FINAL REPORT ◦ JANUARY 2023

San Simeon Creek Instream Flows Assessment

PREPARED FOR

Cambria Community Services District
PO Box 65
Cambria, CA 93428

PREPARED BY

Stillwater Sciences
895 Napa Ave., Suite B-3
Morro Bay, CA 93442

Stillwater Sciences

Suggested citation:
Stillwater Sciences 2023. San Simeon Creek Instream Flows Assessment. Final Report. Prepared by Stillwater Sciences, Morro Bay, California for Cambria Community Services District, Cambria, California.

Cover photos: Overview of San Simeon Creek during winter 2022 (top left), habitat surveys during 2022 (top right and bottom left), and adult steelhead observed in 2022 (bottom right).

Table of Contents

Tables

Figures

Appendices

1 INTRODUCTION

The Cambria Community Services District (CCSD) conducted this instream flow study to quantify the amount of streamflow that will support key species and habitat in lower San Simeon Creek. Water service provided by the CCSD has the potential to influence surface flows in San Simeon Creek but information on how surface flow conditions affect aquatic habitat for sensitive species are lacking. Findings from this study ("Task 1") and concurrent groundwater studies ("Task 2") will be used to identify a sustainable amount of groundwater that can be extracted during operation of the San Simeon groundwater wells and long-term operation of the Water Reclamation Facility (WRF, formerly the Sustainable Water Facility [SWF]) without adversely affecting riparian and wetland habitat or surrounding agricultural activities. This report focuses on surface flow conditions and how those conditions influence aquatic habitat for special status species in lower San Simeon Creek where it flows over the groundwater basin (Figure 1).

The CCSD provides water service to the unincorporated town of Cambria. All of Cambria's potable water is supplied from groundwater wells operated by the CCSD. Three groundwater wells extract water from the basin beneath San Simeon Creek and two groundwater wells extract water from the basin beneath Santa Rosa Creek. In addition to the three groundwater wells operated along San Simeon Creek, the CCSD constructed the WRF in 2014 under an emergency Coastal Development Permit (CDP) to address water shortage conditions in the community of Cambria during a historic drought event. The WRF enables the CCSD to provide a reliable water supply to residents of Cambria during water shortages using a combination of advanced water treatment, groundwater recharge, and groundwater extraction during periods of declared water shortages.

The WRF is designed to supply water through the pumping of brackish subsurface water that is then treated and reinjected back into the groundwater basin upstream near the three existing San Simeon groundwater wells to maintain groundwater levels that allow for extraction. Through groundwater augmentation, the WRF was designed to provide up to 250 acre-feet of water to the community of Cambria during the dry season (typically late spring through fall). Furthermore, the Project was designed to provide up to 100 gallons per minute (gpm) (equivalent to 0.23 cubic feet per second [cfs]) to maintain water levels within the San Simeon Creek lagoon when the WRF is operational. This study will help inform basin management protocols and environmental monitoring plans once the instream flow needs are identified.

Under the CCSD's current emergency CDP, the WRF is only allowed to operate during declared Stage 3 water shortages. As part of its 2020 Urban Water Management Plan, the CCSD replaced its 3-stage Emergency Water Conservation Program ("legacy program") with a new 6-Stage Water Shortage Contingency Plan (WSCP). The legacy program's Stage 3 met the definition of a water shortage emergency per California Water Code Section 350 and was intended to conserve the water supply for critical uses only: human consumption, sanitation, and fire protection. Stages 4, 5, and 6 of the WSCP meet the definition of a water shortage emergency, with Stages 5 and 6 being the closest equivalent to the legacy program Stage 3. Ordinance 03-2021 describes the WSCP in detail, including implementation criteria and procedures to initiate water shortage stages. It can be viewed in the CCSD's Public Repository (www.cambriacsd.org/public-repository).

Sustained, long-term use of the WRF during the dry season is being considered as part of the regular CDP application. Operation of the San Simeon groundwater wells and the WRF may affect the distribution and/or behavior of sensitive aquatic species in stream sections where streamflow is affected by groundwater pumping and groundwater infiltration. Sensitive species that occur in Simeon Creek include federally threatened south-central California coast steelhead (anadromous *Oncorhynchus mykiss*), tidewater goby (*Eucyclogobius newberryi*), and California red-legged frog (*Rana draytoni*) (National Marine Fisheries Service [NMFS] 2013, Rathburn et al. 1993).

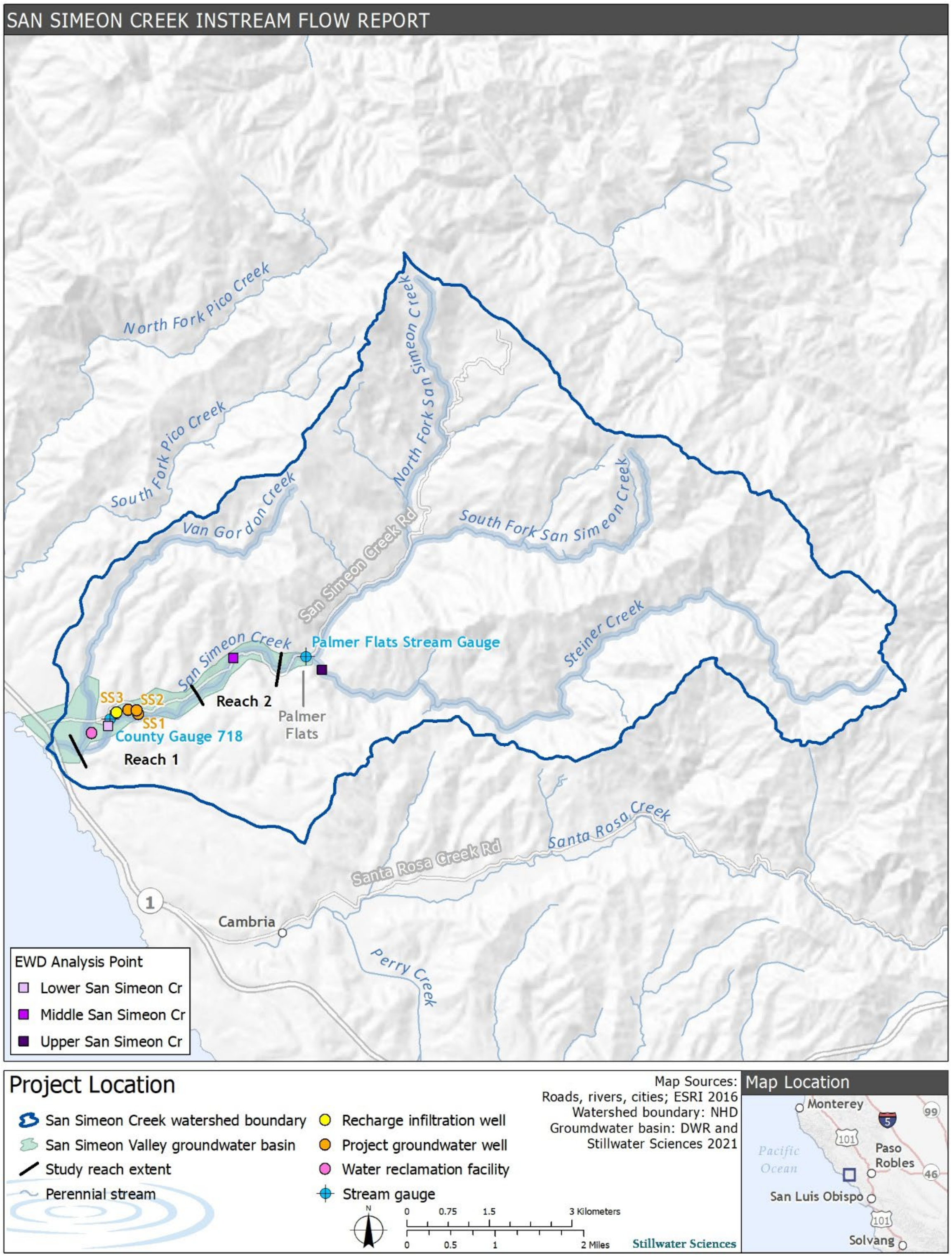


Figure 1. Study Area.

2 BACKGROUND

The San Simeon Creek watershed drains a 35-square-mile area of the southern Coast Range. Originating from the flanks of the Santa Lucia Mountains, San Simeon Creek transitions from mountainous headwater terrain (maximum elevation approximately 3,400 feet [ft] above mean sea level) to lower gradient valley depositional areas before draining to the Pacific Ocean approximately 2.5 miles north of the town of Cambria. San Simeon Creek has two major tributary basins with their headwaters in the Santa Lucia Mountains: Van Gordon Creek and Steiner Creek (Figure 1). Streamflow entering from these tributaries has been shown to be important for maintaining surface flows in San Simeon Creek (D.W. Alley and Associates 2004).

Instream flows for San Simeon Creek were previously assessed during a county wide assessment conducted by Stillwater Sciences (2014) to estimate the Environmental Water Demand (EWD) for watersheds throughout San Luis Obispo County. EWD is defined as the minimum amount of surface flows required to sustain aquatic habitat and ecosystem processes. The purpose of the EWD study was to provide a preliminary estimate of the magnitude and timing of instream flows that would support steelhead in creeks of San Luis Obispo County and was not intended to provide sufficient detail for establishing regulatory or mandatory water permit limits. The 2014 report explicitly recommended site-specific analysis to establish flow recommendations, such as the study described here.

In an attempt to avoid estimating EWD for locations that naturally dry out (without human water extractions) during the summer/fall seasons, analysis points for estimating EWD were selected based on modeling which predicted locations with perennial flows and a high potential for suitable summer rearing habitat for juvenile steelhead (Boughton and Goslin 2007). EWD was then estimated at each analysis point based on a predictive model (Stillwater Sciences 2014). Within San Simeon Creek, EWD was estimated at three locations 1) lower San Simeon Creek, just upstream of Van Gordon Creek, 2) middle San Simeon Creek, just upstream of the San Simeon Creek Road Bridge, and 3) upper San Simeon Creek, which is within Steiner Creek just upstream from the confluence with San Simeon Creek (Figure 1 and Table 1).

Table 1. Environmental water demand (EWD) estimates for San Simeon Creek, from Stillwater Sciences 2014.

Analysis Point	Drainage Area (mi^2)	EWD (cfs)	
		Spring	Summer
Lower San Simeon Creek	26.2	1.6	0.5
Middle San Simeon Creek	24.3	1.5	0.5
Upper San Simeon Creek	9.8	0.8	0.3

Similar to other Central Coast Range watersheds, San Simeon Creek naturally exhibits seasonal surface flow and extensive intermittent reaches due to highly variable patterns of precipitation and the complex geology of the region (NMFS 2013). Flows in San Simeon Creek closely follow the seasonal precipitation patterns of the region. Stream gage data from San Simeon Creek shows the highest flows generally occur in the winter when maximum daily flows can exceed 1,000 cfs, while minimum flows during the summer are often 0 cfs (Table 2). Flood flows in San Simeon Creek typically increase, peak, and subside rapidly in response to high-intensity rainfall. This hydrologic attribute is characteristic of a "flashy" hydrograph, whereby a rapid increase in discharge occurs over a relatively short time period with a quickly developed peak discharge in relation to normal baseflow. During the dry season, the lower section of San Simeon Creek often goes dry from near the confluence with Steiner Creek downstream to the lagoon (D.W. Alley and Associates 2004).

Table 2. Mean daily flow for San Simeon Creek based on data collected at the county gage (#718) located just downstream of the CCSD wells based on data collected from 1990 through 2001 and at the Palmer Flats gage based on data collected from 1971 through 1995.

Month	Daily Flow Statistics at County Gage[1]				Daily Flow Statistics at Palmer Flats Gage[1]			
	Min (cfs)	Mean (cfs)	Max (cfs)	Median (cfs)	Min (cfs)	Mean (cfs)	Max (cfs)	Median (cfs
October	0.0	0.3	51.0	0.0	0.0	0.2	15.0	0.0
November	0.0	8.2	1,200.0	0.0	0.0	12.8	832.0	0.0
December	0.0	18.3	1,020.0	0.0	0.0	26.3	920.0	0.9
January	0.0	95.8	1,480.0	1.2	0.0	66.1	1,592.0	7.9
February	0.0	152.6	2,590.0	40.0	0.0	72.6	1,106.0	12.0
March	0.0	90.2	4,270.0	29.0	0.0	73.4	1,530.0	14.0
April	0.0	20.0	286.0	9.6	0.0	20.4	1,164.0	6.7
May	0.0	4.9	215.0	1.4	0.0	4.9	67.0	1.5
June	0.0	0.9	7.0	0.0	0.0	1.9	20.0	0.2
July	0.0	0.2	3.6	0.0	0.0	1.2	21.0	0.0
August	0.0	0.0	0.2	0.0	0.0	0.4	20.0	0.0
September	0.0	0.0	0.0	0.0	0.0	0.1	18.0	0.0

[1] While data was recorded daily for several seasons, there are periods of time when no flow was recorded. It is unknown if lack of data represents dry conditions or if data was not collected for other reasons. Therefore, blank data cells were not included in calculation of statistics.

NA = Not Available. Indicates statics were not calculated due to insufficient data.

Instream flows provide many functions throughout the year, including sufficient flow for fish migration and rearing (Figure 2), suitable water quality in the lagoon, and essential geomorphic processes. Our central focus in this study is to evaluate a range of flows and assess their ability to protect basic ecological processes which occur throughout the year but are most limiting when flows are at their lowest (dry season; late spring through fall).

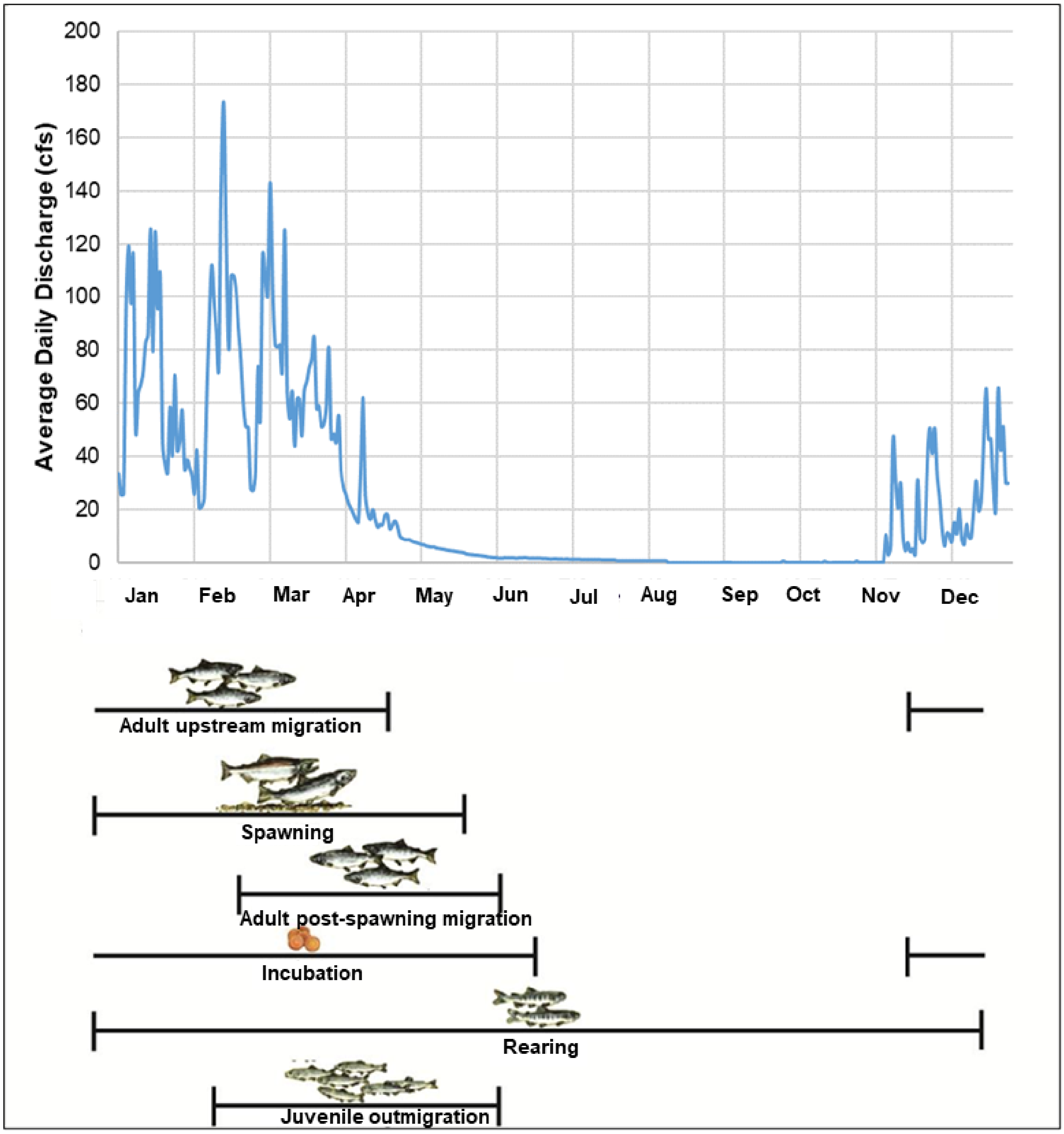


Figure 2. Average daily flows in San Simeon Creek, based on Palmer Flats gage data for the period of 1971 through 1995 with life history timing of steelhead (Shapovalov and Taft 1954).

Streamflow in lower San Simeon Creek is influenced by groundwater levels with generally steady baseflows during the winter months; however, when basin-wide pumping exceeds the amount of streamflow contributions, the groundwater levels quickly decline. This typically begins in the late spring when streamflow reaches about 1.3 cfs at Palmer Flats near the upstream end of the groundwater basin (Yates and Konynenburg 1998). Groundwater levels within the San Simeon groundwater basin generally become saturated after the first stream flow event in the winter and remain full until early summer, when the groundwater levels begin to recede before stabilizing near their minimum elevation, which typically occurs by the beginning of September and remains there until the first stream flow event recharges the groundwater basin (CCSD 2015).

2.1 Special Status Species

Special status aquatic species that occur in San Simeon Creek include two federally listed fish species including steelhead and tidewater goby, and one federally listed amphibian, California red-legged frog (CRLF).

2.1.1 Steelhead

Lower San Simeon Creek supports a population of federally threatened south-central California coast steelhead (NMFS 2013), reducing instream flow and water availability was identified as a potential issue by resource agencies (e.g., California Coastal Commission [CCC]). Steelhead found in the San Simeon Creek watershed belong to the South-Central California Coast Distinct Population Segment (DPS), which includes steelhead populations that inhabit coastal stream networks from the Pajaro River (San Benito County) south to, but not including, the Santa Maria River (NMFS 2013). Within this DPS, the population of steelhead in the San Simeon Creek watershed has been identified as a Core 1 population, which means they have the highest priority for recovery actions, have a known ability or potential to support viable populations, and have the capacity to respond to recovery actions. One critical recovery action listed by NMFS includes the implementation of operating criteria to ensure streamflow allows for essential steelhead habitat functions (NMFS 2013).

Adult steelhead generally leave the ocean to return to their natal streams from December through March and spawn in late winter or spring (Meehan and Bjornn 1991, Behnke 1992). Spawning occurs primarily from January through April (Hallock et al. 1961, Moyle 2002). Female steelhead construct redds in suitable gravels (0.39–1.18 inches in diameter [Moyle 2002]), often in pool tailouts and heads of riffles, or in isolated patches in cobble-bedded streams. Steelhead eggs incubate in the redds for 3–14 weeks, depending on water temperatures (Shapovalov and Taft 1954, Barnhart 1991). After hatching, young steelhead remain in the gravel for an additional two–five weeks while absorbing their yolk sacs, and then emerge in spring or early summer as fry (Barnhart 1991).

After emergence, steelhead fry utilize shallow, low-velocity habitats, typically found along stream margins and in low-gradient riffles (Hartman 1965, Fontaine 1988). As fry grow and improve their swimming abilities in late summer and fall, they increasingly show a preference for higher water velocity and deeper mid-channel areas near the thalweg (the deepest part of the channel) in locations with cover (Hartman 1965, Everest and Chapman 1972, Fontaine 1988). Locations with high water velocity and cover likely provide juvenile steelhead with resting locations while they watch for drifting invertebrates being carried by flow. Aquatic invertebrates comprise a key item in the diet of juvenile steelhead. After rearing in freshwater for one to three years, juvenile steelhead migrate out to the ocean, which typically occurs from March through June.

Lagoon conditions have an important influence on anadromous fish survival since steelhead must pass through these areas during upstream adult migration and downstream smolt outmigration. In some central California coast watersheds, seasonal lagoons have also been shown to provide a critical role in supporting steelhead populations by providing important juvenile steelhead rearing habitat. Juvenile steelhead that rear in lagoon habitat over the summer have been shown to have rapid growth rates compared to growth in upstream locations (Hayes et al. 2008). Larger steelhead that reared in seasonal lagoon habitat in Scott Creek (Santa Cruz County), for example, were found to account for over 80% of the returning adult population (Bond et al. 2008). In some cases, lagoons have the potential to contribute to the majority of steelhead smolt produced in small coastal watersheds (Smith 1990). Water quality conditions within lagoon habitat reported to support steelhead rearing include the following criteria:

- water temperatures between 15–24°C (59–75.2°F) (Hayes et al. 2008).
- salinities less than 10 parts per thousand (ppt) (Daniels et al. 2010).
- Dissolved Oxygen (DO) concentrations greater than 5 mg/L (ISU 2008, as cited in Daniels et al. 2010).

Flows to support steelhead migration in San Simeon Creek were previously assessed D. W. Alley and Associates (1992). The study focused on water depth at critical riffles located within the lower four miles of San Simeon Creek. D. W. Alley estimated that flows to support adult steelhead upstream migration ranged from approximately 21 cfs to 68 cfs, depending on the critical riffle location, while juvenile steelhead downstream migration was supported at flows ranging from approximately 4 cfs to 11 cfs. Studies monitoring the downstream migration of steelhead in San Simeon Creek observed juvenile steelhead migration primarily during April and May with higher catch often occurring during periods of increased flows (Table 3) (Nelson 1995, Nelson et al. 2005).

Table 3. Steelhead outmigrant trapping results summary for San Simeon Creek in 1993 and 2005 (Nelson 1995, Nelson et al. 2005).

Week	Parr	Silvery Parr	Smolt	Rainbow trout coloration	Kelt	Total	Stream flow (date)
1993 Outmigrant Trapping							
April 7	0	0	1	0	0	1	Not recorded
April 12	0	0	0	0	0	0	Not recorded
April 19	0	0	4	0	0	4	Not recorded
April 26	0	0	5	0	0	5	Not recorded
May 3	0	0		0	0	0	6.27 (May 5, 1993)
May 10	0	0		0	0	0	4.41 (May 12, 1993)
May 17	0	0		0	0	0	2.65 (May 19, 1993)
May 24[a]	Na	Na	Na	Na	Na	Na	5.29 (May 25, 1993)
2005 Outmigrant Trapping							
March 14	1	2	0	0	0	3	Not recorded
April 11	1	4	16	0	0	21	Not recorded
April 18	1	5	11	0	1	18	15.8 (April 20,2005)
April 25	0	33	17	3	0	53	31.3 (April 28,2005)
May 2	8	11	2	0	0	21	9.6 (May 4,2005)
May 9	49	10	1	0	0	60	11.6 (May 11,2005)
May 16	11	0	0	0	0	11	7.2 (May 18,2005)
May 23	9	0	0	0	0	9	4.9 (May 24,2005)
May 30	30	0	0	0	0	30	3.7 (June 2,2005)
June 6	1	0	0	0	0	1	2.4 (June 7,2005)

[a] Traps were removed after the week of May 17th in 1993; however, the week of May 24 is included in the table to show an increase in flow that may have triggered additional smolt migration

2.1.2 Tidewater goby

Tidewater goby are federally listed as endangered under the FESA (59 FR 5494 5499) and designated as a species of special concern by the State of California. Critical habitat was designated for tidewater goby in San Simeon Creek lagoon (USFWS 2013). Tidewater goby are an estuarine/lagoon adapted species that are endemic to the California coast, mainly in small lagoons and near stream mouths in the uppermost brackish portion of larger bays (Moyle 2002, USFWS 2005).

Tidewater gobies are short-lived (generally one year) and highly fecund fish (females produce 300–500 eggs per batch and spawn multiple times per year) that disperse infrequently via marine habitat but have no dependency on marine habitat for their life cycle (Swift et al. 1989, Lafferty et al. 1999). Reproduction is generally associated with the closure and filling of the estuary (late spring to fall), typically beginning in late April or May and continuing into the fall, although the greatest numbers of fish are usually produced in the first half of this time period. Breeding occurs in slack shallow waters of seasonally disconnected or tidally muted lagoons, estuaries, and sloughs. Males dig burrows vertically into sand, 4 to 8 inches deep and defend the burrows until hatching (SCR Project Steering Committee 1996). Their diet consists mainly of small animals, usually mysid shrimp (*Mysidopsis bahia*), gamarid amphipods (*Gammarus roeseli*), and aquatic insects, particularly chironomid midge (Diptera: Chironomidae) larvae (Swift et al. 1989, Swenson 1997, Moyle 2002). Juvenile and adult tidewater gobies are reported to prefer water temperatures of 54–75°F, within a tolerance range of 42–77°F (Stillwater Sciences 2006).

The USFWS (2013) state that habitat characteristics required to sustain the tidewater goby's life history processes include:

> Persistent, shallow (in the range of approximately 0.3 to 6.6 ft), still-to-slow-moving lagoons, estuaries, and coastal streams with salinity up to 12 ppt, which provide adequate space for normal behavior and individual and population growth that contain one or more of the following: (a) Substrates (e.g., sand, silt, mud) suitable for the construction of burrows for reproduction; (b) Submerged and emergent aquatic vegetation, such as pondweed (Potamogeton pectinatus), widgeongrass (*Ruppia maritima*), bulrush (*Typha latifolia*), and sedges (*Scirpus* spp.), that provides protection from predators and high flow events; or (c) Presence of a sandbar(s) across the mouth of a lagoon or estuary during the late spring, summer, and fall that closes or partially closes the lagoon or estuary, thereby providing relatively stable water levels and salinity.

Monthly visual observation surveys conducted in San Simeon lagoon from May 1992 through April 1993, documented observations of over 7,000 juvenile and over 1,000 adult tidewater goby (Rathburn et al. 1993). More recently, during a single day of beach seining in October 2014, over 1,000 tidewater goby were captured in San Simeon lagoon (D.W. Alley 2015)

2.1.3 California red-legged frog

CRLF is federally listed as threatened and is a California Department of Fish and Wildlife (CDFW) Species of Special Concern. The species' range occurs from south of Elk Creek in Mendocino County to Baja California, with isolated remnant populations occurring in the Sierra foothills from sea level to approximately 8,000 ft (Stebbins 1985, Shaffer et al. 2004). Currently, most CRLF populations are largely restricted to coastal drainages on the central coast of California.

CFLF habitat includes wetlands, wet meadows, ponds, lakes, and low-gradient, slow-moving stream reaches. Breeding generally occurs from December through April in aquatic habitats characterized by still or slow-moving water with deep pools (usually 2.3 ft deep or greater) and emergent and overhanging vegetation (Jennings and Hayes 1994). Breeding sites can be ephemeral or permanent; if ephemeral, inundation is usually necessary into the summer months (through July or August) for successful metamorphosis. Although some adults may remain resident year-round at favorable breeding sites, others may disperse overland up to one mile or more (Fellers and Kleeman 2007). Movements may be along riparian corridors, but many individuals move directly from one site to another without apparent regard for topography or watershed corridors (Bulger et al. 2003). California red-legged frogs sometimes enter a dormant state during summer or in dry weather (aestivation), finding cover in small mammal burrows, moist leaf litter, root wads, or cracks in the soil. However, California red-legged frogs in coastal areas are typically active year-round because temperatures are generally moderate (USFWS 2002, Bulger et al. 2003). CRLF eggs and tadpoles require daily average water temperatures <23°C (73.4°F) (USFWS 2002) and salinities of 4.5 parts per thousand or below (Jennings and Hayes 1990).

2.2 Operations Information

CCSD operates the three groundwater wells located along Lower San Simeon Creek fairly consistently throughout the year (Figure 3). Existing water rights conditions limit pumping to an annual maximum of 799 Acre Feet per Year (AFY) allowed from the San Simeon aquifer and of that amount up to 370 AFY can be pumped during the dry season (defined as "from the time the creek ceases flow at the Palmer Flats gauging station, until October 31") (Water Systems Consulting 2021). Average monthly groundwater extraction ranges between 24 acre-feet to 38 acre-feet (based on data collected between 2012 through July 2022 [Figure 3]), which equates to daily average extraction rates of approximately 0.41 cfs to 0.64 cfs. Groundwater pumping rates are limited to an average 30-day direct diversion rate of 1.43 cfs which equates to 85 acre-feet per month (Water Systems Consulting 2021).

In addition to CCSD, there are numerous private wells that irrigate farmlands on flat areas adjacent to the San Simeon creek channel. Agricultural pumping within the valley has been estimated at approximately 180 AFY (CDM Smith 2014). Just downstream of the CCSD wells at the CCSD wastewater percolation ponds, a private landowner operates a non-potable groundwater well that is allocated up to 183.5 AFY per year; however, recent use has averaged around approximately 15 AFY per year.

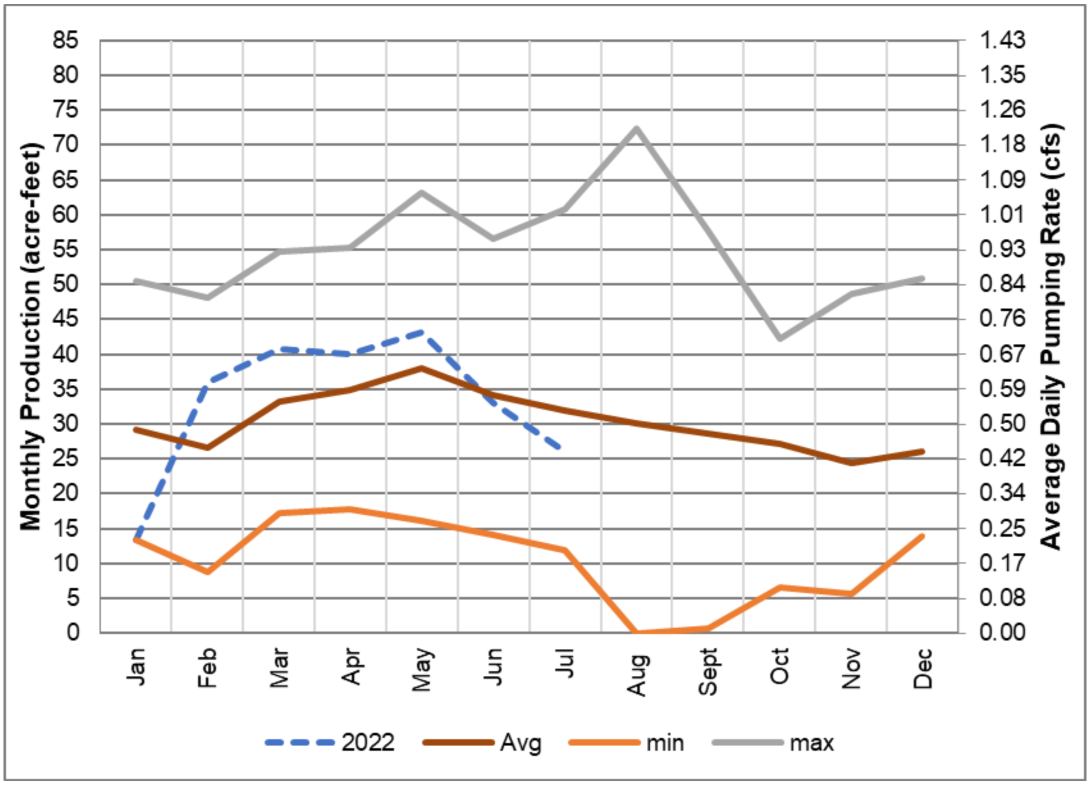


Figure 3. 2022 monthly well extraction volume from CCSD San Simeon basin wells and average, minimum, and maximum monthly well extraction volumes with average daily pumping rates for the period of 2012 through July 2022.

2.3 Study Goals and Objectives

The CCSD initiated two tasks to inform District operations within the San Simeon groundwater basin. Task 1 includes an Instream Flow Study focused primarily on surface flow conditions within lower San Simeon Creek. Groundwater modeling was included under a second task (Task 2) related to the Instream Flow Study efforts. The Task 2 study aims to quantitatively estimate the effects of operational changes on groundwater levels, groundwater inflow to San Simeon Creek lagoon, and ocean boundary outflow using a modified, existing groundwater model of the San Simeon Creek basin. The analysis focuses on drought periods when the WRF would likely be operated and when potential ecological impacts would be most severe. The goal of the Task 1 and 2 studies is to inform water allocation in the San Simeon Creek watershed as it relates to sensitive species that occur in lower San Simeon Creek. Results from both studies will be used to inform the CCSD's Adaptive Management Plan (AMP) for San Simeon Creek.

This report focuses on surface flows and identifies flows needed for sensitive species and habitats in lower San Simeon Creek assessed under Task 1. The study objective is to determine the relationship between habitat and streamflow as it relates to the needs of aquatic species in lower San Simeon Creek, where project operations (San Simeon Well Production and WRF) have the potential to alter surface flow.

2.4 Study Area

The Study Area focuses on the section of San Simeon Creek where surface flows are most likely influenced by groundwater pumping and recharge associated with CCSD operations. It covers an approximately 3.5-mile section of San Simeon Creek that runs along the San Simeon Valley groundwater basin, which begins just upstream of the lagoon and extends upstream to the Palmer Flats area located just downstream of Steiner Creek (Figure 1). This section of San Simeon Creek is between two major tributaries (Van Gordon Creek at the downstream end and Steiner Creek at the upstream end) and within the alluvial section of the watershed, where surface flows infiltrate into the groundwater basin. The stream channel within the Study Area is characterized as a low-gradient, broad channel with substate that is predominately sand and gravel with lesser amounts of cobble channel (Nelson et al. 2005).

Surface flow in San Simeon Creek within the Study Area generally occurs during the late-fall through late-spring with flows typically becoming intermittent between May and July, depending on water year type. Previous habitat mapping efforts in San Simeon Creek noted the section within the Study Area as having diverse channel characteristics and substrate composition; however, it was treated as a single reach because it was intermittent during the 2005 survey (Nelson et al. 2005). For modeling purposes, the two distinct sections within the Study Area were treated as separate reaches with the modeling focused on the larger downstream reach (Reach 1) which extends along the CCSD well field (Figure 1). While this study covered both reaches within the Study Area, modeling was limited to the Reach 1 which was more accessible and closer to CCSD operations.

3 METHODS

3.1 Technical Advisory Committee

This project engaged stakeholders through the creation of a Technical Advisory Committee (TAC). The TAC included individuals from the California Department of Fish and Wildlife (CDFW), California State Parks, the California Coastal Commission, San Luis Obispo County, and the Upper Salinas-Las Tablas Resource Conservation District (USLTRCD). The TAC has met and provided guidance on the technical approach during study plan development.

3.2 Habitat Typing

Surveys to delineate aquatic habitat units were conducted in nearly three miles of continuous stream channel of lower San Simeon Creek. Because this section of San Simeon Creek was dry at the start of this study (early December 2021), habitat mapping was conducted during winter after flows returned to San Simeon Creek within the Study Area and the stream stage level had become stable at the county gauge. Winter base flow conditions were targeted to facilitate the evaluation of habitat composition while low flows made distinct habitat unit breaks most apparent. Habitat units were classified using a three-tiered habitat mapping classification system (Hawkins et al. 1993) to assist in the identification of individual habitat units in the field. Level III categories are generally modified/adopted from McCain et al. (1990). Figure 4 shows the relationship among the three levels.

Habitat mapping was conducted on foot by a team of two biologists within the two study reaches. Individual habitat units were designated a habitat type (e.g., riffle, run, pool) using the habitat types described in Table 4. Each habitat unit was identified where the unit length was greater than the active channel width (Flosi et al. 2010). The length of each habitat unit was measured using a hip chain, which was referenced back to a known starting point or landmark. The mapping was contiguous, with each habitat unit abutted to the next unit. Each distinct habitat unit was numbered consecutively in an upstream direction, beginning at the downstream end of the Study Reach.

Data from the habitat mapping was used to characterize each Study Reach. A single Study Reach (Reach 1) near CCSD Project operations in San Simeon Creek was selected for 1D modeling to assess stream flow conditions and available habitat for steelhead. Habitat typing data was used to establish study sites which were appropriate for use in the 1D model and representative of conditions throughout the study reach to allow for data extrapolation.

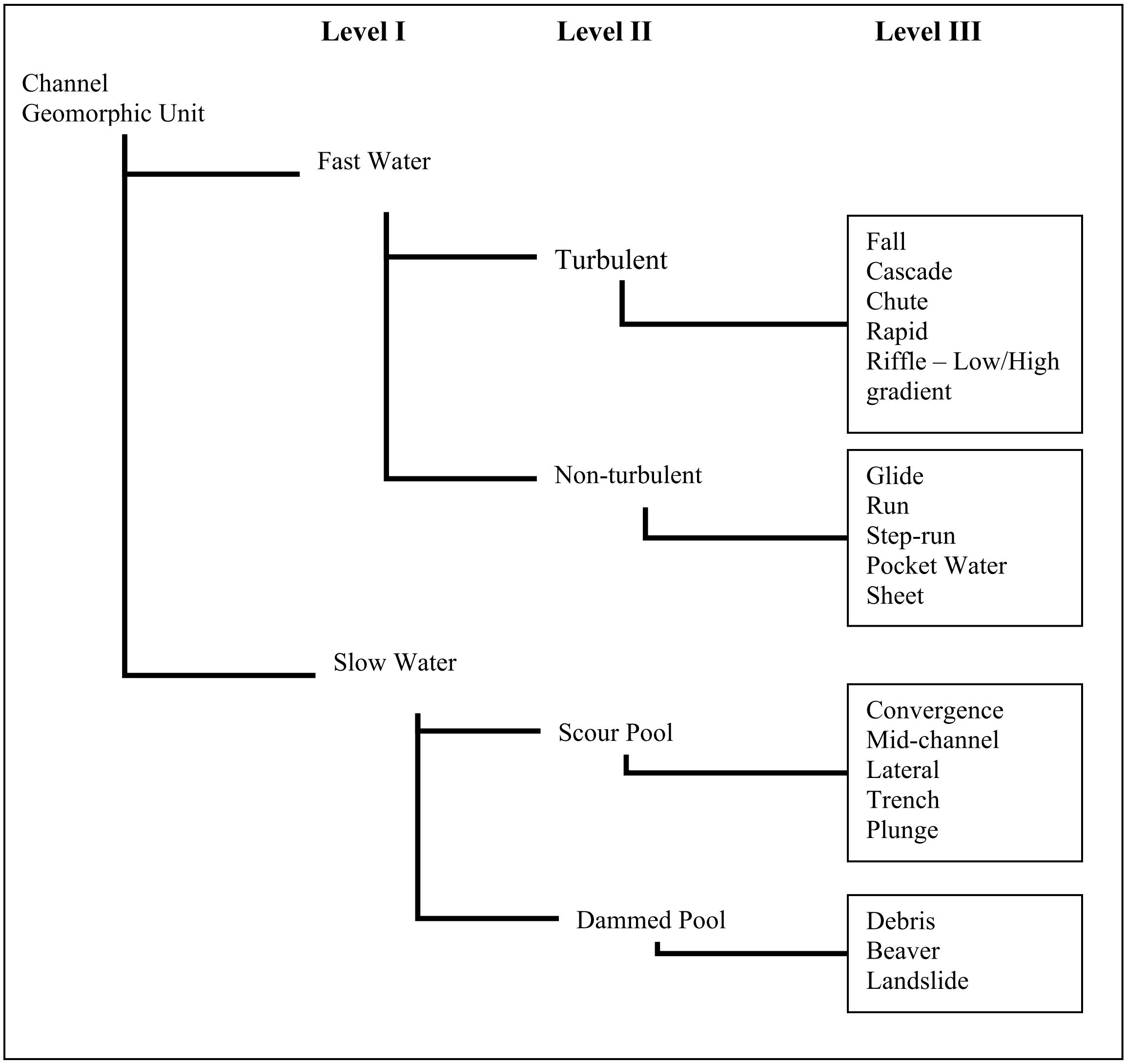


Figure 4. Three-tiered habitat mapping classification system adapted from Hawkins et al. (1993) and McCain et al. (1990).

Table 4. Habitat types to be used in mapping for the San Simeon Creek instream flow study (Adapted from McCain et al. 1990, Armantrout 1998, Payne 1992, McMahon et al. 1996, and Hawkins et al. 1993).

I. Fast Water:	**Riffles, rapid, shallow stream sections with steep water surface gradient.**
A. Turbulent:	**Channel units having swift current, high channel roughness (large substrate), steep gradient, and non-laminar flow and characterized by surface turbulence.**
1. Fall:	Steep vertical drop in water surface elevation. Generally not modellable.
2. Cascade:	Series of alternating small falls and shallow pools; substrate usually bedrock and boulders. Gradient high (more than 4%). Generally not modellable.
3. Chute:	Narrow, confined channel with rapid, relatively unobstructed flow and bedrock substrate.
4. Rapid:	Deeper stream section with considerable surface agitation and swift current; large boulder and standing waves often present. Generally not modellable.
5. Riffles:	Shallow, lower-gradient channel units with moderate current velocity and some partially exposed substrate (usually cobble). • Low gradient—Shallow with swift flowing, turbulent water. Partially exposed substrate dominated by cobble. Gradient moderate (less than 4%). • High gradient—Moderately deep with swift flowing, turbulent water. Partially exposed substrate dominated by boulder. Gradient steep (greater than 4%). Generally not modellable.
B. Non-turbulent:	**Channel units having low channel roughness, moderate gradient, laminar flow, and lack of surface turbulence.**
1. Sheet:	Shallow water flowing over smooth bedrock.
2. Run / Glide:	Shallow (glide) to deep (run) water flowing over a variety of different substrates.
3. Step Run	A sequence of runs separated by short riffle steps. Substrates are usually cobble and boulder dominated.
4. Pocket Water:	Swift flowing water with large boulder or bedrock obstructions creating eddies, small backwater, or scour holes. Gradient low to moderate.
II. Slow Water:	**Pools; slow, deep stream sections with nearly flat-water surface gradient.**
A. Scour Pool:	**Formed by scouring action of current.**
1. Trench:	Formed by scouring of bedrock.
2. Mid-channel:	Formed by channel constriction or downstream hydraulic control.
3. Convergence	Formed where two stream channels meet.
4. Lateral:	Formed where flow is deflected by a partial channel obstruction (streambank, rootwad, log, or boulder).
5. Plunge:	Formed by water dropping vertically over channel obstruction.
B. Dammed Pool:	**Water impounded by channel blockage.**
1. Debris:	Formed by rootwads and logs.
2. Beaver:	Formed by beaver dam.
3. Landslide:	Formed by large boulders.
4. Backwater:	Formed by obstructions along banks (Recorded as a comment or note to mapping).
5. Abandoned Channel:	Formed along main channel, usually associated with gravel bars (Not part of the main active channel. Recorded as a comment or note to mapping).

3.3 Instream Flow Surveys

The Instream Flow Incremental Methodology (IFIM) was used to evaluate the relationship between flow and habitat quantity/quality throughout Reach 1. The IFIM applies a mesohabitat (i.e., riffle, run, and pool) and transect-based approach (commonly referred to as the 1D method) for implementing the 1D modeling component of the IFIM to address flow-habitat relationships. For this analysis the System for Environmental Flow Analysis (SEFA; Jowett et al. 2017) model was applied using a one-flow velocity calibration approach, where transect and cell-specific data were derived from field survey data. The SEFA model calculates a habitat index that reflects the Area Weighted Suitability (AWS) based on simulation of water depths and velocities from the 1D hydraulic models. Cross sections (transects) are used to represent the stream, and habitat suitability criteria (HSC) are applied which define the physical and hydraulic characteristics considered suitable for specific species and life stages. Details of the approach are provided below.

3.3.1 Study Site Selection for 1D Model

Study sites were selected for 1D modeling within Reach 1. Prior to study site selection, Reach 2 was removed from the process due to access limitations. The study sites for 1D modeling were selected within Reach 1 using a combination of random selection and professional judgment following the procedure outlined in CDFW 2015. The procedure is based on the number and overall proportion of habitat types and provides assurance that all major habitat types will be sampled in relative proportion to the overall reach (Table 5). To account for habitat variation within the study reach, Reach 1 was subdivided into three sub-sections of approximately equal length (Table 6).

Within each sub-section, the habitat unit corresponding with the least abundant mesohabitat served as the basis for random selection. These units were assigned sequential numbers and a random number was generated for each unit. The randomly selected units were then located in the field and included as a study site if they appeared representative of that habitat type within Reach 1 and appeared modellable based on perpendicular flow and level water surface area. In the event a randomly selected unit was determined to be unrepresentative or not modellable, the second randomly selected unit was chosen. From that starting habitat unit, transect locations were established in adjacent habitat units (heading upstream or downstream) until the requisite number of transects were placed in the specified habitat units, as described below. This created a cluster of study sites to facilitate collection of transect data.

Table 5. Number of mesohabitat units by type for each Study Reach.

Habitat code	Mesohabitat	Total length (ft)	Length relative freq.	Number	Number relative freq.
Reach 1					
LGR	Low Gradient Riffle	1,751	21.3%	26	34.2%
GLD	Glide	1,290	15.7%	6	7.9%
RUN	Run	2,441	29.7%	21	27.6%
LSP	Lateral Scour Pool	557	6.8%	4	5.3%
MCP	Mid Channel Pool	2,181	26.5%	19	25.0%
	SUM	**8,220**	**100.0%**	**76**	**100.0%**
Reach 2					
LGR	Low Gradient Riffle	1,816	22.1%	23	38.3%
GLD	Glide	134	1.6%	1	1.7%
RUN	Run	2,157	26.2%	18	30.0%
LSP	Lateral Scour Pool	801	9.7%	4	6.7%
MCP	Mid Channel Pool	2,000	24.3%	14	23.3%
	SUM	**6,908**	**100.0%**	**60**	**100.0%**

Table 6. Reach 1 sub-sections for Transect Selection

Mesohabitat	Total length (ft)	Length relative freq.	Number	Number relative freq.
Sub-section A				
Low Gradient Riffle	605	23%	10	37%
Glide	324	12%	2	7%
Run	620	23%	6	22%
Pool	1,101	42%	9	33%
SUM	**2,650**	**100.0%**	**27**	**100.0%**
Sub-section B				
Low Gradient Riffle	709	25%	9	35%
Glide	634	22%	3	12%
Run	1,079	38%	8	31%
Pool	439	15%	6	23%
SUM	**2,861**	**100.0%**	**26**	**100.0%**
Sub-section C				
Low Gradient Riffle	437	16%	7	31%
Glide	332	12%	1	4%
Run	924	34%	8	35%
Pool	1,016	38%	7	30%
SUM	**2,709**	**100.0%**	**23**	**100%**

3.3.2 Transect Placement

Twelve transects were established to model three riffle, three run, three pool, and three glide habitats within Reach 1. Individual transect locations were selected in the field. Transects were placed within representative habitat types for Reach 1. For modeling purposes, individual transects were weighted to represent the proportion of each meso-habitat type (e.g., riffle, run, and pool) in the reach. These proportions were calculated based on habitat unit lengths resulting from the habitat mapping data. Each habitat type was apportioned its respective length of the entire reach (e.g., riffles are 35% of the reach). To develop reach-wide estimates of habitat suitability, each transect in a habitat type was weighted equally based on the reach representation of the habitat type (e.g., each of 5 riffle transects would be weighted at 7% per transect if riffles represented 35% of the reach). Transect weights are shown in Table 7. Transect locations are shown in Figure 5.

Table 7. Transect weighting for San Simeon Creek instream flow study

Habitat type	Number of habitat units	Number of transects	Reach representation (%)[a]	Weight per transect (%)
Pool	23	3	33	11
Riffle	26	3	21	7
Run	21	3	30	10
Glide	6	3	15	5
Total	**76**	**12**	**100**	**--**

[a] Habitat percentage, by length, and normalized to 100 percent.

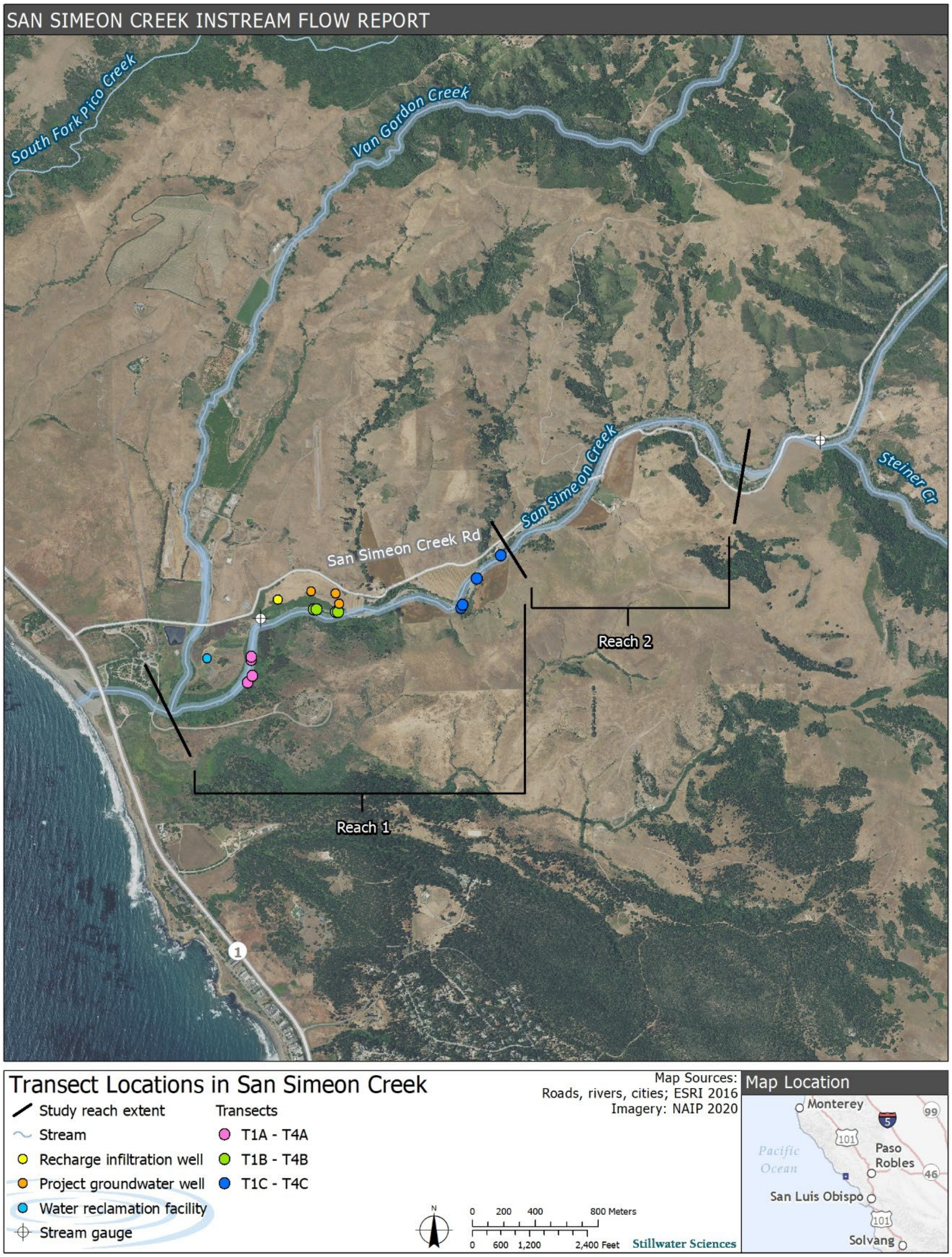


Figure 5. San Simeon Creek transect locations for 1D modeling.

3.3.3 Hydraulic Data Collection and Model Development

Water surface elevation and stream discharge measurements were made at each site during three separate flow events to capture a range of late spring/early summer flow conditions. Depth and velocity were measured for calibration purposes at each transect during a single flow event (the “one flow” method). Data collection and recording were conducted using the standardized procedures and guidelines established in the IFIM field techniques manuals (Trihey and Wegner 1981, Milhous et al. 1984) and procedures described in CDFW 2013. The techniques for measuring discharge followed the guidelines outlined by CDFW 2020. Water surface elevation (WSE) (i.e., stage) measurements were taken across each transect at three calibration flows (low, medium, and high).

Limited surface flow data is available for San Simeon Creek. To approximate a general range of target flows for surveys, data was reviewed from the county gage (#718) located just downstream of the CCSD wells on San Simeon Creek, which includes data from 1991 through 2001 and from the CCSD gage at Palmer Flats (located just downstream of Steiner Creek), which was collected from 1971 to 1995 (Table 1). Based on this available flow data covering the period of 1992 through 2001, calibration flows were selected to allow the models to simulate flows over a range covering mean daily flows for May through August based on the county gage (i.e., 0.2 cfs to 8.0 cfs). Calibration flows typically allow habitat index simulation to be extrapolated down 40% from the low flow and up 250% from the high flow. Therefore, calibration flows targeted a low of approximately 0.5 cfs and a high of approximately 3.2 cfs with a mid-flow between these two values (i.e., 1.85 cfs).

Water depths and mean column water velocities were measured across each transect during the high calibration flow. The number of cells sampled for depth and velocity was based on a goal of retaining a minimum of 15–20 stations that would remain in-water at the low calibration flow. Additional data collected during the field surveys included water surface slope and stage-of-zero-flow (SZF).

3.3.3.1 Velocity measurements

The standard method for determining mean column velocity was a single measurement at six-tenths of the water depth in depths less than 2.5 ft, and a two-tenths and eight-tenths measurement for depths between 2.5 ft and 4.0 ft. All three points were measured where depths exceed 4.0 ft, or where the vertical velocity distribution in the water column does not follow the standard pattern (slowing towards the substrate), and one or two points would not be adequate to derive an accurate mean column velocity. For example, an irregular vertical velocity distribution often occurs behind or adjacent to boulders or downstream from velocity chutes.

3.3.3.2 Model calibration

Existing HSC developed for the Big Sur River (Holmes et al. 2014) were used for this study. The Big Sur HSC includes criteria for water depth, mean column velocity, and focal point velocity for these three life stages of steelhead including steelhead fry (fish < 6 cm) and two size classes of juveniles (6–9 cm and 10–15 cm). Coordinates for HSC are shown in Appendix A.

SEFA version 1.8 build 5 (Jowett et al. 2014) was used for 1D modeling during this study. Stage-discharge relationships were developed from measured discharge and stage using a Stage-Zero-Flow (SZF) log/log regression formula. The SZF method requires a minimum of three sets of stage-discharge measurements and an estimate of the stage-at-zero-flow (SZF) for each transect.

All transects in Reach 1 used three sets of stage-discharge measurements. The SZF estimates were based on either the thalweg depth of a transect or the thalweg depth of a downstream hydraulic control. The quality of the stage-discharge relationships was evaluated by examination of mean error and slope output from the model.

The one-flow velocity method, using a single set of velocities collected at the high calibration flow, was used for all transects for velocity calibration. This technique uses a single set of measured velocities to predict individual cell velocities over a range of flows. Simulated velocities are based on measured data and a relationship between a fixed roughness coefficient (Manning's 'n') and depth. In some cases, roughness is modified for individual cells if substantial velocity errors are noted at simulation flows. Predicted velocities were examined to detect any significant deviations and determine if velocities change consistently with stage and total discharge.

3.3.3.3 Quality control

Considerable effort was applied to maintain strict quality control throughout all aspects of field data collection. To ensure quality control in the collection of field data for the San Simeon Creek instream flow study, the following procedures and protocols were used:

1. Staff plates were established and continually monitored throughout the course of collecting data on each transect. If significant changes were observed, water surface elevations were re-measured following collection of transect water velocity measurements.
2. Each day prior to water velocity measurements, all electromagnetic meters were calibrated as needed. Meters were continually monitored during the daily course of data collection to ensure that they were functioning properly.
3. All transects/cross sections were located using global positioning system (GPS). An independent benchmark was established for each set of transects. This benchmark was placed in either an immovable tree, boulder, or other naturally occurring object that would not be subject to tampering, vandalism, or movement. Upon establishment of headpin and tailpin elevations, a level loop was shot to check the auto-level for measurement accuracy. Allowable error tolerances on level loops were set at 0.02 ft. This tolerance was also applicable to both headpin and tailpin measurements, unless extenuating circumstances (e.g., pins under sloped banks, shots through dense foliage) explained discrepancies and the accompanying headpin or tailpin was free of excessive error. Pins were placed adjacent to the water's edge well above the high-water surface elevation, and the transects were profiled beyond the pins to an elevation estimated to be at least 250 percent of the high target flow.
4. Multiple water surface elevations were measured across complex transects (e.g., riffle, pocket water). The more complex and uneven a transect's water surface, the greater the number of measurement locations. For example, a riffle transect may require more frequent water surface measurements, while a pool transect may require only bank elevations. Water surface elevation measurements at each calibration flow will be made at the same location across each transect.
5. All pin elevations and water surface elevations were calculated during field measurement and compared to previous measurements. Changes in stage since the previous flow measurement were calculated. Patterns of stage change were compared between transects and determined if reasonable. If any discrepancies were discovered, potential sources of error were explored and noted.

6. All data calculations were completed in the field (given adequate time and daylight), including pin elevations, water surface elevations, and discharges. Discharges were compared between all transects measured on the same day and site to ensure that each transect computed flow reasonably (<10 to 15 percent error) and accurately. Velocity data stations were evenly spaced, except near abrupt velocity or depth breaks where they were more frequent. High velocity plumes also had more frequent sample stations to avoid excessive (>5 percent of total flow) station discharges. The total number of stations established across a transect retained at least 20 in-water stations at the lowest measured flow to permit accurate discharge simulation with extrapolation.
7. Digital photographs were taken of all transects from downstream, across (e.g., from head pin to tail pin), and from upstream at the three calibration flows. An attempt was made to shoot each photograph from the same location at each of the three levels of flow. These photographs provide a valuable record of the streamflow conditions (including velocity and depth), water surface levels, and channel configurations that could be used to confirmed site conditions at the time of the hydraulic model calibration.

3.4 Stream Flow Analysis

Stream flow analysis, including exceedance curves, was performed for San Simeon Creek based on the 1971–1995 period of record for the San Simeon Creek gage at Palmer Flats. Stream flow data from the county gage was not included in this analysis because the period of record was less than 10 years. Palmer Flats is located just upstream of the San Simeon Creek groundwater basin and is not affected by groundwater pumping. In addition, there are no tributary inflows between Palmer Flats and the Study Area outside of the rainy season. As such, stream flow at the Palmer Flats gage indicates the maximum potential surface flow available within the Study Area during the late spring through fall, in the absence of CCSD operations. Downstream of the Palmer Flats gage, some amount of surface flow is naturally lost to groundwater infiltration during low flow periods (typically from spring through fall) as San Simeon Creek flows over the groundwater basin. The rate of loss in surface flow within the Study Area is likely increased during periods when CCSD groundwater pumping occurs.

Exceedance curves graphically display the probability that a flow of a given magnitude will be exceeded at a given location. Spring flows (March through June) were assessed for evaluating juvenile steelhead migration. Exceedance curves were also generated to assess low flow conditions during critical juvenile steelhead rearing periods including spring and summer. When applied to each season, the exceedance curves provide an estimate of the percentage of time that passable or rearing flows are equaled or exceeded and achieved under potential Project conditions. Values for San Simeon Creek at Palmer Flats were generated based on mean daily gage data covering 1971–1995.

Streamflow and channel observations were recorded during surveys conducted in the late spring/early summer (May and June) where crews delineated channel locations with intermittent and dry flows within both study reaches. Locations of isolated pools at least 1.0 ft deep were also recorded. Photos and GPS coordinates were recorded at the upstream and downstream ends of intermittent and dry stream sections. Maps were created to show the channel conditions during May and June.

3.5 Juvenile Steelhead Passage Assessment

The number of days when juvenile steelhead passage flows were achieved was estimated based on stream flow data collected at the Palmer Flats gage from 1971 through 1995 during the peak juvenile migration period (April through May). Flows supporting juvenile passage were based on results of the D.W. Alley and Associates 1992 study which reported juvenile passage flows ranged from 4 cfs to 11 cfs at riffles within the Study Area. Stream flows within the Study Area were assumed to be 2 cfs lower than at the Palmer Flats gage location due to groundwater infiltration so that a passage flow of 11 cfs within the Study Area required a flow of 13 cfs recorded at the Palmer Flats gage. The amount of time juvenile steelhead passage would have likely been reduced due to CCSD groundwater pumping was estimated for the 1971 through 1995 period of record using the following assumptions:

- 2.0 cfs of surface flow is lost to the groundwater basin between the Palmer Flats gage and the CCSD well field
- CCSD pumping occurs at a rate of 36 AF/month (a daily average rate of 0.60 cfs), based on monthly average pumping during the juvenile migration season (April and May), and
- 100 percent of CCSD pumping at that time of year derives from concurrent stream flow depletion (conservatively high).

3.6 Lagoon Habitat Assessment

Existing monthly water quality and stage elevation data from the San Simeon lagoon (collected by the California State Parks) was evaluated to assess the relationship between surface flow and aquatic habitat conditions for steelhead and tidewater goby within San Simeon Creek lagoon. Water quality data collected from the San Simeon Creek lagoon were compared to water quality criteria (e.g., temperature, dissolved oxygen, and salinity) reported to be suitable for steelhead (described in Section 1.1.1), tidewater goby (described in Section 1.1.2), and CRLF to assess habitat conditions for special status aquatic species.

Grab samples were collected near the water surface and just above the substrate at three locations distributed throughout the lagoon, including the lower section of the lagoon (downstream of Highway 1), the middle section of the lagoon (approximately 500 ft upstream of Highway 1), and the upper section of the lagoon (just upstream of the footbridge crossing at the State Parks Campground. In addition, observations of the lagoon berm (open versus closed) were recorded during each sampling event. Samples were typically collected each month from December 2019 through July 2022 with the exception of August 2021, December 2021, May 2022, and June 2022 when no samples were collected.

3.7 California Red-legged Frog Habitat Assessment

Suitable breeding habitat for CRLF was assessed during field surveys. CRLF breeding habitat (described in Section 2.1.3) was surveyed within the Study Reach during the habitat typing surveys described under Section 3.2. Locations where suitable breeding habitat was identified were measured for maximum water depth, photographed, and flagged for follow-up measurements and observations. CRLF breeding habitat locations will be surveyed during three flows including approximately 5.0 cfs, 2.0 cfs, and 0.5 cfs (concurrent with the hydraulic model field surveys). Two additional surveys of these CRLF breeding locations were conducted as flows ceased and the channel became dry during May and June 2022. Maximum water depth was recorded during each survey and photos were taken to document habitat conditions.

4 RESULTS

Surveys were conducted in San Simeon Creek between December 2021 and July 2022. Detailed results of all assessment are provided below.

4.1 Habitat Characterization

Stream habitat typing was conducted in December 2021 beginning at the upstream end of the lagoon and extending approximately 2.9 miles upstream. Two distinct reaches were identified during the habitat typing survey. Reach 1 was characterized by a wide active channel flowing through gravel and sand substrate (Figure 6) while Reach 2 had a confined channel with larger substrate (Figure 7). Stream habitat in Reach 1 was primarily composed of nearly equal amounts of pool and run habitat, followed by low gradient riffle habitat and glide habitat (Figure 8). In Reach 2, stream habitat was primarily composed of pool habitat, followed by similar amounts of run and low gradient riffle habitat. Substrate in Reach 1 was dominated by sand and gravel while in Reach 2 the dominant substrate was cobble followed by gravel (Figure 8).

Figure 6. Example of habitat conditions in Reach 1 showing a wide active channel with gravel and sand substrate.

Figure 7. Example of habitat conditions in Reach 2 showing confined channel and cobble substrate.

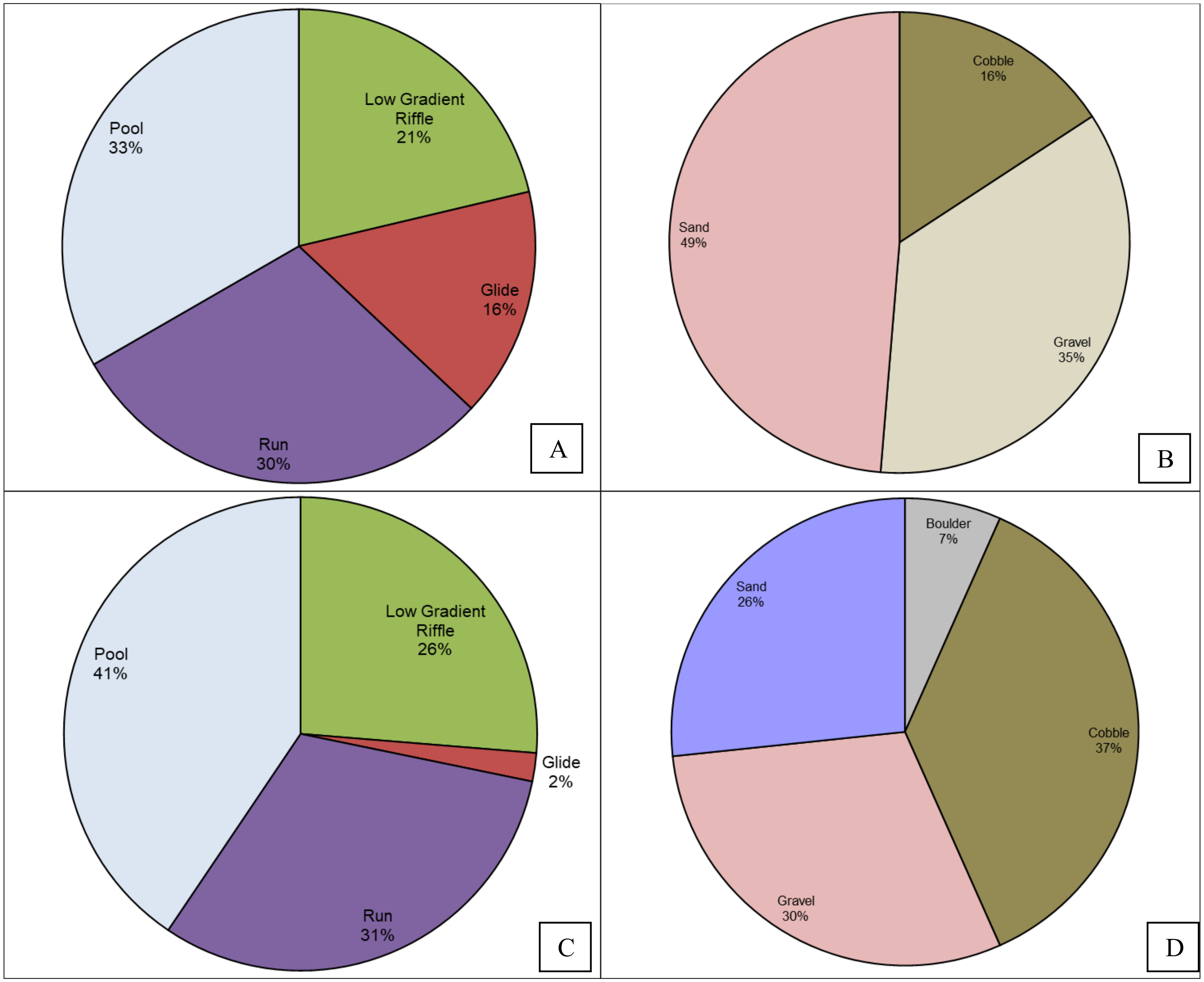


Figure 8. Habitat composition (by length) and dominant substrate in Reach 1 (A and B) and in Reach 2 (C and D).

4.2 Hydraulic Modeling

The following section presents the results of the Hydraulic Modeling described in Section 3.5. A total of 11 transects were used in development of the 1D model. The transects represent the variation in available steelhead habitat present in the Study Area (Figure 1).

4.2.1 Flow habitat relationship

Data were collected on 12 randomly selected survey transects in 2021, with three transects selected per mesohabitat type in Reach 1 of San Simeon Creek. The hydraulic calibration of 1D transects involves applying guidance standards from the literature to the model outputs to ensure the model performance meets existing standards. In situations where transect outputs do not meet the standards, the transect data is 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 transect lateral or longitudinal profile, or if the transect was a poor candidate for hydraulic modeling in 1D.

Based on this assessment, one survey transect had to be omitted from further analyses. Transect T4C was omitted from the modeling analysis due to changes in water surface elevation across the transect detected at lower flows causing it to have poor modeling performance. The final number of survey transects that attained a predictive relationship for the hydraulic model was 11. All transect locations are provided in Figure 5, transect T4C was omitted.

Results of the 1D analysis of AWS versus flow relationships for fry and juvenile steelhead rearing are presented in Figure 9 and Table 8. In order to facilitate comparison and analysis, the results are also presented with a normalized y-axis scale representing "percent of maximum" AWS (Figure 10). The shape of the steelhead fry curves show increasing habitat as a function of flow up until 2.4 cfs when habitat begins to decrease. The curves for both size classes of juvenile steelhead illustrate increasing habitat over the range of simulated flows. Flows that provide 50 percent of the maximum AWS include 0 cfs for steelhead fry and approximately 1 cfs for both size classes of juvenile steelhead (Figure 10 and Table 9) The analysis was based on a total of 11 transects distributed throughout the Study Reach (Table 7). Transect-specific profiles and calibration flows are shown in Appendix B; see Appendix C for modeled velocity distributions. Upstream, downstream, and cross-channel photos of all transects are presented in Appendix D.

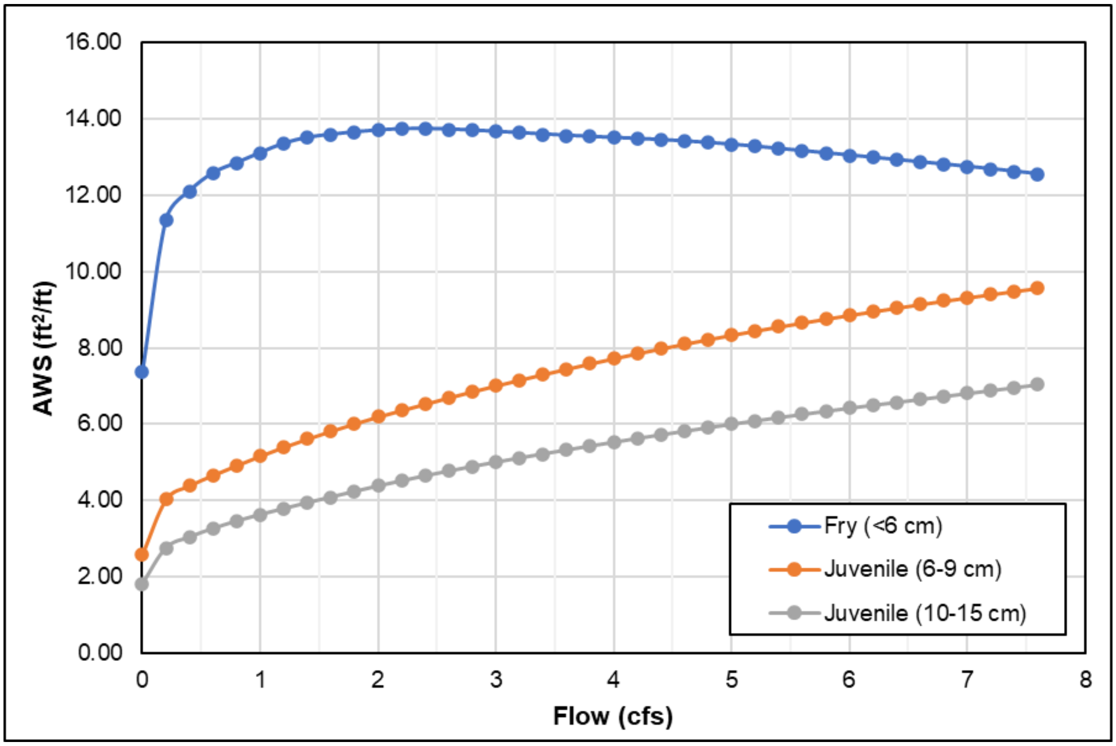


Figure 9. Flow habitat relationships (AWS) for fry and juvenile steelhead rearing in lower San Simeon Creek.

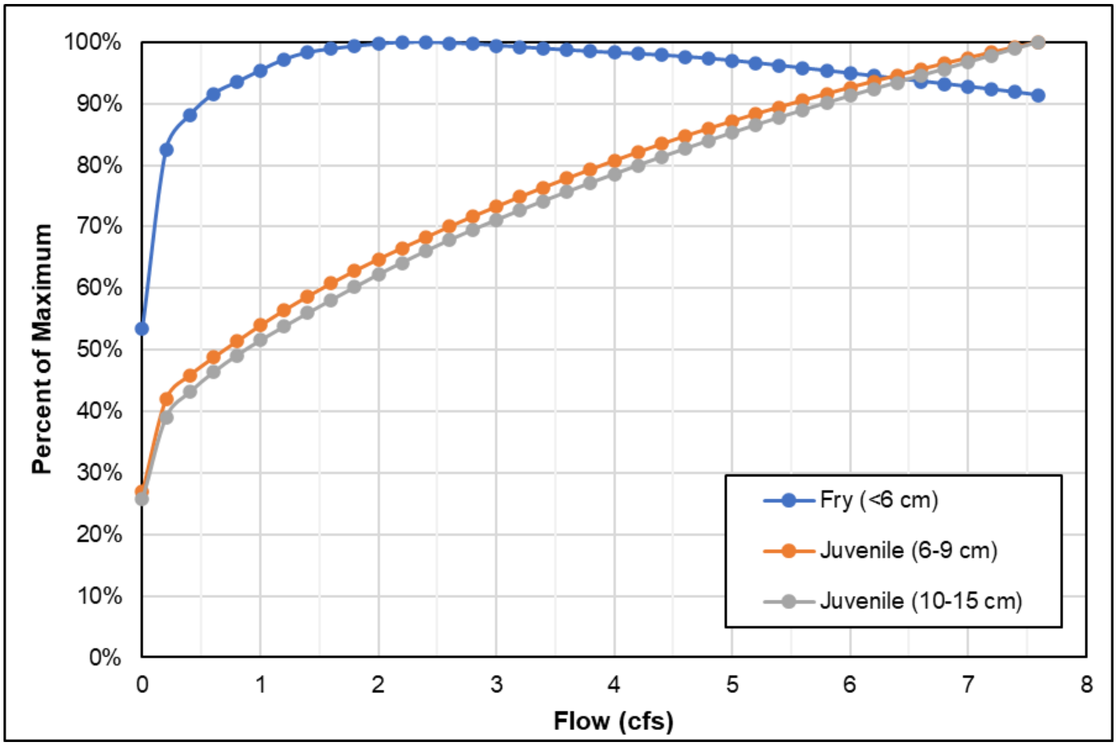


Figure 10. Percent of Maximum AWS for fry and juvenile steelhead rearing in lower San Simeon Creek.

Table 8. Area Weighted Suitability (AWS, ft^2/ft) and percent of maximum habitat area at modeled flows (cfs) for fry, juvenile, and juvenile steelhead rearing life stages in lower San Simeon Creek. Maximum values are underlined and highlighted in yellow.

Flow (cfs)	AWS (ft^2/ft)			Percent of Maximum AWS		
	Fry (<6 cm)	**Juvenile (6–9 cm)**	**Juvenile (10–15 cm)**	**Fry (<6 cm)**	**Juvenile (6–9 cm)**	**Juvenile (10–15 cm)**
0.0	7.36	2.58	1.81	54%	27%	26%
0.2	11.36	4.03	2.75	83%	42%	39%
0.4	12.11	4.39	3.03	88%	46%	43%
0.6	12.59	4.67	3.26	92%	49%	46%
0.8	12.85	4.92	3.46	93%	51%	49%
1.0	13.11	5.17	3.63	95%	54%	52%
1.2	13.36	5.40	3.78	97%	56%	54%
1.4	13.51	5.62	3.94	98%	59%	56%
1.6	13.59	5.82	4.09	99%	61%	58%
1.8	13.66	6.01	4.24	99%	63%	60%
2.0	13.71	6.20	4.38	100%	65%	62%
2.2	13.74	6.37	4.52	100%	67%	64%
2.4	13.75	6.53	4.65	100%	68%	66%
2.6	13.73	6.70	4.77	100%	70%	68%
2.8	13.70	6.86	4.89	100%	72%	69%
3.0	13.67	7.01	5.00	99%	73%	71%
3.2	13.64	7.16	5.11	99%	75%	73%
3.4	13.60	7.31	5.22	99%	76%	74%
3.6	13.57	7.45	5.32	99%	78%	76%
3.8	13.54	7.59	5.43	98%	79%	77%
4.0	13.51	7.72	5.53	98%	81%	79%
4.2	13.48	7.86	5.63	98%	82%	80%
4.4	13.45	7.98	5.72	98%	83%	81%
4.6	13.42	8.11	5.82	98%	85%	83%
4.8	13.38	8.22	5.91	97%	86%	84%
5.0	13.33	8.34	6.00	97%	87%	85%
5.2	13.28	8.45	6.09	97%	88%	87%
5.4	13.22	8.56	6.17	96%	89%	88%
5.6	13.17	8.66	6.26	96%	91%	89%
5.8	13.11	8.76	6.34	95%	92%	90%
6.0	13.05	8.86	6.42	95%	93%	91%
6.2	12.99	8.96	6.50	95%	94%	92%
6.4	12.93	9.05	6.58	94%	95%	93%
6.6	12.87	9.14	6.65	94%	96%	95%
6.8	12.81	9.23	6.73	93%	97%	96%
7.0	12.75	9.32	6.81	93%	97%	97%
7.2	12.69	9.41	6.88	92%	98%	98%
7.4	12.63	9.49	6.96	92%	99%	99%
7.6	12.56	9.57	7.04	91%	100%	100%

Table 9. Area weighted Suitability (AWS, ft^2/ft) for steelhead rearing in lower San Simeon Creek.

Steelhead life stage	Flow for maximum AWS (cfs)	Flow for 50% of Maximum AWS (cfs)
Fry	2.4	0.0
Juvenile (6–9 cm)	7.6	0.8
Juvenile (10–15 cm)	7.6	1.0

The SZF rating statistics were favorable for most of the 11 transects used in the mode with the standard calibration metrics of beta exponents between 2 and 5 and percent mean errors <10% (Table 10). Coefficients greater than 5 were observed at four transects and a single transect had a mean error greater than 10%. However, based on a comparison of measured and simulated WSE, these variances would not significantly influence AWS results (Table 11). The log/log rating curves were created by fitting the line through the survey flow, thus the measured and simulated WSE are the same for the survey flow. The average difference between the calibration and simulated WSE is 0.01 feet for mid flow (Calibration 1) and 0.00 feet for low flow (Calibration 2). The greatest difference between measured and simulated WSE was 0.02 feet for middle flow and 0.01 feet for low flow.

All predicted WSEs were within the threshold in the USFWS guidelines for PHABSIM, which recommended a difference of 0.1 ft or less (USFWS 1994) between surveyed and modeled WSEL (Table 11). Velocities for each reach were simulated using the recommended range up to 2.5 times the highest measured flow (USGS 2001).

Table 10. Stage Zero Flow (SZF) ratings for survey transects.

Transect# and habitat type	Selected rating	Exponent	Constant (A)	SZF	R^2	Mean error
1A glide	SZF rating	5.67	14.71	97.12	0.999	2.19
2A run	SZF rating	6.95	1371.92	98.05	0.992	5.63
3A pool	SZF rating	2.94	25.02	98.65	0.998	2.61
4A glide	SZF rating	3.24	64.06	100.14	0.991	5.54
1B run	SZF rating	4.06	59.64	197.34	1.000	1.20
2B riffle	SZF rating	4.19	127.95	197.43	0.999	2.19
3B pool	SZF rating	3.75	35.02	199.18	0.999	2.01
4B riffle	SZF rating	6.55	13411.81	199.87	0.976	10.15
1C riffle	SZF rating	5.91	90.52	295.16	0.995	3.98
2C run	SZF rating	4.47	47.51	295.91	1.000	0.71
3C pool	SZF rating	4.70	69.70	300.81	0.971	9.78
~~4C glide~~	~~SZF rating~~	~~2.15~~	~~7.04~~	~~301.06~~	~~0.801~~	~~28.41~~

* Transect 4C was removed from analysis because the percent mean error was >10% (indicated by strikethrough).

Table 11. Survey and calibration flow water surface elevation (WSE) details for survey transects.

Transect# and habitat type	WSE at Calibration flow 1 (0.52 cfs)			WSE at calibration flow 2 (1.54 cfs)		
	Measured	Modeled	Difference	Measured	Modeled	Difference
1A glide	97.68	97.67	0.01	97.78	97.79	0.01
2A run	98.37	98.37	0.00	98.43	98.43	0.00
3A pool	98.92	98.92	0.00	99.02	99.04	0.02
4A glide	100.37	100.37	0.00	100.44	100.46	0.02
1B run	197.65	197.65	0.00	197.74	197.75	0.01
2B riffle	197.70	197.70	0.00	197.77	197.78	0.01
3B pool	199.51	199.51	0.00	199.60	199.61	0.01
4B riffle	200.08	200.08	0.00	200.13	200.12	0.01
1C riffle	295.58	295.58	0.00	295.65	295.66	0.01
2C run	296.27	296.27	0.00	296.37	296.37	0.00
3C pool	301.17	301.16	0.01	301.23	301.25	0.02
~~4C glide~~	~~301.41~~	~~301.36~~	~~0.05~~	~~301.43~~	~~301.55~~	~~0.12~~

* Transect 4C failed the WSE standard and was removed from analysis (indicated by strikethrough).

4.3 Stream Flow Analysis

Palmer Flats is located at the upstream end of the groundwater basin and represents “unimpaired” (without influence of CCSD operations) surface flows entering the Study Area. Note that flows at Palmer Flats during the spring and summer are generally expected to be higher than flows within the Study Area even under natural conditions due to groundwater infiltration that naturally occurs where San Simeon Creek flows over the groundwater basin. Stream flow exceedance curves show stream flow at Palmer Flats during the spring is often below 4 cfs (Figure 11). By early summer (June–July) stream flow in the unimpaired condition ceases in most years (Figure 12), and during late summer (August–September) surface flows are uncommon (Figure 13).

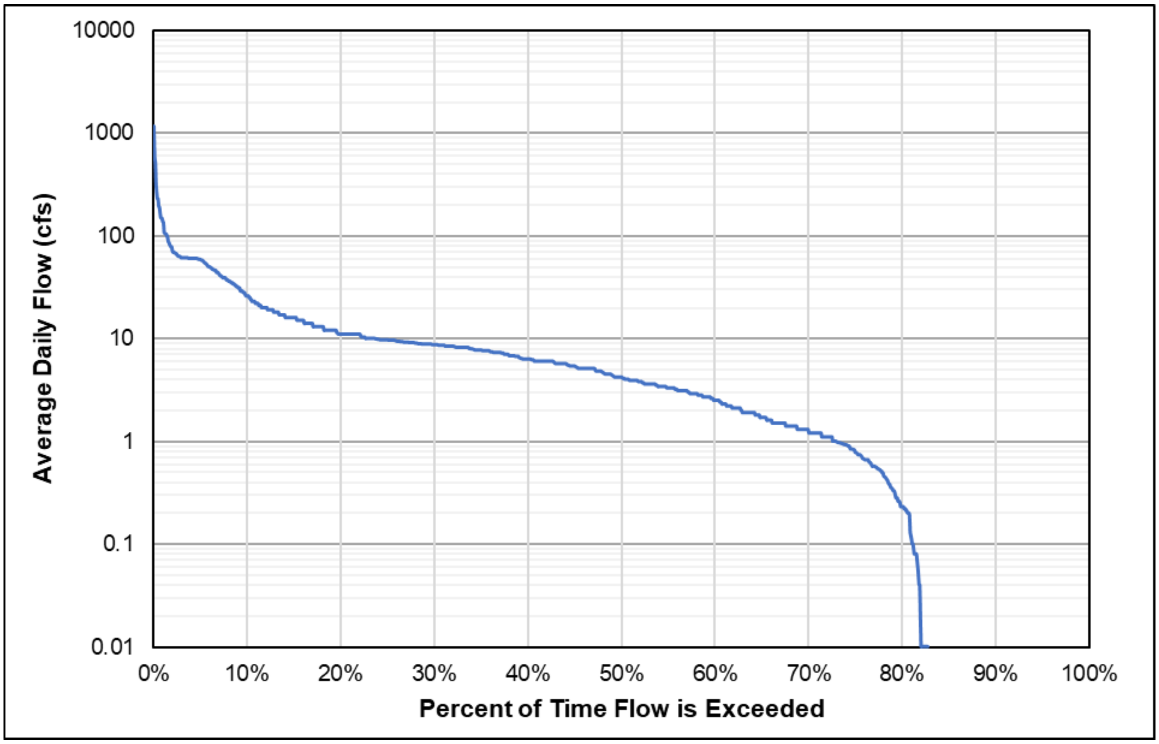


Figure 11. Palmer Flats stream flow exceedance for April and May based on flows from 1971 through 1995.

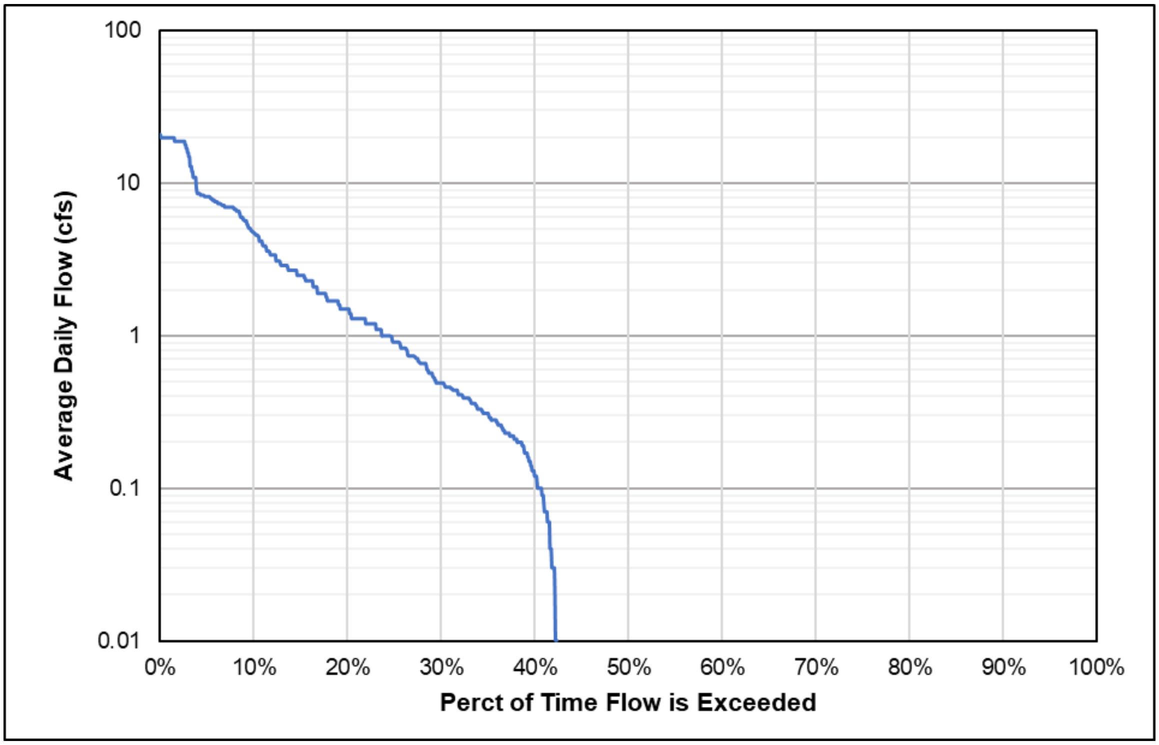


Figure 12. Palmer Flats stream flow exceedance for June and July based on flows from 1971 through 1995.

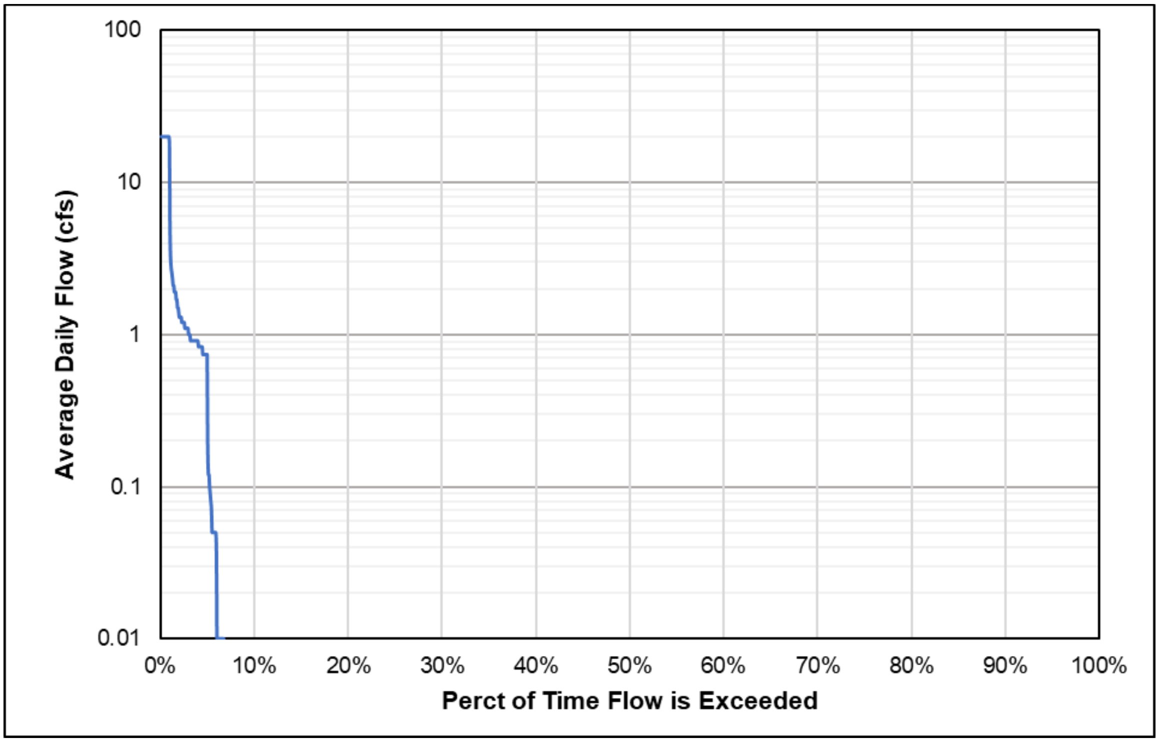


Figure 13. Palmer Flats stream flow exceedance for August and September based on flows from 1971 through 1995.

During streamflow and channel observations, disconnected surface flows were first observed during April field surveys. By May 12, 2022, a large section of Reach 1 had become dry with a short section of intermittent flow and a single isolated pool, while Reach 2 remained wet throughout (Figure 14). By June 21, 2022, most of the channel within the Study Area was dry. In Reach 1 only a small section of channel upstream of the lagoon remained wet along with a single small, isolated pool (Figure 15) while nearly all of Reach 2 was dry with the exception of a few isolated pools (Figure 16).

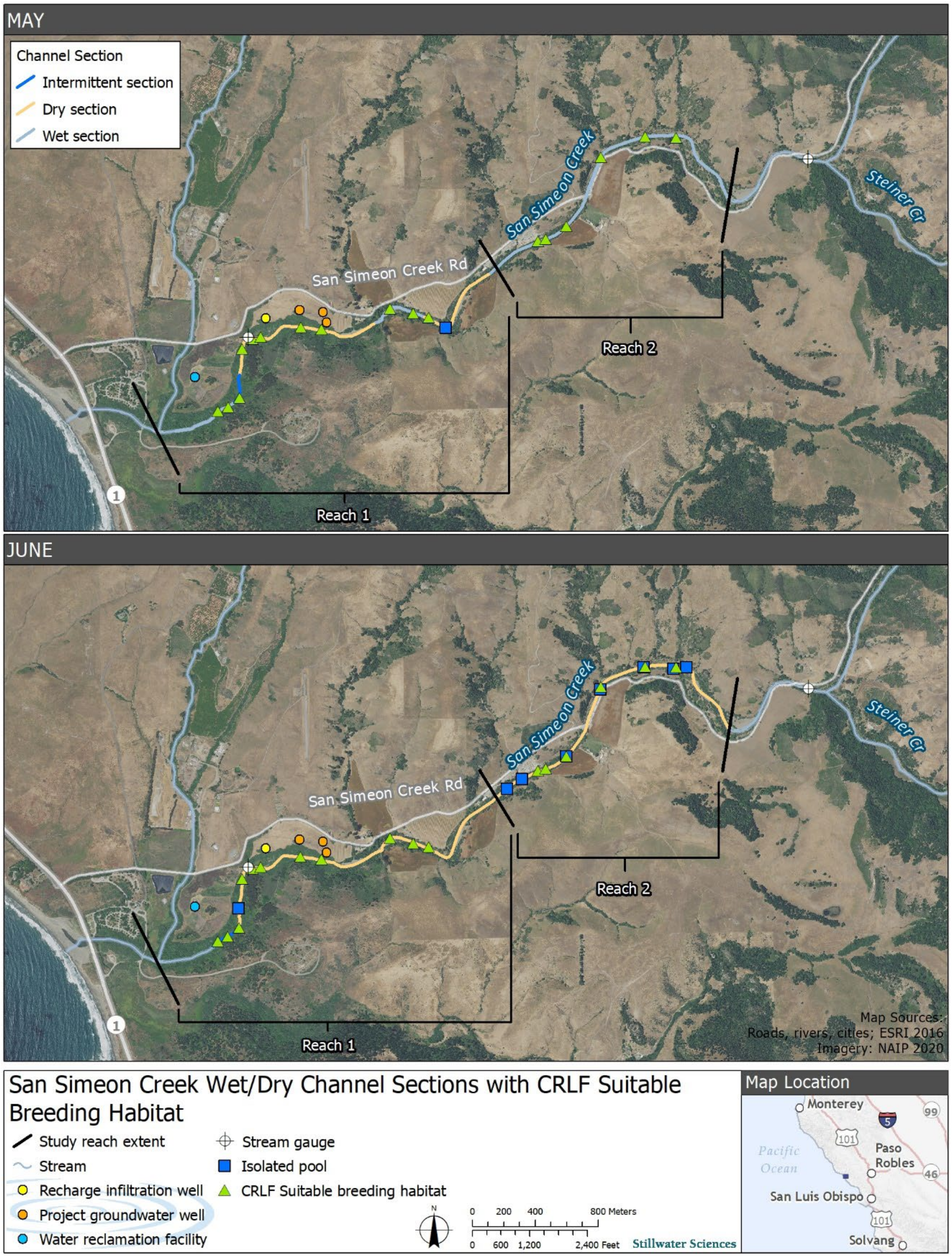


Figure 14. Dry and intermittent sections observed in San Simeon Creek during May and June 2022 with locations of isolated pools and locations were suitable CRLF breeding habitat was observed during winter surveys.

Figure 15. Isolated pool habitat in Reach 1 on May 12, 2022 (top) and on June 21, 2022 (bottom).

Figure 16. Isolated pool habitat in Reach 2 on May 12, 2022 (top) and on June 21, 2022 (bottom).

4.4 Juvenile Steelhead Passage Assessment

The potential influence of CCSD groundwater pumping on juvenile steelhead passage during the peak migration season appears to be very low. During the higher passage flow assessed (11 cfs) CCSD operations are estimated to reduce suitable migration days for juvenile steelhead by a fraction of a day (Figure 17). At the lower passage flow assessed (4 cfs) CCSD operations are estimated to reduce suitable migration days for juvenile steelhead at a higher rate but only accounts for up to a 2-day reduction in suitable migration days during some years for juvenile steelhead (Figure 18). However, higher reduction may occur if pumping rates are above the daily average rate of 0.60 cfs assumed for this analysis.

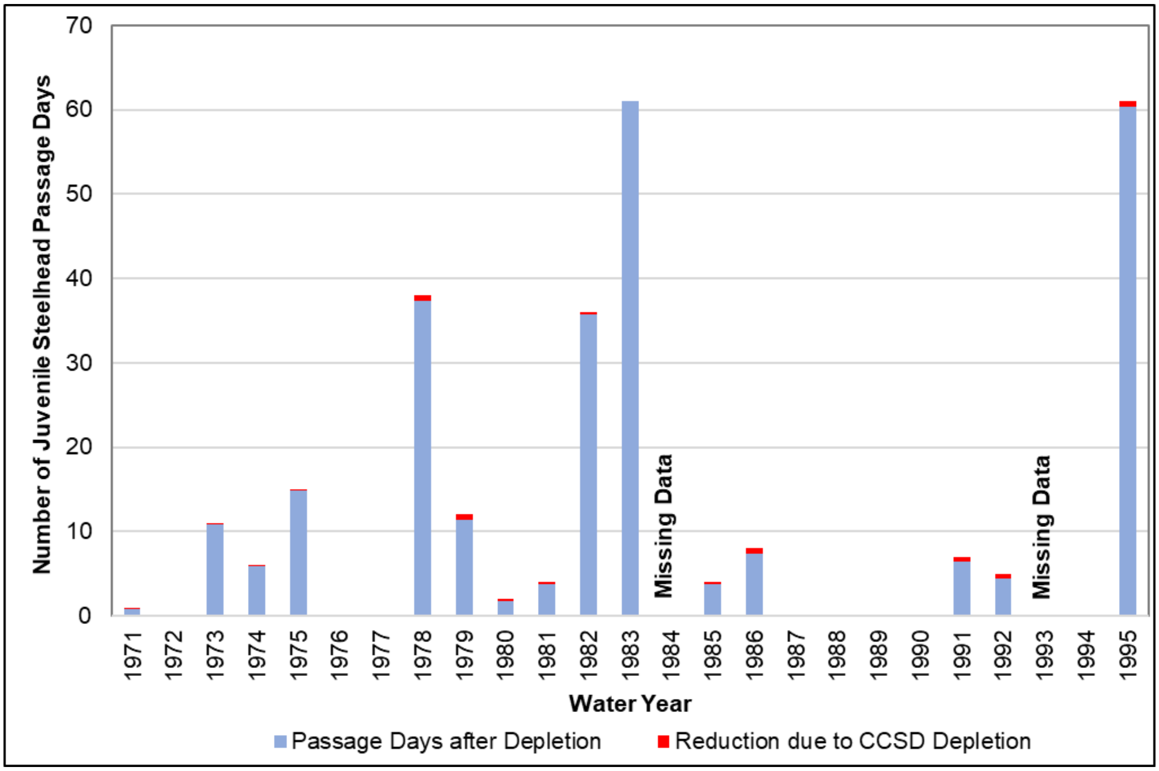


Figure 17. Estimated reduction in juvenile steelhead passage in San Simeon Creek based on stream flows recorded at Palmer Flats (1971–1995) during the peak juvenile steelhead migration season (April-May) assuming CCSD groundwater pumping at 0.60 cfs and passage requires 11 cfs.

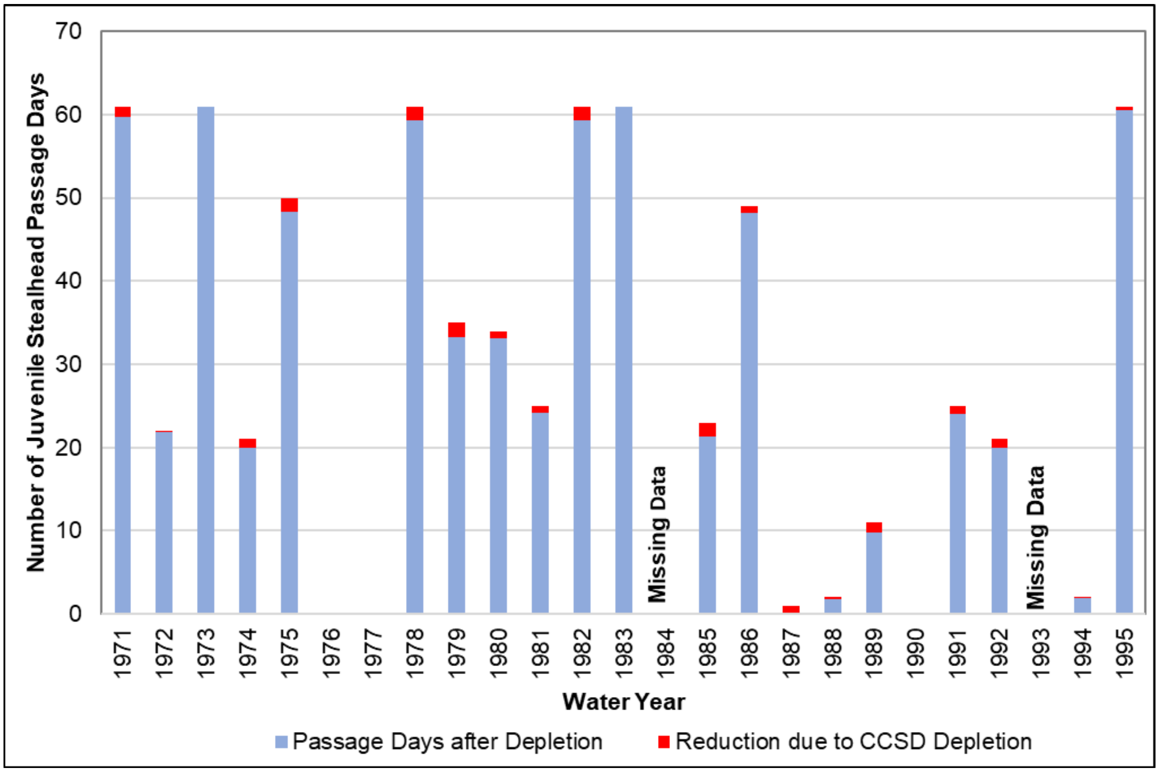


Figure 18. Estimated reduction in juvenile steelhead passage in San Simeon Creek based on stream flows recorded at Palmer Flats (1971–1995) during the peak juvenile steelhead migration season (April–May) assuming CCSD groundwater pumping at 0.60 cfs and passage requires 4 cfs.

4.5 CRLF Habitat

Suitable breeding habitat for CRLF was abundant and widespread during the December 22 habitat surveys conducted in Reach 1 and Reach 2 (Table 12). Most of the suitable CRLF breeding habitat was found in pool habitat which continued to meet the depth criteria for CRLF breeding even as flows decreased to near zero cfs. However, once flows ceased, pool habitat began to dry out with only a few isolated pools that remained wet into June (Figure 14). While CRLF breeding season is typically in the winter and spring, breeding locations need to remain wetted until the tadpoles complete their metamorphosis into terrestrial forms (typically through July or August). Locations where CRLF breeding habitat remained wetted into June were limited to the downstream end of Reach 1 near the lagoon and multiple locations within Reach 2 (Figure 14). Examples of suitable CRLF breeding habitat that went dry between May and June 2022 are shown in Figure 19.

Table 12. California red-legged frog breeding habitat identified in lower San Simeon Creek during December 2021.

Reach	Habitat unit	Avg length (ft)	Avg width (ft)	Area (ft^2)	Avg depth (ft)	Max depth (ft)	Habitat type	Emergent veg. type
1	7	389	30	11,670	2.5	4.5	Off channel Pool	Willow
1	9	146	23	3,358	1.0	2.4	Run	Willow
1	12	91	25	2,275	1.0	2.0	MCP	Willow
1	20	126	18	2,268	0.9	2.3	MCP	Willow
1	26	152	18	2,736	3.0	4.5	MCP	Willow
1	35	122	30	3,660	1.0	2.0	Run	Willow
1	39	182	30	5,460	1.5	2.5	Run	Willow
1	53	129	25	3,225	1.5	3.4	MCP	Branches
1	58	177	35	6,195	1.8	2.8	Run	Willow
1	61	152	30	4,560	2.5	3.6	Run	Willow
2	86	110	25	2,750	2.0	3.2	MCP	Willow
2	88	270	40	10,800	2.7	4.2	MCP	Willow
2	90	164	27	4,428	2.5	4.0	MCP	Willow
2	112	153	50	7,650	4.0	7.5	Off channel Pool	Cattails
2	122	243	30	7,290	2.8	4.5	LSP	Willow

Figure 19. Photos of locations where suitable CRLF breeding habitat remained wetted on May 12, 2022 (top left) and was dry on June 27, 2022 (top right), and where CRLF breeding habitat remained wetted throughout the survey (bottom).

4.6 Lagoon Conditions

Water quality conditions in San Simeon lagoon are generally within the suitable range for sensitive species that are likely to occur there (steelhead, tidewater goby, and CRLF) based on data collected from December 2019 through July 2022. Water temperatures were below the upper thresholds for all three species throughout the water column (Figure 18). Dissolved oxygen and salinity levels were within suitable range for all species during most of the monitoring period with a few exceptions as described below.

Dissolved oxygen levels were below the threshold for steelhead in at least one sample location within the lagoon a few times per year and typically during the late-summer/early fall months when stream flow entering the lagoon is at its lowest (Figure 19). In nearly each event when dissolved oxygen levels dropped below the threshold for steelhead, other locations within the lagoon had higher dissolved oxygen within suitable levels for steelhead. On a single occasion in October 2021, all sample locations within the lagoon had dissolved oxygen levels below the 5.0 mg/L threshold for steelhead.

Salinity levels in San Simeon lagoon were rarely above the threshold for any of the three species likely to occur there. The few times salinity levels did exceed the thresholds for sensitive species, it occurred during the late fall and early winter typically when the lagoon was observed to be open to the ocean (Figure 20). During each event when salinity levels were exceeded the threshold for steelhead, tidewater goby, and CRLF, other locations had lower salinity levels that were within suitable levels for these species.

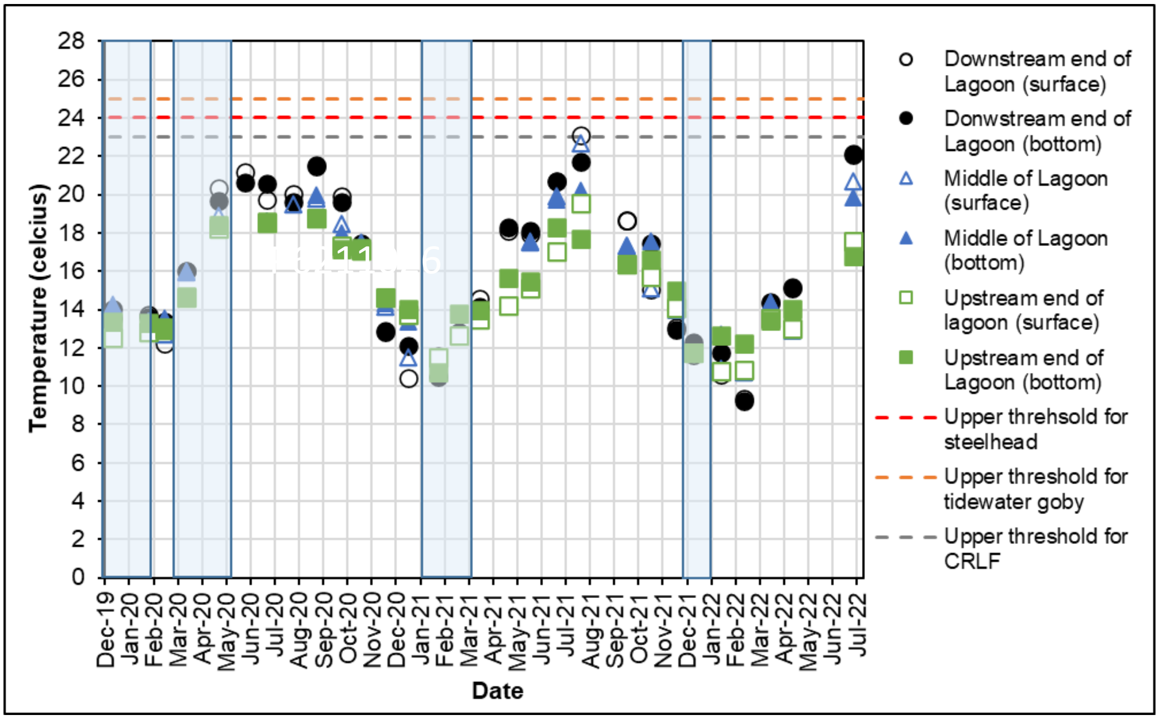


Figure 20. Monitoring results for water temperature in San Simeon lagoon from December 2019 through July 2022 with upper thresholds for steelhead, tidewater goby, and CRLF. *Note, blue shading indicates periods when the lagoon was open to the ocean during sample events.*

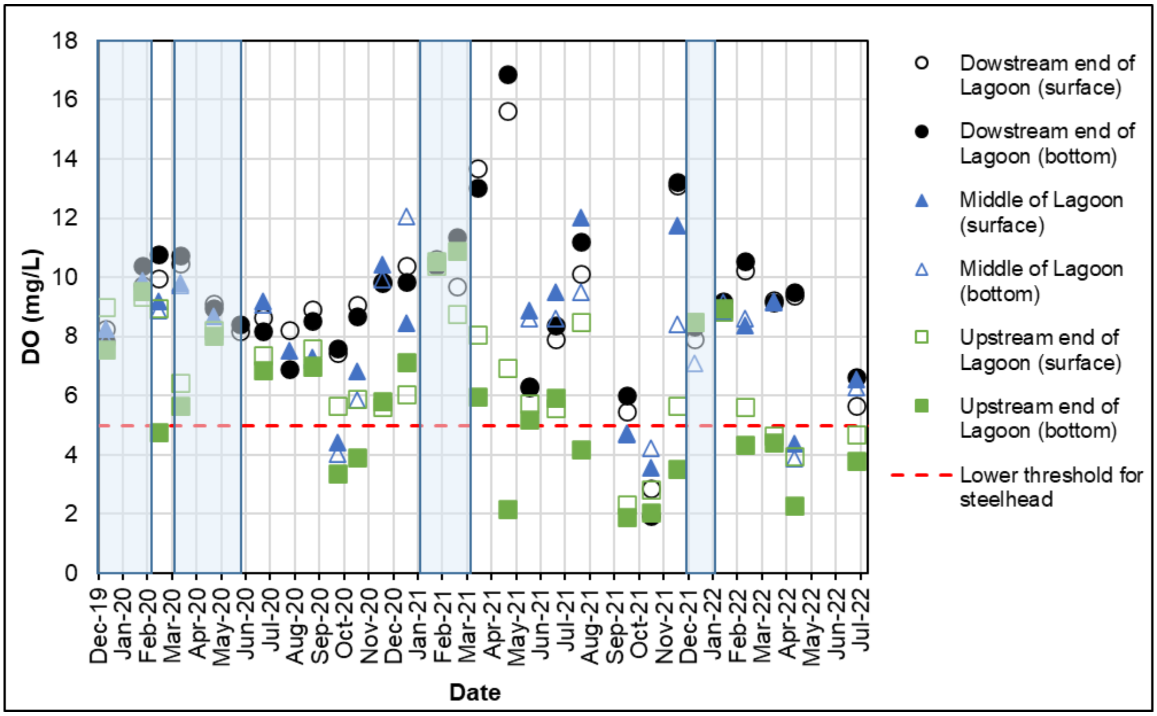


Figure 21. Monitoring results for dissolved oxygen (DO) levels in San Simeon lagoon from December 2019 through July 2022 with lower thresholds for steelhead. *No values reported for lower thresholds for tidewater goby, and CRL. Note, blue shading indicates periods when the lagoon was open to the ocean during sample events.*

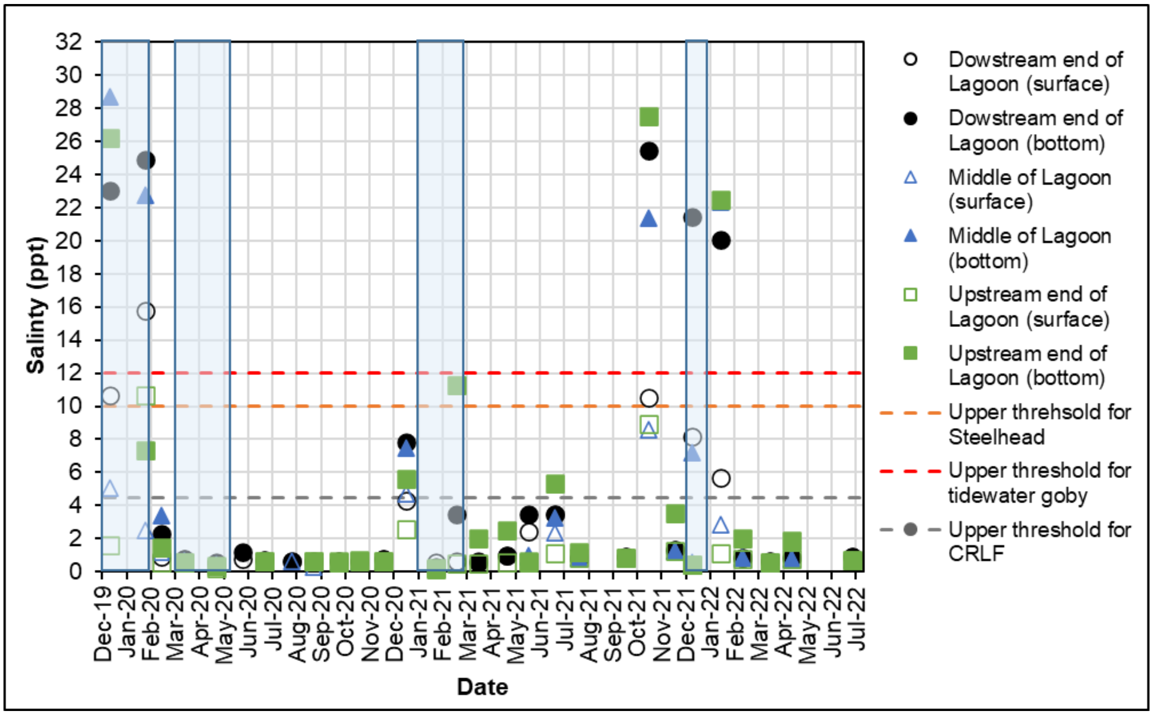


Figure 22. Monitoring results for salinity in San Simeon lagoon from December 2019 through July 2022 with upper thresholds for steelhead. *Note, blue shading indicates periods when the lagoon was open to the ocean during sample events.*

5 CONCLUSIONS

The lower reach of San Simeon Creek in the absence of CCSD pumping operations potentially provides migratory and rearing habitat for steelhead in the winter and spring and is typically dry during the summer and fall. This reach would only provide steelhead rearing habitat during the dry season infrequently. Results of the hydraulic modeling show that habitat for steelhead fry is available even when flows are less than 0.5 cfs in the Study Area, and available for juveniles at flows greater than 1 cfs.

In contrast to our assessment of the Palmer Flats gage data, the modeling conducted by Boughton and Goslin (2006) predicated a high potential for juvenile steelhead summer rearing habitat throughout San Simeon Creek, including the lower reach within the Study Area. It is possible that this modeled result reflects historical conditions but based on flow monitoring these would be conditions that have not occurred in at least the last 50 years.

In recognition of the flow data from 1971 to 1995 indicating an intermittent lower San Simeon Creek, the lowermost analysis points used in the EWD study (Stillwater Sciences 2014) should be relocated upstream of the groundwater basin to the confluence of Steiner Creek or adjusted to reflect natural groundwater losses in lower San Simeon Creek.

Migration conditions for steelhead within the Study Area are generally supported under current CCSD operations. Adult steelhead passage which requires high flows (21–60 cfs [D. W. Alley and Associates 1992]) associated with large precipitation events are not likely to be influenced by CCSD's average pumping rates ranging from 0.41 cfs to 0.64 cfs or even the maximum pumping rate of 1.43 cfs. Juvenile steelhead passage requires lower flows than adult passage (4–11 cfs [D. W. Alley and Associates 1992]), typical of the spring recession flows. It appears that CCSD operations may reduce juvenile steelhead migration by a small percent of total days when migration flows are achieved (Figure 17 and Figure 18).

In summary, based on pumping capacity of 1.43 cfs and stream flows of 1 cfs required to provide juvenile steelhead rearing habitat, CCSD pumping operations have the potential to reduce the amount and quality of juvenile steelhead rearing habitat within the Study Area at flows less than 2.5 cfs. Whenever pumping reduces surface flows to less than 1 cfs a reduction in suitable juvenile rearing habitat will occur, and if pumping occurs at flows less than 1.5 cfs rearing habitat could become dry, resulting in stranding and mortality of individuals. In contrast, when surface flows are greater than 2.5 cfs, or less than zero entering the Study Area, CCSD operations are unlikely to substantially reduce steelhead migratory or rearing habitat. The same conclusions would also apply to the operations of the private wells that are outside of the jurisdiction of the CCSD to manage.

In addition to steelhead, the Study Area provides abundant suitable breeding habitat for CRLF with many isolated pool locations staying wet well after surface flows cease. CCSD pumping when stream flows are less than 1.5 cfs is likely to increase the rate at which pool habitat becomes isolated and the rate at which pools dry out leading to stranded CRLF tadpoles. Additional suitable habitat for CRLF is located within the San Simeon lagoon.

Habitat conditions in the San Simeon lagoon are suitable for juvenile steelhead, tidewater goby, and CRLF under current conditions based on water temperature, dissolved oxygen, and salinity levels reported throughout most of the year. During the few events when water quality thresholds are exceeded for any of these species, other locations within the lagoon were still within the suitable range.

Key conclusions of this study are listed below:

- CCSD pumping operations are not expected to influence adult steelhead migration in San Simeon Creek due to the magnitude of flow required to support adult steelhead passage.
- CCSD pumping operations likely have little effect on juvenile downstream passage within San Simeon Creek during the migratory period.
- CCSD pumping operations that occur when flows in Reach 1 are between 0 and 2.5 cfs likely leads to reduced habitat area and a reduction in the quality of habitat for juvenile steelhead within the Study Area.
- CCSD pumping operations that occur after surface flows cease may affect juvenile steelhead rearing and CRLF rearing in isolated pools by accelerating the rate at which isolated pools dry out leaving juvenile steelhead and CRLF tadpoles stranded.
- CCSD pumping operations are not expected to impact aquatic habitat once the channel within the Study Area goes dry, which happens for extended periods of most years during the summer through fall.
- CCSD pumping operations do not appear to be impacting habitat conditions within the lagoon.
- CCSD pumping operations do not appear to be impacting habitat conditions for tidewater goby.

6 LONG TERM MONITORING

Long term monitoring efforts are suggested to ensure CCSD operations are minimizing impacts to sensitive aquatic species in lower San Simeon Creek, as detailed below.

6.1 Stream Flows

Stream flow monitoring is recommended to develop a better long-term record of stream flows within San Simeon Creek. Continuous monitoring of stream flow should be conducted near the San Simeon well field and upstream of the Study Area at the Palmer Flats gage location. The collection of a validated continuous flow record that includes low flows is recommended for these sites. In general terms, four general steps are required to develop an accurate continuous flow record: 1) The installation of a continuous stage measuring device in accordance with standard practice (e.g., USGS 1982); 2) The collection of flow data across a range of flows to develop a stage-flow relationship in accordance with standard practice (e.g. USGS 1982, Turnipseed 2010); 3) On-going validation of the stage-flow relationship, and, 4) The development of new stage-flow relationships and/or correction of stage data if channel conditions change, as needed. The stage-flow relationship is a mathematical relationship relating flow and stage and if hydraulic conditions significantly change at the gaging site, the relationship may need to be redeveloped or the stage data may need to be adjusted. Corrections and monitoring are typically more intensive at sites which require accurate lower flows or at sites that are composed of erodible beds. Common channel changes which can impact the stage-flow relationship include cross-sectional scour or deposition, changes in the distribution of riparian vegetation, or changes in downstream hydraulic controls. Annual cross-sectional surveys to document scour and deposition at the gaging sites are also recommended to assess potential channel changes.

The County of San Luis Obispo currently operates a stream gage near the San Simeon well field which continuously records water levels. However, a stage-discharge rating curve needs to be developed and validated to apply to the stage data collected at this existing gage. A continuous stage measuring device is needed at the Palmer Flats location, and additional flow data collection is required to develop a continuous flow record as described above.

6.2 Isolated Pools

Monitor isolated pool habitat within the Study Area to assess the risk of juvenile steelhead stranding. Monitoring should be conducted using visual observations of isolated pool habitat within the Study Area to assess relative abundance of juvenile steelhead "trapped" in isolated pools. Surveys should be conducted during the spring once surface flows cease in lower San Simeon Creek. Biologists familiar with the identification of juvenile steelhead should walk the channel within the Study Area identifying locations of isolated pool habitats and visually inspecting pools from the shore to estimate the number of steelhead within each pool. All observations should be reported to CDFW for rescue and relocation consideration.

6.3 Lagoon Conditions

Pending access approval, lagoon stage and water quality conditions (temperature, dissolved oxygen, and salinity) should be monitored at the upstream and downstream ends of the lagoon during the late spring through fall. Samples should be collected monthly near the upper, middle, and lower sections of the water column.

7 REFERENCES

Armantrout, N. B. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland.

Barnhart, R. A. 1991. Steelhead (Oncorhynchus mykiss). Pages 324-336 in J. Stolz and J. Schnell, editor. Trout. Stackpole Books, Harrisburg, Pennsylvania.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society, Bethesda, Maryland.

Bond, M. H., S. A. Hayes, C. V. Hanson, and R. B. MacFarlane. 2008. Marine survival of steelhead (*Oncorhynchus mykiss*) enhanced by a seasonally closed estuary. Canadian Journal of Fisheries and Aquatic Sciences 65: 2,242–2,252.

Bulger, J. B., N. J. Scott, Jr., and R. B. Seymour. 2003. Terrestrial activity and conservation of adult California red-legged frogs (*Rana aurora draytonii*) in coastal forests and grasslands. Biological Conservation 110: 85–95.

CCSD (Cambria Community Services District). 2015. Groundwater management plan November 19.

CDFW (California Department of Fish and Wildlife). 2013. Standard operating procedure for streambed and water surface elevation data collection in California. Instream flow Program. Sacramento, CA.

CDFW. 2015. Study site and transect location selection guidance for instream flow hydraulic habitat analyses. Available online: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=93989

CDFW. 2020. Standard operating procedure for discharge measurements in wadeable streams in California. Instream Flow Program. Sacramento, CA. Available: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=74169&inline.

CDM Smith. 2014. Cambria emergency water supply project San Simeon Creek Basin groundwater modeling report. Prepared by CDM Smith, Sacramento, California for Cambria Community Services District, Cambria, California.

Daniels, M., D. Frank, R. Holloway, B. Kowalski, P. Krone-Davis, S. Quan, E. Stanfield, A. Young, and F. Watson. 2010. Evaluating good water quality habitat for steelhead in Carmel Lagoon: fall 2009. Publication No. WI-2010-03. The Watershed Institute, California State Monterey Bay.

D.W. Alley and Associates. 1992. Passage requirements for steelhead on San Simeon Creek, San Luis Obispo County, California. 1991. Prepared by Donald W. Alley for the Cambria Community Services District, Cambria, California.

D.W. Alley and Associates. 2004. Trends in juvenile steelhead production in 1994-2003 for San Simeon Creek, San Luis Obispo County, California, with habitat analysis and an index of adult returns. Prepared by Donald W. Alley for the Cambria Community Services District, Cambria, California.

D.W. Alley and Associates. 2015. October monitoring of tidewater goby populations and water quality in San Simeon and Santa Rosa Lagoons, San Luis Obispo County, California. February.

Everest, F. H., and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile Chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29: 91–100.

Fellers, G. M., and P. M. Kleeman. 2007. California red-legged frog (*Rana draytonii*) movement and habitat use: implications for conservation. Journal of Herpetology 41: 271–281.

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 2010. California salmonid stream habitat restoration manual, 4th ed. California Department of Fish and Game.

Fontaine, B. L. 1988. An evaluation of the effectiveness of instream structures for steelhead trout rearing habitat in the Steamboat Creek basin. Master's thesis. Oregon State University, Corvallis.

Hallock, R. J., W. F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (Salmo gairdnerii gairdnerii) in the Sacramento River system. California Department of Fish and Game, Fish Bulletin 114.

Hartman, G. F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 22: 1035-1081.

Hawkins, C. P., J. L Kershner, P. A. Bisson, M. D. Bryant, L. M. Decker, S. V. Gregory, D. A. McCullough, C. K. Overton, G. H .Reeves. R. J. Steedman, and M. K. Young. 1993. A hierarchical approach to classifying habitats in small streams. Fisheries 18: 3–12.

Hayes, S. A., M. H. Bond, C. V. Hanson, E. V. Freund, J. J. Smith, E. C. Anderson, A. J. Ammann, and R. B. MacFarlane. 2008. Steelhead growth in a small central California watershed, upstream and estuarine rearing patterns. Transactions of the American Fisheries Society 137: 114–128.

Holmes, R.W., M. A. Allen, and S. Bros-Seeman. 2014. Habitat suitability criteria juvenile steelhead in the Big Sur River, Monterey County. California Department of Fish and Wildlife, Water Branch Instream Flow Program Technical Report 14-1. CDFW, Sacramento, California.

ISU (Iowa State University). 2008. Managing Iowa fisheries water quality. In cooperation with the U.S. Department of Agriculture. Originally published by J. Morris, Iowa State University Extension aquaculture specialist and updated by R. Clayton.

Jennings, M. R., and M. P. Hayes. 1990. Final report of the status of the California red-legged frog (Rana aurora draytonii) in the Pescadero Marsh Natural Preserve. Prepared for the California Department of Parks and Recreation under contract No. 4-823-9018 with the California Academy of Sciences.

Jennings, M. R., and M. P. Hayes. 1994. Amphibian and reptile species of special concern in California. Final Report. Prepared by California Academy of Sciences, Department of Herpetology, San Francisco and Portland State University, Department of Biology, Portland, Oregon for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Lafferty, K. D., C. C. Swift, and R. F. Ambrose. 1999. Extirpation and decolonization in a metapopulation of an endangered fish, the tidewater goby. Conservation Biology 13: 1,447–1,453.

McCain, M., D. Fuller, L. Decker, and K. Overton. 1990. Stream habitat classification and inventory procedures for northern California. FHR Currents: R-5's fish habitat relationships technical bulletin, No. 1. USDA Forest Service, Pacific Southwest Region, Arcata, California.

McMahon, T. E., A. V. Zale, and D. J. Orth. 1996. Aquatic habitat measurements. Pages 83–120 in B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Meehan, W. R., and T. C. Bjornn. 1991. Salmonid distributions and life histories. Pages 47–82 in W. R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication No. 19. Bethesda, Maryland.

Milhous, R. T., D. L. Wegner, and T. Waddle. 1984. User's guide to the Physical Habitat Simulation System (PHABSIM). Instream Flow Information Paper 11. U.S. Fish and Wildlife Service FWS/OBS-81/43.

Moyle, P. B. 2002. Inland fishes of California. Revised edition. University of California Press, Berkeley.

Nelson, J., E. 1995. Summary of steelhead population and habitat sampling San Simeon Creek, San Luis Obispo County, 1993. Prepared by California Department of Fish and Game.

Nelson, J., E. Baglivio, and T. Kahles. 2005. San Simeon Creek steelhead habitat and population survey, 2005. Prepared by California Department of Fish and Game and California Conservation Corps.

NMFS (National Marine Fisheries Service). 2013. South-Central California Coast steelhead recovery plan. West Coast Region, California Coastal Area Office, Long Beach, California.

Payne, T. R. 1992. Stratified random selection process for the placement of Physical Habitat Simulation (PHABSIM) transects. Paper presented at AFS Western Division Meeting, July 13–16, Fort Collins, Colorado.

Rathburn, G. B., M. R. Jennings, T. G. Murphey, and N. R. Siepel. 1993. Status and ecology of sensitive aquatic vertebrates in lower San Simeon and Pico Creeks, San Luis Obispo County, California. Final report.

SCR (Santa Clara River) Project Steering Committee. 1996. Santa Clara River enhancement and management plan study. Biological Resources, Volume 1.

Shaffer, H. B., G. M. Fellers, S. R. Voss, J. C. Oliver, and G. B. Pauly. 2004. Species boundaries, phylogeography and conservation genetics of the red-legged frog (*Rana aurora/draytonii*) complex. Molecular Ecology 13: 2,667–2,677.

Shapovalov, L., and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Fish Bulletin 98. California Department of Fish and Game.

Smith, J. J. 1990. The effects of sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell and Pornponio Creek Estuary/Lagoon systems, 1985–1989. Department of Biological Sciences, San Jose State University, San Jose, California.

Stebbins, R. C. 1985. Red-legged frog. Pages 82-83 *in* A field guide to western reptiles and amphibians. Second edition. Houghton Mifflin Company, Boston and New York.

Stillwater Sciences. 2006. Guidelines to evaluate, modify, and develop estuarine restoration projects for tidewater goby habitat. Prepared by Stillwater Sciences, Arcata, California for U. S. Fish and Wildlife Service, Arcata, California.

Stillwater Sciences. 2014. San Luis Obispo County regional instream flow assessment. Prepared by Stillwater Sciences, Morro Bay, California for Coastal San Luis Resource Conservation District, Morro Bay, California.

Swenson, R. O. 1997. The ecology, behavior, and conservation of the tidewater goby, Eucyclogobius newberryi. Museum of Vertebrate Zoology, Department of Integrative Biology, University of California, Berkeley, California.

Swift, C. C., J. L. Nelson, C. Maslow, and T. Stein. 1989. Biology and distribution of the tidewater goby, Eucyclogobius newberryi (Pisces: Gobiidae) of California. Contribution Science. Natural History Museum of Los Angeles County, Los Angeles, California 404: 19 pp.

Trihey, E. W., and D. L. Wegner. 1981. Field data collection for use with the Physical Habitat Simulation system of the Instream Flow Group. United States Fish and Wildlife Service Report.

Turnipseed, D. P., and V. B. Sauer. 2010. Discharge measurements at gaging stations. Techniques and Methods 3–A8. Prepared by U.S. Geological Survey, Reston, Virginia.

USFWS (U.S. Fish and Wildlife Service). 1994. Using the computer based Physical Habitat Simulation System (PHABSIM)..

USFWS. 2002. Recovery plan for the California red-legged frog (*Rana aurora draytonii*). U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS. 2005. Recovery plan for the tidewater goby (Eucyclogobius newberryi). U. S. Fish and Wildlife Services, Portland, Oregon.

USFWS. 2013. Endangered and threatened wildlife and plants; designation of critical habitat for tidewater goby; final rule. Federal Register 78:8746-8819.

USGS (U.S. Geological Survey). 1982. Measurement and computation of streamflow: Volume 2. Computation of discharge. Geological Survey Water-Supply Paper 2175. https://pubs.er.usgs.gov/publication/wsp2175

USGS. 2001. PHABSIM for Windows, User's manual and exercises. U.S. Geological Survey, Midcontinent Ecological Science Center (USGS), Fort Collins, CO. Open File Report 01-340

Water Systems Consulting, Inc. 2021. Cambria Community Services District 2020 Urban Water Management Plan. June 2021.

Yates, E. B. and K. M. Van Konyenburg. 1998. Hydrogeology, water quality, water budgets, and simulated responses to hydrologic changes in Santa Rosa and San Simeon Creek ground-water basins, San Luis Obispo County, California. U.S. Geological Survey, water resources investigations report 98-4061.

Appendices

Appendix A

Habitat Suitability Criteria

Table A-1. Habitat suitability criteria for steelhead fry (<6 cm) developed for the Big Sur River (Holmes et al. 2014).

Depth (ft)	Suitability	Velocity (ft/s)	Suitability	Depth (ft)	Suitability	Velocity (ft/s)	Suitability
0.00	0.00	0.00	0.89	1.48	0.31	1.41	0.17
0.04	0.00	0.04	0.92	1.52	0.30	1.44	0.15
0.08	0.69	0.07	0.95	1.56	0.28	1.48	0.14
0.11	0.74	0.11	0.97	1.60	0.26	1.52	0.13
0.15	0.78	0.14	0.99	1.63	0.24	1.55	0.12
0.19	0.83	0.18	1.00	1.67	0.23	1.59	0.11
0.23	0.86	0.22	1.00	1.71	0.21	1.62	0.10
0.27	0.90	0.25	1.00	1.75	0.20	1.66	0.09
0.30	0.93	0.29	0.99	1.79	0.18	1.70	0.09
0.34	0.95	0.32	0.98	1.82	0.17	1.73	0.08
0.38	0.97	0.36	0.96	1.86	0.16	1.77	0.07
0.42	0.99	0.40	0.94	1.90	0.15	1.80	0.07
0.46	1.00	0.43	0.91	1.94	0.14	1.84	0.06
0.49	1.00	0.47	0.88	1.98	0.13	1.88	0.05
0.53	1.00	0.51	0.85	2.01	0.12	1.91	0.05
0.57	0.99	0.54	0.82	2.05	0.11	1.95	0.05
0.61	0.98	0.58	0.78	2.09	0.10	1.99	0.04
0.65	0.96	0.61	0.74	2.13	0.09	2.02	0.04
0.68	0.94	0.65	0.71	2.17	0.09	2.06	0.03
0.72	0.91	0.69	0.67	2.20	0.08	2.09	0.03
0.76	0.88	0.72	0.63	2.24	0.07	2.13	0.03
0.80	0.85	0.76	0.60	2.28	0.07	2.17	0.02
0.84	0.82	0.79	0.56	2.32	0.06	2.20	0.02
0.87	0.79	0.83	0.52	2.36	0.06	2.24	0.02
0.91	0.75	0.87	0.49	2.39	0.05	2.27	0.02
0.95	0.72	0.90	0.46	2.43	0.05	2.31	0.02
0.99	0.68	0.94	0.43	2.47	0.04	2.35	0.01
1.03	0.65	0.97	0.40	2.51	0.04	2.38	0.01
1.06	0.61	1.01	0.37	2.55	0.04	2.42	0.01
1.10	0.58	1.05	0.35	2.58	0.03	2.45	0.01
1.14	0.55	1.08	0.32	2.62	0.03	2.49	0.01
1.18	0.51	1.12	0.30	2.66	0.03	2.53	0.01
1.22	0.49	1.16	0.28	2.70	0.03	2.56	0.01
1.25	0.46	1.19	0.26	2.74	0.02	2.60	0.01
1.29	0.43	1.23	0.24	2.77	0.02	2.64	0.01
1.33	0.40	1.26	0.22	2.81	0.02	2.67	0.01
1.37	0.38	1.30	0.21	2.85	0.02	2.71	0.00
1.41	0.36	1.34	0.19	2.89	0.02	2.74	0.00
1.44	0.34	1.37	0.18	2.93	0.02	2.78	0.00

Depth (ft)	Suitability	Velocity (ft/s)	Suitability
2.96	0.02	2.82	0.00
3.00	0.01	2.85	0.00
3.04	0.01	2.89	0.00
3.08	0.01	2.92	0.00
3.12	0.01	2.96	0.00
3.15	0.01	3.00	0.00
3.19	0.01	3.03	0.00
3.23	0.01	3.07	0.00
3.27	0.01	3.10	0.00
3.31	0.01	3.14	0.00
3.34	0.01	3.18	0.00
3.38	0.01	3.21	0.00
3.42	0.01	3.25	0.00
3.46	0.01	3.29	0.00
3.50	0.01	3.32	0.00
3.53	0.01	3.36	0.00
3.57	0.01	3.39	0.00
3.61	0.01	3.43	0.00
3.65	0.01	3.47	0.00
3.69	0.01	3.50	0.00
3.72	0.01	3.54	0.00
3.76	0.01	3.57	0.00
3.80	0.01	3.61	0.00
3.81	0.00		

Table A-2. Habitat suitability criteria for steelhead juveniles (6-9 cm and 10–15 cm) developed for the Big Sur River (Holmes et al. 2014).

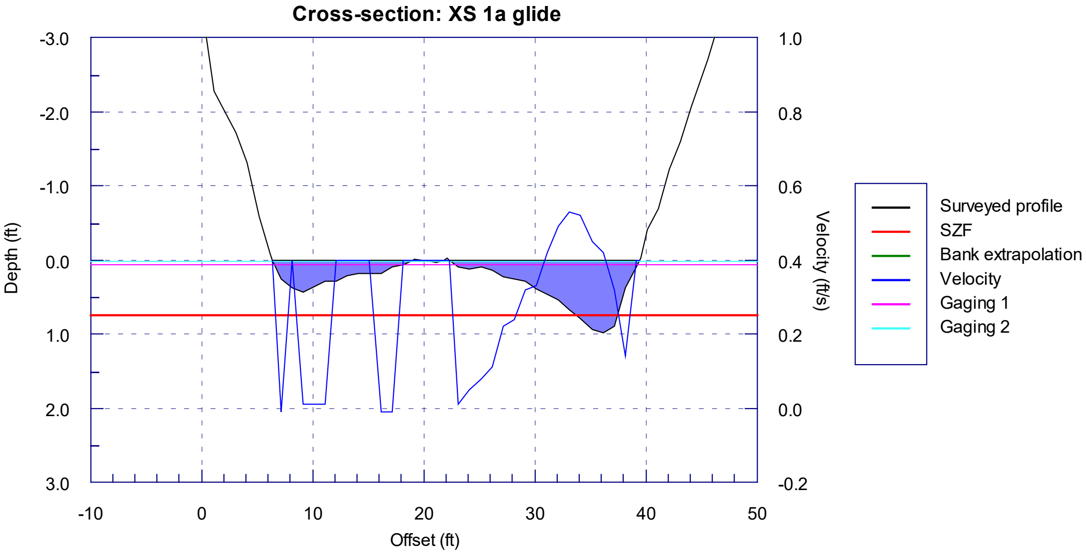
Steelhead Juvenile 6–9 cm				Steelhead Juvenile 10–15 cm			
Depth (ft)	**Suitability**	**Velocity (ft/s)**	**Suitability**	**Depth (ft)**	**Suitability**	**Velocity (ft/s)**	**Suitability**
0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.48
0.05	0.00	0.05	0.53	0.05	0.00	0.05	0.53
0.10	0.00	0.11	0.57	0.10	0.00	0.11	0.57
0.14	0.00	0.16	0.61	0.15	0.00	0.16	0.61
0.19	0.00	0.21	0.65	0.20	0.00	0.21	0.65
0.24	0.00	0.27	0.70	0.24	0.00	0.27	0.70
0.29	0.00	0.32	0.74	0.29	0.00	0.32	0.74
0.33	0.38	0.38	0.77	0.34	0.00	0.38	0.77
0.38	0.43	0.43	0.81	0.39	0.00	0.43	0.81
0.43	0.47	0.48	0.84	0.44	0.00	0.48	0.84
0.47	0.52	0.54	0.88	0.49	0.00	0.54	0.88
0.52	0.56	0.59	0.90	0.54	0.00	0.59	0.90
0.57	0.61	0.64	0.93	0.59	0.40	0.64	0.93
0.62	0.65	0.70	0.95	0.62	0.46	0.70	0.95
0.67	0.70	0.75	0.97	0.67	0.51	0.75	0.97
0.71	0.74	0.80	0.98	0.71	0.55	0.80	0.98
0.76	0.78	0.86	0.99	0.76	0.60	0.86	0.99
0.81	0.82	0.91	1.00	0.81	0.64	0.91	1.00
0.85	0.86	0.96	1.00	0.85	0.68	0.96	1.00
0.90	0.89	1.00	1.00	0.90	0.73	1.00	1.00
0.95	0.92	1.05	1.00	0.95	0.77	1.05	1.00
1.00	0.94	1.10	1.00	1.00	0.80	1.10	1.00
1.04	0.96	1.15	1.00	1.04	0.84	1.15	1.00
1.09	0.98	1.21	1.00	1.09	0.87	1.21	1.00
1.14	0.99	1.26	1.00	1.14	0.90	1.26	1.00
1.19	1.00	1.31	1.00	1.19	0.93	1.31	1.00
1.24	1.00	1.36	1.00	1.24	0.95	1.36	1.00
1.25	1.00	1.41	1.00	1.28	0.97	1.41	1.00
1.29	1.00	1.47	1.00	1.33	0.98	1.47	1.00
1.33	1.00	1.52	0.99	1.38	0.99	1.52	0.99
1.38	1.00	1.57	0.98	1.43	1.00	1.57	0.98
1.42	1.00	1.62	0.97	1.47	1.00	1.62	0.97
1.46	1.00	1.68	0.95	1.52	1.00	1.68	0.95
1.50	1.00	1.73	0.94	1.57	1.00	1.73	0.94
1.55	0.99	1.78	0.92	1.62	1.00	1.78	0.92
1.59	0.99	1.83	0.89	1.67	1.00	1.83	0.89
1.63	0.98	1.89	0.87	1.72	0.99	1.89	0.87
1.68	0.96	1.94	0.84	1.76	0.98	1.94	0.84

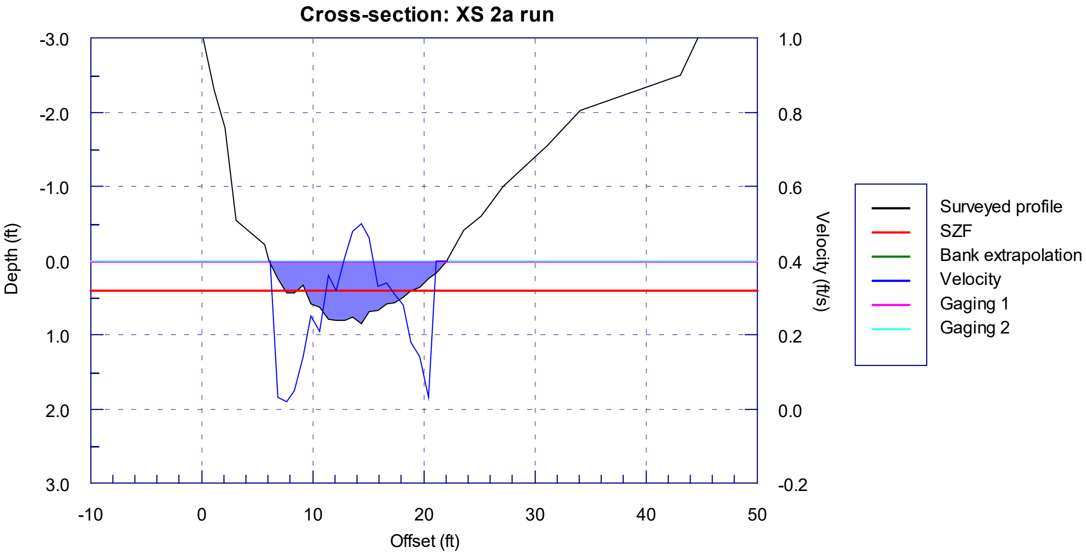
Steelhead Juvenile 6–9 cm				Steelhead Juvenile 10–15 cm			
Depth (ft)	Suitability	Velocity (ft/s)	Suitability	Depth (ft)	Suitability	Velocity (ft/s)	Suitability
1.72	0.94	1.99	0.81	1.81	0.97	1.99	0.81
1.76	0.92	2.04	0.78	1.86	0.95	2.04	0.78
1.81	0.90	2.10	0.74	1.91	0.93	2.10	0.74
1.85	0.88	2.15	0.71	1.96	0.91	2.15	0.71
1.89	0.85	2.20	0.68	2.01	0.89	2.20	0.68
1.93	0.82	2.25	0.64	2.06	0.86	2.25	0.64
1.98	0.79	2.31	0.61	2.11	0.83	2.31	0.61
2.02	0.76	2.36	0.57	2.16	0.80	2.36	0.57
2.06	0.72	2.41	0.54	2.21	0.77	2.41	0.54
2.11	0.69	2.46	0.50	2.25	0.74	2.46	0.50
2.15	0.66	2.52	0.47	2.30	0.71	2.52	0.47
2.19	0.63	2.57	0.44	2.35	0.68	2.57	0.44
2.24	0.60	2.62	0.41	2.40	0.65	2.62	0.41
2.28	0.57	2.67	0.38	2.45	0.62	2.67	0.38
2.32	0.54	2.72	0.35	2.50	0.58	2.72	0.35
2.36	0.51	2.78	0.32	2.55	0.55	2.78	0.32
2.41	0.48	2.83	0.30	2.60	0.52	2.83	0.30
2.45	0.46	2.88	0.27	2.65	0.50	2.88	0.27
2.49	0.43	2.93	0.25	2.70	0.47	2.93	0.25
2.54	0.41	2.99	0.23	2.74	0.44	2.99	0.23
2.58	0.39	3.04	0.21	2.79	0.42	3.04	0.21
2.62	0.37	3.09	0.19	2.84	0.39	3.09	0.19
2.67	0.36	3.14	0.17	2.89	0.37	3.14	0.17
2.71	0.34	3.20	0.16	2.94	0.35	3.20	0.16
2.75	0.33	3.25	0.14	2.99	0.33	3.25	0.14
2.79	0.32	3.30	0.13	3.04	0.31	3.30	0.13
2.84	0.31	3.35	0.12	3.09	0.30	3.35	0.12
2.88	0.30	3.41	0.11	3.14	0.28	3.41	0.11
2.92	0.29	3.46	0.10	3.19	0.27	3.46	0.10
2.97	0.28	3.51	0.09	3.23	0.25	3.51	0.09
3.01	0.27	3.56	0.08	3.28	0.24	3.56	0.08
3.05	0.26	3.62	0.07	3.33	0.23	3.62	0.07
3.10	0.26	3.67	0.06	3.38	0.21	3.67	0.06
3.14	0.25	3.72	0.06	3.43	0.20	3.72	0.06
3.18	0.25	3.77	0.05	3.48	0.19	3.77	0.05
3.22	0.24	3.83	0.05	3.53	0.18	3.83	0.05
3.27	0.23	3.88	0.04	3.58	0.17	3.88	0.04
3.31	0.23	3.93	0.04	3.63	0.16	3.93	0.04
3.35	0.22	3.98	0.03	3.68	0.15	3.98	0.03
3.40	0.22	4.03	0.03	3.72	0.14	4.03	0.03

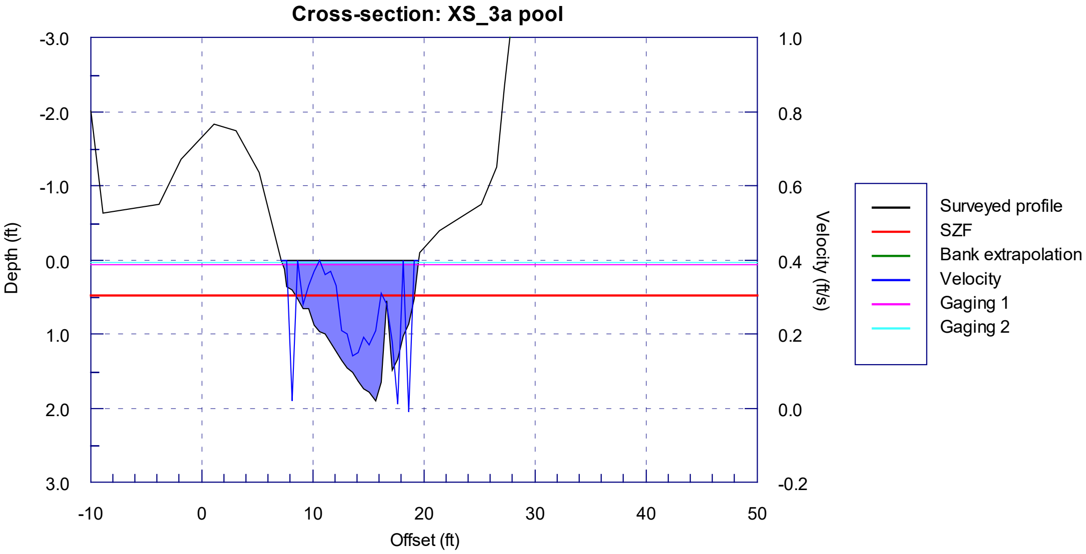
Steelhead Juvenile 6–9 cm				Steelhead Juvenile 10–15 cm			
Depth (ft)	**Suitability**	**Velocity (ft/s)**	**Suitability**	**Depth (ft)**	**Suitability**	**Velocity (ft/s)**	**Suitability**
3.44	0.21	4.09	0.03	3.77	0.13	4.09	0.03
3.48	0.21	4.14	0.02	3.82	0.13	4.14	0.02
3.53	0.21	4.19	0.02	3.87	0.12	4.19	0.02
3.57	0.20	4.24	0.02	3.92	0.11	4.24	0.02
3.61	0.20	4.30	0.02	3.97	0.10	4.30	0.02
3.65	0.19	4.35	0.02	4.02	0.10	4.35	0.02
3.70	0.18	4.40	0.02	4.07	0.09	4.40	0.02
3.74	0.18	4.45	0.01	4.12	0.08	4.45	0.01
3.78	0.17	4.51	0.01	4.17	0.08	4.51	0.01
3.83	0.17	4.56	0.01	4.21	0.07	4.56	0.01
3.87	0.16	4.61	0.01	4.26	0.06	4.61	0.01
3.91	0.15	4.66	0.01	4.31	0.06	4.66	0.01
3.96	0.15	4.72	0.01	4.36	0.05	4.72	0.01
4.00	0.14	4.77	0.01	4.41	0.05	4.77	0.01
4.04	0.13	4.82	0.01	4.46	0.05	4.82	0.01
4.08	0.13	4.87	0.01	4.51	0.04	4.87	0.01
4.13	0.12	4.93	0.01	4.56	0.04	4.93	0.01
4.17	0.11	4.98	0.01	4.61	0.03	4.98	0.01
4.21	0.11	5.03	0.01	4.66	0.03	5.03	0.01
4.26	0.10	5.08	0.01	4.70	0.03	5.08	0.01
4.30	0.09	5.14	0.01	4.75	0.02	5.14	0.01
		5.19	0.01	4.80	0.02	5.19	0.01
		5.24	0.01	4.85	0.02	5.24	0.01
		5.25	0.00	4.90	0.02	5.25	0.00

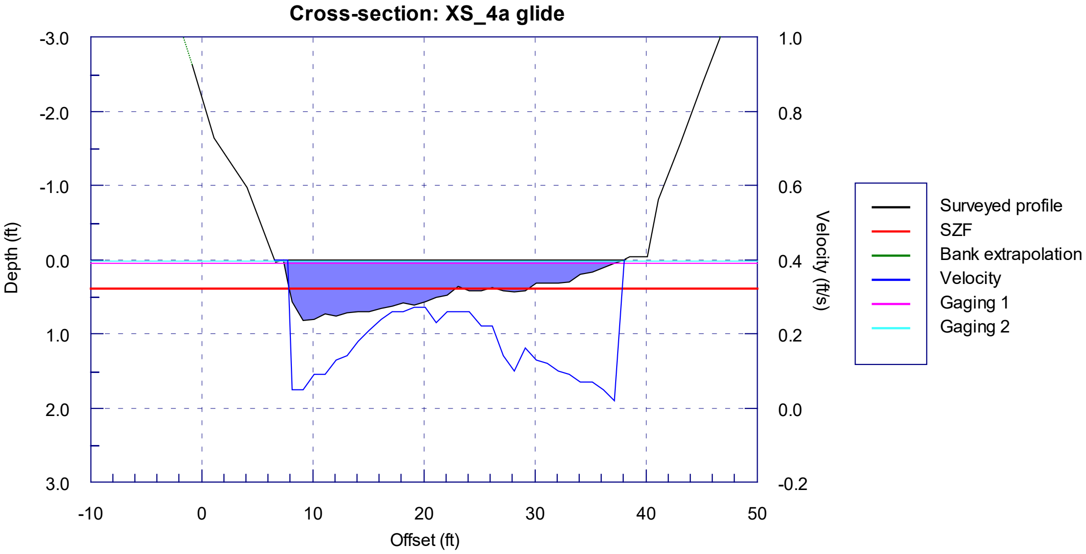
Appendix B

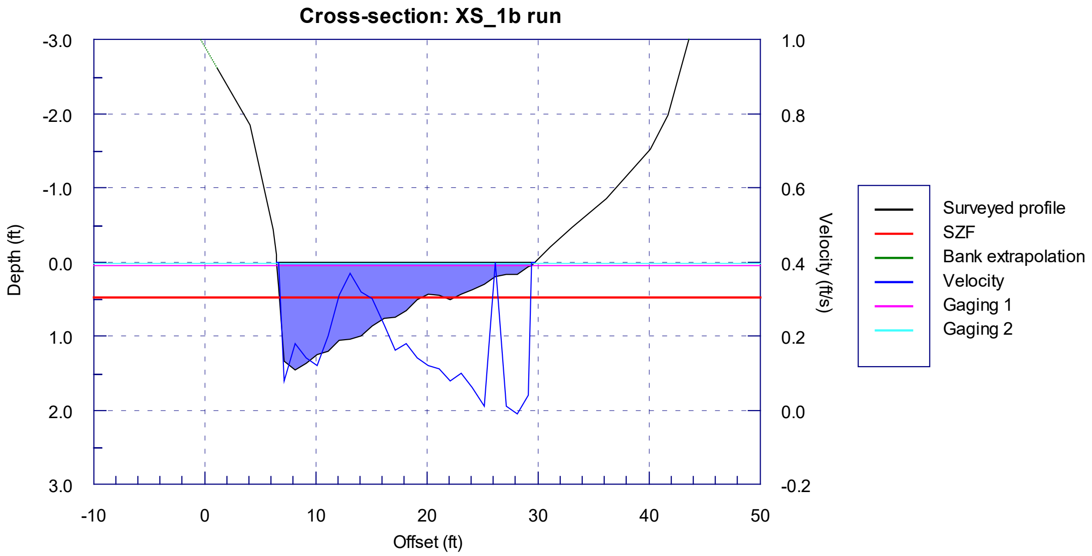
Transect Profiles Showing Calibration Flows

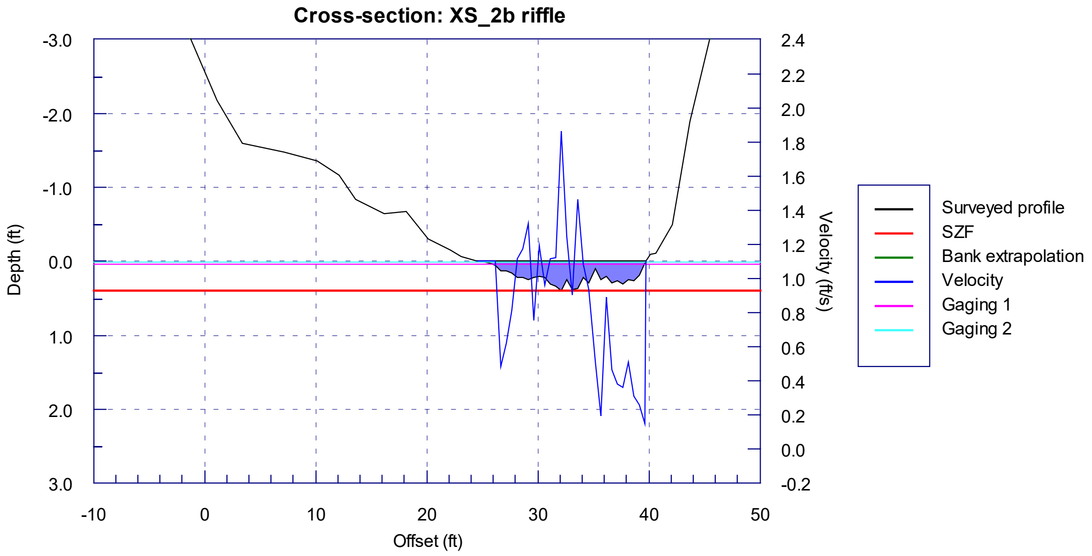

Cross-section: XS 1a glide
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2

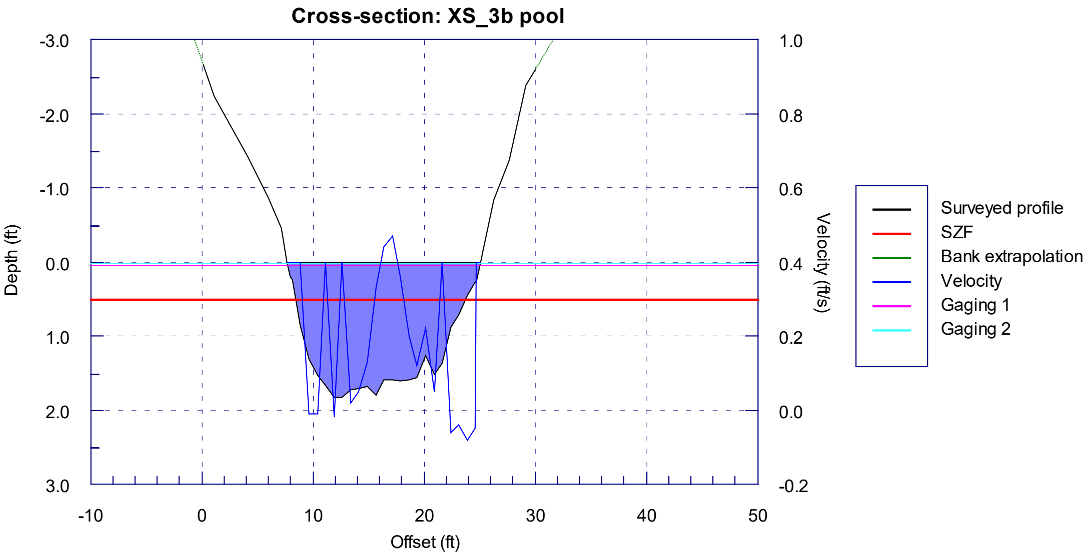

Cross-section: XS 2a run
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2

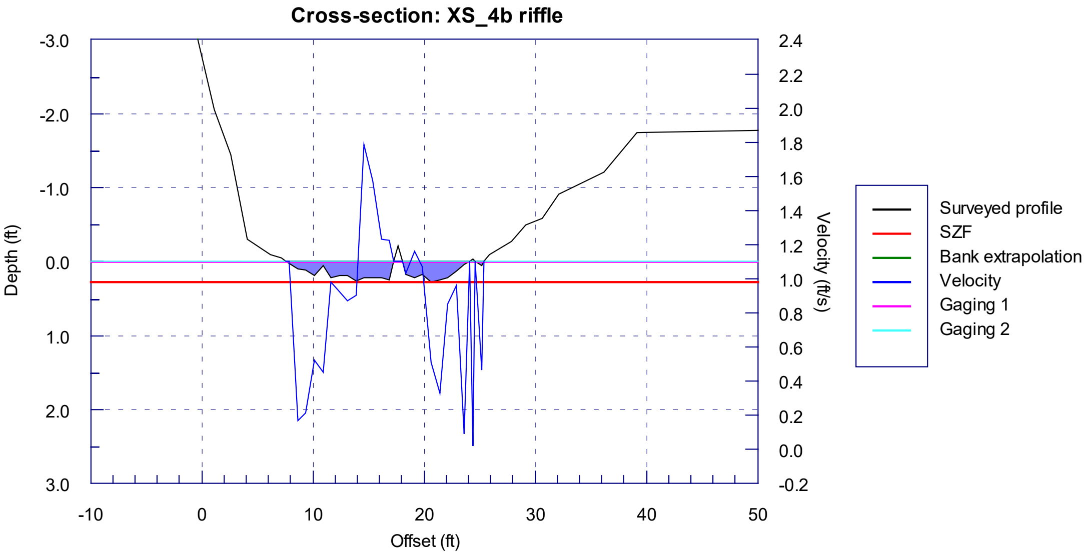

Cross-section: XS_3a pool
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2

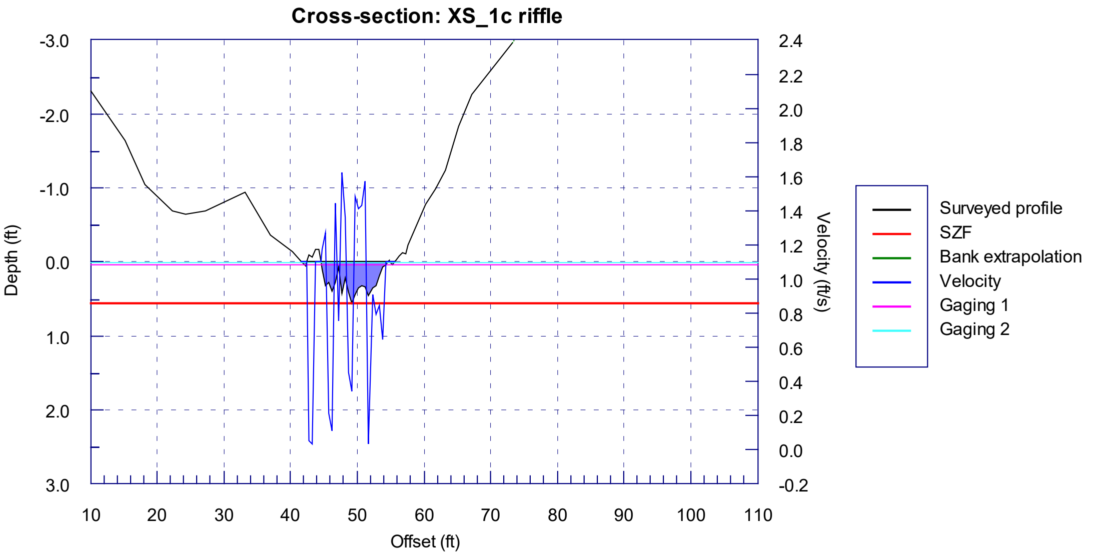

Cross-section: XS_4a glide
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2

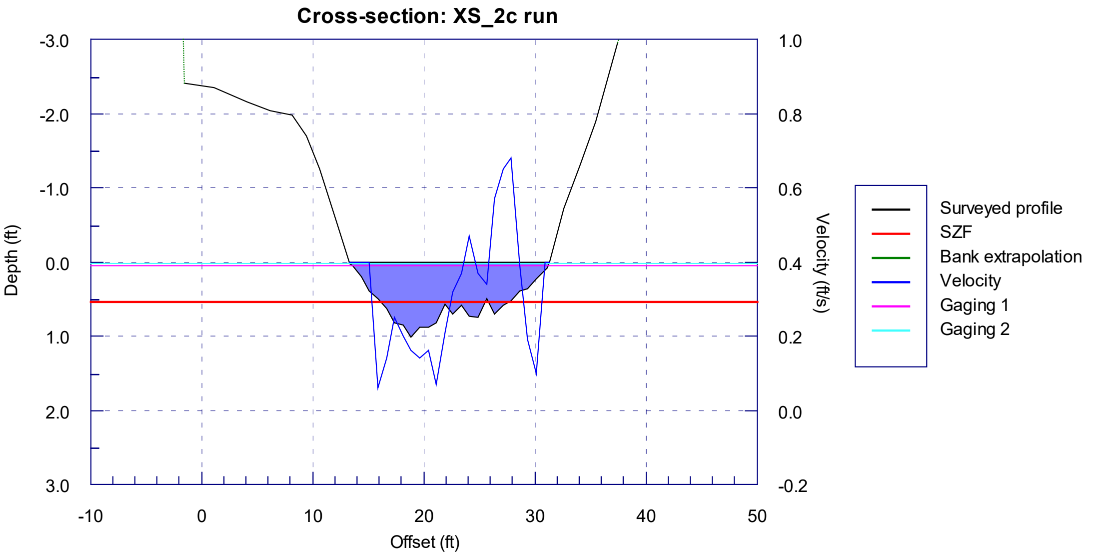

Cross-section: XS_1b run
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2

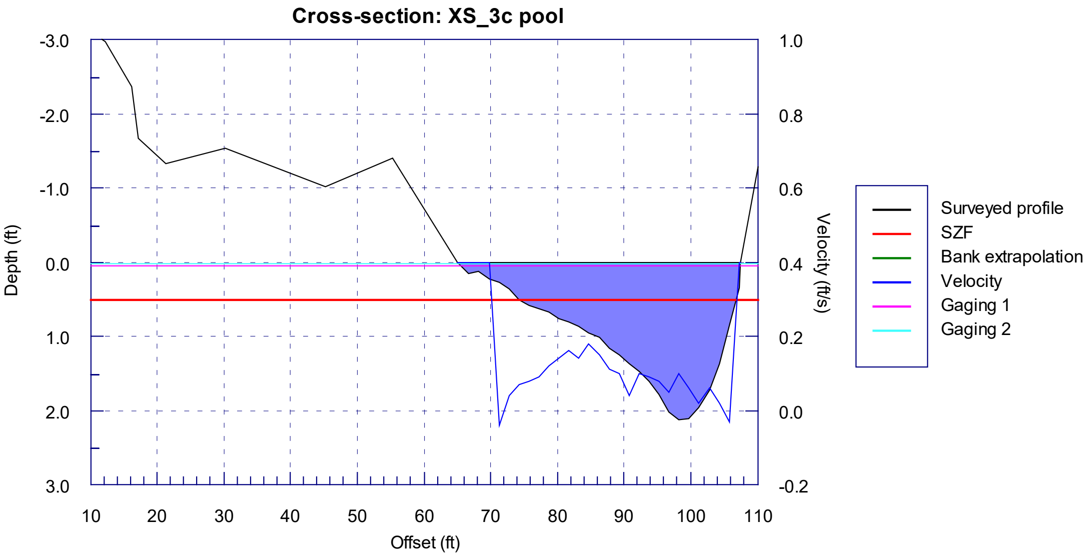

Cross-section: XS_2b riffle
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2


Cross-section: XS_3b pool
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2


Cross-section: XS_4b riffle
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2

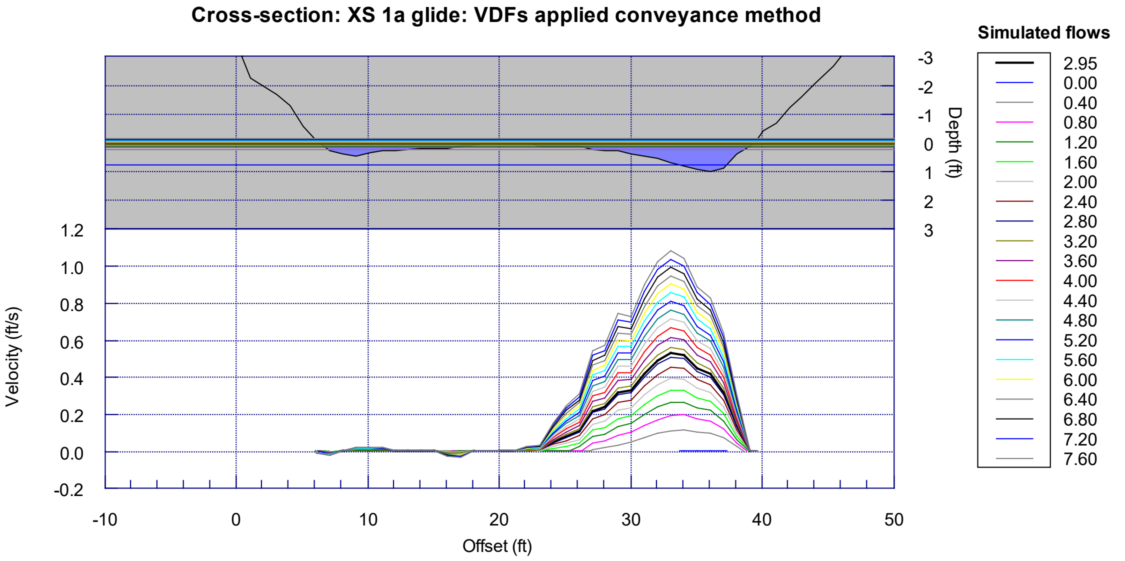

Cross-section: XS_1c riffle
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
10
20
30
40
50
60
70
80
90
100
110
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2


Cross-section: XS_2c run
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-10
0
10
20
30
40
50
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2

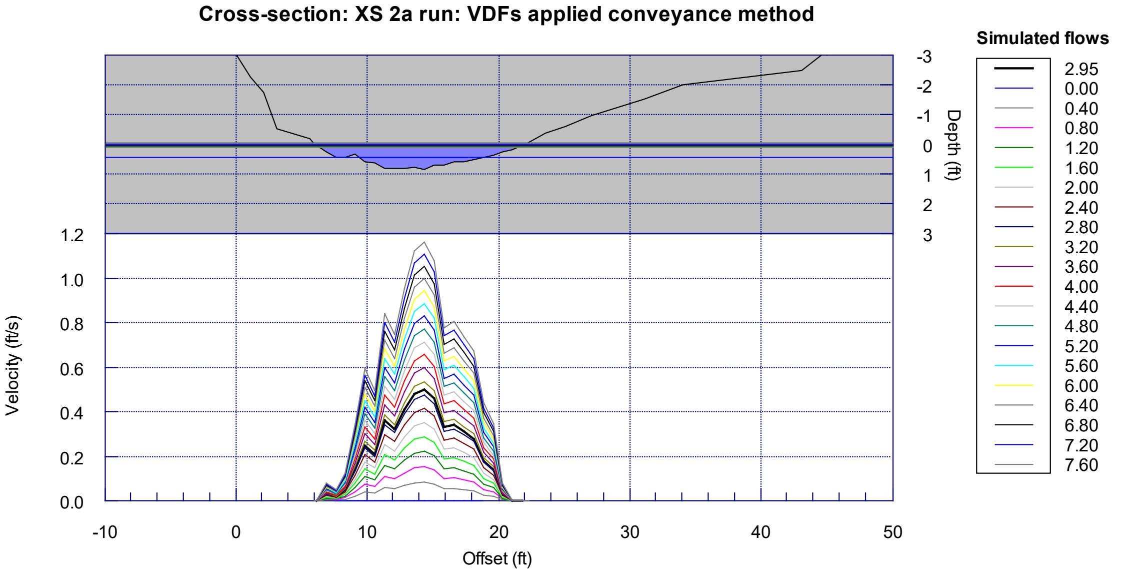

Cross-section: XS_3c pool
Depth (ft)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
10
20
30
40
50
60
70
80
90
100
110
Offset (ft)
Surveyed profile
SZF
Bank extrapolation
Velocity
Gaging 1
Gaging 2

Appendix C

Transect Velocity Distributions

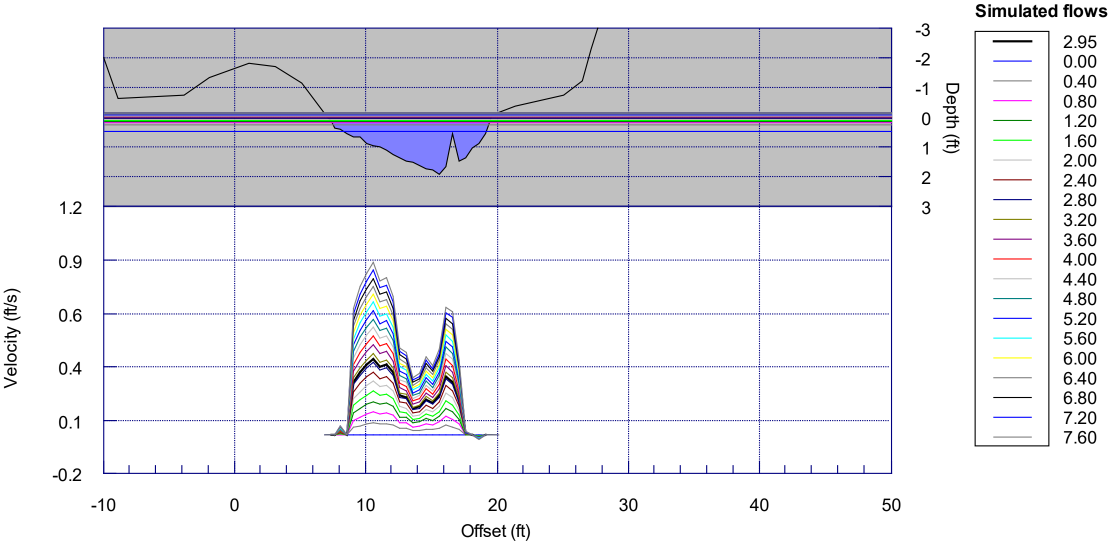


Cross-section: XS 1a glide: VDFs applied conveyance method

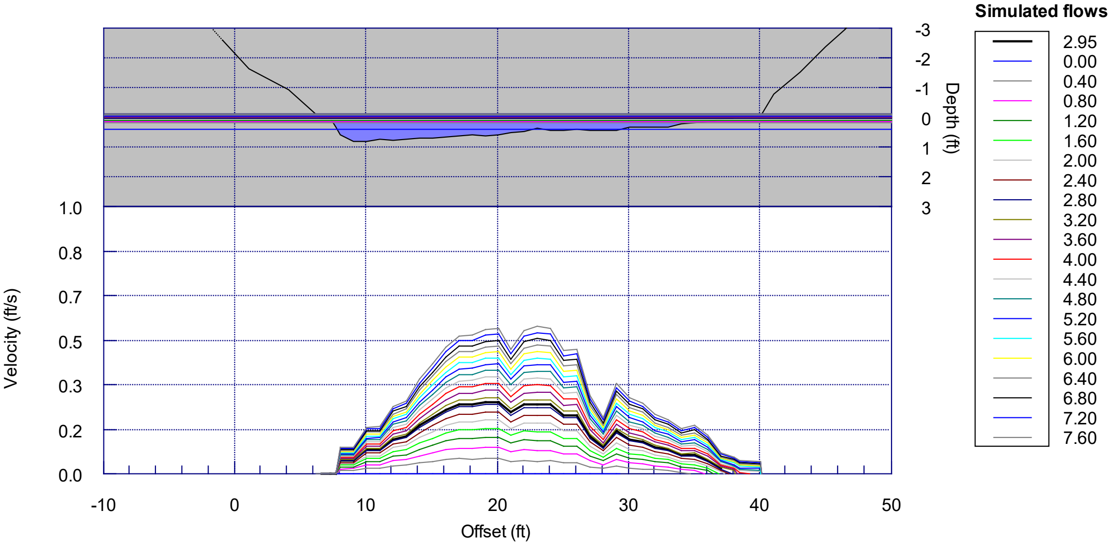


Cross-section: XS 2a run: VDFs applied conveyance method

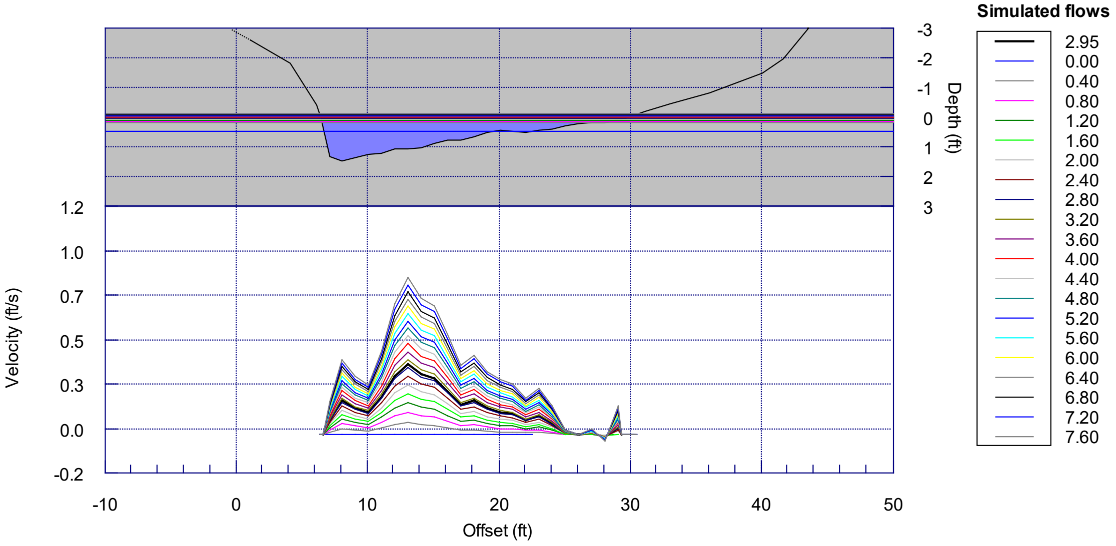
Cross-section: XS_3a pool: VDFs applied conveyance method



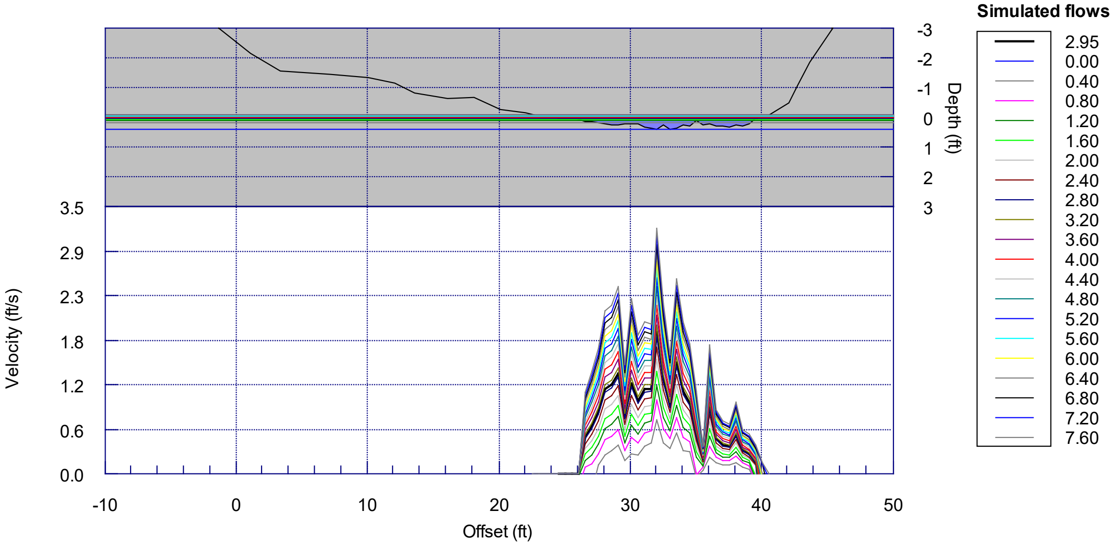
Cross-section: XS_4a glide: VDFs applied conveyance method

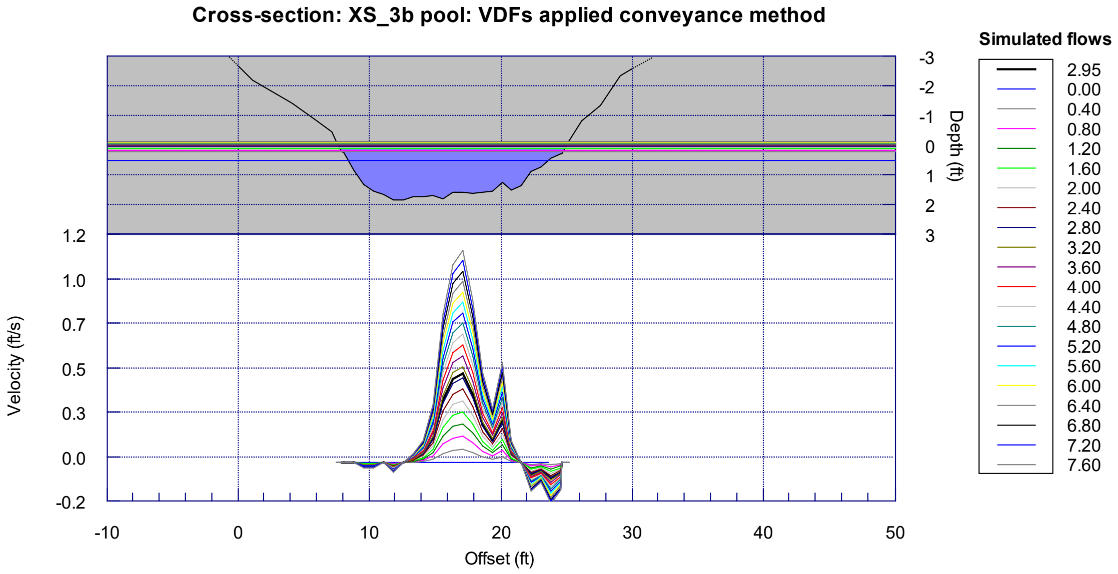


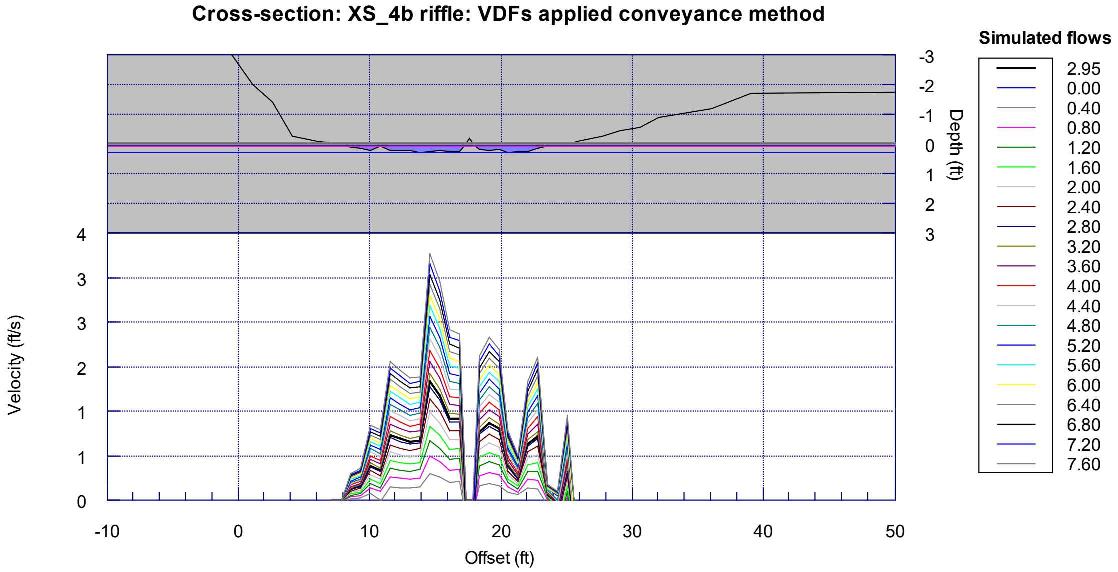
Cross-section: XS_1b run: VDFs applied conveyance method



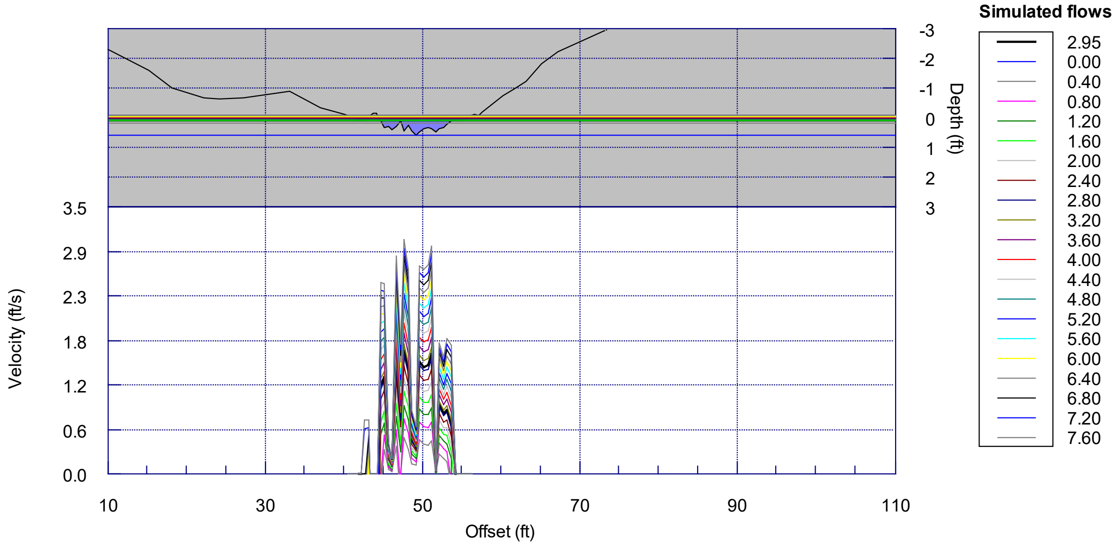
Cross-section: XS_2b riffle: VDFs applied conveyance method



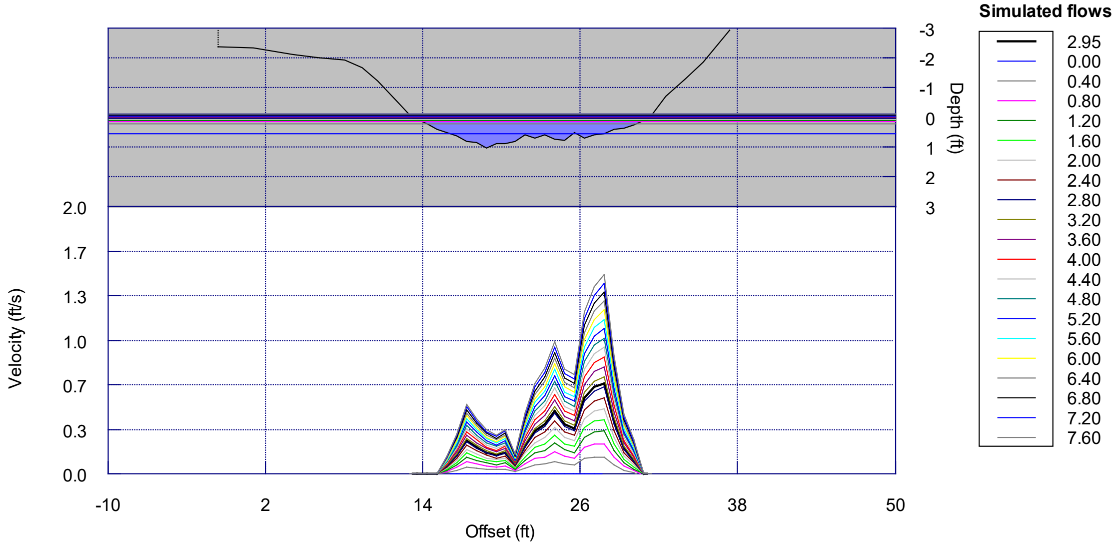

Cross-section: XS_3b pool: VDFs applied conveyance method

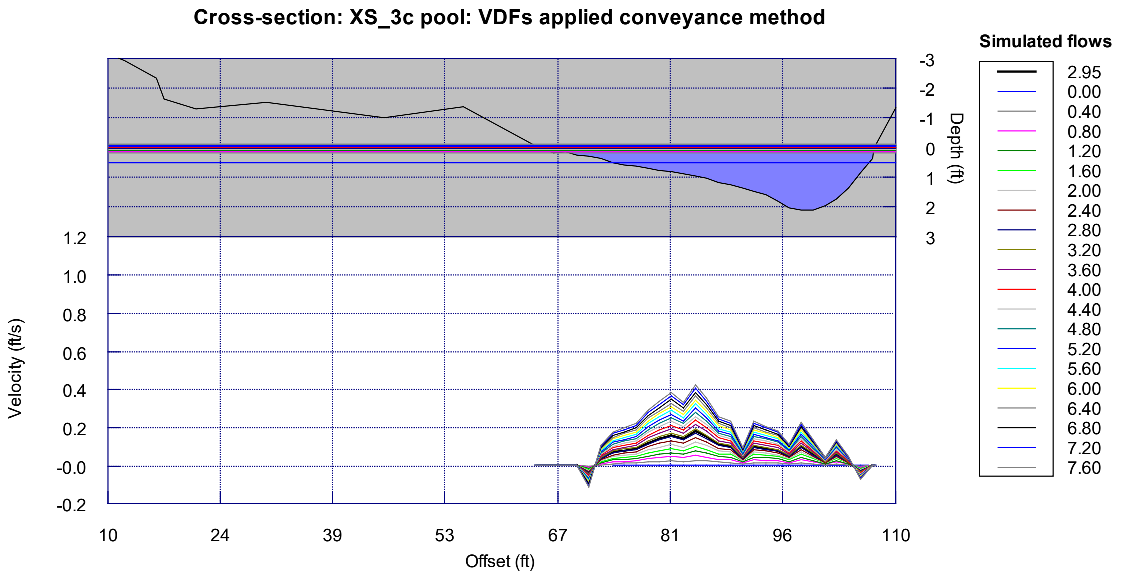

Cross-section: XS_4b riffle: VDFs applied conveyance method

Cross-section: XS_1c riffle: VDFs applied conveyance method



Cross-section: XS_2c run: VDFs applied conveyance method




Cross-section: XS_3c pool: VDFs applied conveyance method
Simulated flows
2.95
0.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
3.20
3.60
4.00
4.40
4.80
5.20
5.60
6.00
6.40
6.80
7.20
7.60
-3
-2
-1
0
1
2
3
Depth (ft)
1.2
1.0
0.8
0.6
0.4
0.2
-0.0
-0.2
Velocity (ft/s)
10
24
39
53
67
81
96
110
Offset (ft)

Appendix D

Transect Photographs

Figure D-1. Transect 1A looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and < 0.10 cfs (d).

Figure D-2. Transect 2A looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and 0.00 cfs (d).

Figure D-3. Transect 3A looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and < 0.10 cfs (d).

Figure D-4. Transect 4A looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and 0.00 cfs (d).

Figure D-5. Transect 1B looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and 0.00 cfs (d).

Figure D-6. Transect 2B looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and 0.00 cfs (d).

Figure D-7. Transect 3B looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and 0.00 cfs (d).

Figure D-8. Transect 4B looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and 0.00 cfs (d).

Figure D-9. Transect 1C looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and 0.00 cfs (d).

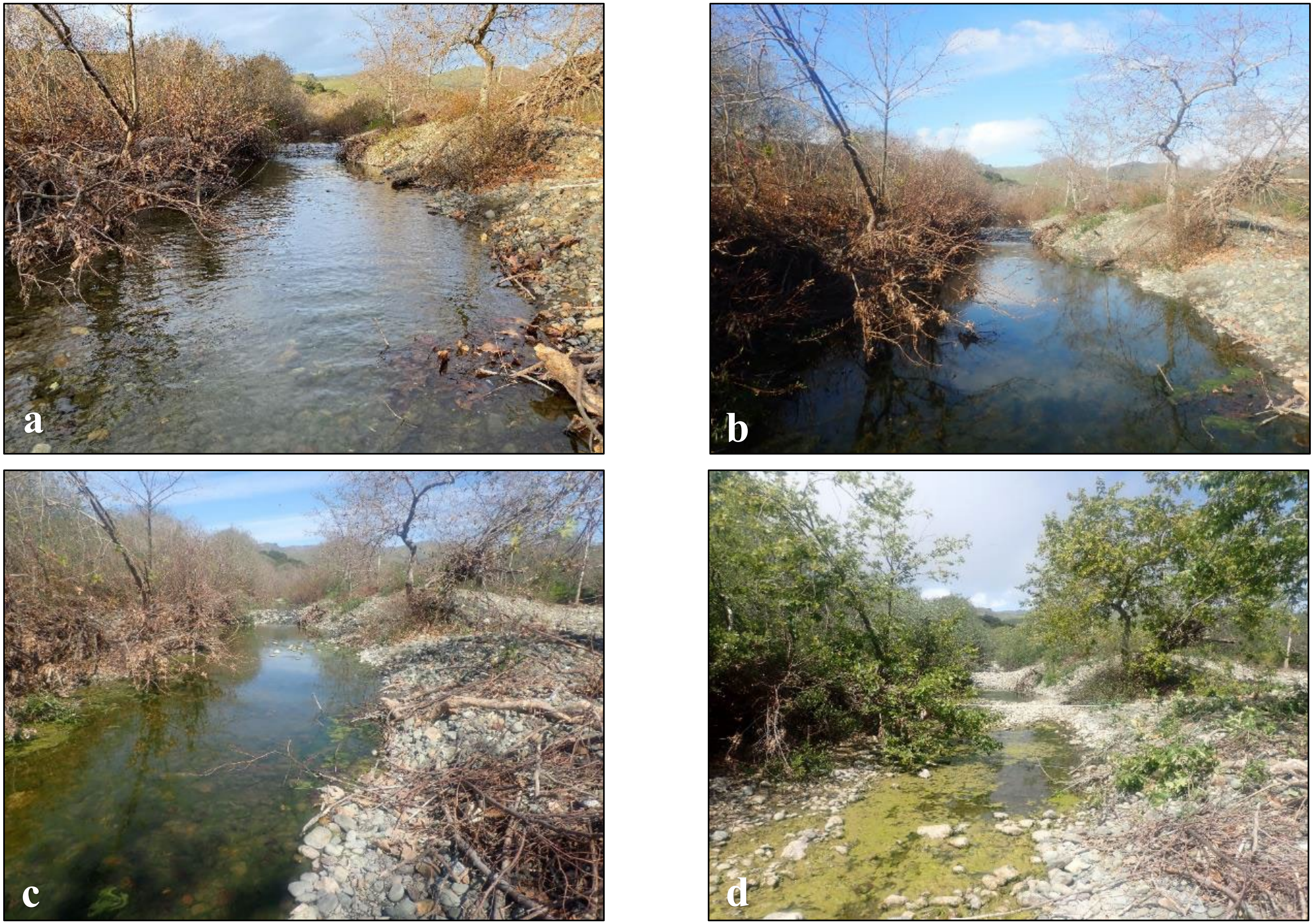


Figure D-10. Transect 2C looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and 0.00 cfs (d).

Figure D-11. Transect 3C looking upstream at 2.95 cfs (a), 1.46 cfs (b), 0.52 cfs (c), and < 0.10 cfs (d).

Figure D-12. Transect 4C looking upstream at 2.95 cfs (a), 1.46 cfs (b) and 0.52 cfs (c).