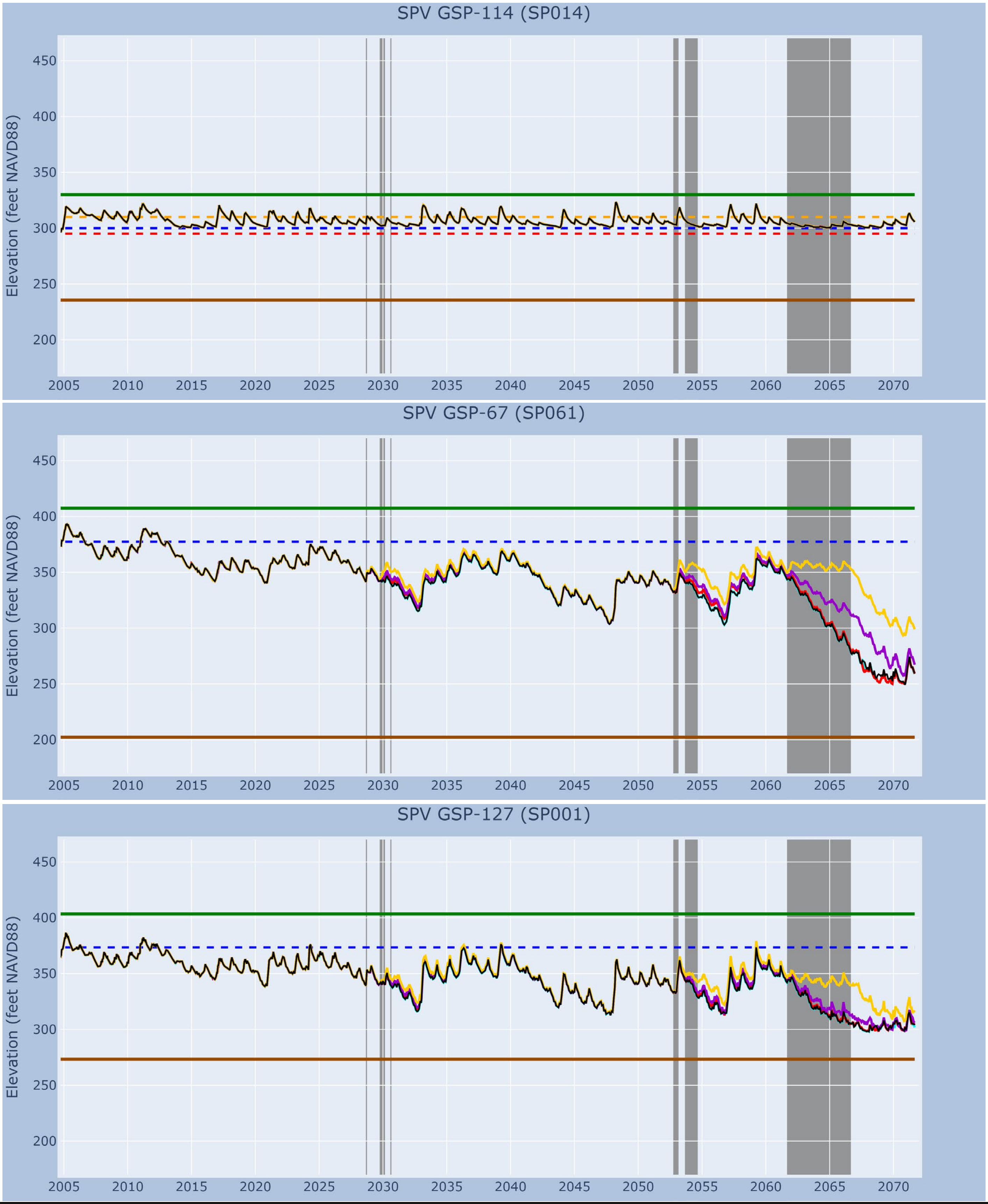

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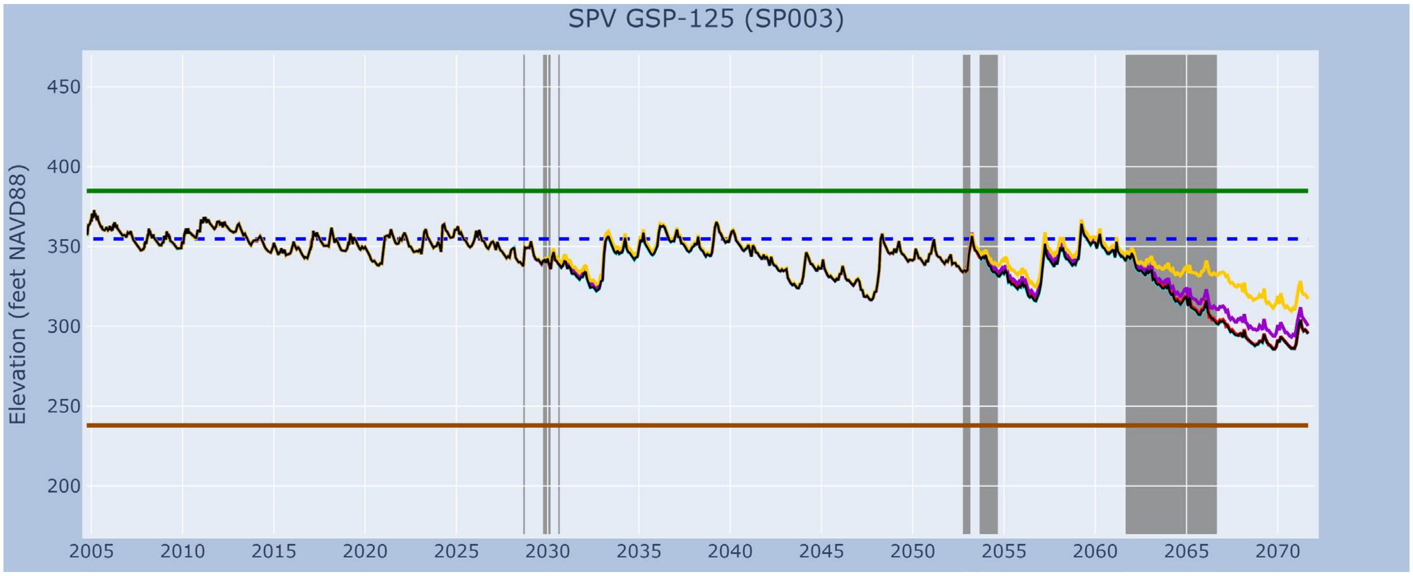

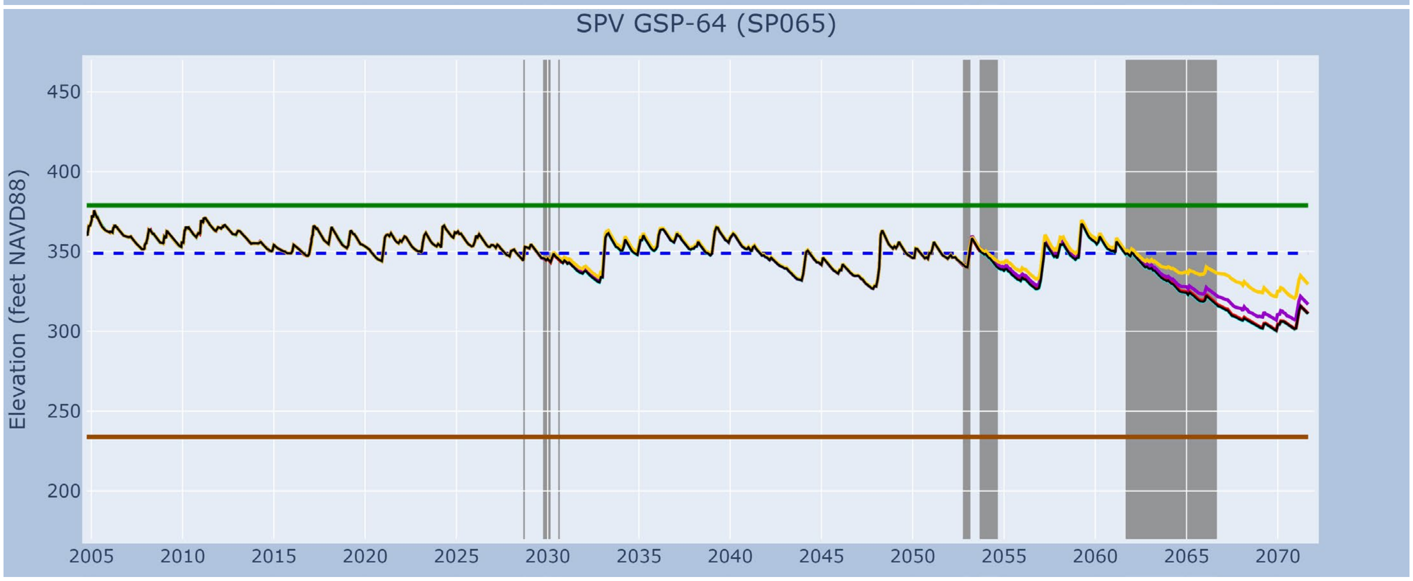

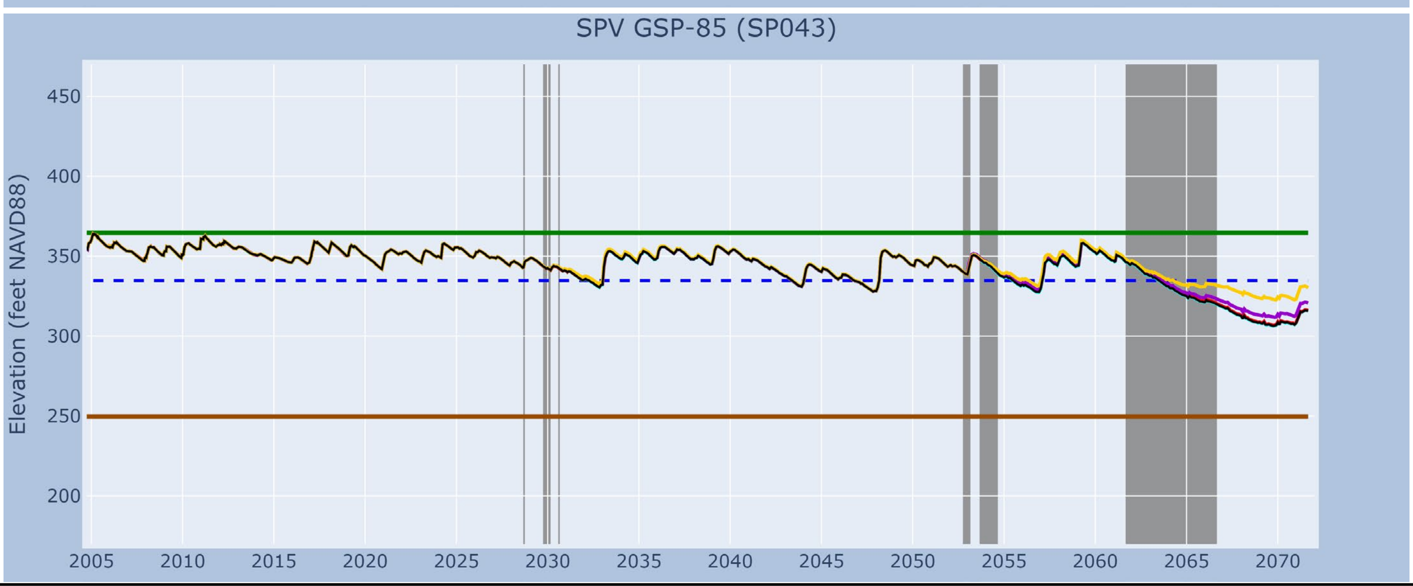

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Figure E-7
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

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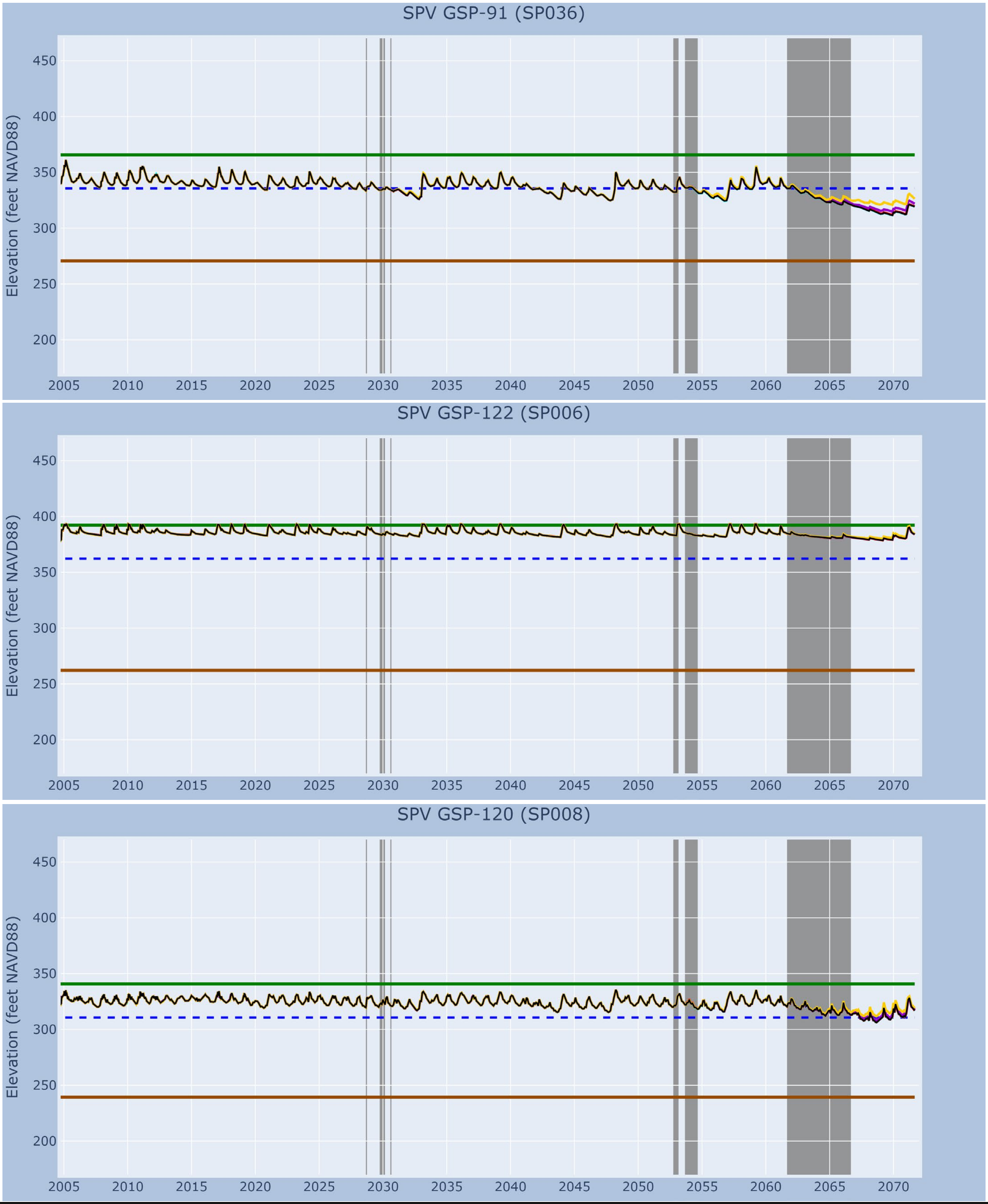

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Figure E-8
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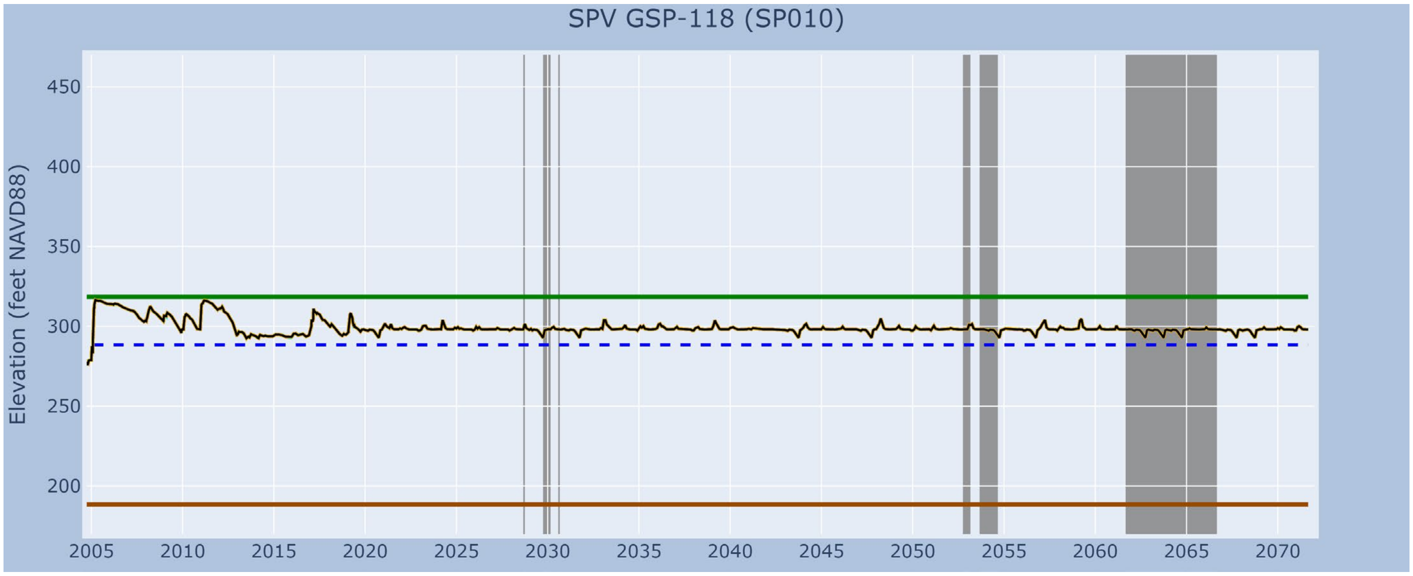

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Figure E-9
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

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APPENDIX F: TM 6: BENEFITS TO GROUNDWATER DEPENDENT ECOSYSTEMS

TECHNICAL MEMORANDUM

TO: San Pasqual Valley Groundwater Sustainability Agency

PREPARED BY: Will Medlin/W&C, Clayton Marcotte/W&C, Sam Castro/W&C

REVIEWED BY: Sally Johnson/W&C, Nate Brown/Jacobs

DATE: August 22, 2023

RE: Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 6: Possible Benefits to Potential Groundwater Dependent Ecosystems

TABLE OF CONTENTS

ACRONYMS & ABBREVIATIONS

bgs	below ground surface	NCCAG	Natural Communities Commonly Associated with Groundwater
CDFW	California Department of Fish and Wildlife	PMA	Project and Management Action
CNDDB	California Natural Diversity Database	Ramona MWD	Ramona Municipal Water District
CNRA	California Natural Resources Agency	SPV	San Pasqual Valley
DWR	California Department of Water Resources	TM	Technical Memorandum
EIR	Environmental Impact Report	US	United States
GDE	Groundwater Dependent Ecosystem	USDA	United States Department of Agriculture
GIS	Geographic Information System	USFS	United States Forest Service
GSA	Groundwater Sustainability Agency	USFWS	United States Fish and Wildlife Service
GSP	Groundwater Sustainability Plan	USGS	United States Geological Survey
HCM	hydrogeological conceptual model		

EXECUTIVE SUMMARY

This technical memorandum (TM) evaluates possible benefits to potential groundwater dependent ecosystems (GDEs) that may result from the implementation of four potential surface water recharge strategies under the San Pasqual Valley (SPV) Groundwater Sustainability Plan (GSP). This TM is part of a broader effort to develop a Preliminary Feasibility Study, comprised of components developed under separate tasks including evaluation criteria and ranking process of recharge strategies (Task 1), streambed investigation (Task 2), potential water sources for recharge (Task 3), potential recharge strategies (Task 4), approach and results of strategy modeling (Task 5), and possible benefits to potential GDEs (which will be addressed in this TM). An updated model, SPV GSP Model v2.0, was used to evaluate the four recharge strategies developed from the Task 4 assessment (City, 2023b) and their impacts to the SPV Groundwater Basin (Basin).

The intent of this Task 6 evaluation is to better understand the potential effects of the recharge strategies on groundwater level as it relates to GDE ability to access groundwater based on average GDE maximum vegetation rooting depth and modeled groundwater levels per year for each of the four strategies. These recharge strategies are as follows:

- Strategy 1B: Enhance Streamflow Infiltration with In-stream Modifications
- Strategy 2A: Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases
- Strategy 3A: Augment Santa Ysabel Creek Streamflow with Ramona MWD Deliveries
- Strategy 3D: Injection Wells with Ramona MWD Deliveries

The four recharge strategies would primarily target the Santa Ysabel Creek drainage upstream of Ysabel Creek Road in the eastern portion of the Basin. The eastern portion of the Basin is generally a groundwater recharge area, where the aquifer receives water primarily from streambed infiltration of Santa Ysabel, Guejito, and Santa Maria Creeks. Within the Basin, Santa Ysabel Creek is approximately 50 to 150 feet wide with coarse sandy substrates and mid channel bars vegetated by willow (*Salix* spp.), salt cedar (*Tamarisk ramosissima*), and other riparian shrubs typical for the region. Normal stream flow within the channel of Santa Ysabel Creek is intermittent and primarily results from heavy rainfall runoff during the wettest months of the year. The eastern portion of the Basin is the target recharge area for the proposed strategies based on the potential benefits groundwater recharge would have on the deeper water table in that area of the Basin. Additionally, accessibility to existing infrastructure and roadways, proximity to representative monitoring wells, and minimization of disturbance to nearby agricultural lands make the eastern portion of the Basin ideal for potential long-term groundwater recharge. Typical average groundwater depths in the portion of the Basin east of Ysabel Creek Road range between approximately 65 to 105 feet below ground surface (bgs). Refer to Attachment A: Figures for project location and other mapping of the Basin, existing groundwater monitoring wells, and the four recharge strategies.

Based on the modeled recharge strategy hydrographs, the strategies appear to increase groundwater levels compared to baseline in many of the modeled groundwater wells within the target area in the eastern portion of the Basin. Though the modeled groundwater levels increase, they still remain between 30 and 90 feet below ground surface and therefore may not intersect with the average maximum rooting depths for potential non-GDEs. This would suggest that while the strategies may be good for overall groundwater supply replenishment and potential maintenance of groundwater levels above minimum thresholds, they may not have a direct long-term benefit to GDE vegetation accessing the aquifer. Further, the modeled recharge strategy hydrographs appear to indicate a long-term downward trend for groundwater levels in the target area despite augmenting groundwater and therefore further analysis of potential benefits to GDEs was not completed for future implementation years beyond 2030 – 2032. Refer to Attachment A: Figures for recharge strategies and GDEs, and Attachment C for the recharge strategy groundwater-level hydrographs.

Despite the minimal effect on groundwater levels in relation to GDE rooting depths, it should be noted that augmented stream flows and/or prolonged surface water inundation resulting from recharge strategies 1B, 2A, and 3A would likely still produce benefits to potential non-GDEs and sensitive or special-status species that may exist in the Basin and rely on riparian vegetation and wetland communities for breeding, feeding, and sheltering. Agricultural runoff, wastewater, and man-made surface water retention structures may also have a possible effect on potential GDEs. Shallow groundwater monitoring (e.g. piezometer readings) within 10-ft of ground surface may be used to determine water accessibility to potential GDEs and potential non-GDEs in the Basin. Further study could potentially discern how potential GDEs within the Basin are currently sustained and whether augmented surface flows may provide additional support to potential GDEs and potential non-GDEs.

1. INTRODUCTION

As part of the California Sustainable Groundwater Management Act (SGMA), Groundwater Sustainability Agencies (GSAs) are required to develop a GSP to help ensure that groundwater is available for long-term, reliable water supply uses. SGMA was signed into law in 2014.

The San Pasqual Valley GSA – composed of the City of San Diego (City) and the County of San Diego (County) – adopted the San Pasqual Valley GSP and submitted it to the California Department of Water Resources (DWR) in January 2022 (City and County, 2021). The GSP provides guidance and quantifiable metrics to provide for the continued sustainable management of groundwater resources within the San Pasqual Valley Groundwater Basin (Basin) over the 20-year GSP implementation period. To accomplish this, the GSP includes a hydrogeological conceptual model, monitoring requirements, sustainable management criteria, and several projects and management actions (PMAs). The PMAs included in the GSP provide opportunities to enhance water supply, reduce demands, and otherwise support sustainable groundwater management in the Basin, allowing the GSA to respond to changing conditions and help avoid undesirable results defined in the GSP. The Basin is currently sustainably managed, meaning no undesirable results are being experienced, so no additional PMAs are currently needed to achieve sustainability. However, implementing PMAs could improve resilience against challenging future hydrologic conditions, such as extended droughts.

Consideration of GDEs is a required component of a GSP, and potential non-GDEs were included in the 2021 GSP for the Basin. SGMA defines GDEs as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." Potential GDEs identified in this TM are defined as mapped natural communities commonly associated with groundwater (NCCAG) community polygons where the vegetative community's average maximum rooting depths intersect with measured groundwater. Potential non-GDEs identified in this TM are defined as being mapped NCCAG polygons with average maximum rooting depths that do not intersect groundwater. This TM is the last of six that specifically focuses on PMA No. 7 and how initial surface water recharge strategies could influence potential GDEs and potential non-GDEs identified within the Basin. While not a full GDE study, this TM is part of a broader effort to develop a Preliminary Feasibility Study of potential recharge strategies to augment groundwater within the Basin. Further desktop and field study beyond the scope of this TM may be required to determine the presence, extent, and status of potential GDEs in the Basin to inform the SPV GSP.

2. BASIN ECOLOGICAL SETTING

The Basin is located in southern California, southeast of the City of Escondido, in San Diego County, California. The Basin sits entirely within the Southern California / Northern Baja Coast Environmental Protection Agency (EPA) Level III ecoregion (85). The Southern California / Northern Baja Coast ecoregion is made up of coastal and alluvial plains, marine terraces, and foothills along the coast of Southern California. The ecoregion also extends southward for over 200 miles along the coast of Baja California. Dominant communities of coastal sage shrub and chaparral plants once characterized much of the area; however, large-scale urbanization and agricultural land clearing activities have altered the landscape (Griffith et al. 2016).

Much of the Basin is within the Diegan Coastal Valleys and Hills (85f) EPA Level IV ecoregion, as shown in **Figure 1**. This ecoregion is characterized by terraces and steep foothills. Numerous canyons exist along with a few wide valleys and the geology primarily consists of sedimentary and granitic rocks. Oceanic influence drives and changes the climate in this ecoregion. Soils are typically hot and dry, and the native vegetative communities include coastal scrub, chaparral, grasslands and meadows, and some small areas of coastal oak woodland. The westernmost portions of the Basin are located within the Diegan Western Granitic Foothills (85g) Level IV ecoregion. This ecoregion consists of low, somewhat steep, foothills that are part of the lower Peninsular Ranges. Valleys in the ecoregion vary in width. Marine air does not affect the climate as much as in the neighboring ecoregions to the west, however, soil temperature and moisture regimes and vegetative communities are similar.

The Basin is in a wide valley situated between Highland Valley and Starvation Mountain to the south, and Rockwood Canyon to the north. According to the United States Geological Survey (USGS) 7.5-minute topographic map Escondido, California (1975) and San Pasqual, California (1988) quadrangles, the approximate elevation of the eastern extent of the Basin is approximately 480 feet above mean sea level and the approximate elevation of the western extent of the Basin is 300 feet above mean sea level. Surface drainage within the eastern portion of the San Pasqual Valley is mainly comprised of two streams, Guejito Creek and Santa Ysabel Creek. Guejito Creek flows southward through Rockwood Canyon and into Santa Ysabel Creek, which then flows westward through the valley eventually draining into the San Dieguito River. The San Dieguito River then continues flowing west-southwest through the Basin eventually entering Lake Hodges. Refer to Attachment A: Figures for project location, ecoregion, and other relevant mapping of the Basin.

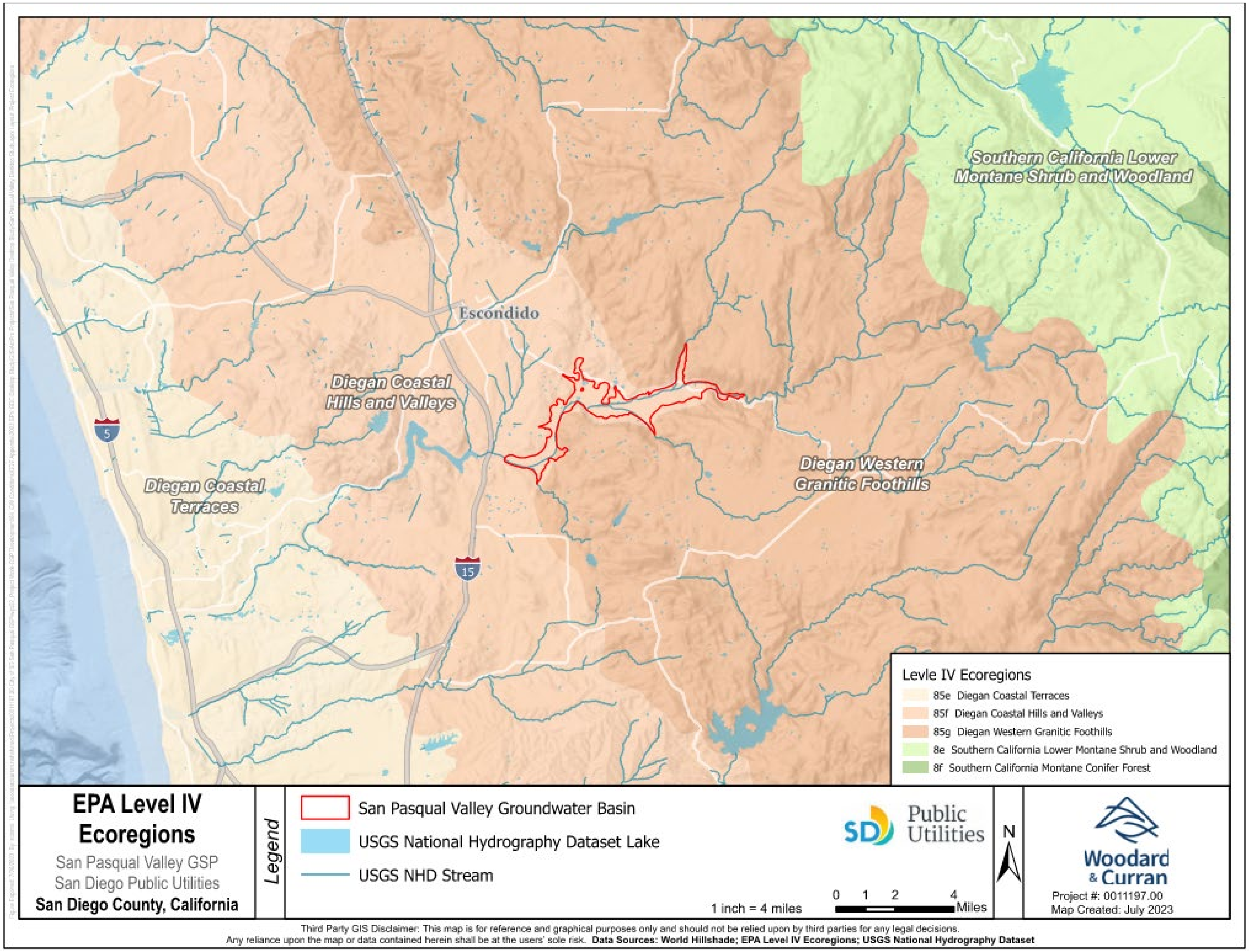

Figure 1: Basin Location in EPA Level IV Ecoregion

3. GROUNDWATER DEPENDENT ECOSYSTEMS AND INTERCONNECTED SURFACE WATERS

GDEs are communities and species that rely on groundwater for all or a portion of their life cycle. Reliance on groundwater varies between GDEs and may be considered direct, such as in the case of deep-rooted phreatophytes accessing groundwater via root systems, or indirect, such as animals that depend on riparian, wetland, or other groundwater-dependent vegetation. GDEs may include upland vegetation communities, springs, seeps, coastal wetlands, and riparian vegetation found along rivers, streams, and lakes (TNC 2020). The NCCAG dataset developed by California DWR was used to develop a Basin map of GDE indicators, shown in **Figure 2**. The NCCAG database includes a set of GIS data for vegetative communities and a separate data set for wetlands.

3.1 Methodology for Assessing GDEs

As documented in the separate TM for Task 5 (City, 2023c), the SPV GSP Model was updated from the version used to support the development of the GSP. The new model, SPV GSP Model V2.0, improved its representation of streams and aquifer characteristics in the Basin. This updated model incorporates more permeable stream channels, a more permeable alluvial aquifer, and more realistic streamflow behavior as compared with the previous version used to support GSP development. The SPV GSP Model v2.0 updates were conducted using information obtained during the Task 2 streambed investigation (City, 2023a) and recalibrated using a combination of daily and monthly stress periods. A stress period is an interval of time during which different values of precipitation, stream inflows at the perimeter of the model, and groundwater pumping are measured and weighed within the model. The model was used to generate predicted future groundwater levels in the Basin both without recharge strategy implementation (Baseline) and with each recharge strategy implemented. These modeled groundwater levels were then compared to the NCCAG-mapped polygons within the Basin to assess the recharge strategy impacts to GDEs.

Within the Basin, there are 72 NCCAG-mapped polygons (19 vegetation and 53 wetland) indicating potential GDEs or potential non-GDEs. The vegetative communities are described in the United States Forest Service (USFS) South Coast and Montane Ecological Province (CALVEG Zone 7) report (2009 USFS) and the wetland communities are described under the Cowardin classification system (1979 USFWS). There are six different vegetative communities mapped within the Basin: *coast live oak alliance, riparian mixed hardwood alliance, riparian mixed shrub alliance, riversidean alluvial scrub alliance, tule-cattail alliance, and willow (shrub) alliance*. The three different freshwater wetland communities mapped within the Basin consist of *palustrine emergent marsh, palustrine scrub-shrub, and palustrine forested systems*. The various vegetative and wetland communities include a number of species designated by California as phreatophytes or "deep-rooting" vegetation that rely on access to groundwater for long-term survival. Though these defined communities may include phreatophytic species, not all representative species within a community are considered phreatophytes. While these communities access shallow soil moisture, surface water, or perched groundwater during periods of drought or other dry conditions, they may also rely on access to the deeper regional aquifer for long-term survivability.

Each of the various vegetative and wetland community types have typical, representative plant species that occur within those habitats according to the 2009 USFS South Coast and Montane Ecological Province report. Those species have corresponding typical maximum rooting depths based on the 2021 Groundwater Resource Hub plant rooting database. Using this information and field observations of plant species within the vegetative and wetland communities from the 2020 GDE study, an average maximum rooting depth for each of the nine community types was calculated and applied to the NCCAG polygons mapped within the Basin. The vegetative and wetland community types and their associated average maximum rooting depths are described in **Table 1**. Potential GDEs identified in this TM are defined as mapped NCCAG community polygons with average maximum rooting depths that intersect groundwater. Potential non-GDEs identified in this TM are defined as being mapped NCCAG polygons with average maximum rooting depths that do not intersect groundwater. The average maximum rooting depths for each NCCAG-mapped community type were then compared against 10 years (2013-2022) of measured average groundwater level data for the Basin. If the average maximum rooting depth was at or below the average annual groundwater level, then the polygon was classified as a potential GDE. If the maximum rooting depth of a NCCAG community polygon was above the average annual groundwater level and did not intersect groundwater, the polygon was considered a potential non-GDE (**Figure 3**). Out of the 72 NCCAG-mapped polygons, only 14 polygons had average maximum rooting depths that intersected with the groundwater level contours, meaning groundwater depth was within the rooting zone's depth, and were therefore classified as potential GDEs. The remaining 58 NCCAG-mapped polygons with average maximum rooting depths that did not intersect groundwater were classified as potential non-GDEs.

Some surface waters may also support potential non-GDEs through their ability to recharge the Basin. Surface waters can generally be classified as interconnected surface waters or disconnected surface waters. SGMA defines interconnected surface waters as "surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted". Within the Basin, there are several intermittent stream channels that carry surface water at times during the year. The six primary intermittent drainage systems are Santa Ysabel Creek, Guejito Creek, Santa Maria Creek, Cloverdale Creek, Sycamore Creek, and the San Dieguito River. Based on a review of aerial photography, USGS gage station data, and field observations, each of these drainages dries up completely during certain portions of the year (typically Fall). However, groundwater modeling does appear to indicate that Cloverdale Creek, Sycamore Creek, and the San Dieguito River are potentially interconnected surface waters. Guejito Creek, Santa Maria Creek, and Santa Ysabel Creek in the eastern portion of the Basin are designated as disconnected streams because measured groundwater levels in nearby wells and the simulated groundwater levels do not intersect the streambed in these reaches. These streams are considered losing streams and can recharge groundwater when surface flows are available.

Table 1: NCCAG Vegetative and Wetland Community Types Found Within SPV Basin and Corresponding Community Average Maximum Rooting Depths

Community Type	Dominant Species Associated with Community Type (Species Average Maximum Root Depth)	Community Average Maximum Root Depth (feet bgs)	Present within Target Recharge Area
Vegetative Community			
Coast Live Oak Alliance	*Quercus agrifolia* (35 ft)	35	No
Riparian Mixed Hardwood Alliance	*Anemopsis californica* (1 ft), *Baccharis salicifolia* (2 ft*),* *Eucalyptus globulus* (10 ft), *Populus balsamifera* (4 ft), *Populus fremontii* (7 ft), *Populus trichocarpa* (4 ft), *Quercus agrifolia* (35 ft), *Salix spp.* (3 ft)	8	No
Riparian Mixed Shrub Alliance	*Arundo donax* (16 ft), *Baccharis salicifolia* (2 ft), *Salix spp.* (3 ft), *Tamarix ramosissima* (72 ft)	23	Yes
Riversidean Alluvial Scrub Alliance	*Arundo donax* (16 ft), *Baccharis salicifolia* (2 ft), *Encelia farinose* (2 ft), *Eriogonum fasciculatum* (4 ft), *Salvia apiana* (5 ft), *Tamarix ramosissima* (72 ft), *Yucca whipplei* (2 ft)	15	No
Tule – Cattail Alliance	*Avena fatua* (1 ft)	1	No
Willow (Shrub) Alliance	*Anemopsis californica* (1 ft), *Arundo donax* (16 ft), *Baccharis salicifolia* (2 ft), *Eucalyptus globulus* (10 ft), *Populus fremontii* (7 ft), *Salix spp.* (3 ft) *Tamarix ramosissima* (72 ft*),* *Typha domingensis* (1 ft)	14	Yes
Wetland Community			
Palustrine Emergent Marsh (PEM)	*Avena fatua* (1 ft)	1	Yes
Palustrine Scrub-Shrub (PSS)	*Arundo donax* (16 ft), *Baccharis salicifolia* (2 ft), *Encelia farinose* (2 ft), *Eriogonum fasciculatum* (4 ft), *Salix spp.* (3 ft*),* *Salvia apiana* (5 ft), *Tamarix ramosissima* (72 ft), *Yucca whipplei* (2 ft)	13	Yes
Palustrine Forested (PFO)	*Anemopsis californica* (1 ft), *Arundo donax* (16 ft), *Bacchari salicifolia* (2 ft), *Eucalyptus globulus* (10 ft), *Populus balsamifera* (4 ft), *Populus fremontii* (7 ft), *Populus trichocarpa* (4 ft), *Quercus agrifolia* (35 ft), *Salix spp.* (3 ft), *Tamarix ramosissima* (72 ft), *Typha domingensis* (1 ft)	14	No

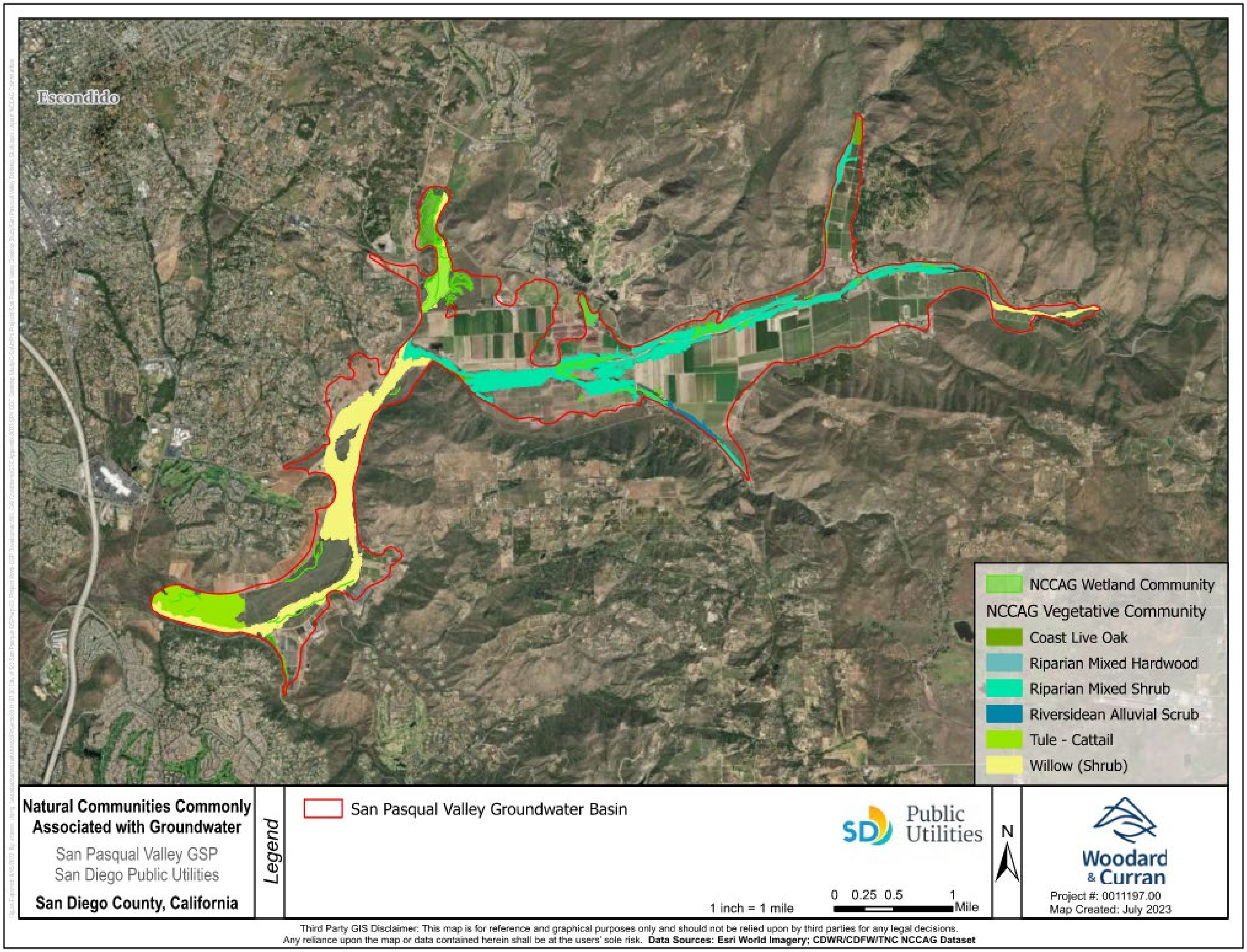

Figure 2: Potential GDEs and Potential Non-GDEs in the San Pasqual Valley Groundwater Basin

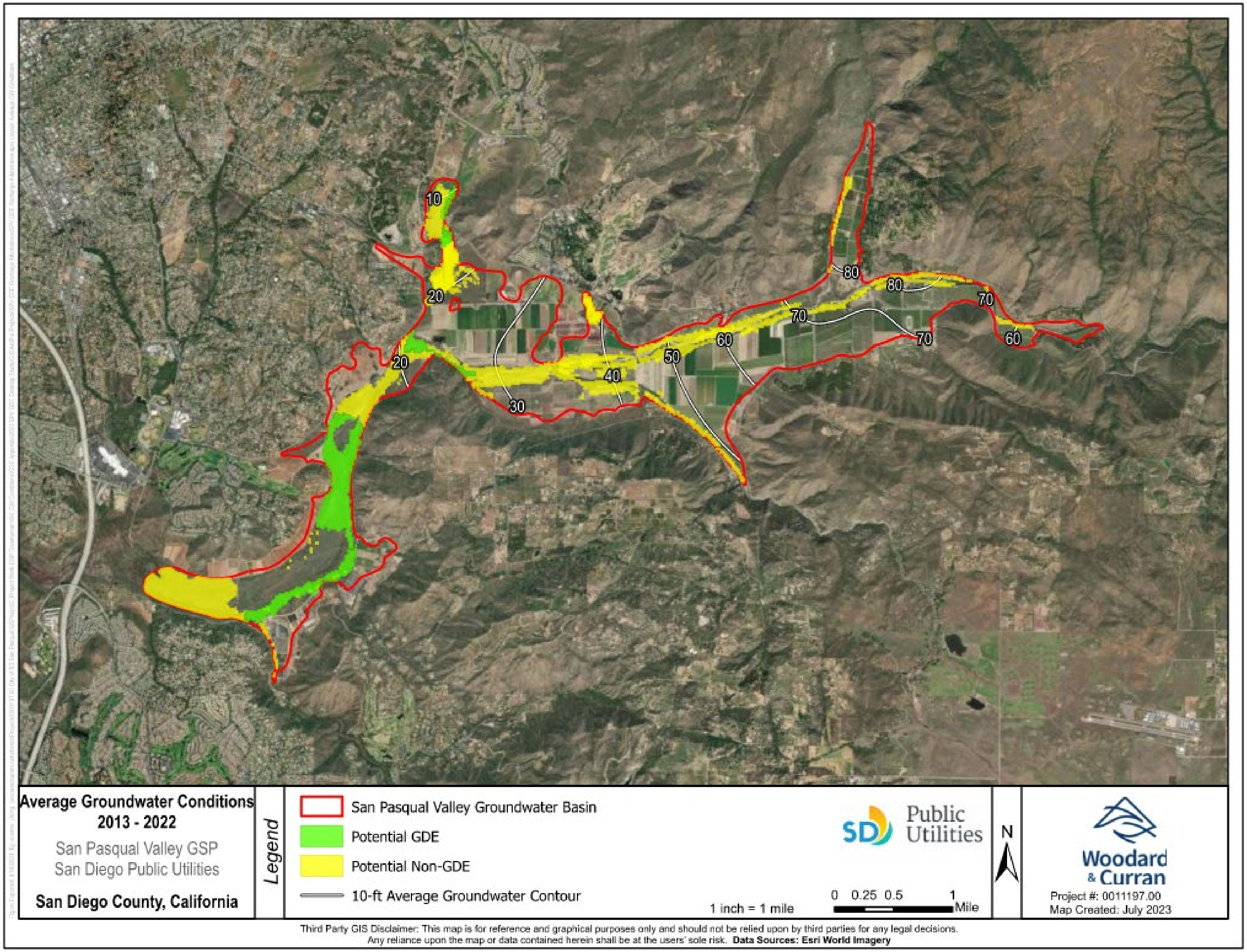

Figure 3: Average Measured Groundwater Levels from 2013-2022 in the San Pasqual Valley Groundwater Basin

4. SURFACE WATER RECHARGE STRATEGIES

The updated SPV GSP Model v2.0 was used to evaluate the four recharge strategies retained from the Task 4 assessment of potential recharge strategies. The intent of the evaluation is to better understand potential benefits of the recharge strategies, should they require implementation as part of adaptive management to avoid undesirable results. Additional discussion on the four recharge strategies and considerations for implementation can be found in TM 5 (City, 2023c). The recharge strategies are shown in **Figure 4** and include:

> **Strategy 1B: Enhance Streamflow Infiltration with In-stream Modifications;** A permanent, channel-spanning, inflatable rubber dam across Santa Ysabel Creek will be installed. The rubber dam would be inflated during selected periods to detain stormwater and increase the opportunity for additional infiltration and groundwater recharge behind the dam and deflated when Santa Ysabel Creek is dry or during higher-streamflow periods to allow stormwater in the creek to flow past the dam. The conditions under which the dam was inflated when modeling this strategy are described in TM 5 (City, 2023c).

> **Strategy 2A: Augment Santa Ysabel Creek Streamflow with Sutherland Controlled Releases;** Streamflow in Santa Ysabel Creek would be augmented with controlled releases from Sutherland Reservoir. The timing of recharge strategy implementation would occur based on certain conditions established in the GSP related to current groundwater levels in the target area, future predicted water availability due to precipitation and weather events, availability of water in Sutherland Reservoir, and current streamflow with Santa Ysabel Creek.

> **Strategy 3A: Augment Santa Ysabel Creek Streamflow with Ramona MWD Deliveries;** Santa Ysabel Creek streamflow would be augmented with deliveries of raw water from Ramona MWD. Deliveries of raw water would occur upstream of River Mile 3 near the San Pasqual Valley Road bridge. This location was ultimately determined to maximize the potential for streambed infiltration by conveying water along a realistic hypothetical pipeline route from Ramona MWD's existing untreated water conveyance system to Santa Ysabel Creek and delivering the water in the eastern portion of the Basin.

> **Strategy 3D: Injection Wells with Ramona MWD Deliveries;** Recharge water from Ramona MWD would be injected directly into the Basin aquifer through three injection wells. During the modeled Strategy 3D implementation periods, the monthly volume of water available from Ramona MWD would be conveyed to and evenly distributed across each of the three injection wells.

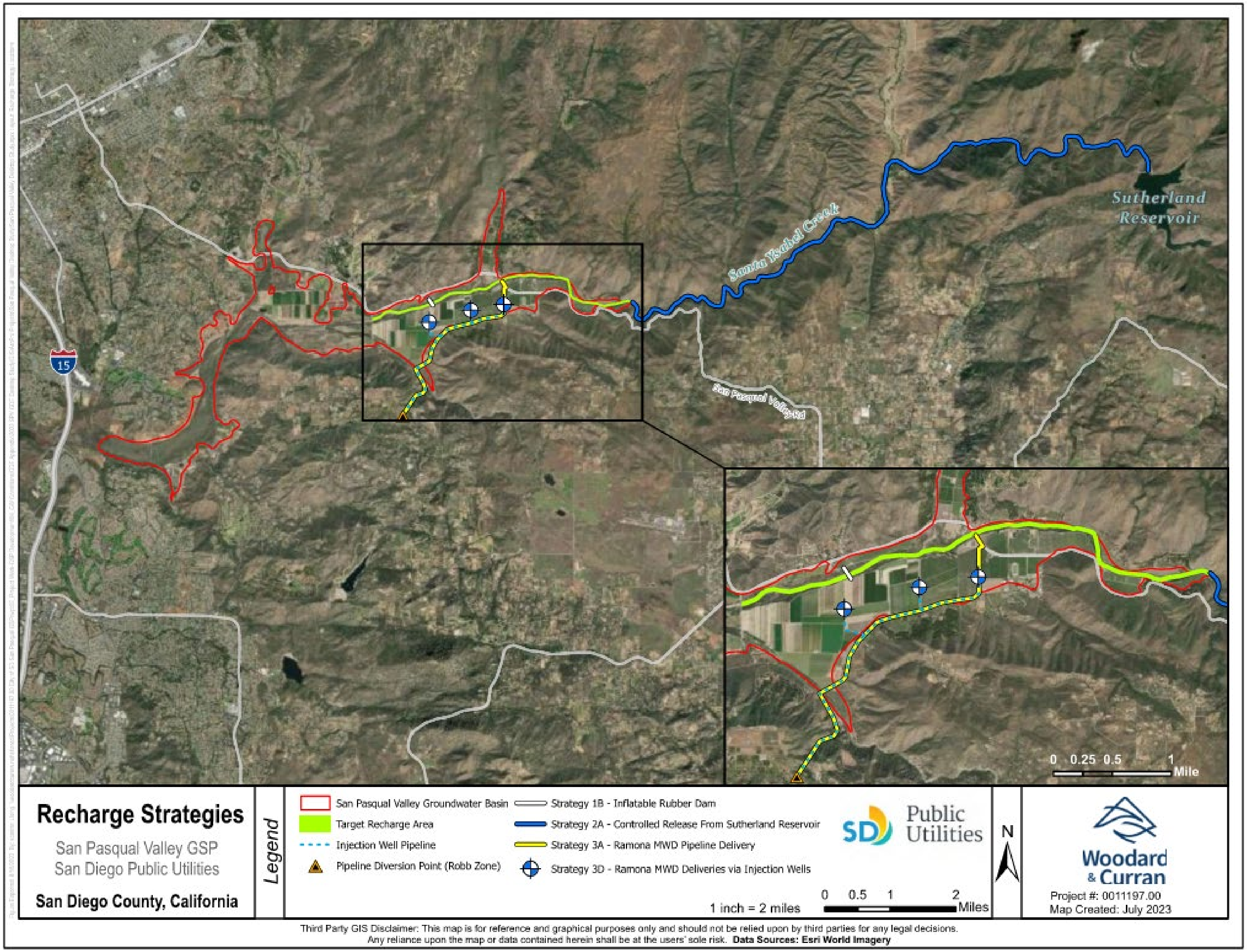

Figure 4: Location of Proposed Recharge Strategies

5. POTENTIAL BENEFITS FOR GDES

When assessing future modeled groundwater levels resulting from the four recharge strategies over the first three years of implementation (2030 – 2032) it appears that the most significant gains in groundwater level would likely be realized in the eastern portion of the Basin. Based on the modeled recharge strategy hydrographs, the strategies do appear to indicate an increase compared to baseline in many of the modeled groundwater wells within the target area in the eastern portion of the Basin, yet the groundwater levels remain between 30 and 90 feet bgs. The recharge strategies may still not be substantially beneficial because the average maximum rooting depth for the various NCCAG-mapped vegetative and wetland communities located in the target recharge area along Santa Ysabel Creek does not extend below 23 feet bgs (riparian mixed shrub alliance). Thus, the maximum average rooting depth and predicted groundwater levels do not intersect within the target recharge area for any of the modeled recharge strategies; suggesting that the recharge strategies offer minimal to no benefit to potential non-GDEs accessing groundwater in the target recharge area.

The average annual groundwater levels are shown in contours, along with the location of potential GDEs and potential non-GDEs for baseline and each of the four strategies for the year 2031 (midpoint of the three-year initial assessment period) are provided in Attachment A: Figures to show an example of the anticipated changes in groundwater levels and potential GDEs resulting from the recharge strategies as modeled. **Table 2** displays the potential GDE area for the baseline, the modeled area east and west of Ysabel Creek Road, and the total potential GDE area for each implementation year and recharge strategy. There is effectively no substantial difference between the baseline and modeled recharge strategies' potential GDE and potential non-GDE area. This would suggest that while the strategies may be good for overall groundwater supply replenishment and potential maintenance of groundwater levels above minimum thresholds, they may not have a direct long-term benefit to GDE vegetation accessing the aquifer.

Further analysis of possible benefits to potential non-GDEs was not completed for future implementation years beyond 2030 – 2032 because the modeled recharge strategy hydrographs appear to indicate an overall long-term downward trend for groundwater levels in the target area that would not come within 23 feet bgs even with the additional water provided by the recharge strategies as modeled. Refer to Attachment C for the recharge strategy groundwater-level hydrographs. Despite the minimal effect on groundwater levels as modeled, it should be noted that augmented stream flows and prolonged surface water inundation resulting from recharge strategies 1B, 2A, and 3A would likely produce benefits to potential GDEs, potential non-GDEs, and sensitive or special-status species that may exist in the Basin and rely on riparian vegetation and wetland communities for breeding, feeding, and sheltering. The additional surface water flows will support potential non-GDEs through near-surface root hydration to further plant growth and development of riparian communities. Also, additional surface water within the stream channel would potentially support birds, reptiles, amphibians, and macroinvertebrates within potential non-GDEs that might not otherwise survive prolonged dry periods. Due to the variability in species' reliance on groundwater, further study of species and habitats local to the Basin may be required to determine the beneficial impacts the recharge strategies may have on shallow groundwater, soil moisture, and surface water and potentially on the communities that rely on these resources.

Table 2: Baseline Potential GDE Area and Modeled Change for the Four Surface Recharge Strategies

Recharge Strategy	Baseline Potential GDE Area (acres)	Modeled Potential GDE Area West of Ysabel Creek Rd/ Percent Change	Modeled Potential GDE Area East of Ysabel Creek Rd/ Percent Change	Total Potential GDE Area (acres)
Implementation Year 2030				
Recharge Strategy 1B	198.45	198.68 / 1.00%	0.00 / 0%	198.68
Recharge Strategy 2A	198.45	199.36 / 1.00%	0.00 / 0%	199.36
Recharge Strategy 3A	198.45	207.55 / 1.05%	0.00 / 0%	207.55
Recharge Strategy 3D	198.45	210.05 / 1.06%	0.00 / 0%	210.05
Implementation Year 2031				
Recharge Strategy 1B	105.14	105.14 / 1.00%	0.00 / 0%	105.14
Recharge Strategy 2A	105.14	106.28 / 1.01%	0.00 / 0%	106.28
Recharge Strategy 3A	105.14	110.15 / 1.05%	0.00 / 0%	110.15
Recharge Strategy 3D	105.14	115.15 / 1.10%	0.00 / 0%	115.15
Implementation Year 2032				
Recharge Strategy 1B	65.54	65.54 / 1.00%	0.00 / 0%	65.54
Recharge Strategy 2A	65.54	68.27 / 1.04%	0.00 / 0%	68.27
Recharge Strategy 3A	65.54	72.60 / 1.11%	0.00 / 0%	72.6
Recharge Strategy 3D	65.54	80.34 / 1.23%	0.00 / 0%	80.34

6. DISCUSSION AND NEXT STEPS

To better understand the current conditions of potential GDEs and potential non-GDEs within the Basin, it is recommended that additional study be conducted to assess the biological communities that currently exist within the Basin, and additional assessment of potential shallow groundwater levels that may persist above the deeper regional aquifer groundwater levels. For consistency and comparative purposes, it may be useful to return to the 16 different 2020 GDE study field assessment locations and establish permanent bio-monitoring stations so that changes over time may be observed. The following studies could be conducted to better understand GDEs and how the recharge strategies might affect them:

- Establish permanent photo stations to monitor community health and landscape-scale disturbances.
- Conduct California Rapid Assessment Method (CRAM) at 2020 GDE study field assessment locations. The CRAM is a scientifically defensible methodology for monitoring and assessing wetlands throughout California.
- Conduct avian point count surveys at 2020 GDE study field assessment locations using the North American Breeding Bird Survey program method.
- Conduct sampling for terrestrial amphibians and reptiles following established scientific methods such as USFS methodology.
- Establish vegetation plots and conduct quantitative sampling for species inventory and monitoring.
- During the wet season while there is water present in the GDEs, conduct environmental DNA (eDNA) sampling to determine what aquatic species have historically or are currently inhabiting these communities.

As modeled, the recharge strategies may not provide meaningful benefits to potential GDEs and potential non-GDEs, however changes to how the recharge strategies are implemented could have different effects on the potential benefits to GDEs, which should be considered as the recharge strategies are further developed.

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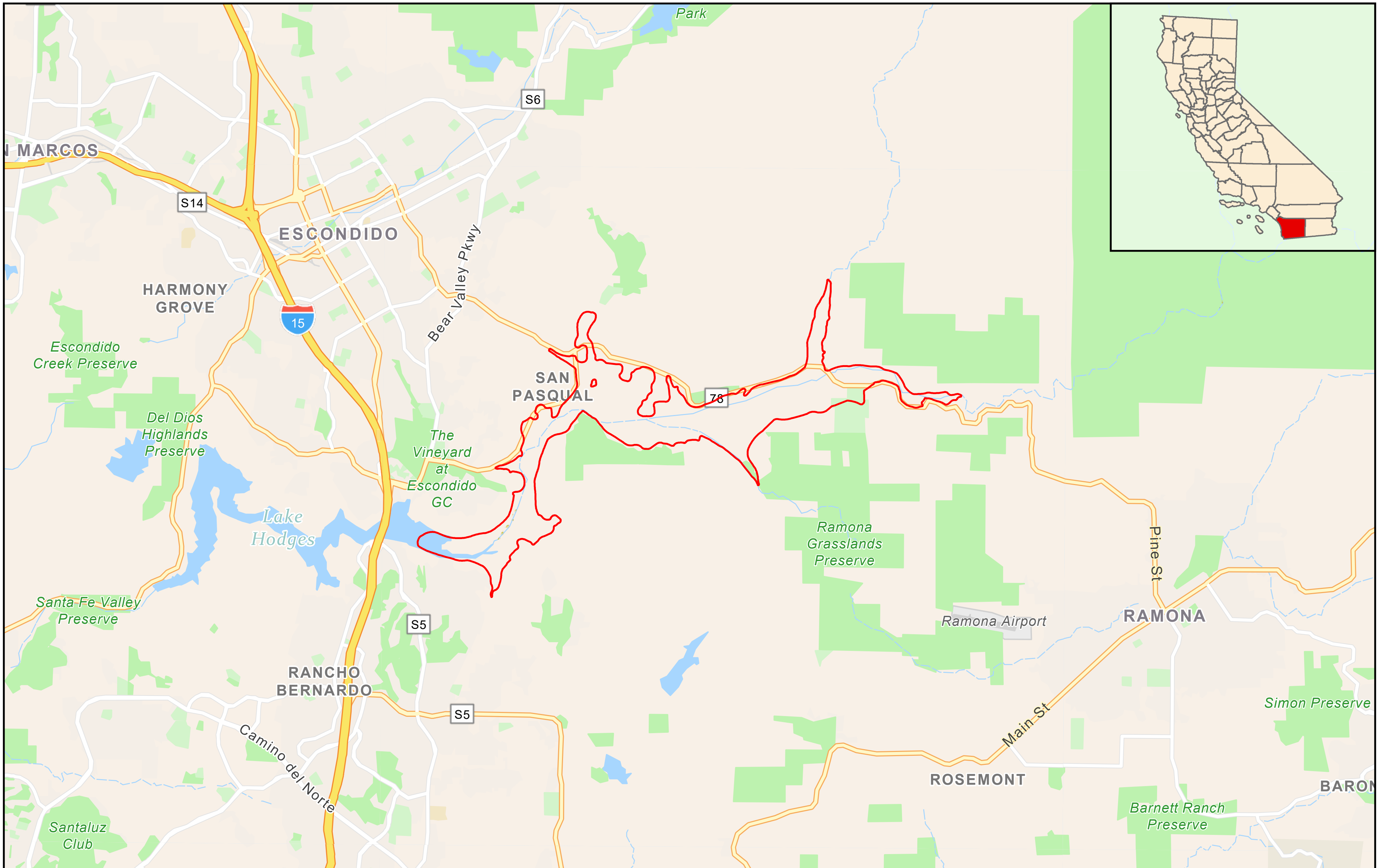
Attachment A: Figures



Project Location

San Pasqual Valley GSP
San Diego Public Utilities

San Diego County, California

Legend

San Pasqual Valley Groundwater Basin

SD Public Utilities

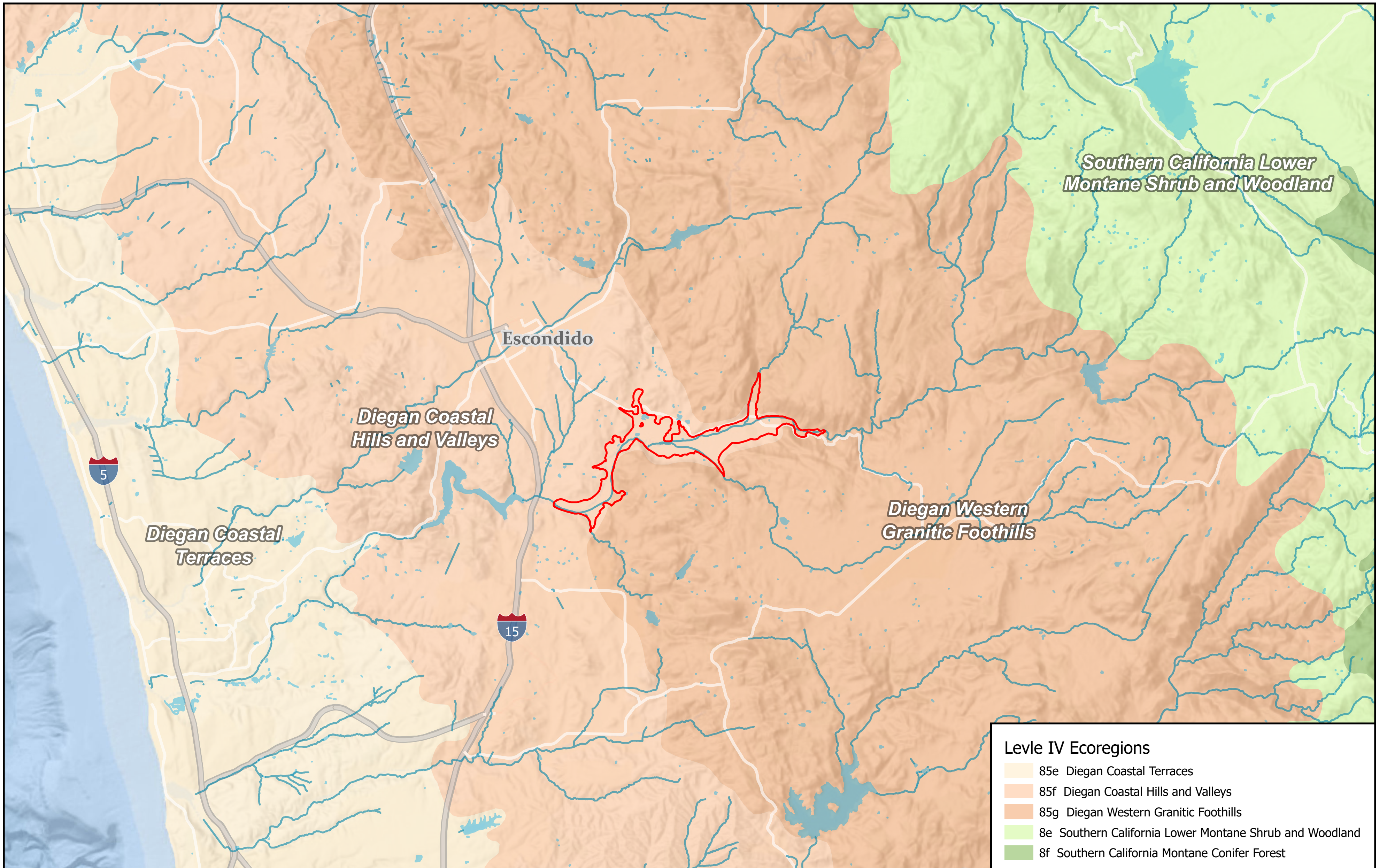
N

0 0.5 1 2 Miles

1 inch = 2 miles

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023



EPA Level IV Ecoregions

San Pasqual Valley GSP
San Diego Public Utilities
San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- USGS National Hydrography Dataset Lake
- USGS NHD Stream

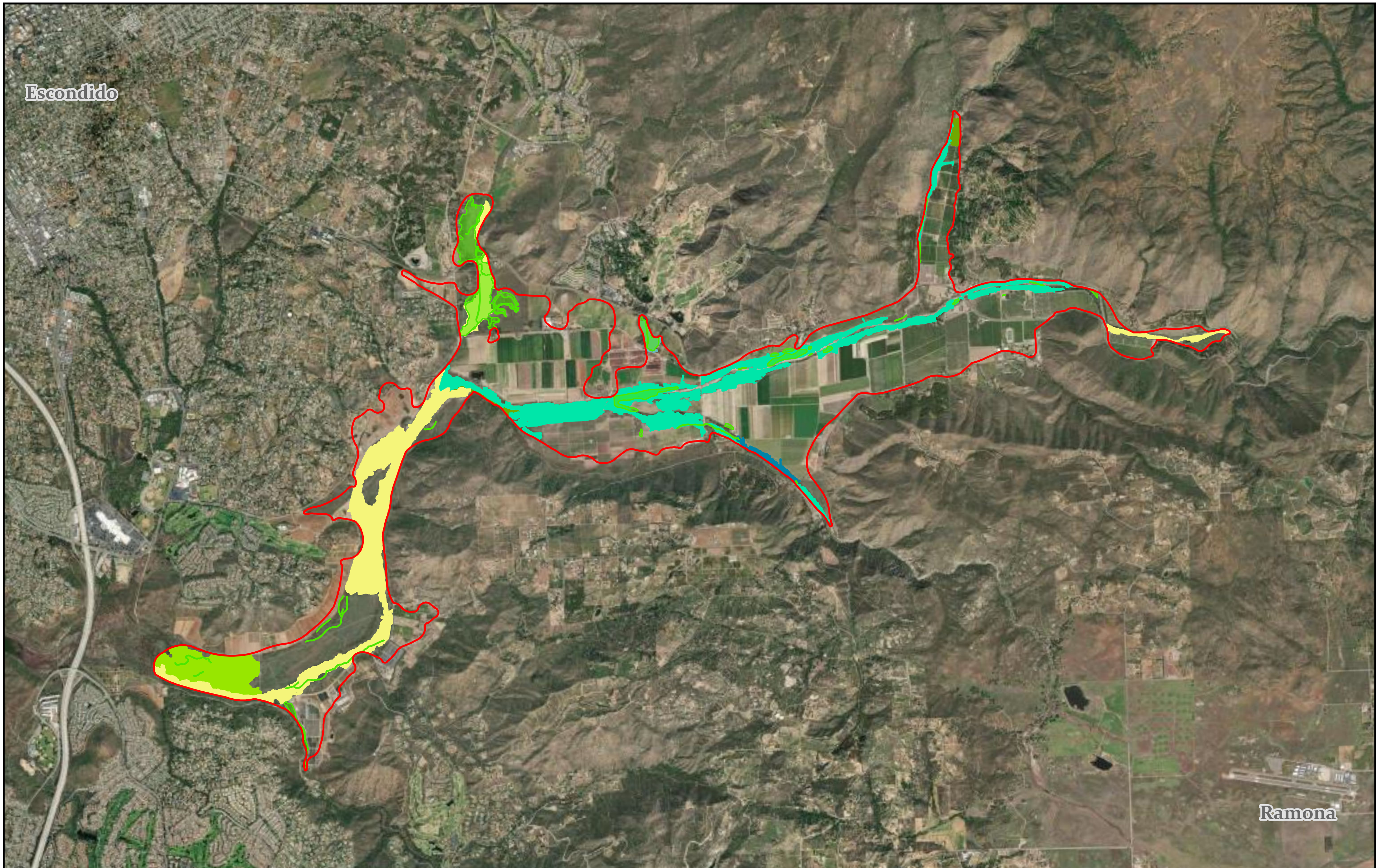
0 1 2 4 Miles
1 inch = 4 miles

N

SD Public Utilities

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023



Natural Communities Commonly Associated with Groundwater

San Pasqual Valley GSP
San Diego Public Utilities

San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- NCCAG Wetland

NCCAG Vegetation

- Coast Live Oak
- Riparian Mixed Hardwood
- Riparian Mixed Shrub
- Riversidean Alluvial Scrub
- Tule - Cattail
- Willow (Shrub)

1 inch = 1 mile

0 0.25 0.5 1 Mile

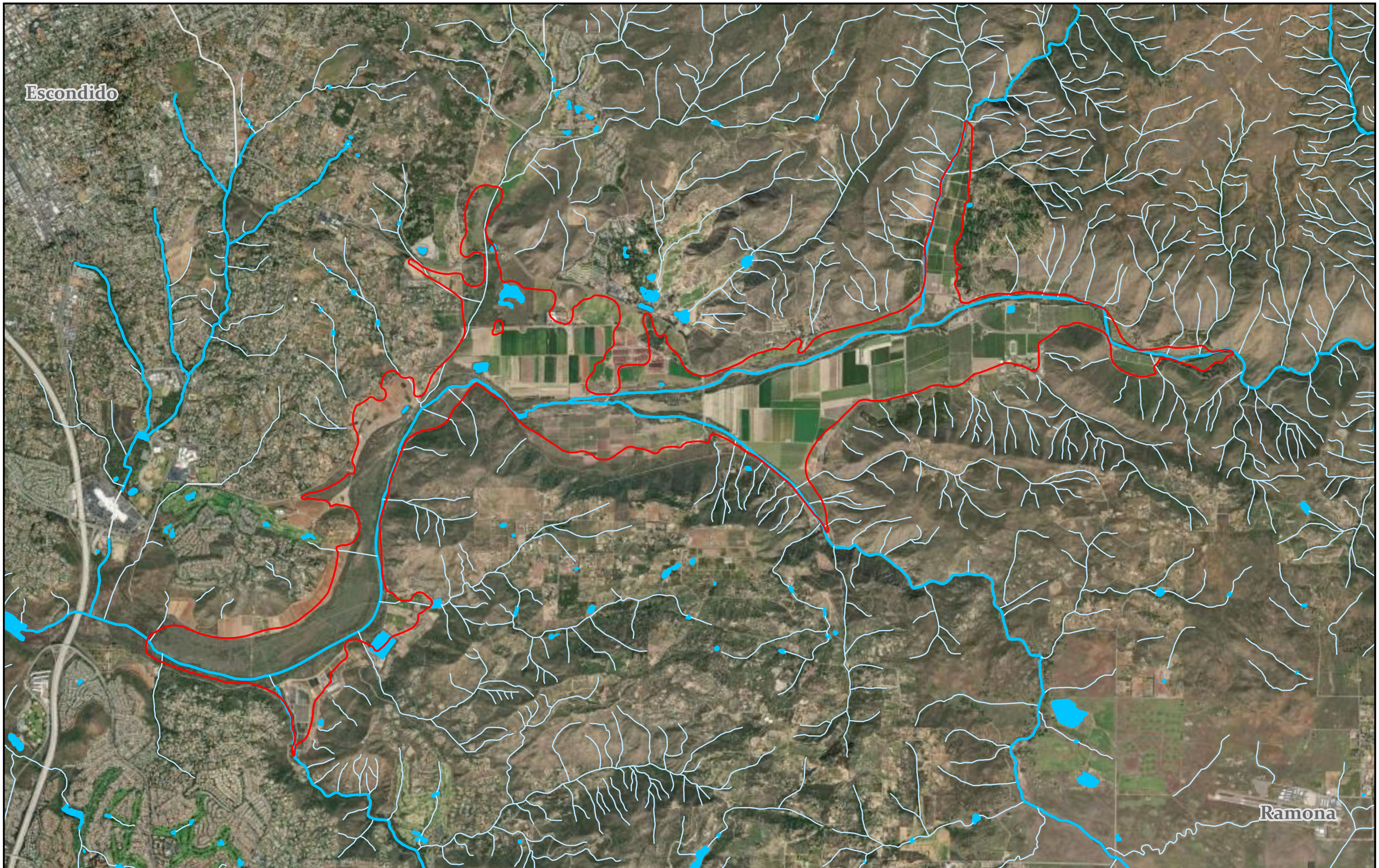
N

SD Public Utilities

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: Esri World Imagery; CDWR/CDFW/TNC NCCAG Dataset**



NHD Streams and Other Surface Waterbodies

San Pasqual Valley GSP
San Diego Public Utilities
San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- NHD Waterbody

NHD Stream
- Intermittent
- Ephemeral
- Connector

SD Public Utilities

1 inch = 1 mile

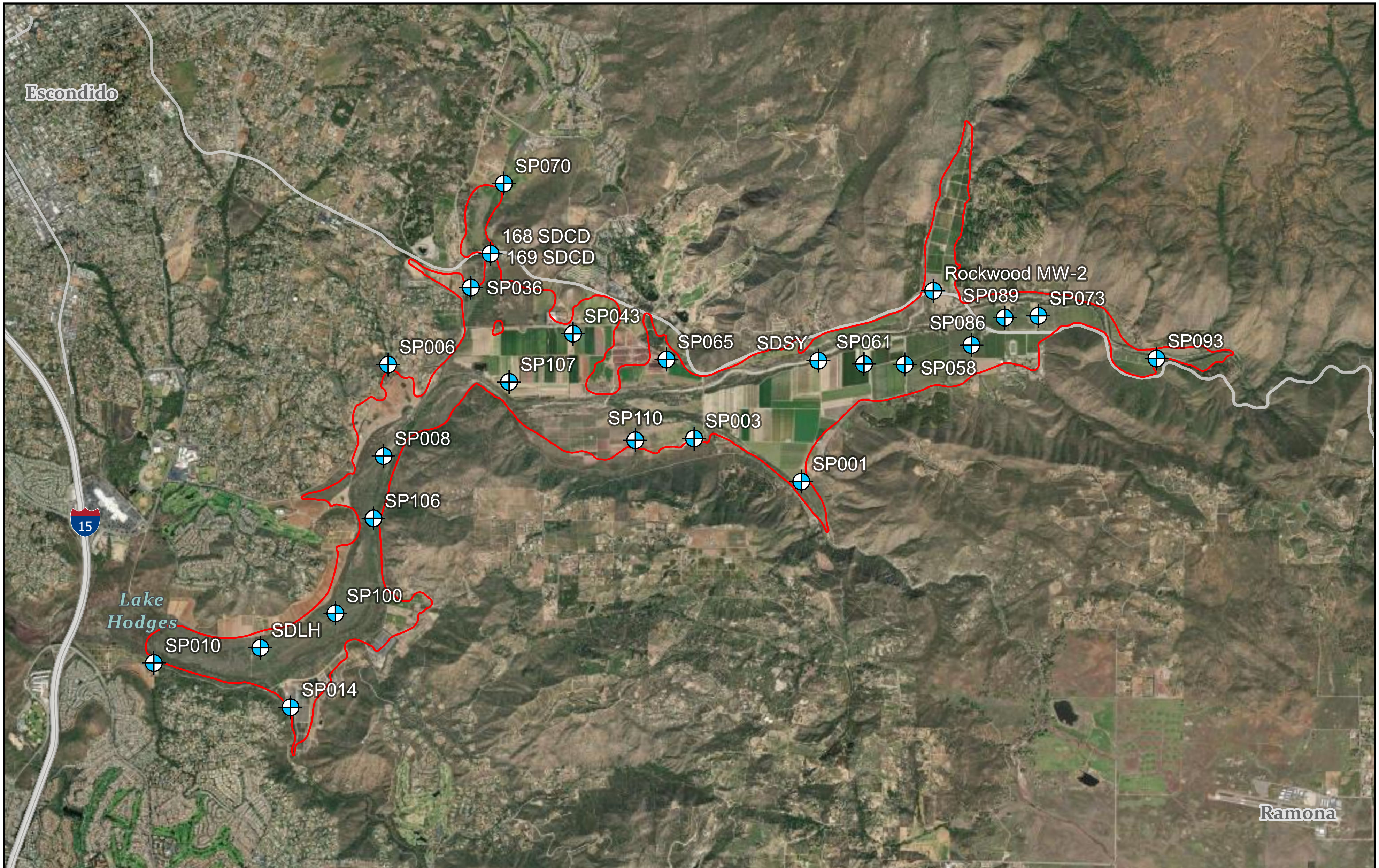
0 0.25 0.5 1 Mile

N

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: Esri World Imagery; USGS National Hydrography Dataset**



Monitoring Wells

San Pasqual Valley GSP
San Diego Public Utilities

San Diego County, California

Legend

San Pasqual Valley Groundwater Basin

Monitoring Wells

SD Public Utilities

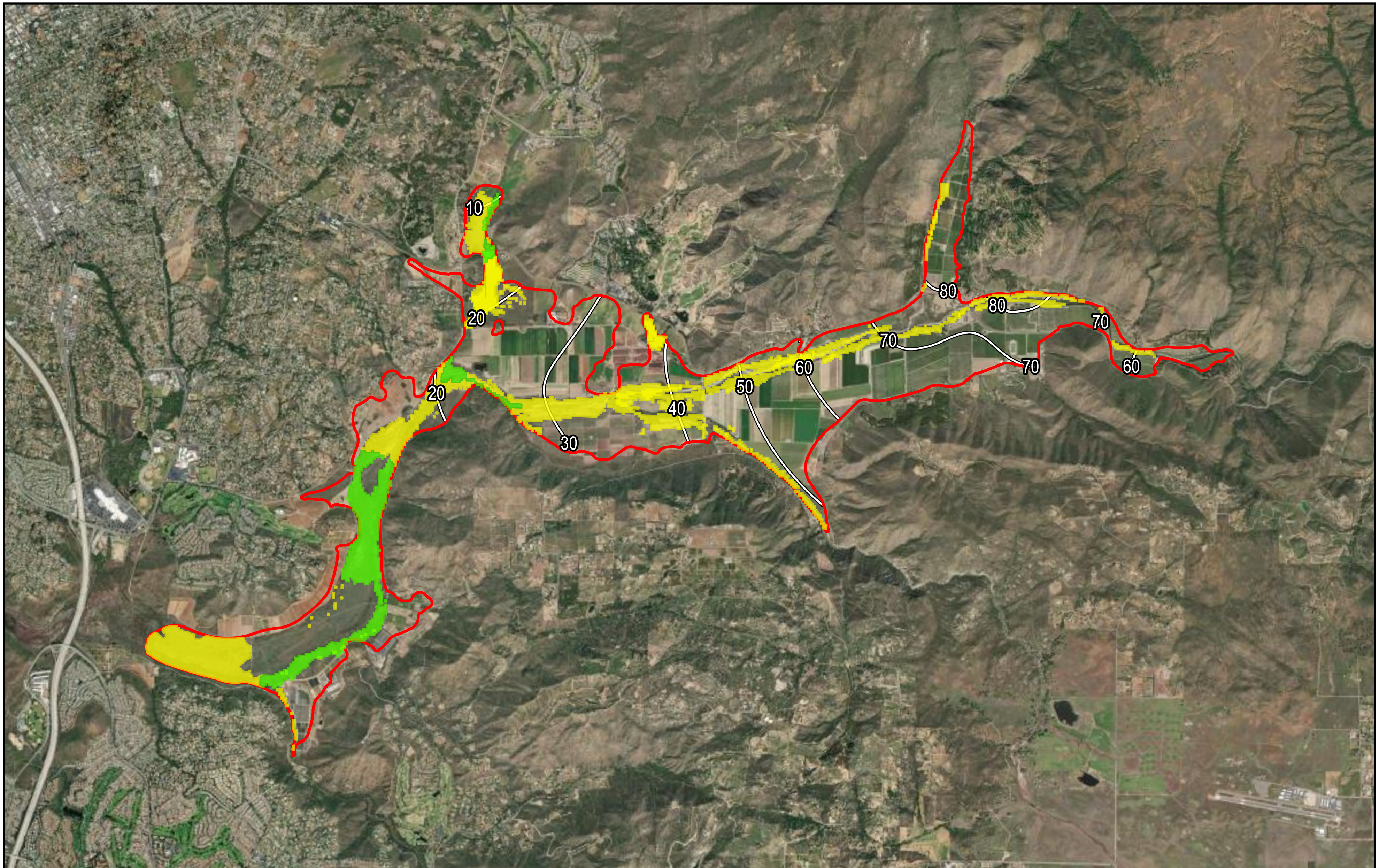
N

1 inch = 1 mile

0 0.25 0.5 1 Mile

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023



Average Groundwater Conditions 2013 - 2022

San Pasqual Valley GSP
San Diego Public Utilities

San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- GDE
- Potential GDE
- 10-ft Average Groundwater Contour

1 inch = 1 mile

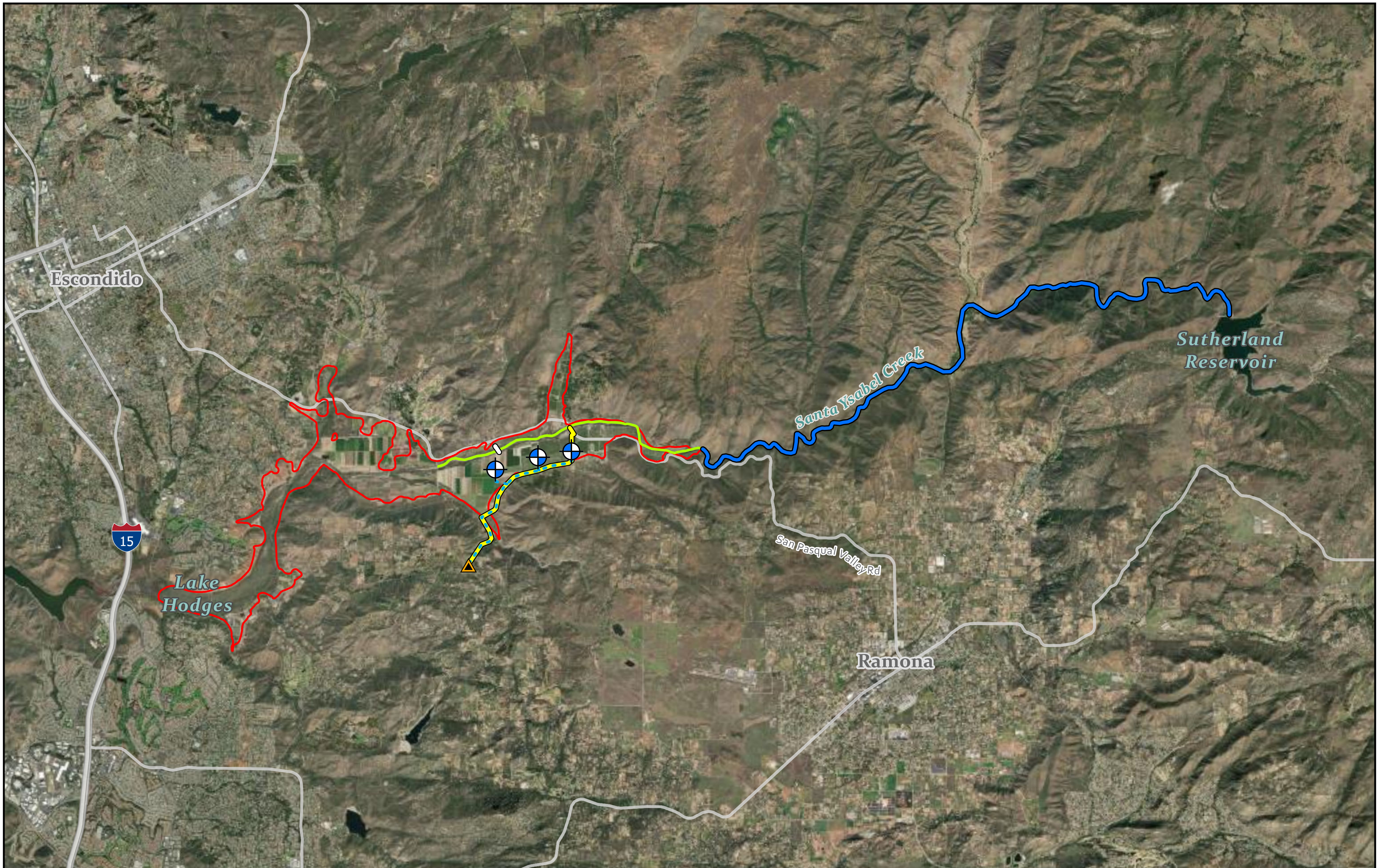
0 0.25 0.5 1 Mile

N

SD Public Utilities

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023



Recharge Strategies

San Pasqual Valley GSP
San Diego Public Utilities

San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- Target Recharge Area
- Injection Well Pipeline
- Pipeline Diversion Point (Robb Zone)
- Strategy 1B - Inflatable Rubber Dam
- Strategy 2A - Controlled Release From Sutherland Reservoir
- Strategy 3A - Ramona MWD Pipeline Delivery
- Strategy 3D - Ramona MWD Deliveries via Injection Wells

SD Public Utilities

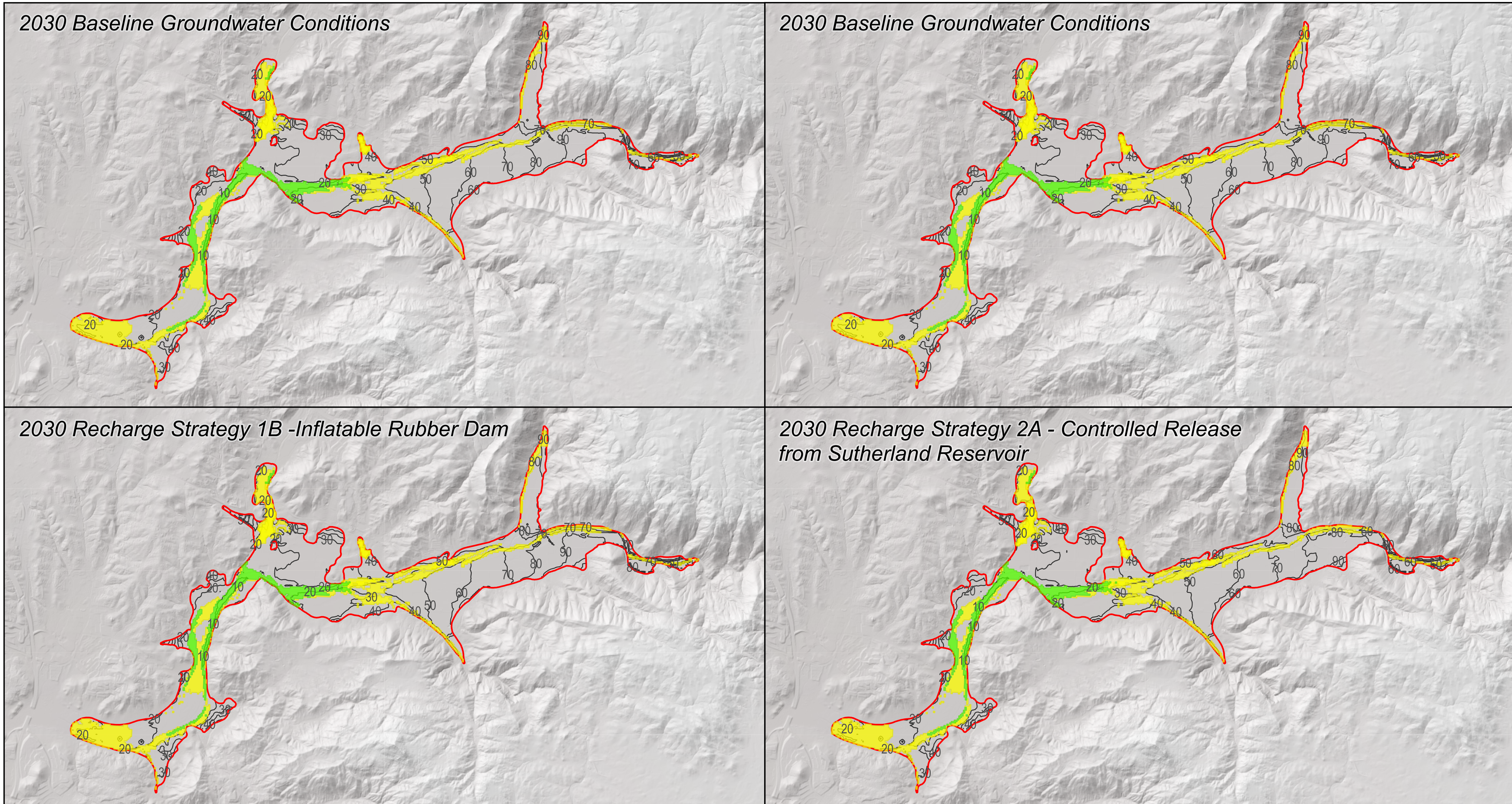
N

0 0.5 1 2 Miles

1 inch = 2 miles

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023



2030 Recharge Strategies 1B and 2A

San Pasqual Valley GSP
San Diego Public Utilities
San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- GDE
- Potential GDE
- 10-ft Groundwater Contour

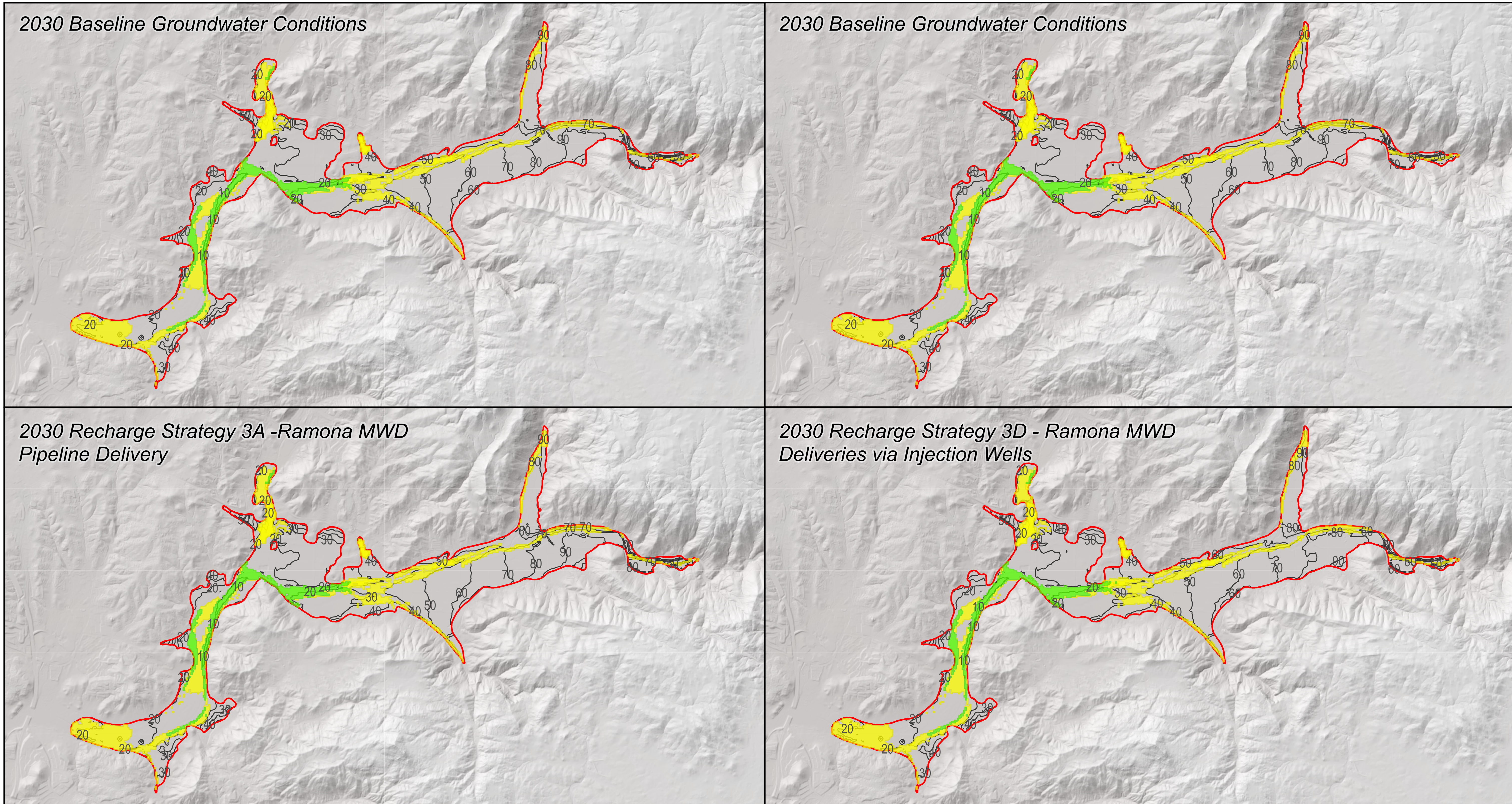
SD Public Utilities

1 inch = 1 mile

0 0.5 1 2 Miles

N

Woodard & Curran
Project #: 0011197.00
Map Created: July 2023



2030 Recharge Strategies 3A and 3D

San Pasqual Valley GSP
San Diego Public Utilities
San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- GDE
- Potential GDE
- 10-ft Groundwater Contour

1 inch = 1 mile

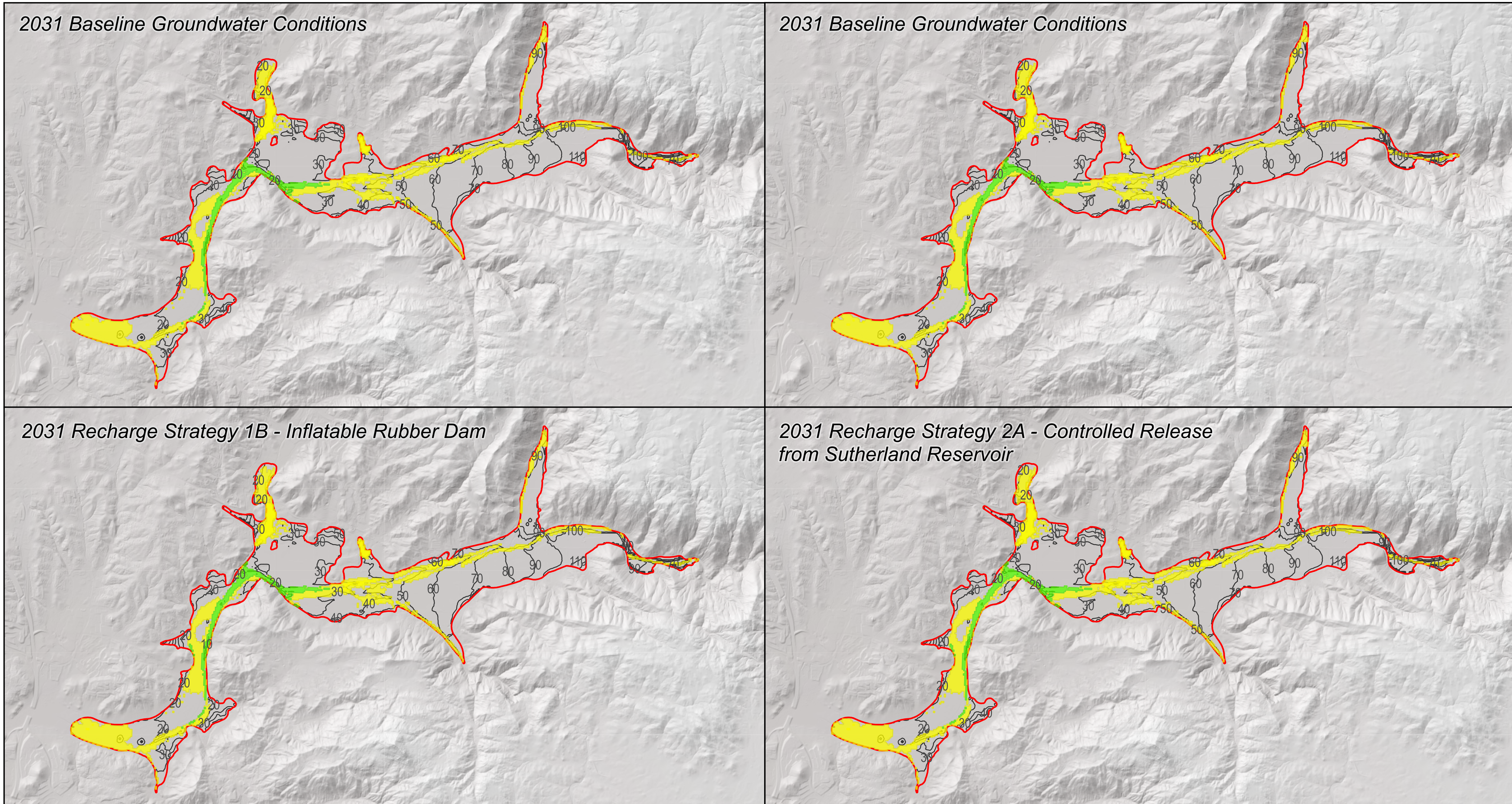
0 0.5 1 2 Miles

N

SD Public Utilities

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023



2031 Recharge Strategies 1B and 2A

San Pasqual Valley GSP

San Diego Public Utilities

San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- GDE
- Potential GDE
- 10-ft Groundwater Contour

1 inch = 1 mile

0 0.5 1 2 Miles

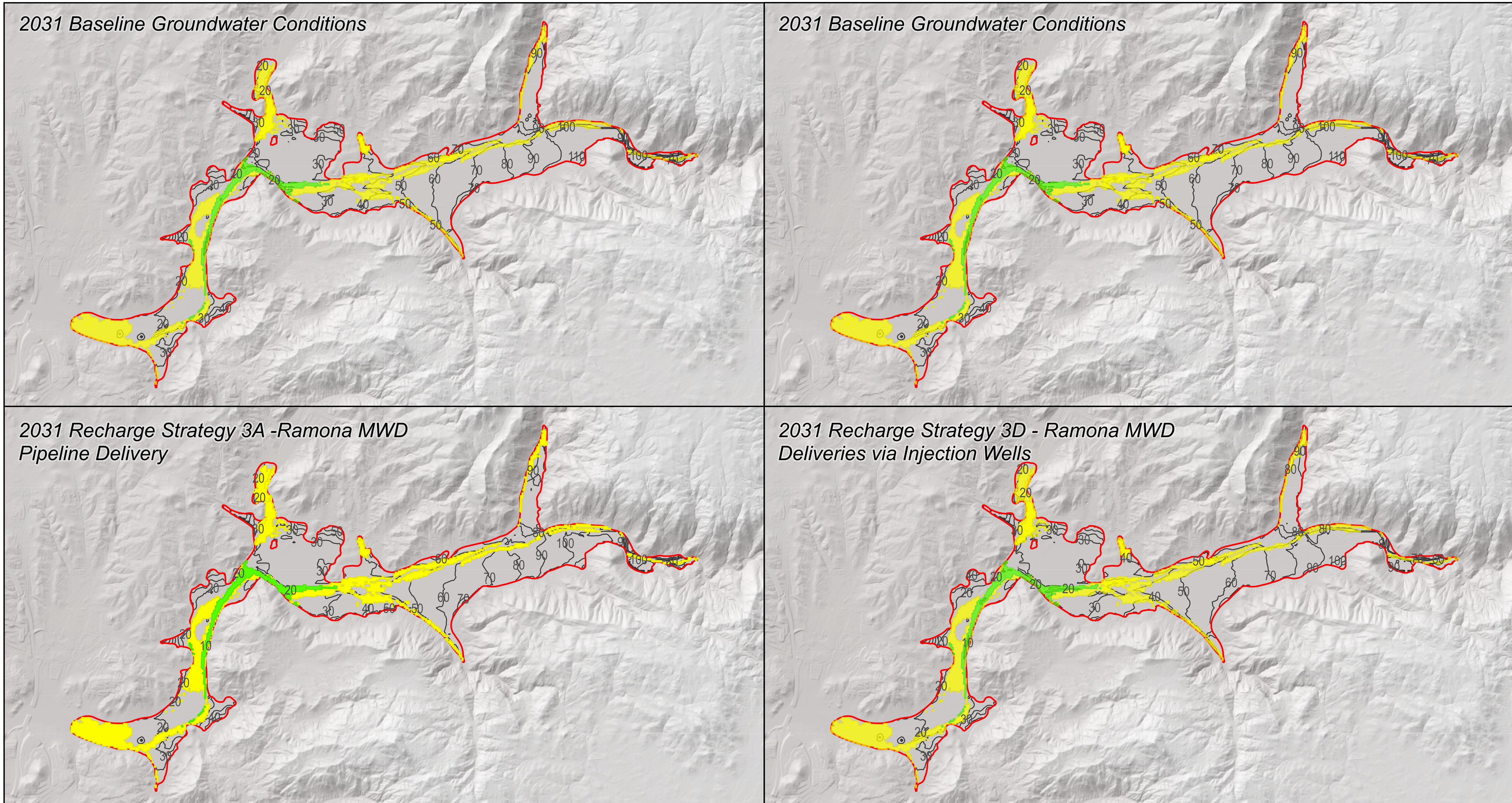
N

SD Public Utilities

Woodard & Curran

Project #: 0011197.00

Map Created: July 2023



2031 Recharge Strategies 3A and 3D

San Pasqual Valley GSP
San Diego Public Utilities
San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- GDE
- Potential GDE
- 10-ft Groundwater Contour

SD Public Utilities

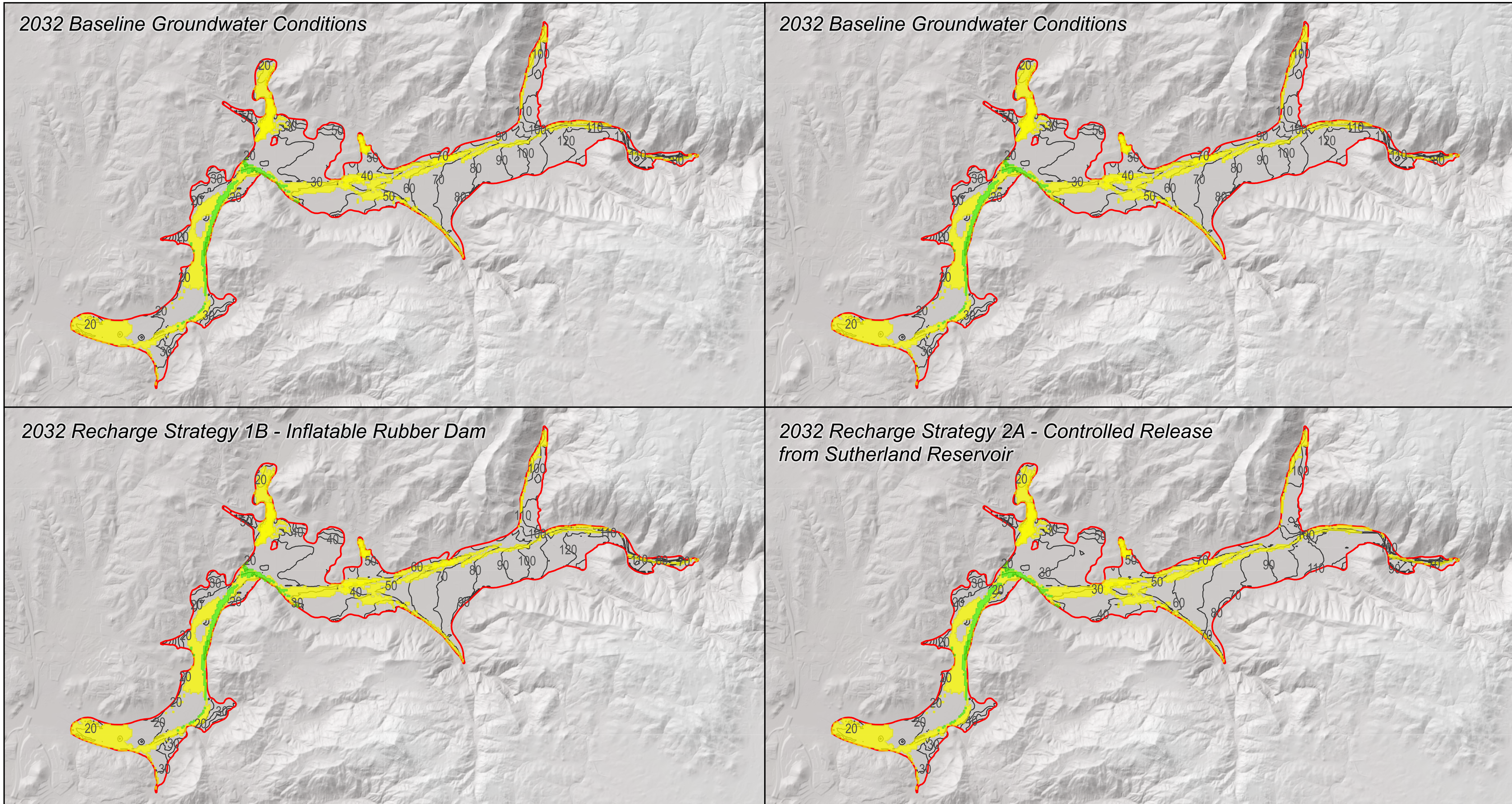
1 inch = 1 mile

0 0.5 1 2 Miles

N

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023



2032 Recharge Strategies 1B and 2A

San Pasqual Valley GSP
San Diego Public Utilities
San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- GDE
- Potential GDE
- 10-ft Groundwater Contour

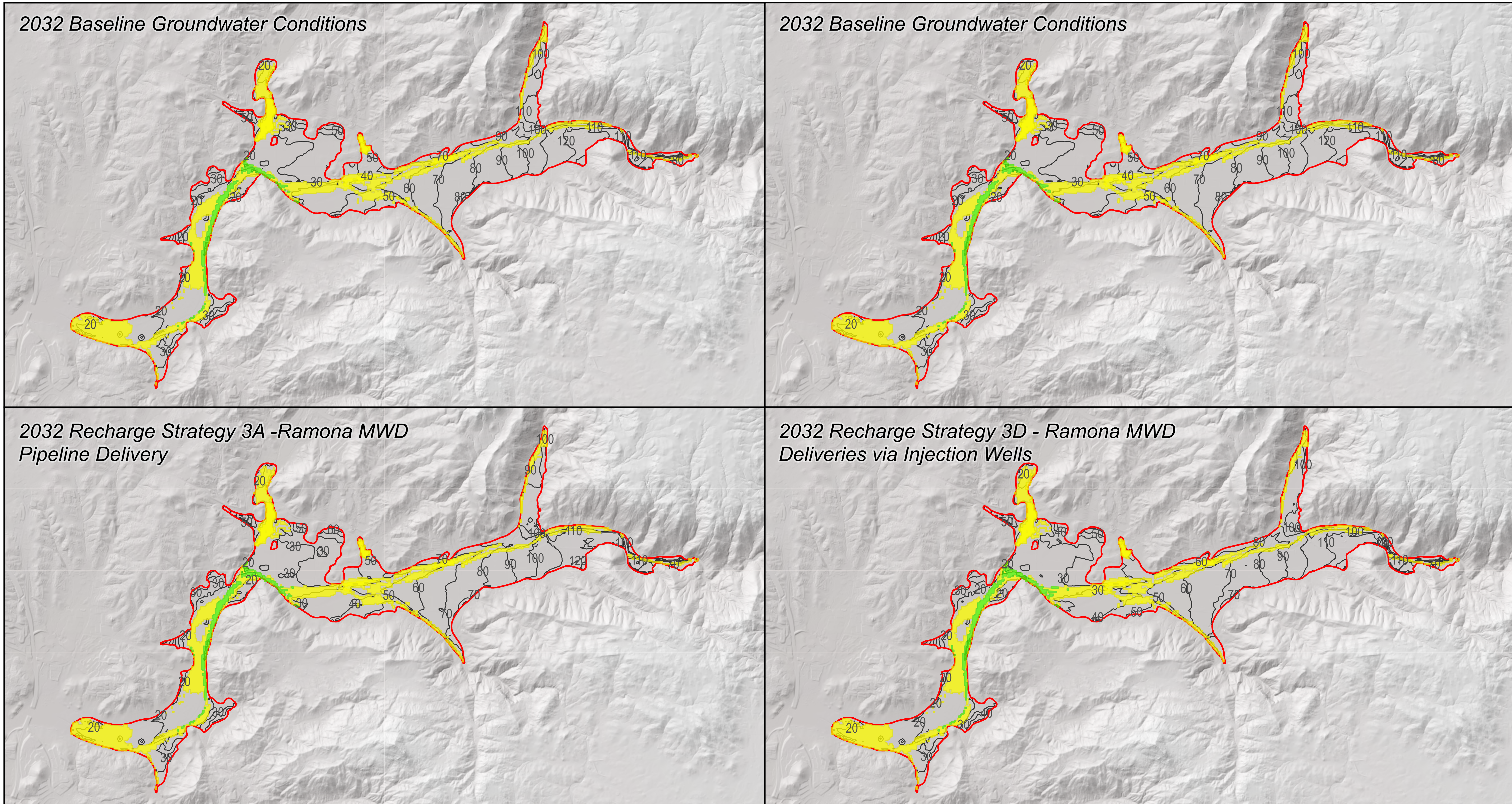
1 inch = 1 mile

0 0.5 1 2 Miles

N

Public Utilities

Woodard & Curran
Project #: 0011197.00
Map Created: July 2023



2032 Recharge Strategies 3A and 3D

San Pasqual Valley GSP
San Diego Public Utilities
San Diego County, California

Legend

- San Pasqual Valley Groundwater Basin
- GDE
- Potential GDE
- 10-ft Groundwater Contour

1 inch = 1 mile

0 0.5 1 2 Miles

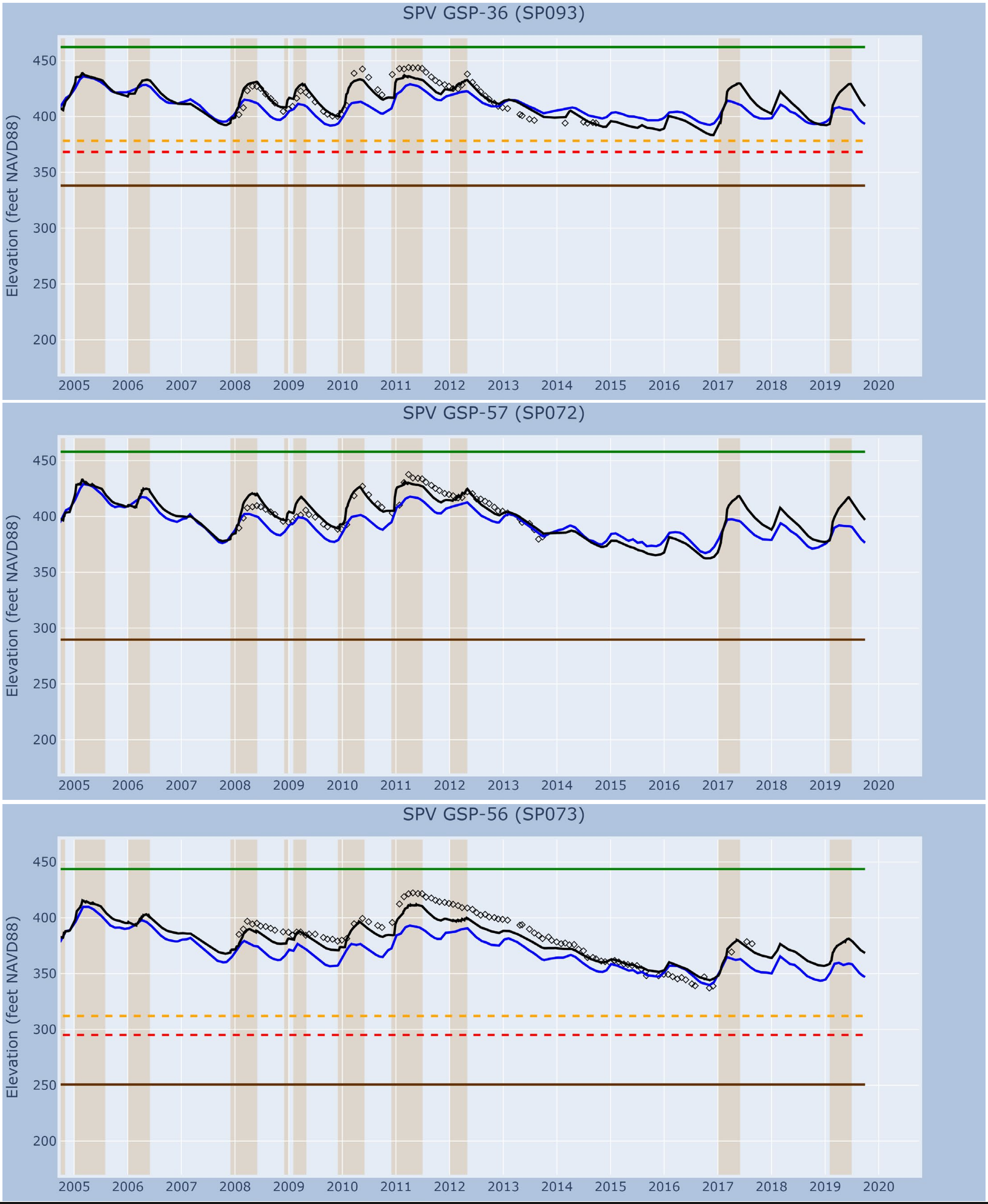
N

SD Public Utilities

Woodard & Curran

Project #: 0011197.00
Map Created: July 2023

Attachment B: Historical Groundwater Hydrographs



Legend

- Ground Surface Elevation (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measured Groundwater Elevation (feet NAVD88)
- SPV GSP Model v1.0 Head (feet NAVD88)
- SPV GSP Model v2.0 Head (feet NAVD88)
- Daily Stress Period in the SPV GSP Model v2.0 (monthly otherwise)

Figure D-1

Modeled Versus Target Groundwater Head Hydrographs

PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

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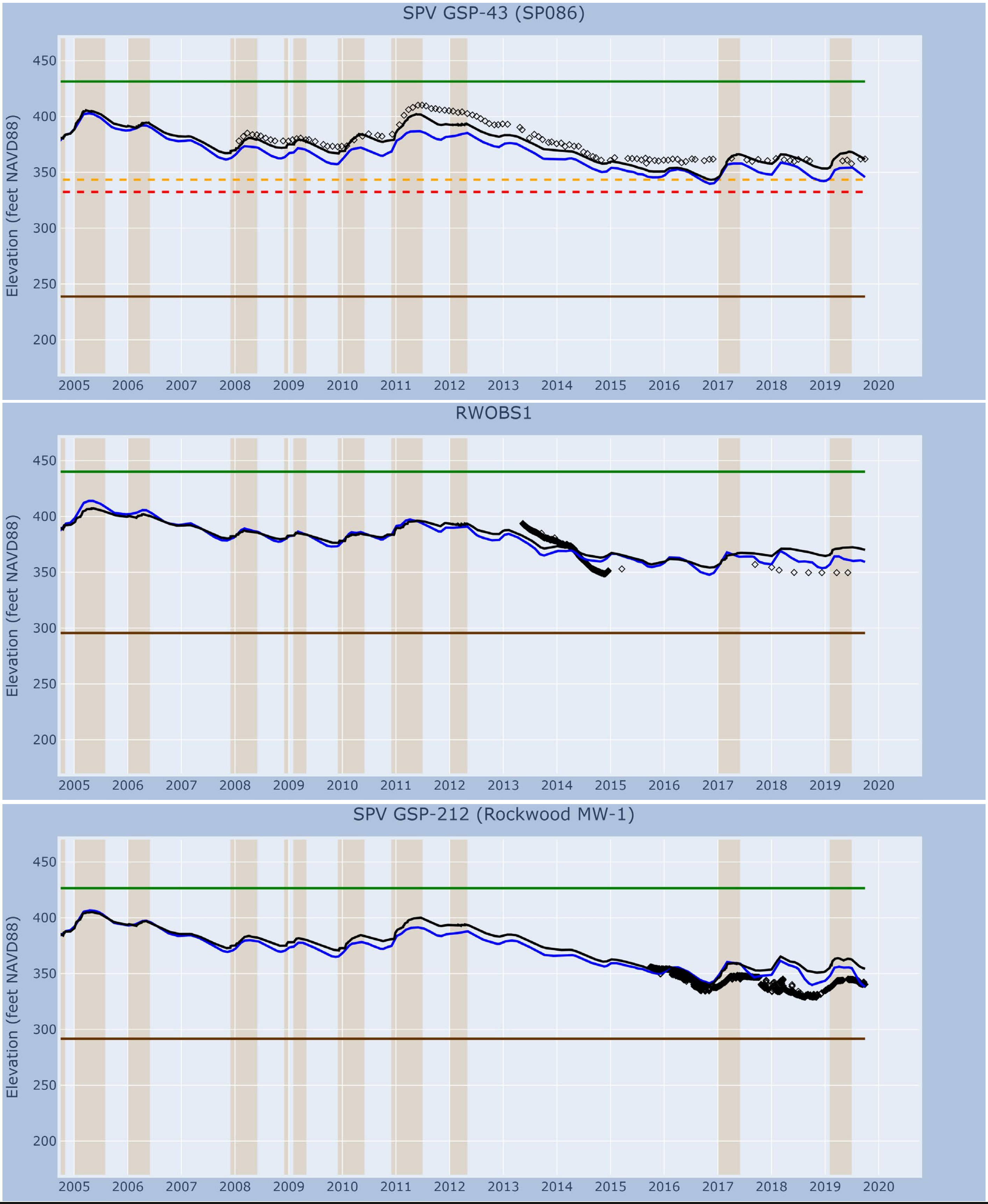

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- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
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- SPV GSP Model v1.0 Head (feet NAVD88)
- SPV GSP Model v2.0 Head (feet NAVD88)
- Daily Stress Period in the SPV GSP Model v2.0 (monthly otherwise)

Figure D-2
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

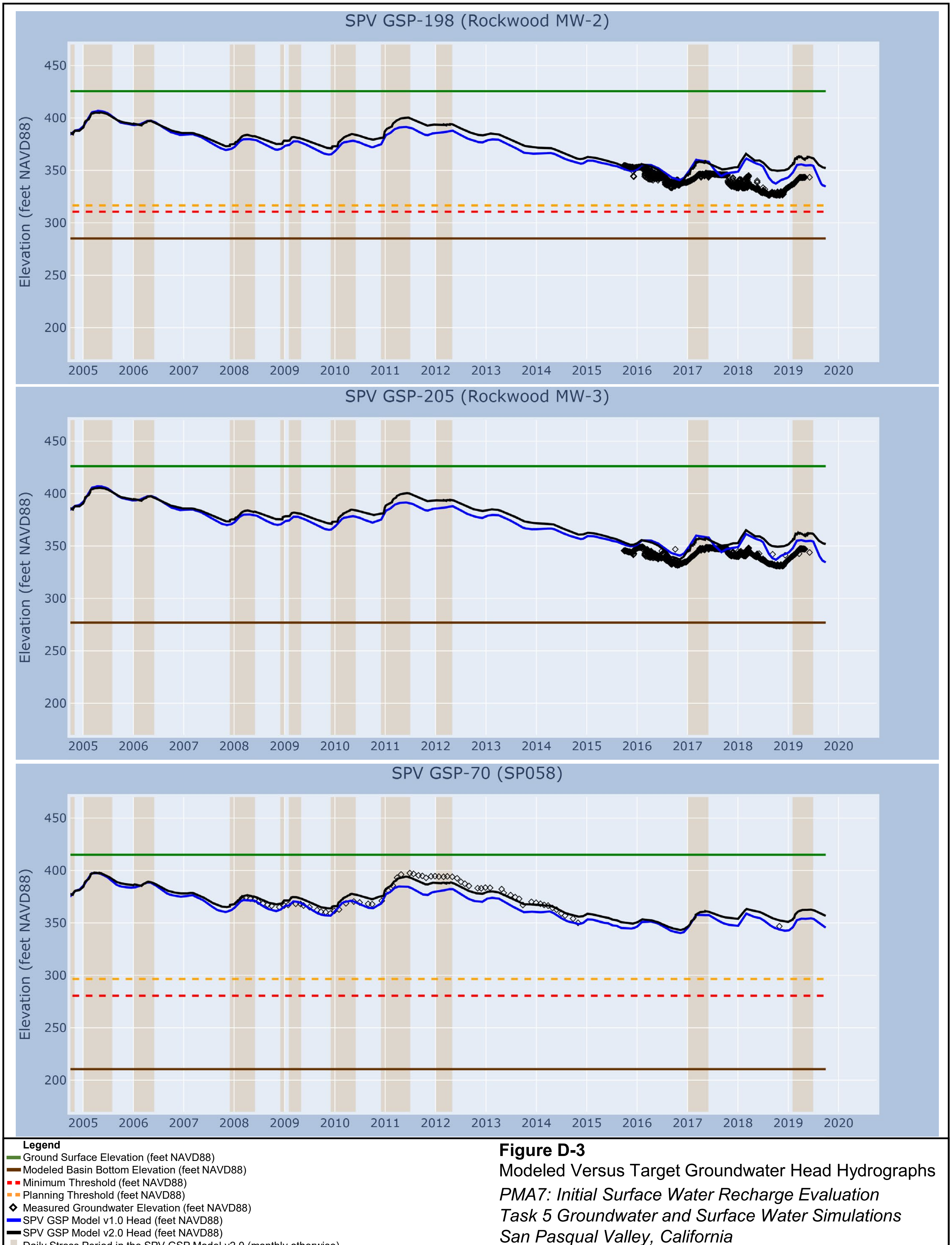

Figure D-3
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

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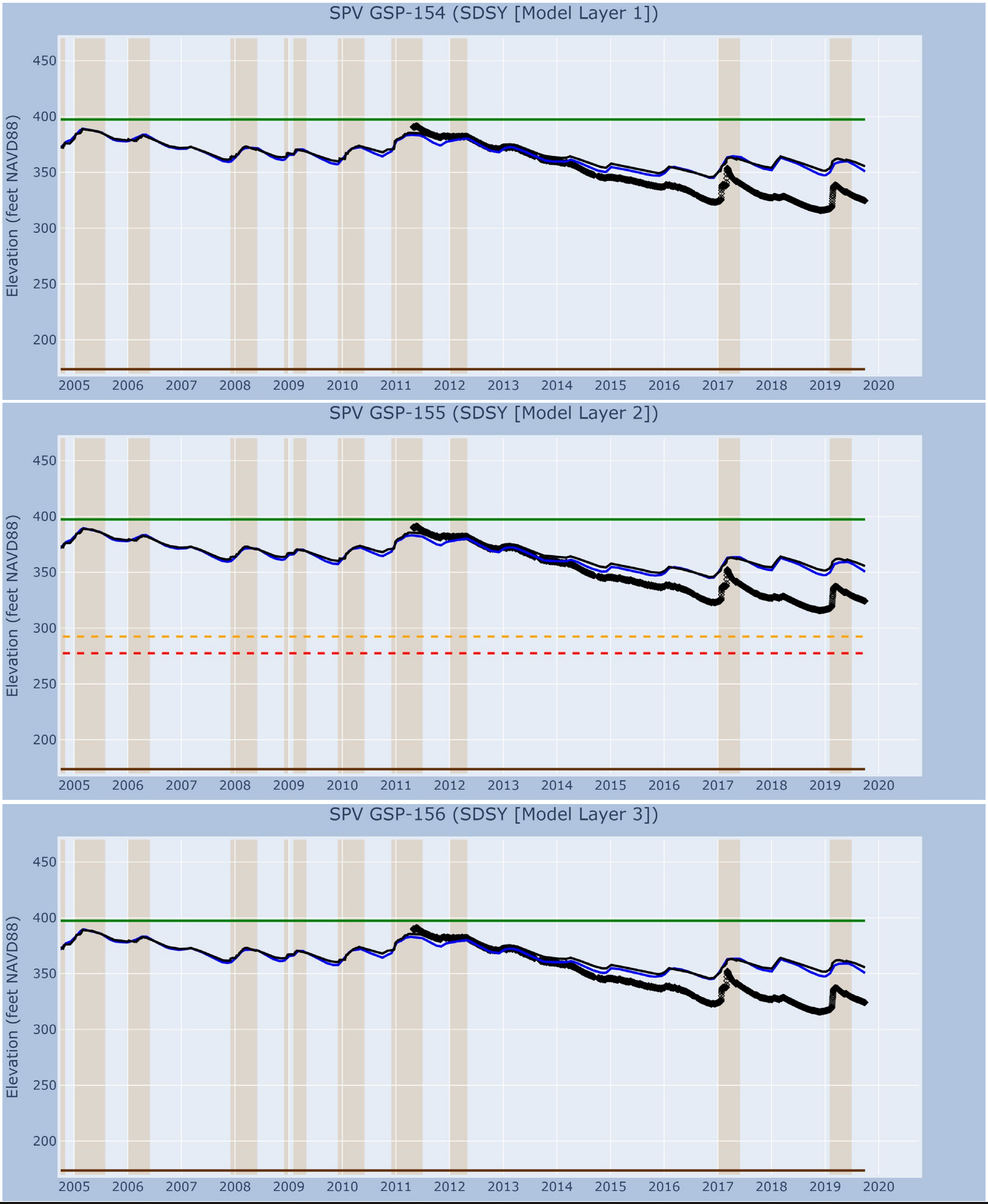

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- Modeled Basin Bottom Elevation (feet NAVD88)
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- Measured Groundwater Elevation (feet NAVD88)
- SPV GSP Model v1.0 Head (feet NAVD88)
- SPV GSP Model v2.0 Head (feet NAVD88)
- Daily Stress Period in the SPV GSP Model v2.0 (monthly otherwise)

Figure D-4
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

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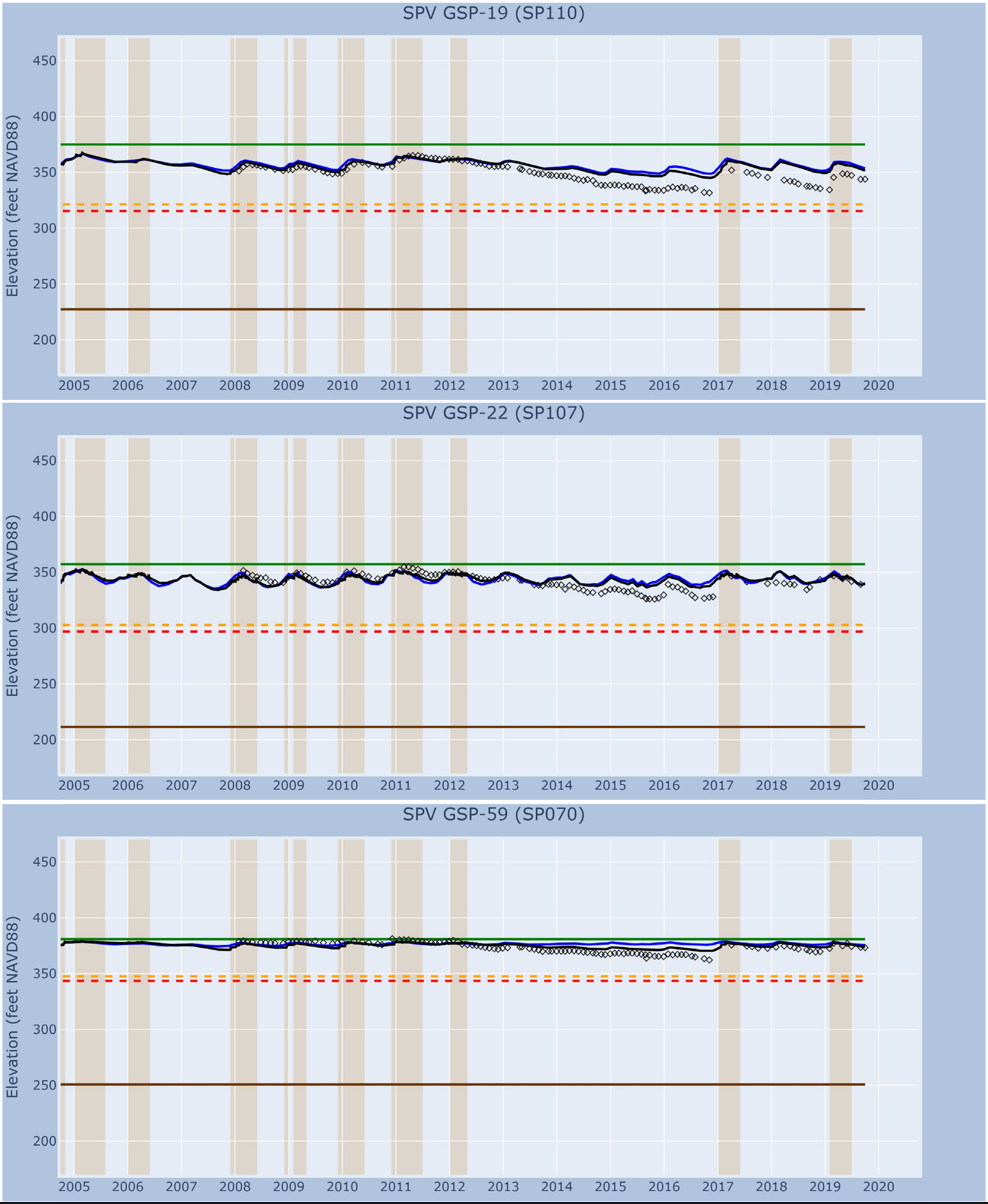

Legend
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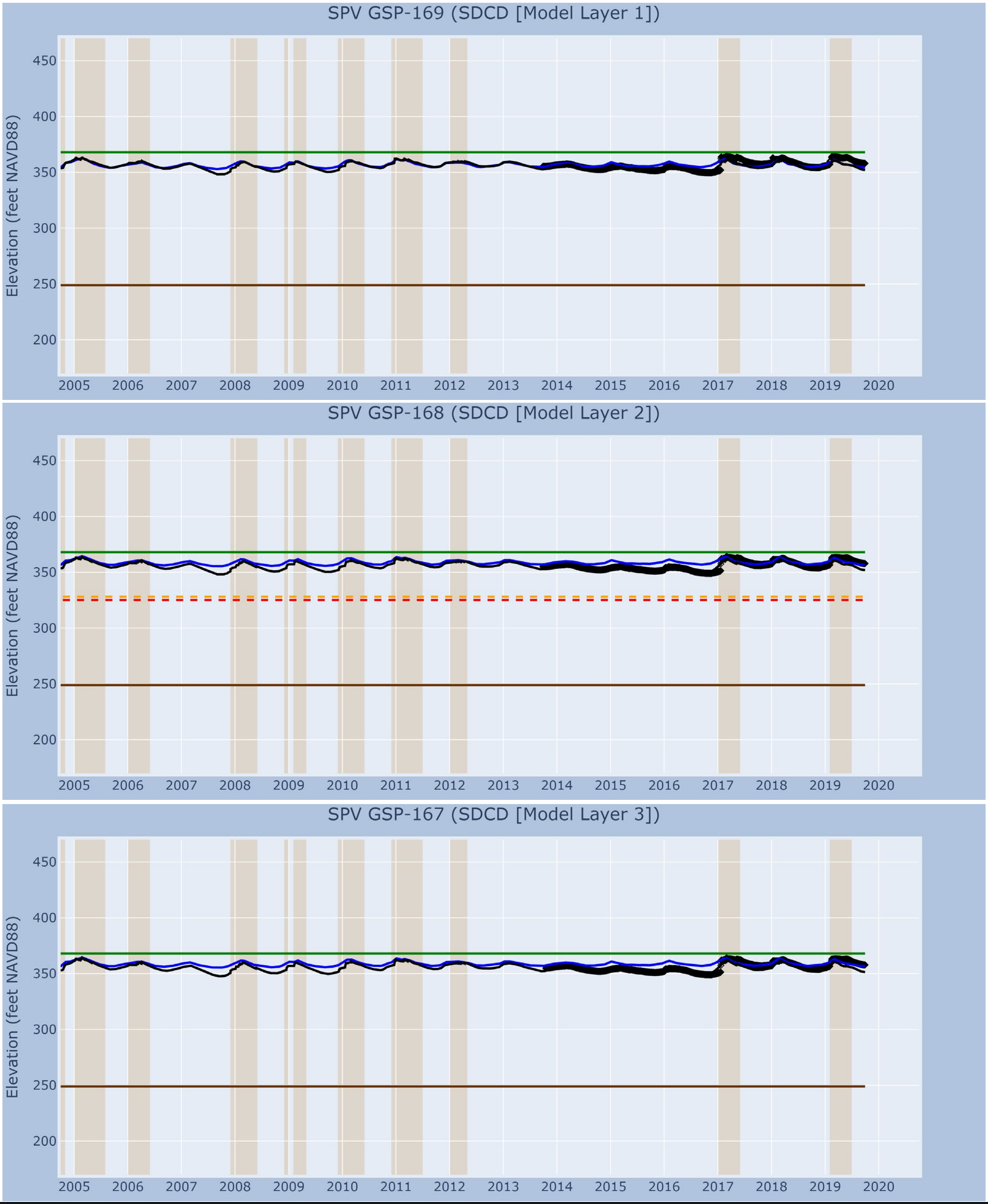
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measured Groundwater Elevation (feet NAVD88)
- SPV GSP Model v1.0 Head (feet NAVD88)
- SPV GSP Model v2.0 Head (feet NAVD88)
- Daily Stress Period in the SPV GSP Model v2.0 (monthly otherwise)

Figure D-5
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California



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- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measured Groundwater Elevation (feet NAVD88)
- SPV GSP Model v1.0 Head (feet NAVD88)
- SPV GSP Model v2.0 Head (feet NAVD88)
- Daily Stress Period in the SPV GSP Model v2.0 (monthly otherwise)

Figure D-6
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs

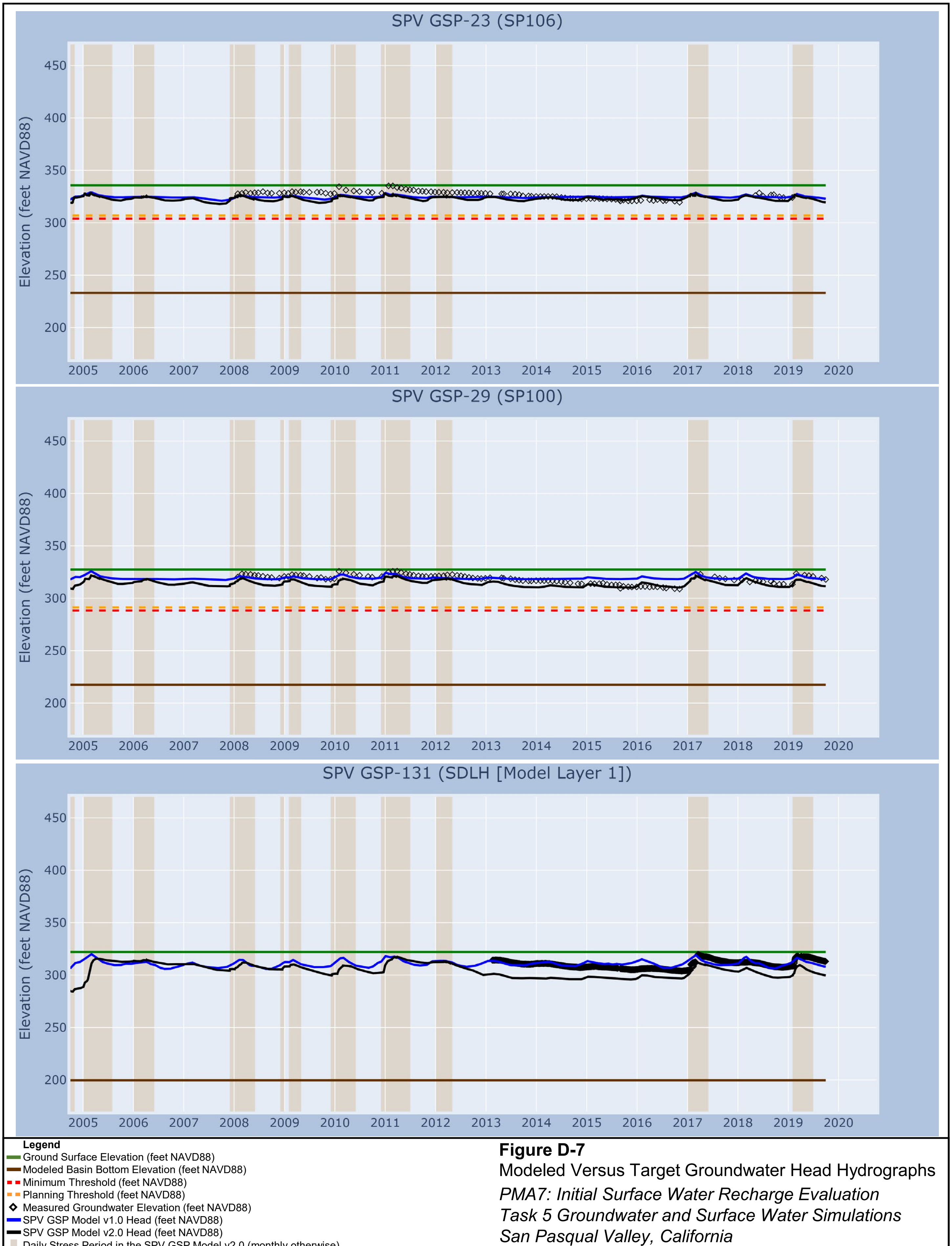
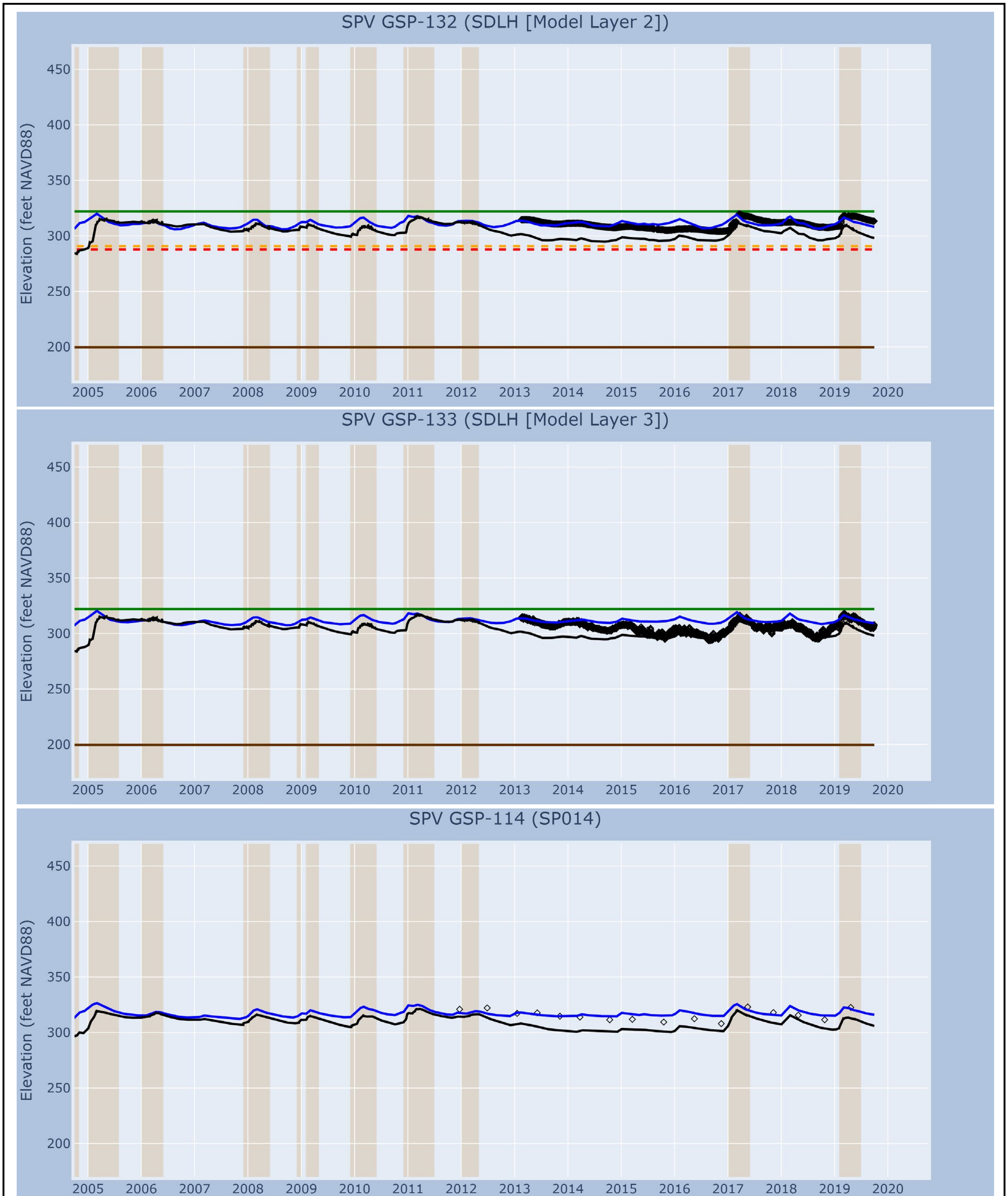


Figure D-7
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

Jacobs



Legend
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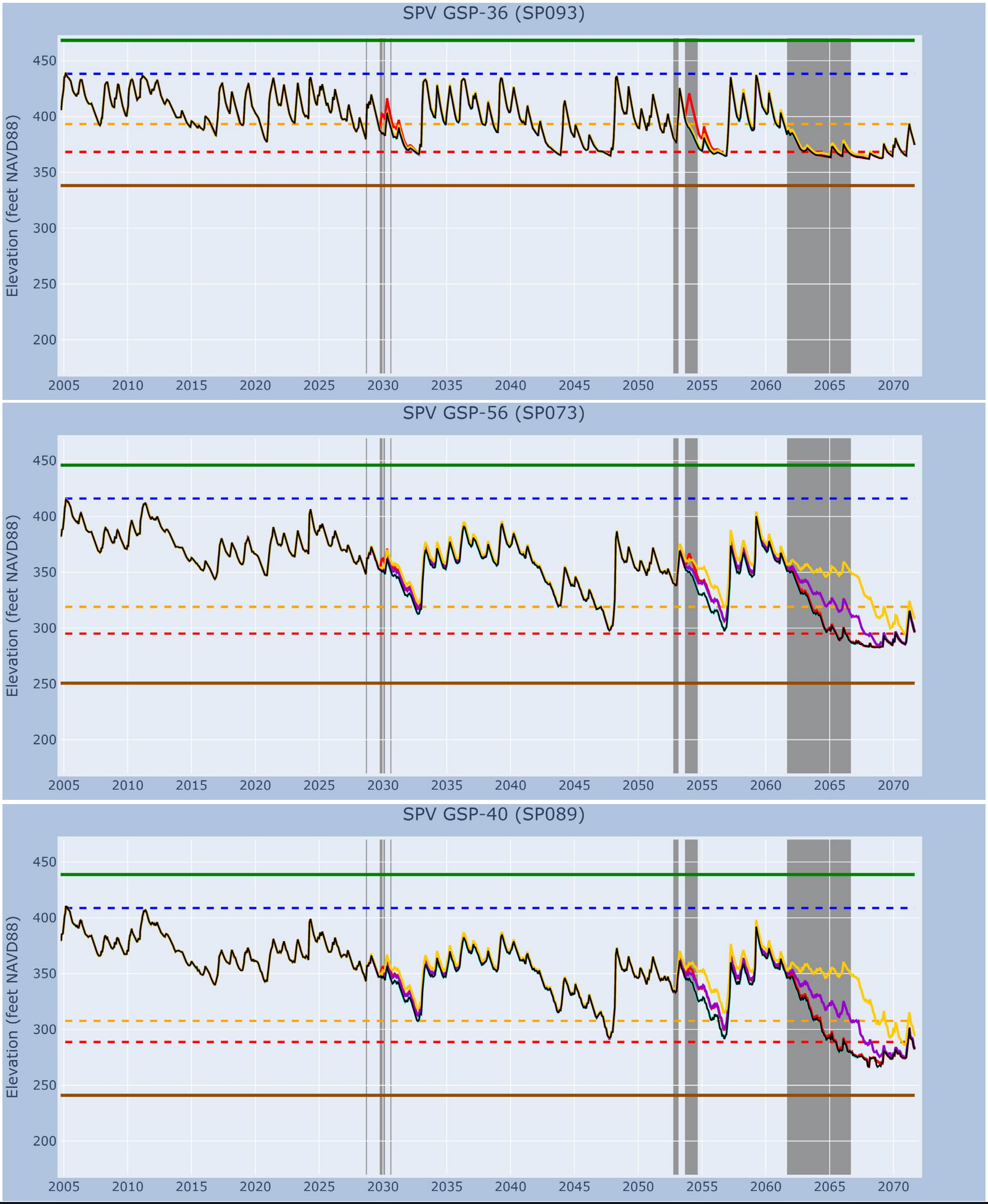
- Daily Stress Period in the SPV GSP Model v2.0 (monthly otherwise)

Figure D-8
Modeled Versus Target Groundwater Head Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater and Surface Water Simulations
San Pasqual Valley, California

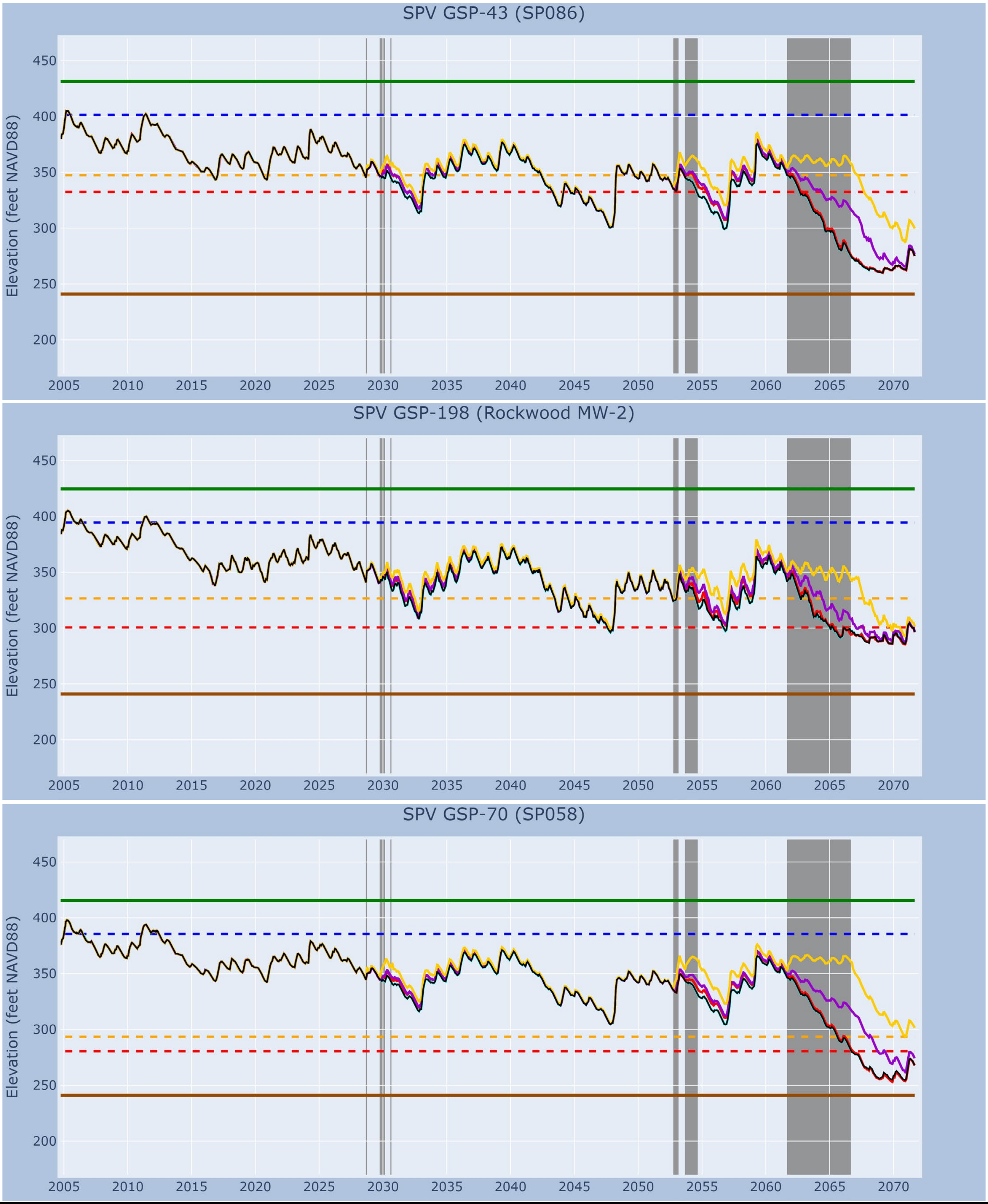
Attachment C: Recharge Strategy Groundwater-Level Hydrographs



Legend
- Ground Surface Elevation (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- 30-feet below ground surface
- Recharge Implementation Timing (Condition 1 & Condition 2 met)
- Baseline Modeled Head (feet NAVD88)
- Strategy 1B Modeled Head (feet NAVD88)
- Strategy 2A Modeled Head (feet NAVD88)
- Strategy 3A Modeled Head (feet NAVD88)
- Strategy 3D Modeled Head (feet NAVD88)

Figure E-1
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

Jacobs



Legend

- Ground Surface Elevation (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
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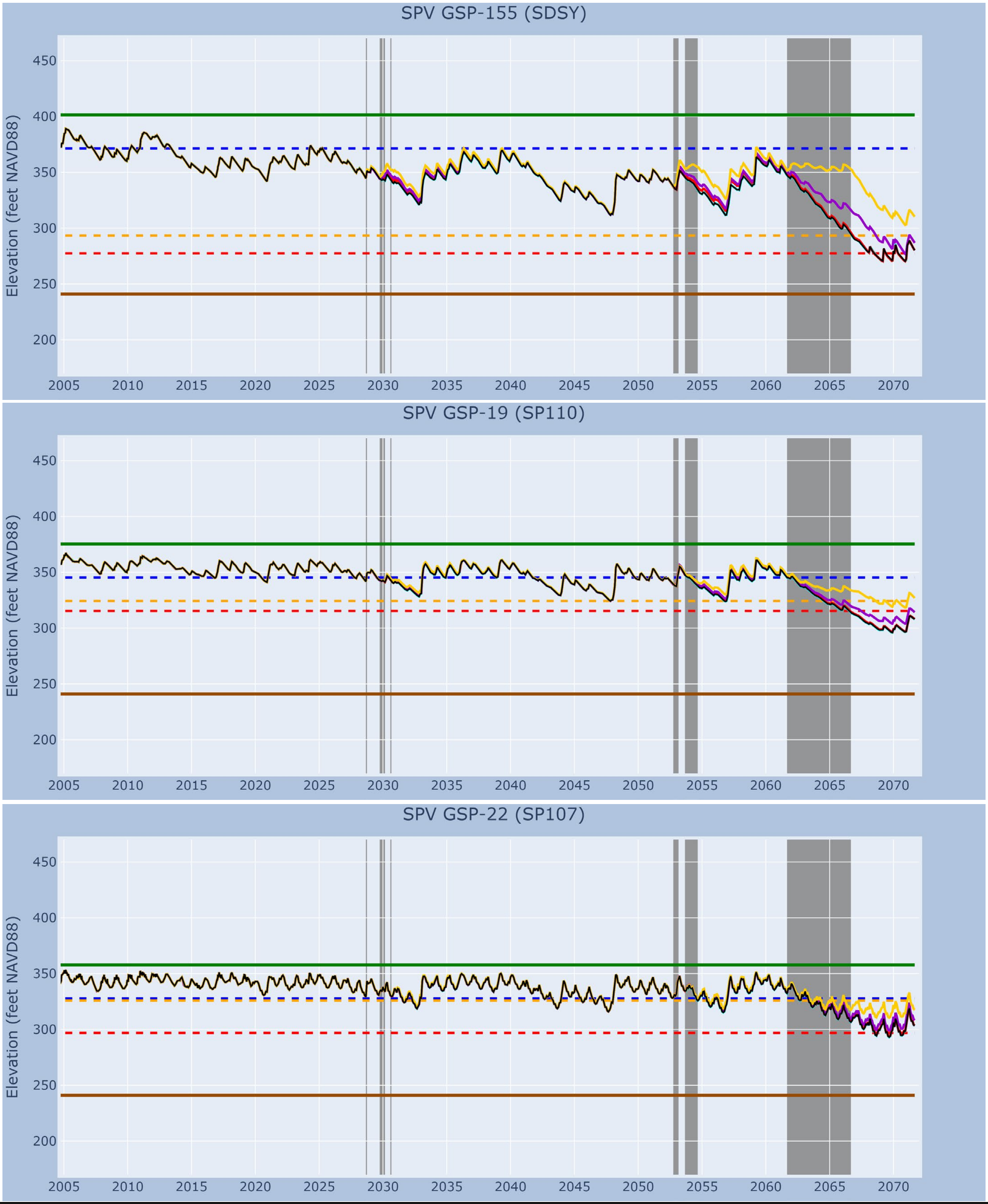
- Strategy 3D Modeled Head (feet NAVD88)

Figure E-2
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

Jacobs



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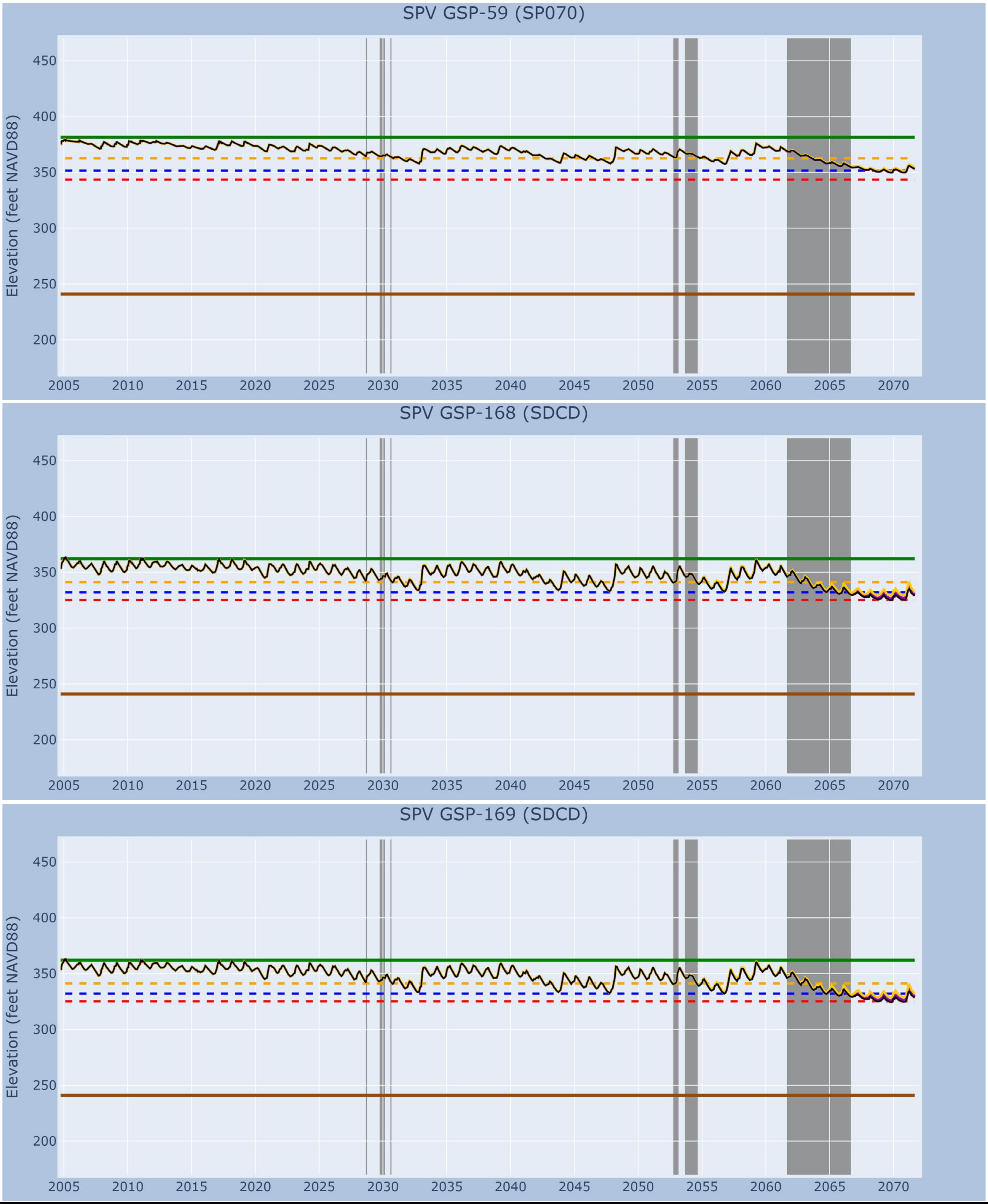
- Strategy 2A Modeled Head (feet NAVD88)
- Strategy 3A Modeled Head (feet NAVD88)
- Strategy 3D Modeled Head (feet NAVD88)

Figure E-3
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

Jacobs



Legend

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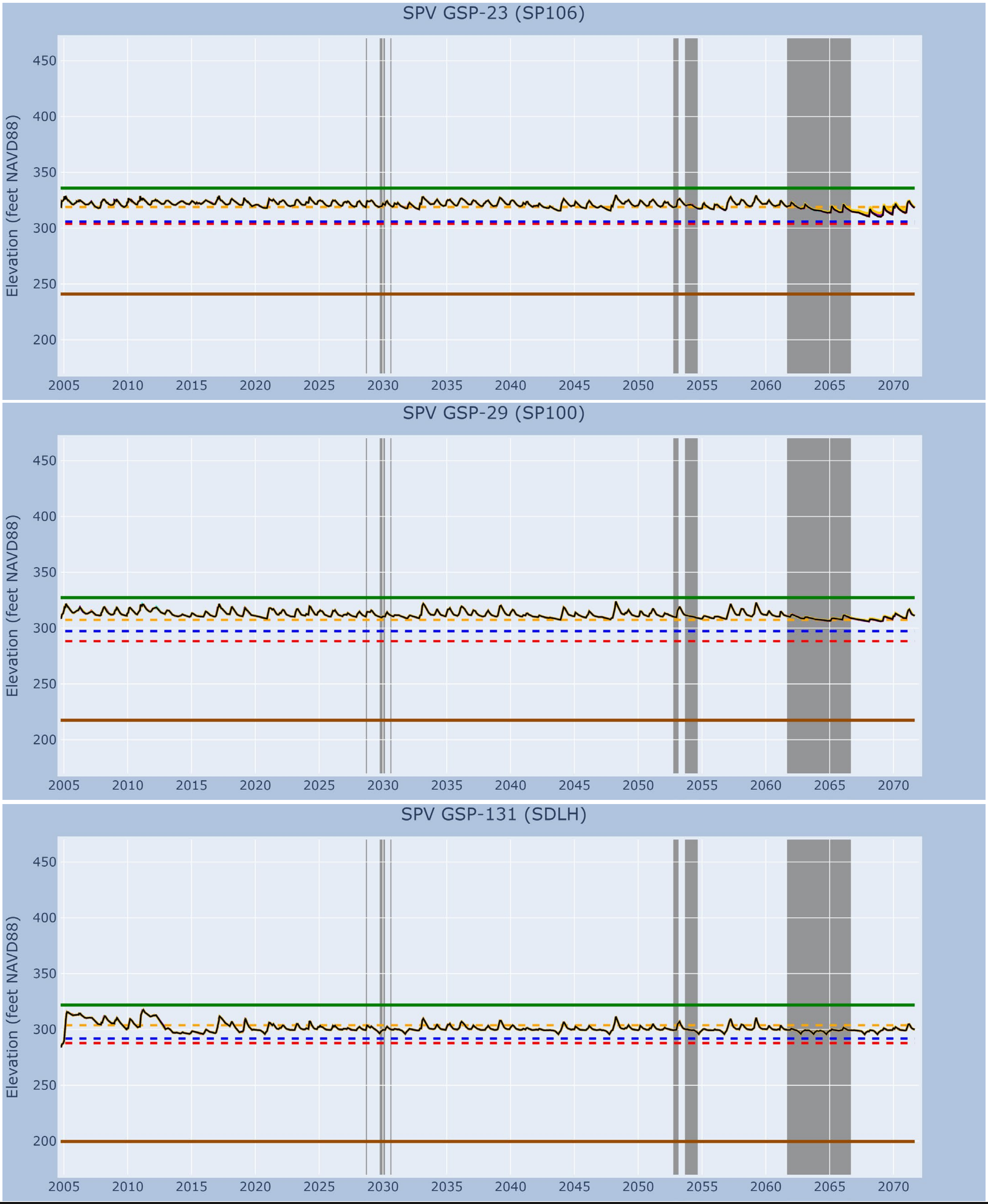
- Strategy 3D Modeled Head (feet NAVD88)

Figure E-4
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

Jacobs



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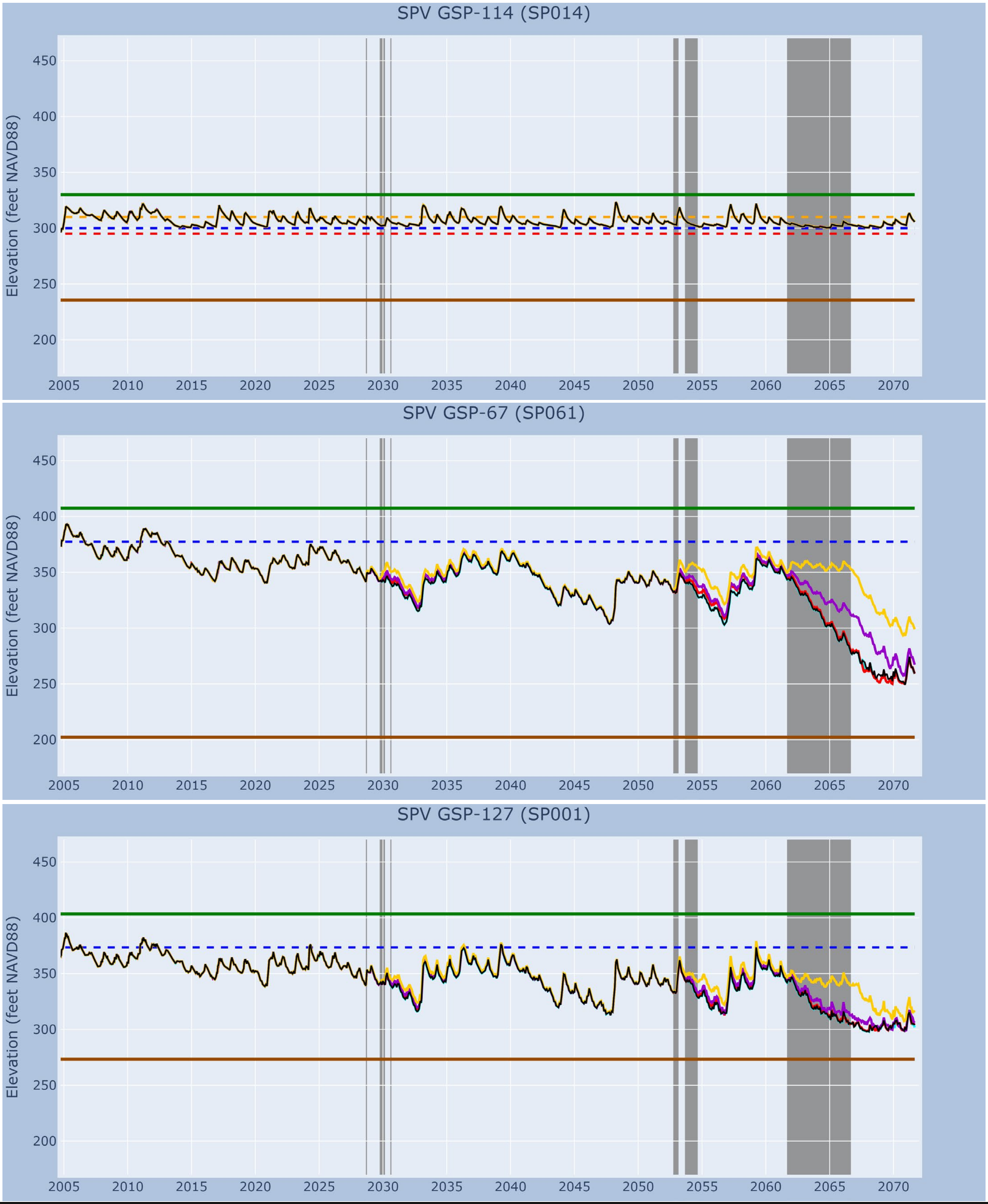
- Strategy 3D Modeled Head (feet NAVD88)

Figure E-5
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

Jacobs



Legend

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- Modeled Basin Bottom Elevation (feet NAVD88)
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- Strategy 3D Modeled Head (feet NAVD88)

Figure E-6
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

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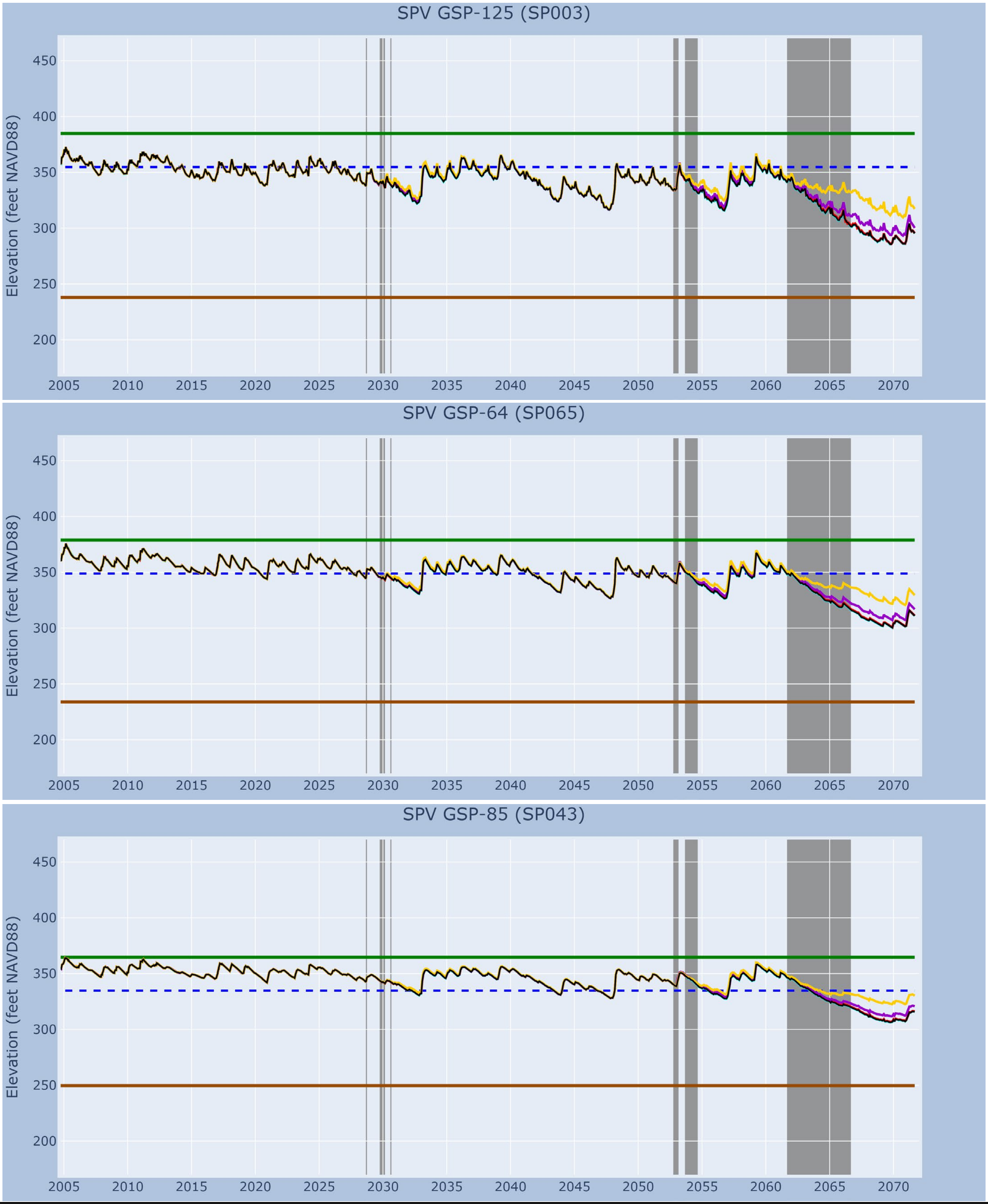

Legend

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- Minimum Threshold (feet NAVD88)
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- Strategy 3D Modeled Head (feet NAVD88)

Figure E-7
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

Jacobs

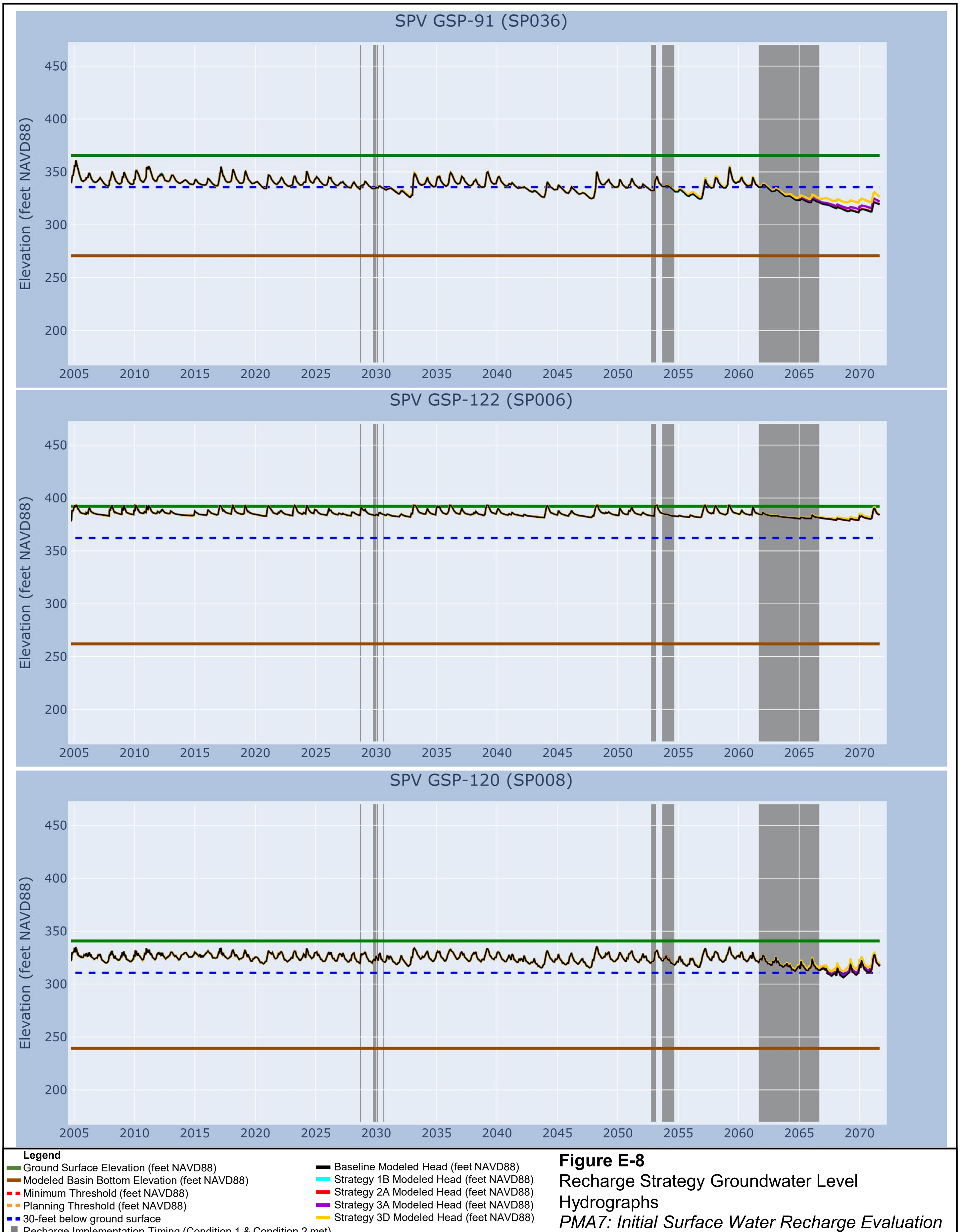
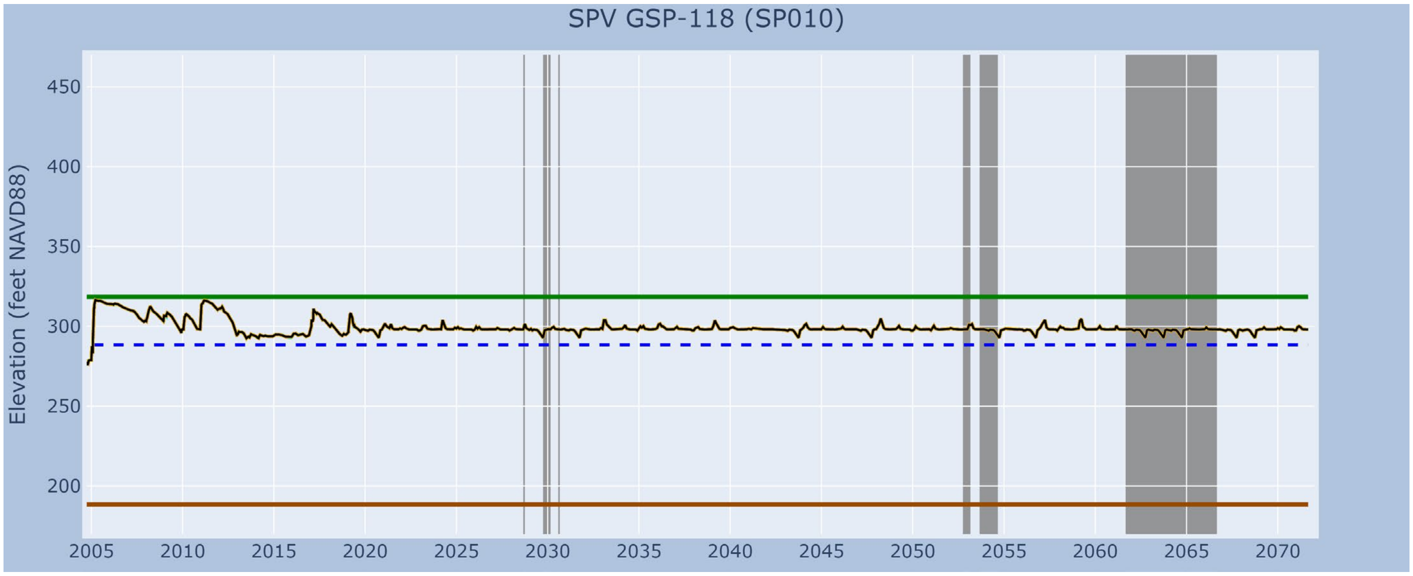


Figure E-8
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

Jacobs



Legend
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- Minimum Threshold (feet NAVD88)
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- Strategy 1B Modeled Head (feet NAVD88)
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- Strategy 3A Modeled Head (feet NAVD88)
- Strategy 3D Modeled Head (feet NAVD88)

Figure E-9
Recharge Strategy Groundwater Level Hydrographs
PMA7: Initial Surface Water Recharge Evaluation
Task 5 Groundwater & Surface Water Simulations
San Pasqual Valley, California

Jacobs

Attachment D: 2020 GDE Study for the San Pasqual Valley Groundwater Basin

Groundwater-Dependent Ecosystems Study for the San Pasqual Valley Groundwater Basin

Prepared for:

SD Public Utilities

Prepared by:

WOODARD & CURRAN

September 2020

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Table of Contents

Tables

Figures

Attachments

Acronyms and Abbreviations

Term	Abbreviation
CDFW	California Department of Fish and Wildlife
CNDDB	California Natural Diversity Database
DWR	California Department of Water Resources
GDE	Groundwater Dependent Ecosystem
GIS	geographic information systems
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	hydrogeologic conceptual model
NCCAG	Natural Communities Commonly Associated with Groundwater
TM	Technical Memorandum
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

SECTION 1. INTRODUCTION AND REGULATORY FRAMEWORK

As part of the California Sustainable Groundwater Management Act (SGMA), Groundwater Sustainability Agencies (GSAs) are required to develop a Groundwater Sustainability Plan (GSP) to help ensure that groundwater is available for long-term, reliable water supply uses. SGMA was signed into law in 2014.

Identifying groundwater-dependent ecosystems (GDEs) is a required component of a GSP. SGMA defines GDEs as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." This Technical Memorandum (TM) specifically focuses on GDEs identified in the San Pasqual Valley Groundwater Basin (Basin).

SECTION 2. SAN PASQUAL VALLEY GROUNDWATER BASIN ECOLOGICAL SETTING

An ecoregion is an area with generally similar ecosystems with similar quantity, quality, and type of environmental resources. Ecoregions are an important geospatial mapping system that are used by many local, state, and federal regulatory agencies and non-governmental organizations as a frame of reference for assessment and management of ecosystems across the United States. In the context of GDEs, it is important to consider the ecoregion where the GDEs are being assessed because biotic and abiotic processes may vary widely between localities.

The Basin is located in Southern California southeast of the City of Escondido, in San Diego County, California. The Basin sits entirely within the Southern California/Northern Baja Coast Level III ecoregion (85). The Southern California/Northern Baja Coast ecoregion is made up of coastal and alluvial plains, marine terraces, and foothills along the coast of Southern California. The ecoregion also extends southward for over 200 miles along the coast of Baja California. Dominant communities of coastal sage shrub and chaparral plants once characterized much of the area; however, large-scale urbanization and agricultural land clearing activities have altered the landscape (Griffith et al. 2016).

Much of the Basin is within the Diegan Coastal Valleys and Hills (85f) Level IV ecoregion. This ecoregion is characterized by terraces and some steep foothills. Numerous canyons exist along with a few wide valleys and the geology primarily consists of sedimentary and granitic rocks. Oceanic influence drives and changes the climate in this ecoregion. Soils are typically hot and dry, and the native vegetative communities include coastal scrub, chaparral, grasslands and meadows, and some small areas of coastal oak woodland.

The westernmost extents of the Basin are located within the Diegan Western Granitic Foothills (85g) Level IV ecoregion. This ecoregion consists of low, somewhat steep, foothills that are part of the lower Peninsular Ranges. Valleys in the ecoregion vary in width. Marine air does not affect the climate as much as in the neighboring ecoregions to the west, however, soil temperature and moisture regimes and vegetative communities are similar. Refer to Figure 1 at the end of this TM for more information about the project location and the Level IV ecoregion.

The Basin is in a wide valley situated between Highland Valley and Starvation Mountain to the south, and Rockwood Canyon to the north. According to U.S. Geological Survey (USGS) 7.5-minute topographic map Escondido, California (1975) and San Pasqual, California (1988) quadrangles, the approximate elevation of the eastern extent of the Basin is approximately 480 feet above mean sea level and the approximate elevation of the western extent of the Basin is 300 feet above mean sea level. Surface drainage in the eastern portion of San Pasqual Valley is mainly comprised of Guejito and Santa Ysabel Creeks. Guejito Creek flows southward through Rockwood Canyon and into Santa

Ysabel Creek which then flows westward through the valley eventually draining into the San Dieguito River. The San Dieguito River then continues flowing west-southwest through the Basin, eventually entering Hodges Reservoir. Refer to Figure 2 at the end of this TM for USGS 7.5-minute topography in the Basin's vicinity.

SECTION 3. THREATENED AND ENDANGERED SPECIES IN SAN PASQUAL VALLEY

As part of GDE assessment, Woodard & Curran conducted a preliminary review of special-status species in the Basin. Study for this TM focused on state- and federally listed species designated as threatened and/or endangered by the California Department of Fish and Wildlife (CDFW) or the U.S. Fish and Wildlife Service (USFWS). Other listed or otherwise unlisted special-status species were excluded from the evaluation. The purpose of this review was to support the determination of ecological value for GDEs in the Basin.

The San Pasqual Valley is covered by the City of San Diego Multiple Species Conservation Program (MSCP) Planning Area (City of San Diego, 1997). The MSCP is designed to conserve regional sensitive ecological habitat by coordinating project impacts and compensatory mitigation through the issuance of take permits for special-status species. The conservation area, or preserve, is known as the Multi-Habitat Planning Area (MHPA). Significant portions of the San Pasqual Valley are located within the MHPA.

Woodard & Curran conducted a literature review of the latest versions of the California Natural Diversity Database (CNDDB) (CDFW, 2020), and the California Native Plant Society (CNPS) Electronic Inventory of Rare and Endangered Plants (CNPS, 2020) for the USGS Topographic Quadrangles covering the San Pasqual Valley. Additionally, Woodard & Curran reviewed the USFWS Critical Habitat Mapper and Information, Planning and Consultation (IPaC) database for the area covering San Pasqual Valley.

A Woodard & Curran senior field biologist surveyed 15 representative locations in the field to document the Basin's vegetative community and general habitat conditions from March 2 through 4, 2020. Field survey locations were selected during the preliminary desktop assessment of GDEs for the Basin. The senior field biologist observed and documented plant and wildlife species during the field visit(s), and took representative photographs. Protocol-level or presence-absence surveys were not conducted as part of this project; they were not in the scope of work. Refer to Figure 3 for a map of state and federal protected species potentially occurring in the Basin. Table 1 below describes state- and federally listed threatened and endangered species in the Basin.

Table 1. State and Federally Threatened and Endangered Species in the San Pasqual Valley Groundwater Basin

Common Name/ Scientific Name	Status	Habitat	Potential to Occur Within the Project Area	Reliance on Groundwater	Individual(s) Observed
Fauna					
Stephen's kangaroo rat *Dipodomys stephensi*	USFWS: Endangered CDFW: Threatened MSCP Coverage: No	Annual grassland and coastal sage scrub with sparse cover.	Presumed absent based on CNDDB (2020) data. However, potential habitat exists within the project area.	No	No
Swainson's hawk *Buteo swainsoni*	USFWS: None CDFW: Threatened MSCP Coverage: Yes	Open grasslands and cultivated areas; deserts, savannas, and pine-oak woodlands.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	Indirect. Species relies on GDE vegetation in riparian woodlands for nesting.	No
tricolored blackbird *Agelaius tricolor*	USFWS: None CDFW: Threatened MSCP Coverage: Yes	Grasslands and other open cultivated areas; freshwater marshes.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	Direct. Species relies on GDE vegetation for breeding and roosting, especially emergent marsh wetlands.	No
southwestern willow flycatcher *Empidonax traillii extimus*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Riparian and wetland thickets.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	Indirect. Species relies on GDE riparian vegetation.	No
coastal California gnatcatcher *Polioptila californica californica*	USFWS: Threatened CDFW: None MSCP Coverage: Yes	Coastal sage scrub; dry slopes, washes, mesas.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	No	No
least Bell's vireo *Vireo bellii pusillus*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Willow-cottonwood forest, streamside thickets, and scrub oak.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	Indirect. Species relies on GDE vegetation in riparian areas for breeding.	No

Table 1. State and Federally Threatened and Endangered Species in the San Pasqual Valley Groundwater Basin					
Common Name/ Scientific Name	Status	Habitat	Potential to Occur Within the Project Area	Reliance on Groundwater	Individual(s) Observed
arroyo toad *Anaxyrus californicus*	USFWS: Endangered CDFW: None MSCP Coverage: Yes	Washes, streams, arroyos, and adjacent riparian uplands; shallow gravelly pools.	Presumed absent based on CNDDB (2020) data. Potential habitat exists within the project area. USFWS critical habitat designated in project area.	Direct and indirect. Species relies on groundwater for breeding and on GDE vegetation for foraging.	No
quino checkerspot *Euphydryas editha quino*	USFWS: Endangered CDFW: None MSCP Coverage: No	Chaparral; coastal sage scrub with Plantago spp.	Presumed absent based on CNDDB (2020) data. However, potential habitat exists within the project area.	N/A*	No
Riverside fairy shrimp *Streptocephalus woottoni*	USFWS: Endangered CDFW: None MSCP Coverage: Yes	Vernal pool complexes in patches of grassland or coastal sage scrub that are hydrologically connected.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Branchinecta sandiegonensis San Diego fairy shrimp	USFWS: Endangered CDFW: None MSCP Coverage: Yes	Vernal pools and ephemeral wetlands that are hydrologically connected.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Flora					
San Diego thornmint *Acanthomintha ilicifolia*	USFWS: Threatened CDFW: Endangered MSCP Coverage: Yes	Heavy clay soils in coastal sage scrub and chaparral; often in open depressions or vernal pools.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
San Diego ragweed *Ambrosia pumila*	USFWS: Endangered CDFW: None MSCP Coverage: Yes	Coastal scrub, grasslands, floodplains, and low valleys; persists in disturbed soils.	Presumed absent based on CNDDB (2020) data. However, potential habitat exists within the project area.	N/A*	No

Table 1. State and Federally Threatened and Endangered Species in the San Pasqual Valley Groundwater Basin

Common Name/ Scientific Name	Status	Habitat	Potential to Occur Within the Project Area	Reliance on Groundwater	Individual(s) Observed
coastal dunes milk-vetch *Astragalus tener var. titi*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Sand/dunes; shallow swales on coastal terraces.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Encinitas baccharis *Baccharis vanessae*	USFWS: Threatened CDFW: Endangered MSCP Coverage: Yes	Shrubland, chaparral; typically found on steep slopes.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
threadleaf brodiaea *Brodiaea filifolia*	USFWS: Threatened CDFW: Endangered MSCP Coverage: Yes	Grasslands, floodplains; vernal pools.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	N/A*	No
salt-marsh bird's beak *Cordylanthus maritimum spp. Maritimum*	USFWS: None CDFW: Endangered MSCP Coverage: Yes	Coastal salt marshes.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Orcutt's spineflower *Chorizanthe orcuttiana*	USFWS: Endangered CDFW: Endangered MSCP Coverage: No	Open areas within coastal, maritime shrubland/chaparral.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
San Diego button-celery *Eryngium aristulatum var. parishii*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Vernal pools.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
spreading navarretia *Navarretia fossalis*	USFWS: Threatened CDFW: None MSCP Coverage: Yes	Vernal pools, alkali playas and sinks; may be found in man-made ditches/depressions with clay soils.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No

Table 1. State and Federally Threatened and Endangered Species in the San Pasqual Valley Groundwater Basin

Common Name/ Scientific Name	Status	Habitat	Potential to Occur Within the Project Area	Reliance on Groundwater	Individual(s) Observed
willowy monardella *Monardella viminea*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Rocky coastal drainages; sandy benches along streambeds.	Presumed absent based on CNDDB (2020) data. However, potential habitat exists within the project area.	N/A*	No
California Orcutt grass *Orcuttia californica*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Grasslands and chaparral; often found in dried beds of vernal pools.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
San Diego mesa mint *Pogogyne abramsii*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Vernal pools on coastal mesas/terraces.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Otay mesa mint *Pogogyne nudiuscula*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Vernal pools; chaparral and coastal sage scrub.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No

Notes:
N/A = Reliance on groundwater unknown or otherwise not fully understood based on species omission from the Critical Species LookBook (2019).*
Source: California Natural Diversity Database (CDFW, 2020); California Native Plant Society Inventory Results (2020); IPaC Trust Resources List (USFWS, 2020).

SECTION 4. GROUNDWATER DEPENDENT ECOSYSTEM ASSESSMENT

4.1 Preliminary Desktop Assessment

Using a geographic information system (GIS), Woodard & Curran completed a preliminary desktop analysis of the California Department of Water Resources' (DWR's) Natural Communities Commonly Associated with Groundwater (NCCAG) database for the Basin. The NCCAG database includes a set of GIS data for vegetative communities and a separate dataset for wetlands. Additional relevant environmental and hydrogeological GIS datasets were also reviewed as part of the desktop assessment. Woodard & Current developed a Basin using these publicly available statewide and regional data layers to understand the extent of the NCCAG dataset within the Basin. Refer to Figure 4 for a map of GDE indicators in Basin. Once the Basin map of GDE indicators was developed, Woodard & Curran then reviewed the Basin and attempted to identify NCCAG polygons that appeared to be probable GDEs based on the following criteria:

- Presence of a USGS-mapped stream, spring, seep, or other waterbody
- Presence of USFWS National Wetlands Inventory (NWI) mapped wetlands
- Inundation visible on aerial imagery
- Saturation visible on aerial imagery
- Dense riparian and/or wetland vegetation visible on aerial imagery
- CNDDB and/or CNPS vegetative community data indicating a concentration of phreatophytes
- California Protected Areas and/or Areas of Conservation Emphasis

If an NCCAG polygon, or a portion of a polygon, included one or multiple of the above characteristics, then it was tentatively marked as a probable GDE for further evaluation and validation as part of the field study. NCCAG polygons that did not appear to exhibit the above criteria (or similar) were considered probable non-GDEs for the purposes of the desktop study, and were subject to further review as part of the field study.

4.2 GDE Field Assessment and Validation

Woodard & Curran completed a GDE field assessment and validation study at representative locations throughout the Basin. Woodard & Curran originally selected 16 representative locations based on geographic position in the Basin, vegetative community/habitat type, land use, topography, and other environmental factors determined via remote sensing. Prior to field work, Woodard & Curran coordinated with the City of San Diego Public Utilities Department to review the selected GDE field assessment sites and property lease information as well as physical access to the sites. Survey permissions were obtained from the appropriate stakeholders prior to mobilization for the field effort.

The field study was conducted from March 2 to 4, 2020. Woodard & Curran Senior Biologist Will Medlin and City of San Diego Public Utilities Department Civil Engineer Michael Bolouri worked together to complete the field study. GDE field assessment Sites 1 through 14 and 16 were visited during the field study. Site 15 was not accessible at time of field deployment and was eliminated from assessment.

Field observations were made at NCCAG-mapped seeps, springs, wetlands, and other riparian habitats to document plant communities, aquatic or semi-aquatic wildlife, indicators of surface and subsurface hydrology, soil-based evidence of a high water table, and other relevant ecological and hydrological data. Soils were sampled to an approximate depth of between 12 and 20 inches depending on restrictive layer to determine moisture content and texture. The soil profile was assessed and classified based on color using a Munsell soil color chart. Photographs were taken in the four cardinal directions (i.e., north, east, south, west) at each GDE field assessment site to document general habitat conditions. Field notes and additional photographs were taken of plant species, wildlife, and other relevant ecological data to support the GDE assessment at each site. Global positioning system (GPS) data points were also collected using a submeter Trimble Geo 7x GPS unit at each GDE field assessment site. Refer to Figure 5 at the end of this TM for GDE field assessment site locations.

Upon completion of the GDE field assessment, Woodard & Curran refined the preliminary desktop GDE assessment data and revised the mapping for probable GDEs and probable non-GDEs based on field observations and further research.

SECTION 5. RESULTS AND DISCUSSION

Out of 72 NCCAG-mapped polygons (i.e., 53 GDE wetland polygons and 19 GDE vegetation polygons), the combined desktop and field assessment yielded 64 potential GDEs and eight potential non-GDEs. In addition, during the desktop assessment, 1,062 individual locations were viewed and a determination of potential GDE status was made for a point on the landscape. Out of 1,062 assessment locations, 285 points were determined to be probable GDEs, 197 points were determined to be probable non-GDEs, and 580 points were determined to be wetland and/or riparian communities. Probable GDEs largely consisted of dense riparian and wetland communities along mapped drainage systems where monitoring well data showed the depth to groundwater at 30 feet or less relative to the ground surface. Probable non-GDEs largely consisted of dry upland areas dominated by shallow-rooted grasses and/or invasive species. Areas that consisted of wetland and/or riparian phreatophytes (i.e., deep-rooted plant species) along drainageways where depth to groundwater was greater than 30 feet were classified as wetland and riparian communities. Refer to Figure 6 at the end of this TM for the draft GDE assessment map.

For the field study, 15 representative locations were assessed for GDE indicators, functions, and values. Of the 15 sites reviewed in the field, one appeared to be a non-GDE, nine appeared to be GDEs, and five appeared to be wetland/riparian communities but not GDEs. The 14 GDE and wetland/riparian community sites had deep-rooted woody riparian or wetland species growing there. Further, five sites (i.e., Sites 5, 7, 9, 10 and 16) had either standing or flowing water observed at the surface. The one potential non-GDE location was Site 1, which did not have any deep-rooted woody riparian or wetland species and was dominated by grasses and other non-native herbaceous species. Table 2 below describes each of the field assessment sites in more detail.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
1	33.056556 N/ 117.054057 W	Yes	Vegetation—Tule-Cattail Wetland—Palustrine, emergent, persistent, seasonally flooded	• *Avena fatua* • *Conium maculatum* • *Rumex crispus* • *Bromus carinatus*	Site is an upland terrace within the floodplain of the San Dieguito River. Soils at data point are low-chroma yet dry and somewhat friable. Site appears to be dominated by non-native grasses and other invasive herbaceous plants. This location does not appear to be a GDE.
2	33.052368 N/ 117.049115 W	Yes	Vegetation—Willow (Shrub)	• *Salix laevigata* • *Tamarisk ramosissima* • *Baccharis salicifolia* • *Schoenoplectus californicus* • *Urtica dioica*	Site is a forested riparian corridor with many large willows. Soils at data point are low-chroma with some organic content. Multiple songbirds were observed/heard at this site. This location appears to be a GDE.
3	33.046929 N 117.042083 W	Yes	Wetland—Palustrine, scrub-shrub, forested, seasonally flooded	• *Eucalyptus globulus* • *Baccharis salicifolia* • *Salix laevigata* • *Eriogonum sp.* • *Conium maculatum* • *Carex sp.*	Site is a forested drainage with a small intermittent/ephemeral stream channel; sediment is deposited throughout the floodplain; soils are low-chroma. Multiple songbirds were observed/heard at this site. This location appears to be a GDE.
4	33.053996 N/ 117.039712 W	Yes	Wetland - Palustrine, emergent, persistent, seasonally flooded	• *Salix laevigata* • *Baccharis salicifolia* • *Rumex crispus*	Site is a dense willow thicket with little herbaceous vegetation; soils are low-chroma with some organic content. This location appears to be a GDE.
5	33.069208N/ 117.031547W	Yes	Vegetation—Willow (Shrub)	• *Salix lasiolepis* • *Salix laevigata* • *Urtica dioica* • *Typha domingensis* • *Schoenoplectus californicus*	Site is a riparian willow thicket. Soils are saturated at the surface by what appears to be groundwater; high organic content observed. Surface water, drainage patterns, drift deposits, and iron-oxidizing bacteria observed. This location appears to be a GDE.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin					
GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
6	33.081393 N/ 117.028357 W	No	N/A	• *Salix lasiolepis* • *Baccharis salicifolia* • *Schoenoplectus californicus* • *Rumex crispus*	Site is an emergent marsh adjacent to an excavated pond/basin that is holding water. Soils are saturated and low-chroma. Dense wetland vegetation. Several waterfowl observed in the open water. This location appears to be a GDE.
7	33.081120 N/ 117.013124 W	Yes	Vegetation—Riparian mixed shrub	• *Tamarisk ramosissima* • *Polygonum sp.* • *Rumex crispus* • *Silybum marianum* • *Plantago sp.*	Site is within what appears to be an excavated pond/basin. Soils are saturated and low-chroma. Standing water observed in western portion of basin. Vegetation favors disturbed sites. Multiple songbirds heard/observed. This location appears to be a GDE.
8	33.091726 N 117.019165 W	Yes	Vegetation—Willow (shrub) Wetland—Palustrine, forested, seasonally flooded	• *Washingtonia filifera* • *Salix laevigata* • *Baccharis salicifolia* • *Urtica dioica* • *Anemopsis californica*	Site is a forested floodplain with a dense understory. Soils are low-chroma through the profile with some organic content. Multiple songbirds heard/observed as well as small mammal. This location appears to be a GDE.
9	33.093791 N/ 117.016029 W	Yes	Wetland—Palustrine, forested, seasonally flooded	• *Salix laevigata* • *Baccharis salicifolia* • *Urtica dioica* • *Schoenoplectus californicus*	Site is an inundated pond/basin with thick scrub-shrub wetland vegetation surrounding and extending into deeper, open water areas. Significant waterfowl and other songbirds heard/observed. This location appears to be a GDE.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
10	33.099183 N/ 117.019179 W	Yes	Wetland—Palustrine, emergent, persistent, seasonally saturated	• *Salix laevigata* • *Tamarisk ramosissima* • *Nasturtium officinale* • *Eleocharis palustris* • *Lobelia sp.* • *Rumex crispus* • *Schoenoplectus californicus*	Site is a wet meadow in a pasture adjacent to a perennial drainage feature. Soils are low-chroma and have a dense upper clay layer that appears to help pond surface water. Surface water is approximately 4-6 inches deep. Algae and macroinvertebrates observed in standing water. This location appears to be a GDE.
11	33.089156 N/ 116.995885 W	Yes	Vegetation—Riparian mixed hardwood Wetland—Palustrine, emergent, persistent, seasonally flooded	• *Washingtonia filifera* • *Salix laevigata* • *Eucalyptus globulus* • *Baccharis salicifolia* • *Urtica dioica* • *Anemopsis californica*	Site is a mature riparian forest. A small intermittent stream was observed just west of the data point and was flowing at time of field survey. Soils are low-chroma in the upper part but become high-chroma below. Soils are very sandy and appear to be well drained. Songbirds heard/observed. This location appears to be a wetland/riparian community, but not a GDE.
12	33.083919 N/ 116.995362 W	Yes	Vegetation—Riparian mixed shrub Wetland—Palustrine, emergent, persistent, seasonally flooded	• *Tamarisk ramosissima* • *Salix lasiolepis* • *Baccharis salicifolia* • *Arundo donax* • *Xanthium strumarium* • *Conium maculatum* • *Madia exigua*	Site is a dry creek bed and adjacent riparian zone. Some vegetated mid-channel bars are present. No evidence of recent flow. Soils are very dry, friable sands. Butterflies and a lizard were observed. This location appears to be a wetland/riparian community, but not a GDE.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
13	33.073991 N/ 116.977904 W	Yes	Vegetation—Riversidean alluvial scrub	• *Tamarisk ramosissima* • *Sambucus nigra spp.* • *Caerulea* • *Salix lasiolepis* • *Baccharis salicifolia* • *Xanthium strumarium* • *Arundo donax*	Site is a dry creek bed just downstream from a roadway bridge. Lots of shrubby vegetation growing in channel and wrack lines are present from past flooding events. Soils are low-chroma and moist in the upper part, but quickly become dry sand below. Bees and songbirds heard/observed; swallow nests were observed under bridge. This location appears to be a wetland/riparian community, but not a GDE.
14	33.092898 N/ 116.956288 W	Yes	Vegetation—Riparian mixed shrub Wetland—Palustrine, scrub-shrub, seasonally flooded	• *Tamarisk ramosissima* • *Sambucus nigra spp.* • *Caerulea* • *Baccharis salicifolia* • *Conium maculatum* • *Galium aparine* • *Xanthium strumarium* • *Madia exigua* • *Bromus diandrus*	Site is a riparian scrub-shrub upland along Santa Ysabel Creek. Streambed is dry and banks are steep and eroded. Soils are somewhat low-chroma, but dry throughout profile. This location appears to be a wetland/riparian community, but not a GDE.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
16	33.088564 N/ 116.923676 W	Yes	Vegetation—Willow (shrub)	• *Populus fremontii* • *Platanus racemose* • *Tamarisk ramosissima* • *Salix lasiolepis* • *Salix laevigata, Eucalyptus globulus* • *Baccharis salicifolia* • *Arundo donax* • *Xanthium strumarium* • *Ricinus communis* • *Mirabilis laevis var. crassifolia*	Site is the streambed of Santa Ysabel Creek with adjacent riparian scrub-shrub and forest. Stream was flowing at time of field survey. Aquatic macroinvertebrates were observed in stream. Soils were moist coarse sands. Wild turkey, wading birds, and songbirds heard/observed. This location appears to be a wetland/riparian community, but not a GDE.

GDEs are present in the Basin as indicated in Table 2. Groundwater monitoring well data from 2015 for depth to water ranges from 8 feet below surface along Cloverdale Creek in the northwestern portion of the Basin to greater than 80 feet below surface along Santa Ysabel Creek near the eastern extent of the Basin. Surface water base flow was observed in the field at five of the GDE assessment sites in March 2020, including in Santa Ysabel Creek near the eastern extent of the Basin. This may suggest that there is a separate shallow, perched groundwater table that was discharging at the time of the field study. This shallow water-bearing zone may be comprised of a type of rock that allows groundwater to exist within interstitial pore spaces and discharge to localized receiving streams prior to connecting to the regional groundwater table or aquifer. Additionally, some GDEs and wetland/riparian communities may be supported by surface waters resulting from storm flows and (possibly) flowing springs outside the Basin boundary.

The major drainages in the San Pasqual Valley have significant riparian or wetland vegetative communities with an abundance of woody phreatophytes such as willows (*Salix* spp.), salt cedar (*Tamarisk ramosissima*), Fremont cottonwood (*Populus fremontii*), California sycamore (*Platanus racemosa*) and California fan palm (*Washingtonia filifera*). These drainageways and their associated riparian communities provide valuable ecological habitat for many species to shelter, feed, and breed. They also provide wildlife corridors for movement and migration through the large agricultural fields and orchards located on the adjacent valley floor.

GDEs in the Basin may also provide habitat for certain state and federal protected species. Of the 23 state- or federally listed threatened and endangered species that have the potential to occur in the Basin, six species (i.e., Swainson's hawk, tricolored blackbird, southwestern willow flycatcher, coastal California gnatcatcher, least Bell's vireo, and threadleaf brodiaea) are presumed extant based on CNDDB (2020) data. Additionally, potential suitable habitat was observed for 11 species (i.e., Stephen's kangaroo rat, Swainson's hawk, tricolored blackbird, southwestern willow flycatcher, coastal California gnatcatcher, least Bell's vireo, arroyo toad, quino checkerspot, San Diego ragweed, threadleaf brodiaea, and willowy monardella) during the field study. Many of these special-status species rely on the riparian scrub-shrub found along drainageways and other wetland ecosystems present in the valley for all or part of their life cycle.

5.1 Conclusion

GDEs and wetland/riparian communities present in the Basin do not appear to depend solely on the regional groundwater table. Many of the GDEs and wetland/riparian communities observed rely on surface flows and stormwater runoff to influence soil moisture requirements for vegetative communities. Further study is recommended to understand if and where a shallow, perched groundwater table exists and if there is an aquitard or other rock layer in the subsurface geology that would influence groundwater discharge at the surface. Also, additional work is recommended to refine and revise the extents of the NCCAG datasets, as this may yield a more realistic map of GDEs for the Basin. Special attention should be given to human-made excavated basins that have naturalized into semi-permanently inundated wetlands and/or open waters where waterfowl and other wetland-dependent species are present. These ecosystems may or may not have a direct connection to groundwater and that should be confirmed.

SECTION 6. REFERENCES

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FIGURES

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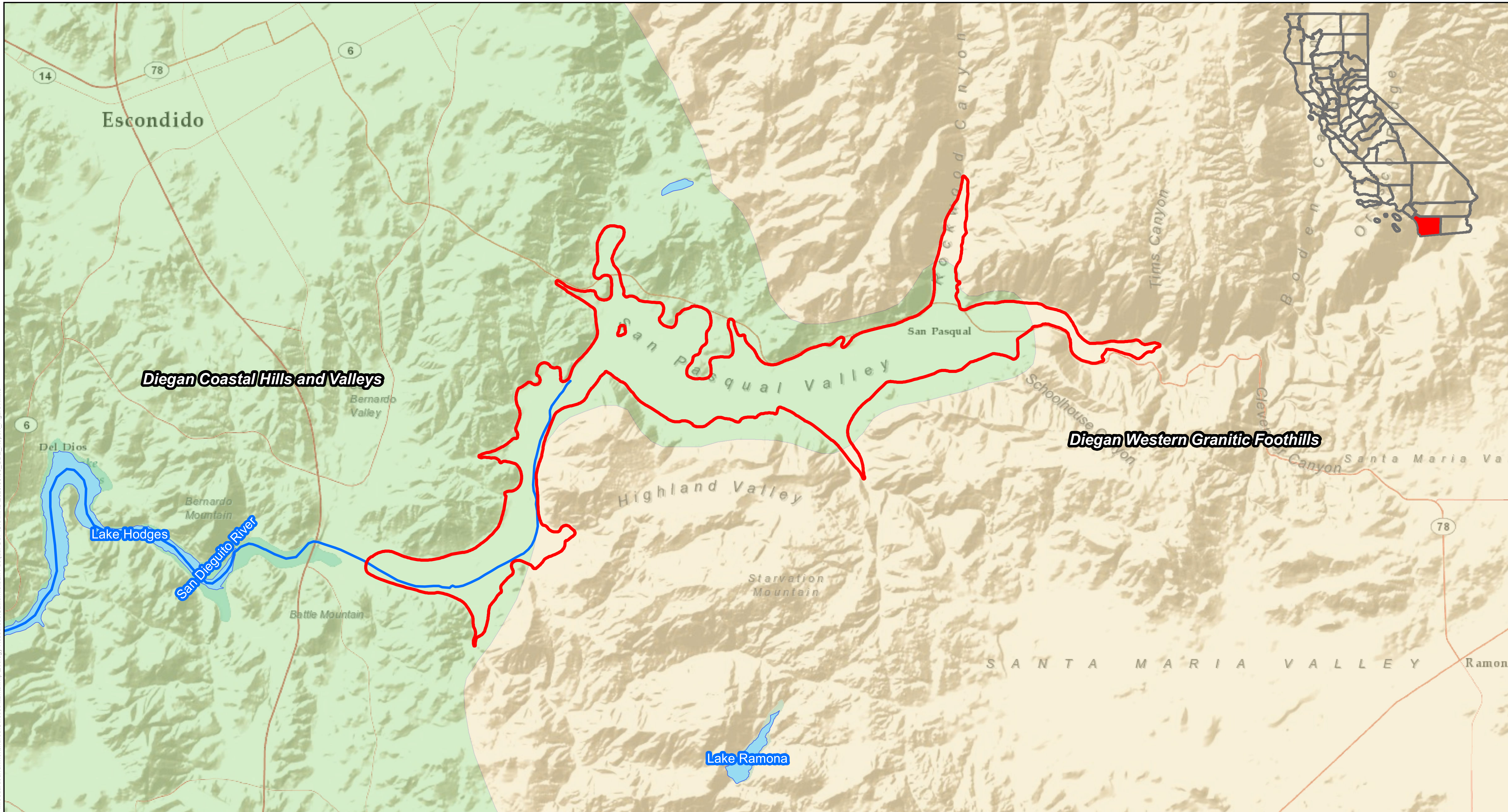

Figure 1
Project Location and Ecoregions
San Pasqual Valley Groundwater Basin
San Diego Public Utilities
San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- USGS National Hydrography Data
- CA DWR Lakes Data

Ecoregion

- Diegan Coastal Hills and Valleys
- Diegan Western Granitic Foothills

SD Public Utilities

1 inch = 6,000 feet
0 3,000 6,000 12,000 Feet

N

WOODARD & CURRAN
Project #: 0011197.00
Map Created: May 2020

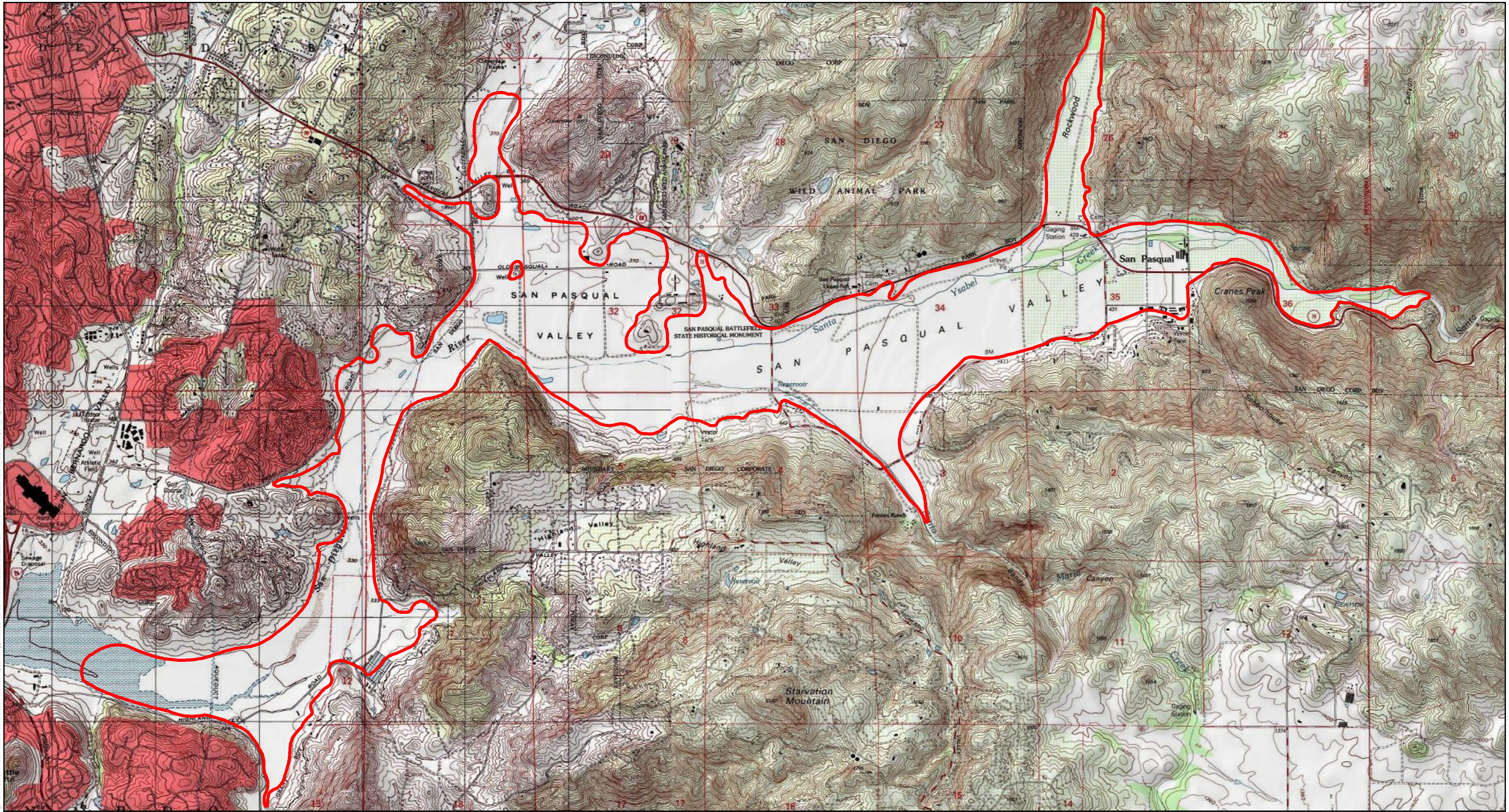

Figure 2
USGS Topography
San Pasqual Valley Groundwater Basin
San Diego Public Utilities
San Diego County, CA

Legend

San Pasqual Valley Groundwater Basin

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

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WOODARD & CURRAN

Project #: 0011197.00
Map Created: May 2020

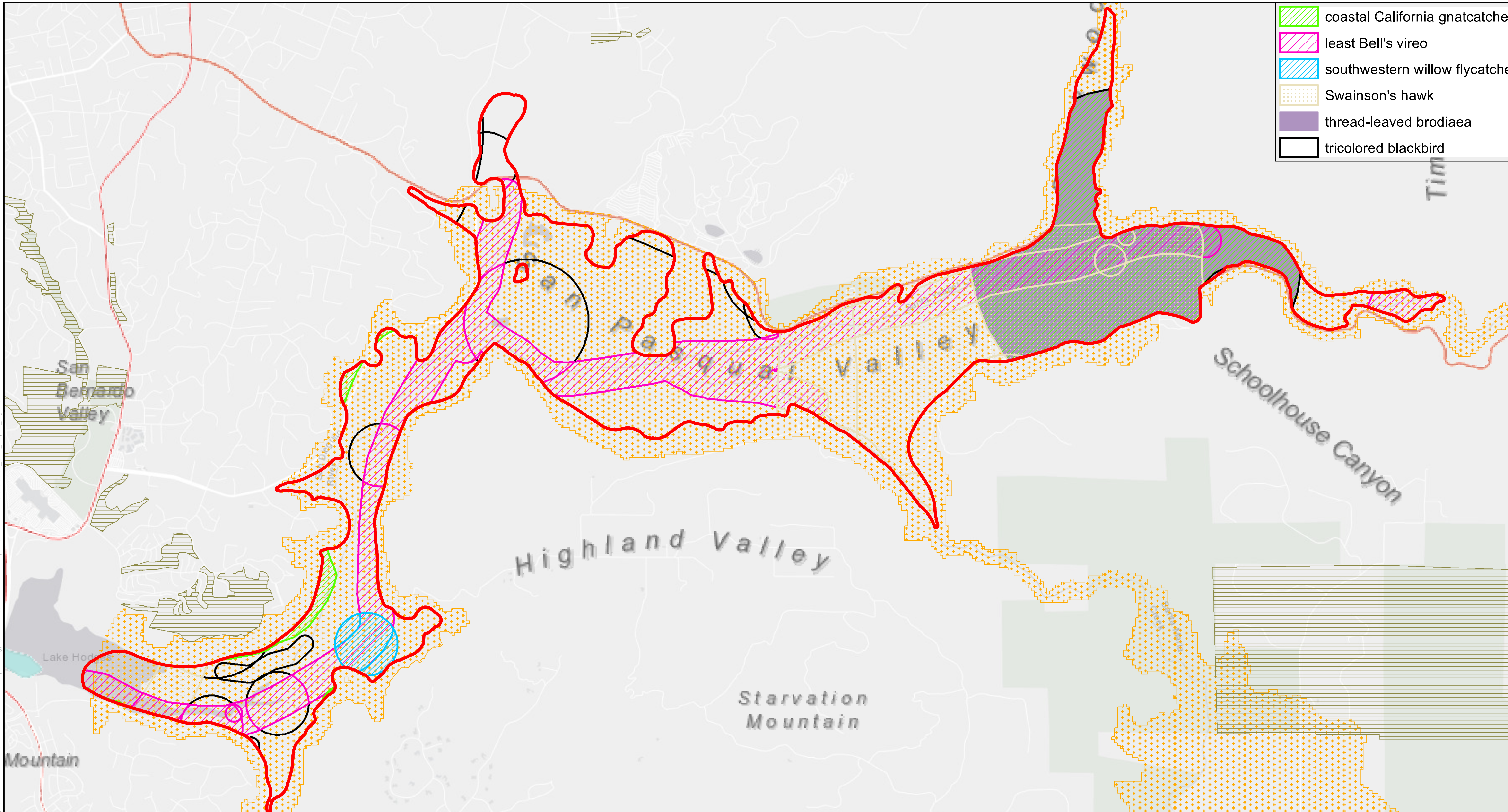

Figure 3
State and Federal Protected Species
San Pasqual Valley Groundwater Basin
San Diego Public Utilities
San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- USFWS Critical Habitat (Arroyo Toad)
- USFWS Critical Habitat (California Gnatcatcher)

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

N

WOODARD & CURRAN

Project #: 0011197.00
Map Created: May 2020

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: ESRI World Light Gray Canvas Base; CA Natural Diversity Database 2020; USFWS Critical Habitat.**

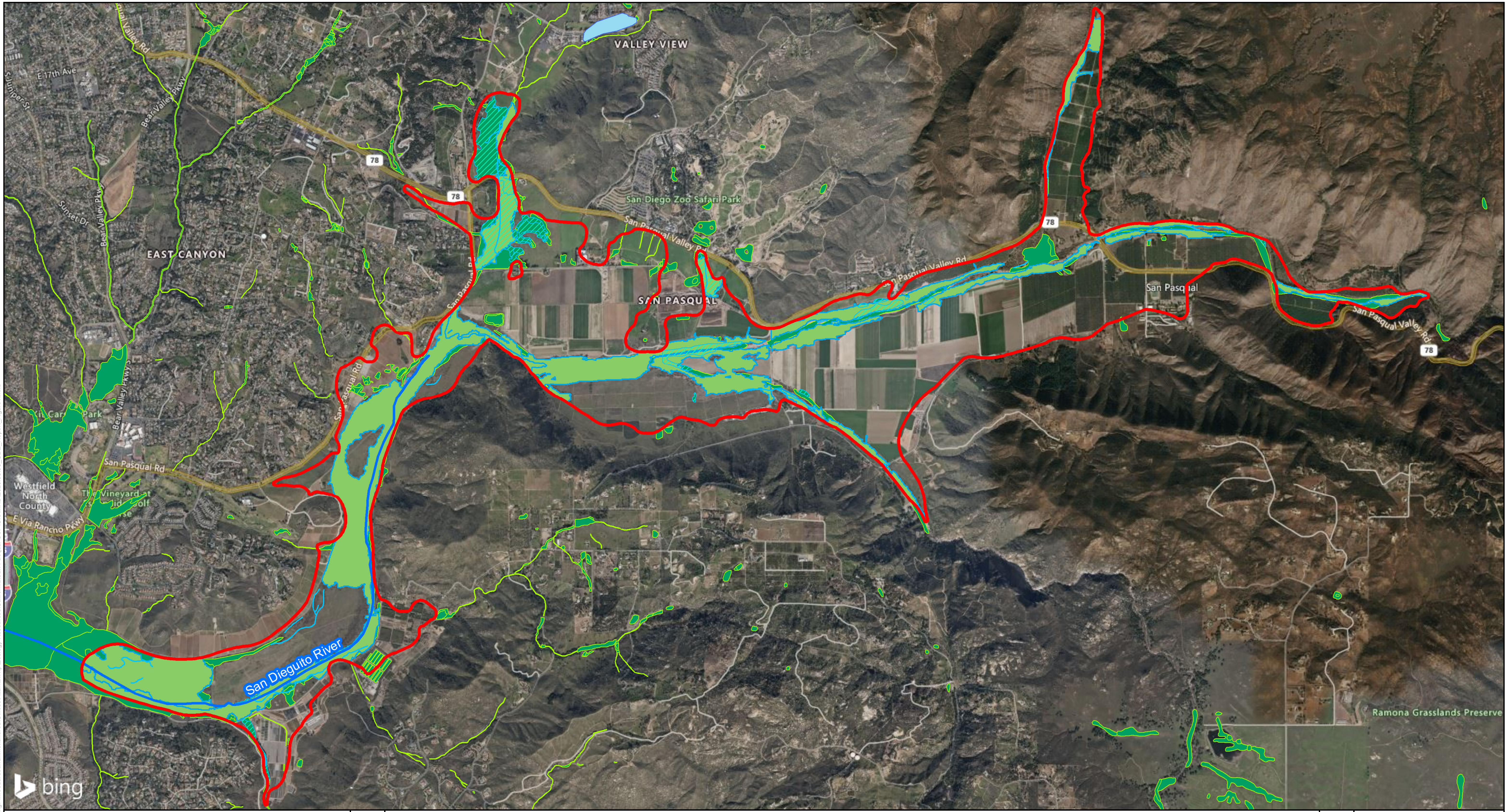

Figure 4
Groundwater Dependent Ecosystem (GDE) Indicators
San Pasqual Valley Groundwater Basin
San Diego Public Utilities
San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- USGS National Hydrography Data
- CA DWR Lakes Data
- NCCAG Wetlands (San Pasqual Valley)
- NCCAG Vegetation (San Pasqual Valley)
- USFWS National Wetlands Inventory

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

N

WOODARD & CURRAN

Project #: 0011197.00
Map Created: May 2020

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: Bing Maps Hybrid; USGS NHD; CA DWR Lakes; CA DWR Natural Communities Commonly Associated with Groundwater; USFWS NWI.**

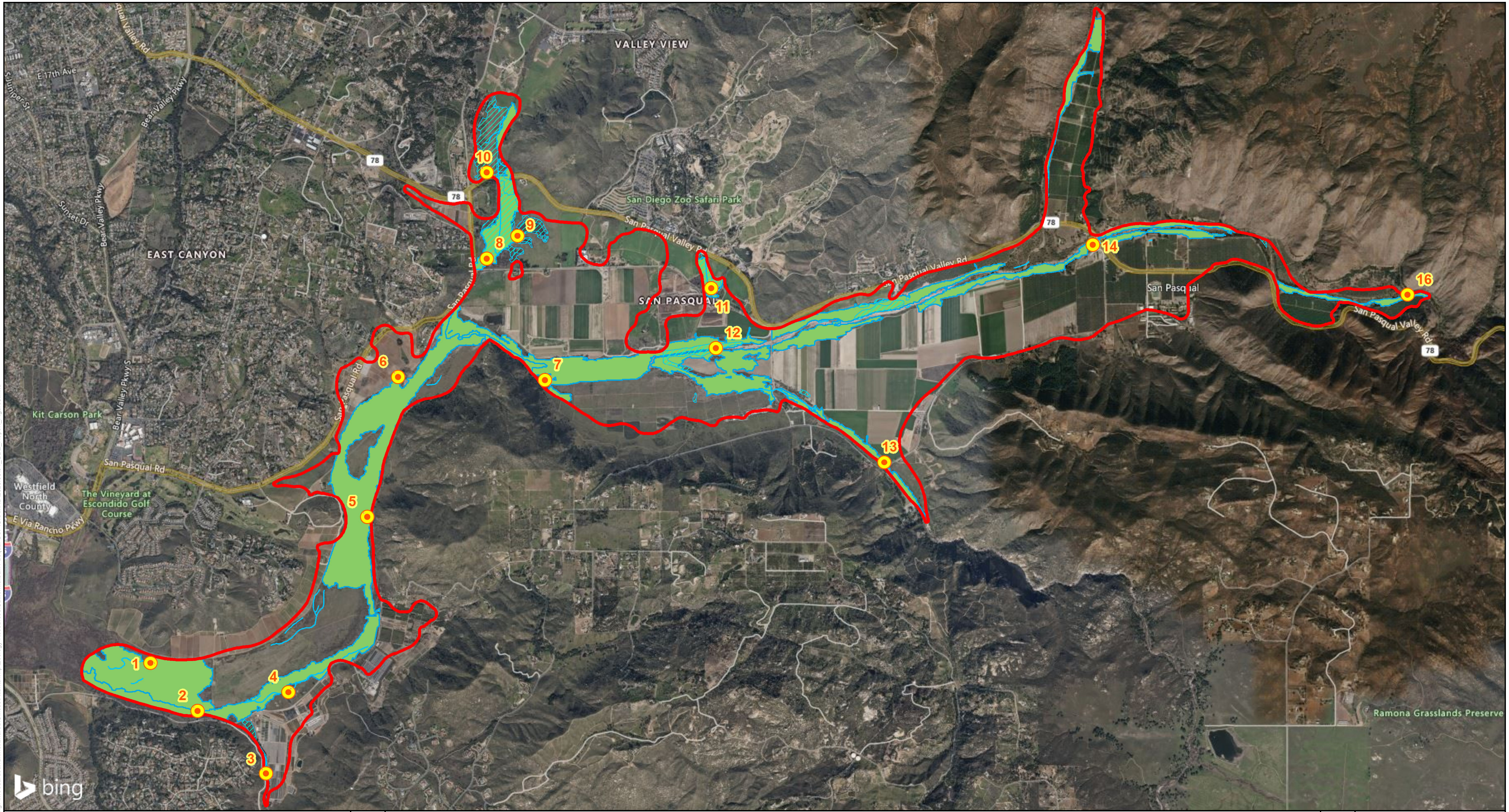

Figure 5
Completed GDE Field Assessments

San Pasqual Valley Groundwater Basin
San Diego Public Utilities

San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- NCCAG Wetlands (San Pasqual Valley)
- NCCAG Vegetation (San Pasqual Valley)
- Completed GDE Field Assessment

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

N

WOODARD & CURRAN

Project #: 0011197.00
Map Created: May 2020

Figure 6
GDE Assessment

San Pasqual Valley Groundwater Basin
San Diego Public Utilities

San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- NCCAG Wetlands (San Pasqual Valley)
- NCCAG Vegetation (San Pasqual Valley)
- Groundwater Contours
- Probable GDE
- Probable Non-GDE
- Wetland & Riparian Vegetation

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

N

WOODARD & CURRAN

Project #: 0011197.00
Map Created: August 2020

Attachment 1
Photographic Log of GDE Field Assessment Sites

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Photo Number: 1 | **View Direction:** West | **Date:** March 2, 2020
Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 2.

Photo Number: 2 | **View Direction:** South | **Date:** March 2, 2020
Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 3.

PhotO Number: 3 | **View Direction:** West | **Date:** October 23, 2018

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 4.

Photo Number: 4 | **View Direction:** West | **Date:** March 2, 2020

Description: Representative photograph taken of potential incorrectly mapped groundwater dependent ecosystem (NCCAG 2020). Photo taken GDE field assessment site 1.

Photo Number: 5 | **View Direction:** North | **Date:** March 2, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken GDE field assessment site 5.

Photo Number: 6 | **View Direction:** North | **Date:** March 2, 2020

Description: Representative photograph taken of unmapped potential groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 6.

Photo Number: 7 | **View Direction:** South | **Date:** March 2, 2020
Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 10.

Photo Number: 8 | **View Direction:** West | **Date:** March 3, 2020
Description: Representative photograph taken of confirmed wetland and riparian vegetation . Photo taken at GDE field assessment site 11.

Photo Number: 9 | **View Direction:** West | **Date:** March 3, 2020
Description: Representative photograph taken of confirmed wetland and riparian vegetation. Photo taken at GDE field assessment site 12.

Photo Number: 10 | **View Direction:** South | **Date:** March 3, 2020
Description: Representative photograph taken of confirmed wetland and riparian vegetation. Photo taken at GDE field assessment site 13.

Photo Number: 11 | **View Direction:** West | **Date:** March 3, 2020
Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 7.

Photo Number: 12 | **View Direction:** West | **Date:** March 3, 2020
Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 14.

Photo Number: 13 | **View Direction:** North | **Date:** March 4, 2020

Description: Representative photograph taken of confirmed wetland and riparian vegetation. Photo taken at GDE field assessment site 16.

Photo Number: 14 | **View Direction:** South | **Date:** March 4, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 8.

Photo Number: 15 | **View Direction:** West | **Date:** March 4, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 9.

APPENDIX G: IMPLEMENTATION ROADMAP ELEMENTS AND ACTIVITIES

Table G-1: Implementation Elements and Activities for Strategy 2A

Roadmap Element	Example Activities
Follow-on Evaluations	
Watershed hydrology update	• Conduct a watershed hydrology study to determine historical and projected runoff draining to the reservoir. The City estimates runoff using a water balance approach that has not been validated with measured flows or an alternative estimation method. • Update assumptions for the Sutherland model to be used in the feasibility study.
Outlet works status and drawdown alternatives study update	• Confirm the recommended Sutherland outlet repair location and approach to address recommendations from the 2022 Sutherland Outlet Works report. This will determine the operations and final capacity for releases to Santa Ysabel Creek to support recharge. The City will be making the decision based on the Drawdown Analysis Report (expected in late 2023) and the ongoing Ramona Intake Restoration Design Work. • If needed, update assumptions for the Sutherland model to be used in the feasibility study.
Reservoir monitoring program	• Design a reservoir real-time monitoring program based on the status of existing gauging stations. In addition to daily storage level currently being measured, controlled releases, spills (uncontrolled releases), and inflows would need to be measured and monitored. • Implement a real-time reservoir monitoring program with new inflow and outflow gauging stations. Comprehensive monitoring is an important aspect of prudent reservoir management to sustain water productivity and operations reliability. • Consider potential optimization opportunities, like forecast-informed operations once the monitoring program is implemented. • Use measured data to validate estimated runoff and to calibrate reservoir operation model.
Toad breeding season operational rules	• Conduct an environmental study to support the operation criteria for releases to San Vicente Reservoir. The initial modeling effort showed high sensitivity to the assumed maximum controlled release of 10 million gallons per day (15.5 cubic feet per second) during the Arroyo Toad breeding season (March to September). Historical records indicate the controlled releases were not constrained by this criteria and flows could go up to 40 cubic feet per second. An environmental study is needed to determine if this limitation is required.
Pilot Reservoir Controlled Releases Plan	
Pilot reservoir controlled releases plan	• Develop Pilot Reservoir Controlled Release Plan to schedule controlled releases from Sutherland Reservoir to Santa Ysabel Creek to assess performance under different conditions of flow and frequency. • Implement Pilot Reservoir Controlled Releases Plan and provide field data measurements of controlled releases performance. Examples of performance criteria would be conveyance efficiency and response of groundwater levels at monitoring wells. • Assessment of the existing controlled releases to San Vicente Reservoir is also recommended to be included. The same performance criteria and measurement approach should be implemented to provide a benchmark for the feasibility study of controlled releases to the Basin. • Update conveyance efficiency assumptions and develop operation scenarios to be evaluated in the feasibility study.

Roadmap Element	Example Activities
Feasibility Study	
Feasibility study	• Build upon the Preliminary Feasibility Study with information from the follow-on evaluations. • Conduct stakeholder outreach during future steps in the planning process to solicit input on planned operational considerations The evaluated scenarios should represent a range of plausible scenarios that include a range of climate conditions as well as San Vicente low and high controlled releases. Involvement of stakeholders would be essential during this part of the process. Direct purchase, as well as water exchanges including the San Diego County Water Authority (SDCWA), should be considered. • Conduct feasibility study using a scenario planning approach and a system operation model. The reservoir operation assumptions and scenario definition should be based on the follow-on evaluation findings. • Provide a recommended operation criterion, potential cost, schedule, and amount of controlled releases to Santa Ysabel Creek. These recommendations would be used to facilitate development of water agreements.
Agreements	
Agreement development	• Develop agreements necessary for implementation and operation of strategy
Update to Reservoir Operation Manual	
Operation manual update	• Update operation manual of Sutherland Reservoir to incorporate operation criteria for new controlled releases to Santa Ysabel Creek and refined manual to include new data from follow-up evaluations and feasibility study. • Implement controlled releases to Santa Ysabel Creek following the updated manual
Information presented in this table is illustrated as a high-level roadmap in **Figure 4-1.**	

Table G-2: Implementation Elements and Activities for Strategy 3A

Roadmap Element	Example Activities
Follow-on Evaluations	
Ramona MWD raw water or treated water system condition update	• Review of Ramona MWD raw water or treated water system existing conditions to update conveyance capacity schedule to San Pasqual Valley Basin. • Ramona MWD to provide updated delivery schedule scenarios
Initial coordination with San Diego County Water Authority (SDCWA)	• Confirm SDCWA's availability to increase untreated or treated water deliveries to Ramona MWD
Feasibility Study	
Feasibility study	• Build upon the Preliminary Feasibility Study with information from the follow-on evaluations. • Coordinate with the SDCWA and Ramona MWD to determine the untreated or treated water delivery scenarios to be evaluated. The evaluated scenarios should represent a range of plausible scenarios that include water supply and water conveyance uncertainty. • Conduct feasibility study using a scenario planning approach and a system operation model. • Provide a recommended operation criterion, potential cost, schedule, and amount of deliveries from SDCWA to Ramona MWD and from Ramona MWD to the San Pasqual Valley Basin. These recommendations would be used for the agreement development.
Agreements	
Update agreement between the SDCWA and Ramona MWD	• Based on the feasibility study, update existing agreement between the SDCWA to include additional untreated or treated water deliveries
Water use agreement between Ramona MWD and City of San Diego	• Develop an agreement for delivering untreated or treated water between Ramona MWD to the Basin based on feasibility study recommendations and aligned with the SDCWA and Ramona MWD's agreement.
Agreement development	• Develop agreements necessary for implementation and operation of strategy
Designs and Permitting	
Conceptual design (15%)	• Advance the design and cost estimates for the conveyance pipeline from Ramona MWD delivery point to Santa Ysabel Creek discharge point • Continue coordinating with relevant agencies.
Design (30%)	• Advance the design and cost estimates. • Assess monitoring infrastructure needs. • Initiate CEQA, NEPA, and other environmental evaluations, as needed. • Prepare permit applications.
Design (60%–90%–100%)	• Complete the design and cost estimates. • Complete CEQA, NEPA, and other environmental documents, as needed. • Track permit applications to completion. • Identify mitigation needs and initiate implementation.

Roadmap Element	Example Activities
Bid and Construction	
Bid and construction	• Prepare specifications and bidding documents. • Select construction contractor(s). • Construct operations and monitoring facilities.
Operation Manual	
Ramona MWD's raw system or treated water operation manual update	• Update the existing Ramona MWD's raw or treated system operation manual to reflect the new delivery point in their system and the specific operation criteria for the implementation of the agreements.
Information presented in this table is illustrated as a high-level roadmap in **Figure 4-2.**	

Table G-3: Implementation Elements and Activities for Strategy 3D

Roadmap Element	Example Activities
Follow-on Evaluations	
Ramona MWD raw water or treated water system condition update	• Review of Ramona MWD raw water or treated water system existing conditions to update conveyance capacity schedule to San Pasqual Valley Basin. • Ramona MWD to provide updated delivery schedule scenarios
Initial coordination with San Diego County Water Authority (SDCWA)	• Confirm SDCWA's availability to increase untreated or treated water deliveries to Ramona MWD
Hydraulics assessment	• Review available hydrogeological reports and data. • Assimilate available information on depth to water, aquifer thickness, transmissivity, grain-size distribution, and groundwater storage properties.
Geochemical compatibility assessment	• Review available water quality data of the source water from Ramona MWD's untreated or treated water system. • Review available groundwater quality data for monitoring wells in relevant geographic areas. • Collect source-water samples and groundwater samples and have them analyzed for constituents listed in **Table G-4**. Total suspended solids (TSS) in the source water should also be quantified. • Apply conventional geochemical analyses to characterize pH, ionic strength, major ion chemistry, redox, trace metal content, buffer capacity and other relevant properties of treated recharge water and groundwater. • Develop and apply geochemical models to assess mineral speciation, potential chemical reactions from mixing source water and groundwater, potential chemical reactions from exposing aquifer minerals to mixtures of source water and groundwater, and potential pretreatment need.
Assess permitting requirements concurrent with hydraulics and geochemical compatibility assessments	• Conduct preliminary environmental impact assessment. • Identify permitting agencies and permits required. • Coordinate with permitting agencies.
Field Investigation	
Contractor Procurement	• Prepare bidding and contract documents to procure drillers, geophysical logging specialists, analytical laboratories, and others, as needed.
Well drilling, installation, sampling, and development	• Drill well boring(s). • Collect aquifer formation samples. • Submit samples for mineralogical and chemical analysis, including leaching tests. • Install and develop well(s).
Testing	• Conduct step-drawdown and constant-rate aquifer tests. • Collect water quality samples. • Conduct other testing as necessary, such as packer tests, flowmeter logging, and depth-discrete sampling, as needed.
Reporting	• Prepare a report to describe results of the field investigations for insertion into permit applications.

Roadmap Element	Example Activities
Develop and Implement Pilot Testing Plan	
Develop injection well pilot testing plan	• Identify location to drill and construct an injection well to be used during pilot testing. • Describe the approach for pilot testing including testing duration, injection cycling, sampling, and monitoring. • Prepare specifications and bidding document to procure mechanical contractor to construct pilot testing facility: wellhead, chemical feed systems, shelter, and other appurtenances. • Acquire aquifer storage and recovery (ASR) permits for pilot testing.
Implement injection well pilot test	• Perform injection and recovery tests, which would likely include storage injection cycle testing, sampling, hydraulic monitoring, well performance analysis, assessment of TSS content, and water quality analysis of recharge and recovered water.
Reporting	• Prepare a report describing results of the pilot testing for submission to regulators.
Feasibility Study	
Feasibility study	• Build upon the Preliminary Feasibility Study with information from the follow-on evaluations. • Evaluate different operational strategies, if desired.
Agreements	
Update agreement between SDCWA and Ramona MWD	• Based on the feasibility study, update existing agreement between the SDCWA to include additional untreated water deliveries
Water use agreement between Ramona MWD and City of San Diego	• Develop an agreement for delivering untreated or treated water between Ramona MWD to the Basin based on feasibility study recommendations and aligned with the SDCWA and Ramona MWD's agreement.
Agreement development	• Develop agreements necessary for implementation and operation of strategy
Designs and Permitting	
Conceptual design (15%)	• Prepare/Advance design and cost estimates. • Continue coordinating with relevant agencies.
Design (30%)	• Advance the design and cost estimates. • Assess monitoring infrastructure needs. • Initiate CEQA, NEPA, and other environmental evaluations, as needed. • Prepare permit applications.
Design (60%–90%–100%)	• Complete the design and cost estimates. • Complete CEQA, NEPA, and other environmental documents, as needed. • Track permit applications to completion. • Identify mitigation needs and initiate implementation.
Bid and Construction	
Bid and construction	• Prepare specifications and bidding documents. • Select construction contractor(s). • Construct operations and monitoring facilities.
Information presented in this table is illustrated as a high-level roadmap in **Figure 4-3.**	

Table G-4: List of Constituents of Interest for Injection Wells

Constituent	Analysis Method	Purpose or Note
Sodium, Na	E200.7	General chemistry
Potassium, K	E200.7	General chemistry
Calcium, Ca	E200.7	General chemistry
Magnesium, Mg	E200.7	General chemistry
Chloride, Cl	E300.0	General chemistry
Total Alkalinity	SM2320B	General chemistry
Sulfate, SO_4	E300.0	General chemistry
Total Dissolved Solids, TDS	SM2540C	General chemistry
Silica, SiO_2	SM4500-SiO2-D	General chemistry
pH	Field probe	Field parameters
Water Temperature	Field probe	Field parameters
Specific Conductance	Field probe	Field parameters
Oxidation-Reduction Potential, ORP	Field probe	Field parameters
Dissolved Oxygen	Field probe	Field parameters
Turbidity	Field probe	Field parameters
Dissolved Iron, Fe	E200.7	Redox indicators
Dissolved Manganese, Mn	E200.7	Redox indicators
Nitrate, NO_3	E300.0	Redox indicators
Ammonia, NH_3	E350.1	Redox indicators
Total Organic Carbon, TOC	SM5310B or C	Redox indicators
Dissolved Aluminum, Al	E200.7	Clay swelling potential
Orthophosphate as P	SM4500-PE	Competitive desorption
Total Phosphorus, P	SM4500-PE	Competitive desorption
Total Kjeldahl Nitrogen, TKN	SM4500-N_{org}B or C	Oxidation of organic material
Total Arsenic, As	E200.7	If known or suspected to be present in groundwater
Dissolved Arsenic, As	E200.7	If known or suspected to be present in groundwater

Table G-5: Implementation Elements and Activities for Strategy 1B

Roadmap Element	Example Activities
Follow-on Evaluations	
Conceptual design (5%) and feasibility assessment	• Develop conceptual design including dam type, preliminary abutment locations, concrete foundation size, dam height, side slope targets, control room location, inlet/outlet piping locations, monitoring infrastructure, and earthwork required. • Determine right of way and agency considerations. • Develop preliminary cost estimates including mitigation. • Conduct hydrologic analysis of Santa Ysabel Creek to determine infiltration basin size, infiltration capacity, water budget, and potential performance. • Determine cost effectiveness.
Assess permitting requirements and feasibility concurrent with conceptual design (5%)	• Conduct preliminary environmental impact assessment. • Identify permitting agencies and permits required. • Coordinate with permitting agencies. • Assess likely mitigation requirements and costs.
Feasibility Study	
Feasibility study	• Build upon the Preliminary Feasibility Study with information from the follow-on evaluations. • Evaluate different operational strategies, if desired.
Agreements	
Agreement development	• Develop agreements necessary for implementation and operation of strategy
Designs and Permitting	
Conceptual design (15%)	• Advance the design and cost estimates. • Continue coordinating with relevant agencies.
Design (30%)	• Advance the design and cost estimates. • Assess monitoring infrastructure needs. • Initiate CEQA, NEPA, and other environmental evaluations, as needed. • Prepare permit applications.
Design (60%–90%–100%)	• Complete the design and cost estimates. • Complete CEQA, NEPA, and other environmental documents, as needed. • Track permit applications to completion. • Identify mitigation needs and initiate implementation.
Bid and Construction	
Bid and construction	• Prepare specifications and bidding documents. • Select construction contractor(s). • Construct operations and monitoring facilities.
Information presented in this table is illustrated as a high-level roadmap in **Figure 4-4.**	