State of California
Natural Resources Agency
California Department of Fish and Wildlife

INSTREAM FLOW EVALUATION: SOUTHERN CALIFORNIA STEELHEAD ADULT SPAWNING AND JUVENILE REARING IN SAN ANTONIO CREEK, VENTURA COUNTY

STREAM EVALUATION REPORT 2021-02

April 2021

Cover photo: San Antonio Creek (Transect 105) at 9 cfs, Ventura County.

California Department of Fish and Wildlife
Stream Evaluation Report 2021-02

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April 2021

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California Department of Fish and Wildlife
Water Branch
Instream Flow Program
Stream Evaluation Report 2021-02

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PREFACE

The Ventura River is an essential watershed for the recovery and perpetuation of native Southern California anadromous rainbow trout (*Oncorhynchus mykiss*), commonly known as steelhead. The Southern California steelhead recovery plan (NMFS 2012) classified the Ventura River basin as a high priority Core 1 watershed, because of its potential to support independent viable populations of the Southern California steelhead distinct population segment. The Ventura River was also identified as a priority stream under the California Water Action Plan (CWAP), which outlines actions to address challenges and promote reliability, restoration, and resilience in the management of California's water (CNRA et al. 2014; CNRA et al. 2016). Under Action 4 of the CWAP, the California Department of Fish and Wildlife (the Department, or CDFW) and State Water Resources Control Board (State Water Board) were directed to implement actions to enhance instream flows within five priority stream systems that support critical habitat for anadromous fish. The Ventura River was selected as one of these five streams because of its high biological resource value and potential for species recovery.

The Department holds fish and wildlife resources in California in trust for the people of the State and has jurisdiction over the conservation, protection, and management of those resources (Fish and Game Code §711.7(a); Fish and Game Code §1802). The Department seeks to manage California's diverse fish, wildlife, plant species, and natural communities for their intrinsic and ecological value and their use and enjoyment by the public. The Department's Instream Flow Program develops scientific information to determine the flows needed to maintain healthy conditions for fish, wildlife, and the habitats on which they depend. The Department recommends using the Instream Flow Incremental Methodology (IFIM) to evaluate and develop instream flow criteria for actions that may affect California's aquatic resources. The IFIM process and instream flow evaluations, in general, should include broad consideration of the structure and function of riverine systems, and examination of five core riverine components (i.e., hydrology, biology, geomorphology, water quality, and connectivity).

To address the CWAP in the Ventura River watershed, the Department has conducted two instream flow studies and produced a watershed-wide flow criteria report. The studies evaluate flows for maintaining ecological condition, adult steelhead passage through the intermittent reach of the mainstem Ventura River, and adult steelhead spawning and juvenile rearing within San Antonio Creek. To fulfill their obligations under the CWAP, the State Water Board is developing a groundwater-surface water model. The groundwater-surface water model will quantify the relationship between surface and subsurface flow, providing a better understanding of water supply, water demand, and instream flows in the watershed. Integration of the Department's study results with the State Water Board's groundwater-surface water model will be essential to enhancing instream flows and informing water management within the Ventura River watershed.

This technical report summarizes results of the instream flow study conducted along 3.7 miles of San Antonio Creek to develop flow-ecology relationships for steelhead adult spawning and juvenile rearing. San Antonio Creek is an important component of the Ventura River study due to the Southern California steelhead spawning and rearing habitat it provides (CDFG 1996; Walter 2015); its potential to enhance species recovery; and the impacts of water diversion, habitat loss, and degradation throughout the Ventura watershed (CDFG 1996). The study design was outlined in the Department's *Study Plan: Habitat and Instream Flow Evaluation for Steelhead in the Ventura River, Ventura County* (CDFW 2017). This report describes the methods employed to develop predictive hydraulic models and resulting flow-habitat relationships in the Ventura River over a range of flows. The results of this study, along with other supporting information and data, are intended to be used to evaluate instream flow needs for adult spawning and juvenile rearing steelhead in San Antonio Creek.

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ABBREVIATIONS AND ACRONYMS

1D	one-dimensional (hydraulic model)
AWS	area-weighted suitability
cfs	cubic feet per second
cm	centimeter
COMID	common identifier (as used by USGS National Hydrography Dataset)
CWAP	California Water Action Plan
Department	California Department of Fish and Wildlife
DPS	distinct population segment
ESA	Endangered Species Act
ft	foot (feet)
mi	mile(s)
mi^2	square mile(s)
HSC	habitat suitability criteria
IFIM	Instream Flow Incremental Methodology
LARWQCB	Los Angeles Regional Water Quality Control Board
NMFS	National Marine Fisheries Service
SEFA	System for Environmental Flow Analysis (computer software)
TMDL	total maximum daily load
TNC	The Nature Conservancy
USGS	United States Geological Survey
VCWPD	Ventura County Watershed Protection District

CONVERSIONS

1 cubic foot per second ≈ 2.83×10^{-2} cubic meters per second
1 inch ≈ 2.54 centimeters
1 foot ≈ 0.31 meters
1 mile ≈ 1.61 kilometers
1 square mile ≈ 2.59 square kilometers

1.0 INTRODUCTION

The Ventura River watershed supports all resident and anadromous life history stages of coastal rainbow trout/steelhead, *Oncorhynchus mykiss*. San Antonio Creek is a major tributary to the Ventura River and provides important spawning and rearing habitat for the Southern California steelhead distinct population segment (DPS). San Antonio Creek's headwater streams begin in the Topatopa Mountains northeast of the City of Ojai in Ventura County, California. San Antonio Creek then flows southwest for nearly 10 miles (mi) before joining the Ventura River, approximately 8 mi upstream of the Pacific Ocean (see Figure 2).

The National Marine Fisheries Service (NMFS) determined that the Southern California steelhead DPS is "ecologically discrete" from other Pacific coastal steelhead populations such as the Northern or Central California Coast steelhead DPS (NMFS 2012). Southern California steelhead spawn and rear in suitable coastal streams from the Santa Maria River in Santa Barbara County to the Tijuana River along the California-Mexico border. The Southern California steelhead DPS was first listed under the federal Endangered Species Act (ESA) by NMFS in 1997 as an evolutionarily significant unit (62 Federal Register 43937). This designation was then replaced with a final DPS listing determination in 2006 (79 Federal Register 20802; NMFS 2012). A federal listing under the ESA requires NMFS to designate critical habitat for ESA-listed species. The Ventura River watershed and its tributaries, including San Antonio Creek, were designated by NMFS as critical Southern California steelhead habitat in 2005 (70 Federal Register 52488; NMFS 2012).

Historically, the 226 mi^2 Ventura River watershed contained one of the largest and most consistent runs of Southern California steelhead (CDFG 1996; Figure 1). A 1946 California Division of Fish and Game staff report estimated annual returns of 4,000–5,000 adult steelhead to the Ventura River system (Clanton and Jarvis 1946), half of which migrated as far as the high-quality upstream spawning areas in Matilija Creek (Titus et al. 2010). A key factor in this success was the abundant habitat within the upper Ventura watershed (Titus et al. 2010). However, the construction of Matilija Dam in 1948 marked the beginning of major declines in the number of returning steelhead by preventing access to significant habitat in the upper tributaries (Titus et al. 2010). The construction of Casitas Dam and the Robles Diversion Dam[a] in 1958 resulted in a further reduction of flow and available upstream habitat (NMFS 2012; Titus et al. 2010). Together, Matilija and Casitas dams block access to an estimated 90% of the highest-

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[a] A fish passage facility at the Robles Diversion Dam became fully operational in 2005.

quality spawning habitat in the watershed (NMFS 2012). Although annual adult runs in the Ventura River watershed had previously numbered in the thousands (Titus et al. 2010), by 1994 the returning steelhead adult abundance had dwindled to approximately a few hundred (Busby et al. 1996).

Figure 1. Adult steelhead on the Ventura River above the Highway 101 bridge (photo from CDFG 1947).

As a result, only two Ventura River tributaries with significant steelhead spawning and rearing habitat remain below these barriers: San Antonio Creek and North Fork Matilija Creek (Allen 2015). However, human land use change and the resulting impacts in the San Antonio Creek watershed limit spawning and rearing habitat. Direct impacts to the creek include surface water and groundwater withdrawals, creek-adjacent development, cattle grazing, and incursion of invasive vegetation (e.g., *Arundo donax*), resulting in steelhead habitat limited by embedded spawning gravel, lack of deep pool habitat, inadequate instream cover, partial low-flow migration barriers, and excessive nitrogen (David Magney Environmental Consulting and Hawks & Associates 2005; Entrix Inc 2003; LARWQCB 2011).

In addition to the impacts of diversions, dams, and land use change, intensifying climate change is expected to result in warmer temperatures and increased precipitation variability, which will lead to more extreme fluctuations from drought to flooding (Hall et al. 2018; Langridge 2018; Swain et al. 2018). These shifts may lead to increased demand for water resources and more challenging conditions for native species.

1.1 Study Goals and Objectives

As described in the *Study Plan: Habitat and Instream Flow Evaluation for Steelhead in the Ventura River, Ventura County* (CDFW 2017), the goal of this study was to develop streamflow versus habitat relationships for juvenile and adult steelhead in San Antonio Creek. An understanding of the connection between streamflow and habitat in San Antonio Creek can be used to develop life-history-based flow criteria that enhance flows for the conservation, restoration, and protection of steelhead.

This technical report is one component of a set of interrelated reports (Figure 2). Flows that support adult steelhead passage through the intermittent reach of the Ventura River are detailed in the report *Instream Flow Evaluation: Southern California Steelhead Passage through the Intermittent Reach of the Ventura River, Ventura County* (Cowan et al. 2021). Flow criteria for ecological flows throughout the Ventura River watershed, including passage flows and a sensitive period indicator flow for San Antonio Creek, are presented in the Watershed Criteria Report *Instream Flow Regime Criteria on a Watershed Scale: Ventura River* (CDFW 2020a). This technical report describes the development of flow-habitat relationships for steelhead spawning and rearing based on one-dimensional (1D) hydraulic modeling and includes a summary of the relevant flow criteria results for steelhead passage flows, sensitive period indicator flows, and ecosystem baseflows for San Antonio Creek as presented in the companion Watershed Criteria Report (CDFW 2020a).

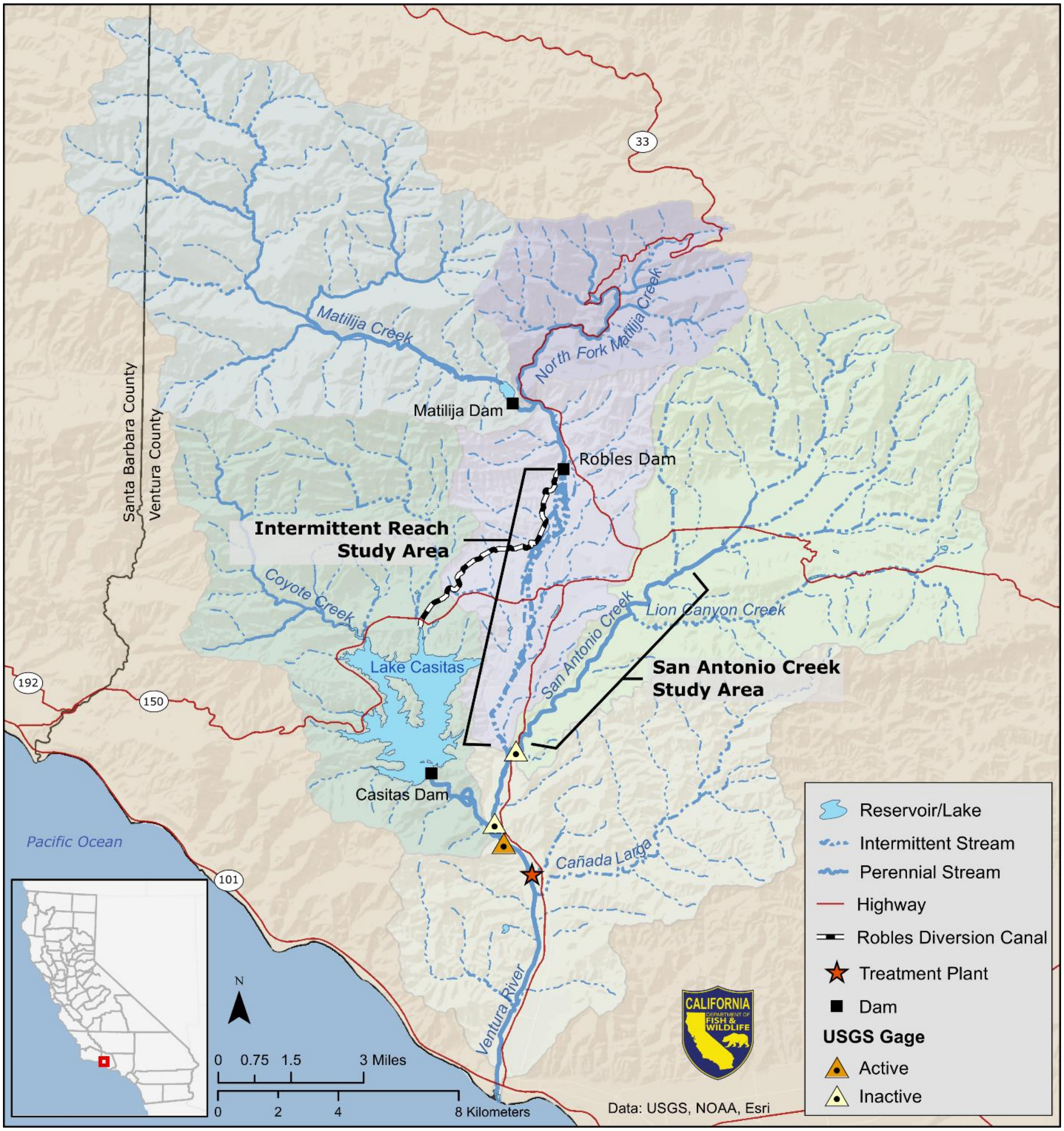

Figure 2. Map of study areas within the Ventura River watershed. In addition to the two study areas shown, a third report (CDFW 2020a) assesses instream flow needs at locations throughout the watershed. Note: intermittent and perennial streams shown here were classified by the United States Geological Survey (USEPA and USGS 2012). Additional USGS gages not used in the San Antonio Creek or intermittent reach reports are not shown.

2.0 DESCRIPTION OF STUDY AREA

The 51 mi^2 San Antonio Creek watershed receives flow from multiple tributaries including Lion Canyon, Stewart Canyon, Reeves, Thacher, McNell, Gridley Canyon, and Senior Canyon creeks, as well as several unnamed ephemeral streams in the higher elevation upper watershed (Figure 3). Over the course of 14.4 mi, the San Antonio Creek drainage descends from an elevation of approximately 4,970 feet (ft) in the Topatopa Mountains to 300 ft at its confluence with the Ventura River. Three small reservoirs store water in the upper San Antonio watershed: Lion Canyon Reservoir, Stewart Canyon Debris Basin, and off-channel Senior Canyon Reservoir. Lion Canyon Reservoir is located on Lion Canyon Creek approximately 5.5 mi upstream from its confluence with San Antonio Creek. The Stewart Canyon Debris Basin (64.6 acre-feet capacity) and Senior Canyon Reservoir (78 acre-feet capacity) are both located north of the City of Ojai near the base of the Topatopa Mountains. The Stewart Canyon Debris Basin blocks access to historically important upstream spawning and rearing habitat within Stewart Canyon Creek (David Magney Environmental Consulting and Hawks & Associates 2005).

In September 2010, the Ventura County Watershed Protection District (VCWPD) filed an application with the State Water Board to appropriate water from upper San Antonio Creek for a groundwater recharge project (SWRCB 2011). The project was designed to maximize water recharge in the Ojai Valley Groundwater Basin by diverting peak flows into an off-stream 4-acre spreading grounds with passive recharge wells (SWRCB 2011). As part of the resulting 2011 water rights protest resolution between the VCWPD and NMFS (McInnis 2011), 1 ft of depth must be maintained for adult steelhead passage in San Antonio Creek downstream of the point of diversion while water is diverted into the spreading grounds. It was determined that a flow of 21 cubic feet per second (cfs), as gaged at the Grand Avenue point of compliance, would achieve the minimum depth requirement in San Antonio Creek (see Figure 3).

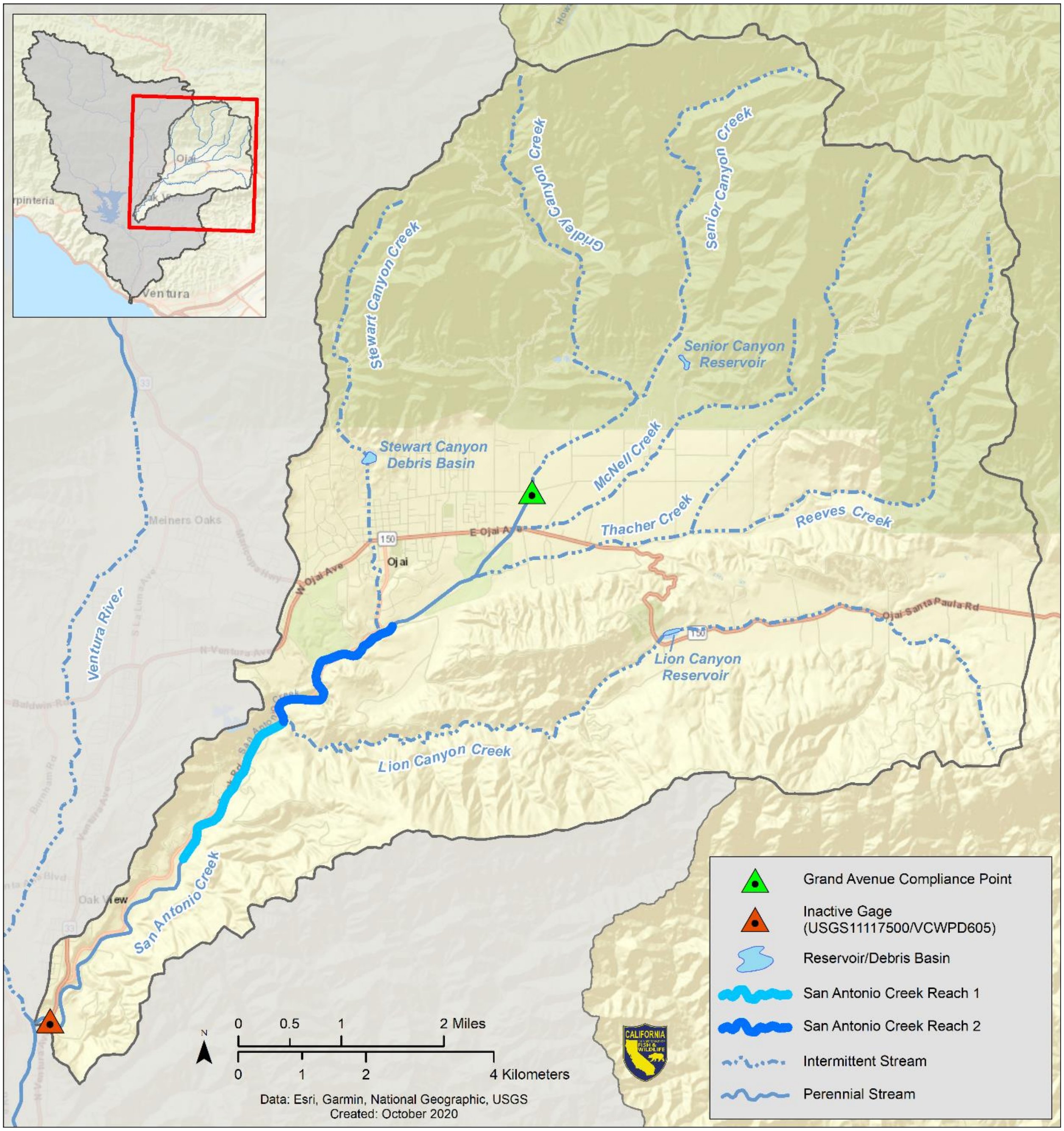

Figure 3. Map of San Antonio Creek watershed. Note: intermittent and perennial streams shown here were classified by the United States Geological Survey (USEPA and USGS 2012). An active gage (VCWPD 605A), not used in this report, is located just upstream of the mapped inactive gage.

Riparian habitat in San Antonio Creek transitions through several vegetation types. The lower section of the creek between the Ventura River and the City of Ojai is primarily surrounded by riparian oak woodland, large riparian stands of invasive giant reed (*Arundo donax*), and annual grassland (Figure 4; USDA 2010; Walter 2015). The middle section of the creek runs through the City of Ojai, with crops and pasture in the portion of the Ojai Valley above the city (Walter 2015). The vegetation in the upper section of the creek (named Senior Canyon Creek above Hermitage Road) transitions back into oak woodland and small sections of riparian valley foothill species (Walter 2015).

Figure 4. Large stands of *Arundo donax* along San Antonio Creek (flow at 6 cfs).

Most of the watershed is privately owned and primarily managed for agricultural (e.g., avocado, citrus, and walnut orchards), rural residential, and urban use (USDA 2010). The only publicly owned properties in the lower watershed are the Ventura River Confluence Preserve, managed by the Ojai Valley Land Conservancy, and Camp Comfort, managed by the Ventura County Parks Department. The high elevation Los Padres National Forest is managed by the United States Forest Service (USDA 2010).

2.1 Fish Species

The San Antonio Creek watershed contains four known species of fish with established populations: coastal rainbow trout/steelhead, Threespine Stickleback (*Gasterosteus aculeatus*), Arroyo Chub (*Gila orcutti*), and Western Mosquitofish (*Gambusia affinis;* non-native to California). Threespine Stickleback and coastal rainbow trout/steelhead are native to the watershed, while Arroyo Chub is native to nearby watersheds. The subspecies Unarmored Threespine Stickleback (*Gasterosteus aculeatus williamsoni*) is present in nearby watersheds and may be present in San Antonio Creek. This subspecies is listed as endangered under the California ESA and the Federal ESA (85 Federal Register 4692; CDFW 2020f). In addition, the Southern California steelhead DPS is listed as endangered under the Federal ESA (71 Federal Register 834), and the Arroyo Chub is listed by the Department as a California species of special concern (CDFW 2020c).

Additional introduced fish species observed in the Ventura River watershed but not the San Antonio Creek drainage include: bullhead (*Ameiurus melas* and *Ameiurus nebulosus*), catfish (*Ictalurus* spp.), Common Carp (*Cyprinus carpio*), sunfish (*Lepomis* spp.), Fathead Minnow (*Pimephales promelas*), and Largemouth Bass (*Micropterus salmoides*). Two additional native species, Pacific Lamprey (*Entosphenus tridentatus*) and Prickly Sculpin (*Cottus asper*), have been recorded in the Ventura River and may have been present in San Antonio Creek historically. Fish observations are based on unpublished snorkel survey data from 2014–2020 from the Department's South Coast Region, and corroborated by other sources (Casitas Municipal Water District 2006; David Magney Environmental Consulting and Hawks & Associates 2005; Goodman and Reid 2015; Santos et al. 2014).

Steelhead are anadromous like other salmonids. Newly hatched steelhead fry grow into juveniles and rear in freshwater for one to three years, after which, some make the transition to smolts and outmigrate to the ocean to mature (NMFS 2012). Adult steelhead often return to their freshwater streams of origin to spawn after one to four years in the ocean. Unlike salmon, some adult steelhead survive their initial spawning effort and have the potential to return to San Antonio Creek over multiple years (NMFS 2012). Figure 5 shows the periodicity for steelhead within San Antonio Creek by life stage.

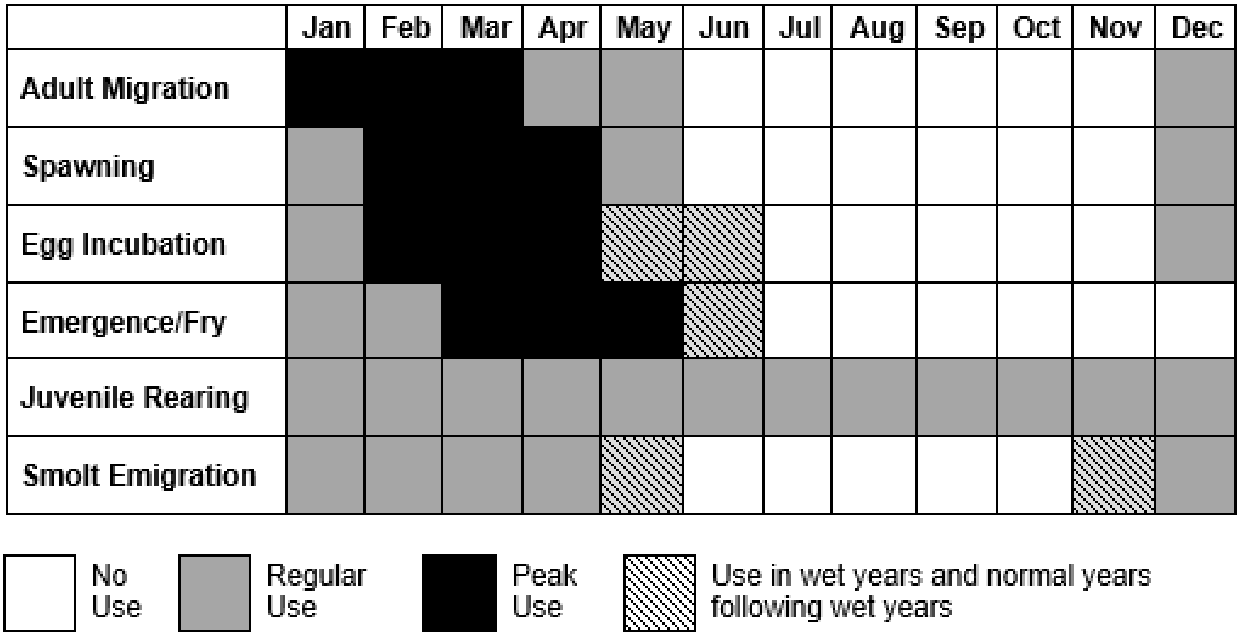

Figure 5. Life stage periodicity for Southern California steelhead in San Antonio Creek.[b]

Most fish passage opportunities in the Ventura River watershed are provided by intermittent high intensity, short duration storms during the wet season between November and March (Walter 2015). Successful upstream adult steelhead passage requires a storm that can breach the naturally occurring sandbar separating the Ventura River from the Pacific Ocean. Once this sandbar has been breached by a significant flow event, adults in the ocean move a short distance upstream into the Ventura Lagoon while juveniles outmigrate to the ocean. The descending limb of stormflow triggers adult migration further up the lower Ventura River to San Antonio Creek (Walter 2015).

Several factors limit adult and juvenile steelhead migration between the Pacific Ocean and San Antonio Creek. Steelhead movement in both the Ventura River and San Antonio Creek is inhibited by low and intermittent streamflows which can create sections with elevated water temperature and low dissolved oxygen content (Walter 2015). Large physical passage barriers can also create passage restrictions during low-flow periods. The *Ventura River Watershed Management Plan* (Walter 2015) identified two partial physical barriers on San Antonio Creek: the Fraser Street Arizona crossing (Figure 6) and the bridge apron at the upstream end of Camp Comfort Park (see Figure 13). However, the Camp Comfort bridge apron was broken apart by flow conditions in the winter of 2019 and is no longer considered a barrier.

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[b] Larson, M., CDFW South Coast Region Fisheries Supervisor, personal communication August 14, 2018.

Figure 6. Photo of a partial passage barrier at the Fraser Street Arizona crossing. Flow pictured at approximately 2 cfs.

2.2 Hydrology

The hydrology of San Antonio Creek and other tributaries in the Ventura River watershed are typical of coastal watersheds in Southern California. The Mediterranean climate in the Ventura River watershed follows a pattern of wet and cooler winters (November–March) and warmer dry summers (April–October). Discharge is characterized by low summer flows and "flashy" short duration, high intensity peak storm events in the winter (Keller and Capelli 1992).

Watershed hydrology is best described by examining trends in flow monitoring data, preferably from stream gages with a long continuous record and where flows have not been significantly impaired by diversions (Cowan 2018). However, a gage meeting these conditions is not available in San Antonio Creek. San Antonio Creek has one gage location with a long-term period of record. Located at Highway 33 near the Ventura River confluence (see Figure 3), United States Geological Survey (USGS) gage 11117500 collected mean daily discharge data during water years 1950–1983. The collection of flow data at the gage was then continued by the VCWPD from the start of water year 1984 until the end of water year 2013[c] as gage 605. Although the continuous period of record is adequate for use in hydraulic modeling, the gage record is affected by significant agricultural and urban diversion within the Ojai Valley and along lower San Antonio Creek near the study area. The gage data are presented below to describe recent conditions in the watershed but are not an adequate representation of natural conditions in the watershed.

Gaged daily flow values were used to represent interannual hydrologic variability in San Antonio Creek under recent conditions. The mean daily flow from the San Antonio Creek gage record is presented in three ways below. First, Figure 7 presents the mean daily flow over the period of record by calendar day. Second, Figure 8 presents daily exceedance flows, using flow duration analysis. Flow duration analysis calculates the percent of days over the period of record that a given mean daily discharge is equaled or exceeded (CDFW 2013b). This percentage is expressed as a percent exceedance probability, and the discharge associated with that probability is referred to as an exceedance flow. Exceedance flows were calculated using the *Standard Operating Procedure for Flow Duration Analysis in California* (CDFW 2013b). Finally, the process was repeated to calculate monthly exceedance values, which show the percent likelihood of a particular flow occurring in any given month (Table 1). In each of these analyses, it is important to remember that the gage record represents recent conditions, not natural conditions.

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[c] Starting in 2014, VCWPD began collecting gage data approximately one-quarter mile upstream of the USGS gage collection site, using gage 605A. These data were recently made available through 2015.

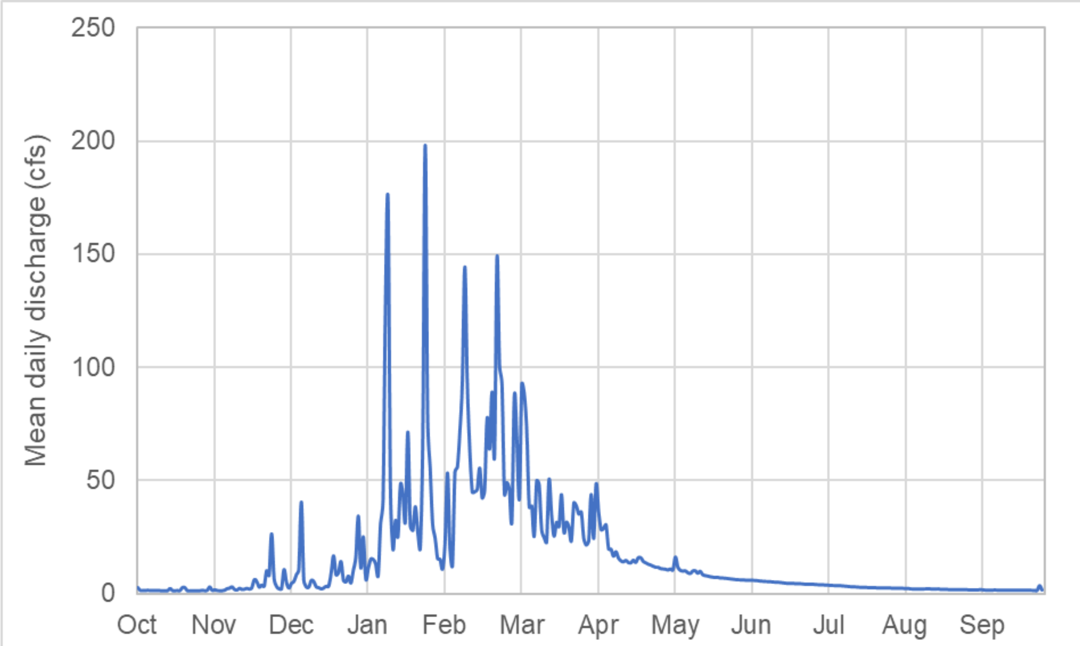

Figure 7. Mean daily flow (in cfs) for San Antonio Creek using the daily flow record for stations USGS 11117500 and VCWPD 605 from October 1, 1949 to September 30, 2013.

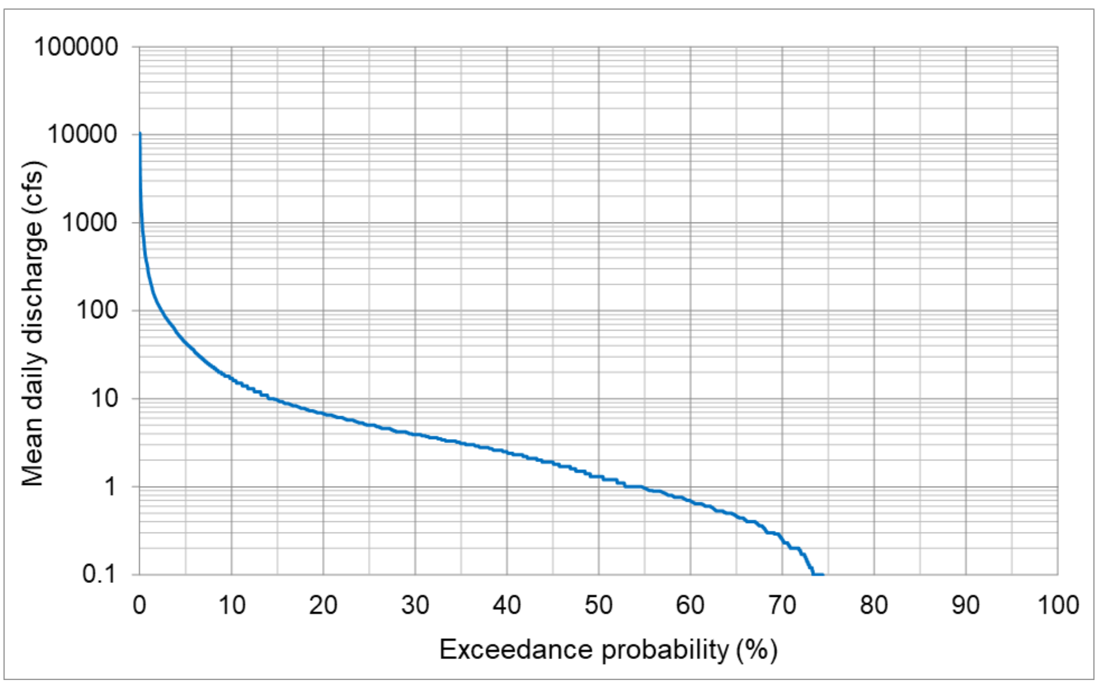

Figure 8. San Antonio Creek daily exceedance flows (in cfs) using the daily flow record for stations USGS 11117500 and VCWPD 605 from October 1, 1949, to September 30, 2013. The plot shows the percent of days that meet or exceed each discharge shown on the y-axis over the period of record.

Table 1. San Antonio Creek monthly exceedance flows (cfs) using the mean daily flow record for stations USGS 11117500 and VCWPD 605 from October 1, 1949, to September 30, 2013. For example, the 70% exceedance flow value for January indicates that a 1 cfs mean daily flow is met or exceeded on 70% of January days over the period of record.

Exceedance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
90%	0.0	0.5	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80%	0.4	1.1	1.0	0.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70%	1.0	2.0	1.8	1.4	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.2
60%	1.7	2.9	3.3	2.4	1.3	0.5	0.2	0.0	0.0	0.0	0.1	0.6
50%	2.7	4.5	5.3	3.9	2.2	1.1	0.6	0.2	0.1	0.1	0.5	1.2
40%	3.4	6.2	7.8	5.8	3.5	2.3	1.3	0.8	0.4	0.5	0.9	2.1
30%	4.8	10.0	12.0	8.5	5.3	3.6	2.1	1.3	1.0	1.0	1.7	3.0
20%	8.5	23.0	33.0	22.0	13.0	8.8	5.8	3.5	2.8	2.2	2.8	4.0
10%	33.0	72.0	97.0	49.0	25.0	16.0	9.8	6.1	4.6	4.0	4.6	7.3

Estimates of natural hydrology in San Antonio Creek are provided by the Natural Flows Database, developed by USGS and The Nature Conservancy (TNC; Zimmerman et al. 2020). This database was developed with machine learning tools (random forest models) that predict flows throughout the state using watershed characteristics, temperature, and precipitation data, along with a series of reference gages. Figure 9 shows median monthly estimates for San Antonio Creek from the USGS/TNC Natural Flows Database plotted against median monthly gaged flows for the same period.

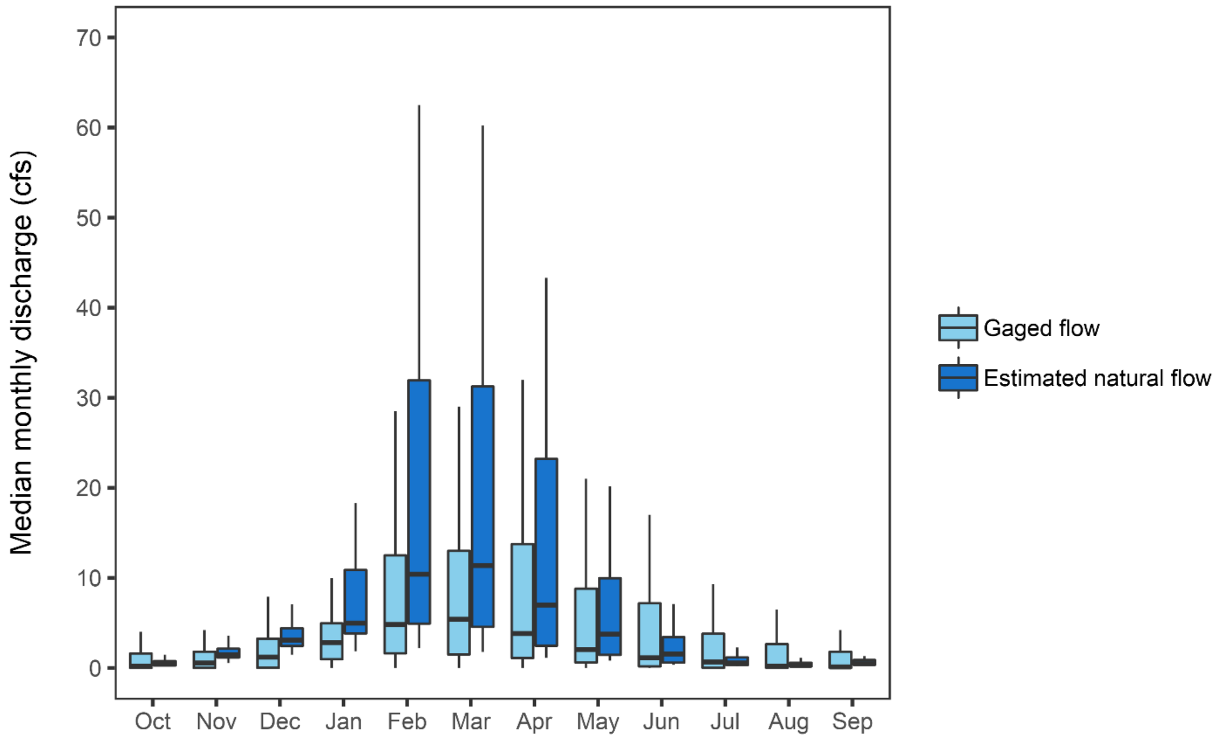

Figure 9. Boxplot comparing median monthly values for estimated natural flow to gage data for water years 1951–2013. Colored bars represent the 25th–75th percentile values, whiskers are 1.5× the interquartile range, and horizontal lines are median values. Outliers are not shown. Gage data: USGS gage 11117500 (USGS 2020) and VCWPD gage 605 (VCWPD 2020). Estimated natural flow data: common identifier (COMID) 17586840 (Zimmerman et al. 2020).

Functional Flows

Predicted functional flow metrics are also available for San Antonio Creek and can provide helpful information on the timing, magnitude, and duration of key functional flows under natural conditions (CDFW 2020b). Functional flows for California include the fall pulse flow, wet-season baseflow, peak flows, spring recession, and dry-season baseflow (California Environmental Flows Working Group 2020; Yarnell et al. 2020). Metrics are predicted using random forest models that were trained on a set of reference gages across the state of California, following the same process described by Zimmerman et al. (2018) for the monthly flow predictions described above.

The functional flows approach has been developed through a collaborative process under the Environmental Flows Technical Workgroup, a subgroup of the California

Water Quality Monitoring Council[d]. This group is currently preparing to release a detailed guidance document describing the California Environmental Flows Framework, which describes a functional flows approach to setting instream flow criteria. The California Environmental Flows Framework was named as a priority in Action 9.1 of the recently released California Water Resilience Portfolio (State of California 2020).

Functional flow metrics for San Antonio Creek Reach 1 and Reach 2 are provided in Table 2 through Table 5 for three water year types: wet, moderate, and dry (see Section 3.1 for reach delineation). The three water year types each represent one-third of the 64-year period of record. Figure 10 plots these functional flow metrics for Reach 1. The median values and ranges characterize key aspects of the five functional flows (Yarnell et al. 2020). Note that the magnitude and duration metrics should be read together; for example, the wet-season magnitude is higher in wet years than dry years but has a shorter duration at this higher flow.

There are some limitations to this statewide tool. Arid watersheds, such as San Antonio Creek, are underrepresented in the reference gage network, and frequently have complex, groundwater-dominated hydrology (Zimmerman et al. 2018). As a result, estimates for these watersheds may be less accurate than for better-represented stream types. In addition, San Antonio Creek may not frequently experience a true spring recession flow due to the rainfall-driven hydrology. However, even if the metrics are not able to precisely quantify low-flow magnitudes and recession flows in San Antonio Creek, they provide helpful information on the frequency, magnitude, and duration of high flow events, and patterns of interannual variation.

[d] For more information, see https://mywaterquality.ca.gov/monitoring_council/environmental_flows_workgroup/index.html.

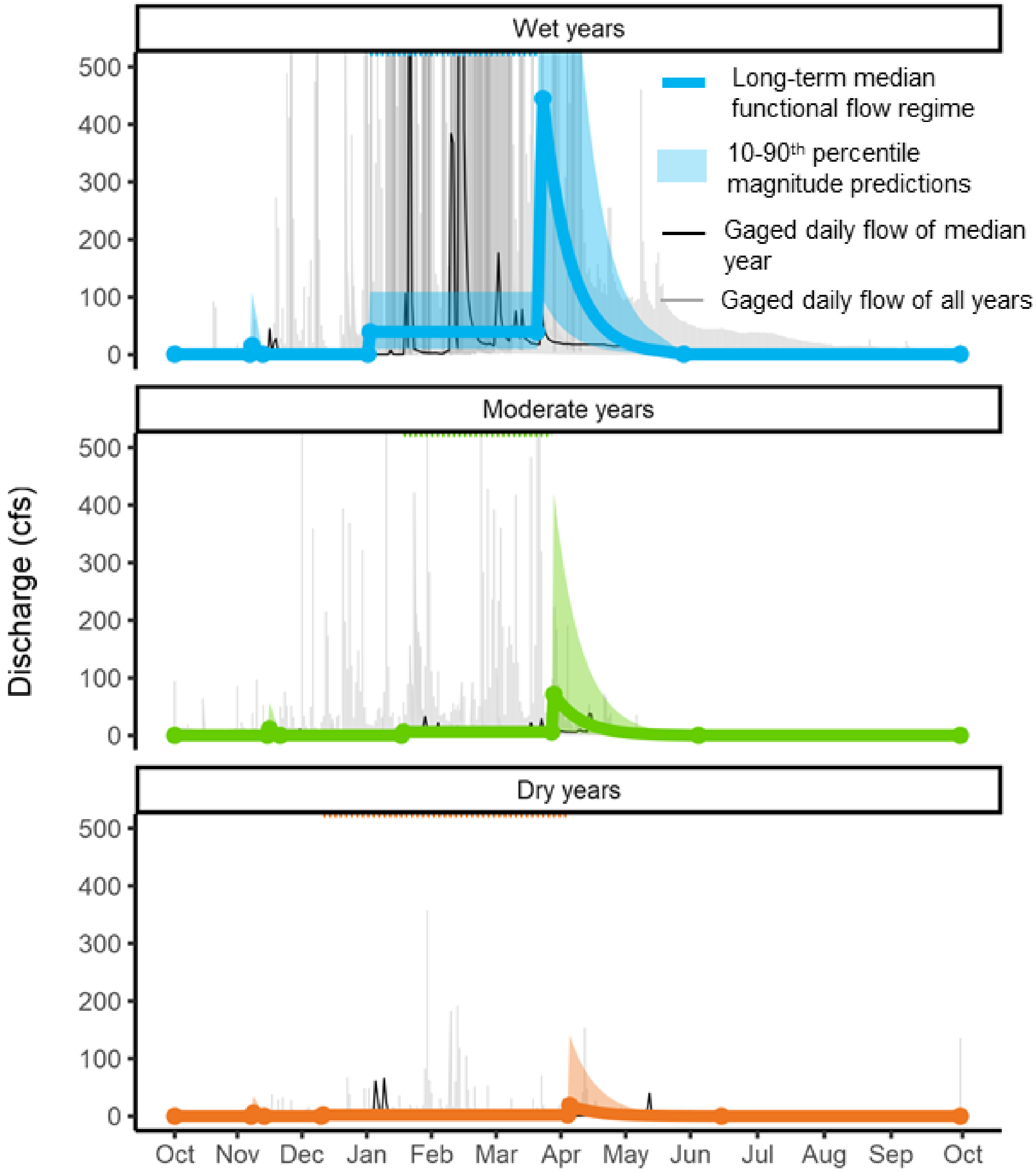

Figure 10. Functional flow regime for Reach 1 by water year type, plotted over gaged daily flow by water year type. This example functional flow regime uses the median values presented in Table 2. Peak flows are not shown but would also be included in the flow regime. Gage data: USGS gage 11117500 (USGS 2020) and VCWPD gage 605 (VCWPD 2020), water years 1950–2013. Functional flow metrics: COMID 17586810 (California Environmental Flows Working Group 2020).

Table 2. Predicted functional flow metrics for San Antonio Creek Reach 1 by water year type. Values represent median predictions within each water year type, with 10^{th}–90^{th} percentile ranges in parentheses. Functional flow metrics with asterisks (*) are not dependent on water year type. Fall pulse flows may not occur every year. Data from the USGS/TNC Natural Flows Database, COMID 17586810 (California Environmental Flows Working Group 2020).

Functional Flow Metric	Wet Year	Moderate Year	Dry Year
Fall pulse flow magnitude (cfs)	16 (4–110)	11 (2–57)	5 (1–35)
Fall pulse flow duration (days)*	5 (2–13)	5 (2–13)	5 (2–13)
Fall pulse flow timing	Nov 5 (Oct 13–Nov 30)	Nov 13 (Oct 12–Dec 3)	Nov 6 (Oct 2–Nov 30)
Median wet-season flow magnitude (cfs)	40 (10–109)	6 (2–17)	2 (<1–5)
Wet-season baseflow magnitude (cfs)	6 (2–18)	2 (<1–5)	1 (<1–3)
Wet-season duration (days)	77 (48–122)	75 (36–134)	124 (46–195)
Wet-season start timing	Dec 30 (Dec 12–Jan 15)	Jan 15 (Dec 9–Jan 30)	Dec 8 (Oct 25–Jan 20)
Spring recession start magnitude (cfs)	445 (96–2,200)	72 (10–422)	19 (2–141)
Spring recession duration (days)	48 (23–111)	56 (21–139)	64 (23–146)
Spring recession start timing	Mar 21 (Mar 6–Apr 7)	Mar 26 (Feb 28–Apr 24)	Apr 2 (Feb 26–May 22)
Spring recession rate of change (%)*	8 (5–18)	8 (5–18)	8 (5–18)
Dry-season baseflow magnitude (cfs)	1 (<1–3)	<1 (<1–2)	<1 (<1–1)
Dry-season high baseflow magnitude (cfs)	6 (2–17)	2 (<1–6)	1 (<1–4)
Dry-season duration (days)	226 (146–284)	205 (127–263)	187 (115–260)
Dry-season start timing	May 25 (Apr 6–Jul 16)	Jun 1 (Apr 8–Jul 31)	Jun 11 (Apr 24–Aug 23)

Table 3. Predicted peak functional flow metrics for San Antonio Creek Reach 1. Values represent median predictions with 10th–90th percentile ranges in parentheses. Peak flows may not occur every year. Data from the USGS/TNC Natural Flows Database, COMID 17586810 (California Environmental Flows Working Group 2020).

Functional Flow Metric	All Years
2-year peak flow magnitude (cfs)	833 (311–1,470)
2-year peak flow days/year when present	3 (1–14)
2-year peak flow events/year when present	2 (1–5)
5-year peak flow magnitude (cfs)	1,730 (923–3,370)
5-year peak flow days/year when present	2 (1–5)
5-year peak flow events/year when present	1 (1–3)
10-year peak flow magnitude (cfs)	2,280 (1,400–4,310)
10-year peak flow days/year when present	1 (1–3)
10-year peak flow events/year when present	1 (1–2)

Table 4. Predicted functional flow metrics for San Antonio Creek Reach 2 by water year type. Values represent median predictions within each water year type, with 10th–90th percentile ranges in parentheses. Functional flow metrics with asterisks (*) are not dependent on water year type. Fall pulse flows may not occur every year. Data from the USGS/TNC Natural Flows Database, COMID 17586736 (California Environmental Flows Working Group 2020).

Functional Flow Metric	Wet Year	Moderate Year	Dry Year
Fall pulse flow magnitude (cfs)	12 (3–75)	9 (1–41)	5 (1–33)
Fall pulse flow duration (days)*	5 (2–13)	5 (2–13)	5 (2–13)
Fall pulse flow timing	Nov 6 (Oct 12–Nov 30)	Nov 13 (Oct 12–Dec 1)	Nov 7 (Oct 3–Dec 1)
Median wet-season flow magnitude (cfs)	26 (7–68)	4 (1–12)	2 (<1–4)
Wet-season baseflow magnitude (cfs)	4 (1–12)	1 (<1–3)	1 (<1–2)
Wet-season duration (days)	82 (48–121)	75 (36–126)	118 (45–181)
Wet-season start timing	Dec 30 (Dec 12–Jan 14)	Jan 15 (Dec 11–Jan 31)	Dec 8 (Oct 24–Jan 22)
Spring recession start magnitude (cfs)	317 (66–1,440)	47 (7–286)	13 (1–107)
Spring recession duration (days)	46 (23–109)	55 (21–137)	65 (22–143)
Spring recession start timing	Mar 22 (Mar 6–Apr 8)	Mar 24 (Feb 28–Apr 21)	Mar 30 (Feb 23–May 13)
Spring recession rate of change (%)*	8 (5–18)	8 (5–18)	8 (5–18)
Dry-season baseflow magnitude (cfs)	1 (<1–2)	<1 (<1–1)	<1 (<1–1)
Dry-season high baseflow magnitude (cfs)	4 (1–11)	1 (<1–5)	1 (<1–3)
Dry-season duration (days)	222 (153–276)	210 (133–269)	194 (120–260)
Dry-season start timing	May 27 (Apr 7–Jul 17)	May 30 (Apr 8–Aug 4)	Jun 13 (Apr 23–Aug 25)

Table 5. Predicted peak functional flow metrics for San Antonio Creek Reach 2. Values represent median predictions with 10th–90th percentile ranges in parentheses. Peak flows may not occur every year. Data from the USGS/TNC Natural Flows Database, COMID 17586736 (California Environmental Flows Working Group 2020).

Functional Flow Metric	All Years
2-year peak flow magnitude (cfs)	557 (258–1,040)
2-year peak flow days/year when present	3 (1–14)
2-year peak flow events/year when present	2 (1–5)
5-year peak flow magnitude (cfs)	1,370 (655–2,570)
5-year peak flow days/year when present	2 (1–5)
5-year peak flow events/year when present	1 (1–3)
10-year peak flow magnitude (cfs)	1,800 (993–3,260)
10-year peak flow days/year when present	1 (1–3)
10-year peak flow events/year when present	1 (1–2)

An associated functional flows calculator permits the user to identify functional flows using existing gage data (Lane et al. 2019; Patterson et al. 2020). Using data from gage stations 11117500 and 605, the calculator shows that fall pulse flows occurred 25 out of the 64 years in the period of record (1950–2013), or 39% of the time. The gage analysis also shows that when it occurred, the fall pulse lasted a median of 8 days in wet years, four days in moderate years, and seven days in dry years.

2.3 Beneficial Uses of Water and Water Quality

Instream flow can also affect water quality and other beneficial uses. The 2011 *Water Quality Control Plan for the Coastal Watersheds of Los Angeles and Ventura Counties* (Basin Plan) designates the beneficial uses of the water supply in San Antonio Creek as municipal and domestic; industrial process and service; agricultural; groundwater recharge; warm and cold freshwater ecosystems; wildlife habitat; wetland habitat; migration of aquatic organisms; and spawning, reproduction, and/or early development of fish (LARWQCB 2011). Additionally, the Basin Plan designates freshwater replenishment as a beneficial use for San Antonio Creek above Lion Canyon Creek.

There are several water quality impairments recognized within the San Antonio Creek watershed, some of which are tied to flow. Stagnant or slow-moving water in the creek results in increased water temperature, lack of dilution of any input (such as nitrogen), and less surface mixing, which leads to lower dissolved oxygen concentrations (Walter 2015). San Antonio Creek is on the United States Environmental Protection Agency's 303(d) list of impaired water bodies under the Clean Water Act due to excessive nitrogen (LARWQCB 2012). Excess nitrogen leads to a host of interconnected water quality issues such as algal growth, low dissolved oxygen, and eutrophic conditions (LARWQCB 2012; Walter 2015). A moderately sized algal bloom within the creek can reduce the survival of fish and other aquatic life (Walter 2015). Thick algal growth is known to occur throughout San Antonio Creek (Figure 11).

In 2012 the Los Angeles Regional Water Quality Control Board (LARWQCB) adopted an amendment to the Basin Plan to incorporate a Total Maximum Daily Load (TMDL) for algae, eutrophic conditions, and nutrients in the Ventura River and its tributaries (LARWQCB 2012). The TMDL includes numeric targets intended to reduce algae-promoting nitrogen within the Ventura River basin and its tributaries, including San Antonio Creek.

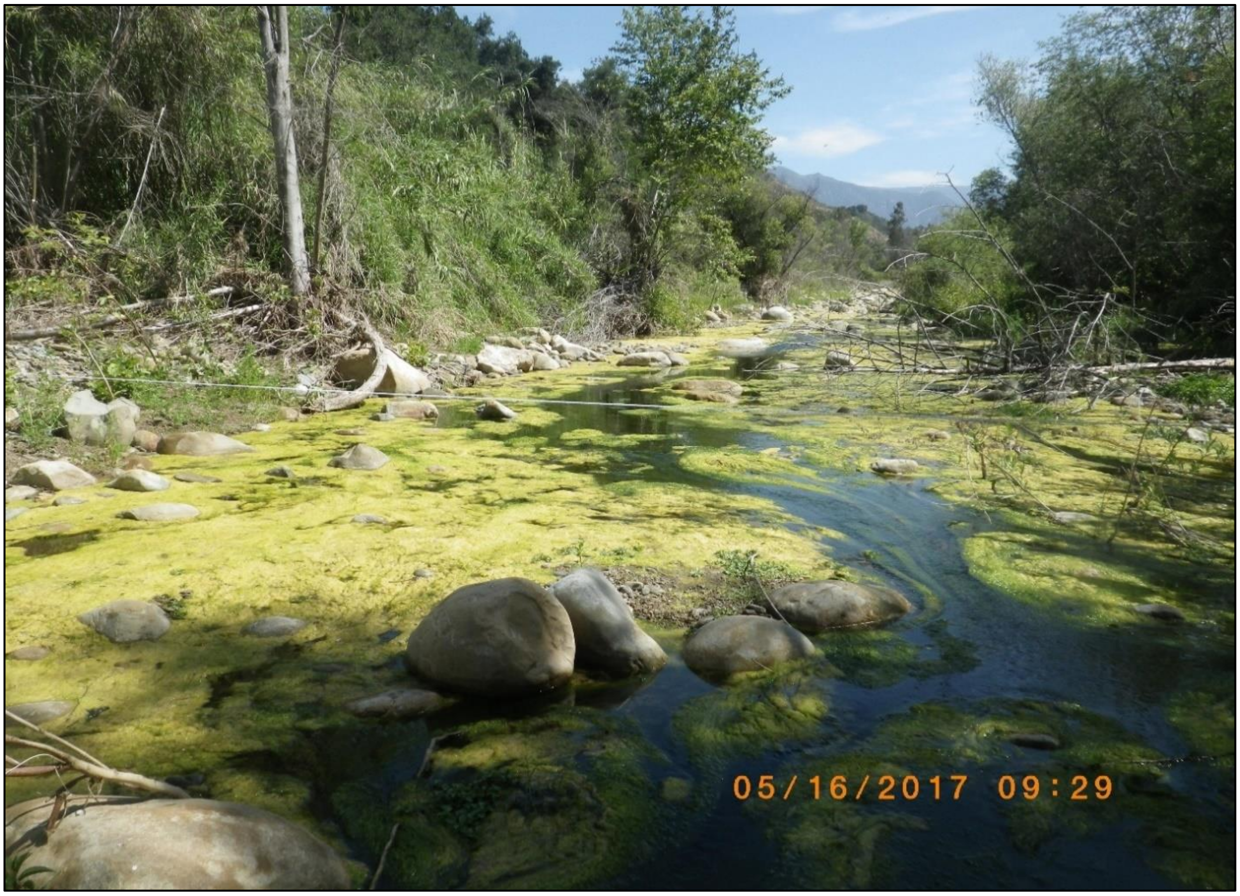

Figure 11. Typical late spring view of San Antonio Creek with abundant algal blooms (flow approximately 1 cfs).

3.0 METHODS

The Department uses the Instream Flow Incremental Methodology (IFIM) to conduct instream flow evaluations in California's streams and rivers (CDFG 2008). The IFIM is a comprehensive framework used to guide incremental instream flow evaluations and associated decision-making processes. In San Antonio Creek, the Department used the IFIM to determine instream flows required for successful adult steelhead spawning and juvenile steelhead rearing. To identify flows that protect spawning and rearing habitat, the Department used 1D hydraulic modeling to characterize the relationship between streamflow and physical habitat. The 1D modeling approach combines three major analytical components: river hydraulics, species and life stage habitat suitability criteria (HSC), and physical habitat modeling (CDFG 2008). Staff defined mesohabitat units, identified reaches, and then used stratified random sampling to collect field data on physical and hydraulic channel characteristics. These field data were used to construct a series of 1D hydraulic models and then to calculate area-weighted suitability (AWS) values for each reach by life stage and flow value. Each of the 1D modeling steps is summarized in Figure 12. Hydraulic data collection and modeling (in green) is covered in more detail in Appendix A.

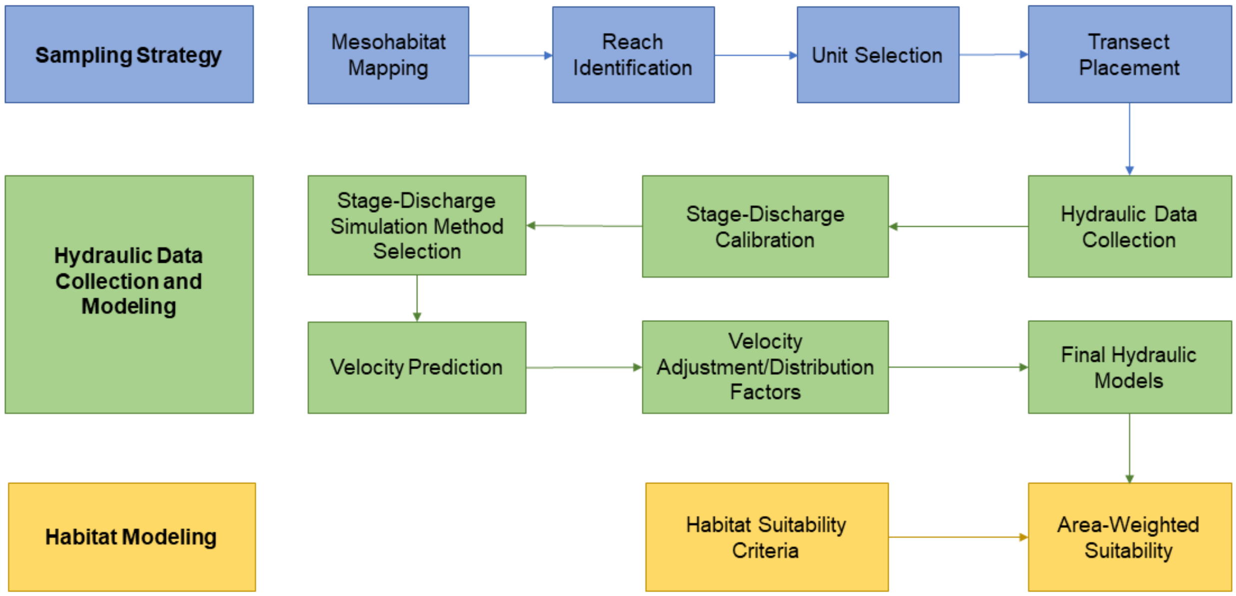

Figure 12. General schematic of 1D model development for physical habitat simulation.

3.1 Identification of Sampling Units and Sampling Strategy

Reach Identification

Mesohabitat mapping data collected by the Department's South Coast Region staff in October and November of 2013 were used to identify study reaches within San Antonio Creek. During the initial habitat mapping survey, several contiguous miles of channel were dry, both in the lower section of San Antonio Creek below Fraser Street and the upper section upstream of Skunk Ranch Road. Dry channel bed could not be assigned a mesohabitat type for use in modeling, so these dry sections were excluded from the study. The remaining portion of San Antonio Creek between these long dry sections was the focus of this study (Figure 13).

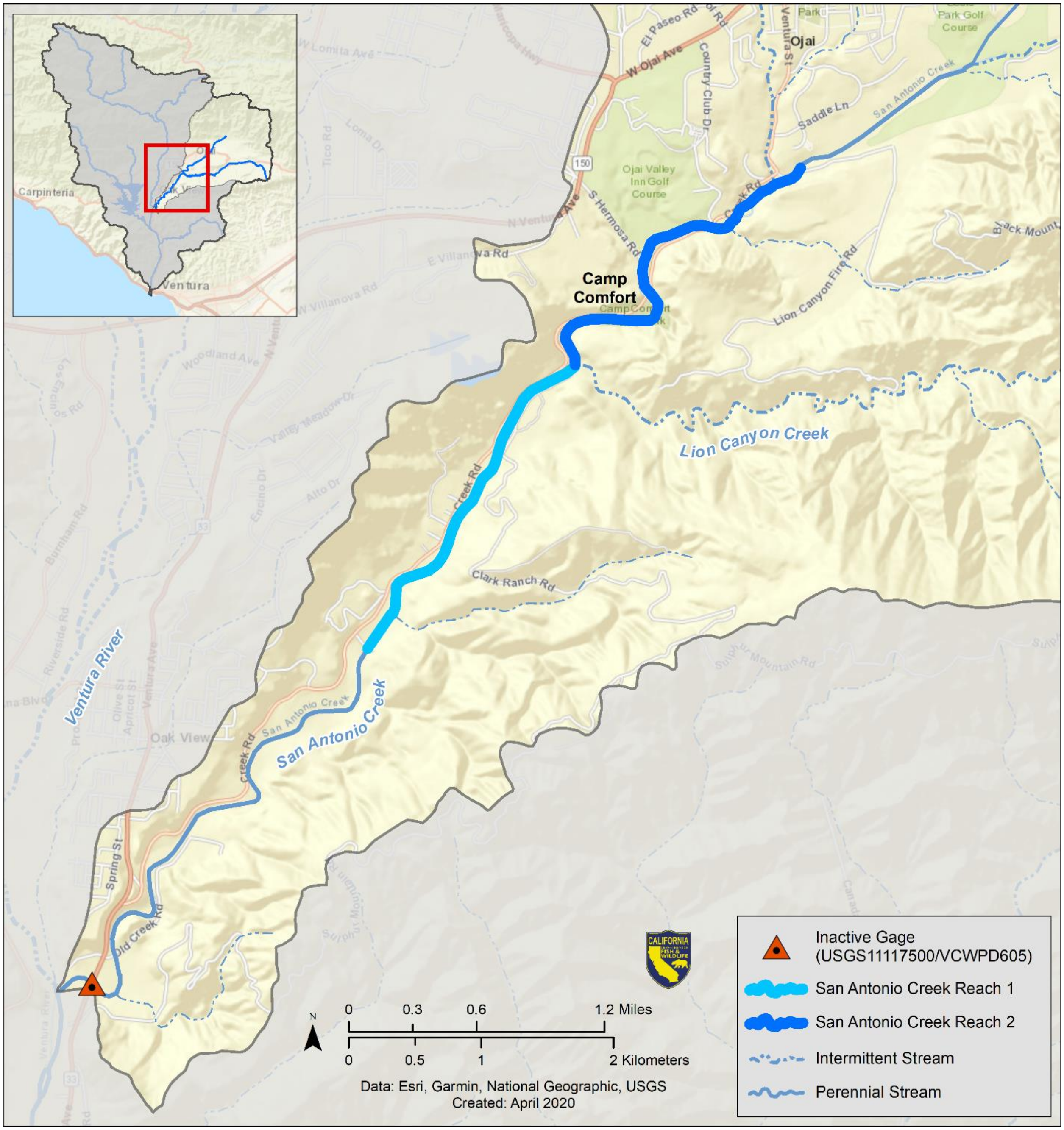

Figure 13. San Antonio Creek study reaches.

Reach 1 of San Antonio Creek begins 2.7 mi upstream from the confluence with the Ventura River and extends 1.8 mi upstream to the confluence with Lion Canyon Creek. Reach 2 is 1.9 mi in length. It begins at the confluence with Lion Canyon Creek, extends past the confluence with Stewart Canyon Creek, and ends 450 ft upstream of the Skunk Ranch Road crossing. The distribution of mapped mesohabitat types within San Antonio Creek was consistent throughout the designated study area (see Table 7 and Table 8), and the two reaches were divided by the confluence of Lion Canyon Creek.

Mesohabitat Mapping

Mesohabitat units were mapped and numbered sequentially by Department staff, beginning at the confluence with the Ventura River and working upstream. Level IV mesohabitat delineation standards were applied as outlined in the *California Salmonid Stream Restoration Manual* (Flosi et al. 2010). Level IV mesohabitat units were aggregated into broader mesohabitat categories of riffle, pool, run, dry, and "other." The "other" classification was applied to one section of culvert. No glide mesohabitat types were observed during mesohabitat mapping. Riffle, pool, and run habitat types are defined in Table 6.

During mesohabitat mapping, unit lengths were identified along with attributes such as maximum depth, presence of flow input or diversion, and artificial influences (e.g., rip rap, weirs, or bridge abutments), as appropriate. Table 7 and Table 8 summarize the mesohabitat types mapped within each of the study reaches.

Dry channel made up 60% of overall mesohabitat length mapped within Reach 1 and 61% within Reach 2 (see Table 7 and Table 8). Mesohabitat type assignment requires an assessment of flow conditions, so these sections of channel were excluded from analysis. Site visits in 2018, when some of these previously dry sections were wetted, confirmed that the initial habitat mapping and survey transects were representative of the overall distribution of habitat types in the two reaches.

Table 6. Mesohabitat type definitions adapted from the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 2010) and Snider et al. (1992).

Mesohabitat Type	Definition
Riffle	Below-average depth, above-average velocity, thalweg has relatively uniform slope going downstream, substrate of uniform size and composed of large gravel and/or cobble, change in gradient noticeable. Primary determinants are relatively high gradient and surface turbulence. High-gradient riffles are defined as boulder-dominated with >4% grade.
Pool	Fine and uniform substrate, below-average water velocity, above-average depth, tranquil water surface. Primary determinant is downstream control - thalweg gets deeper moving upstream from tail of pool. Depth is not used to determine whether a mesohabitat unit is a pool.
Run	Moderate gradient, mixed-substrate particle sizes composed of small cobble and gravel, with some large cobble and boulders, above-average water velocities, usually slight gradient change from top to bottom, generally associated with downstream extent of riffles, thalweg has relatively uniform slope going downstream. Primary determinants are moderate turbulence and average depth.

Table 7. Reach 1 mesohabitats mapped within the study area.

Mesohabitat Type	Number of Mesohabitat Units	% of Total Reach by Length
Riffle	15	9.8%
Pool	18	14.2%
Run	13	15.7%
Dry	6	60.1%
Other	1	0.2%

Table 8. Reach 2 mesohabitats mapped within the study area.

Mesohabitat Type	Number of Mesohabitat Units	% of Total Reach by Length
Riffle	22	15.6%
Pool	20	11.7%
Run	16	11.5%
Dry	13	61.2%

Unit Selection

Survey locations for 1D sampling were selected using a stratified random sampling design in both reaches. Each of the mesohabitat units within a reach were grouped by type (i.e., riffle, pool, and run). Each mesohabitat unit was then assigned a number from one to the total number of mesohabitat units of that type, in order of occurrence from downstream to upstream. The Microsoft Excel random number generator was then used to select a number within the mesohabitat unit type range. For example, there were 14 potential riffle units identified in Reach 1 following habitat mapping surveys. If the random number generator selected the number seven, the seventh riffle unit identified in Reach 1 was selected as the first potential riffle mesohabitat unit. This process was repeated until three survey units of each mesohabitat type (riffle, pool, and run) were selected in each of the two reaches. In total, nine mesohabitat units were initially selected per reach for 1D sampling (18 total). If a selected habitat unit could not be located at the previously surveyed location, the nearest upstream habitat unit of the same type was surveyed in its place.

The 1D models are not able to accurately represent high-gradient riffles. Only one high-gradient riffle was recorded during mesohabitat type mapping. This riffle was included in the calculation of percent riffle mesohabitat, but when it was selected by the random number generator it was thrown out and a new number was generated.

Transect Placement

Staff established transects for sampling within each of the selected mesohabitat units. One transect was surveyed per selected mesohabitat unit, and transects were placed in either the top, middle, or bottom third of the unit. Placement within a unit was determined in the office using the random number generator to reduce placement bias. Figure 14 is a schematic of the transect placement process for a transect placed in the top of the third riffle unit.

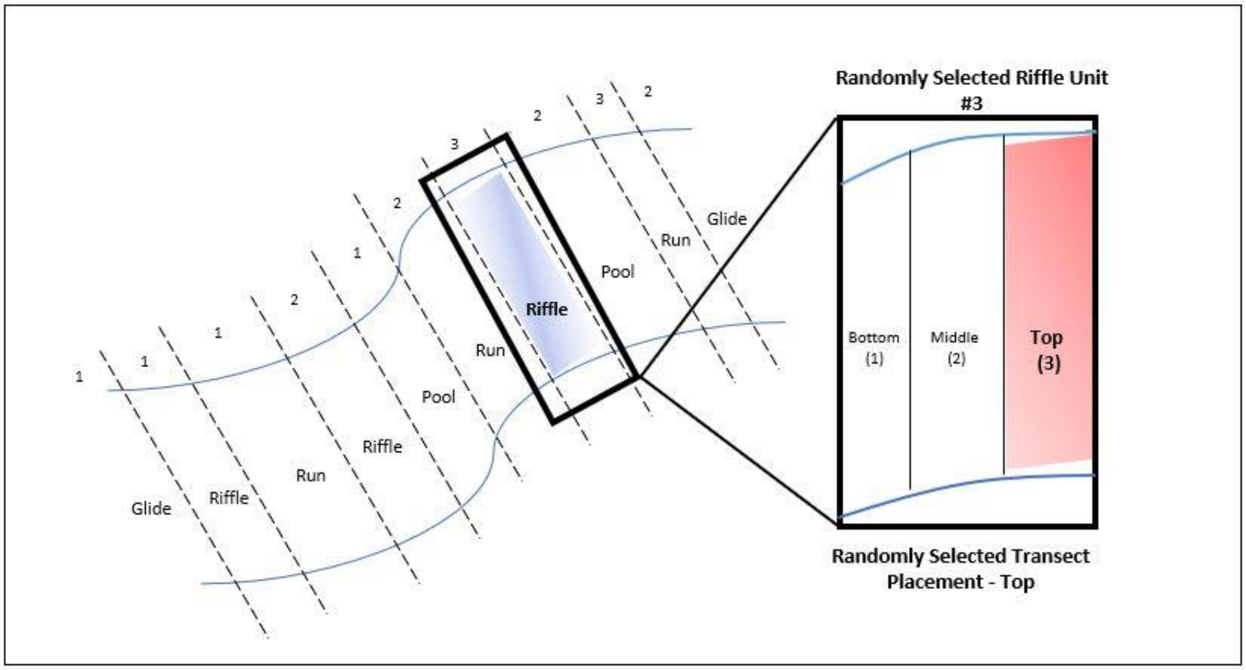

Figure 14. Schematic of mesohabitat unit site selection and transect placement.

3.2 Hydraulic Data Collection and Model Development

The following data were collected at each transect to develop predictive hydraulic models:

- transect elevation profiles (Obedzinski et al. 2016);
- discharge measurements using approved Department methods (CDFW 2013a; CDFW 2020d) in a suitable location close enough to the transect to be representative of the flow passing through the transect;
- water surface elevations using approved Department methods (CDFW 2013c) along the transect line and paired with the discharge measurements;
- velocity profiles taken along the transect line at the mid or high of the three flow levels recorded;
- stage of zero flow elevations in mesohabitat units where the water surface is a function of a downstream control point (typically pools); and
- substrate size distribution.

Discharge, velocity, and water surface elevation data were collected at three distinct flows. Hydraulic data collection procedures were consistent with pre-established standards and protocols intended to characterize the hydraulic habitat potential in each representative mesohabitat unit type (Bovee 1997; CDFW 2013c; CDFW 2020d). A detailed description of the data collection procedures listed above is provided in Appendix A.

The data were compiled in the office by staff and entered in the commercially available program System for Environmental Flow Analysis (SEFA; Jowett et al. 2017). The SEFA program estimates depth and velocity along each transect over a range of flows. Selected model settings, hydraulic model tolerances, and calibration results for each transect are provided in Appendix A. Additional details on model calibration are provided in Appendix B–Appendix E.

3.3 Habitat Suitability Criteria and Area-Weighted Suitability

The relationship between streamflow and physical habitat for fish was modeled using life-stage-specific HSC for steelhead and the outputs of the hydraulic modeling process described in Appendix A. These data were combined to estimate AWS (also known as weighted usable area) for each reach over a range of flows. Defined simply, AWS is a scoring index that describes the amount of suitable habitat per unit of length (e.g., ft, yard) at a specified flow for a given species and life stage (Payne and Jowett 2013).

Steelhead adult spawning and juvenile rearing habitat preferences (HSC) were used in this study to calculate AWS. The adult steelhead spawning HSC were developed using standard curves from the literature (Dettman and Kelley 1986; USDI and USFWS 1997). The juvenile steelhead rearing HSC in this study were originally developed for the Big Sur River, where fish observations were categorized into two size classes: 6-9 centimeters (cm) and 10-15 cm (Holmes et al. 2014). The Big Sur River is located on the Central California coast and is the nearest and most similar watershed with HSC data for steelhead. The Big Sur River study used an equal-area sampling design stratified by the mesohabitat types outlined in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 2010). Habitat units used for sampling were randomly selected within each mesohabitat type. Fish habitat preferences were determined by comparing the distribution of depths and velocities occupied by fish to the total distribution of available depths and velocities.

Habitat suitability (AWS) for steelhead spawning and rearing was evaluated for each transect at a range of flows using HSC and modeled depth and velocity values. To calculate AWS, each transect within a reach was subdivided into cells, and the area of each cell was multiplied by the HSC values associated with that cell's depth and velocity at each simulated flow. Substrate size was included when calculating AWS for spawning adults.

4.0 RESULTS

A total of 15 transects were used in development of the 1D models. The final tally is consistent with the number of transects needed to sufficiently represent the study reaches for robust modeling of flow and habitat relationships (CDFG 2008; Gard 2005; Payne et al. 2004). Results are presented below; modeling calibration results are available in Appendix A Section A.2.

4.1 Hydraulic Model Calibration

Data were collected on 18 randomly selected survey transects in 2018 (Table 9) with three transects selected per mesohabitat type in both reaches. Access to Reach 1 was limited below habitat unit 22 and between habitat units 32 and 52 at the time of the survey, so surveying was concentrated in those portions of Reach 1 that staff were able to access. The transect locations are shown in Figure 15 and Figure 16.

The hydraulic calibration of 1D transects involves applying guidance standards from the literature (Milhous et al. 1989; TRPA 1998; USFWS 1994) to the model outputs to ensure the model performance meets existing standards. In situations where transect outputs did not meet calibration standards, the transect data were further evaluated. Data were evaluated to determine whether an error was made in the data collection or entry process, if the stage-discharge relationship was altered between surveys by a change in the lateral or longitudinal profile of the transect, or if the transect was a poor candidate for hydraulic modeling in 1D.

Three survey transects were omitted from further analysis because the hydraulic model outputs were outside the limits of recommended guidance (indicated by a strikeout and asterisk (*) in Table 9). The rationale for each omission is reported in the footnotes of Table C-2 in Appendix C. One transect, 127, was originally mapped as a pool, but was determined to be a riffle upon further inspection and was analyzed as a riffle unit (127L). The final number of survey transects that attained a predictive relationship for the hydraulic model was 15.

Table 9. San Antonio Creek transects by reach. Strikeout and asterisk (*) indicates transect was omitted from further analysis.

Reach 1 Unit	Mesohabitat Type	Reach 2 Unit	Mesohabitat Type
22R	Run	~~81R~~*	~~Run~~*
23L	Riffle	~~83L~~*	~~Riffle~~*
26P	Pool	88R	Run
29L	Riffle	90P	Pool
30R	Run	95L	Riffle
31P	Pool	105R	Run
32L	Riffle	117P	Pool
52R	Run	127L	Riffle
55P	Pool	~~132L~~*	~~Riffle~~*

To develop reach-wide AWS estimates, AWS values for each transect were weighted by the length of the reach that each transect represented. For example, since pools represented 35.8% of Reach 1, and there were three pool transects, each pool transect received a weight of 11.9%. Table 10 and Table 11 summarize the weight of each mesohabitat type, the final number of calibrated transects in each mesohabitat type, and the resulting transect weights used in SEFA to compute AWS.

Table 10. Reach 1 transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type (%)	Number of Transects	Transect Weights (%)
Riffle	24.7%	3	8.2%
Pool	35.8%	3	11.9%
Run	39.5%	3	13.2%
TOTAL	100%	9	-

Table 11. Reach 2 transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type (%)	Number of Transects	Transect Weights (%)
Riffle	40.3%	2	20.2%
Pool	30.1%	2	15.0%
Run	29.6%	2	14.8%
TOTAL	100%	6	-

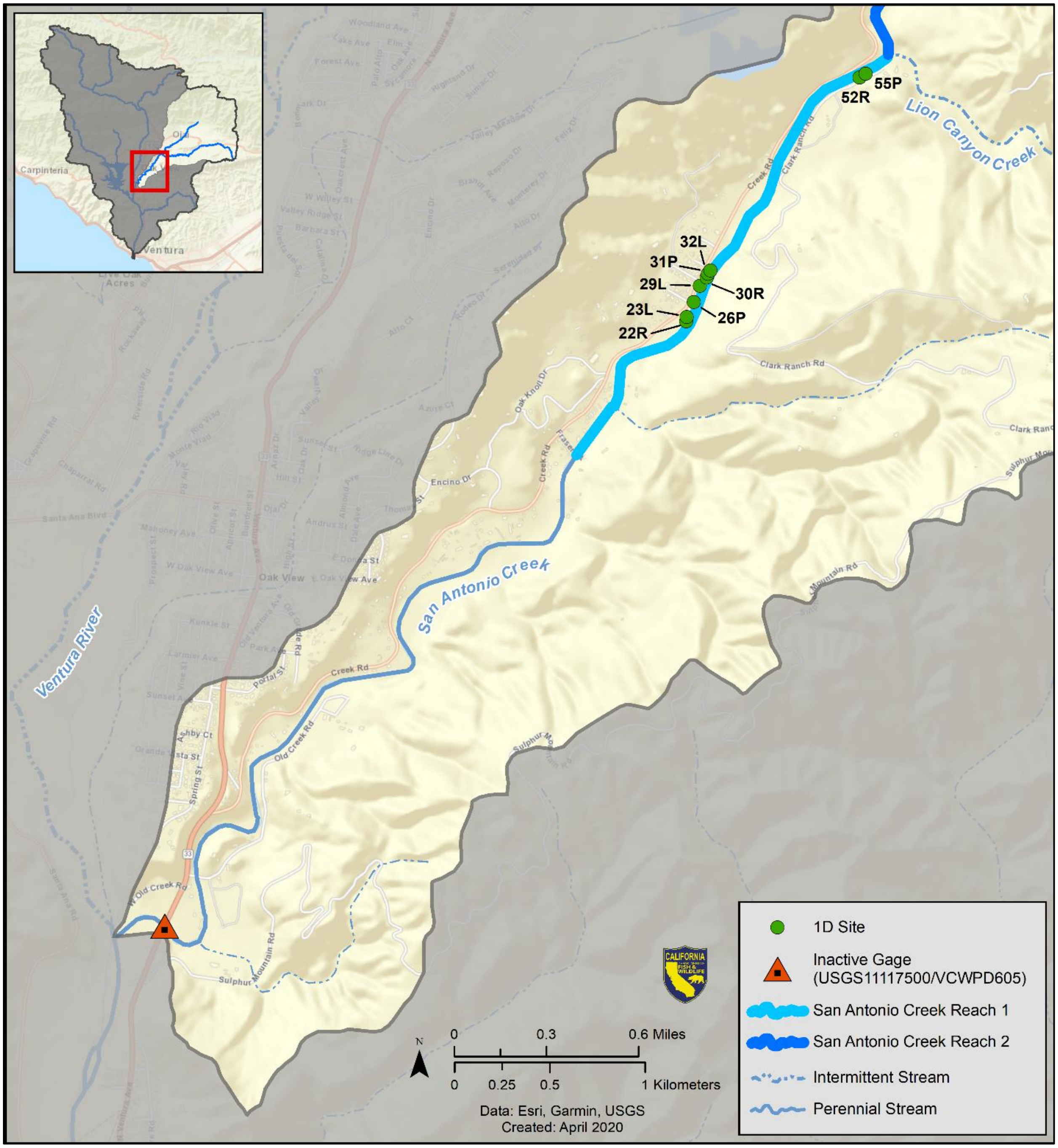

Figure 15. Location of transects within San Antonio Creek Reach 1 (L = Riffle, P = Pool, R = Run). Note: lack of access limited surveying downstream of 22R and between 32L and 52R.

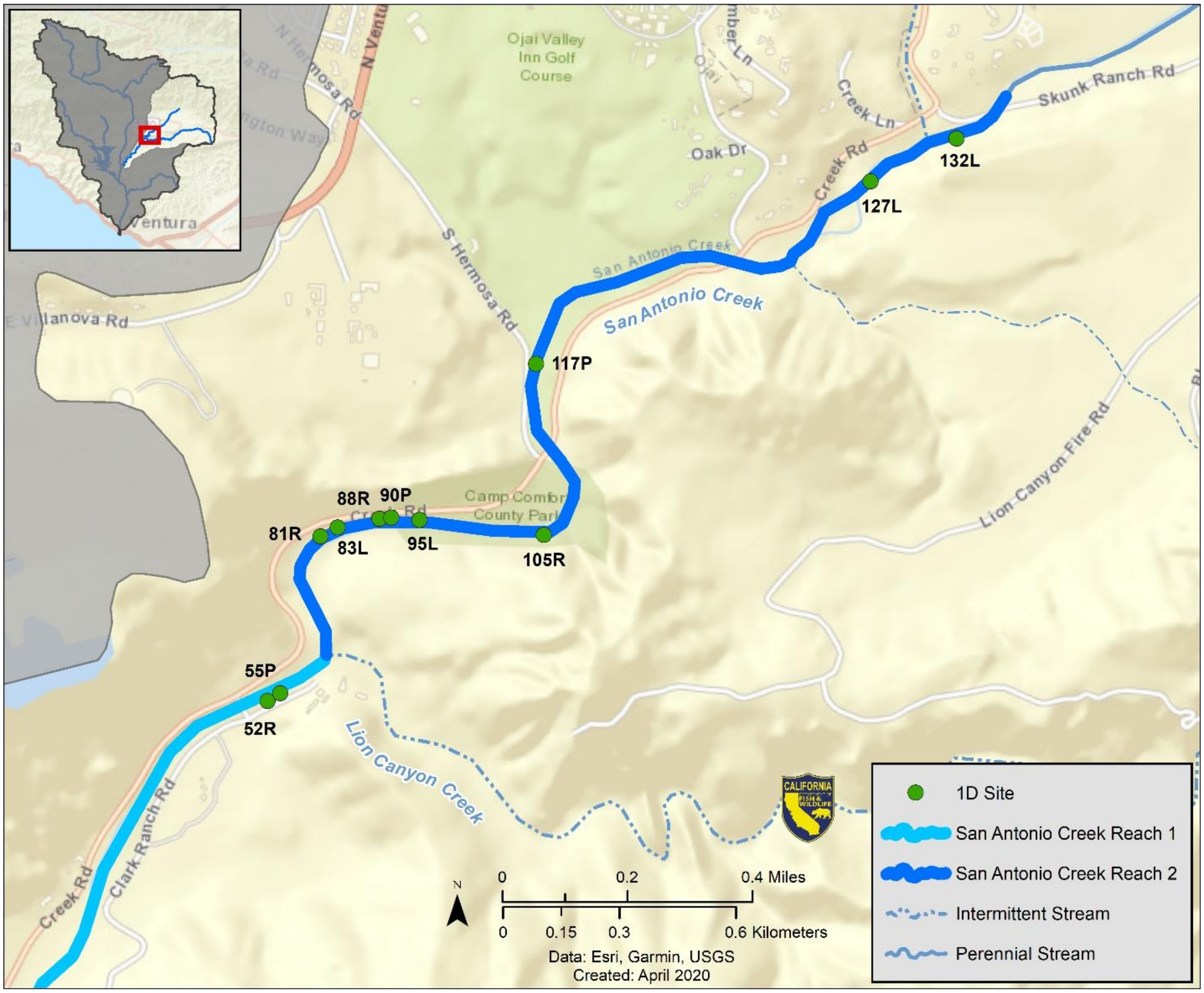

Figure 16. Location of transects within San Antonio Creek Reach 2 (L = Riffle, P = Pool, R = Run).

4.2 Flow and Habitat Relationships

Flows that maximized suitable habitat for steelhead in the San Antonio Creek watershed varied by reach and life stage. Figure 17 and Figure 18 show AWS at simulation flows from 0–30 cfs for each life stage by reach. Suitability is expressed in ft^2 of suitable habitat per foot of reach length but is not a true area. For example, an AWS of 5 ft^2/ft could represent 5 ft^2 of highly suitable juvenile steelhead habitat per linear foot of stream length, 10 ft^2 of 50% suitable habitat, or 20 ft^2 of 25% suitable habitat. The data used to develop these figures are presented in Appendix F.

As is typical for these types of curves, suitability increases to a point and then decreases. The decline in suitability at higher flows indicates that depths or velocities have begun to exceed preferred depths or velocities for the life stage of interest. As a result, total suitability declines. Very high flood flows were not the focus of this study, but a second peak in habitat suitability would likely occur as flows overtop channel banks and spread over floodplain habitats, resulting in a broad diversity of available depths and velocities.

In San Antonio Creek, the preferred flows of 10–15 cm juvenile steelhead are similar to but higher than those of 6–9 cm juveniles. The flow preferences of 10–15 cm juvenile steelhead are therefore considered protective of those in the 6–9 cm size class. In addition, the AWS values for juvenile rearing are relatively consistent across a range of flows surrounding the AWS peak. These flows can be compared to flows observed in San Antonio Creek using the flow exceedance plots and tables in Section 2.2 and the photographs in Section 4.3.

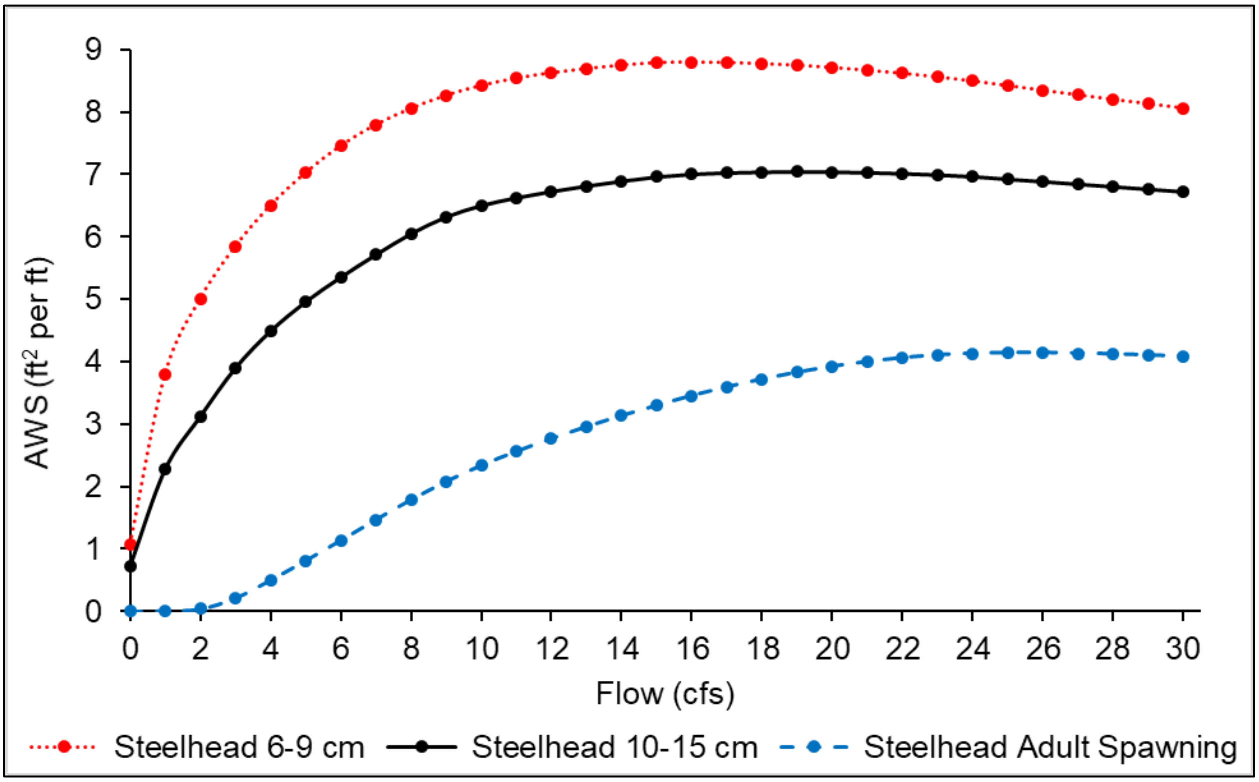

Figure 17. San Antonio Creek Reach 1 streamflow/steelhead habitat relationship.

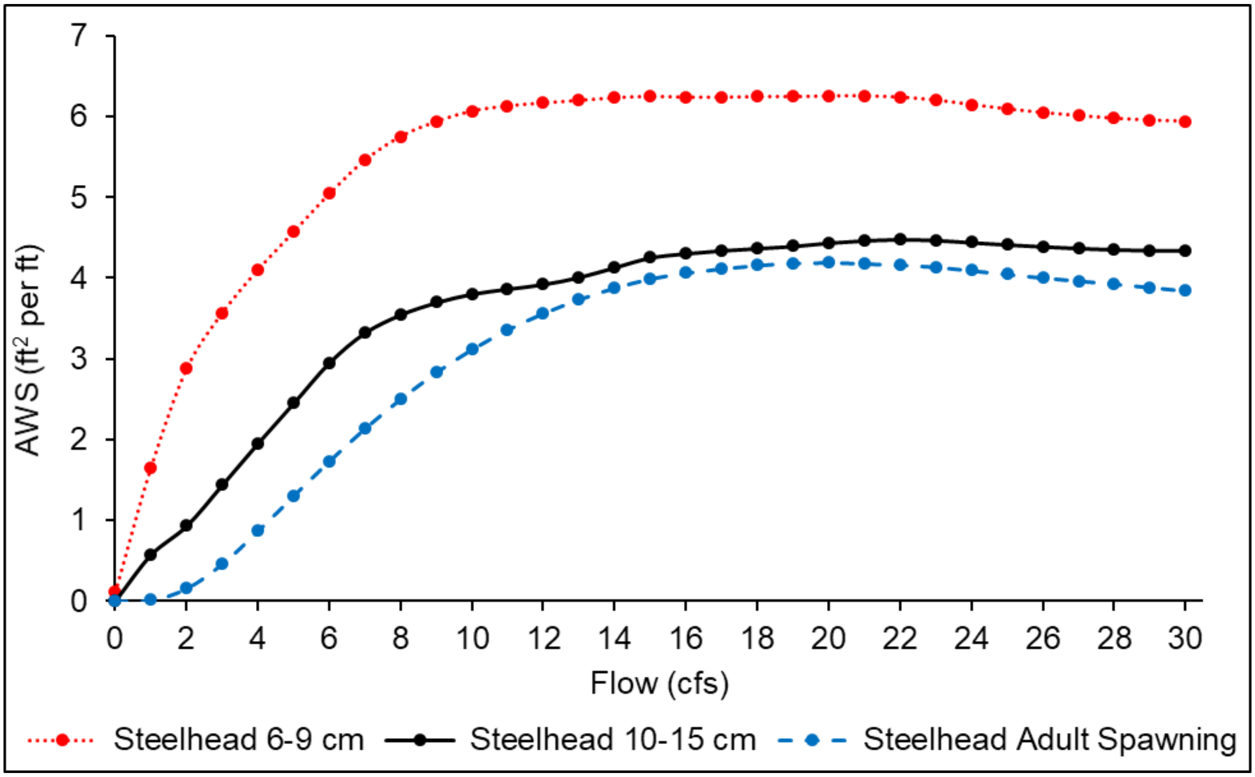

Figure 18. San Antonio Creek Reach 2 streamflow/steelhead habitat relationship.

4.3 Field Observations

Examples of study transects in Reach 1 and Reach 2 are provided in the paired figures below (Figure 19 to Figure 26). Each figure contrasts conditions at the Low and High survey flows used as inputs to the 1D models. Transect locations are shown in Figure 15 and Figure 16.

Figure 19. Downstream view of transect 23L (Reach 1) at 0.2 cfs (upper photo) and 9.2 cfs (lower photo).

Figure 20. Downstream view of transect 29L (Reach 1) at 0.7 cfs (upper photo) and 9.2 cfs (lower photo).

Figure 21. Downstream view of transect 31P (Reach 1) at 0.2 cfs (upper photo) and 9.2 cfs (lower photo).

Figure 22. Downstream view of transect 52R (Reach 1) at 0.3 cfs (upper photo) and 9.2 cfs (lower photo).

Figure 23. Downstream view of transect 95L (Reach 2) at 0.2 cfs (upper photo) and 9.0 cfs (lower photo).

Figure 24. Upstream view of transect 105R (Reach 2) at 0.1 cfs (upper photo) and 9.0 cfs (lower photo).

Figure 25. Downstream view of transect 117P (Reach 2) at 0.4 cfs (upper photo) and 8.5 cfs (lower photo).

Figure 26. Downstream view of transect 127L (Reach 2) at 0.3 cfs (upper photo) and 8.5 cfs (lower photo).

5.0 FLOW CRITERIA

This section summarizes the flow criteria for San Antonio Creek. Water management decisions should incorporate these criteria and other relevant information about ecological flow needs to protect stream ecosystem condition and steelhead rearing and spawning habitat in San Antonio Creek.

A summary of the results of the 1D modeling study described in this report is presented in Table 12. Instream flows in San Antonio Creek should be designed to protect both spawning and rearing flows. The table presents the flows that produce the most suitable habitat for spawning and rearing steelhead, as well as the flows that would produce habitat that is 50% as suitable based on area and steelhead habitat preferences. The comparison of the two numbers shows how available habitat changes with flow. See Figure 17, Figure 18, and Appendix F for more detailed results.

Table 12. Summary of AWS results from 1D analysis.

Reach	Flow for Maximum Juvenile Steelhead Rearing AWS (cfs)	Flow for 50% Maximum Juvenile Steelhead Rearing AWS (cfs)	Flow for Maximum Adult Steelhead Spawning AWS (cfs)	Flow for 50% Maximum Adult Steelhead Spawning AWS (cfs)
1	20	3	25	9
2	22	5	17	7

In addition, water management decisions should consider the criteria developed in the companion Watershed Criteria Report (CDFW 2020a) and summarized in Table 13 and Table 14 below. Steelhead passage flows were developed for the Watershed Criteria Report using the Habitat Retention Method, a field method that identifies maintenance flows for movement and survival of the given steelhead life stage (CDFW 2018). The results for adult steelhead passage are further supported by findings in 2011 that a minimum bypass flow of 21 cfs was needed at the Grand Avenue gage to support steelhead passage (McInnis 2011). The sensitive period indicator flow was developed for the Watershed Criteria Report using the Wetted Perimeter Method (CDFW 2020e), a field method that can be used to identify the timing of the sensitive low-flow period. Ecosystem baseflows were developed using Tessmann's adaptation of the Tennant method (Tennant 1976; Tessmann 1980) and input reference hydrology from the USGS/TNC Natural Flows Database (Zimmerman et al. 2020).

Table 13. Summary of passage and sensitive period indicator results in cfs for San Antonio Creek from *Instream Flow Regime Criteria on a Watershed Scale: Ventura River* (CDFW 2020a).

Reach	Adult Steelhead Passage Flow	Juvenile Steelhead Passage Flow	Sensitive Period Indicator Flow
1	24[e]	8	4
2	24	7	5

Table 14. Ecosystem baseflow results in cfs for San Antonio Creek from *Instream Flow Regime Criteria on a Watershed Scale: Ventura River* (CDFW 2020a).

Reach	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	22	34	20	10	8	3	1	<1	1	2	6	8
2	14	23	13	7	6	2	1	<1	1	1	4	6

In addition, consideration of functional flows should inform decision-making. Fall pulse flows, produced by the first major runoff event of the season, are important for the health of the stream ecosystem when naturally present (see Section 2.2). These flows help to clean spawning gravels and provide important migration cues (Yarnell et al. 2015; Yarnell et al. 2020). Peak flows of varying magnitudes (e.g., two-, five-, and ten-year recurrence interval floods, defined as 50%, 20% and 10% exceedance annual peak flow events) also perform critical functions. Peak flows scour and reshape the channel, recruiting wood, redistributing sediment, and maintaining habitat over time.

Due to the high natural variation of flow in the San Antonio Creek watershed, some of the flows described in this document may not be naturally available every year. However, in years or months where these flows are naturally available[f], they are likely to be critical to the survival of the steelhead population. Appropriate application of these criteria requires professional judgment and responsiveness to dynamic hydrologic conditions.

Water management decision-making processes should consider additional information developed using the State Water Board's groundwater-surface water interaction model (Geosyntec Consultants and David B Stephens & Associates 2019). That model is currently under development and will describe unimpaired flow in the Ventura River watershed. Ecosystem baseflows from the Watershed Criteria Report, which are

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[e] Both transects evaluated for steelhead adult passage in Reach 1 were removed from analysis for exceeding modeling thresholds (i.e., the survey flow was not high enough to model a passage flow through those transects; see CDFW (2020c), Table B-1). Instead, the Reach 2 value represents passage flow needs for both reaches.

[f] Natural flows in this document refer to the flows that would be present in the channel under natural conditions (i.e., flows that would be present at that time without diversions), and does not refer specifically to the Natural Flows that were presented in the Watershed Criteria Report (CDFW 2020a).

presented in Table 14, could potentially be recalculated using the new unimpaired flow dataset when it is available. All of the other flow criteria presented in this section are based on field data and are not expected to change.

In addition to the above concerns, climate change could result in a future adjustment to these criteria. The Department is committed to minimizing the effects of climate change on California's natural resources. Changes in temperature and precipitation could result in alteration to existing freshwater systems and an overall reduced availability of water for fish and wildlife species. In addition, these changes may impact groundwater recharge and overdraft as well as fish passage and water diversion projects. Given the uncertainty associated with climate change impacts, the Department may modify the instream flow regime criteria for the San Antonio Creek watershed as the science and understanding of climate change evolves or as new information becomes available.

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