TECHNICAL MEMORANDUM

TO: San Pasqual Valley Groundwater Sustainability Agency

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DATE: January 27, 2023

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

TABLE OF CONTENTS

ACRONYMS & ABBREVIATIONS

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

1. INTRODUCTION

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

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

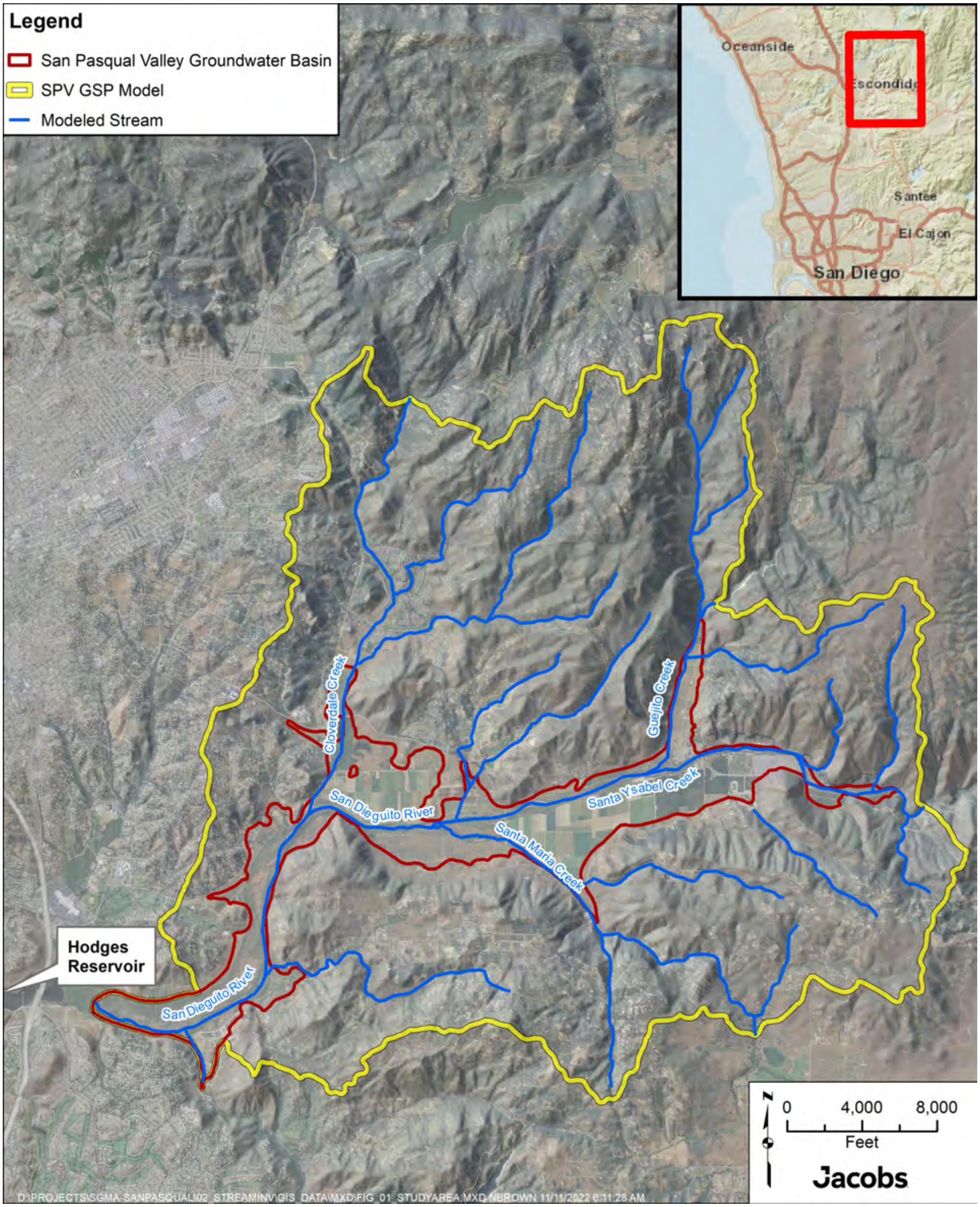

Figure 1-1. Model Domain and Streams

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

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

2. BACKGROUND

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

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

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

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

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

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

3. SCOPE OF WORK AND METHODOLOGY

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

3.1 Stream Channel Surveying

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

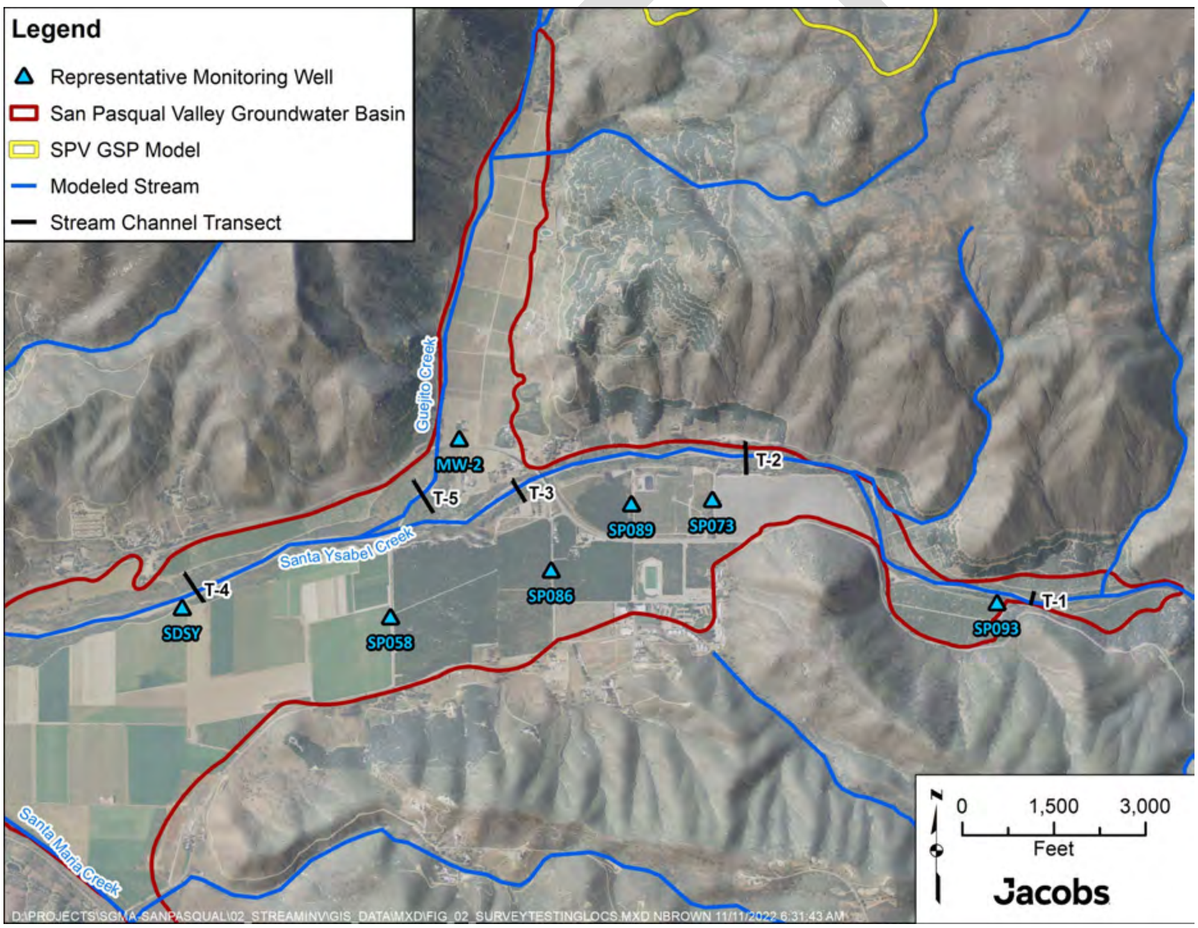

Figure 3-1. Stream Channel Transect Locations

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

3.2 Streambed Infiltration Testing

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

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

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

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

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

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

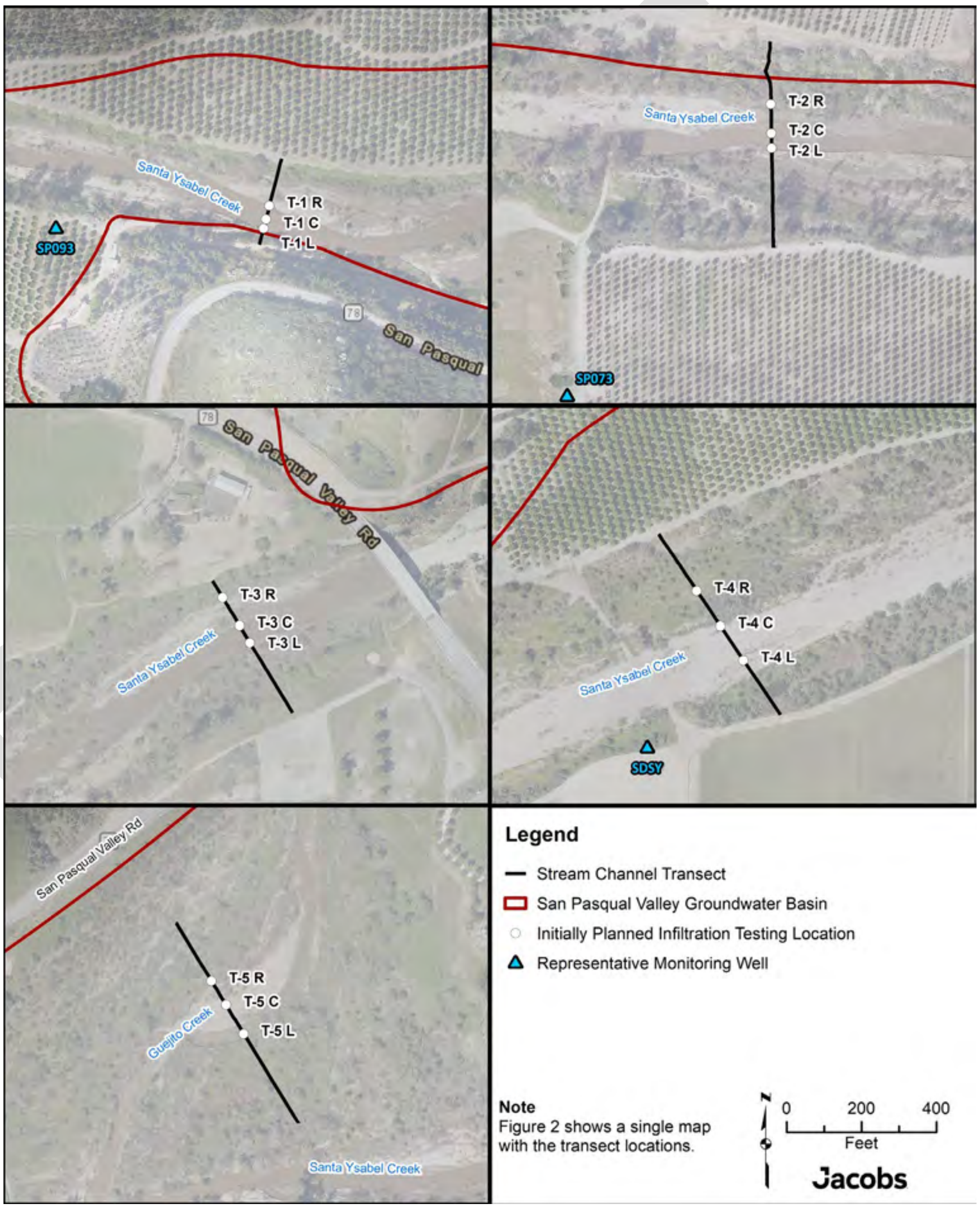

Figure 3-2. Initially Planned Infiltration Testing Locations

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

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

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

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

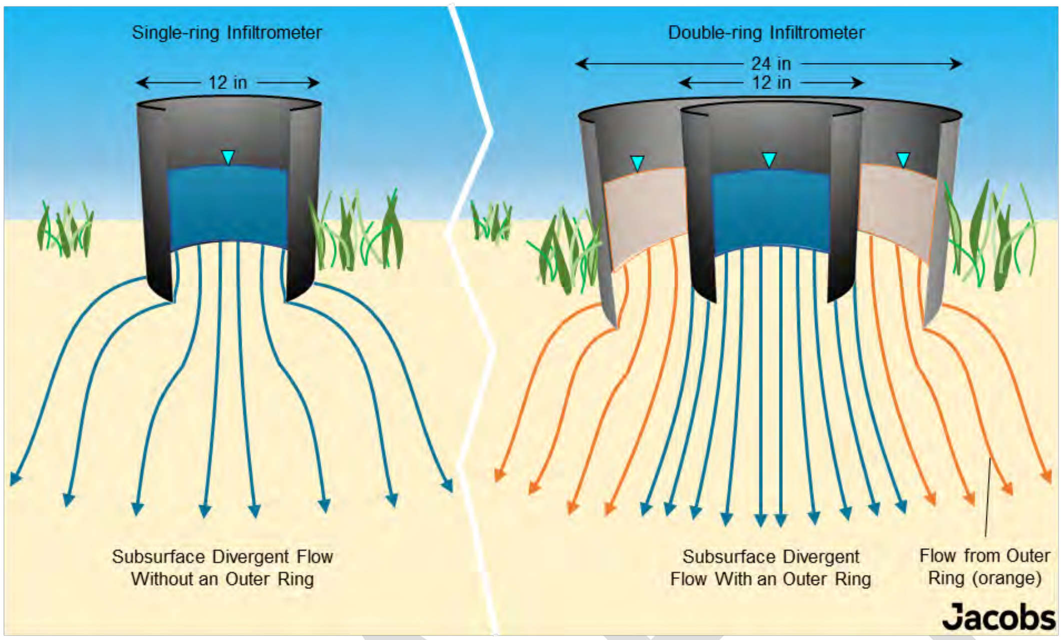

Figure 3-3. Depiction of Divergent Flow Paths with Standard Ring Infiltrometers

3.3 Photographic Surveys

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

4. STREAMBED INVESTIGATION RESULTS

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

4.1 Stream Channel Surveying

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

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

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

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

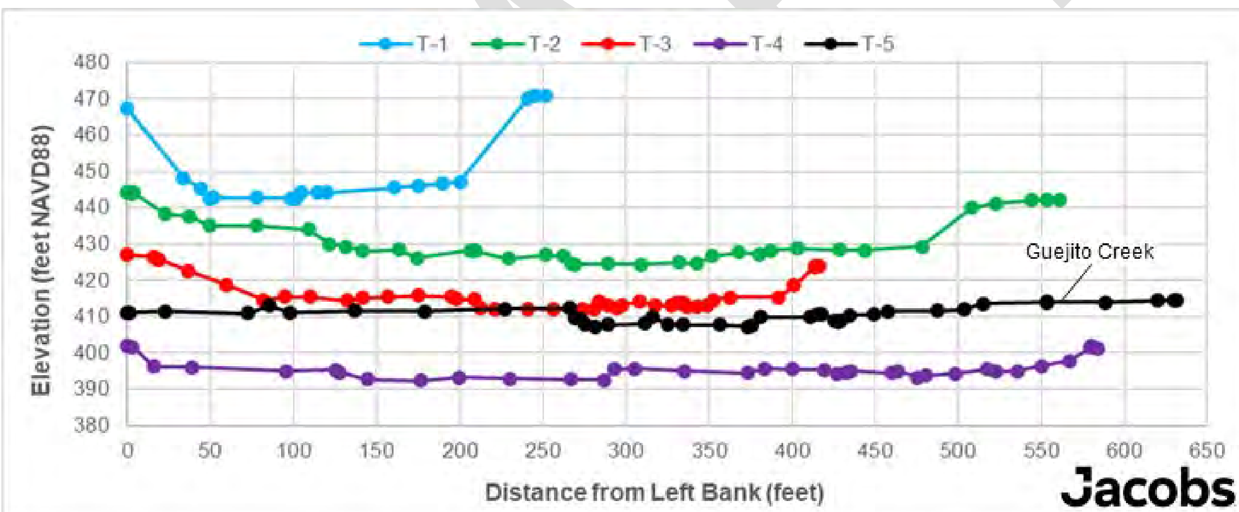

Figure 4-1. Stream Channel Profiles Along the Five Transects

4.2 Streambed Infiltration Testing Results

4.2.1 Modifications to the Infiltration Testing Methodology

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

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

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

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

4.2.2 Infiltration Testing Results

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

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

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

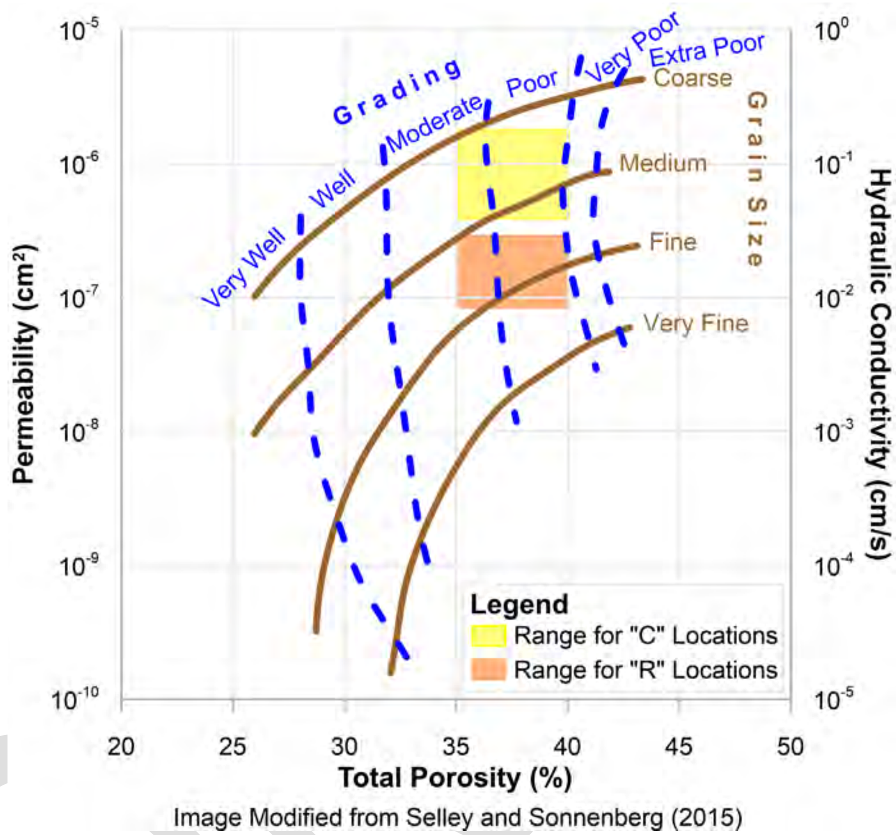

Figure 4-2. Relationships Among Different Physical Soil Parameters

Table 4-1. Summary of Infiltration Testing Results

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

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

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

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

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

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

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

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

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

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

where

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

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

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

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

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

4.3 Photographic Surveys

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

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

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

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

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

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

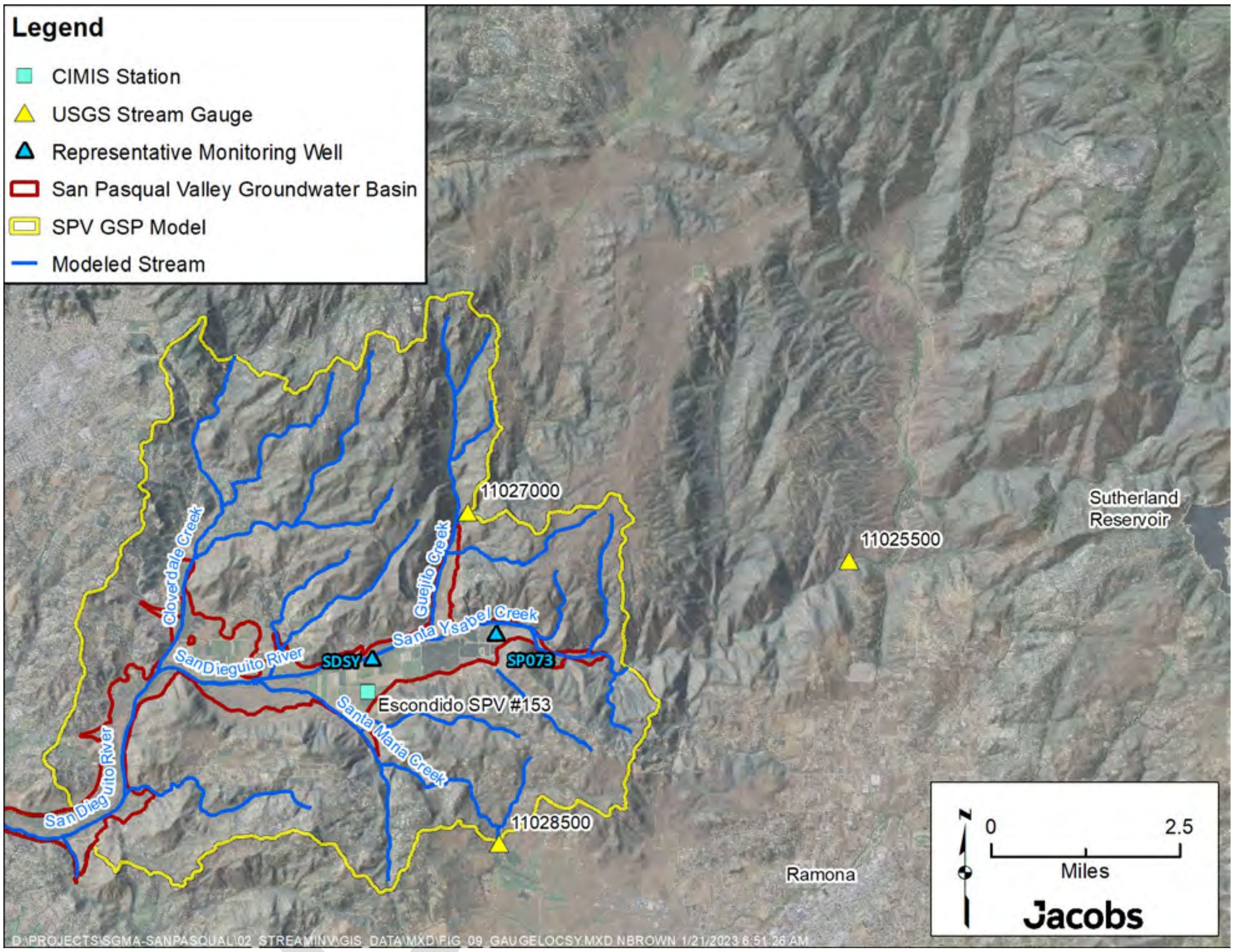

Figure 4-3. Stream and Precipitation Gauge Locations

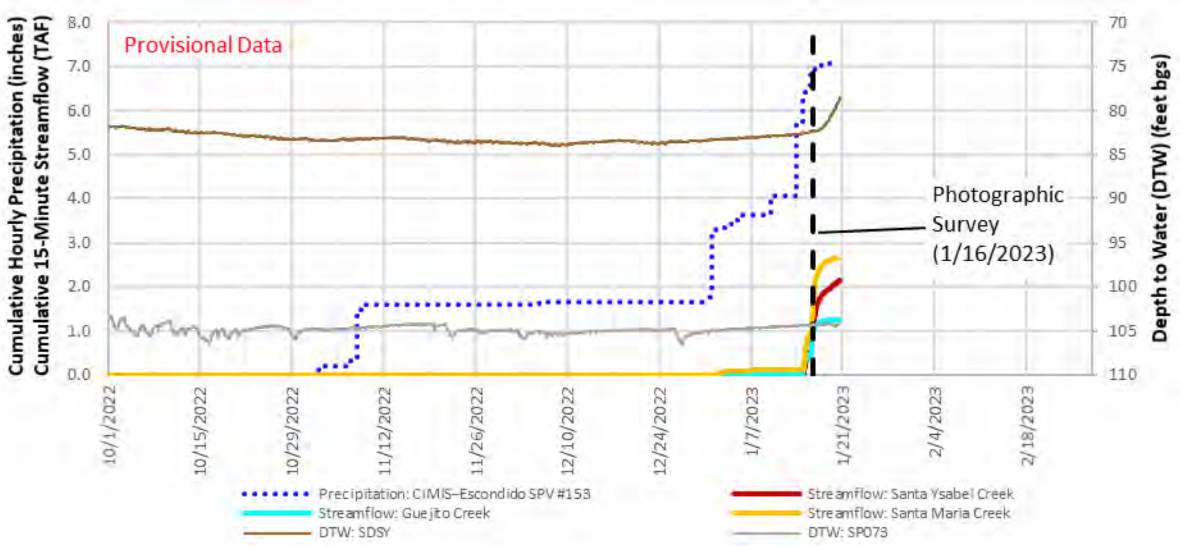

Figure 4-4. Hydrologic Conditions Before, During, and After the Photographic Survey

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

5. RECOMMENDATIONS FOR UPDATING THE SPV GSP MODEL

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

5.1 Stream Channel Definition and Calculation Method

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

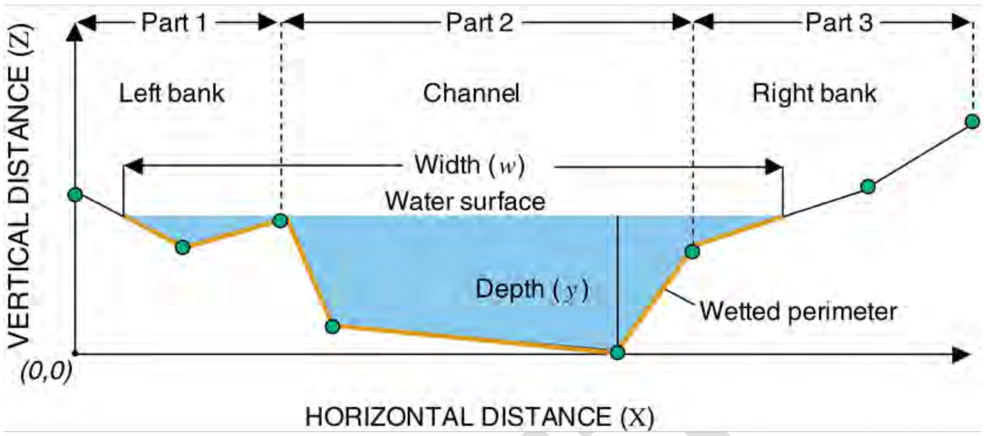

Image Source: Prudic et al. (2004)

Figure 5-1. Conceptual Eight-point Cross Section

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

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

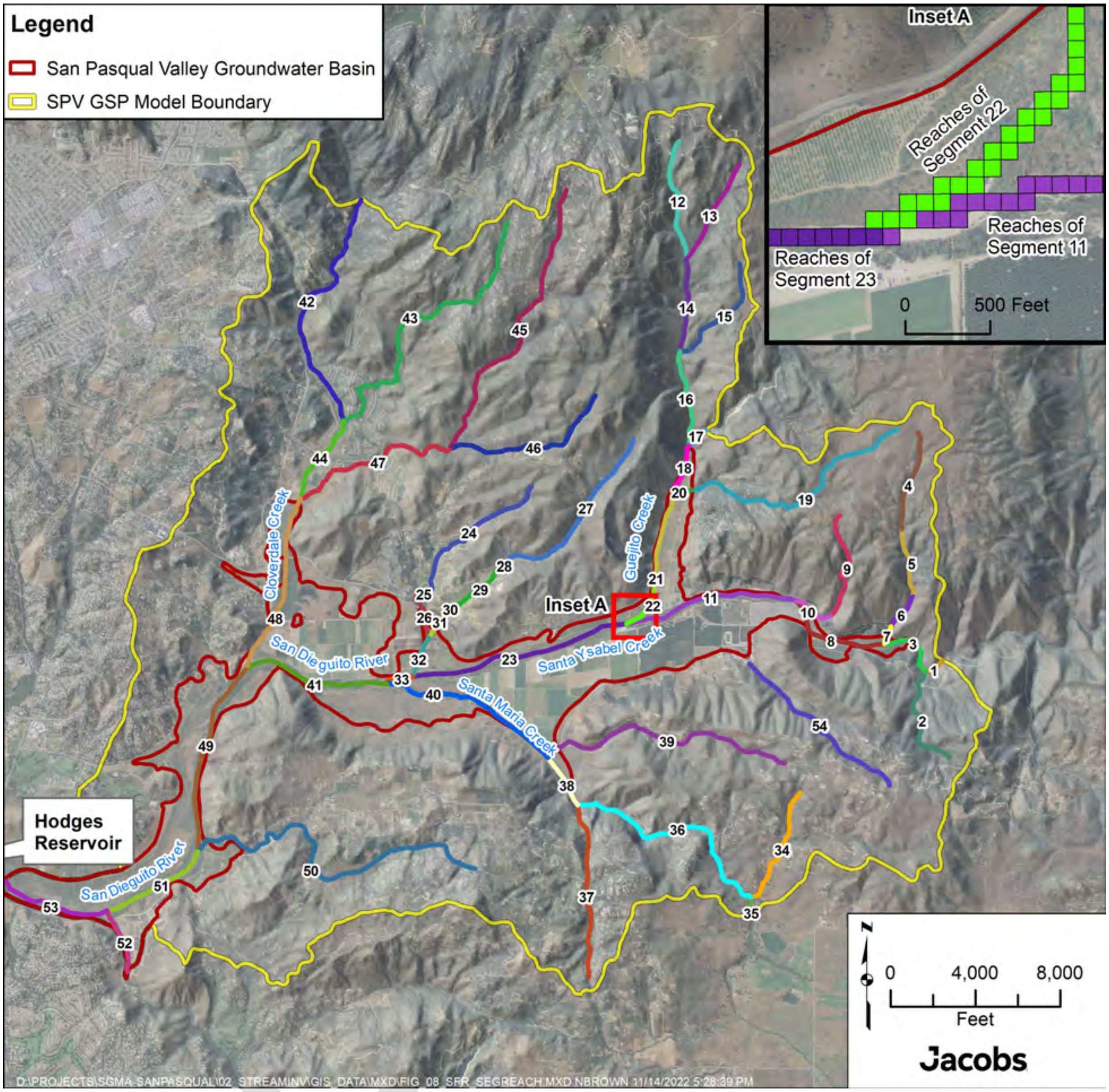

Figure 5-2. Map of Modeled Stream Segment Numbers and Stream Reaches

5.2 Approach for Updating Hydraulic Conductivity Assigned to Modeled Streams

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

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

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

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

where

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

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

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

5.3 Approach for Incorporating Results from the Photographic Survey

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

6. SUMMARY

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

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

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

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8. ATTACHMENT A: INFILTRATION TESTING LETTER REPORT

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November 9, 2022

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

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

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

Dear Ms. Johnson,

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

INTRODUCTION

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

SITE DESCRIPTION

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

SCOPE OF WORK

The geotechnical scope of work performed by Atlas consisted of:

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

INFILTRATION TESTING

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

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

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

GEOTECHNICAL LABORATORY TESTING

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

GEOLOGY AND SUBSURFACE CONDITIONS

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

Table 1: USCS Classifications of the Riverbed Materials

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

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

CLOSURE

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

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

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

Respectfully submitted,
Atlas Technical Consultants LLC

Douglas A. Skinner, CEG 2472
Senior Geologist

Morteza Mirshekari, PhD, PE C92374
Senior Engineer

JRD:JM:DAS:MM:ds

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

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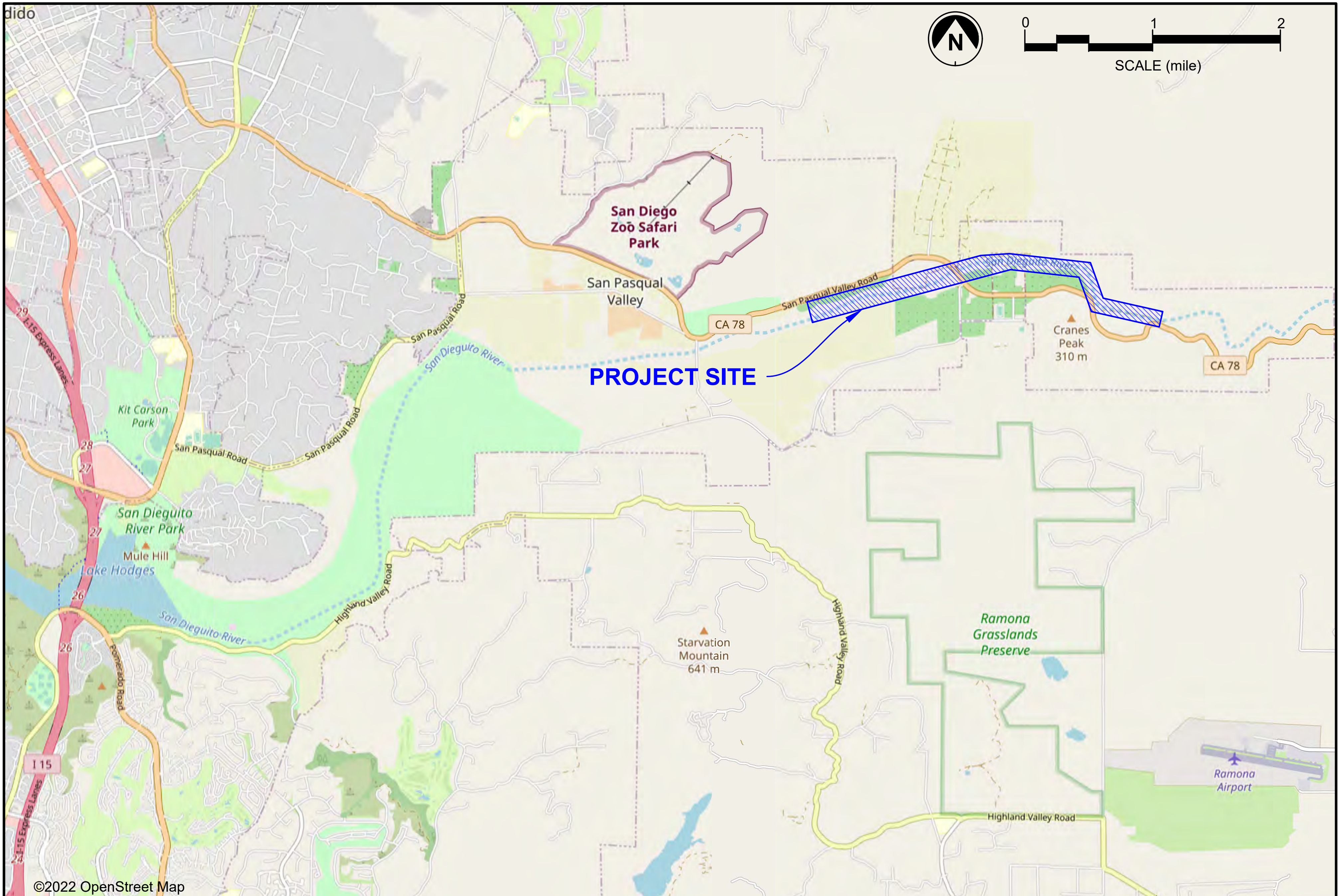


ATLAS

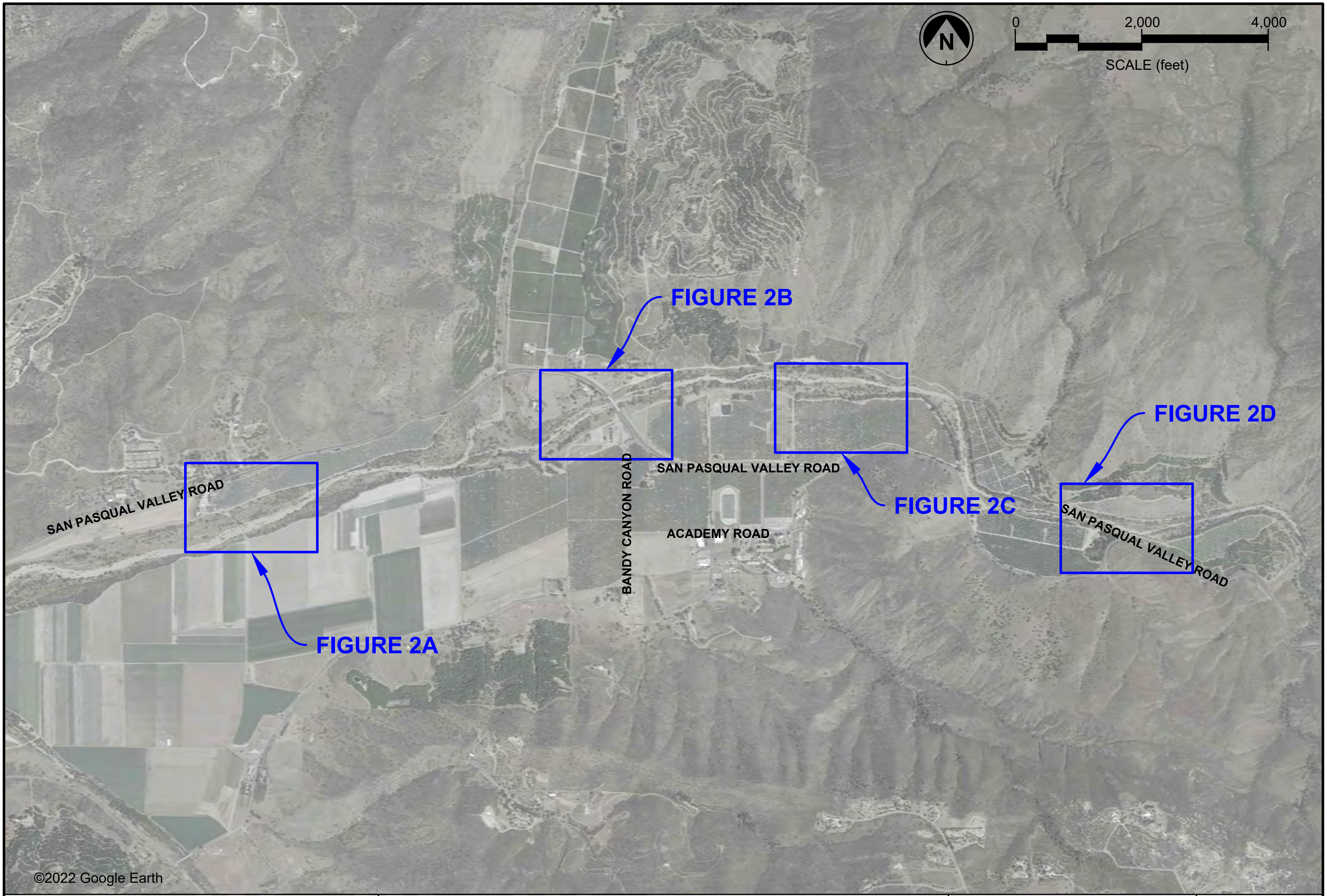
SITE VICINITY MAP

San Pasqual Valley Infiltration Testing

San Diego, California

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

Figure: 1



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

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

Figure:
2

ATLAS

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

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

Figure:
2A

LEGEND:

T3R — Location of Infiltration Testing

ATLAS

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

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

Figure:
2B

LEGEND:

T2R — Location of Infiltration Testing

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

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

Figure: 2C

LEGEND:

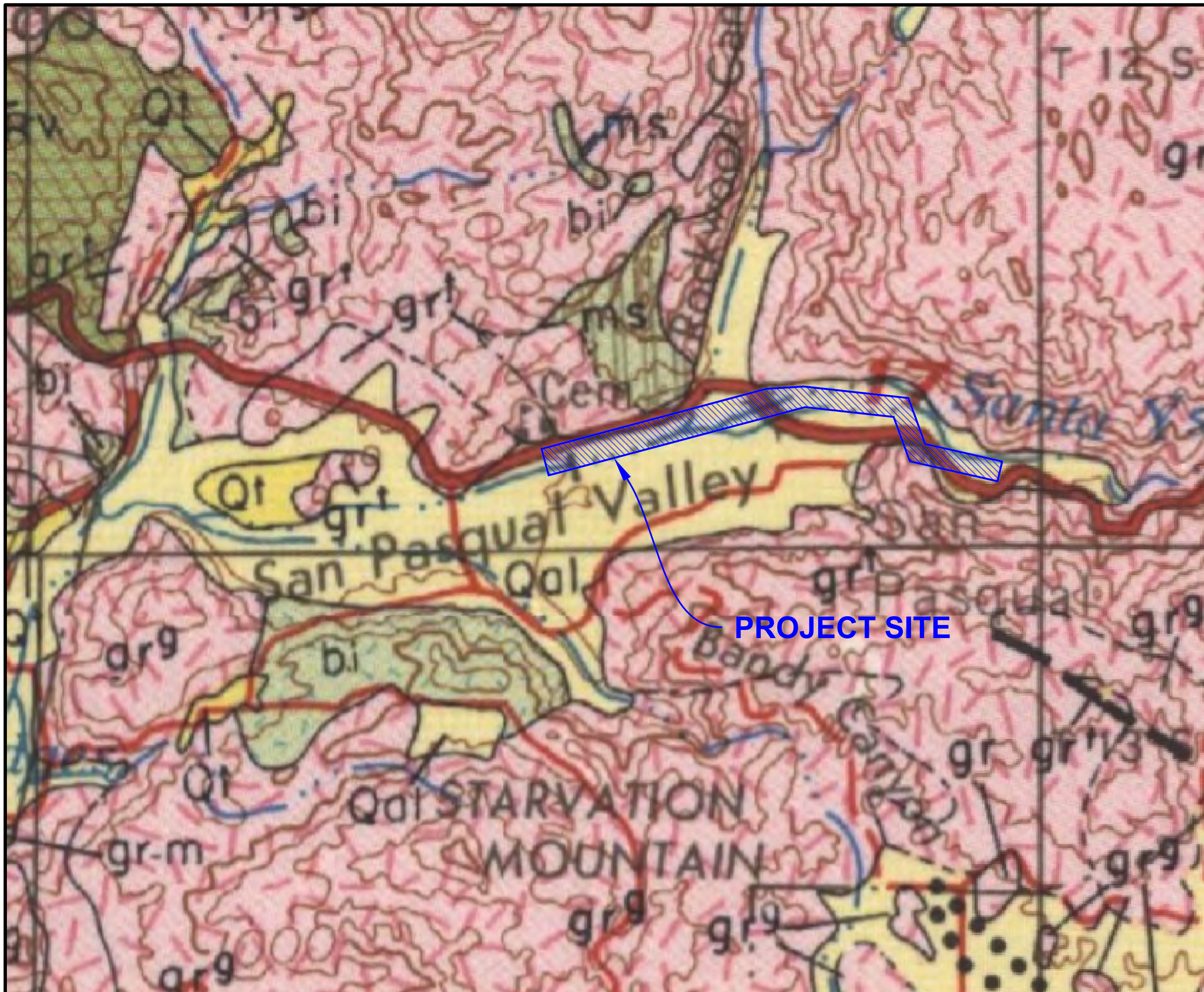
T1R Location of Infiltration Testing

ATLAS

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

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

Figure: 2D



EXPLANATION:

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

N

0 1 2

SCALE (mile)

NOTE: All locations are approximate.

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

ATLAS

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

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

Figure:
3

ATTACHMENT I
WELL PERMEAMETER INFILTRATION TESTING PROCEDURE

Modified Constant Head Well Permeameter Test

Pre-test Procedure

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

Test Procedure

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

Post-test Procedure

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

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

Miscellaneous Considerations

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

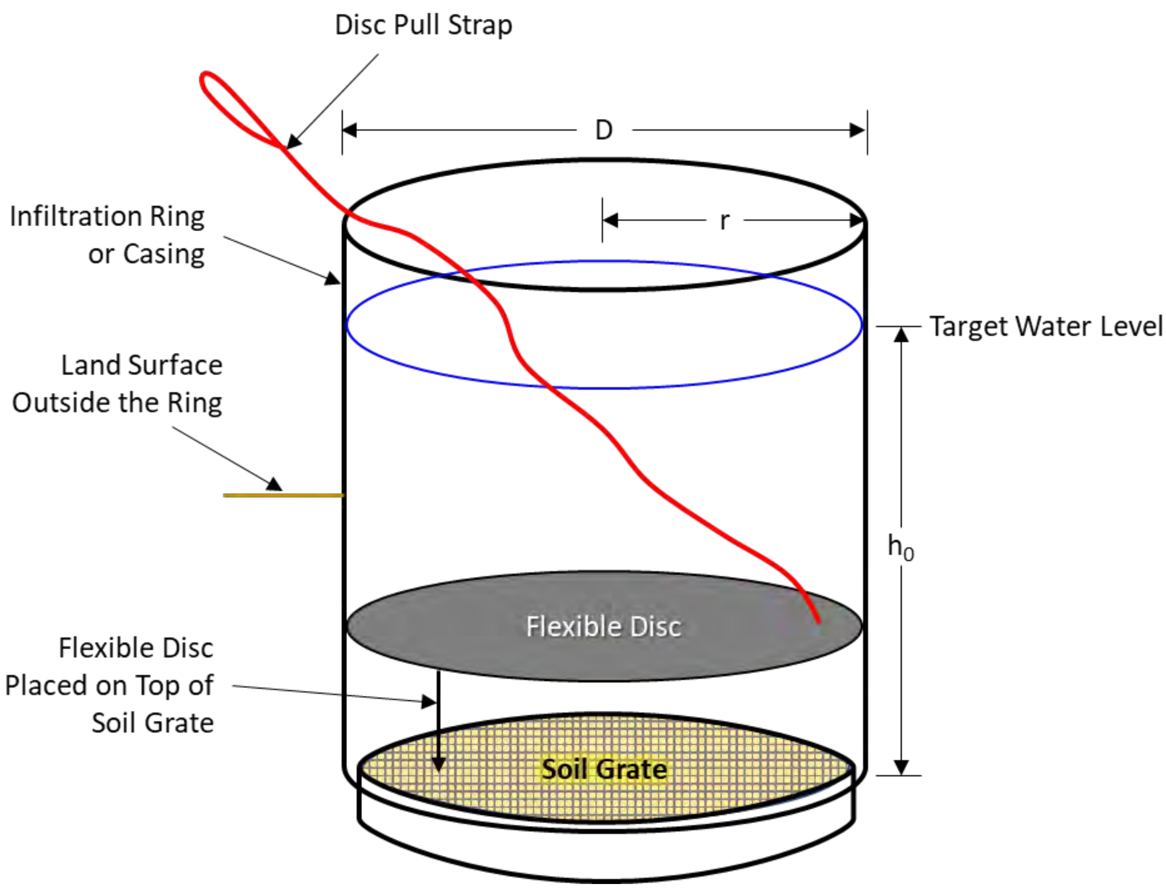


Figure 1. Conceptual Layout of infiltration Apparatus

Figure 2. Example Soil Grate

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

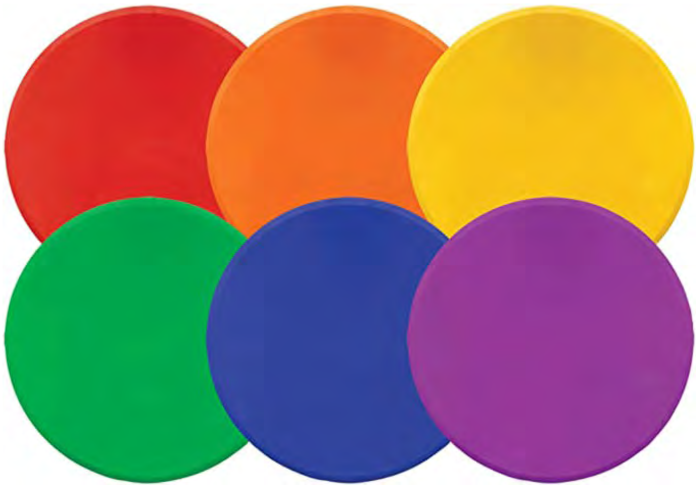


Figure 3. Example Flexible Disc

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

ATTACHMENT II
INFILTRATION TEST DATA

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

WEATHER DESCRIPTION: Partly cloudy.

Date: *10/13/2022*

TEST ID

T1-C

INFILTRATION TEST LOG

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

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

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head

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

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

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

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

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

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 14.7

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

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

WEATHER DESCRIPTION: Partly cloudy.

Date: *10/13/2022*

TEST ID

T1-R

INFILTRATION TEST LOG

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

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

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

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

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

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

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

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

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 0.4

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

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

WEATHER DESCRIPTION: Partly cloudy.

Date: *10/14/2022*

TEST ID

T2-C

INFILTRATION TEST LOG

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

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

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head

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

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

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

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

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

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 14.6

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

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

WEATHER DESCRIPTION: Partly cloudy.

Date: *10/14/2022*

TEST ID

T2-R

INFILTRATION TEST LOG

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

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

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

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

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

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

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

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

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 0.18

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

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

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

Date: *10/11/2022*

TEST ID

T3-C

INFILTRATION TEST LOG

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

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

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head

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

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

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

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

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

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 4.4

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

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

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

TEST ID

T3-R

Date: *10/11/2022*

INFILTRATION TEST LOG

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

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

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

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

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

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

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

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

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 1.1

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

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

WEATHER DESCRIPTION: Partly cloudy. **Date:** *10/12/2022*	**TEST ID** T4-C

INFILTRATION TEST LOG

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

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

TESTING METHOD AND EQUIPMENT USED: Modified Constant-Head

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

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

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

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

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

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 7.3

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

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

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

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

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

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

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

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

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

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

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

INITIAL VOLUMETRIC PERCOLATION RATE, Q_0 (gpm): 0.91

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

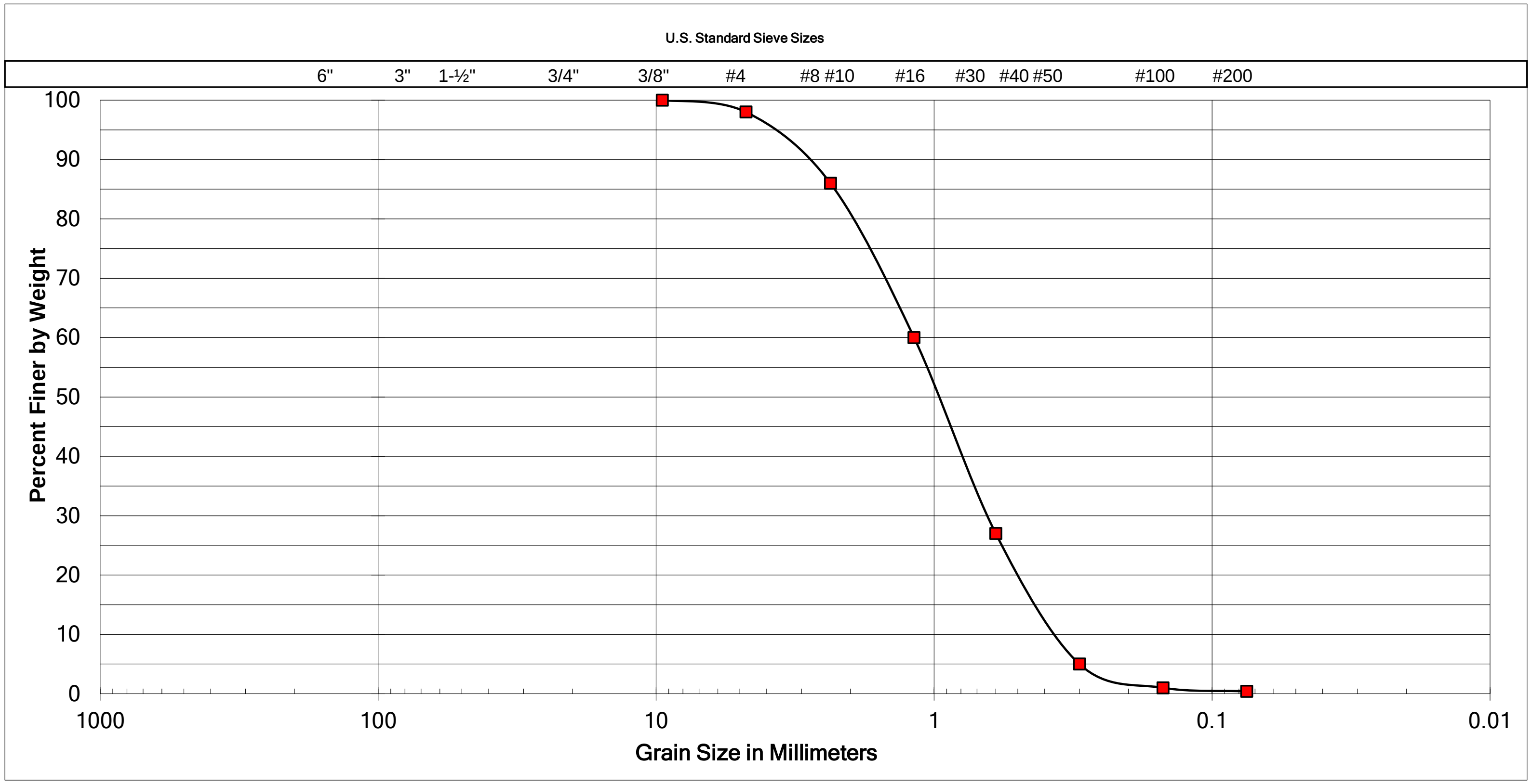
CLOCK TIME	ELAPSED TIME, t (min)	INSTANTANEOUS FLOW RATE, Q_t (gpm)	TOTALIZER (gal)	WATER LEVEL, h_t (in)	WATER TEMPERATURE (°F)	COMMENTS
	1	-	1.59	13.5	-	(-) indicates not observed
	2	-	2.87	14	-	
	3	-	4.06	14	-	
	4	-	5.12	14	-	
	5	-	6.17	14	-	
	6	-	7.12	14	-	
	7	-	8.04	14	-	
	8	-	8.97	14	-	
	9	-	9.87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

ATTACHMENT III
LABORATORY TESTING

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

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

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



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

SAMPLE LOCATION
T1-C
SAMPLE NUMBER
78352

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

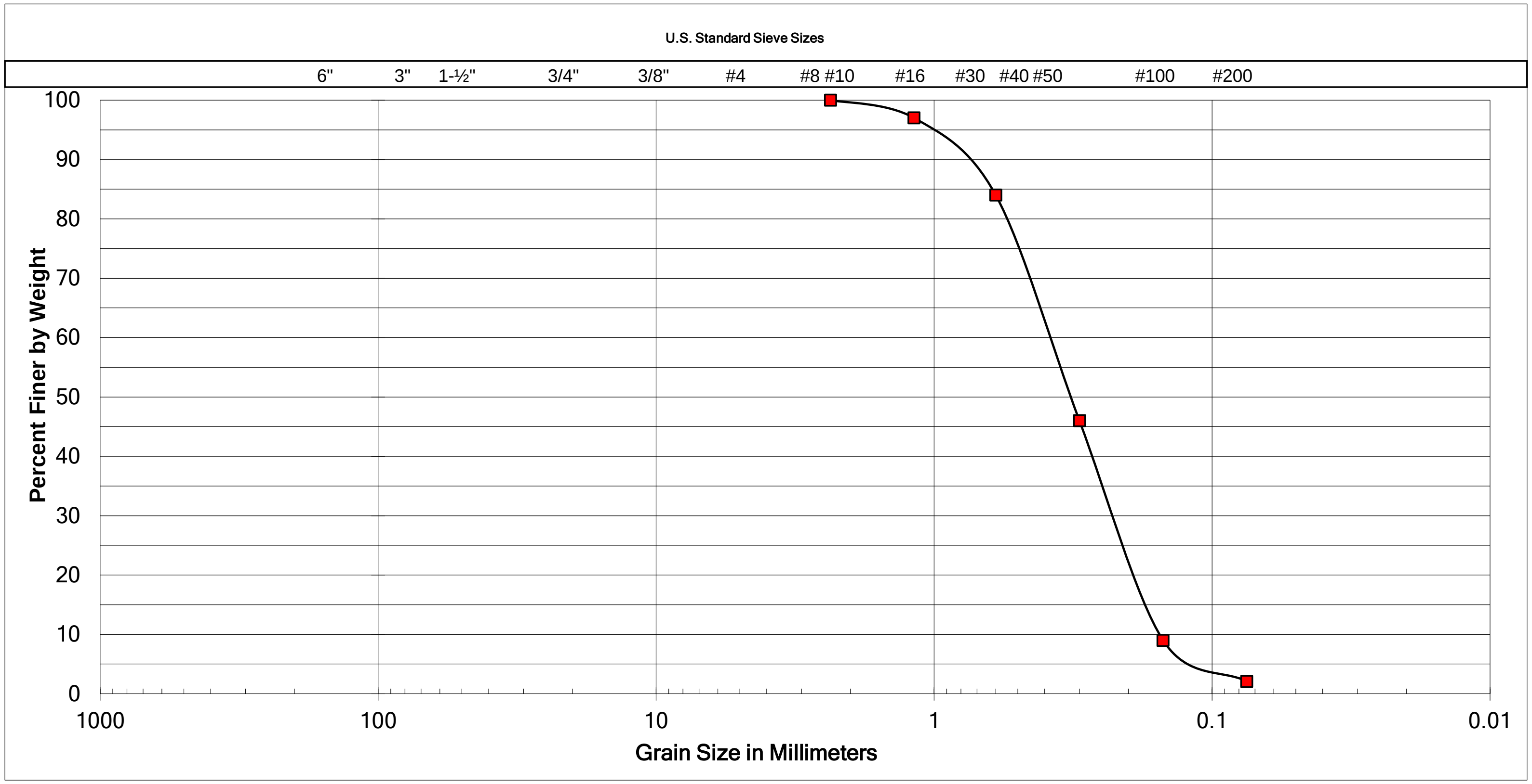
ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing

City of San Diego

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



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

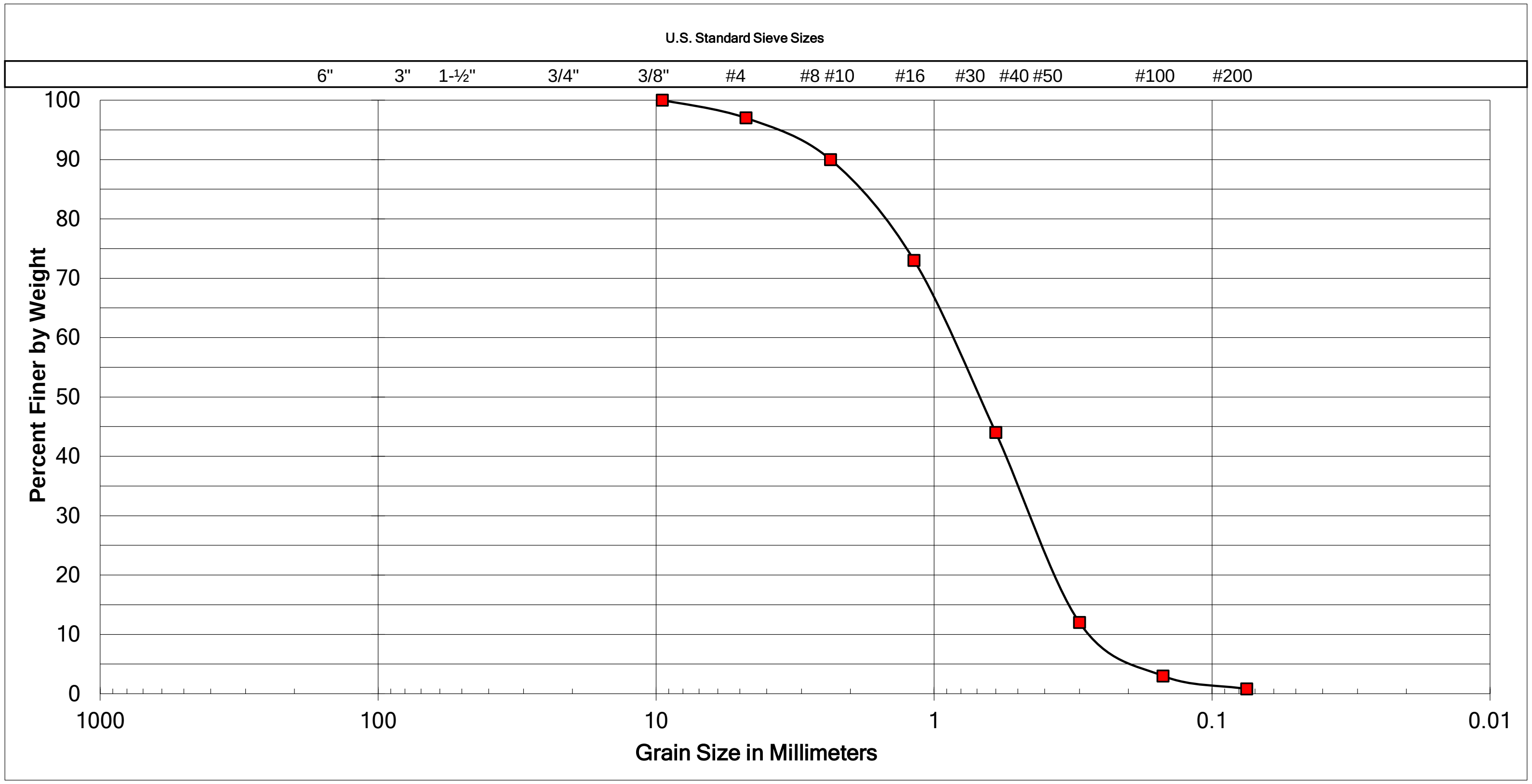
SAMPLE LOCATION
T1-R
SAMPLE NUMBER
78353

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

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



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

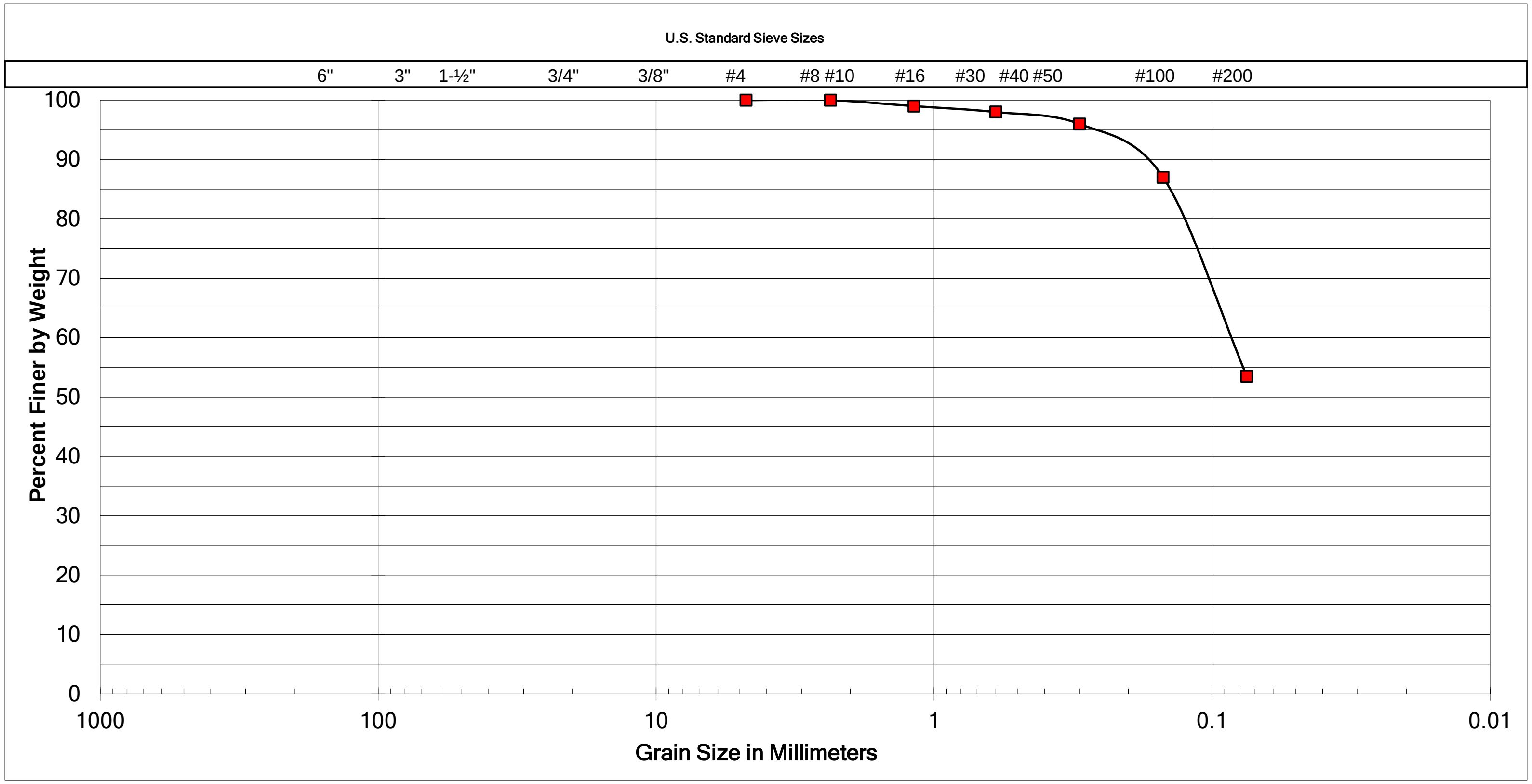
SAMPLE LOCATION
T2-C
SAMPLE NUMBER
78354

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

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



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

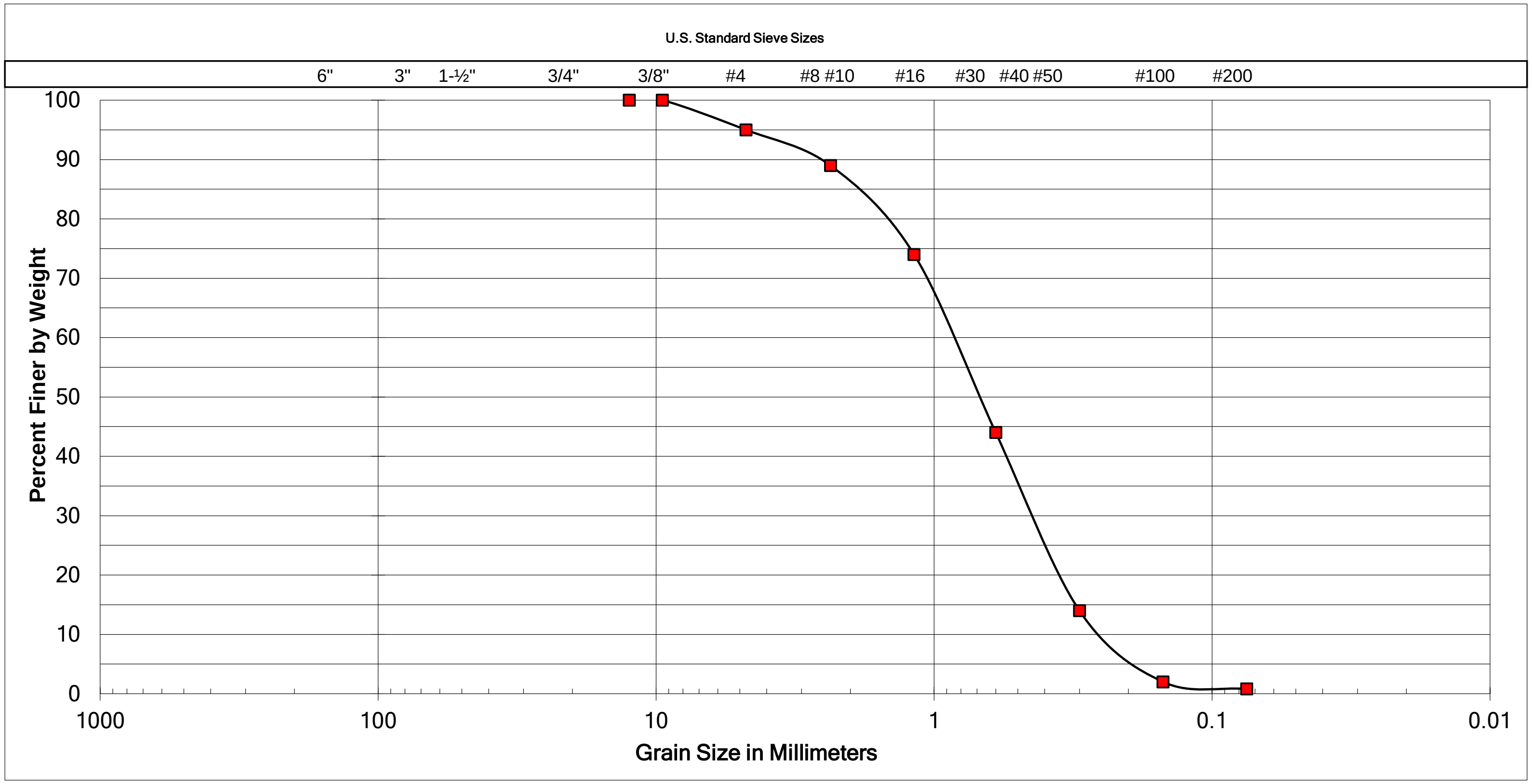
SAMPLE LOCATION
T2-R
SAMPLE NUMBER
78355

UNIFIED SOIL CLASSIFICATION:	ML
DESCRIPTION	SANDY SILT

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

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



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

SAMPLE LOCATION
T3-C
SAMPLE NUMBER
78356

UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

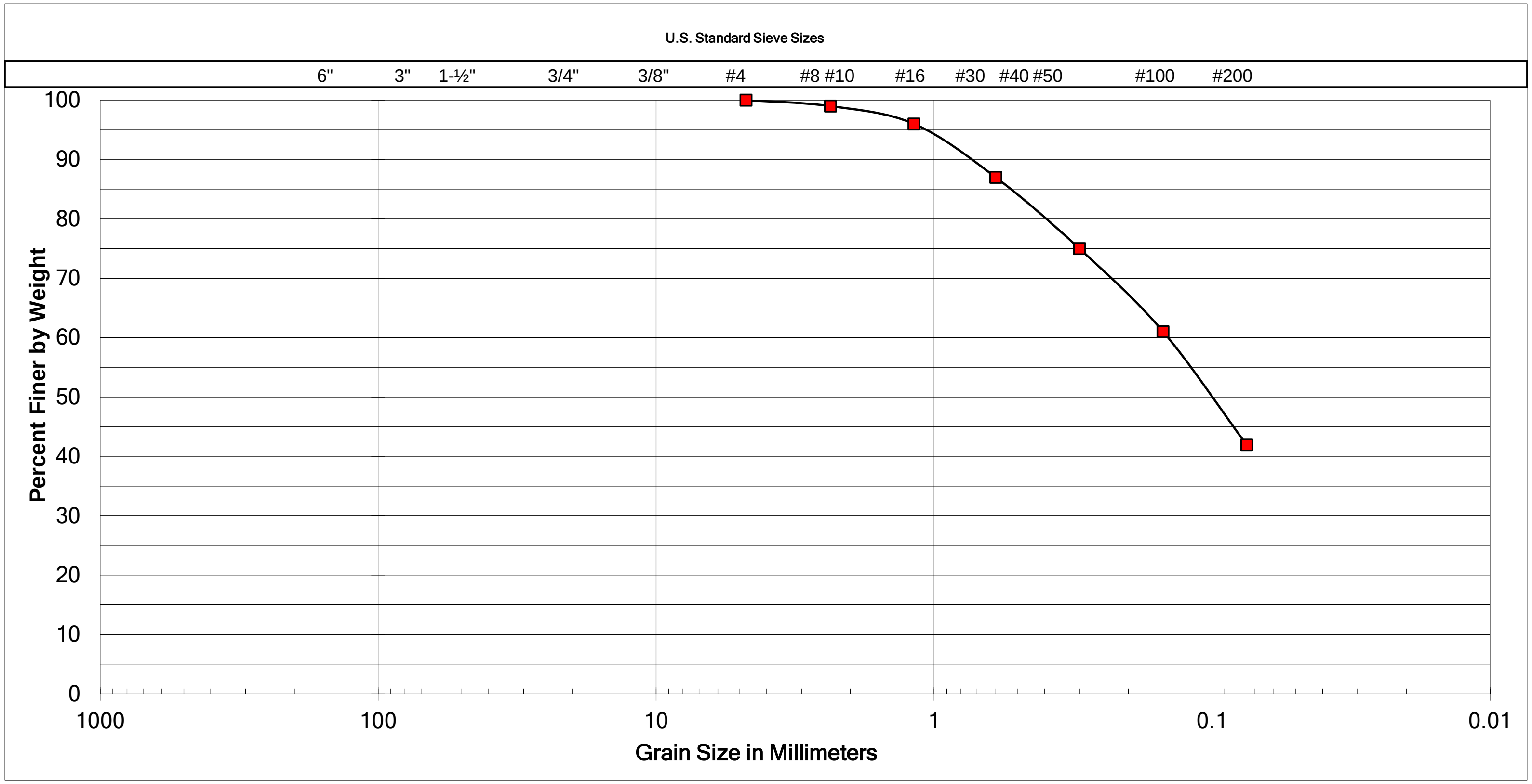
ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing

City of San Diego

By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-5



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

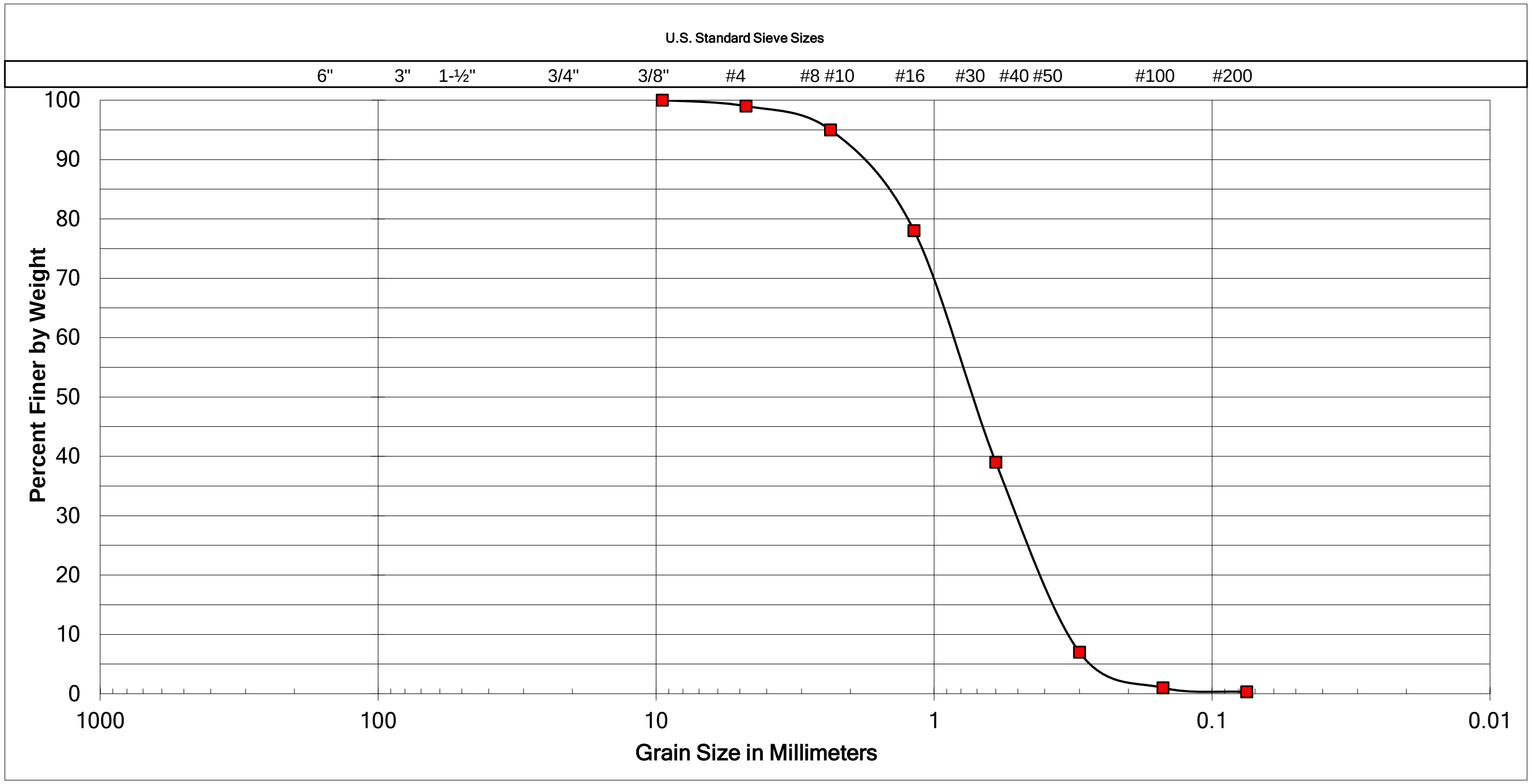
SAMPLE LOCATION
T3-R
SAMPLE NUMBER
78357

UNIFIED SOIL CLASSIFICATION:	SM
DESCRIPTION	SILTY SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

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



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

SAMPLE LOCATION
T4-C
SAMPLE NUMBER
78358

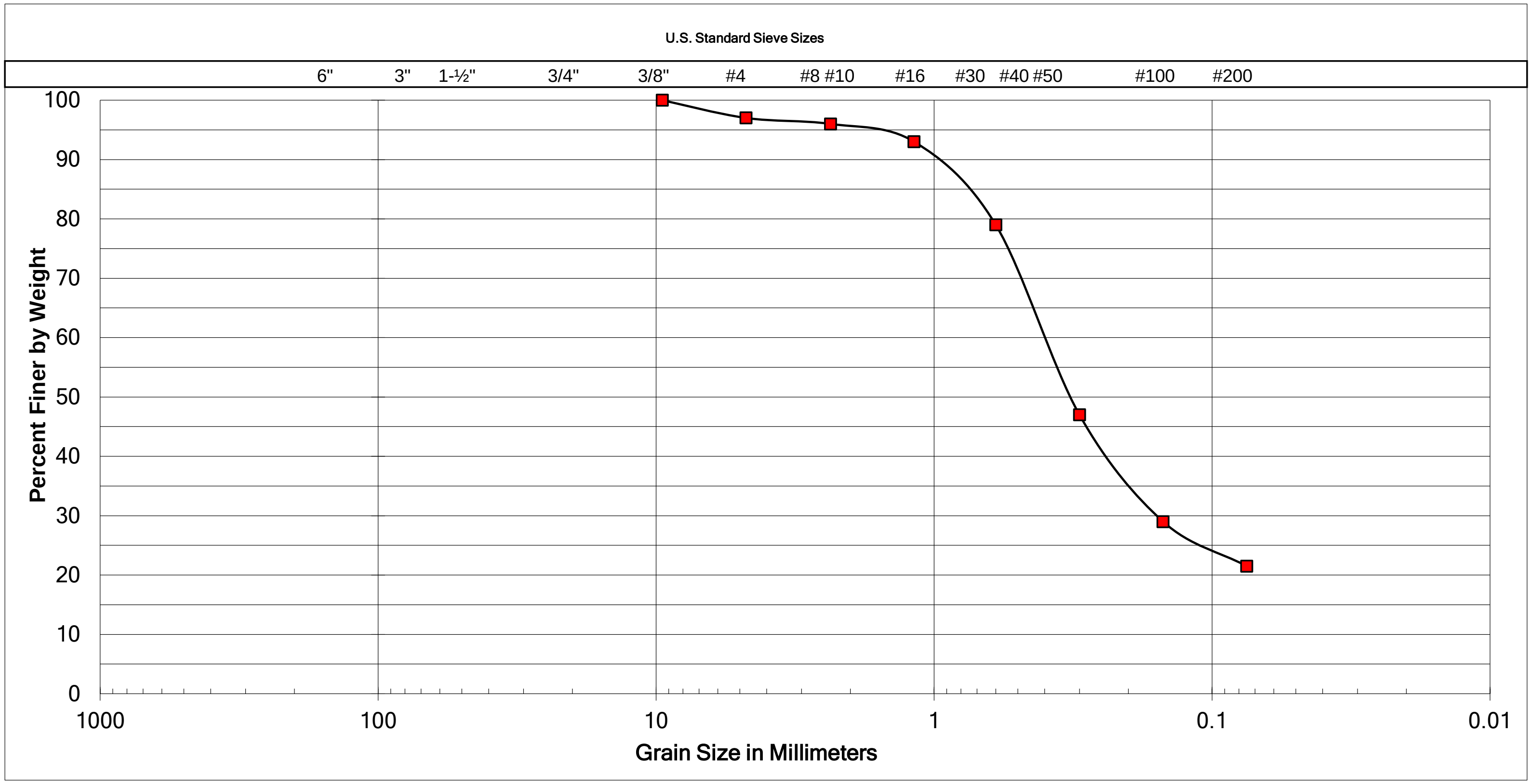
UNIFIED SOIL CLASSIFICATION:	SP
DESCRIPTION	Poorly Graded SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing
City of San Diego

By:	JRD	Date:	November, 2022
Job Number:	1896.000-1	Figure:	I-7



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

SAMPLE LOCATION
T4-R
SAMPLE NUMBER
78359

UNIFIED SOIL CLASSIFICATION:	SM
DESCRIPTION	SILTY SAND

ATTERBERG LIMITS	
LIQUID LIMIT	-
PLASTIC LIMIT	-
PLASTICITY INDEX	-

ATLAS

San Pasual Valley Infiltration Testing

City of San Diego

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

9. ATTACHMENT B: PLANNED MODELED EIGHT-POINT STREAM CHANNELS

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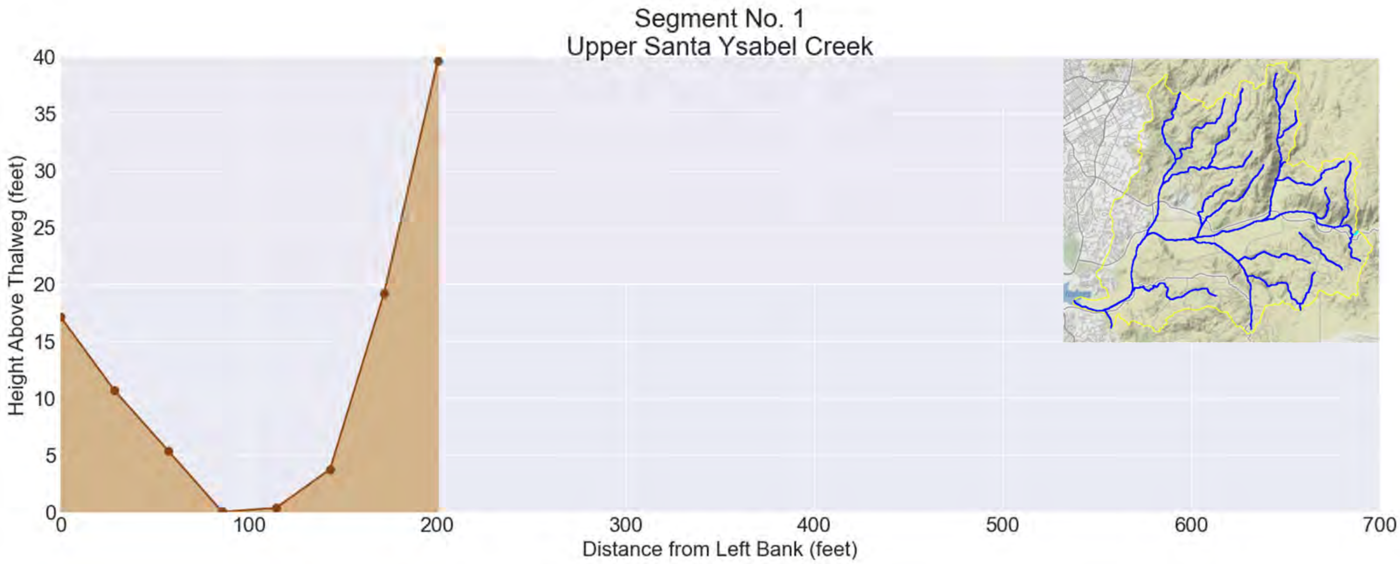
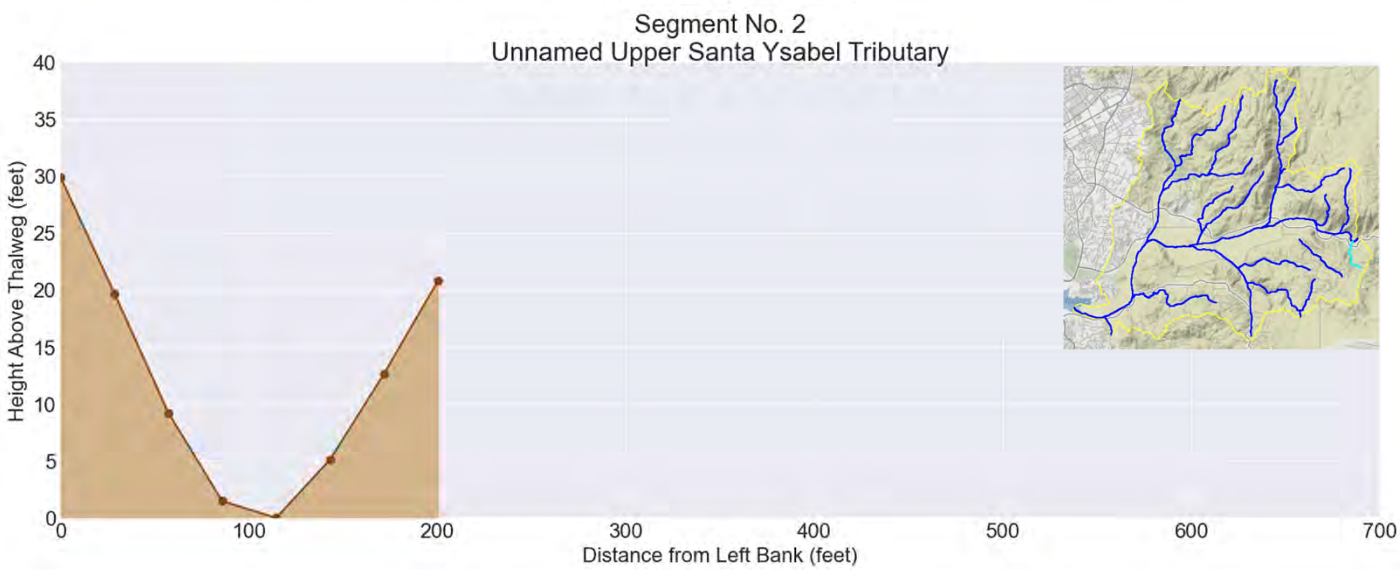
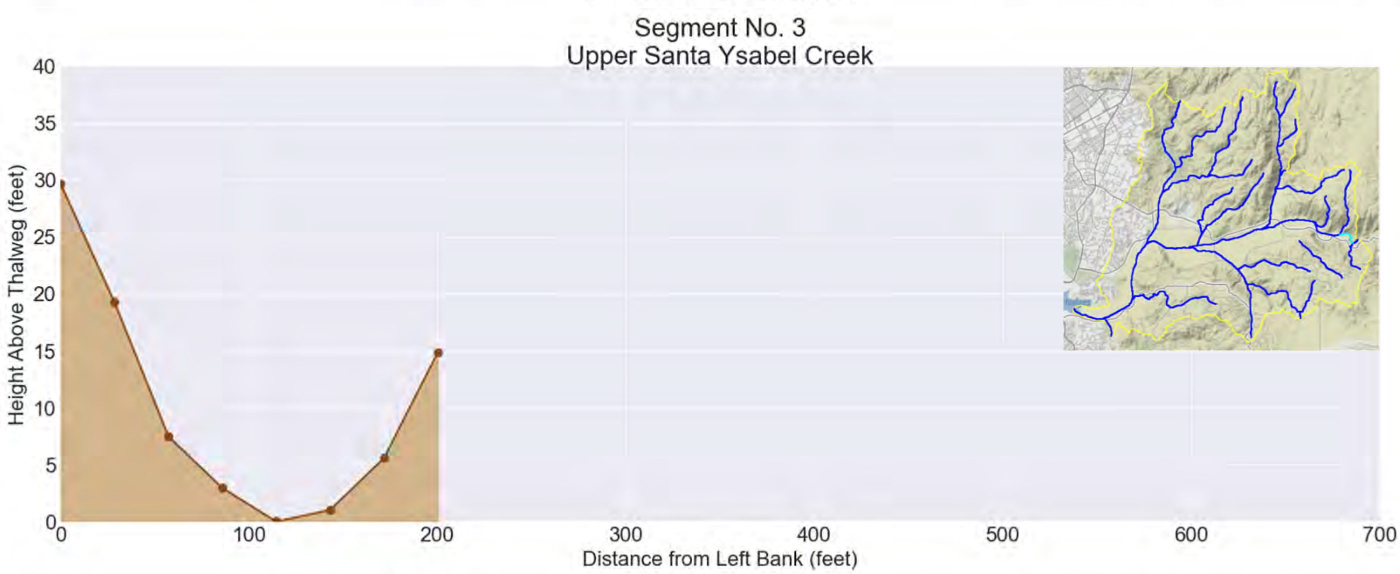






Notes:

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

Map Legend

Modeled Stream

Highlighted Segment of Modeled Stream

Figure B-1

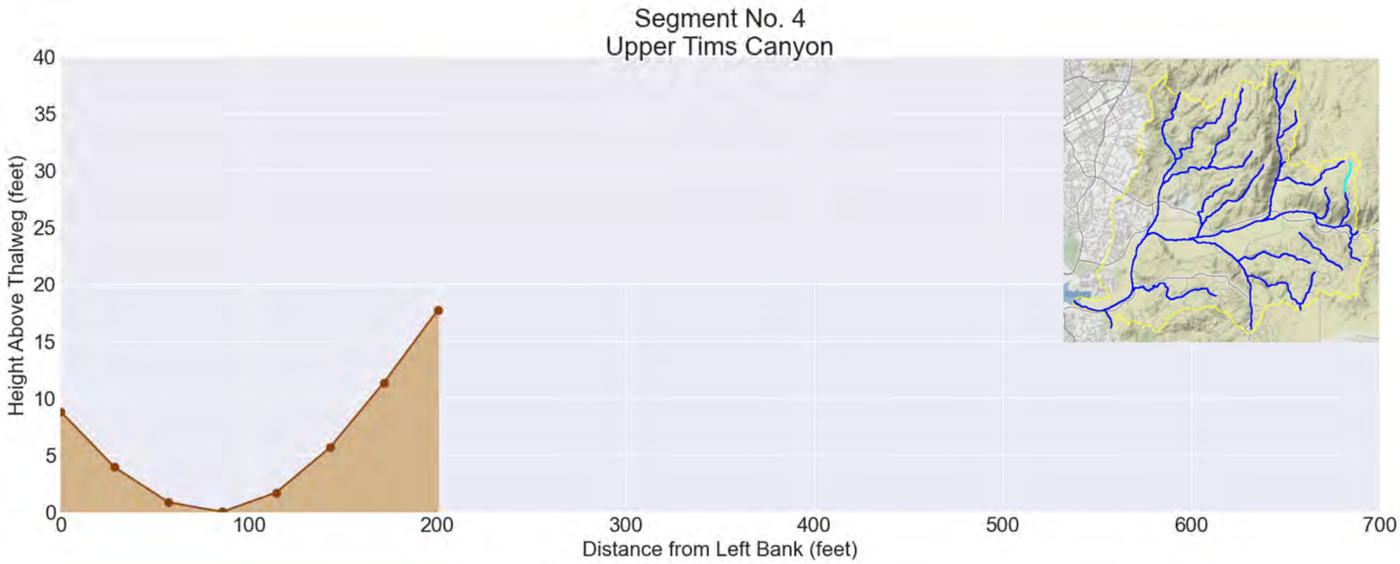
Modeled Eight-point Stream Channels by Segment Number

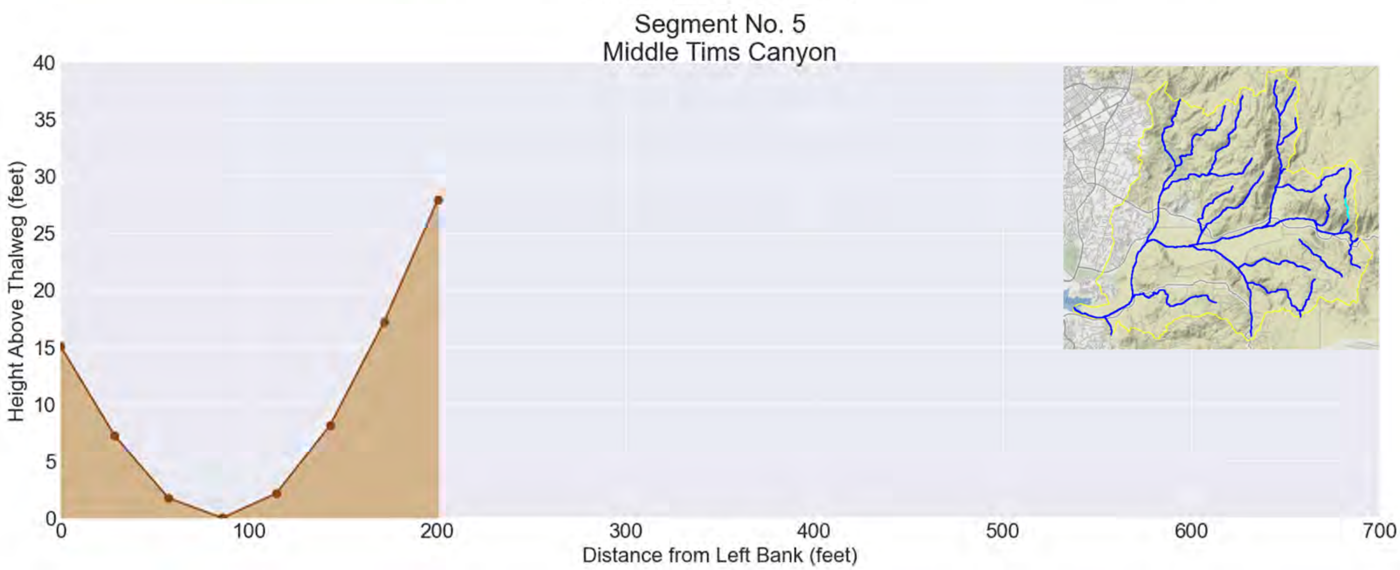
PMA7: Initial Surface Water Recharge Evaluation

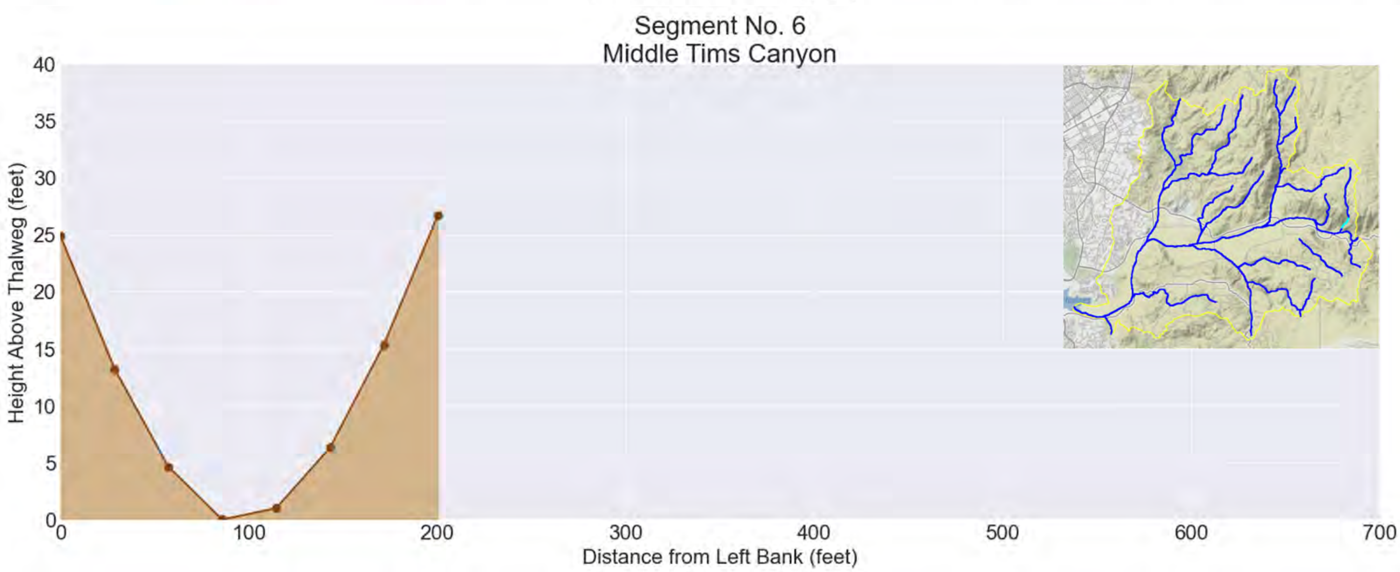
Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs







Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-2

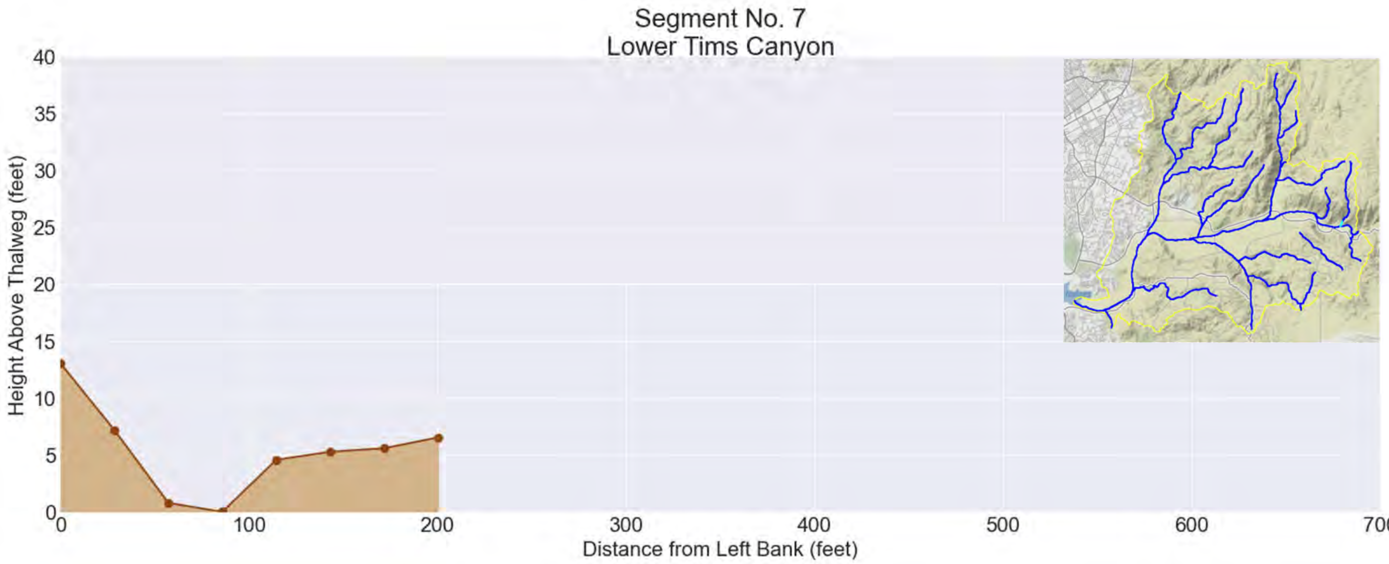
Modeled Eight-point Stream Channels by Segment Number

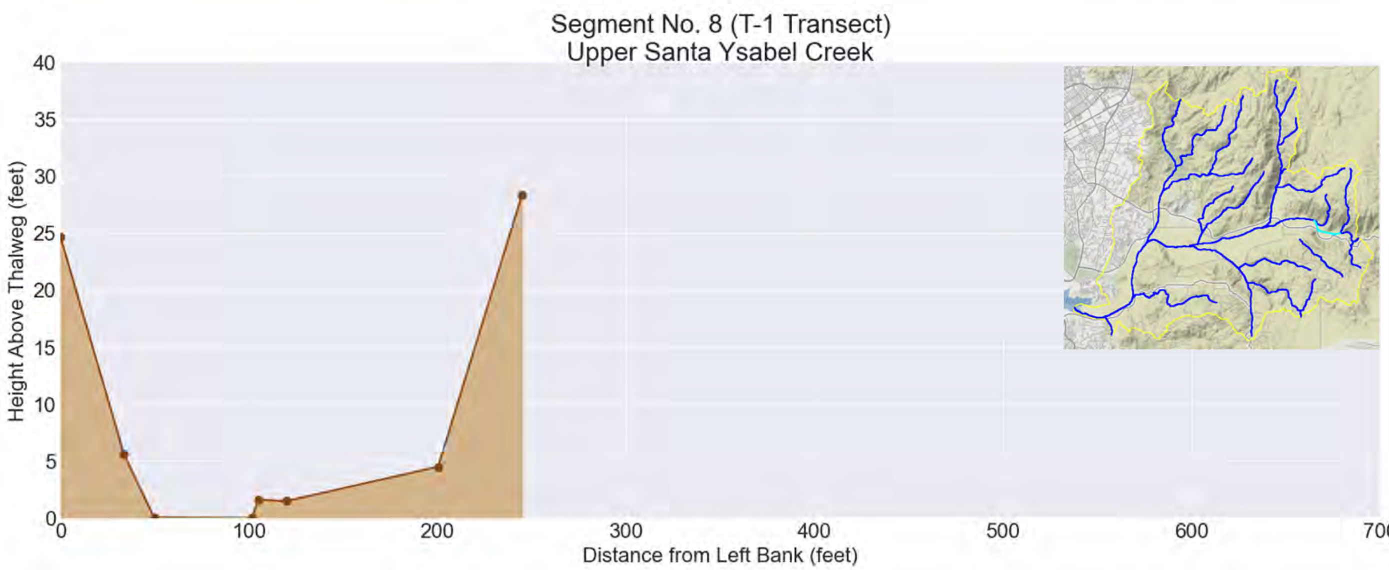
PMA7: Initial Surface Water Recharge Evaluation

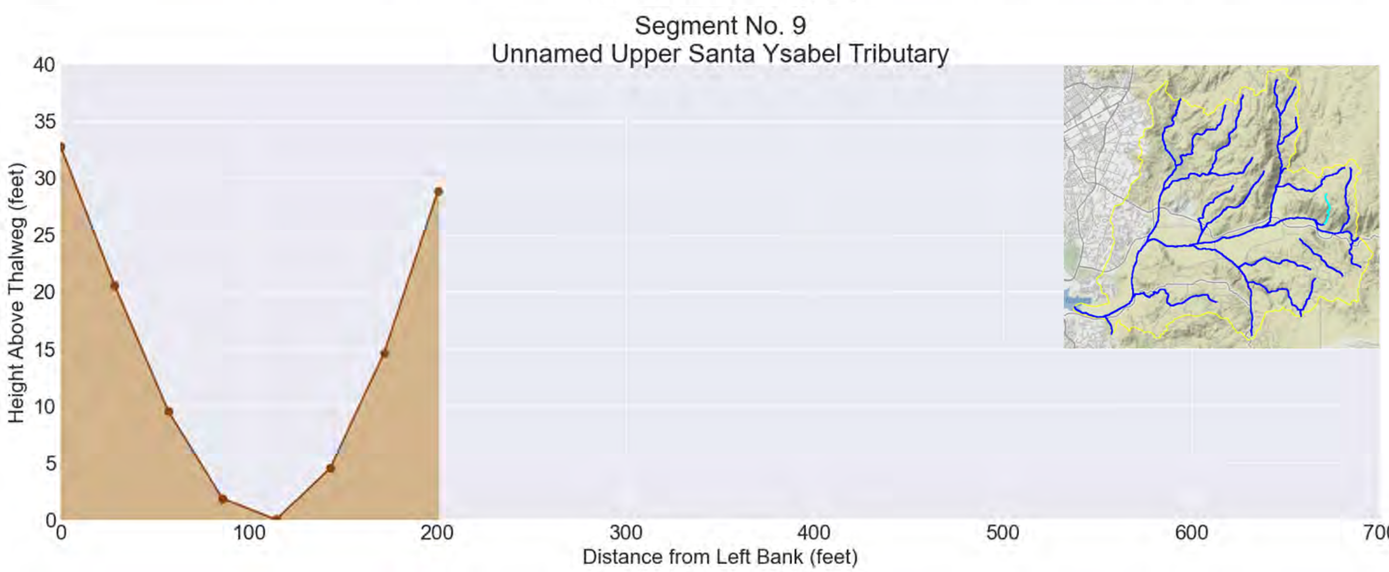
Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs







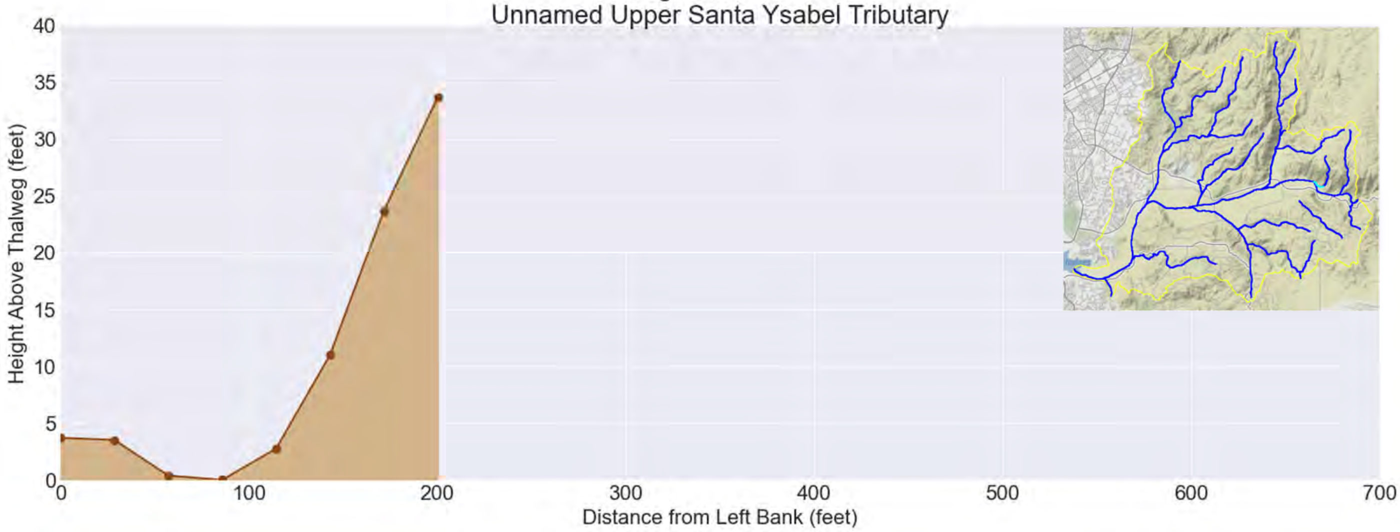
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

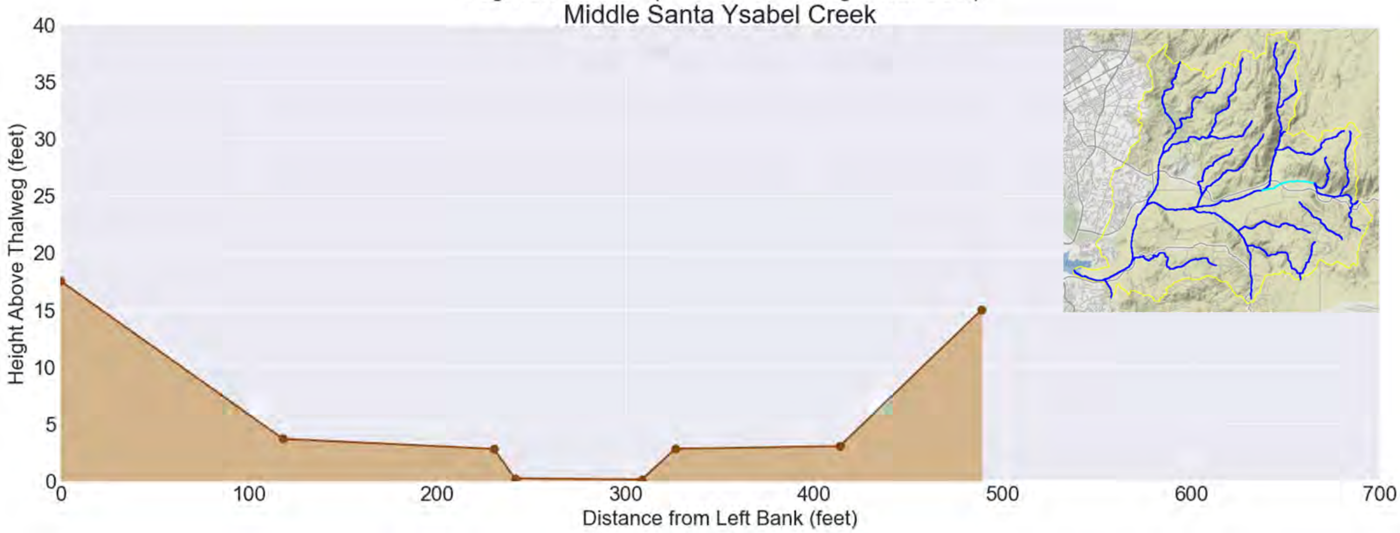
Figure B-3
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs

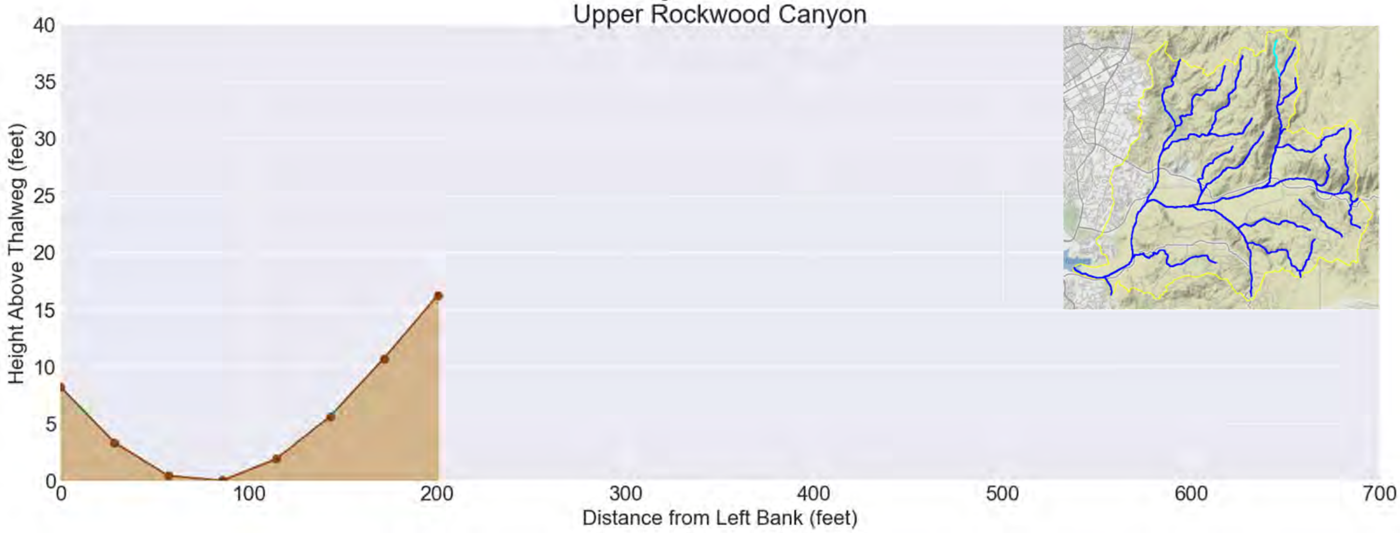
Segment No. 10
Unnamed Upper Santa Ysabel Tributary



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



Segment No. 12
Upper Rockwood Canyon



Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-4

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

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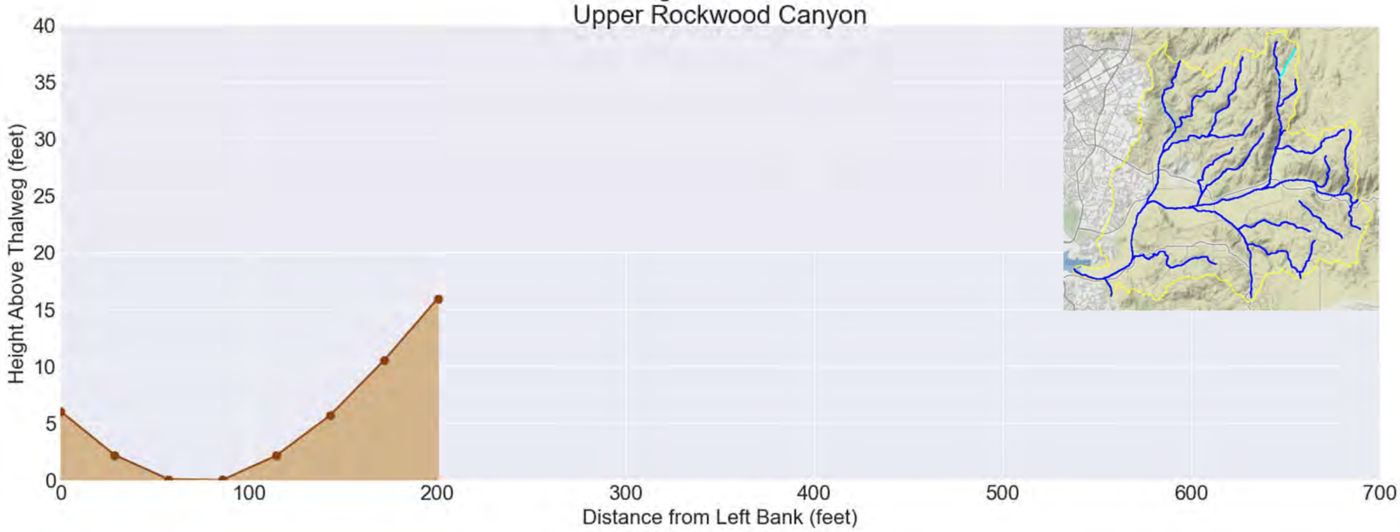
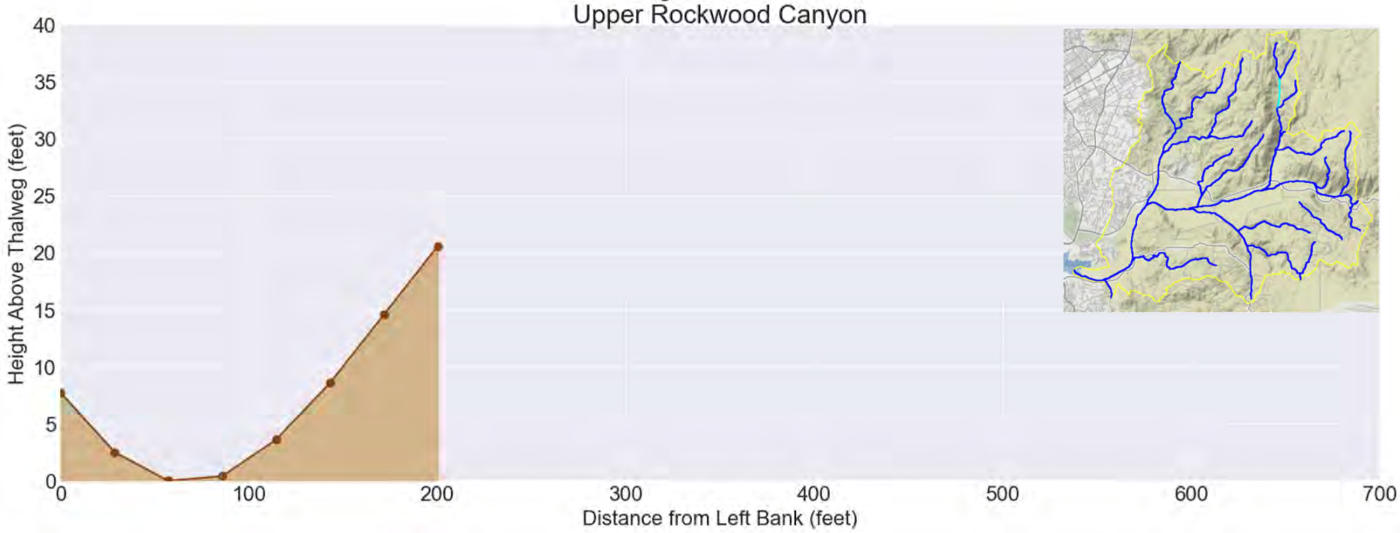
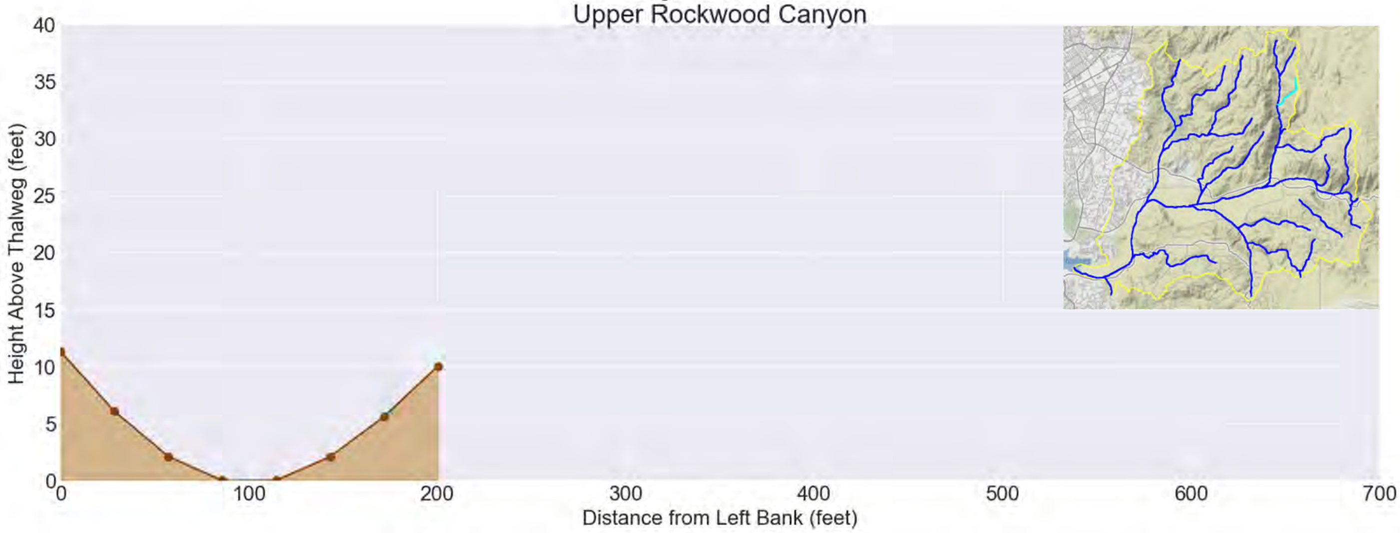
Segment No. 13
Upper Rockwood Canyon



Segment No. 14
Upper Rockwood Canyon



Segment No. 15
Upper Rockwood Canyon



Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-5

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs

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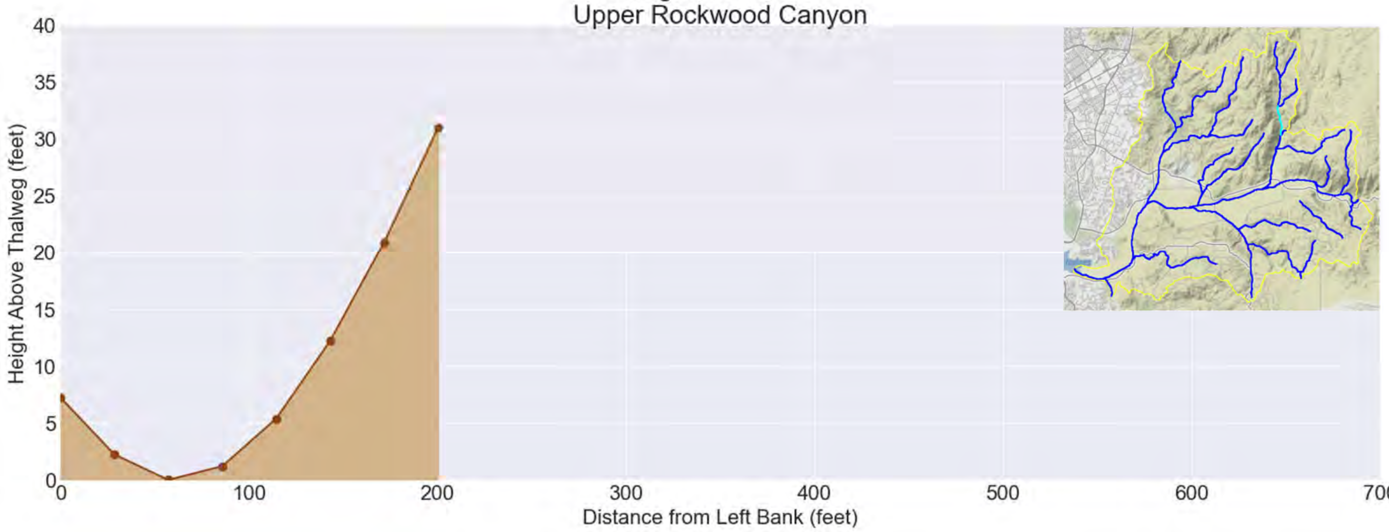
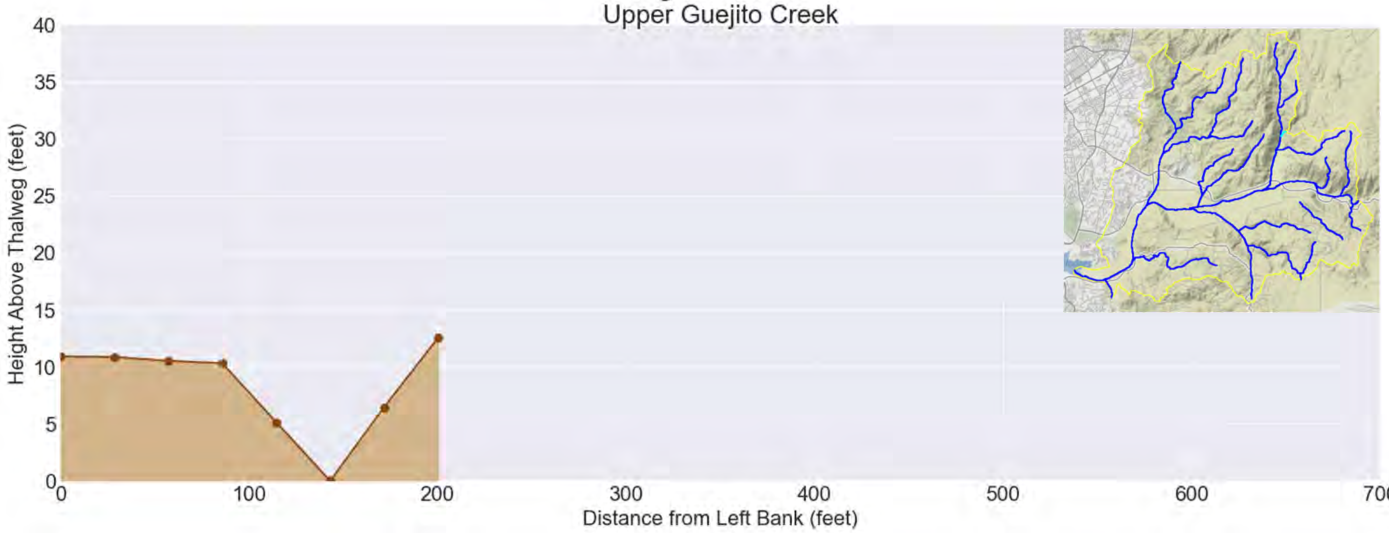
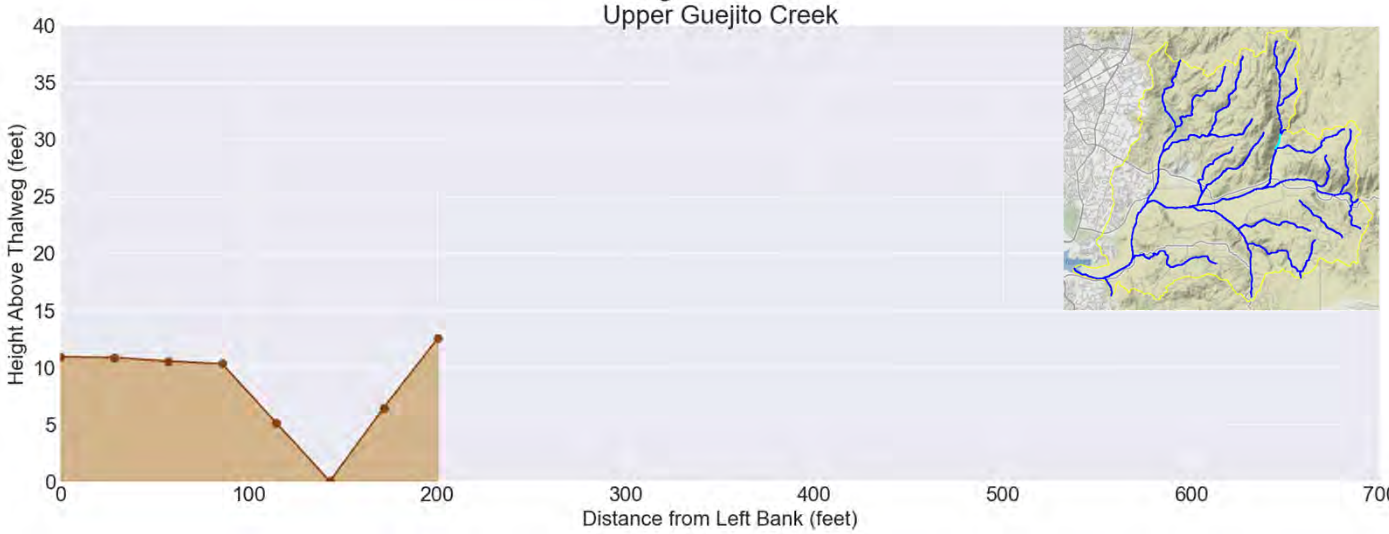
Segment No. 16
Upper Rockwood Canyon



Segment No. 17
Upper Guejito Creek



Segment No. 18
Upper Guejito Creek

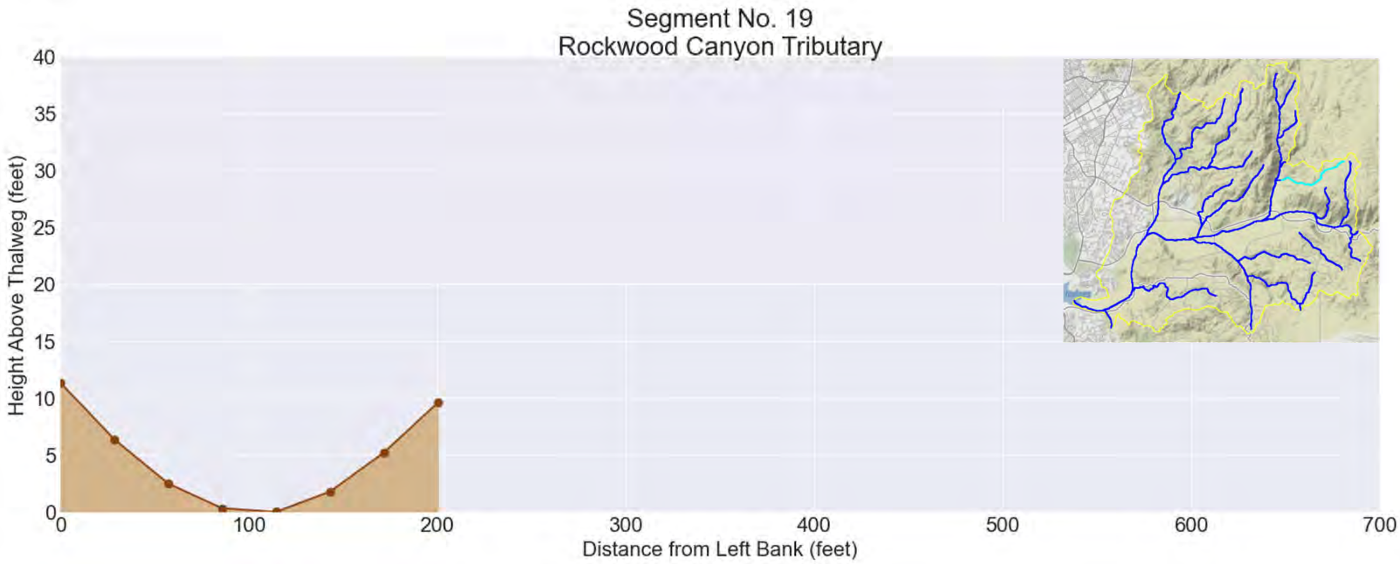


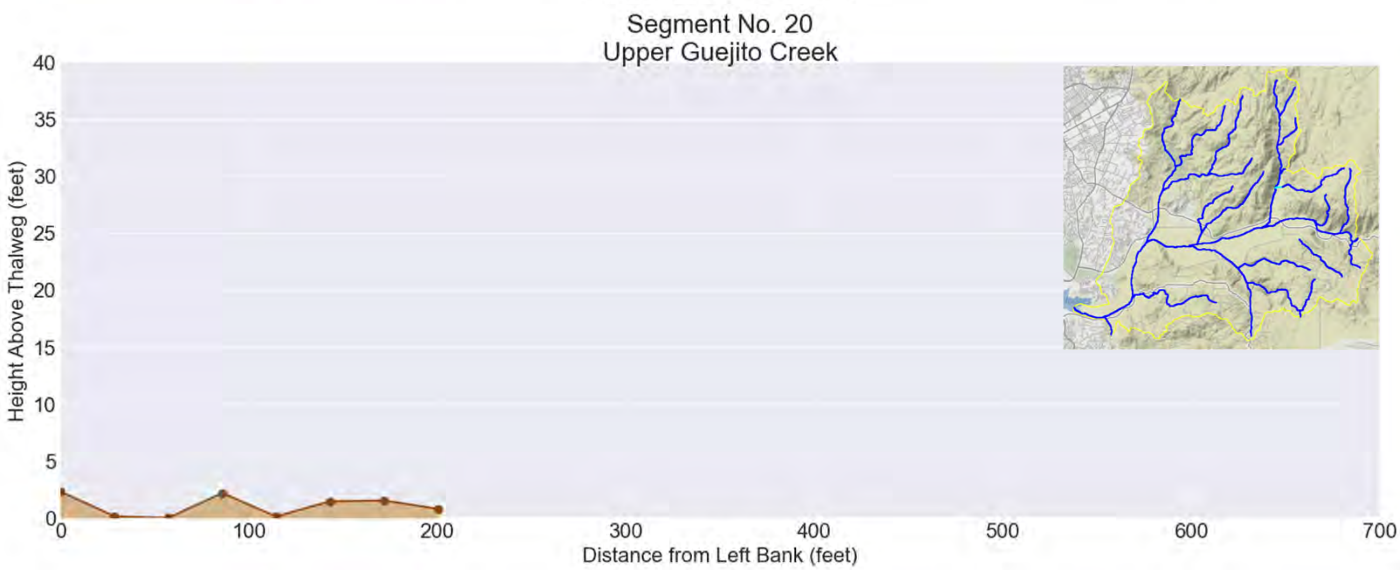
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

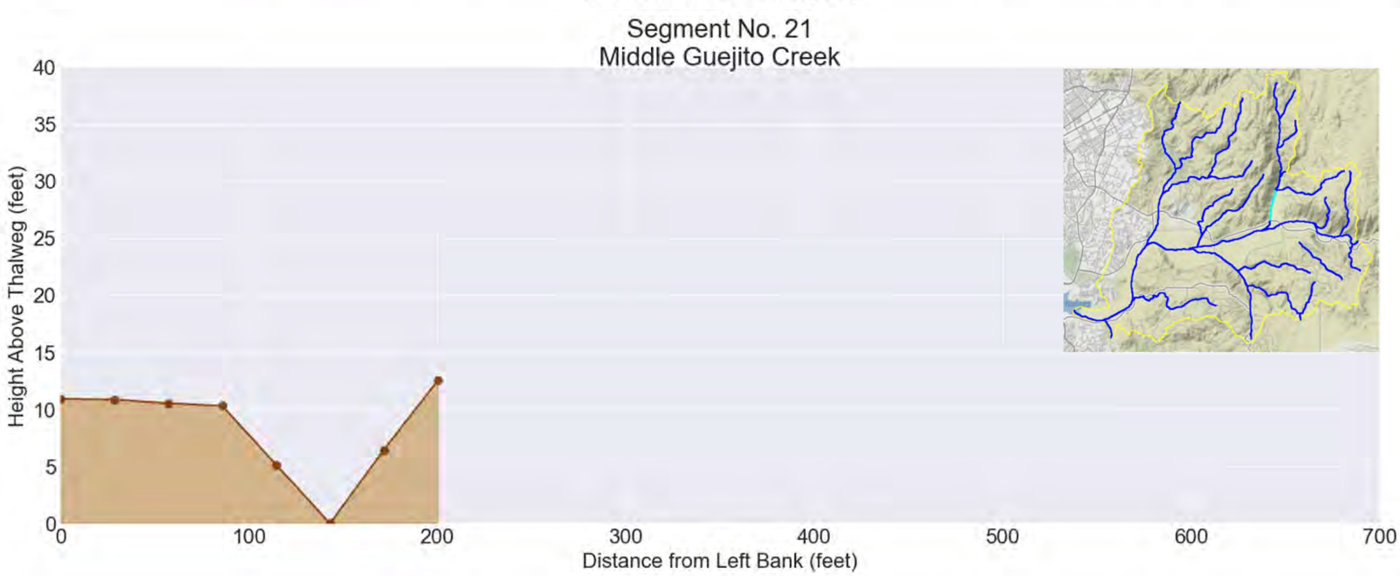
Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

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

Jacobs







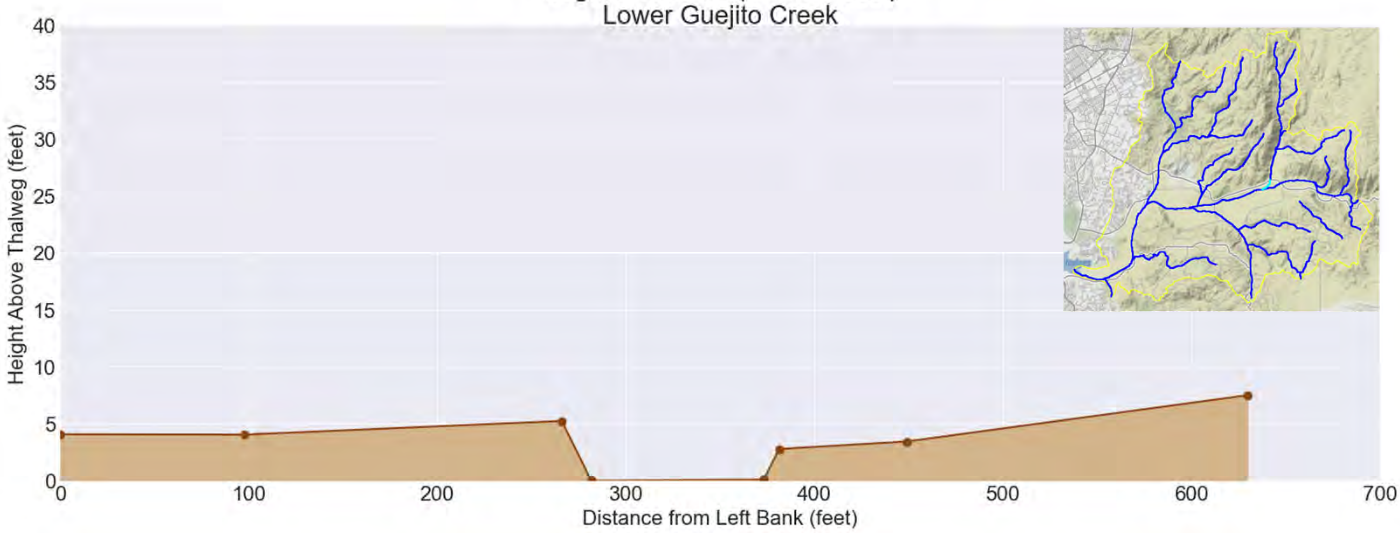
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. “Left Bank” refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

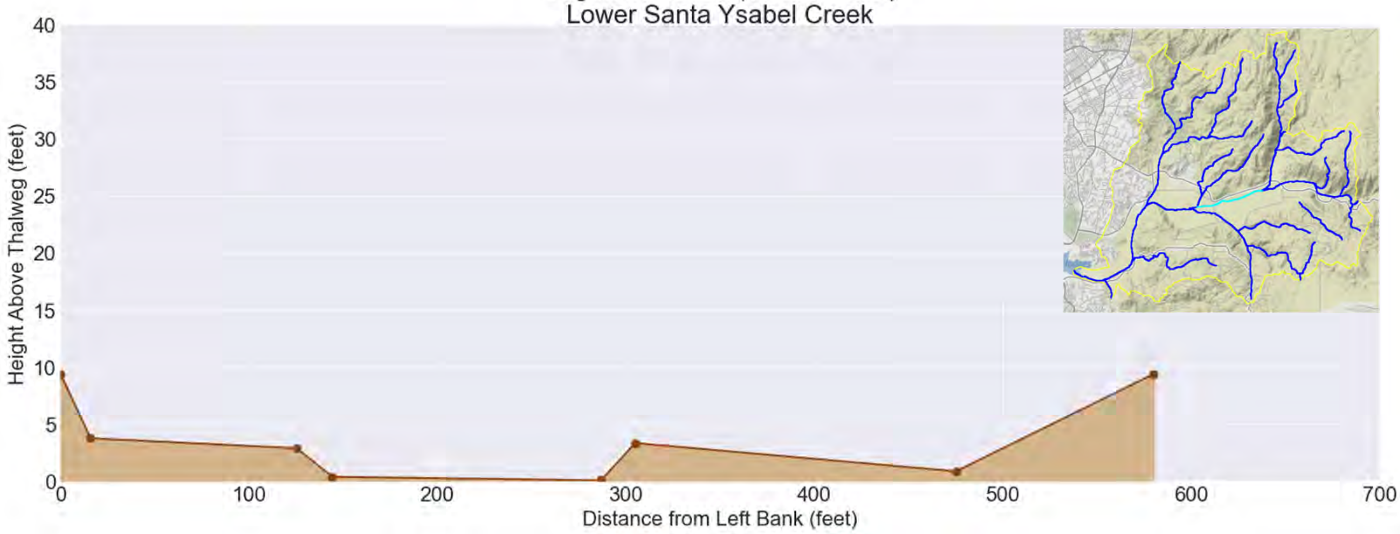
Figure B-7
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs

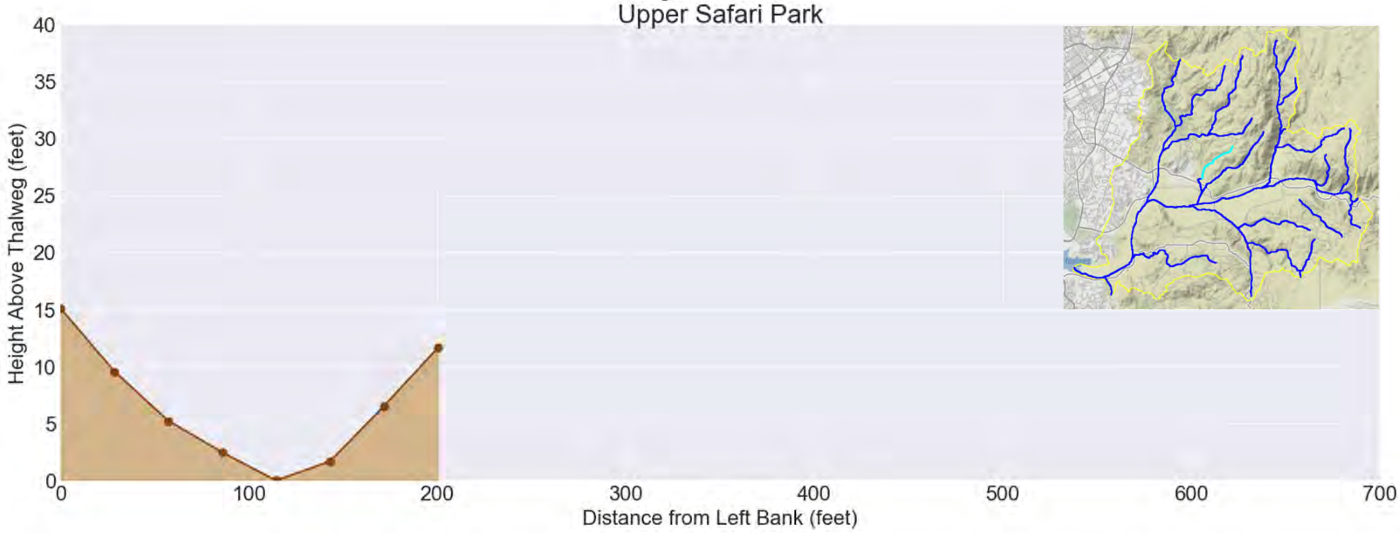
Segment No. 22 (T-5 Transect)
Lower Guejito Creek



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



Segment No. 24
Upper Safari Park



Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-8

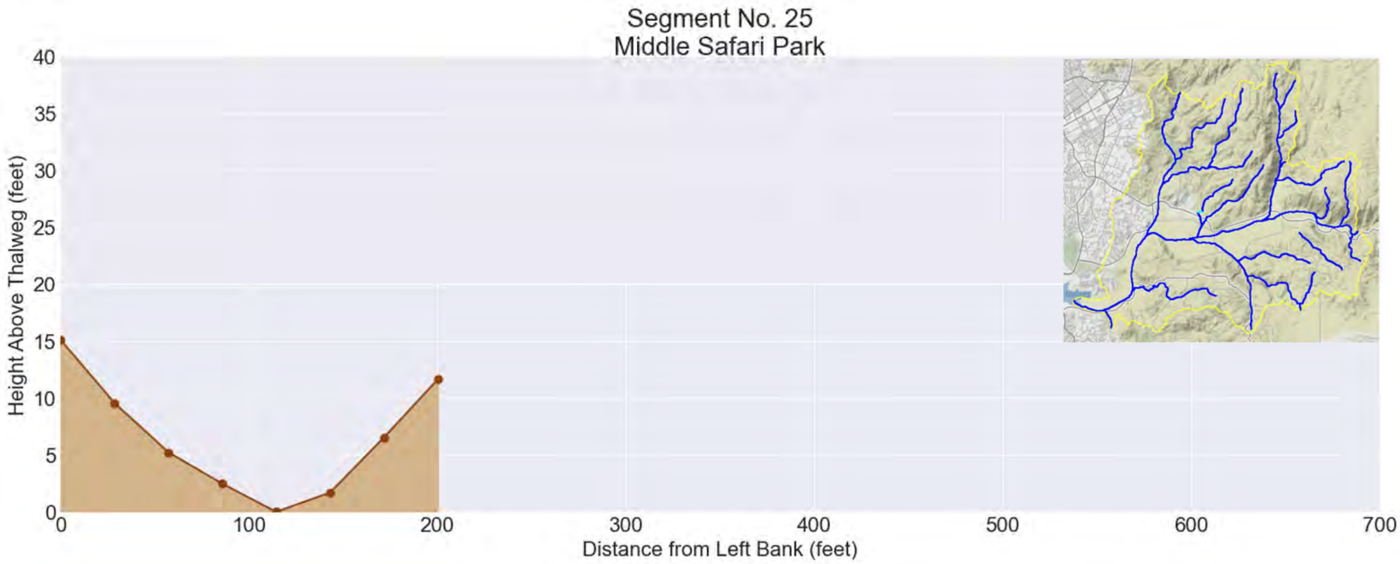
Modeled Eight-point Stream Channels by Segment Number

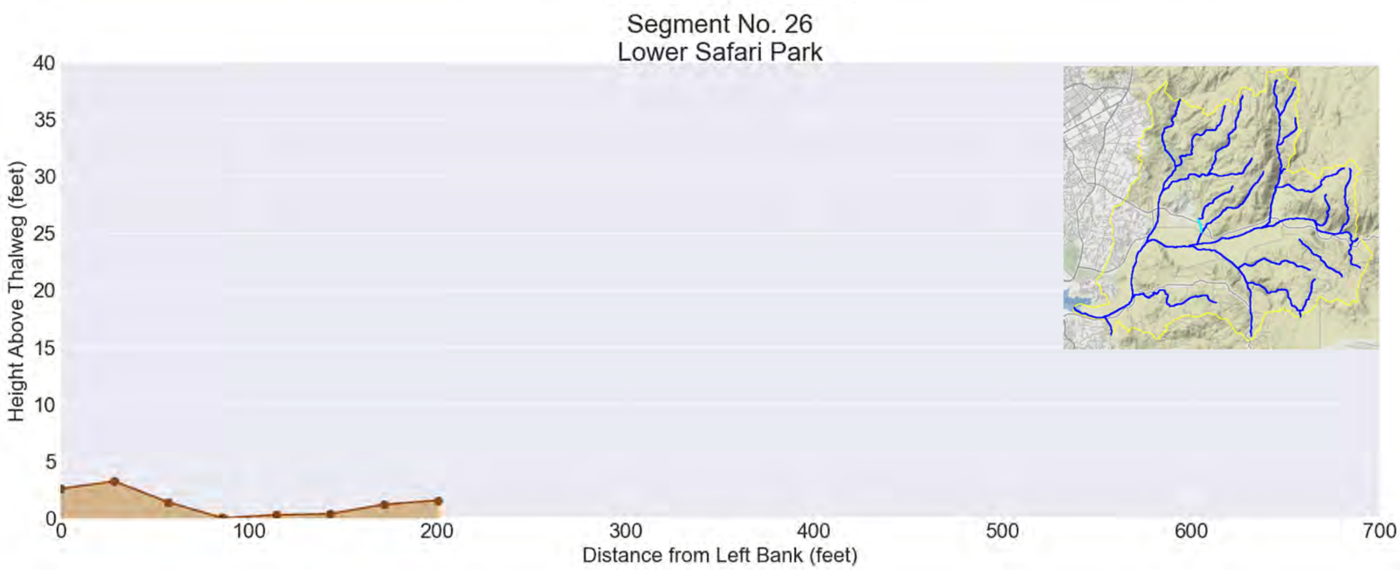
PMA7: Initial Surface Water Recharge Evaluation

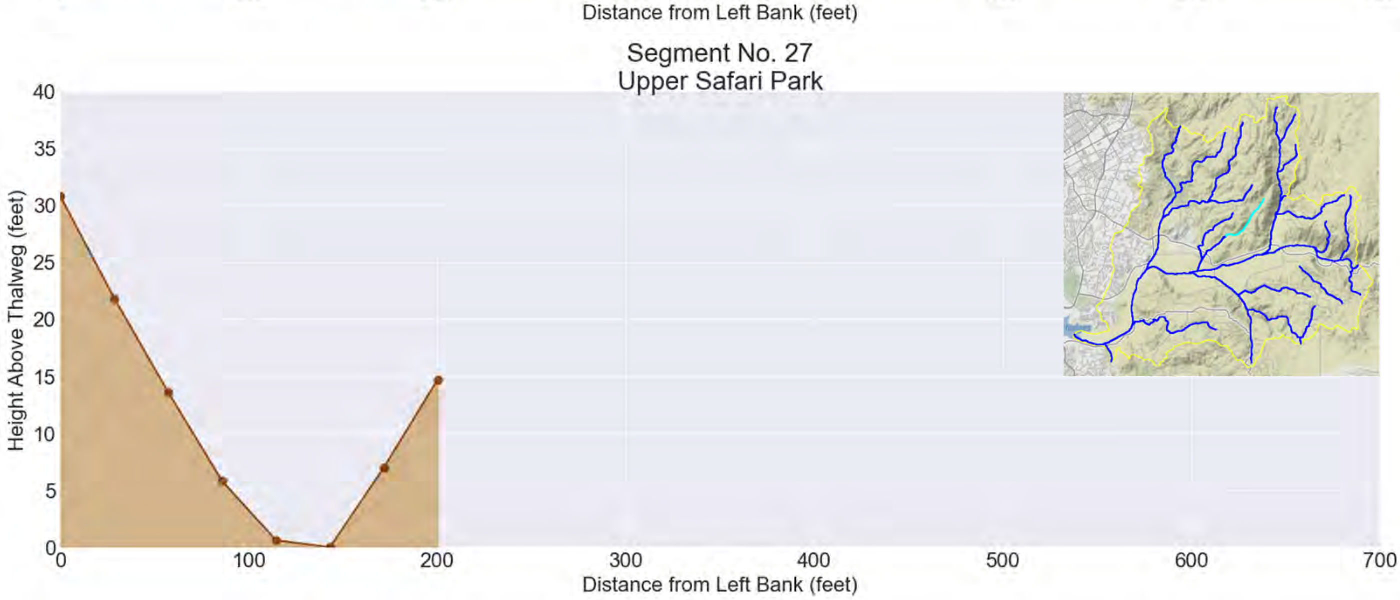
Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs







Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-9

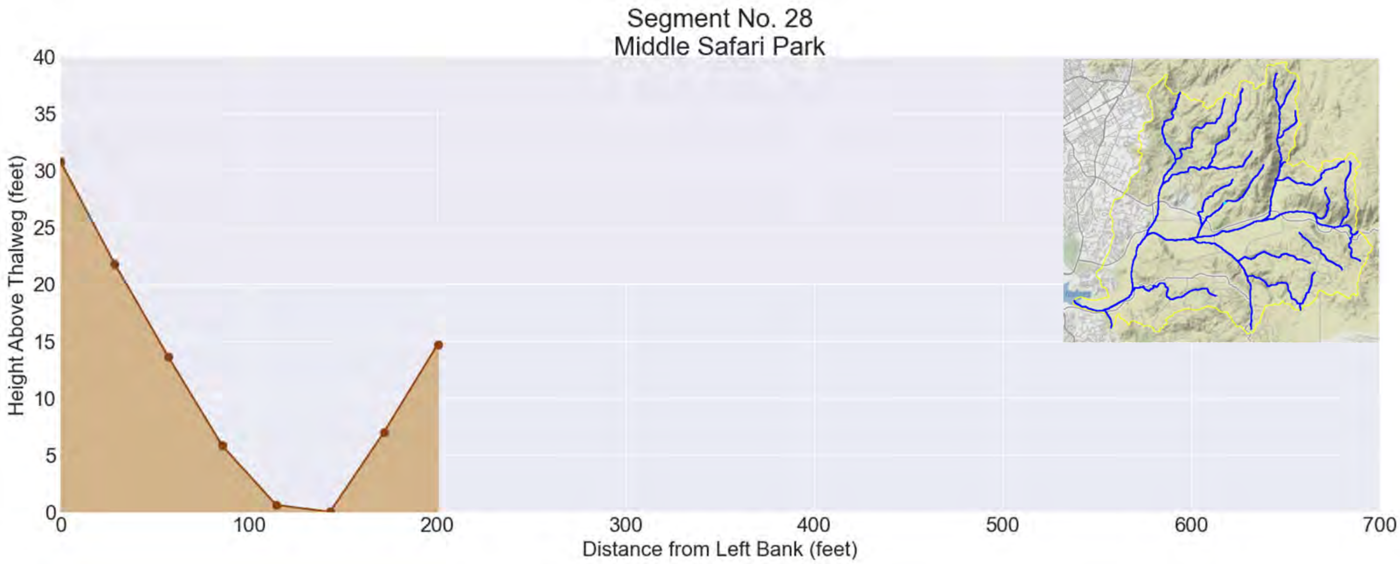
Modeled Eight-point Stream Channels by Segment Number

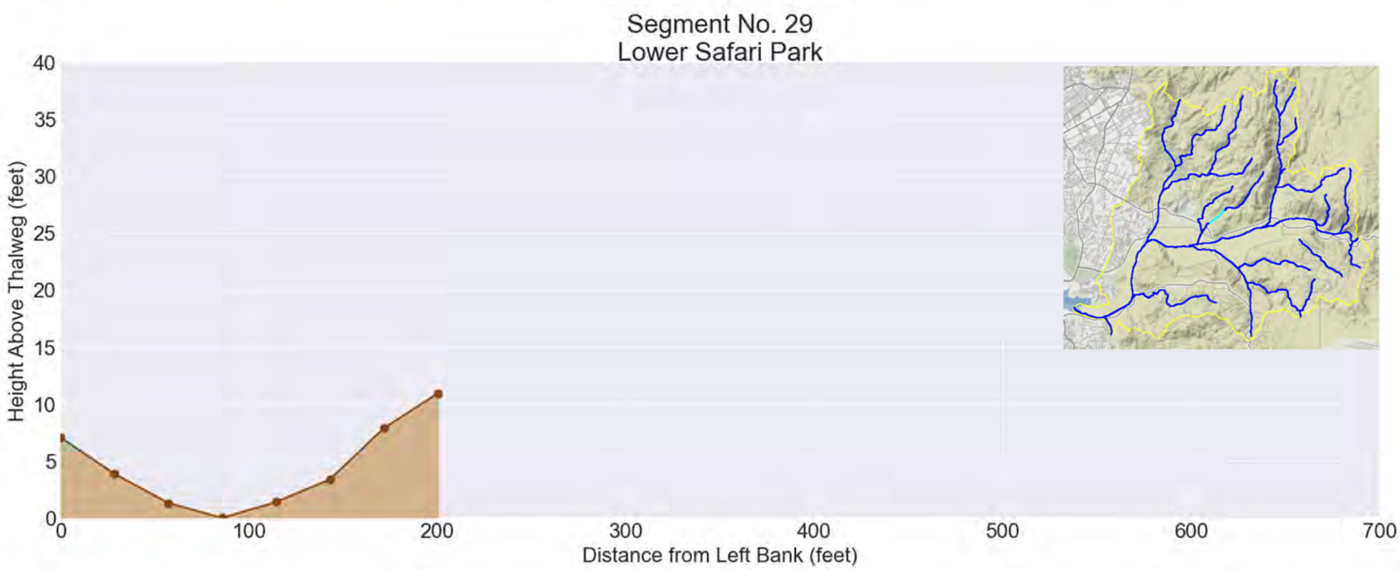
PMA7: Initial Surface Water Recharge Evaluation

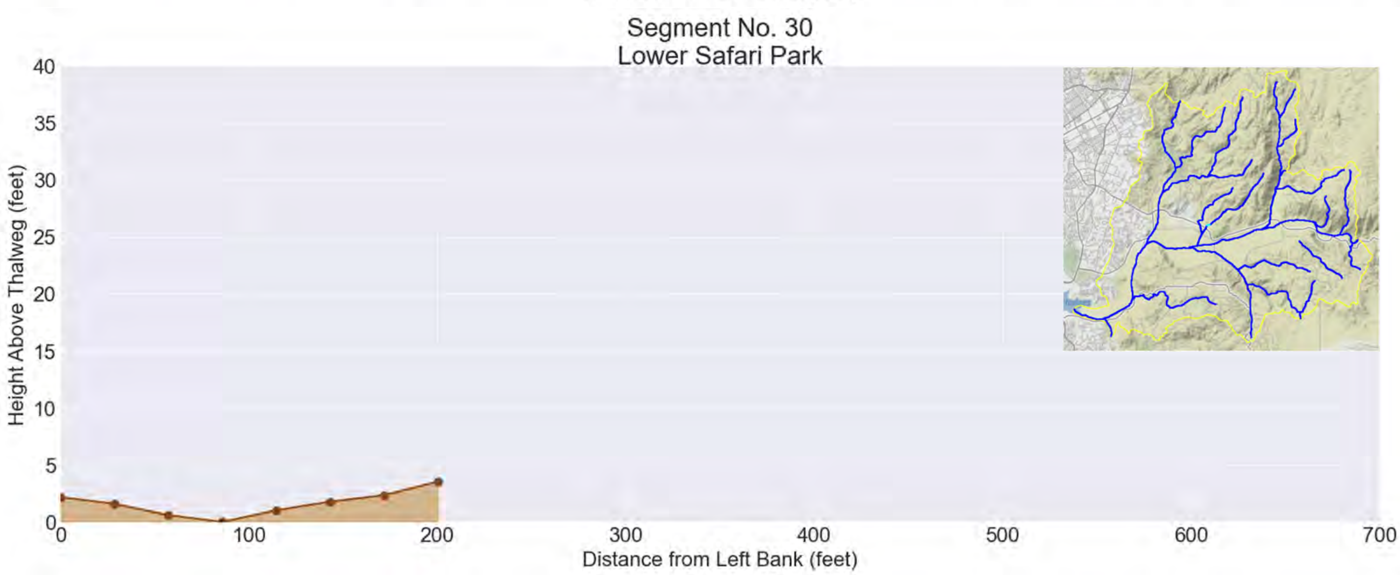
Task 2 Streambed Investigation

San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\PMA7\Task2\Figures\PPTX\Attachment_StreamChannels.pptm







Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-10

Modeled Eight-point Stream Channels by Segment Number

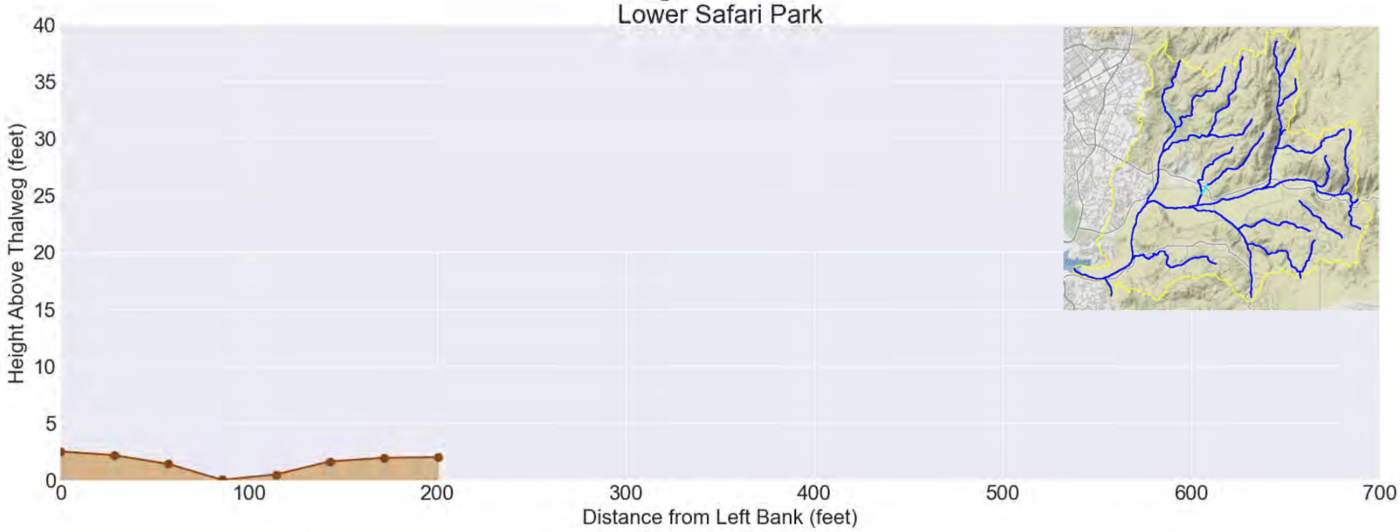
PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

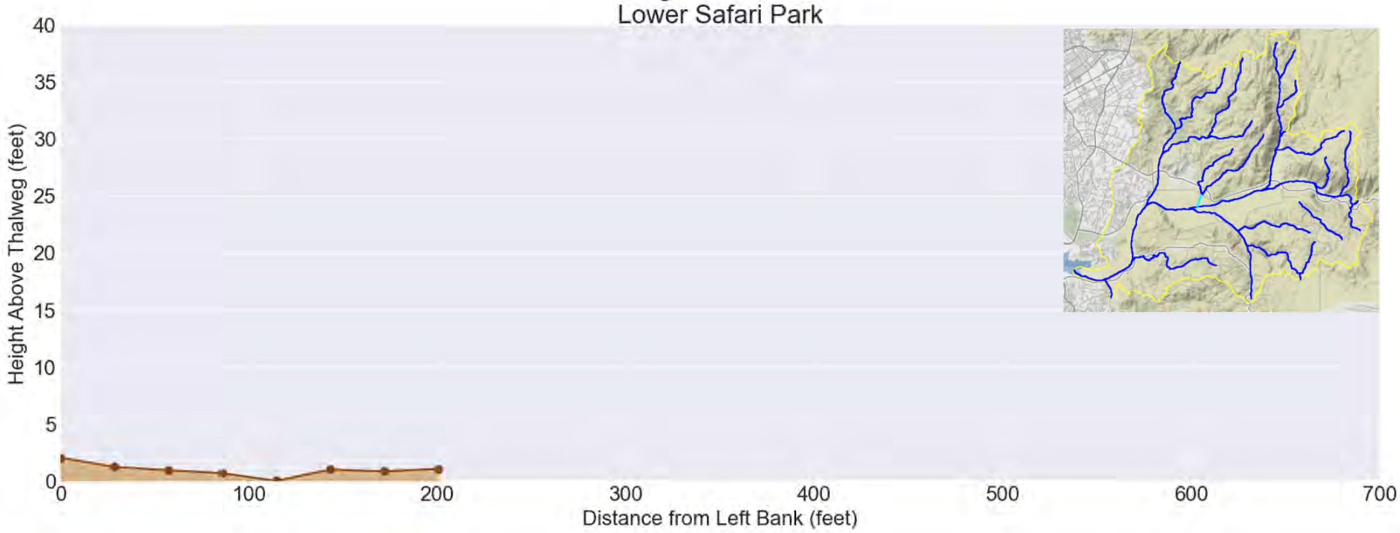
San Pasqual Valley, California

Jacobs

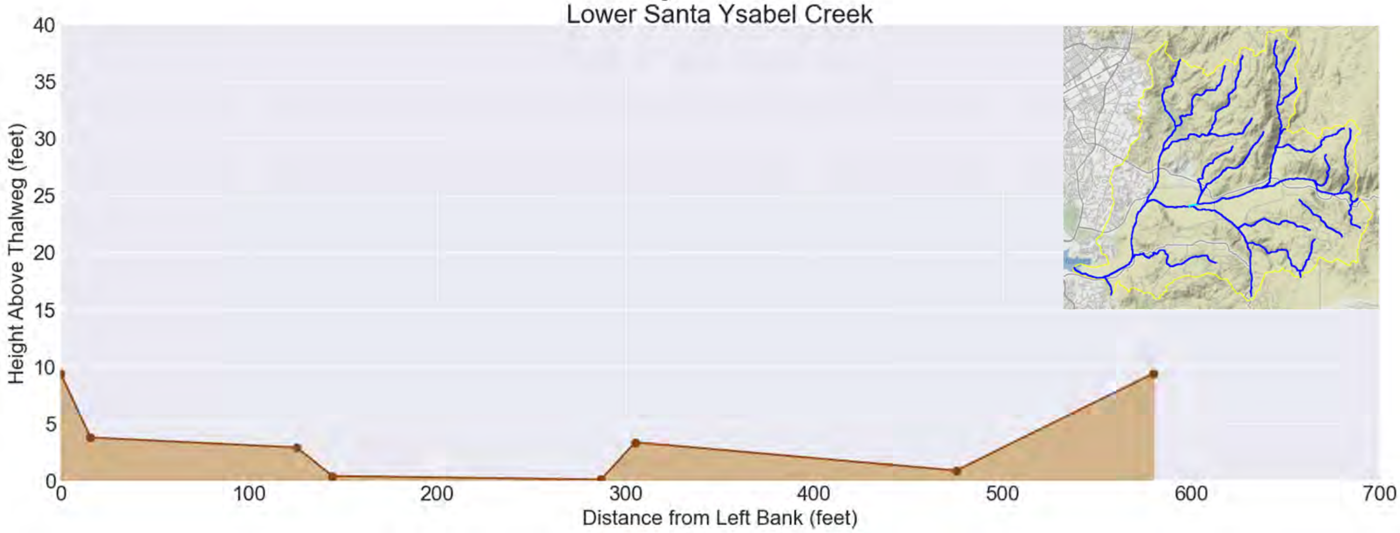
Segment No. 31
Lower Safari Park



Segment No. 32
Lower Safari Park



Segment No. 33
Lower Santa Ysabel Creek



Notes:

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

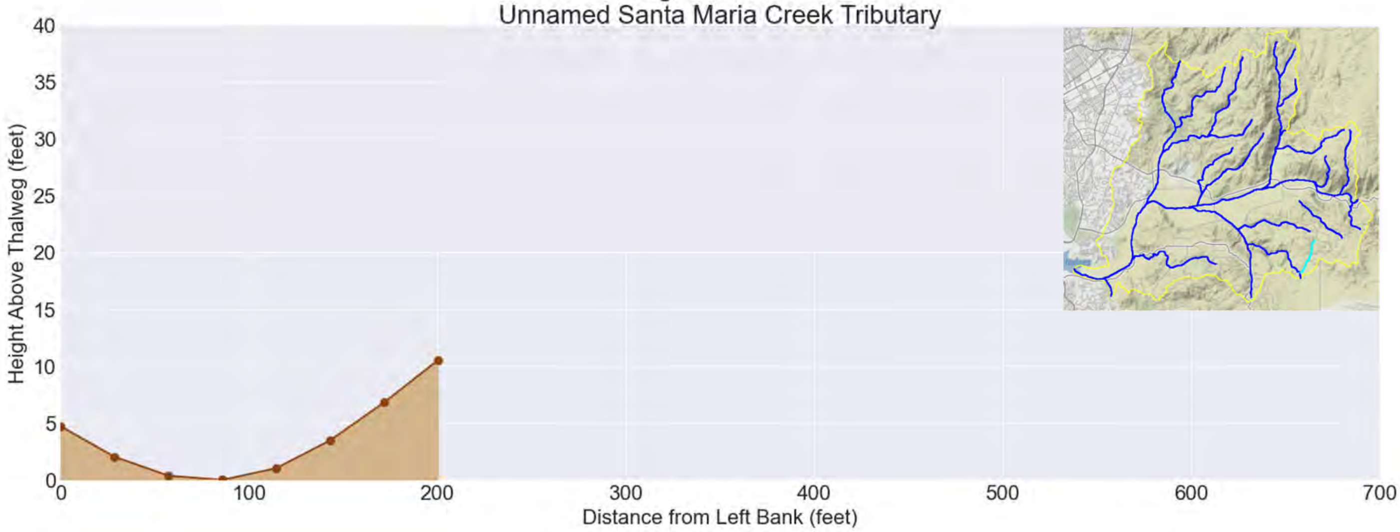
Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

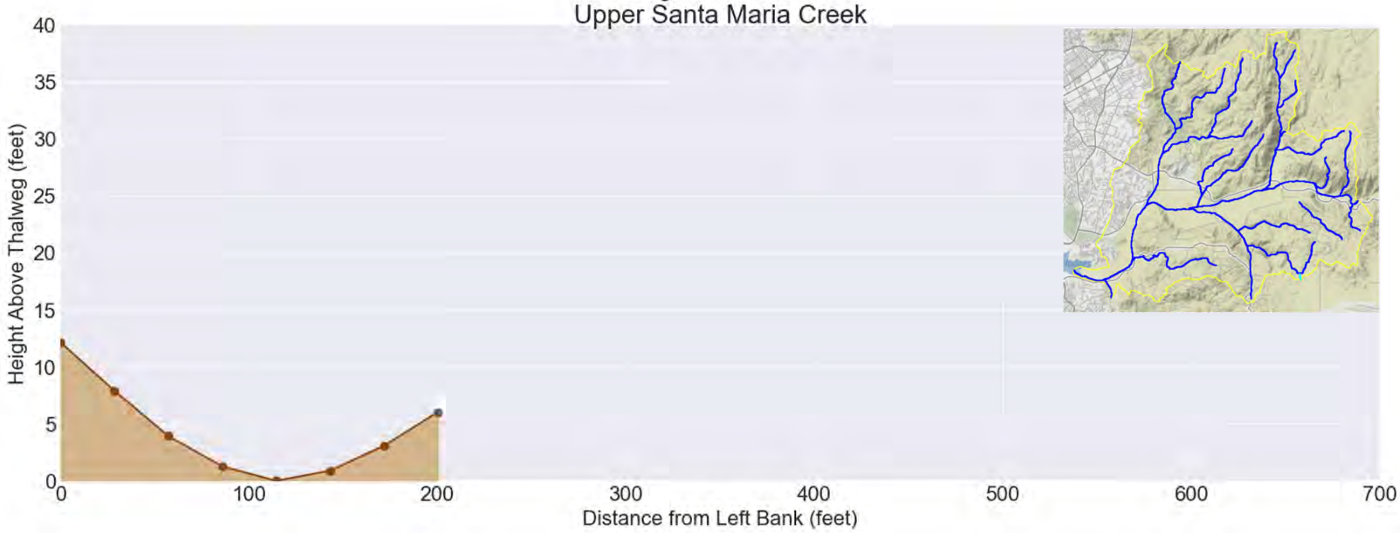
Figure B-11
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs

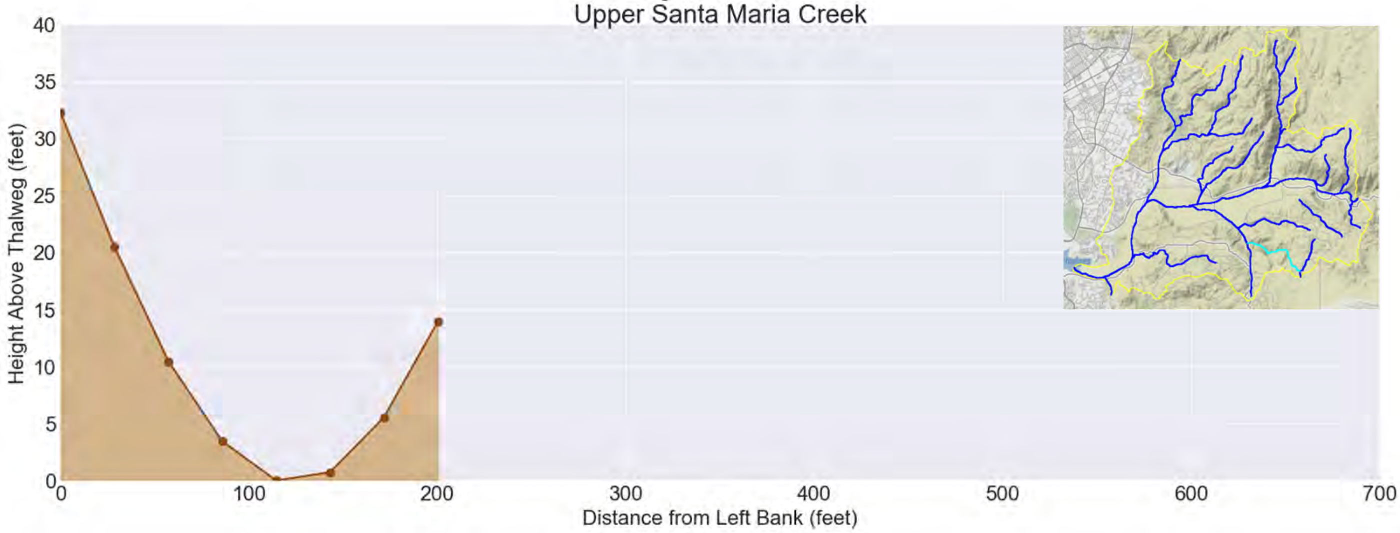
Segment No. 34
Unnamed Santa Maria Creek Tributary



Segment No. 35
Upper Santa Maria Creek



Segment No. 36
Upper Santa Maria Creek



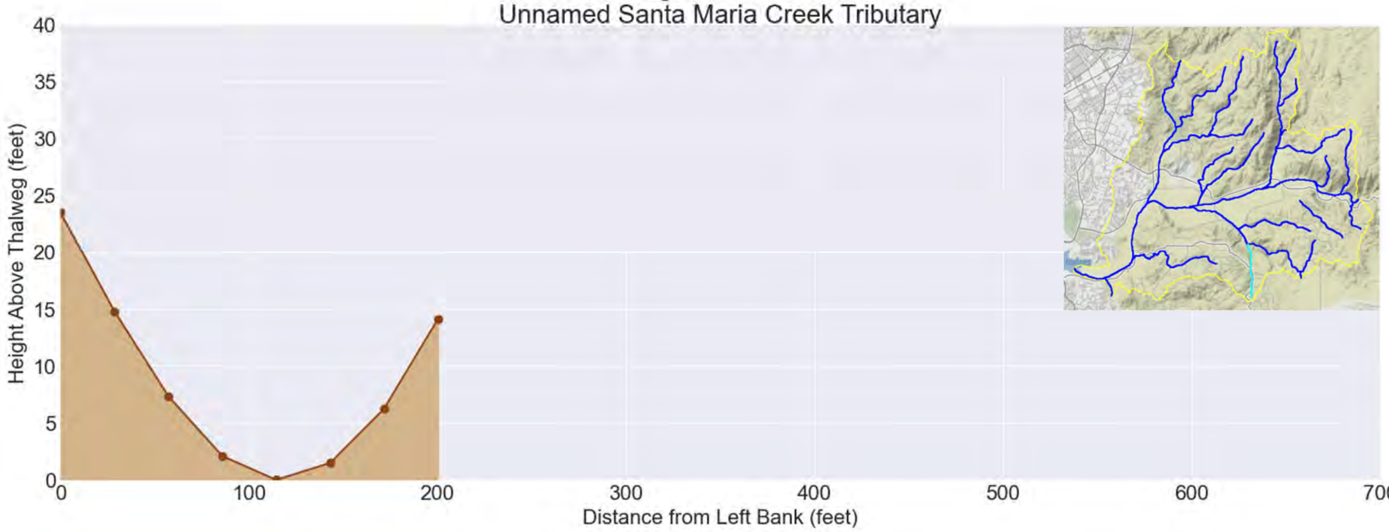
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

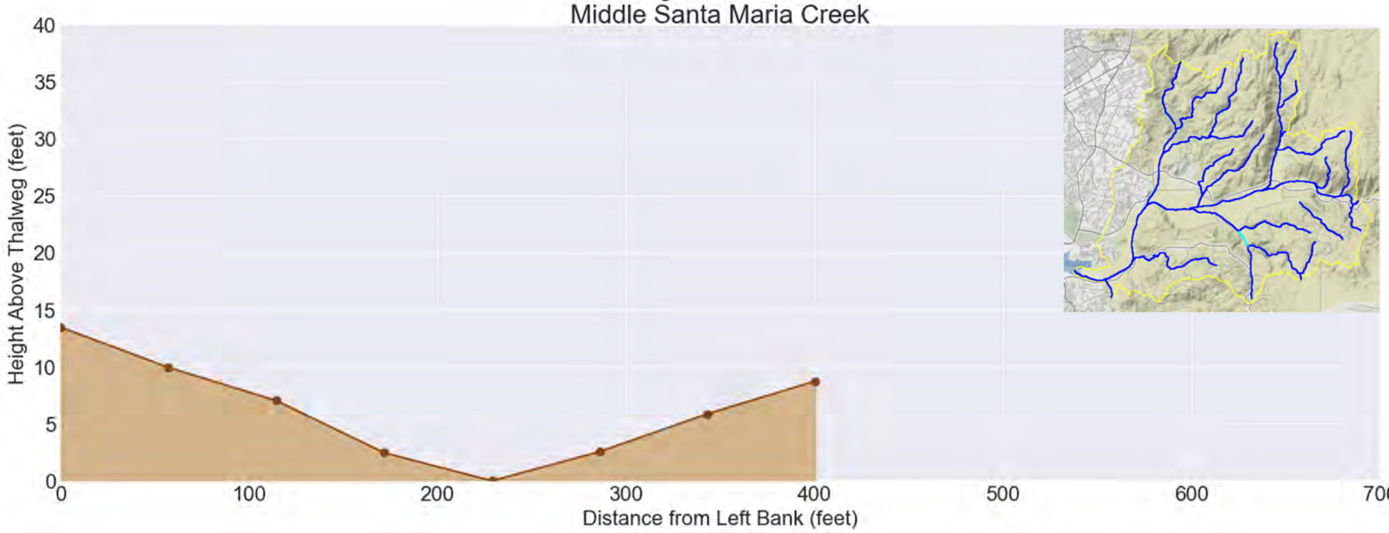
Figure B-12
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs

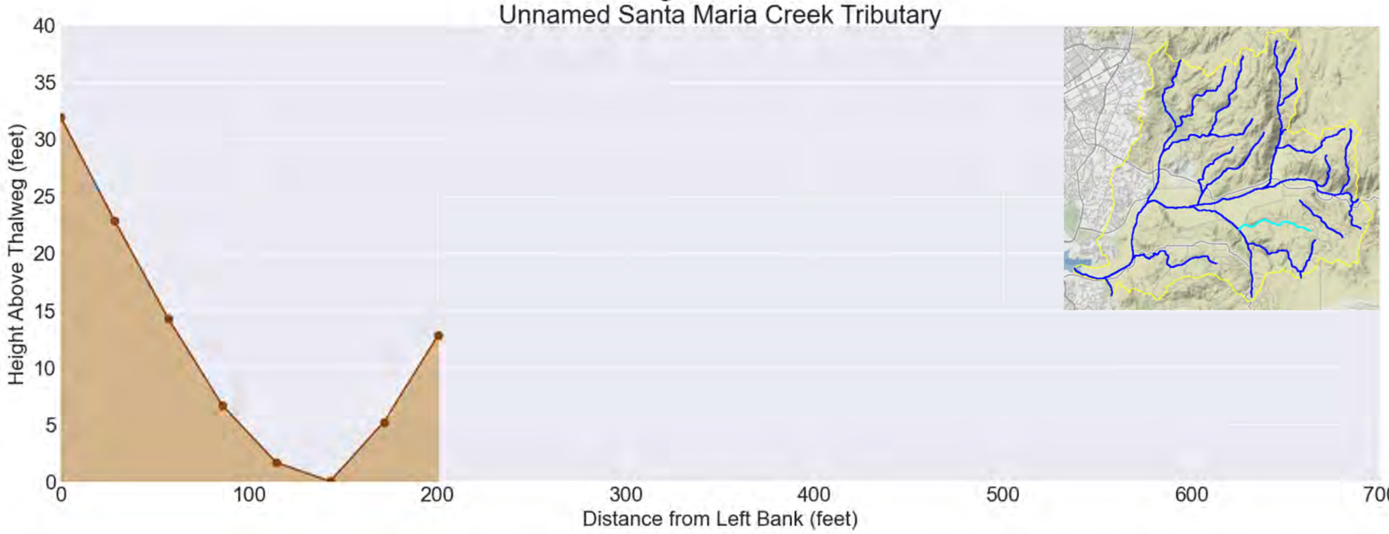
Segment No. 37
Unnamed Santa Maria Creek Tributary



Segment No. 38
Middle Santa Maria Creek



Segment No. 39
Unnamed Santa Maria Creek Tributary



Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-13

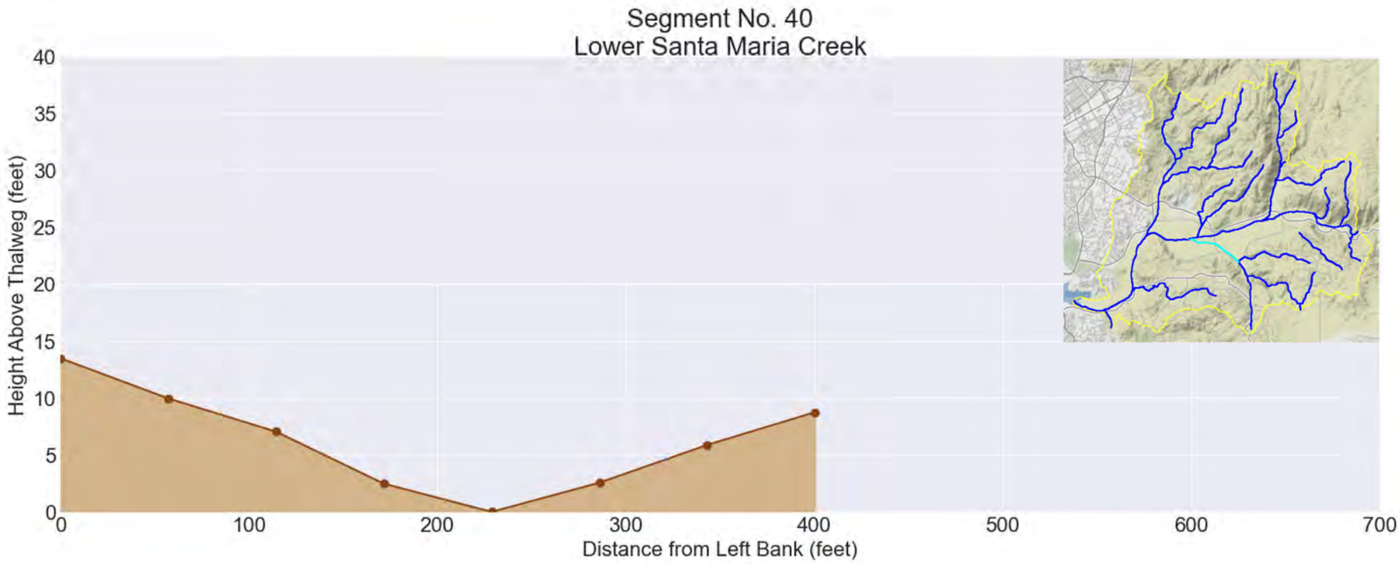
Modeled Eight-point Stream Channels by Segment Number

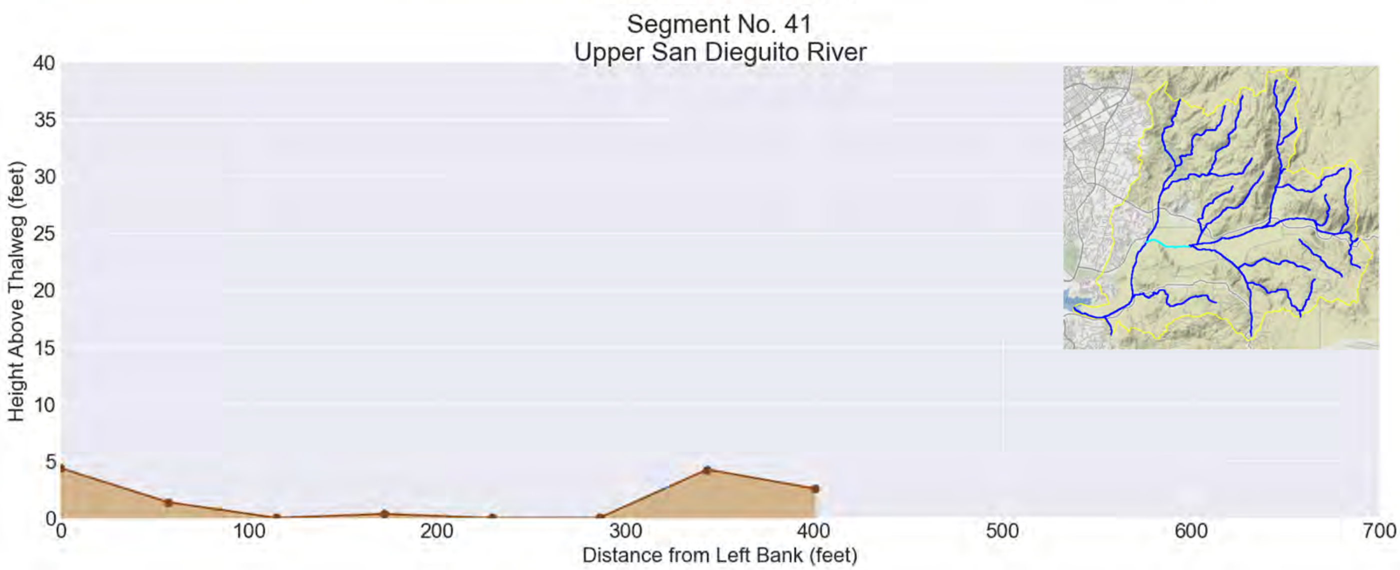
PMA7: Initial Surface Water Recharge Evaluation

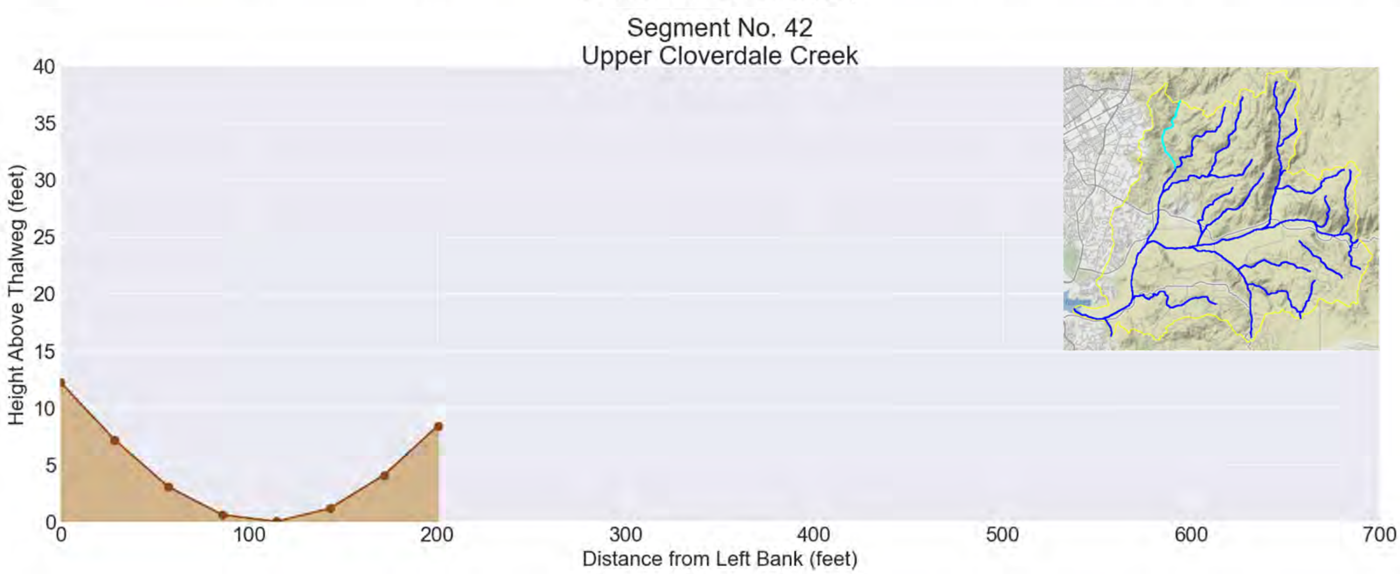
Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs







Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-14

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

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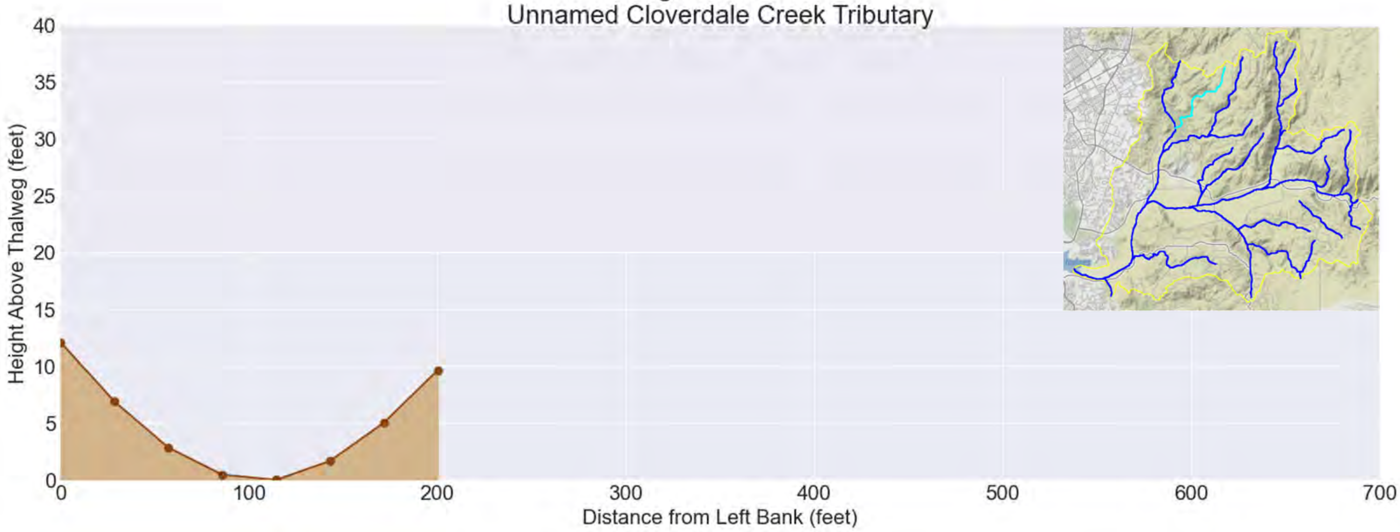
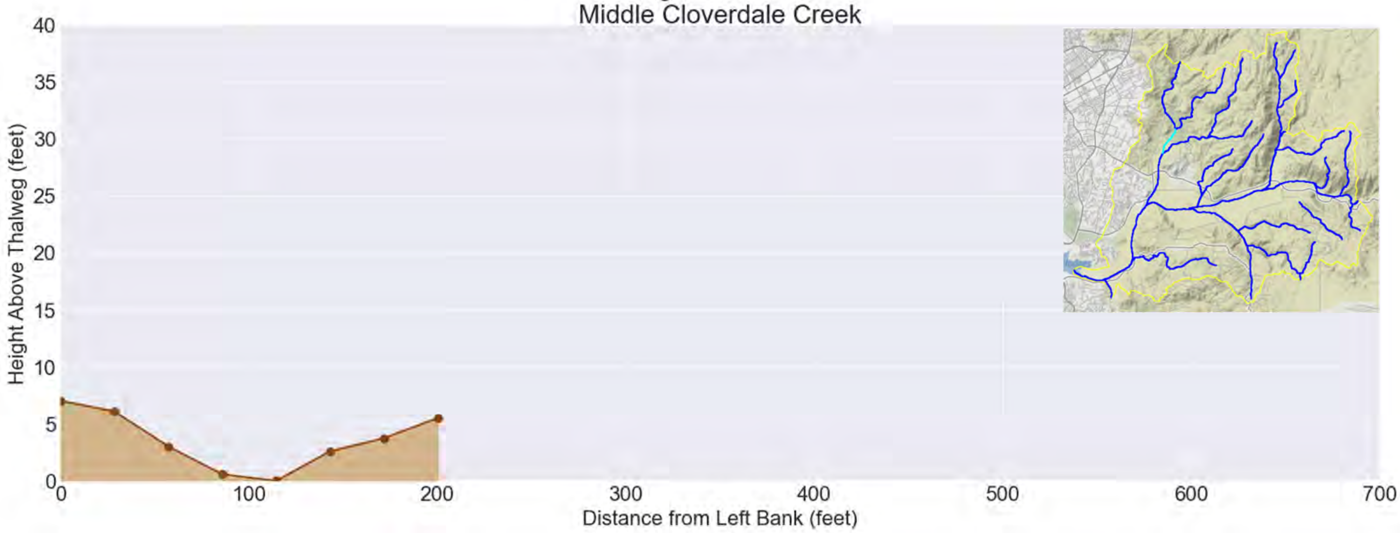
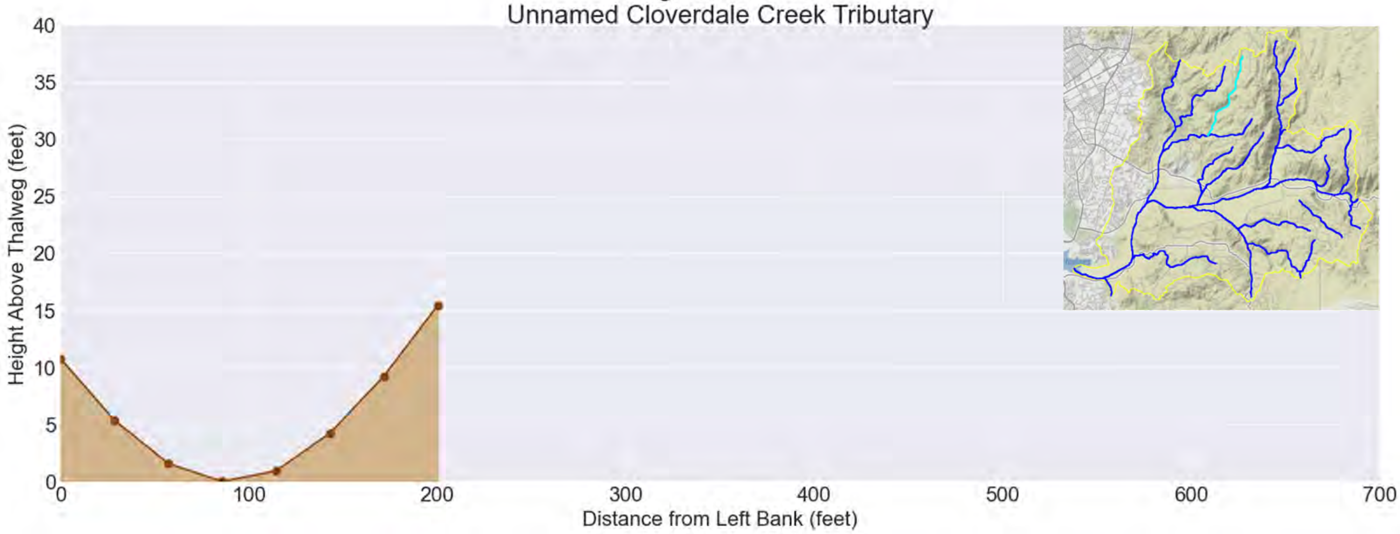
Segment No. 43
Unnamed Cloverdale Creek Tributary



Segment No. 44
Middle Cloverdale Creek



Segment No. 45
Unnamed Cloverdale Creek Tributary



Notes:

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

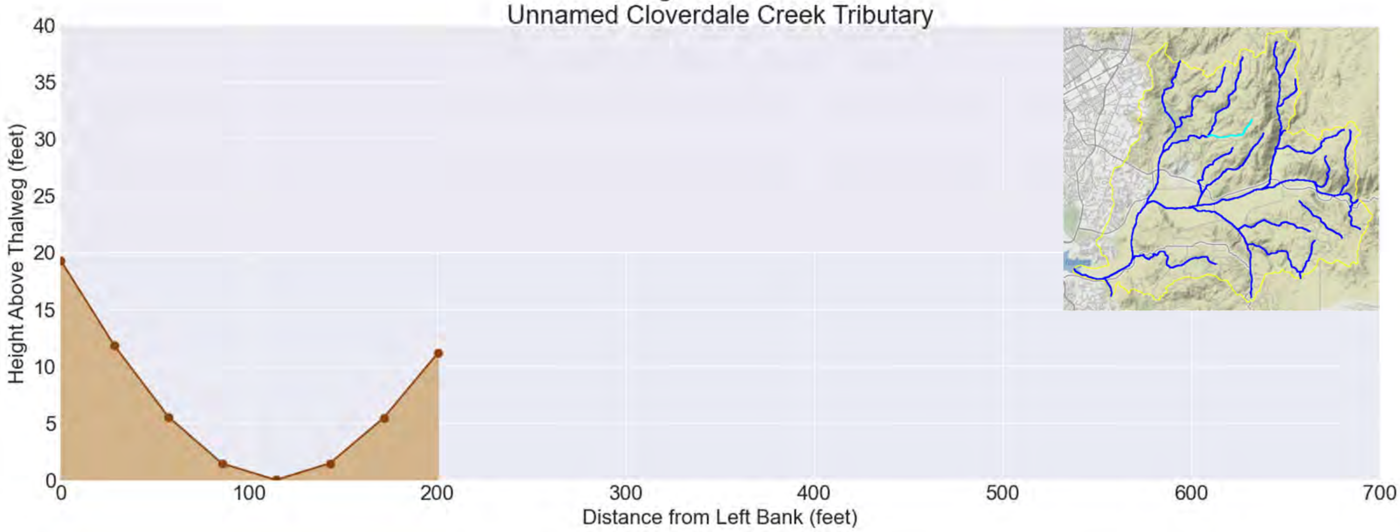
Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

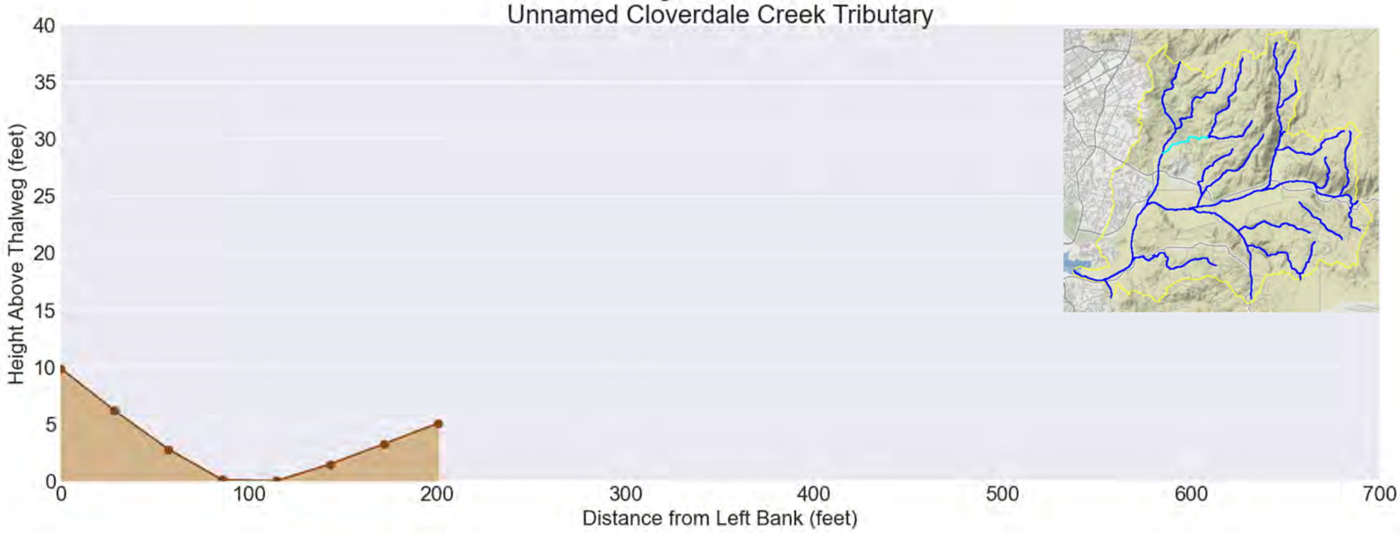
Figure B-15
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs

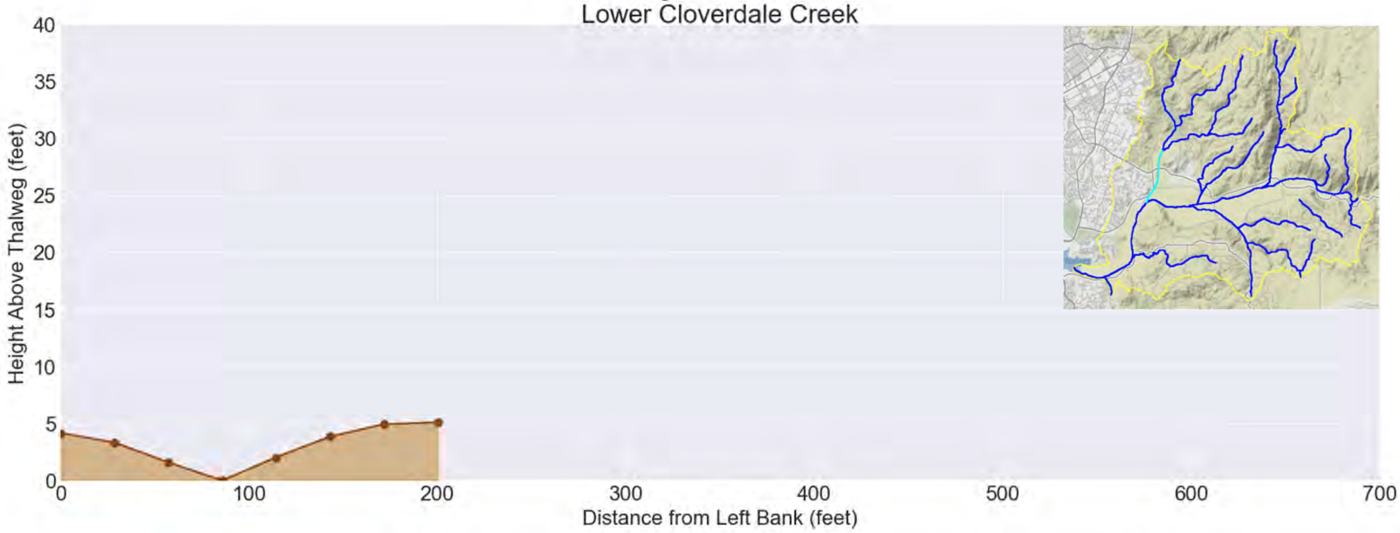
Segment No. 46
Unnamed Cloverdale Creek Tributary



Segment No. 47
Unnamed Cloverdale Creek Tributary



Segment No. 48
Lower Cloverdale Creek



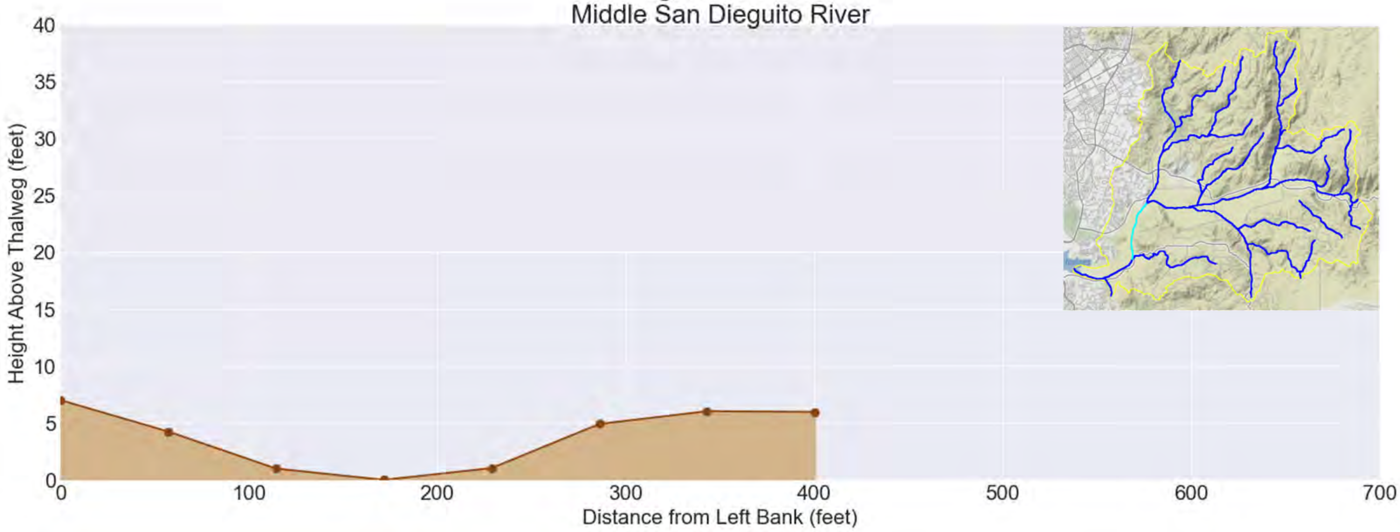
Notes:
1. Vertical axes are exaggerated by 20 times the horizontal axes.
2. "Left Bank" refers to the left side of the channel when facing the downstream direction for the stream segment.
3. Figure 8 in the technical memorandum shows segment locations and numbers on one map.

Map Legend
- Modeled Stream
- Highlighted Segment of Modeled Stream

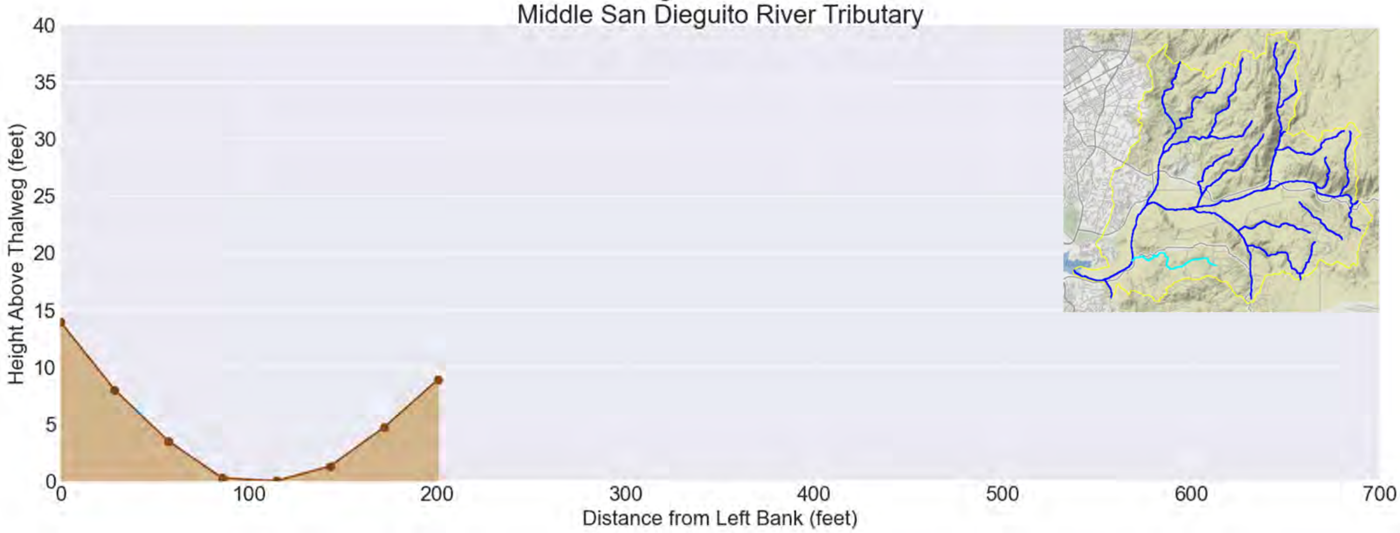
Figure B-16
Modeled Eight-point Stream Channels by Segment Number
PMA7: Initial Surface Water Recharge Evaluation
Task 2 Streambed Investigation
San Pasqual Valley, California

Jacobs

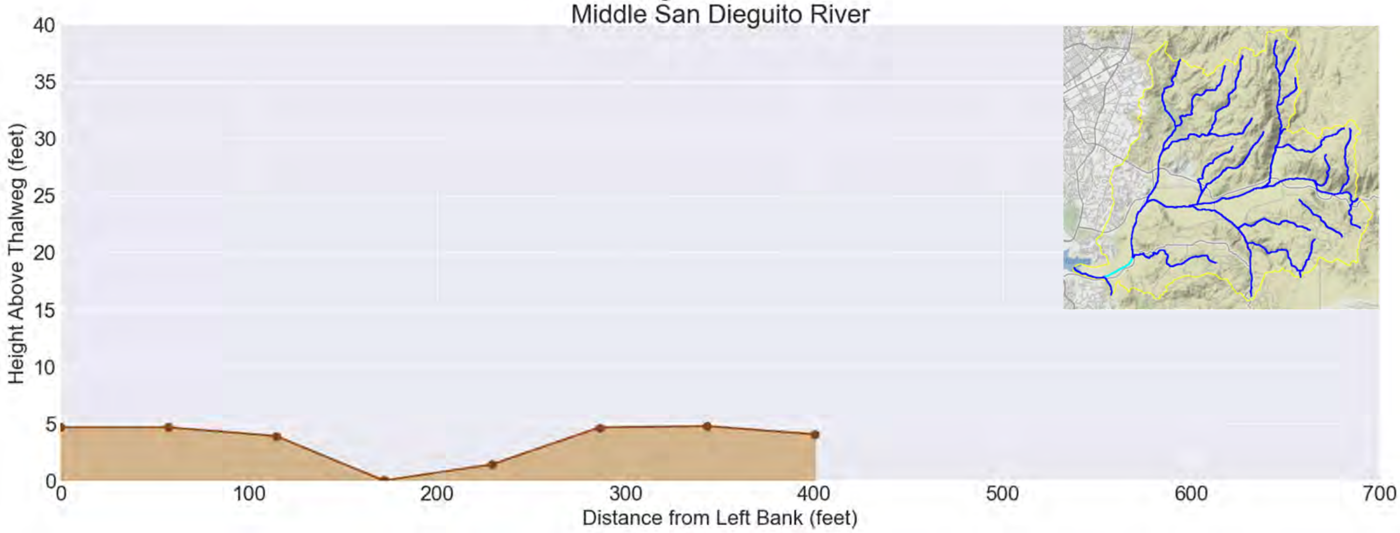
Segment No. 49
Middle San Dieguito River



Segment No. 50
Middle San Dieguito River Tributary



Segment No. 51
Middle San Dieguito River



Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-17

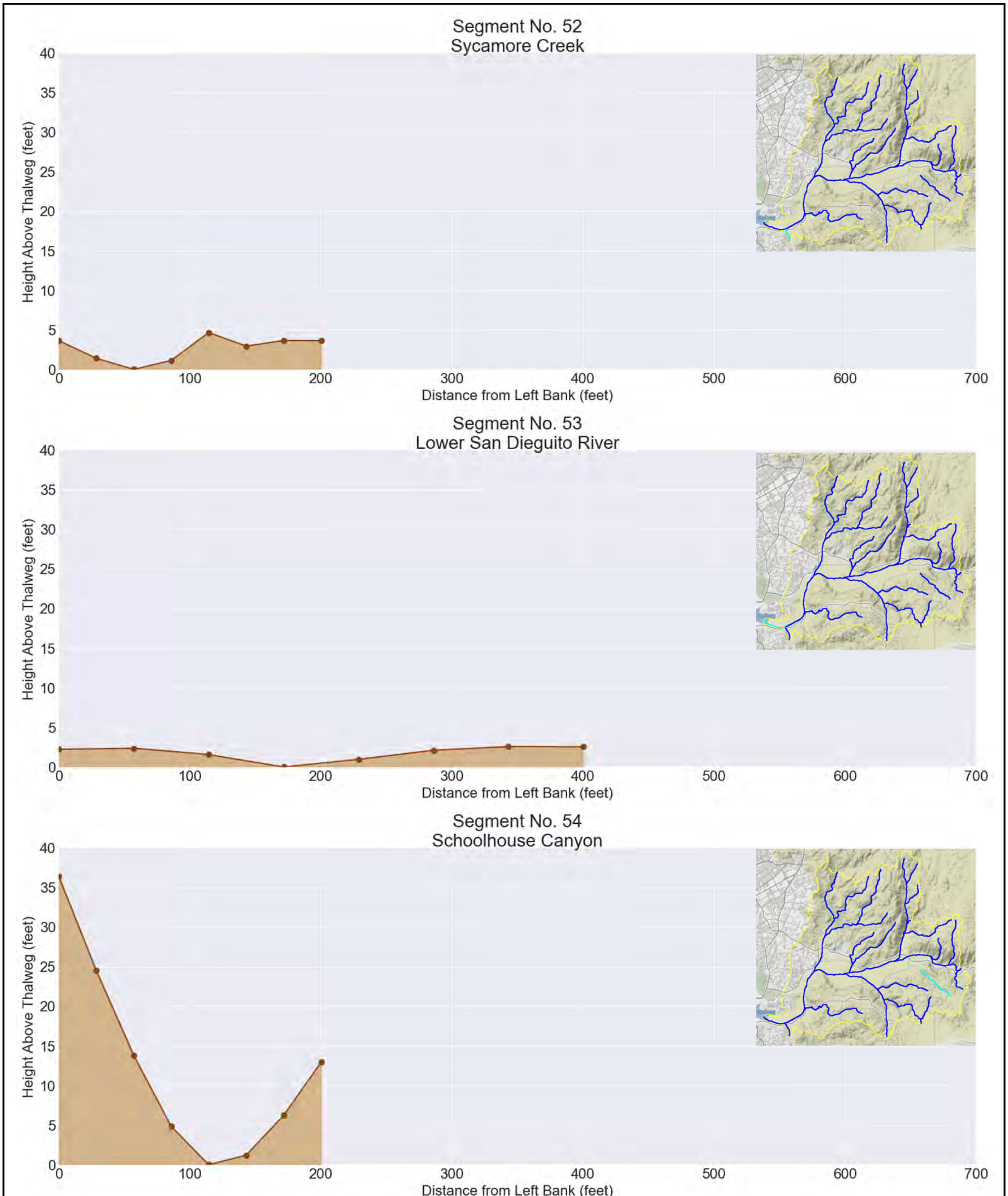
Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs



Notes:

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

Map Legend

- Modeled Stream
- Highlighted Segment of Modeled Stream

Figure B-18

Modeled Eight-point Stream Channels by Segment Number

PMA7: Initial Surface Water Recharge Evaluation

Task 2 Streambed Investigation

San Pasqual Valley, California

Jacobs