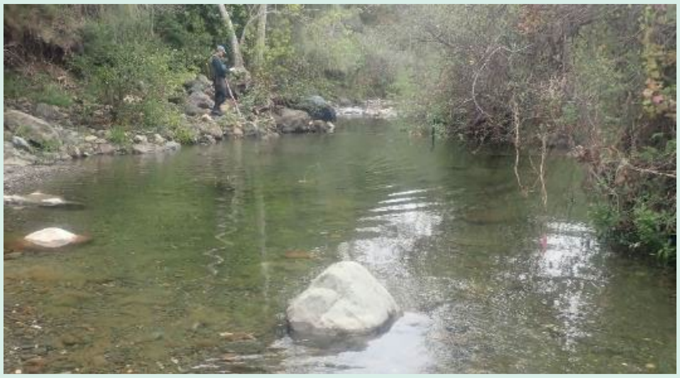
DECEMBER 2022

Pico Creek Instream Flow Study



PREPARED FOR

San Simeon Community Services District
111 Pico Avenue
San Simeon, CA 93452

PREPARED BY

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

and

Cleath-Harris Geologists
75 Zaca Lane, Suite 110
San Luis Obispo, CA 93401

Stillwater Sciences

CHG

For more information:
Ken Jarrett, Stillwater Sciences, (805) 570-7499, ken@stillwatersci.com

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Cover photo: Riffle habitat in Pico Creek at approximately 4 cfs in January 2022 (top left), pool with stage level monitoring equipment (top right), California red-legged frog observed in Pico Creek (bottom left), and riffle habitat in Pico Creek dry in April 2022 (bottom right).

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1 BACKGROUND

The San Simeon Community Services District (District) conducted an Instream Flow Management Study in Pico Creek to assess the relationship between the District's groundwater pumping operations and sensitive aquatic habitat in Pico Creek. Results from this study will be included in an Addendum to the existing District Master Plan (Phoenix 2018), based on the requirements of Urban Water Management Plans.

Operation of the District's groundwater wells 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 Pico 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).

The Pico Creek watershed drains a 15-square-mile area of the southern Coast Range in San Luis Obispo County. Originating from the flanks of the Santa Lucia Mountains, Pico 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 4 miles north of the town of Cambria. Pico Creek is divided into two subbasins with their headwaters in the Santa Lucia Mountains: North Fork Pico Creek and South Fork Pico Creek (Figure 1).

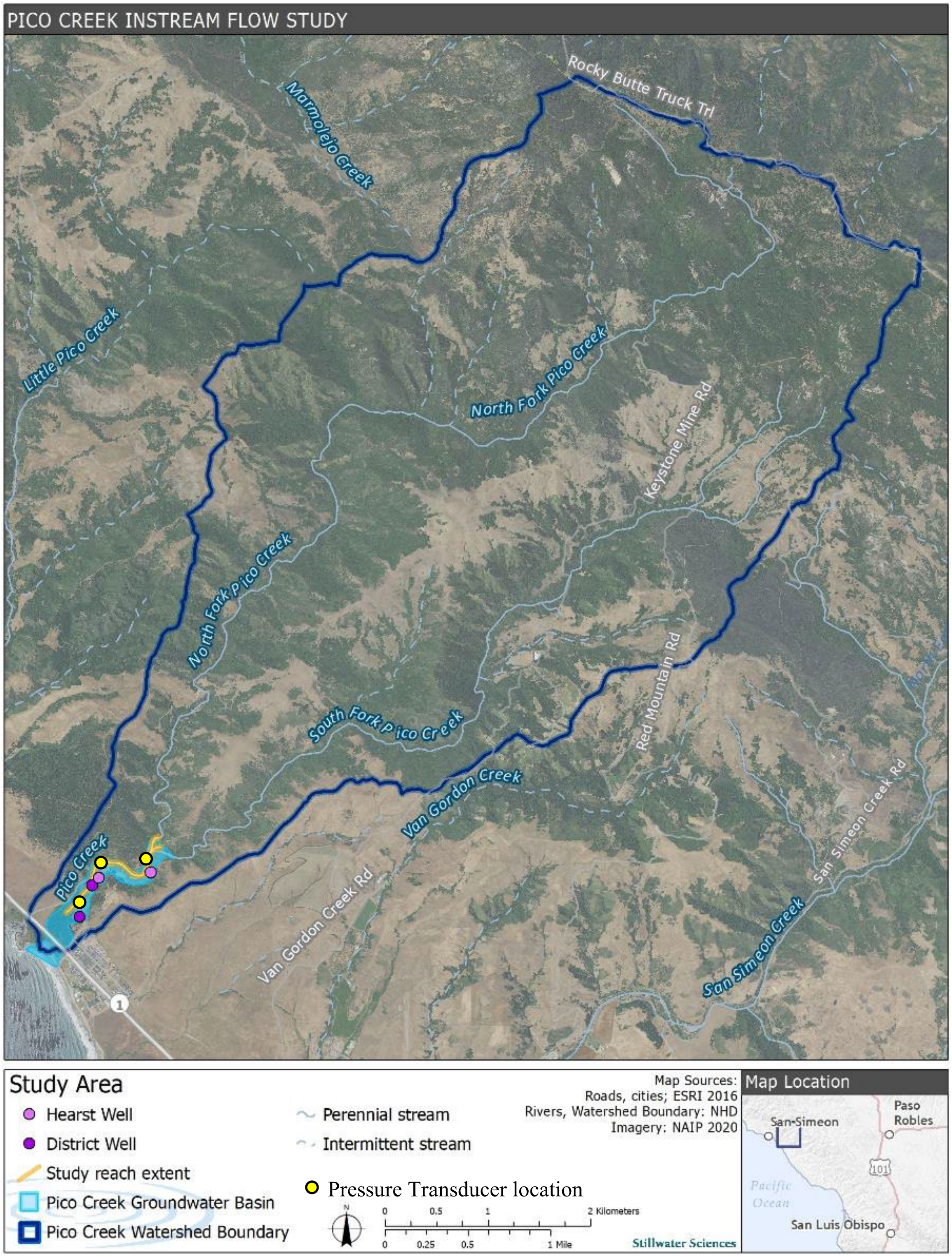

Figure 1. Study Area.

2 INTRODUCTION

Similar to other Coast Range watersheds, Pico 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). The highest flows in Pico Creek generally occur during the winter in response to high-intensity rainfall when stream flows typically increase, peak, and subside rapidly. 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 summer, extensive portions of Lower Pico Creek and North Fork Pico Creek frequently go dry, as would have occurred under natural conditions (NMFS 2013).

There are many functions of instream flows throughout the year, including sufficient flow to support important fish development stages, suitable water quality conditions in the lagoon, and essential geomorphic processes. Figure 2 shows the timing of important development stages for steelhead along with the seasonal flow pattern for Pico Creek and the monthly average District production volumes. Descriptions of special status aquatic species found in Pico Creek are provided below.

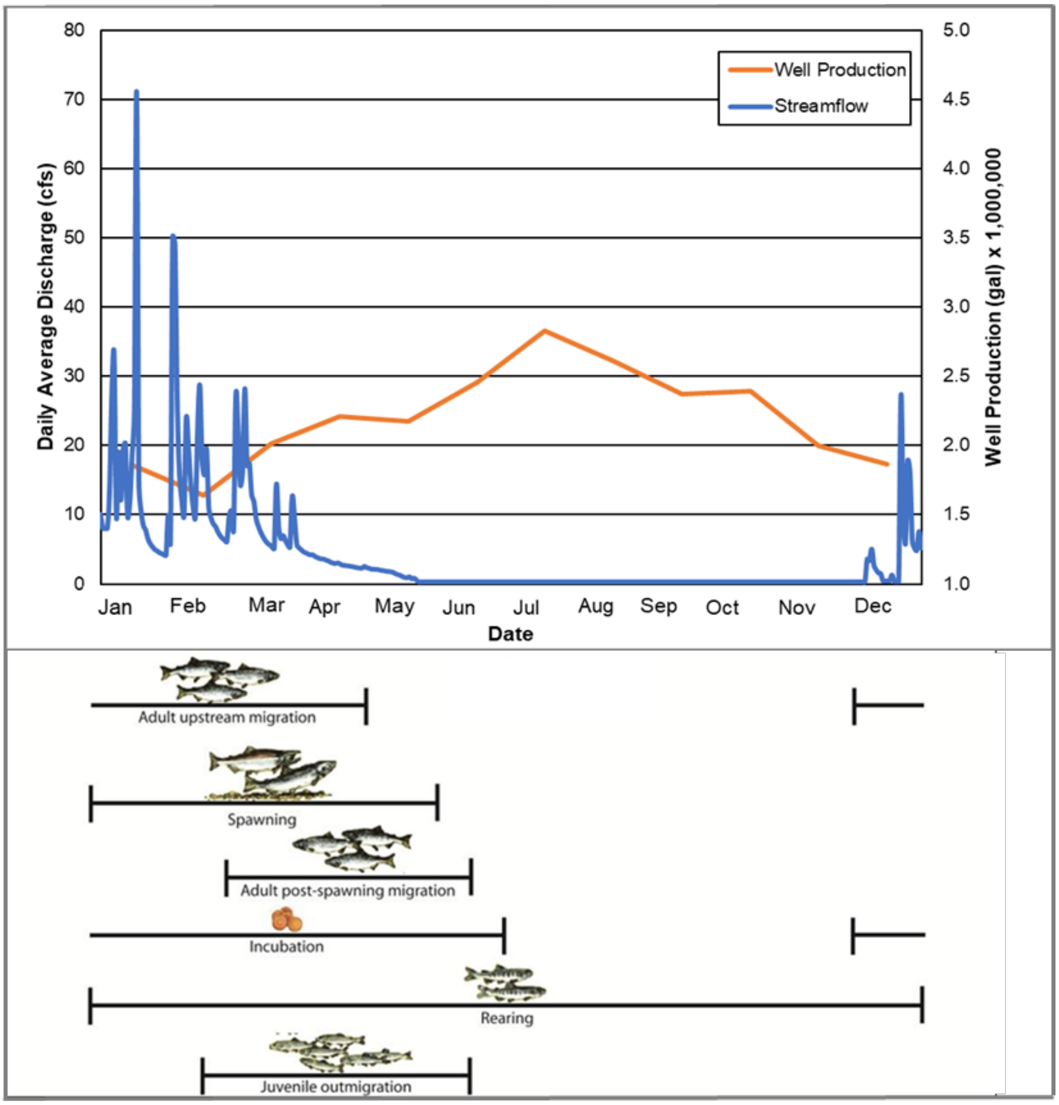

Figure 2. Hypothetical hydrograph showing seasonal flow variation within Pico Creek along with typical district pumping production volumes, and life history timing of steelhead (Shapovalov and Taft 1954).

2.1 Special Status Species

Special status aquatic species that occur in Pico 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

Steelhead found in the Pico 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 Pico Creek watershed has been identified as a Core 2 population, which means they have: (1) a high priority for recovery actions, (2) a known ability or potential to support viable populations, and (3) the capacity to respond to recovery actions. Although Core 2 populations are generally smaller and may have less diverse and complex threats than Core 1 populations, both Core 1 and Core 2 populations are the principal focus of NMFS recovery actions for the DPS (NMFS 2013). NMFS (2013) lists Pico Creek as one of the "best preserved and protected" streams in the region. The only threat rated as "high" for Pico Creek is the frequent channel drying within the mainstem and North Fork Pico Creek, which NMFS reports is natural but can be exacerbated by groundwater extraction and surface water diversions (NMFS 2013).

Steelhead is the anadromous form of *O. mykiss*, in which juveniles rear in freshwater rivers and creeks, migrate to the ocean to mature to adults, and return to freshwater rivers and creeks to spawn. Adult steelhead generally leave the ocean to return to their natal streams from December through March and spawn in late winter or spring (Figure 2) (Meehan and Bjornn 1991, Behnke 1992). 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 (Figure 2) (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 resting locations while they watch for drifting invertebrates being carried by flow. Aquatic invertebrates comprise a key item in the diet of juvenile steelhead.

Juvenile steelhead typically rear in freshwater for two to three years before outmigrating to the ocean as smolts (NMFS 2013). The duration of time juveniles spend in freshwater appears to be related to growth rate, with larger, faster-growing members of a cohort smolting earlier (Peven et al. 1994). Steelhead in areas with warm water temperatures, where feeding and growth are possible throughout the winter, may require a shorter period in freshwater before smolting, while steelhead in colder, more northern, and inland streams may require three or four years before smolting (Roelofs 1983). Juvenile steelhead outmigration typically occurs from March through June (Figure 2). Monitoring efforts in San Luis Obispo Creek documented the majority of juvenile steelhead outmigration from March through May, along with a smaller secondary migration occurring during the fall (Spina et al. 2005).

Habitat requirements for different age classes of juvenile steelhead are relatively similar, except that as fish grow, they require more space for foraging and cover. Age 0+ steelhead use shallow-water and low-velocity habitats, such as stream margins and low-gradient riffles to meet their energetic demands and to escape predators (Hartman 1965, Moyle 2002). Older juvenile steelhead (age 1+/2+), because of their larger size, have higher energetic demands and require deeper, more complex pools, and large rocky substrate or in-channel wood for cover while feeding (Hartman 1965, Fontaine 1988, Spina 2003).

Nearly all elements of juvenile steelhead rearing habitat are strongly influenced by instream flows, which affect rearing habitat area, the depth and volume of pools, connectivity between habitat types, water velocity, and water temperatures. Streamflow also dictates the quantity of drifting invertebrates that reach feeding steelhead (Harvey et al. 2006), with higher summer flows allowing steelhead to better maintain feeding rates during periods of higher water temperatures when metabolic demands are greater (Krug et al. 2012). During periods of low flows and high air temperatures that can occur from the late spring through early fall, water temperature and food availability are critical environmental factors for rearing juvenile steelhead. In general, temperatures less than 20°C are considered suitable for rearing steelhead (Hayes et al. 2008); however, in locations near their southern extent, steelhead have been reported to have optimal performance at temperatures over 24°C (Verhille et al. 2016). In streams along the central California coast, deep pool habitat (>1.5 ft) with sufficient instream cover likely provides critical over-summer refuge habitat for juvenile steelhead in intermittent streams (Spina 2003).

In some central California coast watershed, 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).

During studies conducted in Pico Creek, downstream of Pico Creek Road, during 1992–1993 Rathburn et al. (1993) reported observations of juvenile steelhead during the spring throughout Pico Creek and in the lagoon. By late June, juvenile steelhead were primarily found in isolated pools and the lagoon. In July, the channel was dry upstream of the District wells (Rathburn et al. 1993).

2.1.2 Tidewater goby

Tidewater goby are federally listed as endangered and designated as a species of special concern by the State of California. They 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 goby have been observed in high abundance in Pico Creek lagoon; however, critical habitat for tidewater goby is not designated in the watershed. Critical habitat is designated nearby in Little Pico Creek to the north and in San Simeon Creek to the south (USFWS 2013).

Tidewater goby are small fish that are adapted to estuarine/lagoon environments. The species is considered short-lived (generally for one year), highly fecund (females produce 300–500 eggs per batch and spawn multiple times per year) and 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). Tidewater goby have been documented in high numbers in Pico Creek Lagoon and the lower few hundred meters of stream when surface flows are present (Rathburn et al. 1993).

The USFWS (2013) states 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.

2.1.3 California red-legged frog

California red-legged frog (CRLF) are federally listed as threatened and are 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). Most CRLF populations are currently largely restricted to coastal drainages on the central coast of California. Critical habitat for CRLF is excluded from Pico Creek under a conservation easement (USFWS 2010).

CFLF habitat includes wetlands, wet meadows, ponds, lakes, and low-gradient, slow-moving stream habitat. Breeding generally occurs from December through April in aquatic habitats characterized by still or slow-moving water with deep pools (usually 1.6 ft deep or greater) and emergent and overhanging vegetation (Jennings and Hayes 1994). CRLF egg masses contain between 2,000 and 5,000 eggs (USFWS 2002). Breeding sites can be ephemeral or permanent; if ephemeral, inundation is usually necessary into the summer months (through July or August) for successful metamorphosis. However, locations that dry out after successful metamorphosis occurs can be beneficial to CRLF because it helps prevent invasive predators such as bullfrogs (*Lithobates catesbeianus*) from becoming established (USFWS 2010). Eggs require approximately 20-22 days to develop into tadpoles, and tadpoles require 11 to 20 weeks to develop into juveniles capable of surviving in upland habitats (Bobzien et. al. 2000; Storer 1925; Wright and Wright 1949, as cited in USFWS 2002). CRLF eggs and tadpoles require daily average water temperatures <23°C (73.4°F) (USFWS 2002).

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). CRLF 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, CRLF frogs in coastal areas are typically active year-round because temperatures are generally moderate (USFWS 2002, Bulger et al. 2003).

2.2 District Pumping Operations

The District provides water services to the unincorporated town of San Simeon through the operation of two groundwater wells located along lower Pico Creek, with a third well located on the Hearst Pico Creek Ranch that provides additional capacity during emergency drought conditions (Figure 1) (Cleath-Harris Geologists 2014). The Hearst Corporation also operates two wells along lower Pico Creek as part of the Hearst Pico Creek Stables, which provide irrigation and water to livestock at an average of 10-acre feet per year (AFY). The District has a water rights license issued by the California State Water Resources Control Board to extract up to 140-AFY from the Pico Creek Valley groundwater basin; however, average annual production averages between 70- and 80-AFY. Groundwater extraction typically increases during the spring and peaks during the summer due to the influx of tourists to the community of San Simeon during this time (Figure 3).

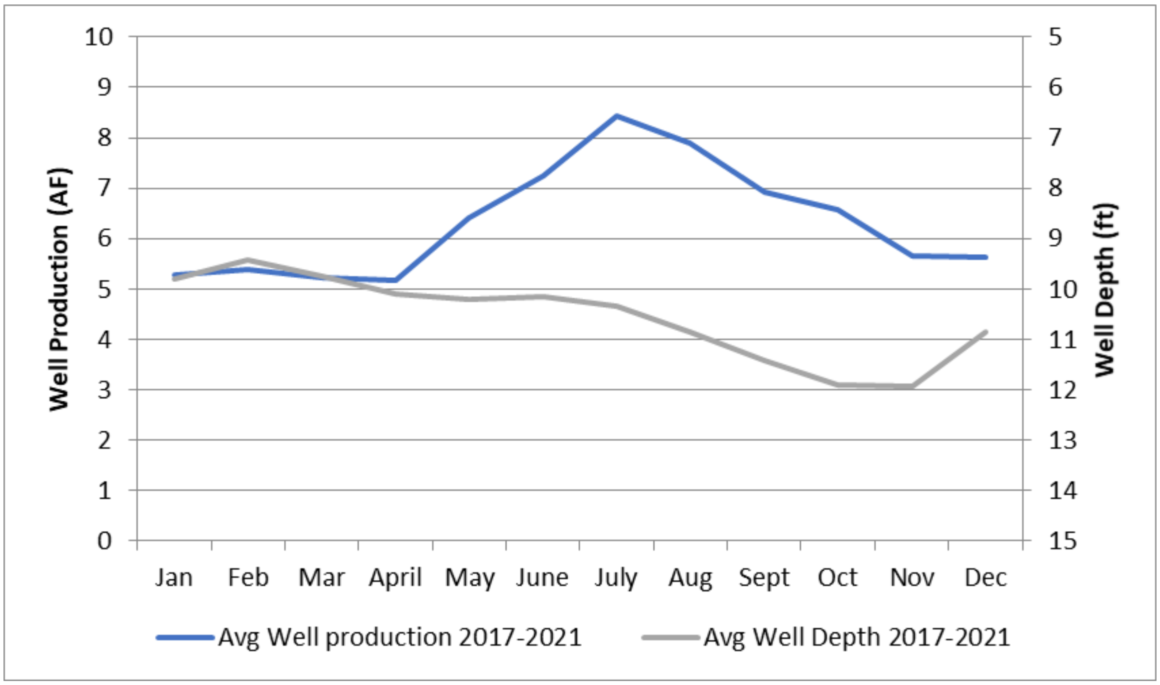

Figure 3. Monthly average groundwater well production and average well depth from District wells during 2017 through 2021.

Average monthly groundwater extraction ranges from 5.28 AF during the winter up to 8.44 AF a month during the summer (based on data collected between 2017–2021) (Figure 3), which is equivalent to daily average rates of 0.09 cfs and 0.14 cfs, respectively. Both wells are equipped with pumps that produce about 325 gallons per minute (0.72 cfs). However, water rights for the District limit groundwater extraction rates to a maximum daily average rate of 0.27 cfs.

Groundwater levels within the Pico Creek Valley groundwater basin generally become saturated after the first rain event in the winter (Cleath-Harris Geologists 2014) and begin to decrease in early spring until groundwater levels reach a minimum elevation during the fall months (Figure 3). The groundwater basin has been defined in earlier investigations. A map prepared of the alluvial deposits (1986 and updated in 2014) show that the alluvium beneath the stream channel adjacent to the District wells is shallower than where the wells are located. The base of the basin sediments also rises upstream, with the bedrock contact above mean sea level upstream of the Hearst Upper Well (Figure 4).

A previous pumping test (performed February 17, 2006) demonstrated that there is drawdown in the shallower well when the deeper well is pumped. However, the test did not show a flattening of the groundwater level indicating a recharge boundary, such as when a stream inflow boundary is encountered. The flow in the creek was not monitored during the previous test.

Well #1 produces water from aquifers at depths of 15–47 ft. Well #2 produces water from the deepest sand and gravel beds in the basin from depths of 50–60 ft. There is a clayey bed (aquitard) in the groundwater basin beneath the District's wells at depths from approximately 26 to 36 ft below ground. Where present, the aquitard inhibits downward groundwater movement from the shallower sand and gravels to the deeper sand and gravel layers. However, there are areas in the basin where sand and gravels extend from the surface to bedrock and no aquitard is present (e.g., near the Hearst Upper well) (Figure 4).

Test hole logs indicate that the main aquitard is not fully extensive over the basin. Therefore, the semi-confined deeper aquifer can be indirectly recharged from stream flow in the adjacent stream channel, as well as directly recharged from Pico Creek upstream of the Hearst Main Well (Figure 4).

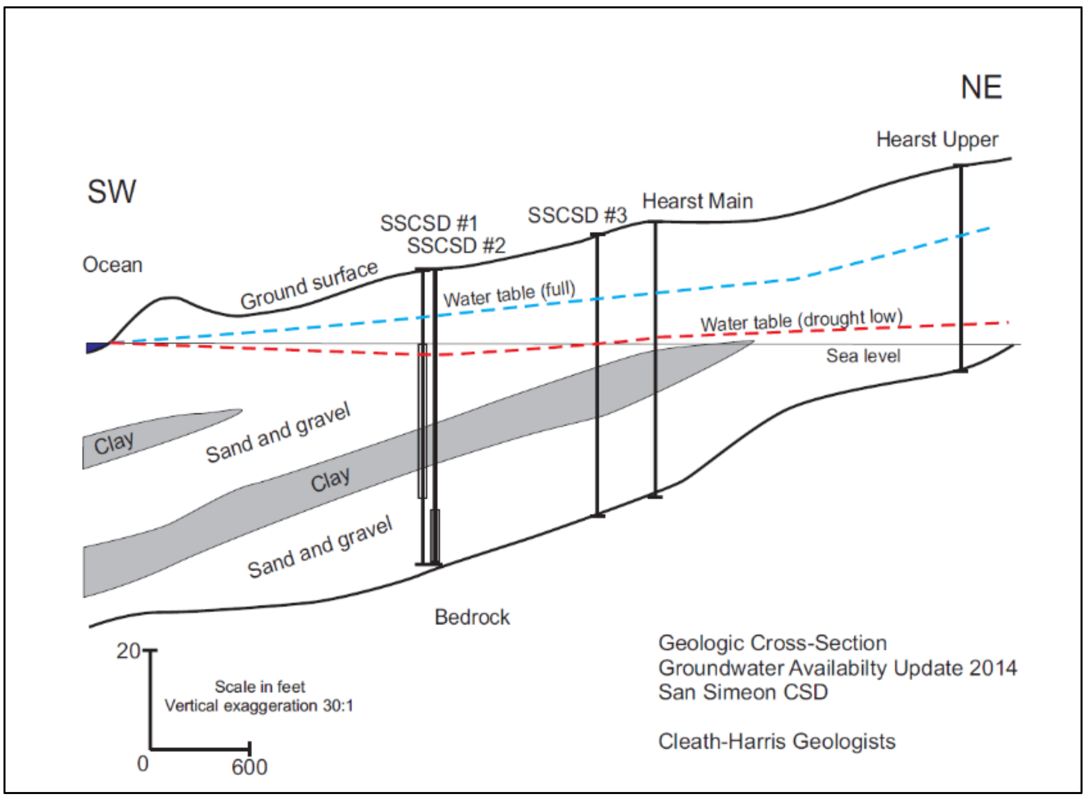

Figure 4. Cross section of Pico Creek groundwater basin and District pumps from Cleath-Harris (2014).

District pumping operations are expected to have the greatest potential influence on aquatic habitat when surface flows are low. With a maximum daily average groundwater pumping rate of 0.27 cfs, District pumping operations are not expected to influence habitat conditions during precipitation driven events when high migratory flows for steelhead likely occur. District pumping operations are also not expected to influence habitat conditions in lower Pico Creek during the summer months when the stream channel is dry, which is expected to occur frequently even under natural conditions (NMFS 2013). However, District pumping operations may potentially influence habitat conditions during relatively low flows (<5 cfs) that occur after the rainy season. During the spring, as surface flows are declining from 3 cfs to 1 cfs, and eventually drying up completely, critical life stages of sensitive aquatic species may be using lower Pico Creek. Juvenile steelhead are potentially rearing within the lower watershed or migrating as smolts downstream to the lagoon and ocean before the stream dries up (as described in Section 2.1.1). CRLF are potentially using this area to develop from eggs and tadpoles prior to metamorphosis into juveniles capable of surviving out of water (as described in Section 2.1.3). This spring period is therefore the most critical for understanding the potential for District pumping operations to influence surface flows and conditions for sensitive aquatic species.

2.3 Goals and Objectives of Study

The goal of the instream flow study is to inform District Master Plan as it relates to sensitive aquatic species that occur in lower Pico Creek. The study objective is to evaluate the relationship between aquatic habitat for sensitive species and District pumping operations in lower Pico Creek.

Results from this study will be used to (1) assess how District pumping operations might affect the biological needs of steelhead, CRLF, and tidewater goby in lower Pico Creek, (2) evaluate District pumping operations to identify constraints and opportunities to contribute towards meeting the biological needs of special status aquatic species in lower Pico Creek, and (3) develop operational and long-term monitoring recommendations to ensure District pumping operations in the Pico Creek watershed minimize any potential impacts to special status aquatic species due to alterations in surface flows from groundwater pumping.

2.4 Study Area

The Study Area included lower Pico Creek where it flows over the Pico Creek Valley groundwater basin and where District pumps are located. A single Study Reach was established on Pico Creek within the Study Area and focused on the area most likely to be influenced by the District’s groundwater pumping. The Study Reach began at the upstream end of the lagoon and extended 0.83 miles upstream to the confluence of the North and South Fork Pico Creek, overlapping with the Pico Creek Valley groundwater basin (Figure 1).

Stream flow data is limited for Pico Creek; however, surface flows within the Study Reach generally sustain steady baseflows during the winter months after the groundwater basin recharges following the first significant rain event. Flows begin to recede after the rainy season as the groundwater level recedes, typically during late spring (Figure 2). By early summer, surface flows typically cease and the channel remains dry through the fall until the groundwater basin refills.

The section of Pico Creek within the Study Area likely serves as a migratory corridor for steelhead, with adult spawning and juvenile rearing limited to the upper watershed where year-round flows are found. Modeling by Boughton and Goslin (2006) suggests similar historic use of Pico Creek by steelhead based on high potential over-summer habitat for juvenile steelhead predicted in the North Fork and South Fork of Pico Creek and "low potential" within Pico Creek downstream of the confluence (which was the researchers' lowest designation of habitat quality and assigned to intermittent reaches).

3 METHODS

3.1 Technical Advisory Committee

This project engaged stakeholders through the creation of a Technical Advisory Committee (TAC). The TAC includes individuals from CDFW. The TAC met regularly to assist and advise the project team in the instream flow assessment activities described in Section 3.2 through Section 3.7. The methods described here reflect input from the TAC received on March 3, 2022 and October 5, 2022.

3.2 Habitat Typing

Surveys to characterize physical habitat conditions within the Study Reach were conducted at the beginning of the study. Habitat mapping was conducted when flows were near winter baseflow conditions to facilitate the evaluation of habitat composition while distinct habitat unit breaks were expected to be most apparent. Habitat mapping was conducted following methods developed by Hawkins et al. (1993), McCain et al. (1990), and Flosi et al. (2010), which uses a three-tiered habitat mapping classification system to assist in the identification of individual habitat units in the field. Level III categories are adopted from McCain et al. (1990). Figure 5 shows the relationship among the three levels.

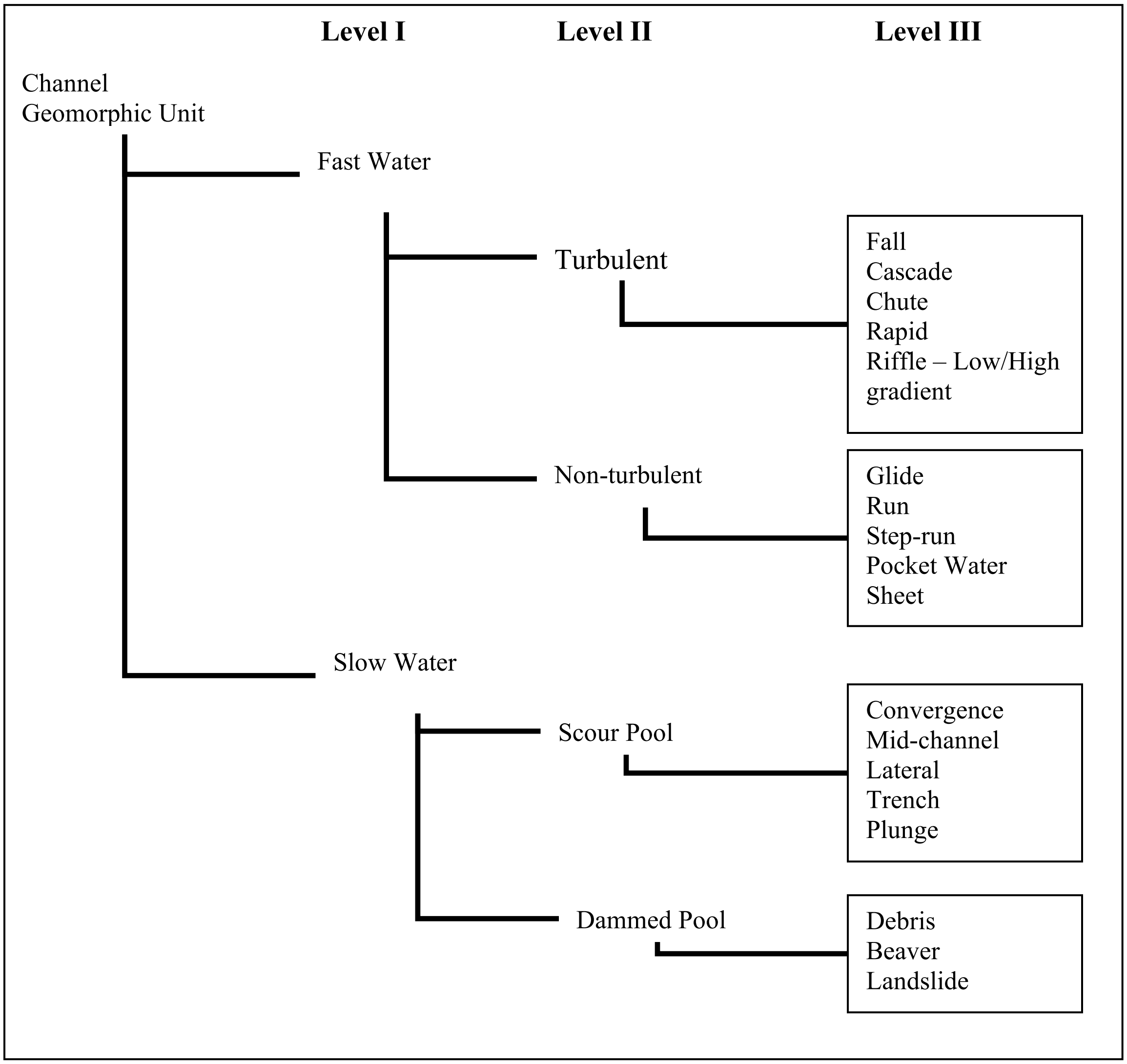

Figure 5. Three-tiered habitat mapping classification system adapted from Hawkins et al. (1993) and McCain et al. (1990).

The Study Reach was divided into individual habitat units that were designated a habitat type (e.g., riffle, run, pool) using the habitat types described in Table 1. Each habitat unit was separately identified where the unit length was at least equal to one to two times the active channel width (McCain et al. 1990, Flosi et al. 2010), or if the unit was otherwise distinctive. The team recorded the length of each habitat unit 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 Study Reach. Habitat types used for reach characterization are listed in Table 1. Data from the habitat mapping were used to characterize the Study Reach and establish appropriate study sites.

Table 1. Habitat types to be used in mapping for the Pico 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 modelable.
2. Cascade:	Series of alternating small falls and shallow pools; substrate usually bedrock and boulders. Gradient high (more than 4%). Generally not modelable.
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 modelable.
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 modelable.
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).

The following information was gathered during the habitat typing survey:

- Habitat unit number,
- Habitat unit type,
- Habitat unit length,
- Average width,
- Maximum pool depth,
- Substrate composition (two most dominant substrate types),
- Fish cover type, and
- Suitable CRLF breeding habitat based on depth (>1.6 ft) and emergent or overhanging vegetation for egg deposition (Jennings and Hayes 1994).

All habitat data were entered into a Microsoft Excel spreadsheet and checked for quality control. Analytical tasks included a description of existing stream habitat and conditions including the frequency of pool, riffle, and run habitat. Habitat type composition was calculated using the individual unit lengths as well as the number of representative habitat units. The substrate composition for the streambed was presented along with the average stream width, average pool depths, and available fish cover. Physical habitat conditions were summarized based on percent habitat composition (e.g., riffle, run, pool) within the Study Reach.

3.3 Water Surface Level and Temperature Monitoring

To assess habitat conditions for juvenile steelhead rearing, CRLF breeding, and CRLF over-summer rearing as surface flows recede, water depth and water temperature were monitored in three pool habitat locations within the upper, middle, and lower sections of the Study Reach. Hobo pressure transducers were placed within three deep pools (≥3 ft), that provide rearing habitat for juvenile steelhead and CRLF breeding. A fourth pressure transducer was installed above the stream to compensate for changes in barometric pressure. Locations monitored with pressure transducers (PT's) are shown on Figure 2 and Figure 6 and include the following locations:

- **PT1** located near the District groundwater wells, upstream of the lagoon;
- **PT2** located approximately halfway between the lagoon and the confluence of North Fork Pico Creek and South Fork Pico Creek; and
- **PT3** located downstream of the confluence North Fork Pico Creek and South Fork Pico Creek at the upstream end of the Pico Creek groundwater basin.

Data were collected during the spring through early summer to assess habitat conditions prior to desiccation. Monthly site visits were conducted to download pressure transducer data and measure water surface levels. Photos were taken of each pool where pressure transducers were installed and of the adjacent riffles. When surface flows were present, discharge was measured within at least one location in the Study Reach. A stage discharge rating curve was fit to the pressure transducer data to estimate stream flow over the course of the study period. Pressure transducers recorded water stage level and water temperatures at 15-minute intervals.

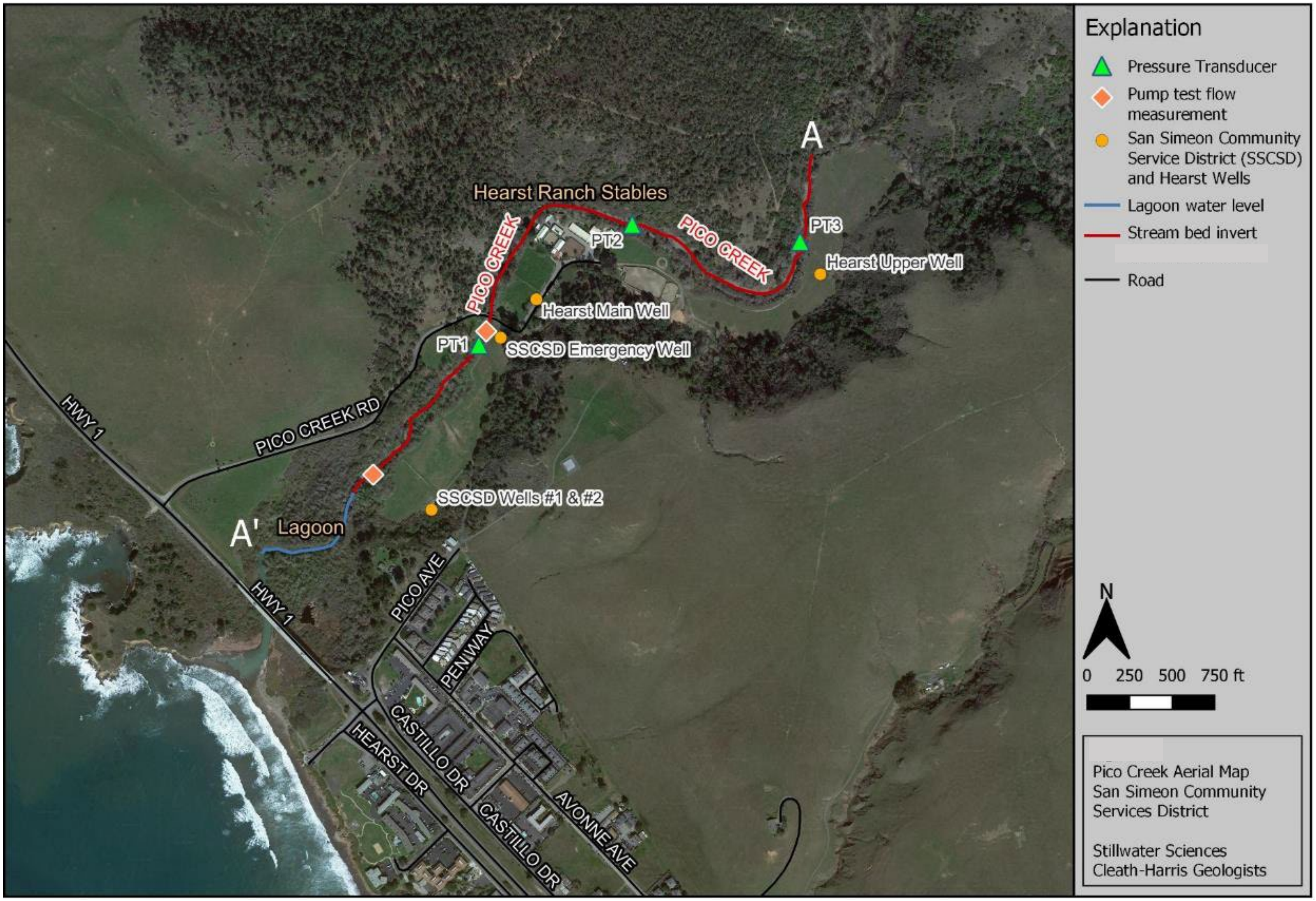

Figure 6. Study Area showing pressure transducer locations (PT1, PT2, and PT3) and pump test stream flow monitoring locations.

Water surface levels and water temperature data monitored using pressure transducers within pool habitats were evaluated to identify locations within the Study Reach where suitable habitat for steelhead and CRLF exists, and at which flows suitable habitat begins to diminish. Data collected from the water surface level and water temperature level monitoring effort were plotted against depth and temperature thresholds required to support suitable juvenile steelhead rearing and CRLF breeding habitat to assess what flows provide suitable habitat within pools. A stage discharge rating curve was fit to the pressure transducer data to estimate stream flows throughout the study period. Water elevation data from the pressure transducers were reviewed during the period when pump tests were conducted to assess changes in pool habitat that may be influenced by ground water pumping.

3.4 Riffle Habitat Assessment

Benthic macroinvertebrate (BMI) production and juvenile steelhead passage conditions were assessed within riffle habitat during each survey. Photo points were established at a minimum of five riffle locations and photographed during each survey. Observations of suitable BMI production in riffles were noted during each survey to assess food production and invertebrate drift into the upstream end of pool habitat where juvenile steelhead are likely to feed. Suitable BMI production was determined in riffles based on estimated water velocity of ≥1.0 ft/second and inundation of median substrate particles (D_{50}) per Orth and Maugham 1983, Gore et al. 2001, and Taylor et al. 2009. Fish passage conditions for juvenile steelhead were assessed by measuring water depths within each riffle where photo points occur. Water depths of 0.4 ft or greater within the thalweg of riffle crests were considered suitable for juvenile passage based on CDFW 2017. BMI production and juvenile steelhead passage conditions were referenced to discharge measurements collected during each site visit.

Observations from the riffle assessments were evaluated to understand the amount and distribution of suitable BMI habitat within the Study Reach and the stream flows required to support BMI production and juvenile steelhead passage. Photos collected from the riffle assessment were assessed to help characterize BMI habitat and juvenile steelhead passage conditions over a range of flows.

3.5 Dry and Intermittent Stream Segment Mapping

To help understand where suitable habitat for steelhead and CRLF occurs as stream flow recedes, surface flow conditions within the Study Reach were monitored during each site visit. Surface flow conditions were monitored by mapping dry and intermittent stream sections during each site visit. GPS coordinates of the upstream and downstream extent of each dry section were recorded during each site visit to document when and where surface flow become intermittent as flows receded. Data from the dry and intermittent stream segment mapping were analyzed to describe the seasonal pattern of declining surface flows. Results were compared to the water surface level monitoring data collected within pool locations to assess the ability of isolated pools to retain water without input from surface flows.

3.6 Lagoon Habitat

Pico Creek lagoon was monitored during the study to assess how aquatic habitat for sensitive species that use the lagoon may change as stream flow in Pico Creek recedes. Changes in lagoon size during the study were assessed by monitoring the upstream extent of the lagoon. The upstream extent of the lagoon was recorded during each site visit using handheld GPS and representative photos of the upstream section of the lagoon were collected. A pressure transducer was installed within the lagoon as part of the Surface Water/Groundwater Connectivity assessment described below (Section 3.7).

Locations of the upstream end of the lagoon were mapped to show changes in lagoon extent over the course of the study. Habitat conditions within the Pico Creek lagoon were assessed based on changes in the lagoon extent during the study period and changes in lagoon stage levels during the pumping tests. Pressure transducer data from the lagoon were assessed for elevation changes during the study period with and during the pumping tests to evaluate the potential influence from District pumping operations on lagoon habitat.

3.7 Surface Water/Groundwater Connectivity

Assessments of the relationship between groundwater extraction and surface flows were conducted to assess stream flow loss during groundwater pumping at each of the two main District Wells. Pumping tests were performed at each of the two District wells in conjunction with the water surface level monitoring discussed above (Section 3.4). Groundwater extractions during the pumping tests were maximized to the extent possible based on water availability and storage capabilities. Pumping tests were performed on weekends when maximum demand typically occurs and the longest duration of pumping could occur. Separate pumping tests were run for each of the two main District wells. All of the water produced during the pumping tests was used to replenish the District reservoir that was drained to a minimum level prior to the testing in order to maximize the duration of the test; none was discharged to waste, per direction from the District.

During these tests, Pico Creek stream flow was monitored to observe evidence of stream flow depletion due to pumping from the District wells. Stream flow monitoring points were established upstream of the wells near PT1 and downstream of the wells just upstream of the lagoon (Figure 6). Measurements were collected at each steam flow monitoring point just before pumping began and then approximately every 15 to 30 minutes throughout the pump test. In addition, the stage levels at PT1, PT2, PT3, and the lagoon level were monitored during these tests to assess the potential influence of groundwater pumping on pool and lagoon habitat.

4 RESULTS

4.1 Habitat Typing

Stream habitat typing was conducted throughout the Study Reach on January 14, 2022 beginning at the upstream end of the lagoon and extending approximately 0.83 miles upstream. The Study Reach is dominated by pool habitat (both mid-channel and lateral scour pools were observed), followed by riffle habitat and run habitat (Figure 7). Substrate withing pool habitat was predominantly sand while the riffle and run habitats were dominated by cobble and gravel substrates, respectively (Figure 8). The majority of the channel (43%) contained no cover for fish. The dominant cover type was overhanging vegetation followed by boulder (Figure 9).

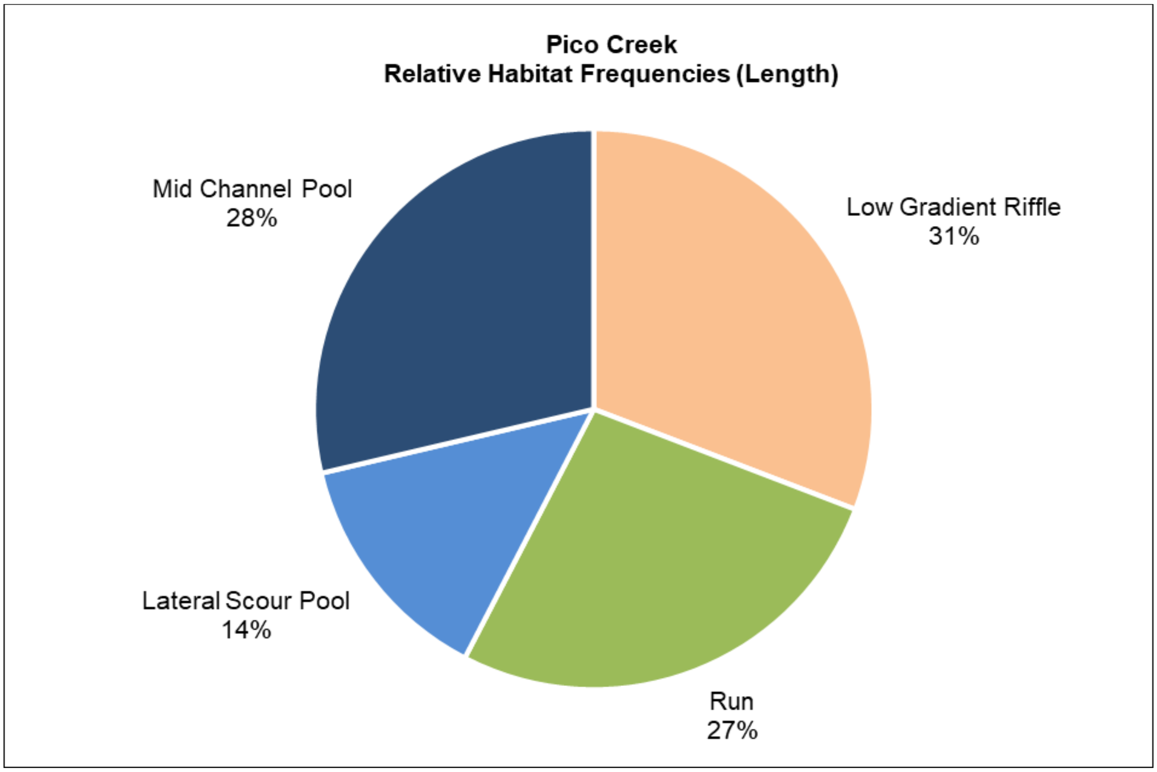

Figure 7. Relative frequency of habitat types (by length) in the Study Reach.

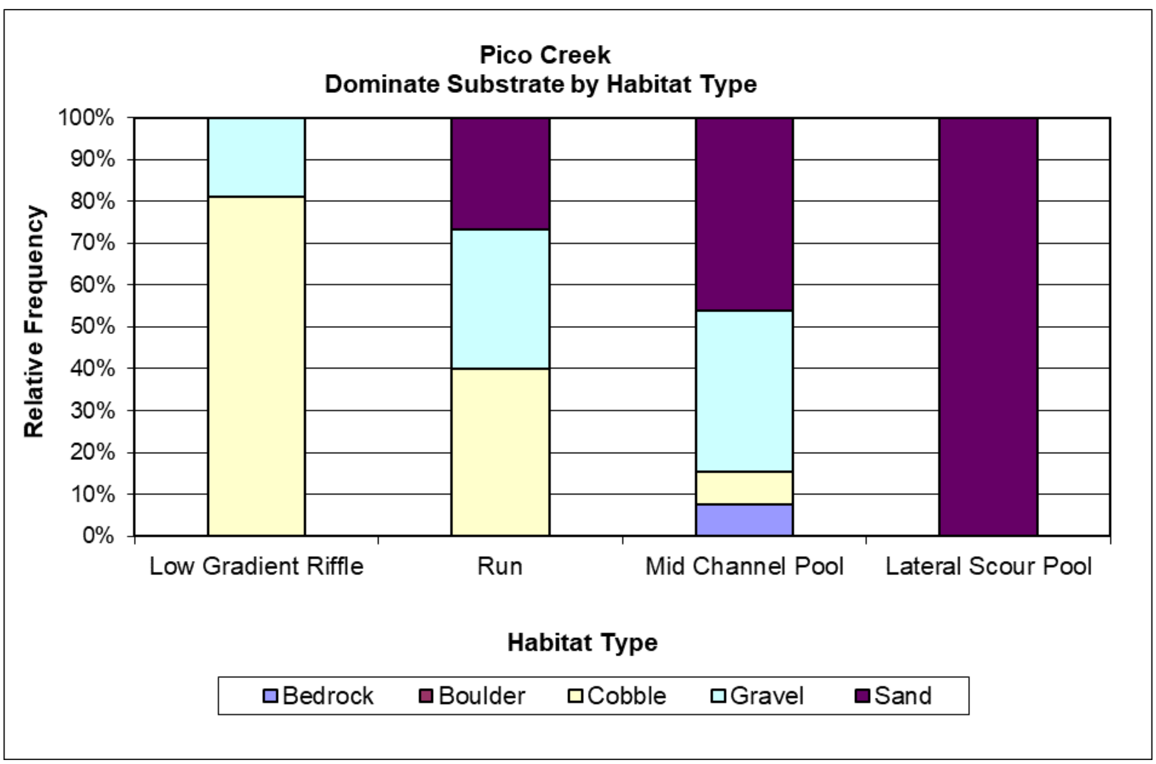

Figure 8. Dominant substrate by habitat type in the Study Reach.

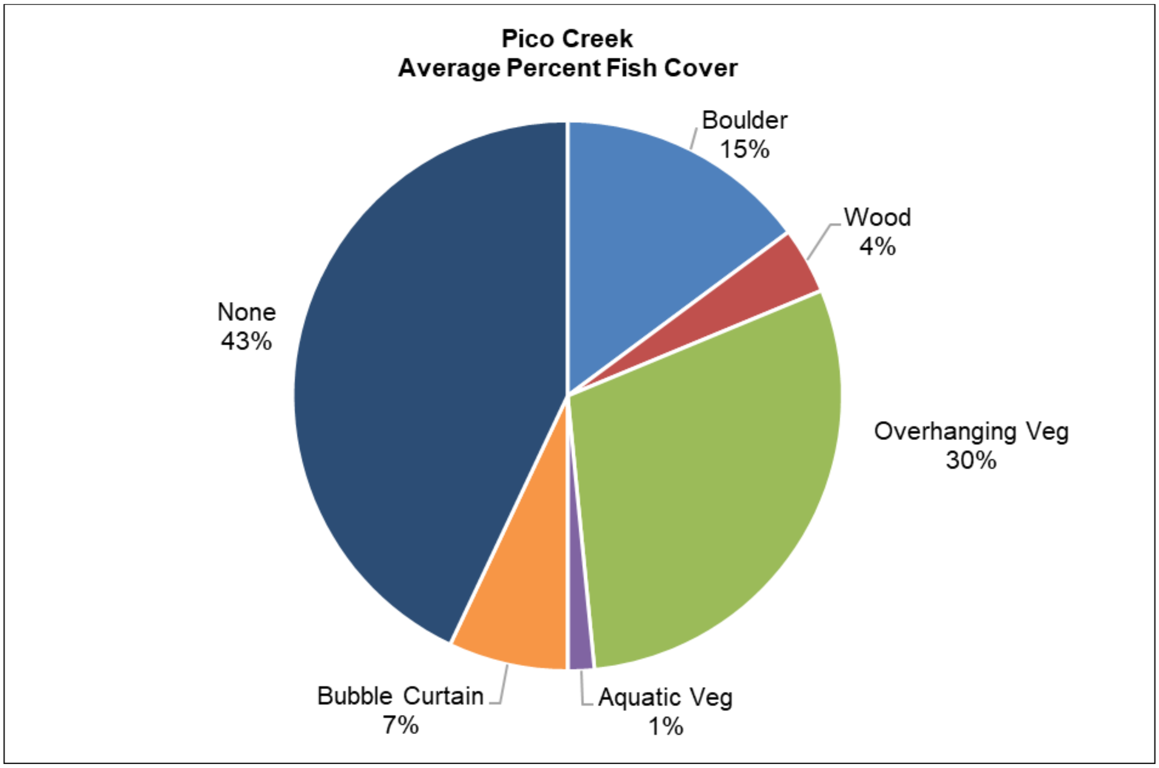

Figure 9. Average percent of fish cover within the Study Area.

4.2 Water Surface Level and Temperature

Pressure transducers were installed in Pico Creek on March 15, 2022 when stream flow was 0.35 cfs. Water levels in pools were generally stable until surface flows became disconnected, at which point pool depths began to decrease quickly. Pool depths showed a quick response to rain events that occurred in late March and in late April. The April rain event occurred after stream flows had become disconnected in the upper section of the Study Reach, when water depths at the pools where PT2 and PT3 were located began to drop. Following the April rain event, water levels in these locations briefly rose by approximately 0.5 ft but then began dropping almost immediately (Figure 10). Photos of each pool where pressure transducers were installed are shown in Figures 11–13.

The downstream pool monitored with a pressure transducer (PT1) had stable pool depths later into the year compared to the upper pools, with water depths remaining stable until early June before levels began dropping. Suitable depths for CRLF breeding and juvenile steelhead rearing remained at this location until early July (Figure 10). Water depths within pools at the upper end of the Study Reach (PT2 and PT3) were generally stable during March and April with the exception of a few spikes following rain events, then began to decrease in depth by late April (Figure 10). In these locations, water depths were suitable for CRLF breeding habitat until late May. Because the pressure transducers were not installed in the deepest part of the pools, PT2 and PT3 were out of the water by late May before the pools dried up. Both pools were observed to be completely dry during the next site visit, which occurred on June 13, 2022, and the pools no longer provided suitable habitat for juvenile steelhead.

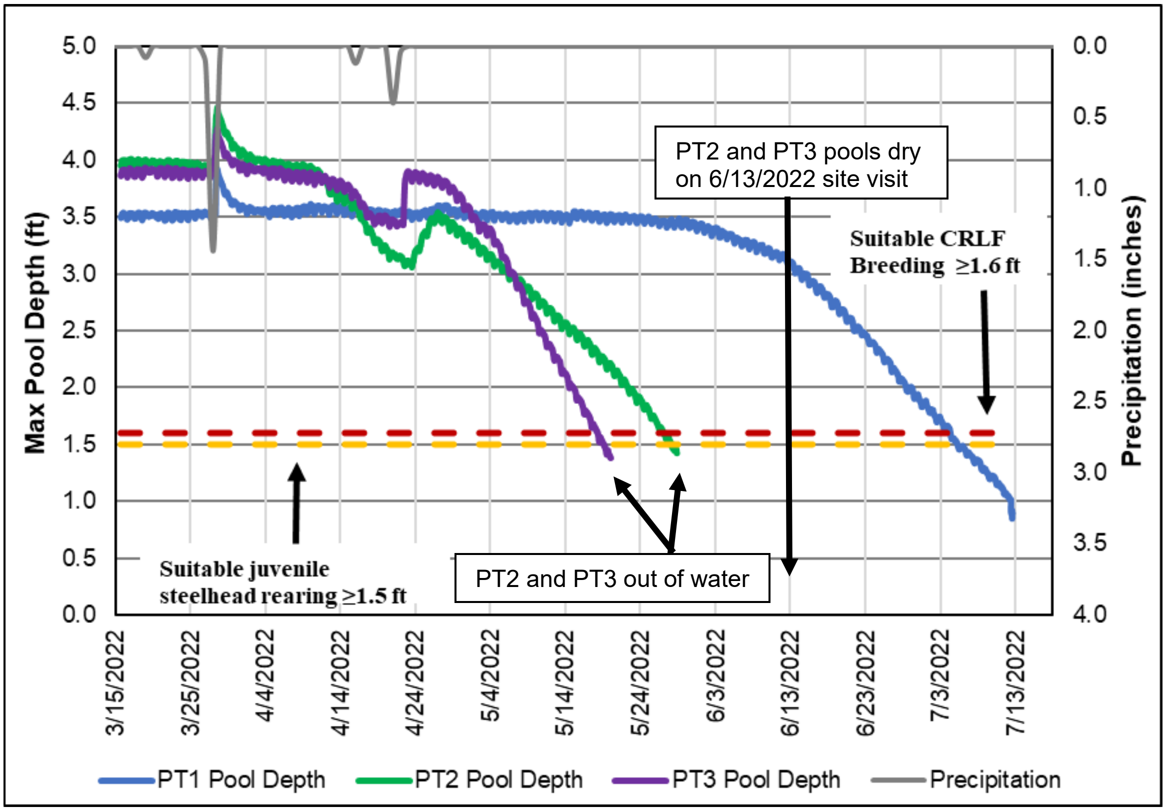

Figure 10. Pool depths in Pico Creek with depth thresholds for CRLF breeding and juvenile steelhead rearing.

** Note, pressure transducers were installed outside of the thalweg to prevent unit movement or loss during storm events and were installed above the stream bed to reduce sediment fouling of equipment, which resulted in Pressure transducers being 1.0 ft to 1.5 ft above the max pool depth.*

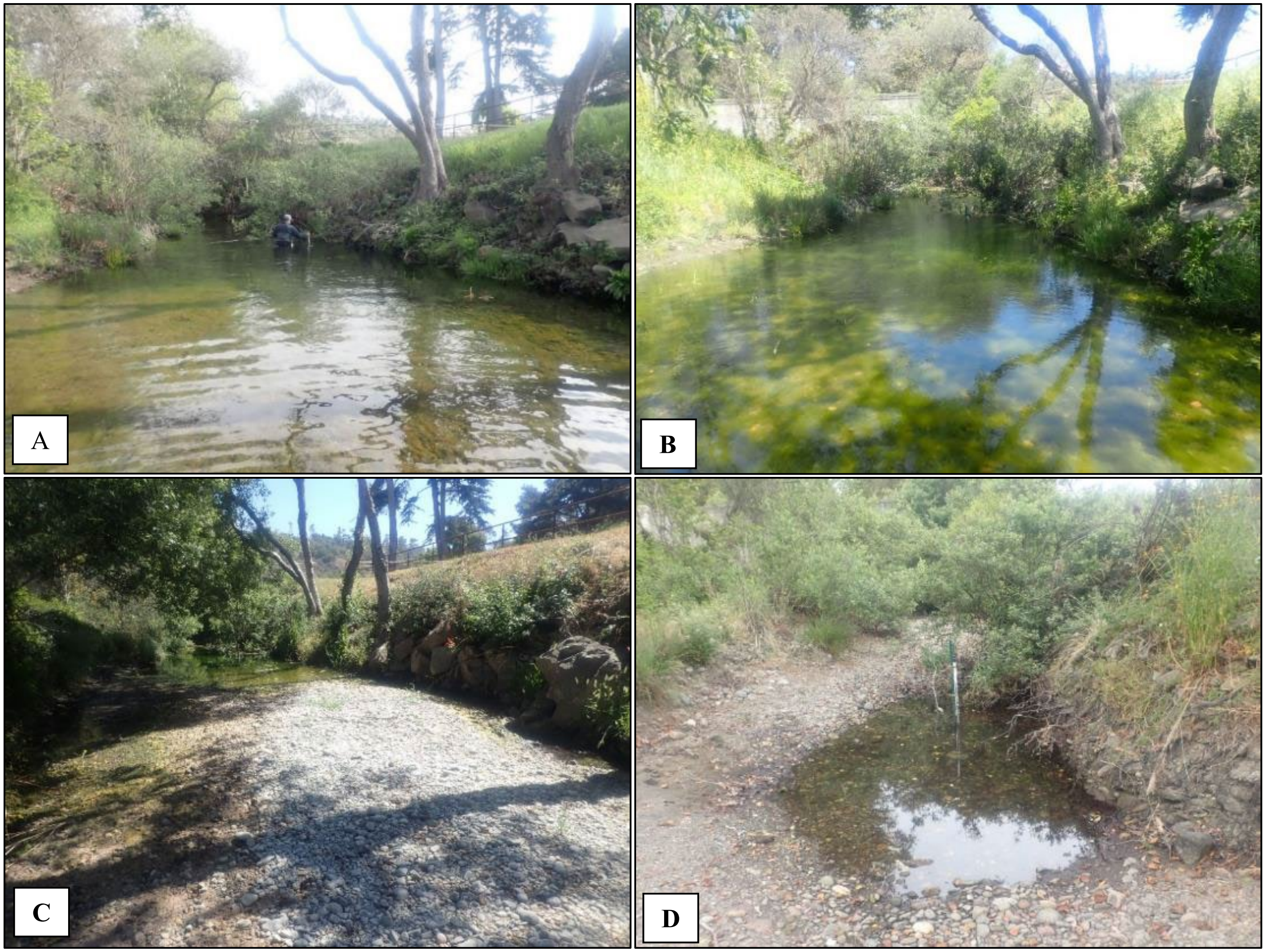

Figure 11. Looking upstream at pool where PT1 was installed on: (A) March 30 (0.86 cfs), (B) May 9 (0.05 cfs), (C) June 13 (0.0 cfs), and (D) July 12, 2022 (0.0 cfs).

Figure 12. Looking upstream at pool where PT2 was installed on: (A) March 30 (0.86 cfs), (B) April 15 (0.14 cfs), (C) May 9 (0.05 cfs), and (D) June 13, 2022 (0.0 cfs).

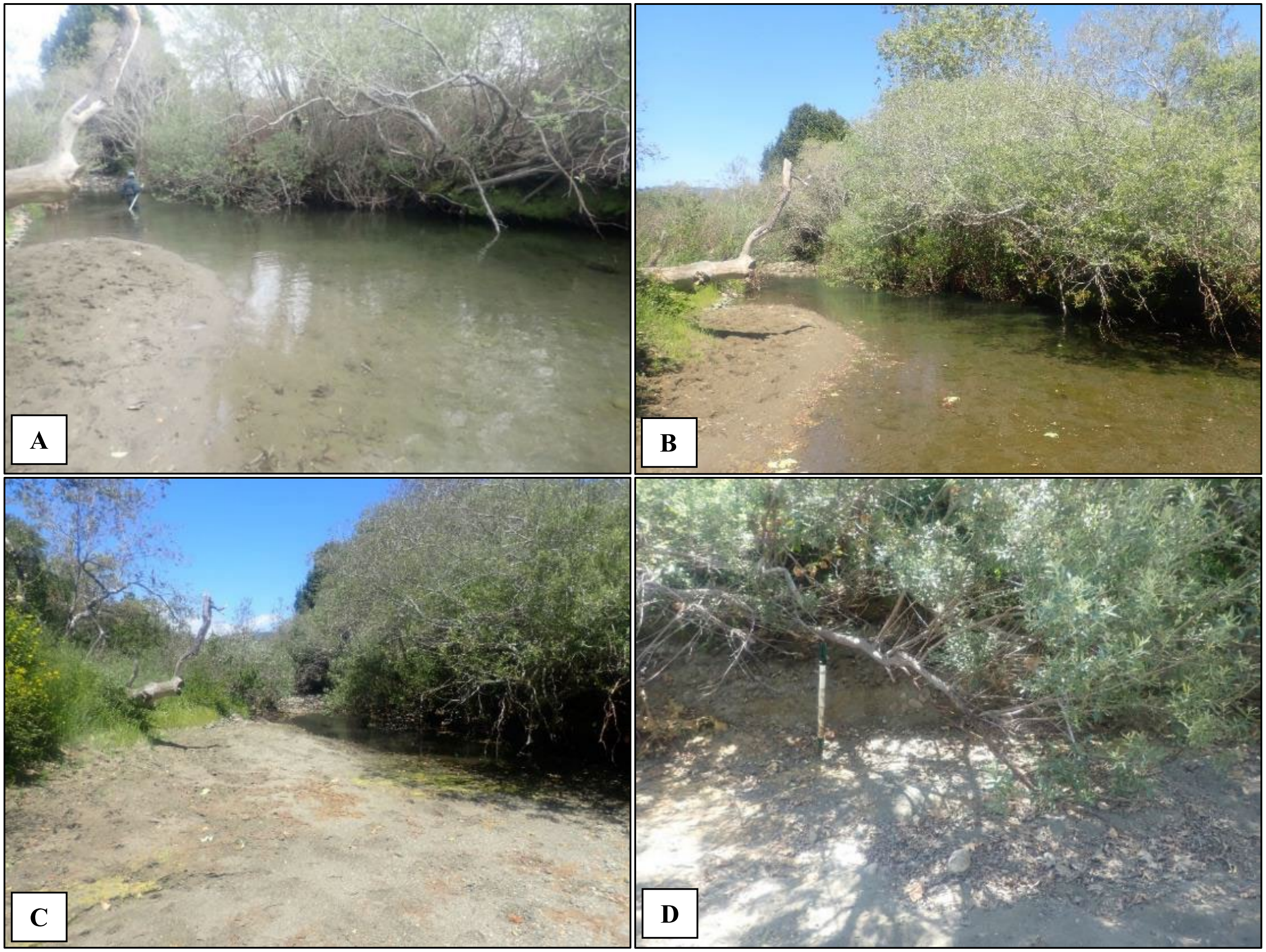

Figure 13. Looking upstream at pool where PT3 was installed on: (A) March 30 (0.86 cfs), (B) April 15 (0.14 cfs), (C) May 9 (0.05 cfs), and (D) June 13, 2022 (0.0 cfs).

4.2.1 Stage discharge ratings

Stream flow was measured throughout the study and ranged from 4.10 cfs on January 14, 2022 to 0.00 cfs on June 13, 2022 (Table 2). A stage discharge rating curve was applied to the pressure transducer stage levels collected at PT1 using the flow measurements collected after PT1 was installed in Pico Creek (March 13, 2022 and after). Estimated stream flow in Pico Creek at PT1 was less than 1.0 cfs for most of the monitoring period, with the exception of a brief spike in stream flow following a large rain event (>1.0 inches of precipitation) in late March 2022 (Figure 14).

Table 2. Stream flow measurements in Pico Creek downstream of the Pico Creek Road bridge.

Date	Stream Flow (cfs)	Notes
01/14/2022	4.10	Flow measured before pressure transducers were installed
2/8/2022	1.56	Flow measured before pressure transducers were installed
3/15/2022	0.35	Pressure transducers installed
3/30/2022	0.86	
4/15/2022	0.14	
4/28/2022	0.11	Outlier, removed from rating curve
5/9/2022	0.05	
6/13/2022	0.00	

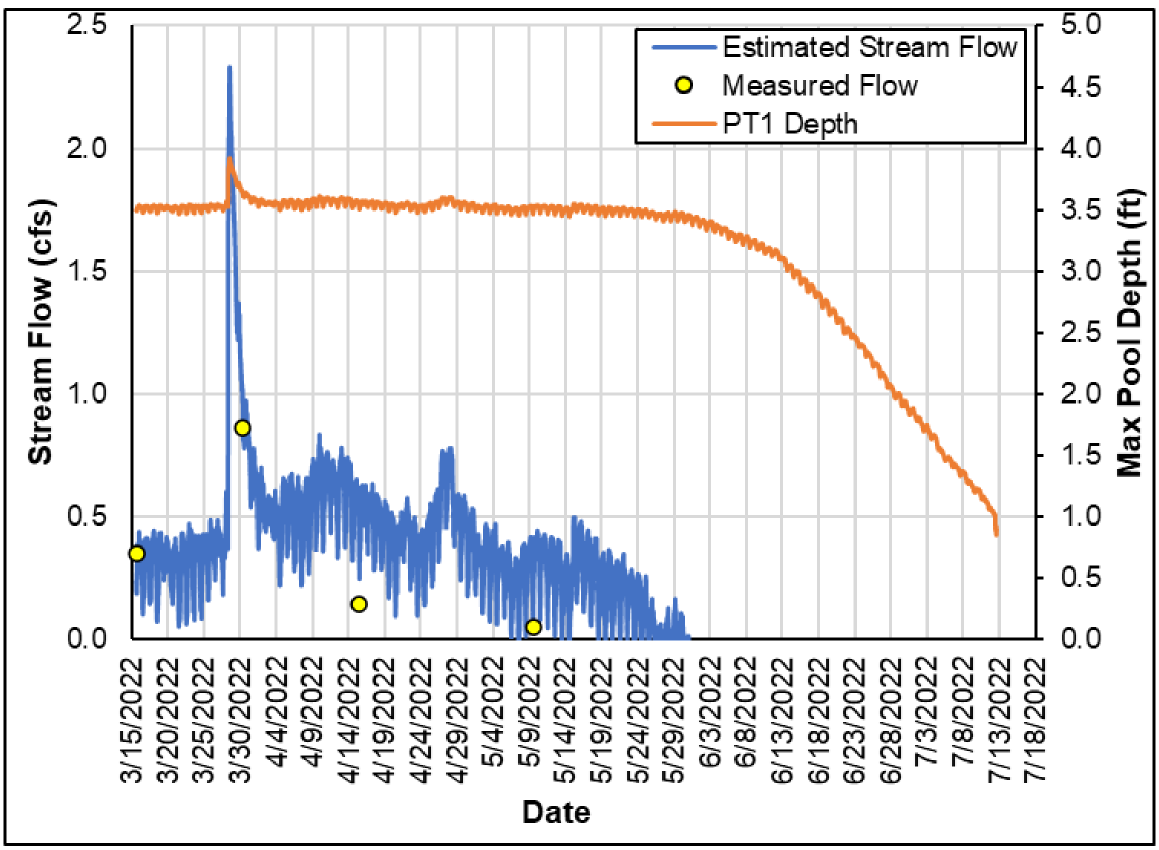

Figure 14. Estimated stream flow in Pico Creek based on stage discharge rating curve for PT1.

4.2.2 Water temperatures

Ambient temperature was recorded on PT1, PT2, and PT3 during the study. All three pools where pressures transducers were installed provided suitable water temperatures for steelhead and CRLF until the pools became dry. Stable and cool water temperatures were recorded on the PTs until pool depths began to decrease. As pool depths decreased, water temperatures became more responsive to the daily fluctuations in air temperature. The downstream end of the Study Reach remained wet later into summer than pools at the upstream end of the Study Reach. Water temperatures recorded at PT1, which remained under water throughout the study, never exceeded suitable levels for steelhead or CRLF (Figure 15) while water temperatures recorded at PT2 and PT3 remained suitable for steelhead and CRLF until they became dry in late May (Figure 16 and Figure 17).

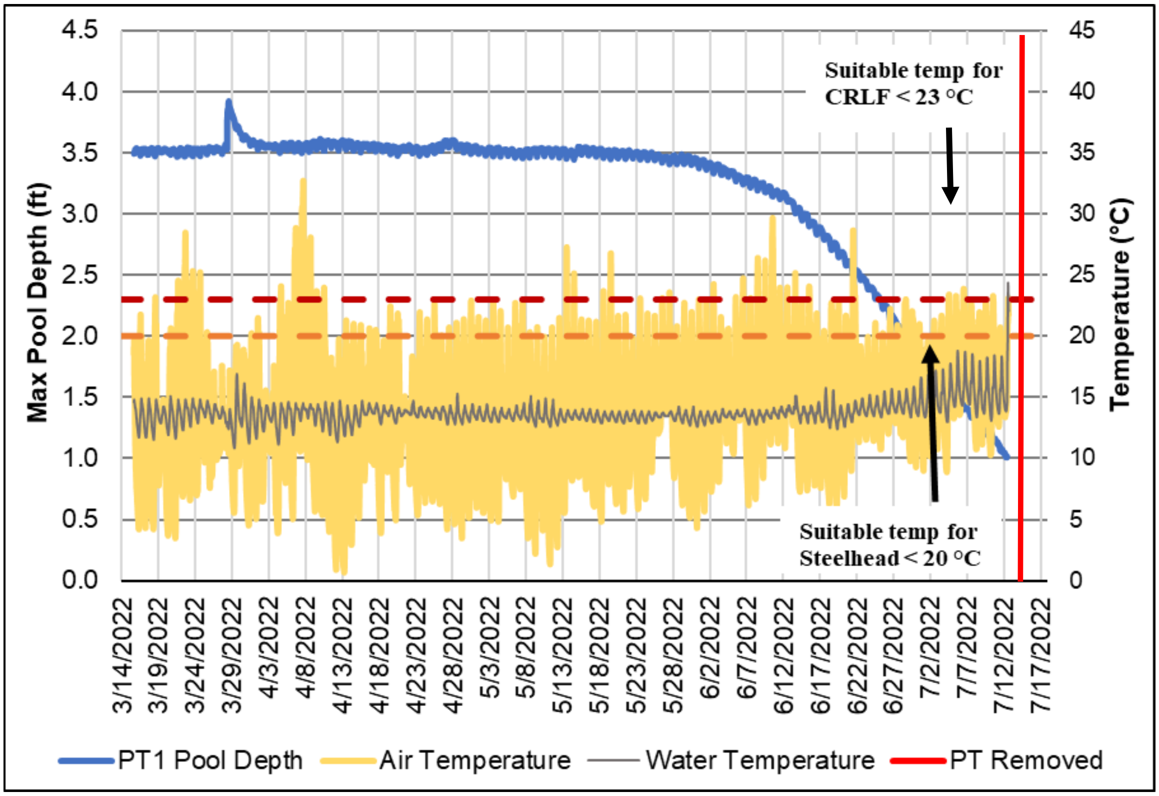

Figure 15. Pool depth and water temperature monitored at PT1.

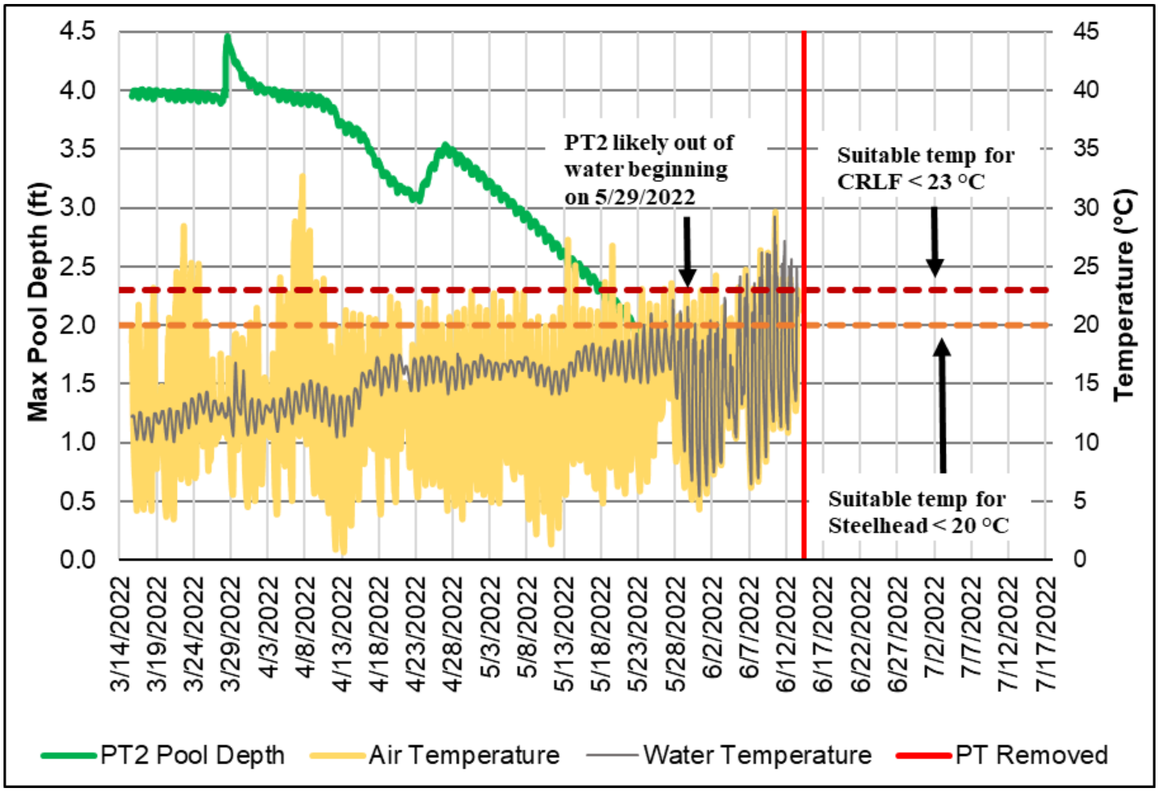

Figure 16. Pool depth and water temperature monitored at PT2.

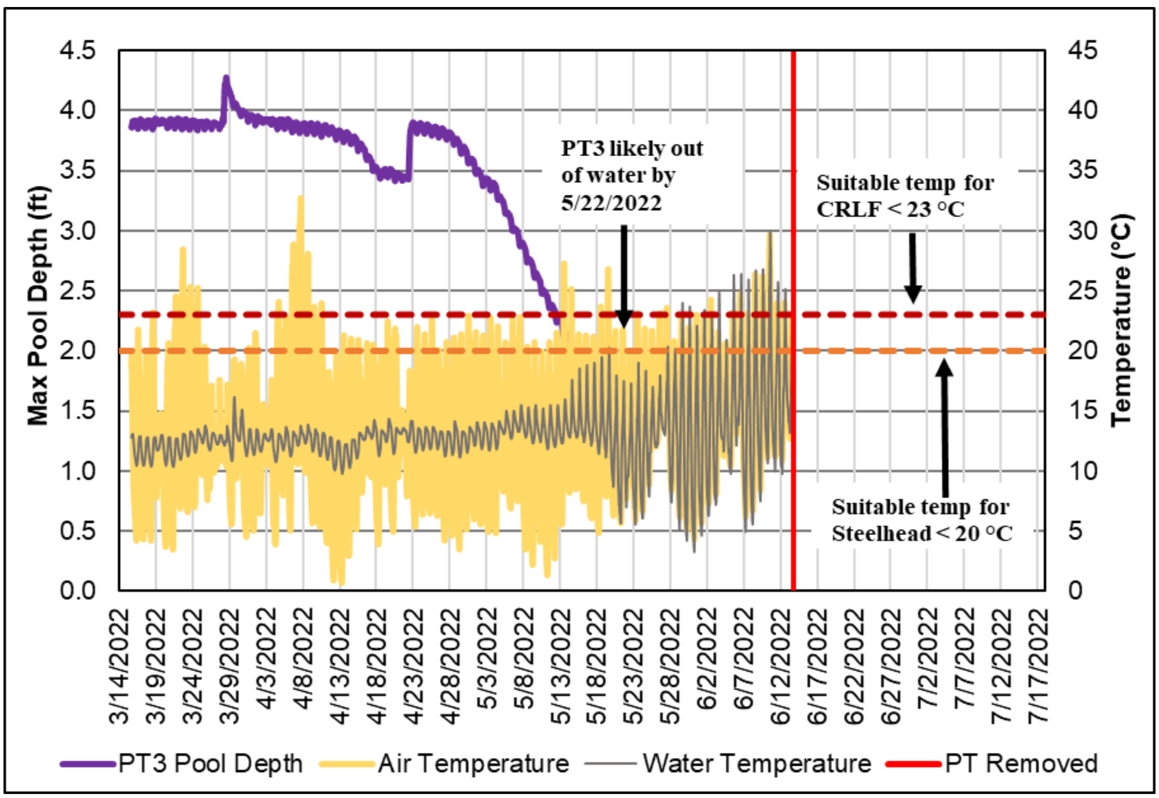

Figure 17. Pool depths and water temperature monitored at PT3.

4.3 Riffle Habitat Conditions

Observations from the riffle assessments were evaluated to understand what flows supported productive BMI habitat and passage conditions for juvenile steelhead within the Study Reach. Suitable conditions to support BMI production in riffles were observed at all riffles assessed when flows ranged from 4.10 cfs to 0.86 cfs. At flows of 0.35 cfs suitable BMI habitat was observed, although in substantially lower abundance than at higher flows. At flows less than 0.35 cfs, no suitable BMI habitat was observed at any of the riffles assessed (Table 3). Photos showing riffle conditions over a range of flows are included in Figures 18–23.

Flows that provide passage for juvenile steelhead likely occur throughout the Study Reach at flows of 4 cfs and greater. Suitable conditions for juvenile steelhead were observed at all riffles assessed at 4.10 cfs and at most riffles assessed at 1.56 cfs. At 0.86 cfs, conditions to support juvenile steelhead passage were observed at just over half of the riffles assessed. When flows were at 0.35 cfs and below, conditions did not provide passage for juvenile steelhead at any of the riffles assessed (Table 3).

Table 3. Results of Pico Creek riffle habitat assessment for BMI production and juvenile steelhead passage conditions observed during surveys conducted between January 14 through April 28, 2022. *Note, surveys were conducted through July 12, 2022 but conditions no longer supported BMI production or juvenile fish passage after the April 15, 2022 survey.*

Location		Jan. 14, 2022 (4.10 cfs)		Feb. 8, 2022 (1.56 cfs)		March 30, 2022 (0.86 cfs)		March 15, 2022 (0.35 cfs)		April 15, 2022 (0.14 cfs)		April 28, 2022 (0.11 cfs)	
Habitat unit number	**PPT#**	**BMI production**	**Juvenile passage**	**BMI production**	**Juvenile passage**	**BMI production**	**Juvenile passage**	**BMI production**	**Juvenile passage**	**BMI production**	**Juvenile passage**	**BMI production**	**Juvenile passage**
13	1*	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No
15	1	--	--	--	--	Yes	Yes	Yes	No	No	No	No	No
17	2	--	--	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
29	3	--	--	--	--	Yes	Yes	Yes	No	No	No	No	No
33	4	--	--	--	--	Yes	No	No	No	No	No	Dry	Dry
35	5	--	--	--	--	Yes	Yes	No	No	No	Dry	No	Dry
37	6	Yes	Yes	Yes	No	Yes	No	Dry	Dry	No	No	Dry	Dry
40	7	--	--	--	--	Yes	Yes	No	No	Dry	Dry	Dry	Dry
46	8	--	--	Yes	Yes	Yes	Yes	Yes	No	Dry	Dry	Dry	Dry
50	9	--	--	--	--	Yes	No	Yes	No	Yes	No	Yes	No

-- indicates location was not assessed on the specified date. Photo points were established on March 15, 2022; however, some locations were photographed during earlier surveys conducted at higher flows during January and February 2022.

Figure 18. Riffle habitat at PPT1* showing suitable BMI habitat and juvenile steelhead passage at 4.10 cfs (A) and 1.56 cfs (B), BMI habitat but no juvenile steelhead passage at 0.86 cfs (C), and no BMI habitat or juvenile steelhead passage at 0.11 cfs (D).

Figure 19. Riffle habitat at PPT1 showing suitable BMI habitat and juvenile steelhead passage at 0.86 cfs (A), BMI habitat but no juvenile steelhead passage at 0.35 cfs (B) and 0.11 cfs (C), and no BMI habitat or juvenile steelhead passage at 0.05 cfs (D).

Figure 20. Riffle habitat at PPT2 showing suitable BMI habitat and juvenile steelhead passage at 1.56 cfs (A) and 0.86 cfs (B), BMI habitat but no juvenile steelhead passage at 0.35 cfs (C), and no BMI habitat or juvenile steelhead passage at 0.14 cfs (D).

Figure 21. Riffle habitat at PPT6 showing suitable BMI habitat and juvenile steelhead passage at 4.10 cfs (A), BMI habitat but no juvenile steelhead passage at 1.56 cfs (B) and 0.86 cfs (C), and no surface flow when flows measured downstream were 0.35 cfs of less (D).

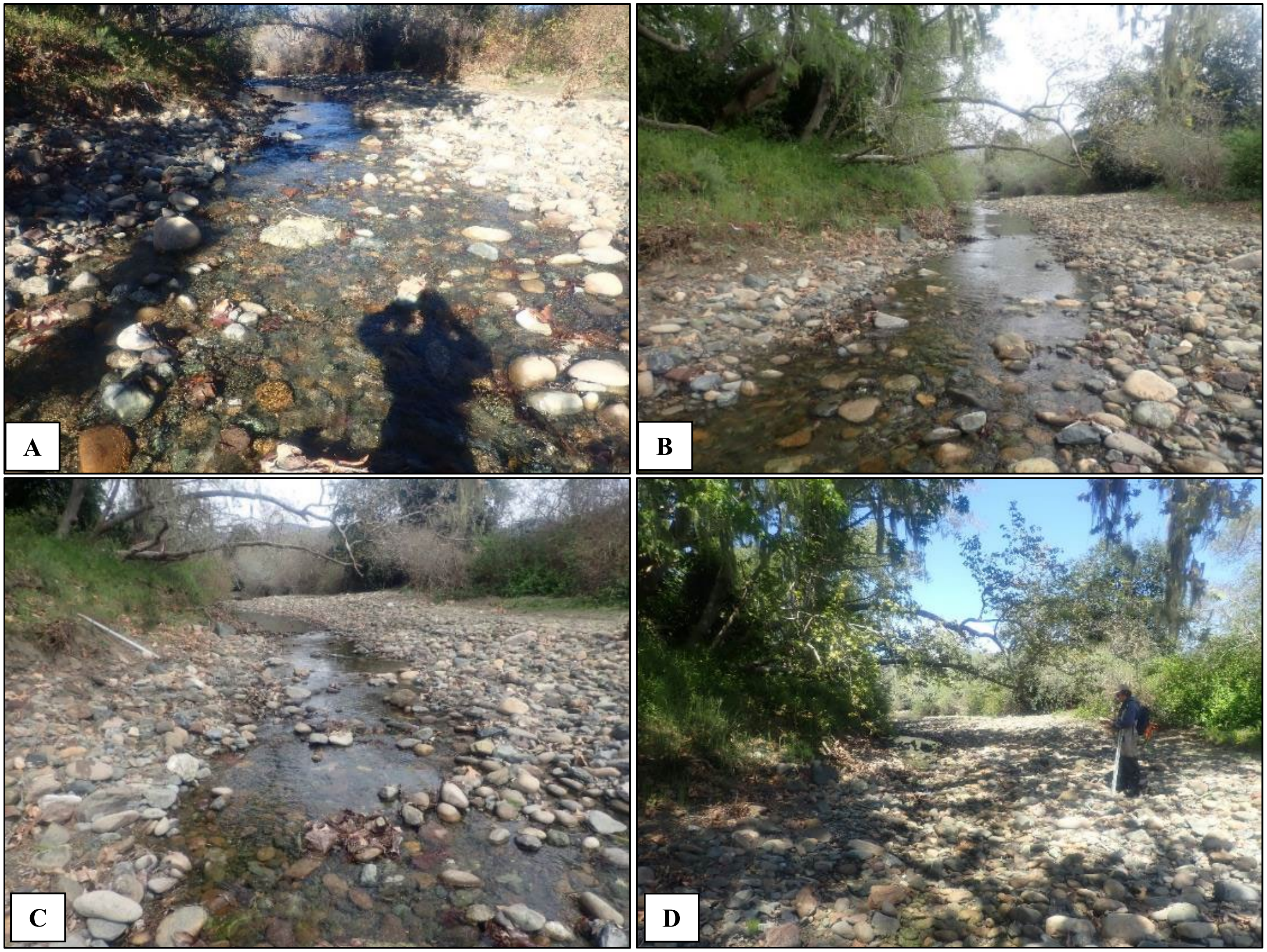

Figure 22. Riffle habitat at PPT8 showing suitable BMI habitat and juvenile steelhead passage at 1.56 cfs (A) and 0.86 cfs (B), BMI habitat but no juvenile steelhead passage at 0.35 cfs (C) and no surface flow when flows measured downstream were 0.14 cfs.

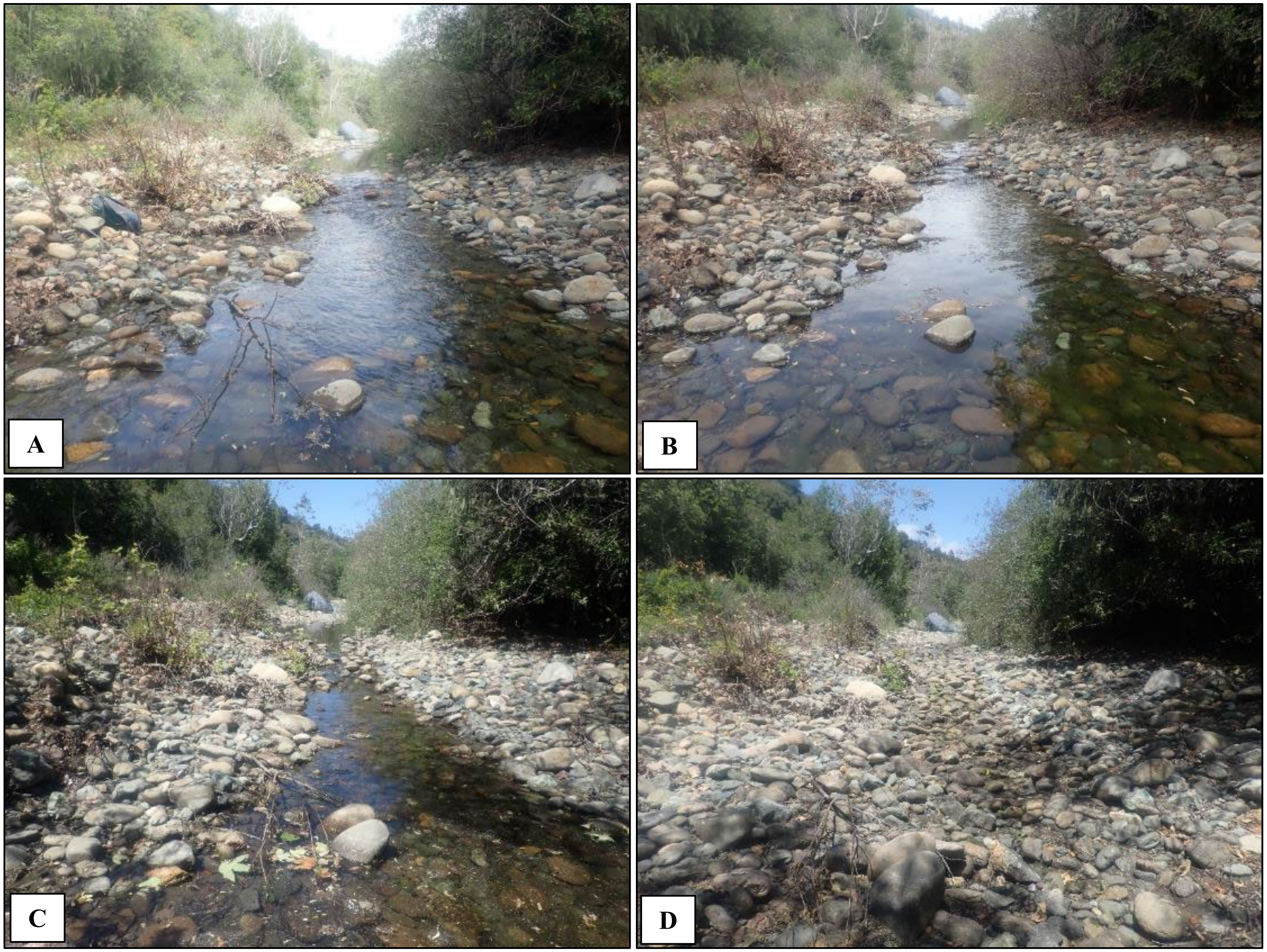

Figure 23. Riffle habitat at PPT9 showing suitable BMI habitat but no juvenile steelhead passage at 0.86 cfs (A), 0.35 cfs (B), and 0.14 cfs (C), and and no surface flow when flows measured downstream were 0.05 (D).

4.4 Wet and Dry Stream Channel Mapping

Observations of the stream channel drying out within the Study Reach were observed early in the study. The first observation of disconnected stream flow was observed during March 15, 2022 when a short segment within the middle of the Study Reach (at PPT6) was dry. Following a substantial rain event (1.44 inches) on March 28, 2022, surface flows were observed throughout the entire Study Reach. By April 15, 2022 dry stream channel conditions were observed in two sections within the upper half of the Study Reach and both sections were dry again on April 28, 2022, even after a 0.40 inch rain event occurred on April 21, 2022. On May 9, 2022 the upper half of the Study Reach had no surface flow and water was limited to a few isolated pools. On June 13, 2022, the upper half of the Study Reach was completely dry with no surface flow and no water in isolated pools upstream of the Pico Creek Bridge to the confluence of North Fork and South Fork Pico Creek (Figure 24 and Figure 25). No surface flow was observed throughout the Study Reach on July 12, 2022 but a few small isolated pools were observed between Pico Creek Road and the lagoon.

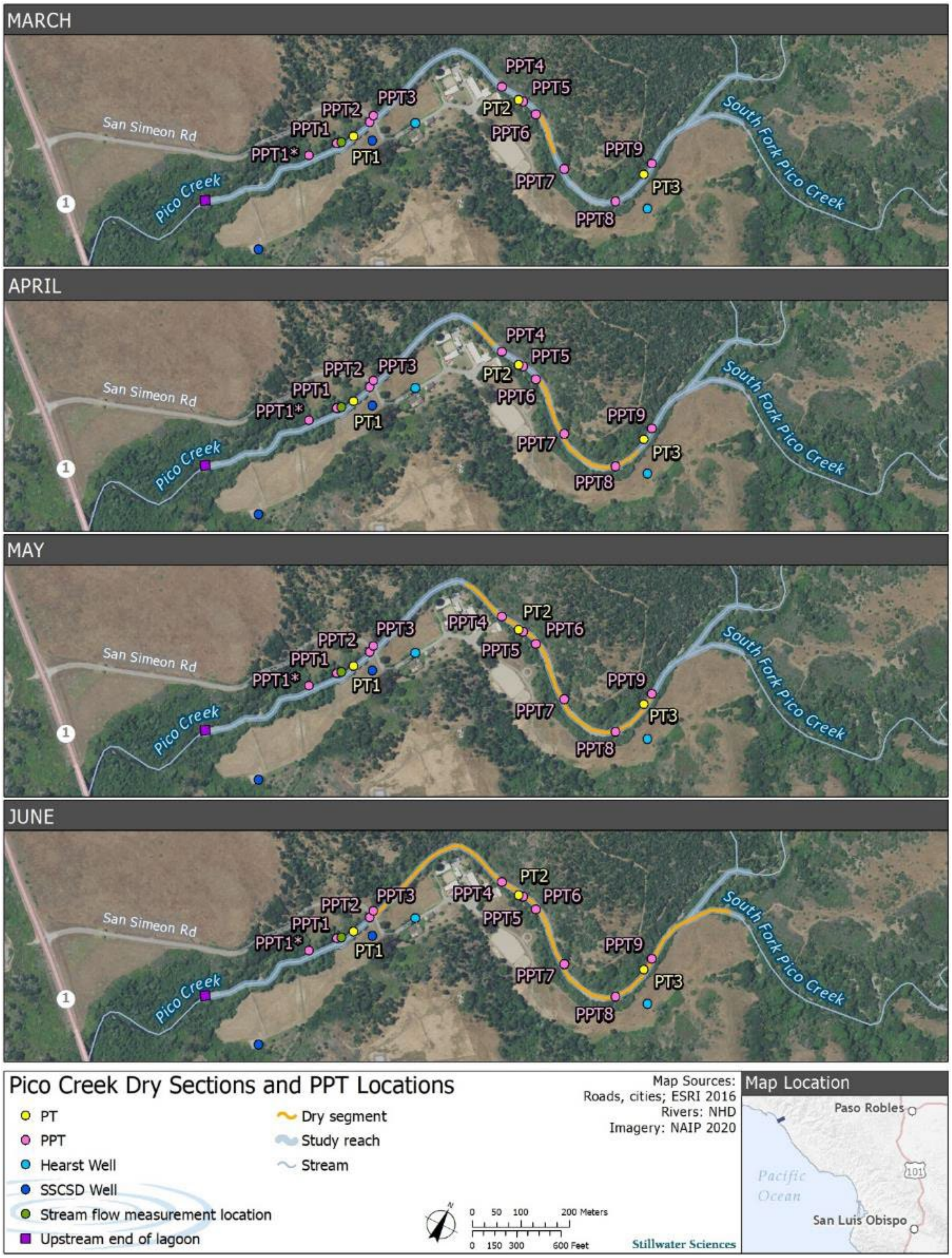

Figure 24. Pico Creek dry segment locations observed during surveys conducted during March through June 2022.

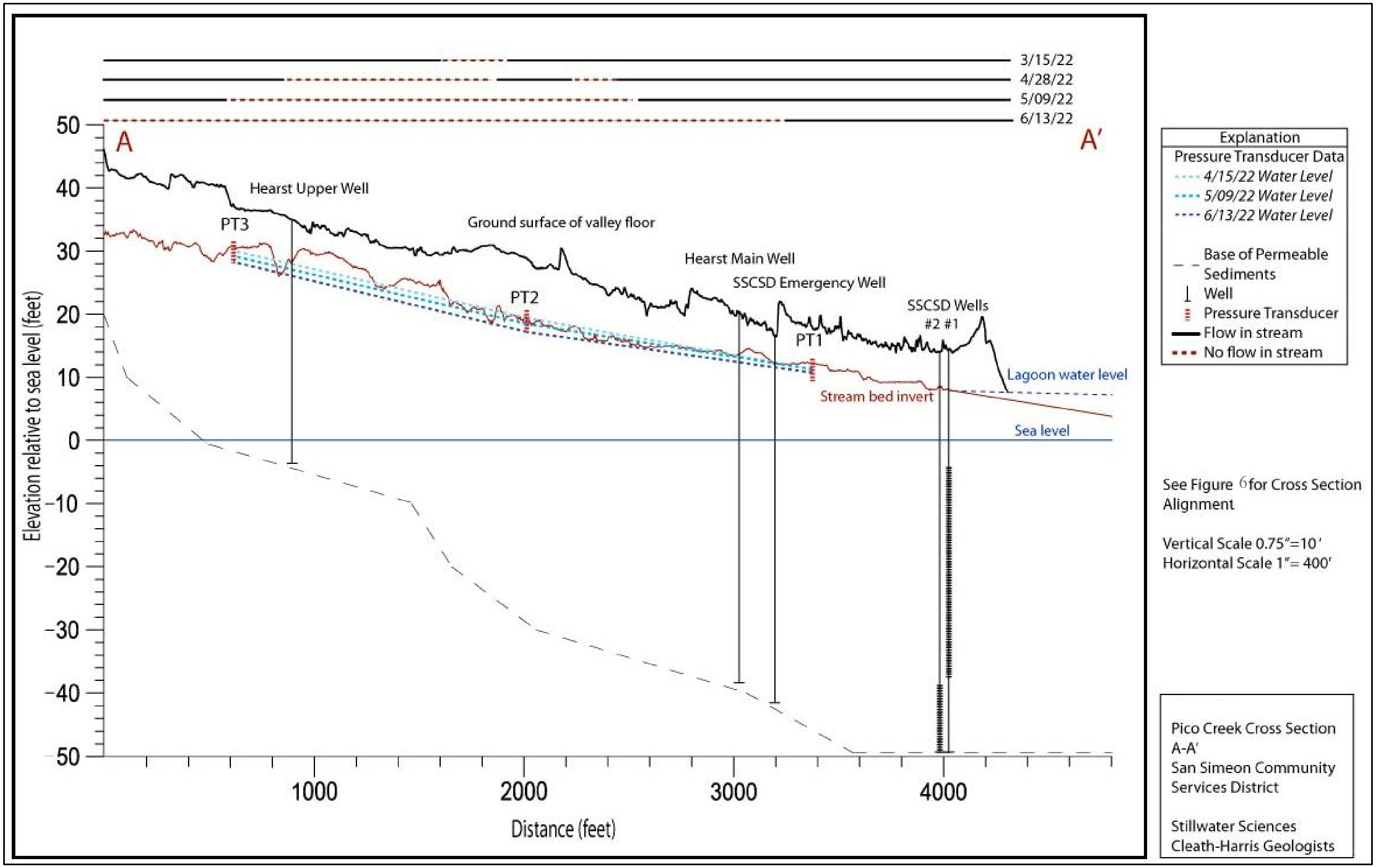

Figure 25. Pico Creek longitudinal elevation profile showing extent of intermittent stream flows in relation to groundwater wells along the Study Reach.

4.5 Surface Water/Groundwater Connectivity

Pump tests were conducted on April 16, 2022 at Well #1 which pumps from depths of 15–47 ft and on April 23, 2022 at Well #2 which pumps from depths of 50–60 ft. The volume of water pumped from the shallow well (Well #1) was 90,284 gallons and occurred over an 8-hour period (equivalent to a rate of 0.42 cfs). The volume of water pumped from the deep well (Well #2) was 108,834 gallons and occurred over a 9-hour period (equivalent to a rate of 0.45 cfs).

Stream flow during the pump tests at the upstream monitoring point was about half the rate at the downstream monitoring point. Stream flow measurements fluctuated during the tests up to roughly 0.20 cfs during testing at Well #1 and by roughly 0.05 cfs during testing at Well #2. However, the overall trend when the shallow well (Well #1) was pumped shows stream flows decrease by approximately 0.1 cfs at the upstream monitoring point while stream flow at the downstream monitoring point increased by approximately 0.1 cfs (Figure 26). The increase in flow observed downstream of the wells may be due to bank storage-drainage from the shallow aquifer into the stream channel. Stream flow at the upstream monitoring point of the deep well (Well #2) shows a decrease in stream flow of approximately 0.04 cfs, and no detectable trend in stream flow was observed at the downstream monitoring point (Figure 27). The sensor depth at PT1 for both tests declined by approximately 0.05 ft during pumping and then recovered after pumping ceased (Figure 26 and Figure 27). However, the fluctuation in sensor depth observed at PT1 during the pump tests were similar to the daily fluctuations observed during days when District well production was more than half the amount during the pump tests (Figure 28, see daily fluctuations for PT1 on 4/07/2022 and 4/25/2022 when daily well production was around 30,000 gallons).

Based on the daily fluctuations in sensor depths at all three PT sensors monitoring points, the drop in stage level observed at PT1 during the pump tests is likely in part due to evapotranspiration of phreatophyte/riparian vegetation that increases during the daylight hours and decreases as daily light fades. Steep declines in sensor depths observed at PT2 and PT3 began to occur in mid-April, which coincides with the timing when disconnected surface flow was increasing. A sharp increase in sensor depth occurred at PT2 on April 24, 2022 and at PT3 on April 23, 2022 (Figure 28), which are shortly after a 0.4 inch rain event occurred on April 21, 2022 that likely reconnected surface flow and refilled pool habitat (Figure 10). Overall, it appears that groundwater is connected to surface flows in the Study Reach, such that District pumping operations result in a small but detectable reduction in surface flow.

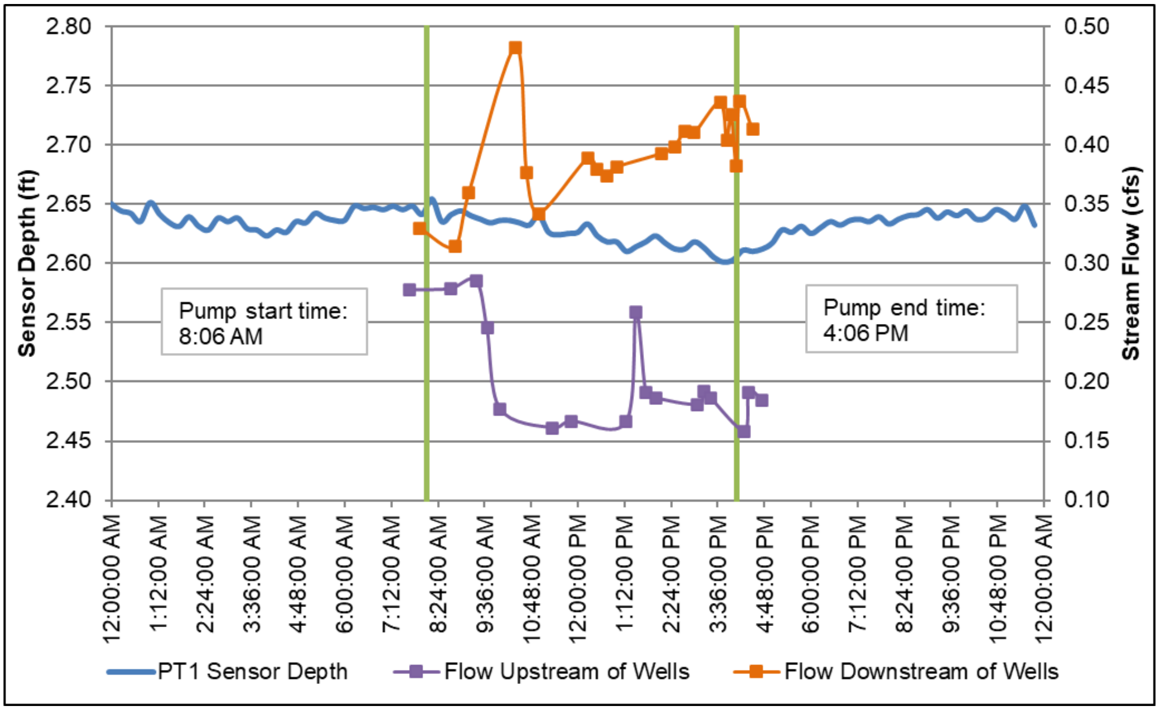

Figure 26. Pico Creek stream flow and PT1 sensor depths during April 16, 2022 pump test at District Well #1. Pumping volume on April 16, 2022 was 90,284 gallons, which is equivalent to a rate of 0.42 cfs.

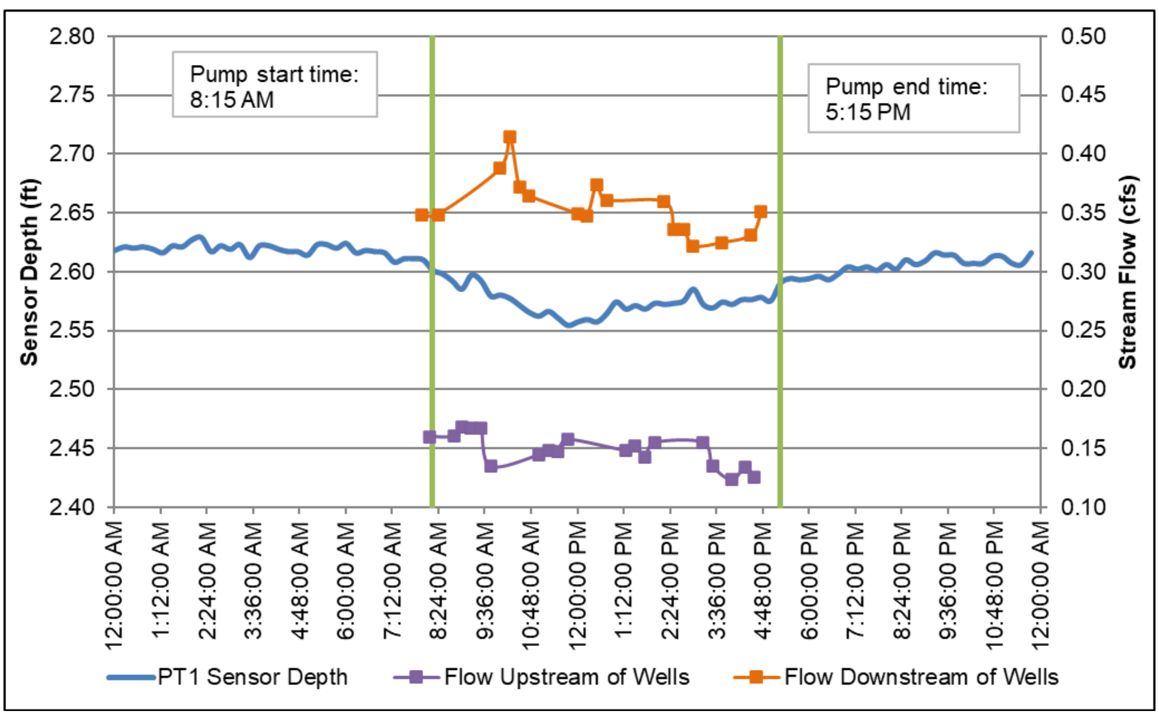

Figure 27. Pico Creek stream flow and PT1 sensor depths during April 23, 2022 pump test at District Well #2. Pumping volume on April 23, 2022 was 108,834 gallons, which is equivalent to a rate of 0.45 cfs.

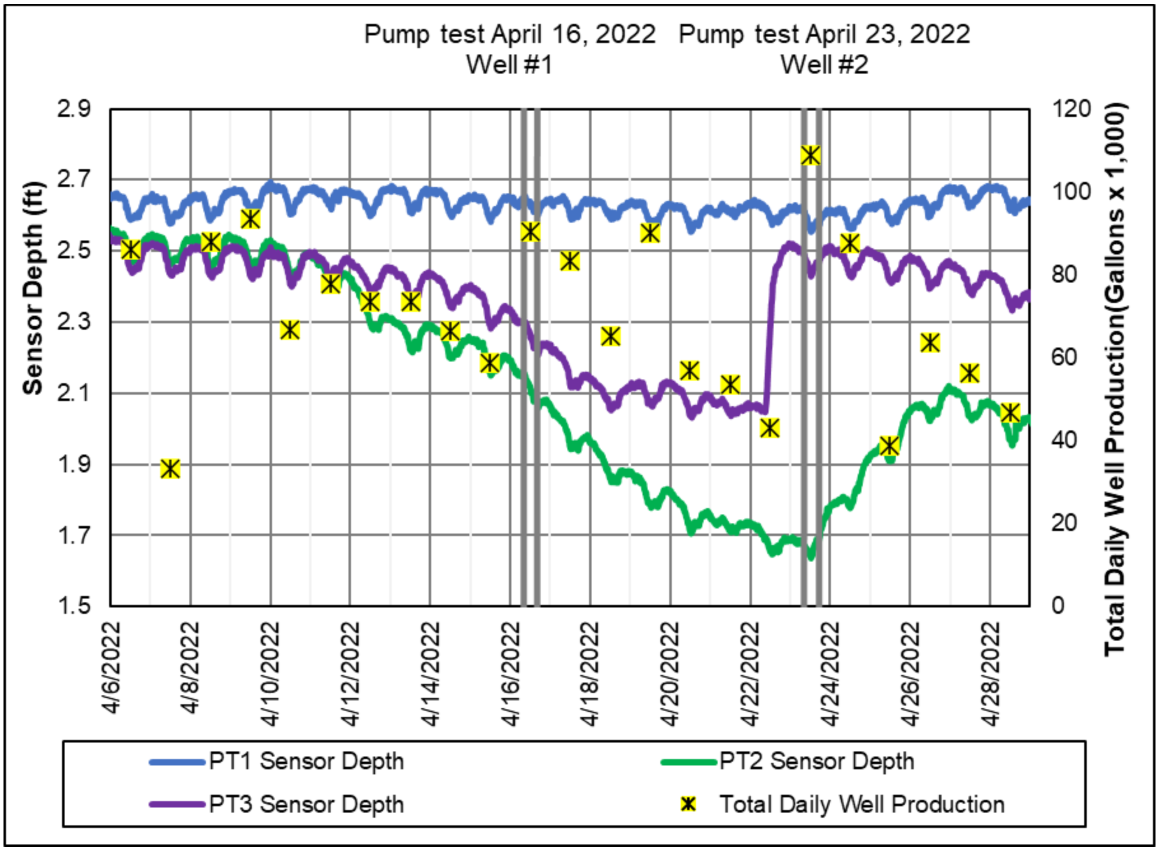

Figure 28. Pico Creek pressure transducer depths and daily well production during April 2022.

4.5.1 Lagoon habitat

The wetted area of the lagoon remained relatively stable throughout the study. The upstream end of the lagoon begins at the end of a gravel bar with the channel quickly dropping in elevation as it enters the lagoon (Figure 29).

Water levels recorded in the lagoon showed minor fluctuations (<0.05 ft) on a regular basis each day. These daily fluctuations appear to be correlated with ocean tide heights, as increased sensor depths were generally recorded at high tides while reduced depths were generally recorded at low tides (Figure 29 and Figure 30). Lagoon depths showed a temporal pattern with increased depths in the morning and decreased depths in the afternoon, which suggests evapotranspiration influences lagoon water levels as well.

The magnitude and timing of daily fluctuations in the lagoon water levels appeared similar during the pump tests compared to days when pumping was reduced. The fluctuation observed in lagoon water levels appears to be the result of tidal activity and evapotranspiration. No impact to the lagoon due to pumping was evident during the test.

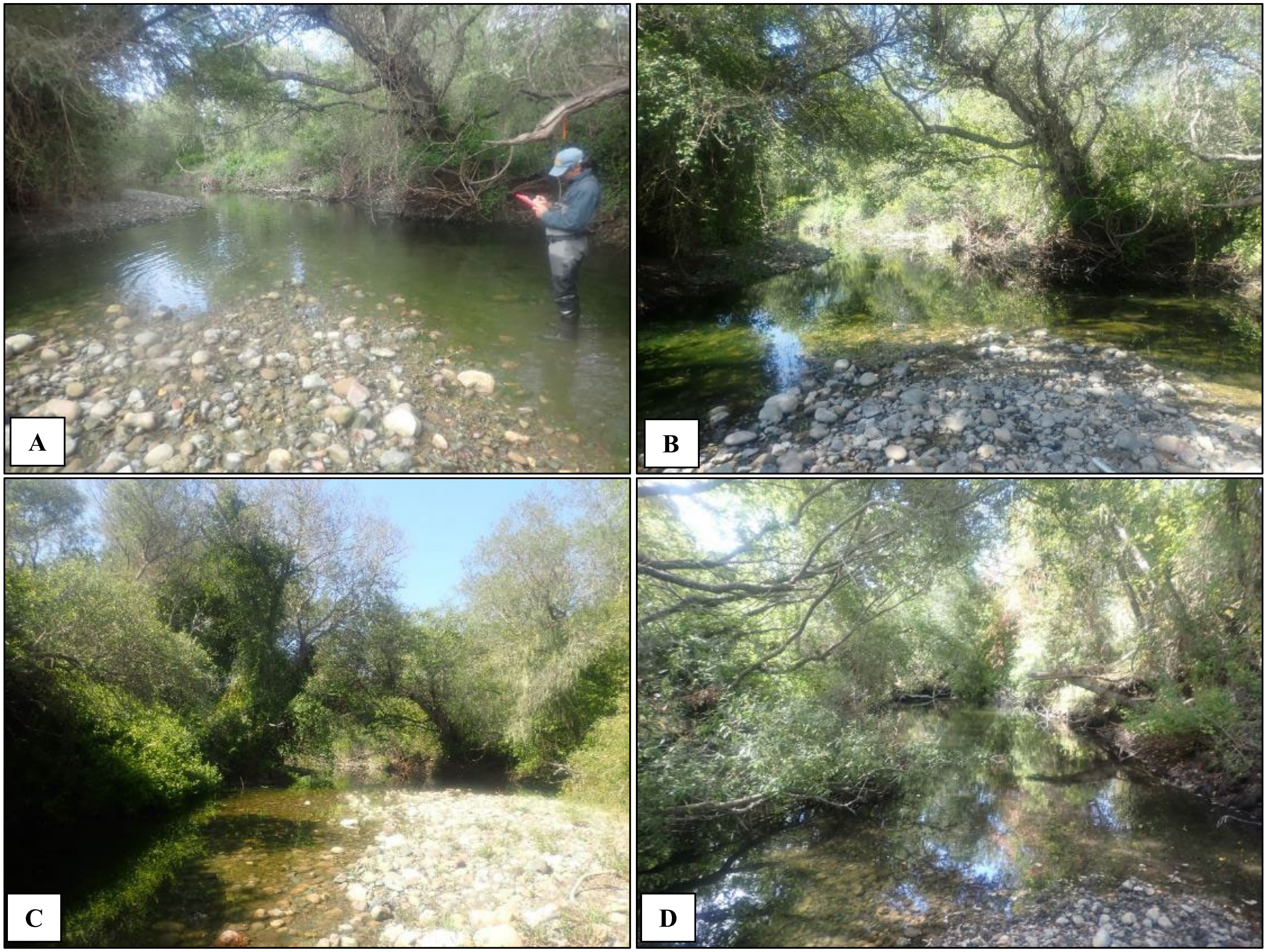

Figure 29. Upstream end of Pico Lagoon on March 30 (A), April 15 (B), April 28 (C), and July 12, 2022 (D).

Figure 30. Pico Creek Lagoon sensor depths during April 16, 2022 pump test at District Well #1.

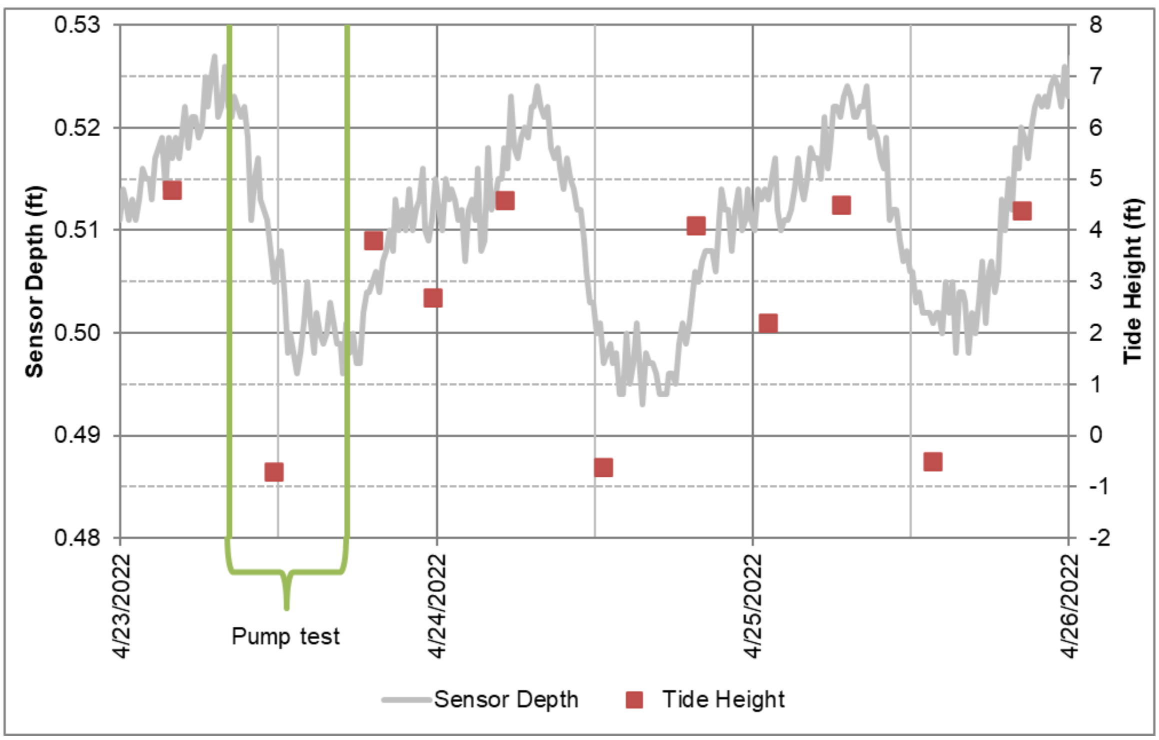

Figure 31. Pico Creek Lagoon sensor depths during April 23, 2022 pump test at District Well #2.

5 RECOMMENDATIONS FOR INSTREAM FLOW MANAGMENT

Pico Creek follows the northern side of the groundwater basin over much of the Study Reach. The basin sediments are highly permeable and allow for percolation of stream flow, particularly upstream of the Pico Creek Road Bridge. As the inflow from the watershed declines, the groundwater level also declines and typically by early summer Pico Creek upstream of the Pico Creek Road Bridge is dry. The stream channel, near where the District wells are located, has a longer duration of water presence than this upstream recharge area, but still dries by mid-summer. The lagoon at the mouth of Pico Creek has water year-round.

District pumping operations were observed to influence surface flows in Pico Creek in the vicinity of District pumps (i.e., downstream of the Pico Creek Road Bridge). Of the two main District wells, Well #1, which pumps water from shallower in the groundwater basin layer, has the most influence on surface flows, while Well #2, which pumps from the deeper groundwater basin layer, has less influence. Additional monitoring in the lagoon would be needed to evaluate if any changes in lagoon water depth are occurring due to pumping versus other natural factors, such as tidal influence or evapotranspiration. However, the level of lagoon water depth fluctuation observed during this study appeared to be minimal (<0.05 ft).

In the absence of District pumping operations, the lower reach of Pico Creek within the Study Area potentially provides migratory and rearing habitat for steelhead in the winter and spring when surface flows occur. Migration conditions for steelhead within the Study Area are expected to be supported under current District pumping operations. Adult steelhead passage, which requires high flows associated with large precipitation events, is not likely to be influenced by the District's maximum daily average pumping rate of 0.27 cfs. Juvenile steelhead passage conditions assessed in riffle habitat during this study indicate passage for juvenile steelhead occurs at flows of approximately 4 cfs and greater, which is also not likely to be influenced by District pumping operations due to the limited capacity of the District wells.

At low stream flows (less than 1.56 cfs), habitat in lower Pico Creek is sensitive to changes in surface flows. Results of the surface water monitoring and riffle habitat assessments found suitable rearing habitat for juvenile steelhead and potential BMI production is abundant at stream flows of 1.56 cfs and greater. When stream flows were at 0.86 cfs or less, habitat was disconnected with limited passage in riffles for juvenile steelhead, and at 0.35 cfs BMI habitat was substantially reduced. It appears that a small reduction in flow when stream flow is less than 1.56 cfs, even by a small amount (e.g., 0.1 cfs) would reduce the quantity and quality of juvenile steelhead habitat in lower Pico Creek by reducing food availability from BMI, migration conditions, and pool depth.

Pools in the Study Area provide suitable water depth and temperature for rearing juvenile steelhead when surface occurs. Once surface flows cease, pools quickly dry up and become unsuitable for juvenile steelhead. During this study, conditions in pool habitat appeared suitable for steelhead rearing until around July, at which time surface flows ceased and nearly all wetted habitat in the Study Reach went dry. Since pool habitat remains suitable after surface flows cease temporarily, District pumping operations increase the risk of steelhead stranding and desiccation in isolated pool habitat that remains wetted after surface flows cease.

In summary, based on pumping capacity, District pumping operations have the potential to reduce the amount and quality of juvenile steelhead rearing habitat within Study Area at flows of around 1.56 cfs or less. These results are consistent with estimates for spring environmental Water

Demand which are 0.9 cfs (Stillwater 2014). District pumping operations will not influence aquatic habitat in Pico Creek after the channel has gone dry.

In addition to steelhead, the Study Area provides abundant suitable breeding habitat for CRLF with many pool locations observed with habitat conditions that remained suitable through the CRLF breeding season. In isolated pools that remain wet after surface flows cease, District pumping operations are likely to increase the rate at which pool habitat dries out, leading to egg desiccation or tadpole stranding. Suitable habitat for CRLF breeding is located within the Pico Creek lagoon and excavated ponds near the lagoon just upstream of the Highway 1 Bridge.

Key conclusions of this study are listed below:

- District pumping operations appear to influence surface flows in lower Pico Creek
- District pumping operations are not expected to influence adult steelhead migration in Pico Creek due to the magnitude of flow required to support adult steelhead passage.
- District pumping operations are not expected to influence juvenile steelhead migration in Pico Creek due to the magnitude of flow required to support juvenile steelhead passage.
- At low stream flows, habitat in lower Pico Creek is sensitive to changes in surface flows, particularly when flows are at or below 1.56 cfs and stream flow reductions when flows are in this range lead to reduced habitat quantity and habitat quality for juvenile steelhead
- District pumping operations that occur after surface flows cease may affect juvenile steelhead and CRLF rearing in isolated pools by decreasing pool water levels or speeding up the process by which pools dry out increasing the risk of stranding for juvenile steelhead and CRLF tadpoles.
- District 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 summer and fall.
- District pumping operations do not appear to be affecting or reducing habitat conditions within the lagoon.
- District pumping operations do not appear to be affecting or reducing habitat conditions for tidewater goby.

During this study we made empirical measurements at 0.86 cfs and 1.56 cfs. Rearing habitat was abundant at 1.56 cfs and beginning to decline at 0.86 cfs. In a related regional assessment of instream flow needs for steelhead, Stillwater Sciences (2014) estimated that flow needs for steelhead in lower Pico Creek would be protected during spring at 0.9 cfs. Taking all of this available data and observations into account, we infer that pumping operations at flows less than 1.56 cfs likely reduce habitat suitability for steelhead. Therefore, our recommendations for District pumping operations to provide protection to steelhead include restricting pumping during periods when stream flows are between 0.0 and 1.56 cfs year-round. Avoiding pumping when stream flows are between 0.0 cfs and 1.56 cfs will protect downstream migration for juvenile steelhead, habitat connectivity, and habitat quality and quantity for juvenile steelhead within the Study Area year-round.

In addition to recommending operational changes, we also recommend long term monitoring of stream flow in Pico Creek near the District wells using a stream gage that provides real-time information. Stream flow data is recommended to help inform pumping operations during sensitive flow conditions (i.e., 0 to 1.56 cfs) and to develop a long-term record of stream flows in the watershed. The most suitable location for real-time stream gage monitoring is just upstream of the District wells at the Pico Creek Road Bridge.

If District pumping operations are restricted when stream flows are between 0.0 cfs and 1.56 cfs and District pumping from the Pico Creek groundwater basin only occurs outside this range of stream flows, then no further recommendations are provided. However, if pumping occurs during these sensitive stream flows, we also recommend the District monitor isolated pool habitat within the Study Area as surface flows cease to evaluate potential fish stranding and fish health.

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