TECHNICAL MEMORANDUM

TO: San Pasqual Valley Groundwater Sustainability Agency

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DATE: May 22, 2023

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

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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.

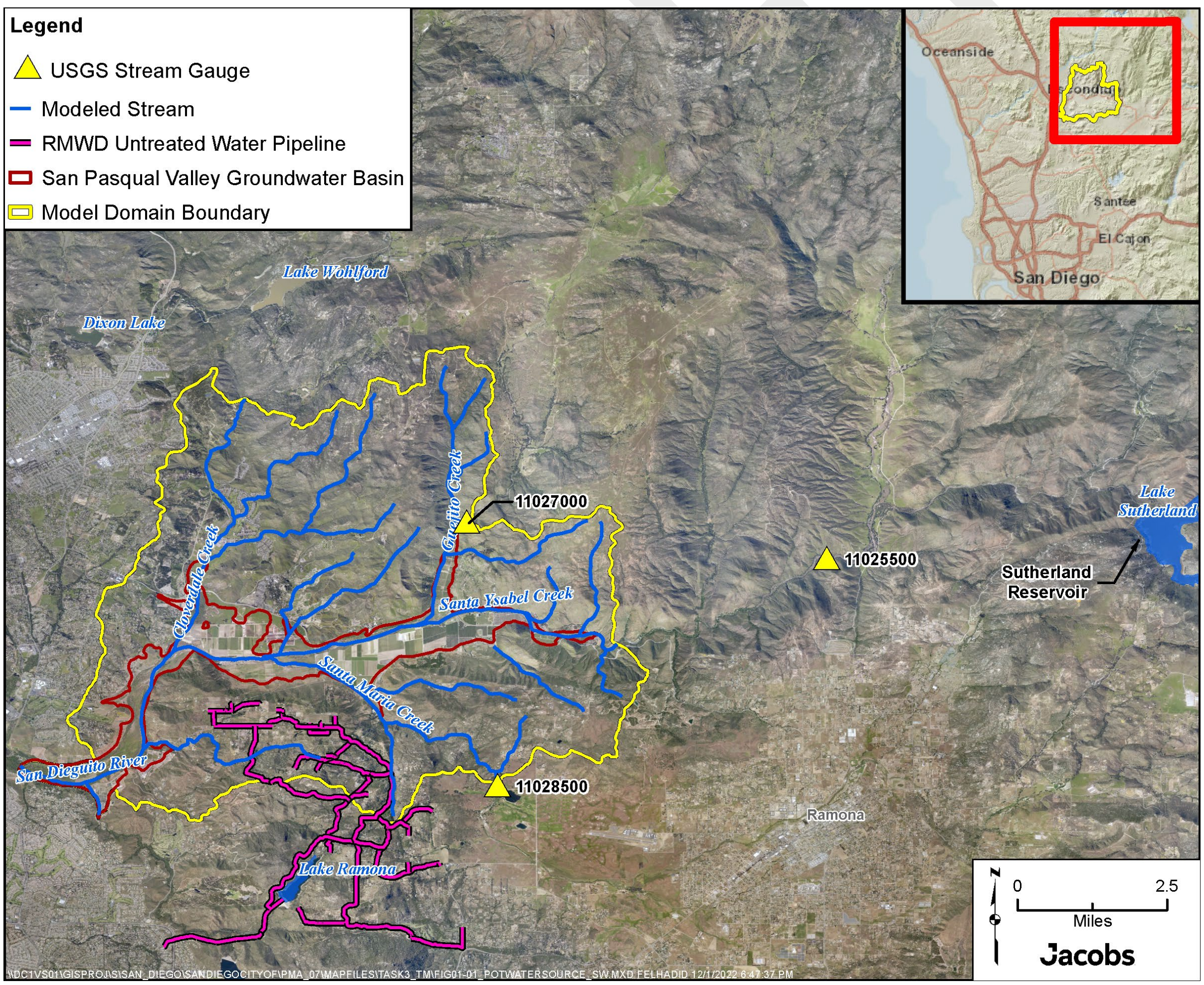

Figure 1-1 Regional Location Map

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

<table>
<tr><th>Recharge Strategy</th><th>Anticipated Benefits</th><th>Anticipated Challenges</th></tr>
<tr><td>Strategy 3D: Enhance groundwater recharge via injection wells with Ramona MWD’s untreated water system deliveries</td><td>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</td><td>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</td></tr>
<tr><td colspan="3">[a] Frequency of backflushing is determined during the pilot test phase and could be as frequent as daily to weekly</td></tr>
</table>

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.

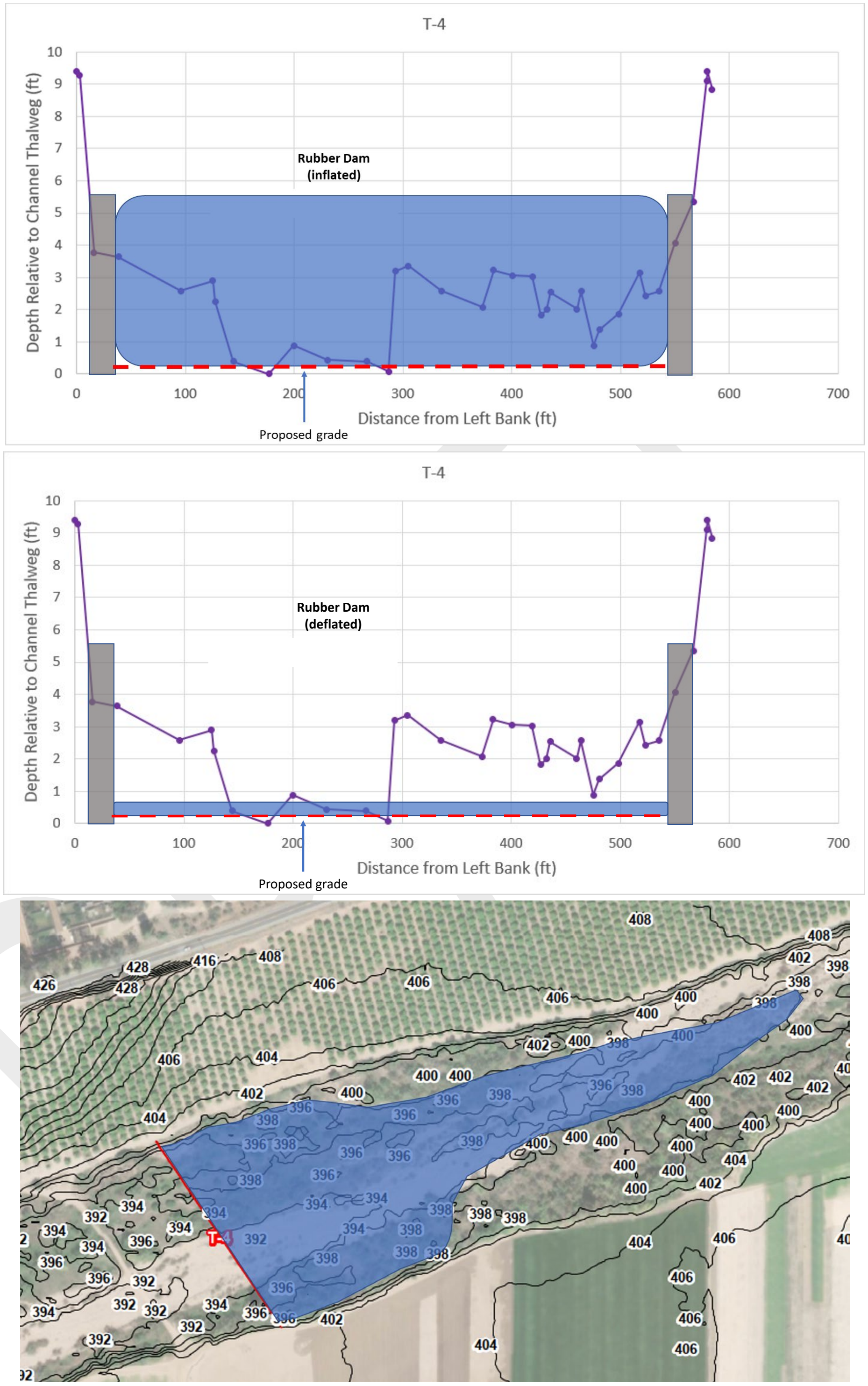

Figure 3-1 Concept Design for Permanent Rubber Dam Across Entire Santa Ysabel Creek Channel at Transect 4

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.

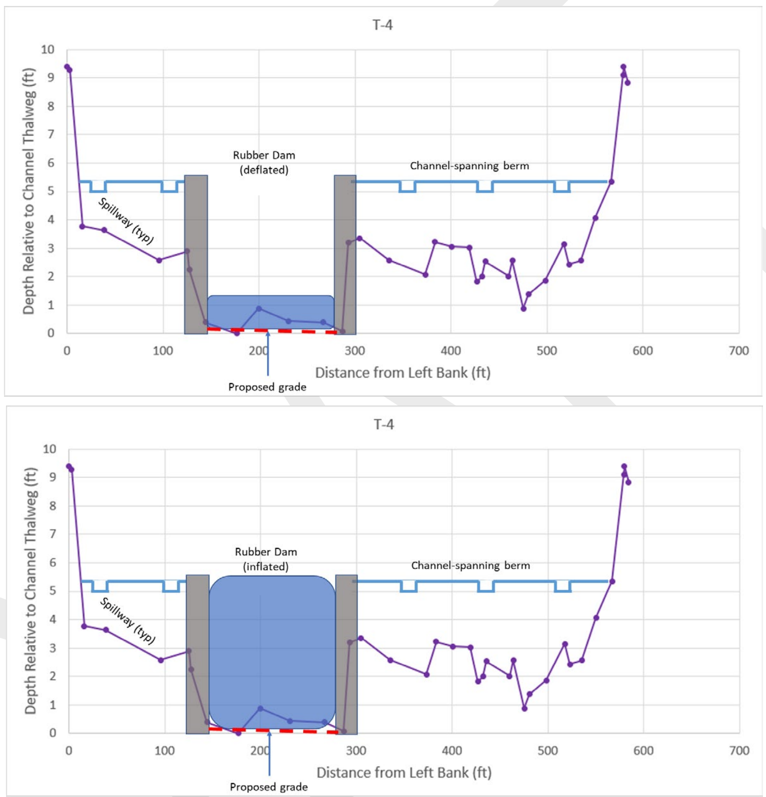

Figure 3-2 Permanent Rubber Dam in main channel with berms in remaining flood plain

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.

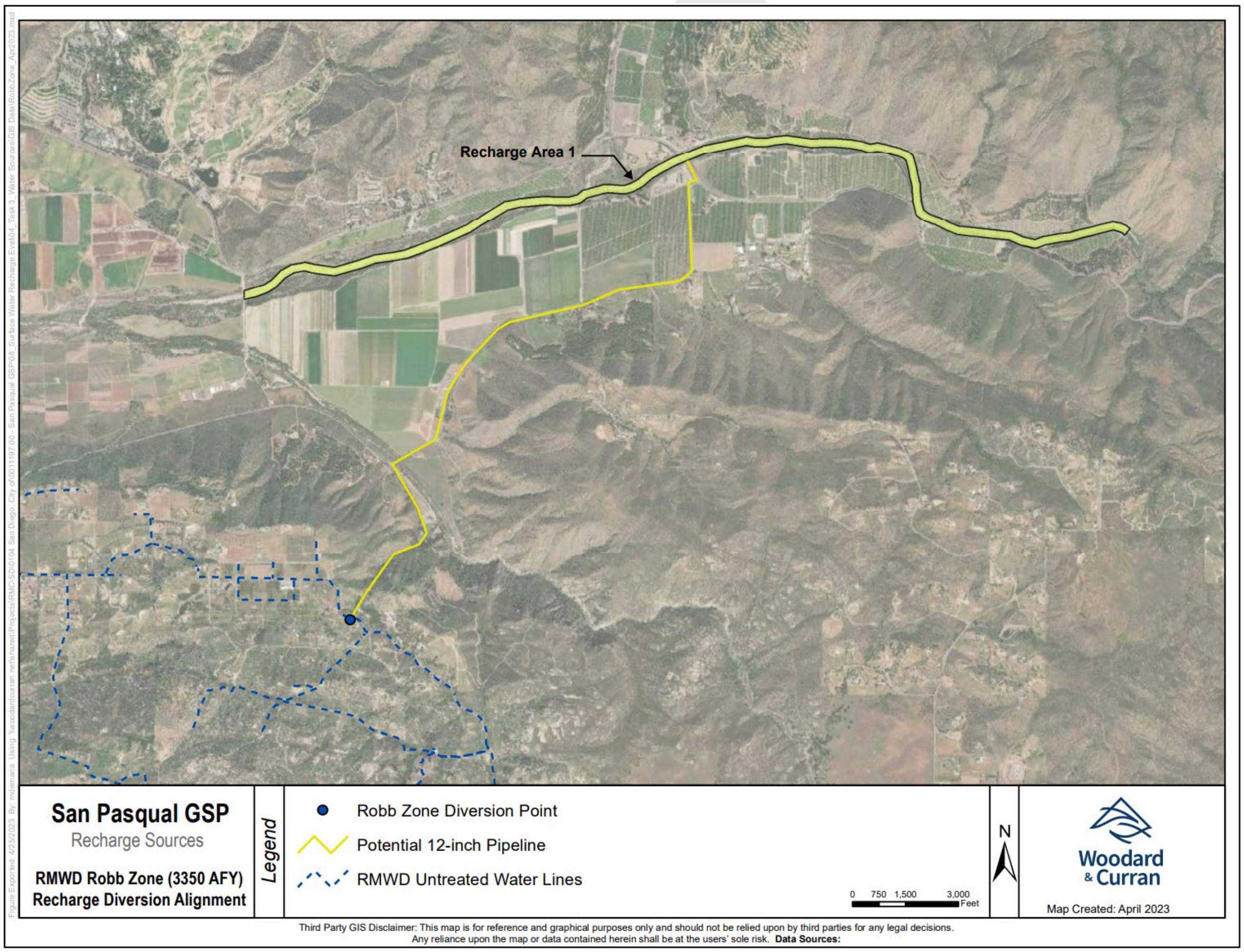

Figure 3-3 Potential Pipeline Route to Santa Ysabel Creek from Robb Zone Diversion Point

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

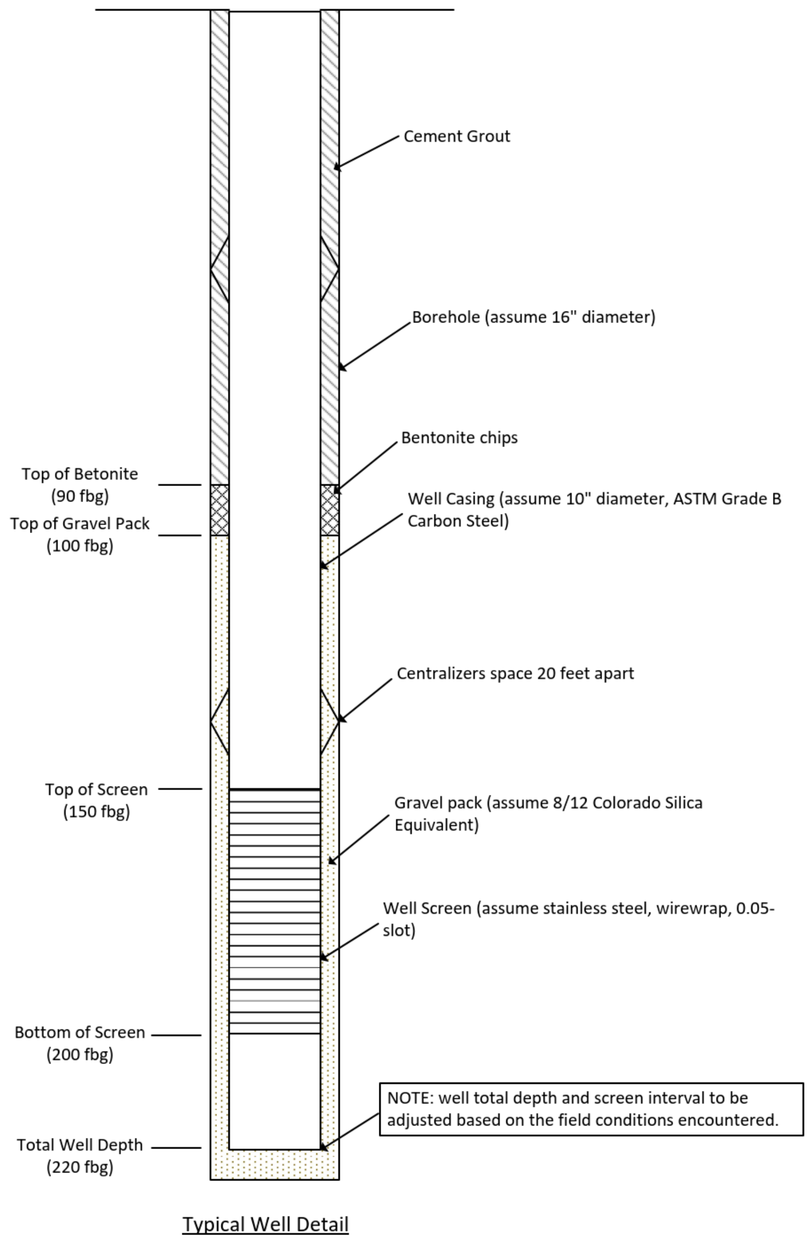

Figure 3-4 Typical Injection Well Concept Schematic

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.

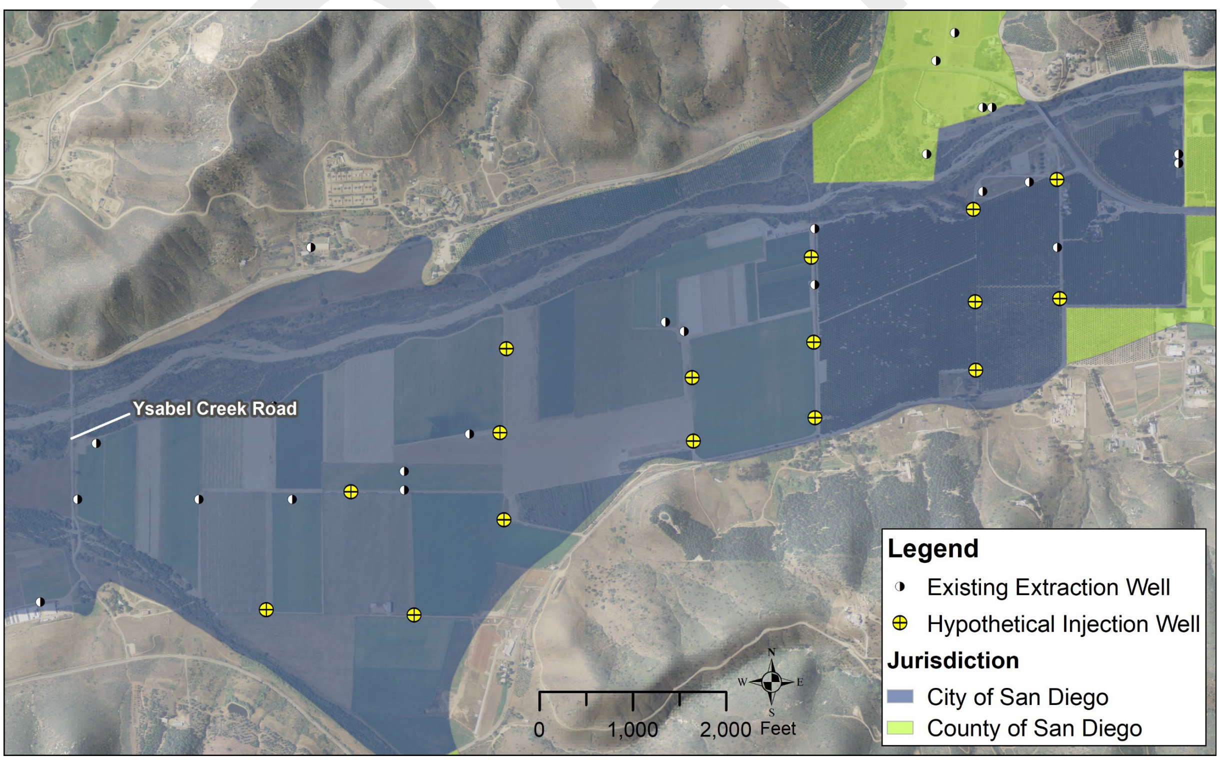

Figure 3-5 Conceptual Injection Well Locations (planning purposes only)

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.

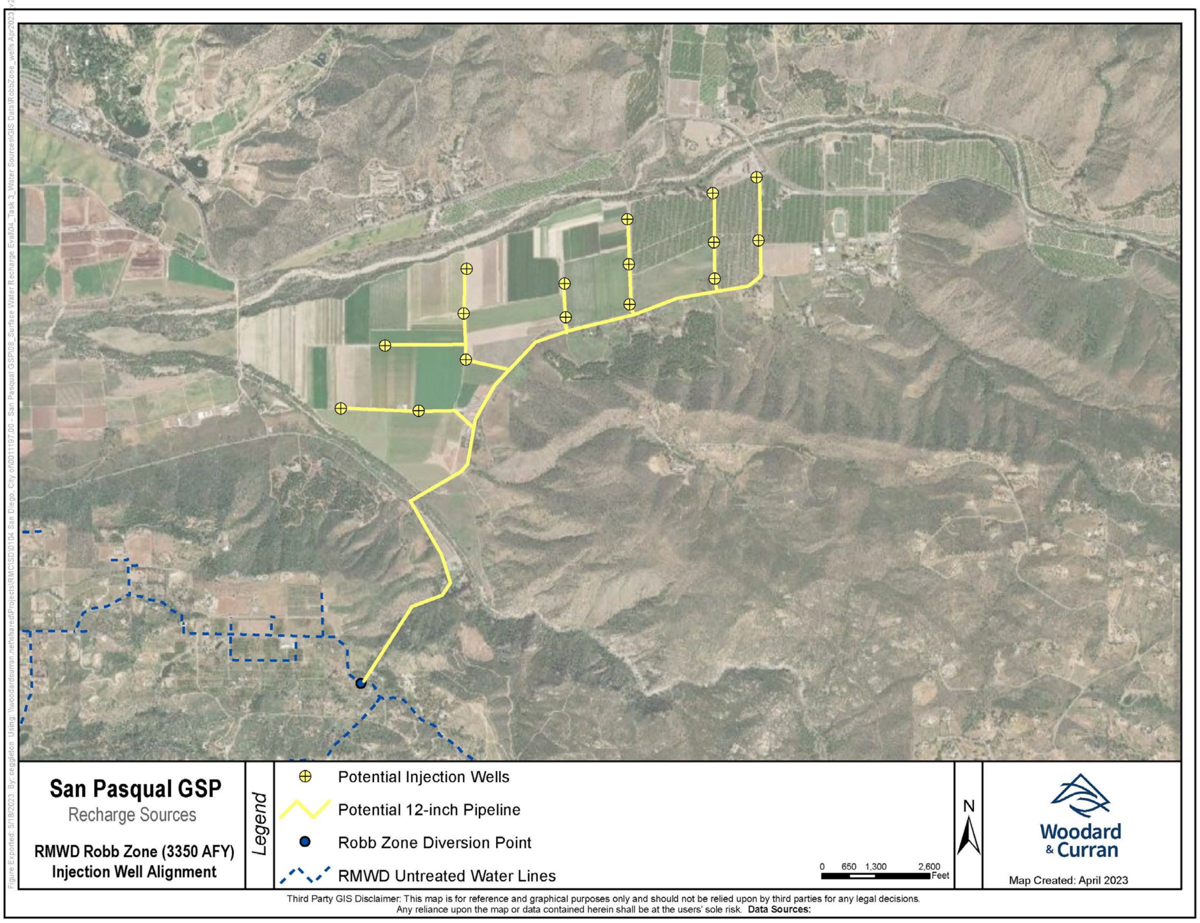

Figure 3-6 Potential Conveyance Pipelines for Strategy 3D

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.

5. REFERENCES

California Regional Water Quality Control Board (Water Board). 2021. Water Quality Control Plan for the San Diego Basin (9). San Diego Region. September 8, 1994 with amendments effective on or before September 1, 2021).

CH2M HILL Engineers, Inc (CH2M). 2016. *Technical Memorandum. San Pasqual Valley Groundwater Recharge Options.* Prepared for George Adrian and Larry Abutin of City of San Diego. December.

City of San Diego (City). 2008. Letter to Ralph Melintosh, Operations Manager. Subject Line: Water Available to Sutherland Reservoir.

City of San Diego (City). 2010. *San Pasqual Groundwater Conjunctive Use Study. Final Study Report.* Prepared by CDM. May.

City of San Diego (City). 2015. *2015 Watershed Sanitary Survey Chapter* 2: Description of Source Water System.

City of San Diego (City). 2020. *2020 Sutherland Outlet Works Status and Drawdown Alternatives*. Prepared by City of San Diego, Public Utilities Department, Water System Operations Division, Water Resources Engineering Section.

City of San Diego (City). 2021. *Area vs Capacity Curve of Sutherland Reservoir*. Data provided in spreadsheet format by the City of San Diego Public Utilities Department of Production Engineering. File: Sutherland 2021 Area Capacity Excel Table.xlsx.

City of San Diego (City). 2022a. *Technical Memorandum. Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 1: Development of Evaluation Criteria.* Prepared by Woodard & Curran. May.

City of San Diego (City). 2022b. *Spillway capacity curve of Sutherland Reservoir*. Data provided in spreadsheet format by the City of San Diego Public Utilities Department of Production Engineering. File: Sutherland Spillway Capacity.xlsx.

City of San Diego (City). 2022c. *Sutherland Monthly Historic Hydrograph for the period of March 1954 – May 2022.* Data provided in spreadsheet format by the City of San Diego Public Utilities Department of Production Engineering. May, 2022.

City of San Diego (City). 2022d. *Responses to information requests on Sutherland Reservoir from the City of San Diego Public Utilities Department of Production Engineering.* Data provided in pdf format by the City of San Diego Public Utilities Department of Production Engineering. File: WPD Responses_Sutherland Reservoir Information Request.pdf. July, 2022.

City of San Diego (City). 2023a. *Technical Memorandum. Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 2: Streambed Investigation.* Prepared by Jacobs. January 2023.

City of San Diego (City). 2023b. *Technical Memorandum. Project Management Action (PMA) No. 7: Initial Surface Water Recharge Evaluation, Task 3: Water Sources for Potential Recharge.* Prepared by Jacobs and Woodard & Curran. January.

City of San Diego (City) and County of San Diego (County). 2022. *San Pasqual Valley Basin Groundwater Sustainability Plan Annual Report for Water Years 2020 and 2021.* Prepared by Woodard & Curran. March.

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.

Flint, L.E. and Flint, A.L., 2014, California Basin Characterization Model: A Dataset of Historical and Future Hydrologic Response to Climate Change, (ver. 1.1, May 2017): U.S. Geological Survey Data Release, https://doi.org/10.5066/F76T0JPB.

Flint, L.E., Flint, A.L., Thorne, J.H., and R. Boynton, 2013. Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance. Ecol Process 2, 25 (2013). https://doi.org/10.1186/2192-1709-2-25.

Ramona Municipal Water District (Ramona WMD) 1992. Letter to Pete Silva, Water Utilities Department. Subject Line: Lake Sutherland Water Exchange Agreement

Ramona Municipal Water District and City of San Diego (Ramona MWD and City). 2000. Agreement for Water Exchange and Water Transportation Between the City of San Diego and the Ramona Municipal Water District.

Ramona Municipal Water District (Ramona WMD) 2006. Letter to Mark Stone, Director of Water Operations. Subject Line: Water Exchange Report

Ramona Municipal Water District and City of San Diego (Ramona MWD and City). 2010. Amendment No. 1, To the Agreement for Water Exchange and Transportation Between the City of San Diego and the Ramona Municipal Water District.

Ramona Municipal Water District (Ramona MWD). 2021. *2020 Urban Water Management Plan*. Prepared for the District by Dudek. Encinitas, California: Dudek. June.

Ramona Municipal Water District (Ramona MWD). 2022a. Water Operations Department. Systems Divisions. Accessed November 10, 2022. https://www.rmwd.org/about-us/water-operations

Ramona Municipal Water District (Ramona MWD). 2022b. *Water Master Plan Update*, January 2022. Carollo.

Ramona Municipal Water District (Ramona MWD). 2022c. 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.

San Diego County Water Authority (CWA). 1990. *Optimal Storage Study Reservoir Summary Report* Prepared by James M Montgomery Consulting Engineers, Inc. March 1990.

San Diego County Water Authority (CWA). 2014. *Final 2013 Regional Water Facilities Optimization and Master Plan Update.* Prepared by CH2M HILL and Black & Veatch. March.

San Diego County Water Authority (CWA). 2021a. "Reservoirs: Reservoir Storage Data." Last updated September 26, 2022. Accessed November 10, 2022. https://www.sdcwa.org/your-water/reservoirs-rainfall/reservoirs/.

San Diego County Water Authority (CWA). 2021b. *2020 Urban Water Management Plan*. Public Review Draft. San Diego: Water Authority. March 2021.

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.

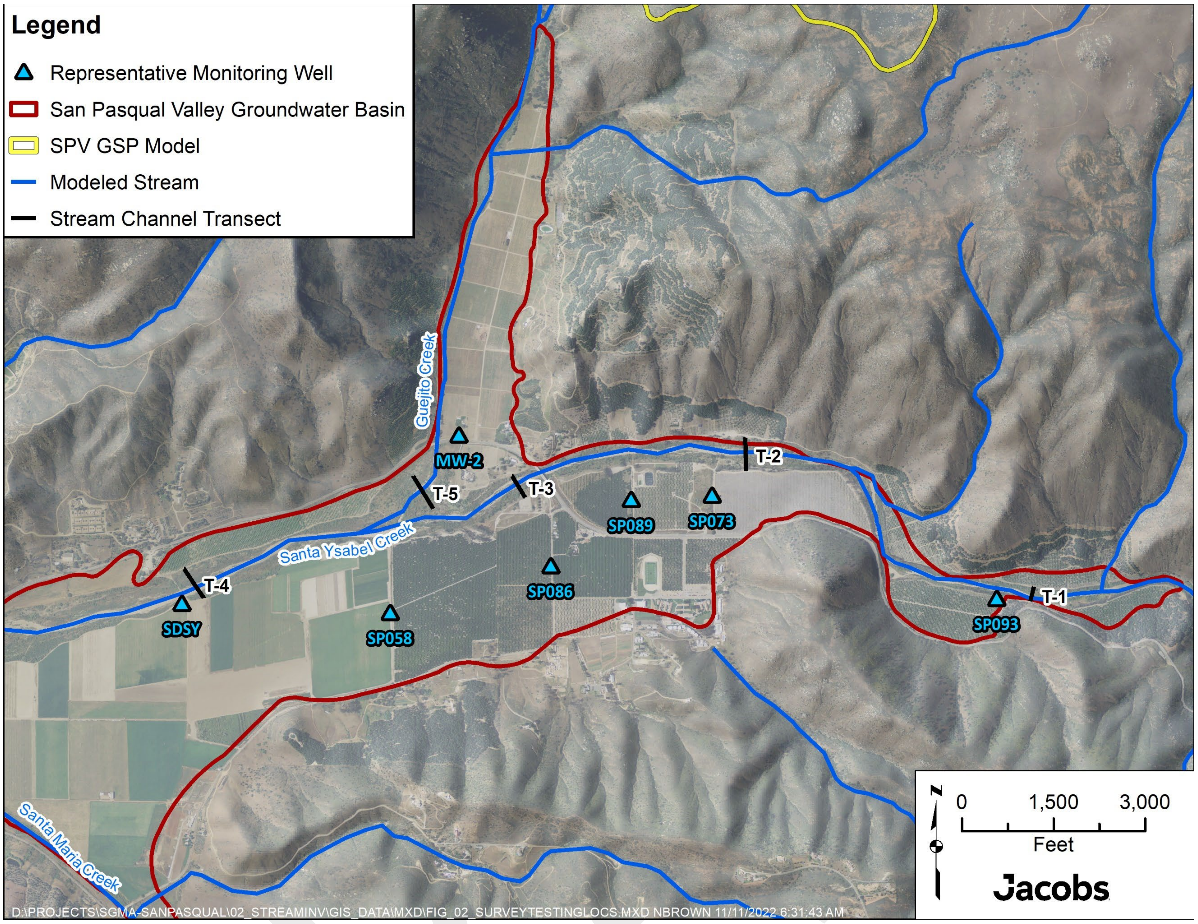

Figure A-3 Stream Channel Transect Locations

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.

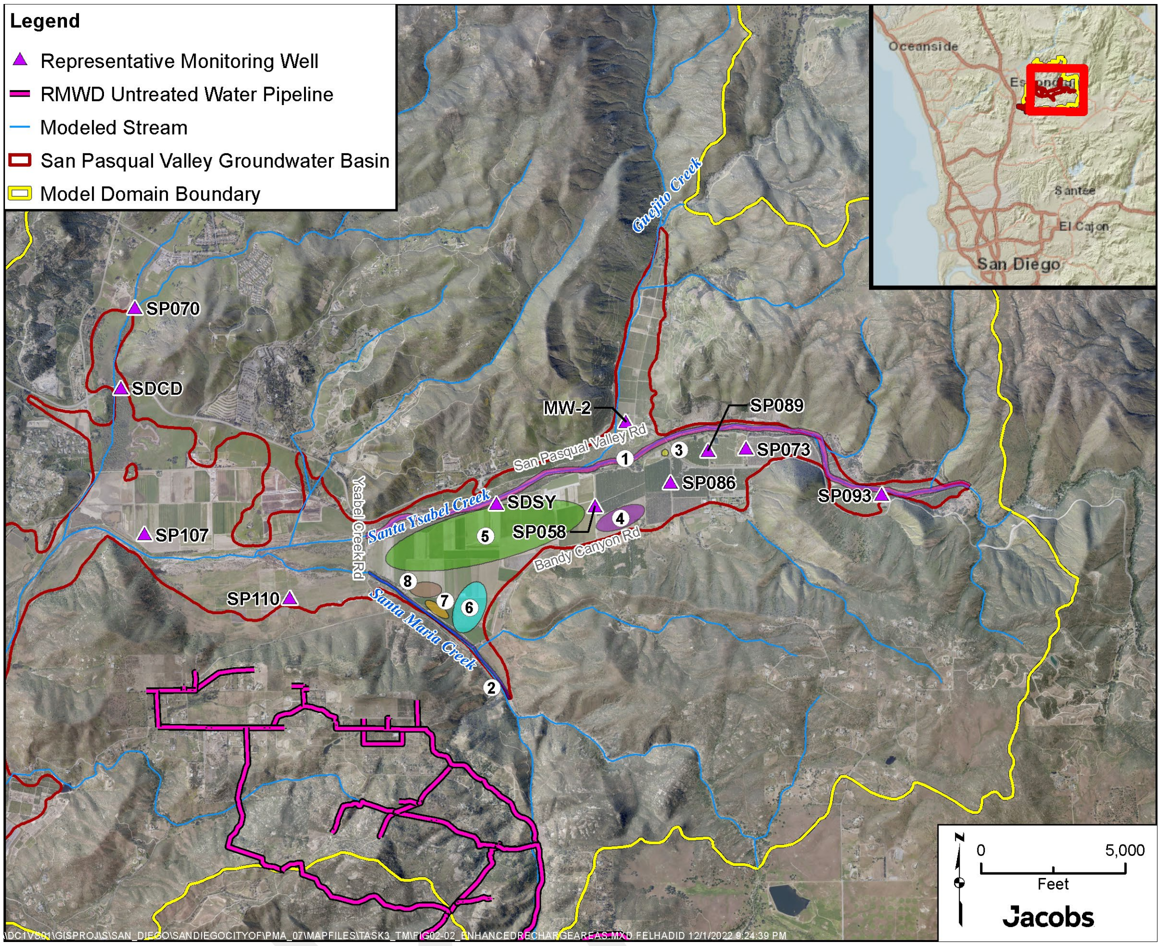

Figure A-4 Hypothetical Areas for Recharge (Areas 1 through 8) (City, 2023a)

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.

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)

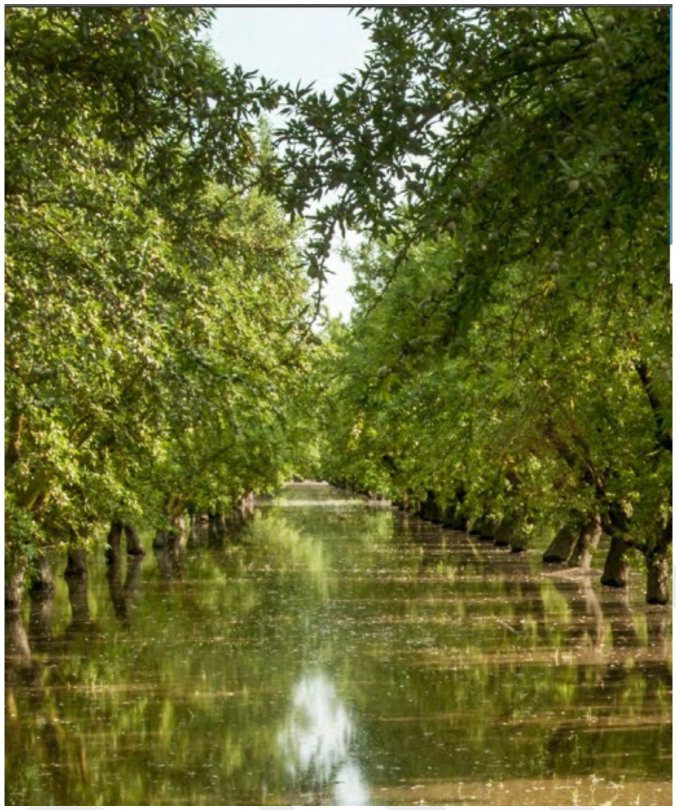

Figure A-5. Flooded orchard as a method to recharge aquifers.

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.

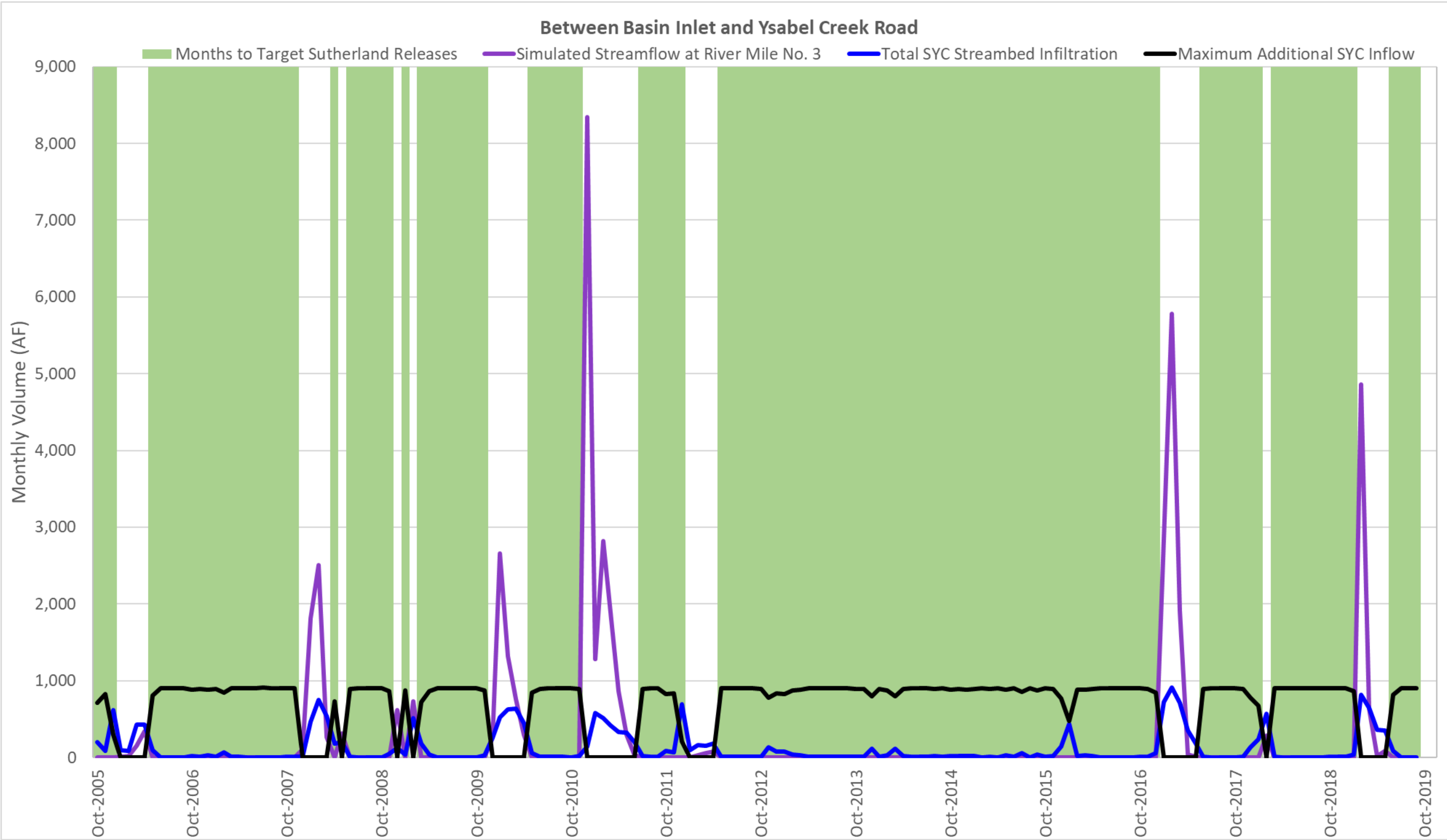

Figure D-0-1 Santa Ysabel Creek Streambed Infiltration Analysis to Support Development of Controlled Sutherland Releases

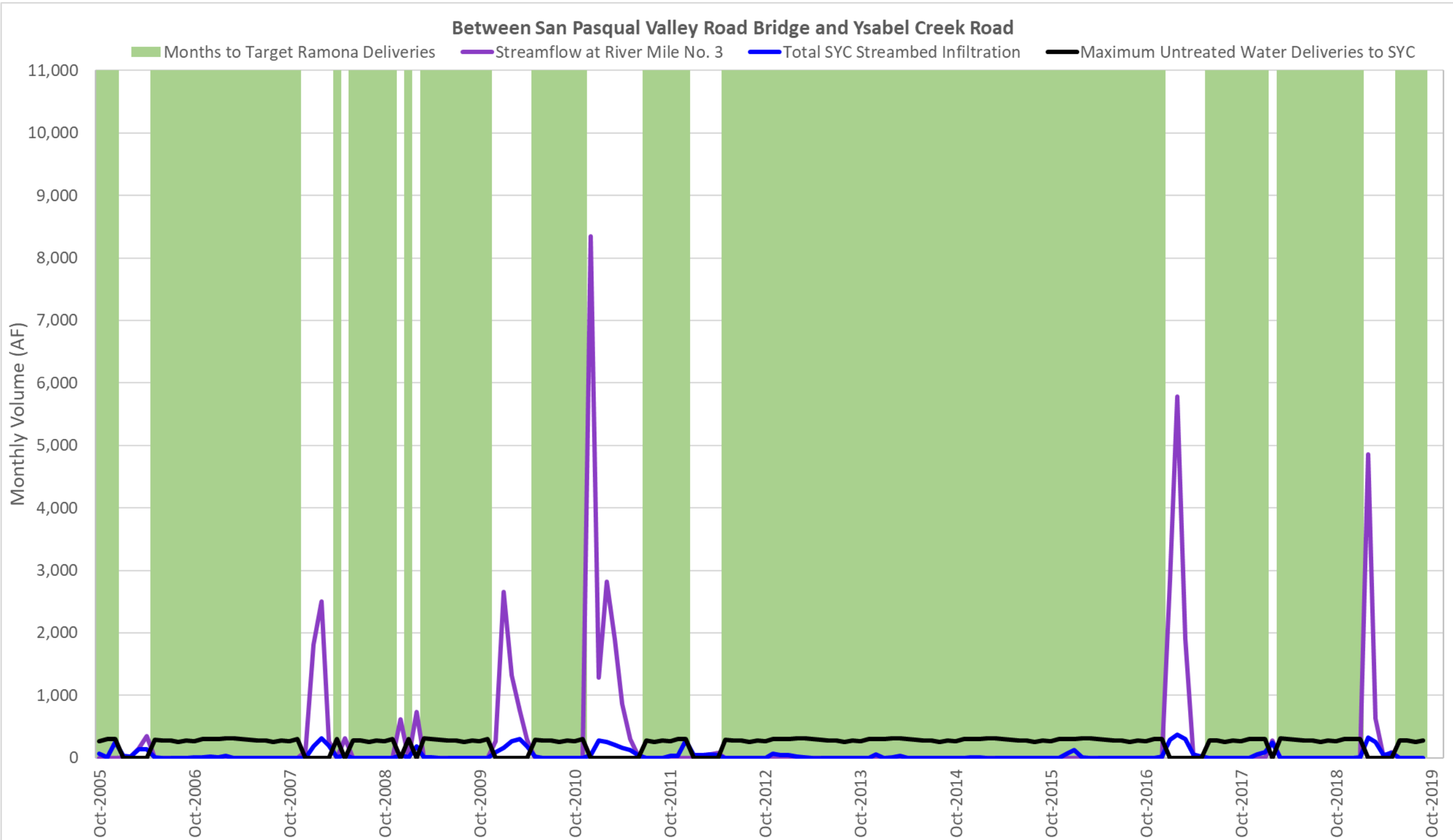

Figure D-0-2 Santa Ysabel Creek Streambed Infiltration Analysis to Support Development of Deliveries from Ramona MWD

ATTACHMENT E. ENHANCE STREAMFLOW INFILTRATION WITH IN-STREAM MODIFICATIONS

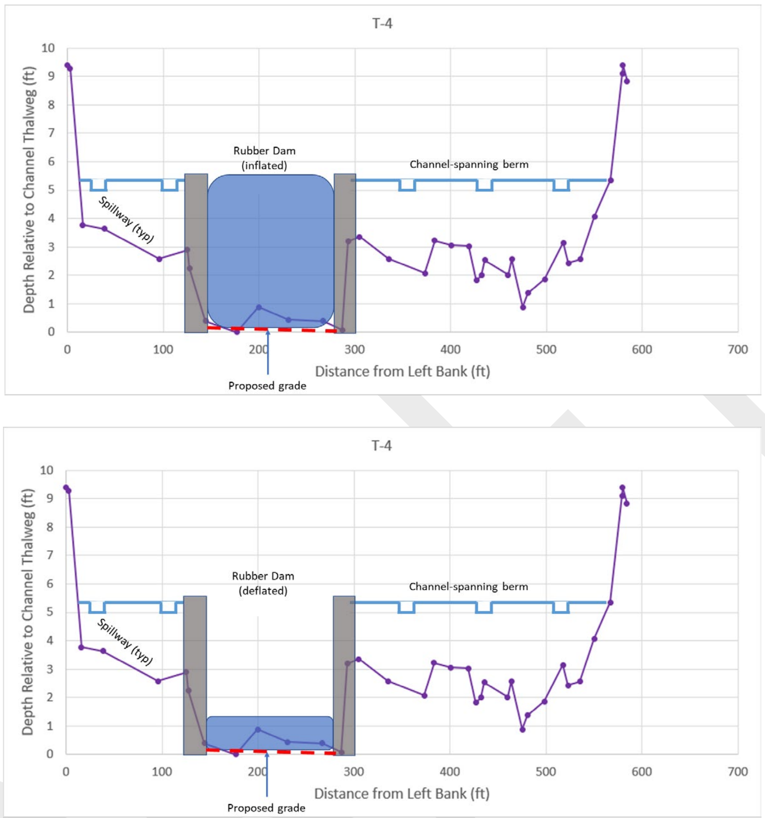

Figure E-0-3 Permanent Rubber Dam in main channel with berms in remaining flood plain

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.