# Russian River Biological Opinion Status and Data Report

**Year 2018 – 2019**

Sonoma Water

**October 2022**

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# CHAPTER 1 Introduction

On September 24, 2008, the National Marine Fisheries Service (NMFS) issued a 15-year Biological Opinion for water supply, flood control operations, and channel maintenance conducted by the U.S. Army Corps of Engineers (USACE), Sonoma County Water Agency (Sonoma Water), and Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed (NMFS 2008). The Biological Opinion authorizes incidental take of threatened and endangered Chinook salmon, coho salmon, and steelhead pending implementation of a Reasonable and Prudent Alternative (RPA) to status quo management of reservoir releases, river flow, habitat condition, and facilities in portions of the mainstem Russian River, Dry Creek, and Russian River Estuary. Mandated projects to ameliorate impacts to listed salmonids in the RPA are partitioned among USACE and Sonoma Water. Each organization has its own reporting requirements to NMFS. Because coho salmon are also listed as endangered by the California Endangered Species Act (CESA), Sonoma Water is party to a Consistency Determination issued by the California Department of Fish and Wildlife (CDFW) in November 2009. The Consistency Determination mandates that Sonoma Water implement a subset of Biological Opinion projects that pertain to Coho Salmon and Sonoma Water is required to report progress on these efforts to CDFW.

Project implementation timelines in the Biological Opinion, and Consistency Determination, specify Sonoma Water reporting requirements to NMFS and CDFW and encourage frequent communication among the agencies. Sonoma Water has engaged both NMFS and CDFW in frequent meetings and has presented project status updates on many occasions since early 2009. Although not an explicit requirement of the Biological Opinion or Consistency Determination, Sonoma Water has elected to coalesce reporting requirements into one annual volume for presentation to the agencies. The following document represents the tenth report for year 2018-2019. Previous annual reports can be accessed at http://www.sonomawater.gov.

Sonoma Water projects mandated by the Biological Opinion and Consistency Determination fall into six major categories:

- Biological and Habitat Monitoring;
- Habitat Enhancement;
- California Environmental Quality Act (CEQA) Compliance and Permitting;
- Planning and Adaptive Management;
- Water and Fish Facilities Improvements; and
- Public Outreach.

This report contains status updates for planning efforts, environmental compliance, and outreach but the majority of the technical information we present pertains to monitoring and habitat enhancement. The Biological Opinion requires extensive fisheries data collection in the mainstem Russian River, Dry Creek, and Estuary to detect trends and inform habitat enhancement efforts. The report presents each data collection effort independently and the primary intent of this document is to clearly communicate recent results. However, because

Chinook salmon, coho salmon, and steelhead have complex life history patterns that integrate all of these environments, we also present a synthesis section to discuss the interrelated nature of the data. Some monitoring programs are extensions of ongoing Sonoma Water efforts that were initiated a decade or more before receipt of the Biological Opinion.

## References

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation District in the Russian River Watershed. September 24, 2008.

# CHAPTER 2 Public Outreach

## Biological Opinion Requirements

The Biological Opinion includes minimal *explicit* public outreach requirements. The breadth and depth of the RPAs, however, *implies* that implementation of the Biological Opinion will include a robust public outreach program.

RPA 1 (Pursue Changes to D1610 Flows) mandates two outreach activities. First, it requires Sonoma Water, with the support of NMFS staff, to conduct outreach "to affected parties in the Russian River watershed" regarding permanently changing Decision 1610. Second, the RPA requires Sonoma Water to update NMFS on the progress of temporary urgency changes to flows during Section 7 progress meetings and as public notices and documents are issued.

RPA 2 (Adaptive Management of the Outlet Channel) requires that within six months of the issuance of the Biological Opinion, Sonoma Water, in consultation with NMFS, "conduct public outreach and education on the need to reduce estuarine impacts by avoiding mechanical breaching to the greatest extent possible."

Finally, RPA 3 (Dry Creek Habitat Enhancements, refers to public outreach in the following mandate, "Working with local landowners, DFG[1] and NMFS, Water Agency[2] will prioritize options for implementation" of habitat enhancement.

The remaining RPAs do not mention public outreach.

## Sonoma Water Public Outreach Activities – 2018

### Meetings

*Public Policy Facilitating Committee (PPFC) meeting* - The PPFC met in February 2018 at the Lake Sonoma Visitors Center, and included a walking tour of one reach of the Dry Creek Habitat Enhancement Project. Notices for the meetings were sent out to approximately 800 individuals and agencies and a press release was issued. Approximately 50 people attended the meeting and about 20 went on the walking tour (which was held in the rain).

In 2018, the meeting included a presentation by Jessica Martini Lamb (Sonoma Water) on the Fish Flow Habitat and Water Rights Project and Russian River Estuary Adaptive Management, followed by a presentation by David Manning (Sonoma Water) on the Dry Creek Habitat Enhancement Project.

*Community Meetings, Events & Tours* – The tenth Russian River Estuary Lagoon Management Community Meeting was held on May 31, 2018 at the Jenner Community Center. The meeting included discussions of 2017 Lagoon Management efforts and the 2018 plan (Martini Lamb);

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[1] DFG (Department of Fish and Game) is now known as the California Department of Fish and Wildlife.

[2] Water Agency (Sonoma County Water Agency) is now know as Sonoma Water.

results from 2017 water quality monitoring and 2018 plans (Jeff Church, Sonoma Water); pinniped monitoring (Andrea Pecharich, Sonoma Water); and the beach morphology of the Goat Rock Beach. About 30 people attended the meeting.

A community meeting on Dry Creek habitat enhancement was held in February 2018, following a Dry Creek walking tour and the PPFC meeting. The meeting was co-hosted by the Dry Creek Valley Association, the Winegrape Growers of Dry Creek, the USACE and Sonoma Water. Informational mailers were sent to more than 700 people and about 55 people attended (primarily Dry Creek residents). Manning provided an overview of the project.

Tours held for public officials and others (coordinated with NMFS, DFG, Corps and Sonoma Water staff) included PPFC members, Sonoma Water's water contractors, representatives from the Governor's Office (Michal McCormick, Debbie Franco and Greta Soos) and climate change officials from the Western Cape government. The Dry Creek Habitat Enhancement was featured in a tour of approximately 45 people that was held in conjunction with the Global Climate Action Summit. Attendees include Assemblymember Cecilia Aguiar-Curry, representatives from USGS, California's Natural Resources Agency, Bangladesh, and Puerto Rico. In addition, the Mirabel Fish Passage Improvement Project was featured in the Water Education field tours, introducing more than 1,000 students to the project and its purpose. Other Outreach

*Free Media* – In 2018, press releases were issued on community meetings regarding the estuary and Dry Creek, the Public Policy Facilitating Committee meeting and possible flooding in Jenner (December 2018, when the river mouth closed). The Water Advisory Committee (comprised of elected officials from cities and water districts that receive water from Sonoma Water) received Monthly Updates of Biological Opinion activities.

*Electronic Media* – Sonoma Water continually updated its Biological Opinion webpage, including links on new documents and meetings. Email alerts regarding activities in the estuary were issued about half a dozen times in 2018.

*Materials* – 2018 kicked off planning efforts for both a series of graphic images and videos to supplement the Fish Flow project and a permanent exhibit for the Mirabel Fish Passage Improvement Project.

Nearly 800 copies of the Dry Creek Habitat Enhancement Bulletin were mailed to residents throughout the Dry Creek Valley and distributed at meetings and during tours. The four-page newsletter covered topics including: Plans for construction of habitat features in the summer of 2018 and an article on the use of drone for habitat monitoring.

# CHAPTER 3 Pursue Changes to Decision 1610 Flows

Two major reservoir projects provide water supply storage in the Russian River watershed: 1) Coyote Valley Dam/Lake Mendocino, located on the East Fork of the Russian River three miles east of Ukiah, and 2) Warm Springs Dam/Lake Sonoma, located on Dry Creek 14 miles northwest of Healdsburg. Sonoma Water is the local sponsor for these two federal water supply and flood control projects, collectively referred to as the Russian River Project. Under agreements with the USACE, Sonoma Water manages the water supply storage space in these reservoirs to provide a water supply and maintain summertime Russian River and Dry Creek streamflows.

Sonoma Water holds water-right permits[1] issued by the State Water Resources Control Board (SWRCB) that authorize the Sonoma Water to divert[2] Russian River and Dry Creek flows and to re-divert[3] water stored and released from Lake Mendocino and Lake Sonoma. Sonoma Water releases water from storage in these lakes for delivery to municipalities, where the water is used primarily for residential, governmental, commercial, and industrial purposes. The primary points of diversion include Sonoma Water's facilities at Wohler and Mirabel Park (near Forestville). Sonoma Water also releases water to satisfy the needs of other water users and to contribute to the maintenance of minimum instream flow requirements in the Russian River and Dry Creek established in 1986 by the SWRCB's Decision 1610. These minimum instream flow requirements vary depending on specific hydrologic conditions (normal, dry, and critical) that are based on cumulative inflows into Lake Pillsbury in the Eel River watershed.

NMFS concluded in the Russian River Biological Opinion that the artificially elevated summertime minimum flows in the Russian River and Dry Creek currently required by Decision 1610 result in high water velocities that reduce the quality and quantity of rearing habitat for coho salmon and steelhead. NMFS' Russian River Biological Opinion concludes that reducing Decision 1610 minimum instream flow requirements will enable alternative flow management scenarios that will increase available rearing habitat in Dry Creek and the upper Russian River, and provide a lower, closer-to-natural inflow to the estuary between late spring and early fall, thereby enhancing the potential for maintaining a seasonal freshwater lagoon that would likely support increased production of juvenile steelhead and salmon.

Changes to Decision 1610 are under the purview of the SWRCB, which retained under Decision 1610 the jurisdiction to modify minimum instream flow requirements if future fisheries studies identified a benefit. NMFS recognized that changing Decision 1610 would require a multi-year (6 to 8 years) process of petitioning the SWRCB for changes to minimum instream flow

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[1] SWRCB water-right permits 12947A, 12949, 12950 and 16596.
[2] Divert – refers to water diverted directly from streamflows into distribution systems for beneficial uses or into storage in reservoirs.
[3] Re-divert – refers to water that has been diverted to storage in a reservoir, then is released and diverted again at a point downstream.

requirements, public notice of the petition, compliance with CEQA, and a SWRCB hearing process. To minimize the effects of existing minimum instream flows on listed salmonids during this process, the Russian River Biological Opinion stipulated that Sonoma Water “will seek both long term and interim changes to minimum flow requirements stipulated by D1610.” The permanent and temporary changes to Decision 1610 minimum instream flow requirements specified by NMFS in the Russian River Biological Opinion are summarized in Figure 3.1.

# Permanent Changes

The Russian River Biological Opinion requires Sonoma Water to begin the process of changing minimum instream flows by submitting a petition to change Decision 1610 to the SWRCB within one year of the date of issuance of the final Biological Opinion. Sonoma Water filed a petition with the SWRCB on September 23, 2009, to permanently change Decision 1610 minimum instream flow requirements. The requested changes are to reduce minimum instream flow requirements in the mainstem Russian River and Dry Creek between late spring and early fall during normal and dry water years and promote the goals of enhancing salmonid rearing habitat in the upper Russian River mainstem, lower river in the vicinity of the Estuary, and Dry Creek downstream of Warm Springs Dam. NMFS’ Russian River Biological Opinion concluded that, in addition to providing fishery benefits, the lower instream flow requirements “should promote water conservation and limit effects on in-stream river recreation.” NMFS’ recommended changes, based on observations during the 2001 interagency flow-habitat study and the 2007 low flow season, to achieve these goals are provided in the Russian River Biological Opinion (NMFS 2008) and are summarized in Figure 3.1.

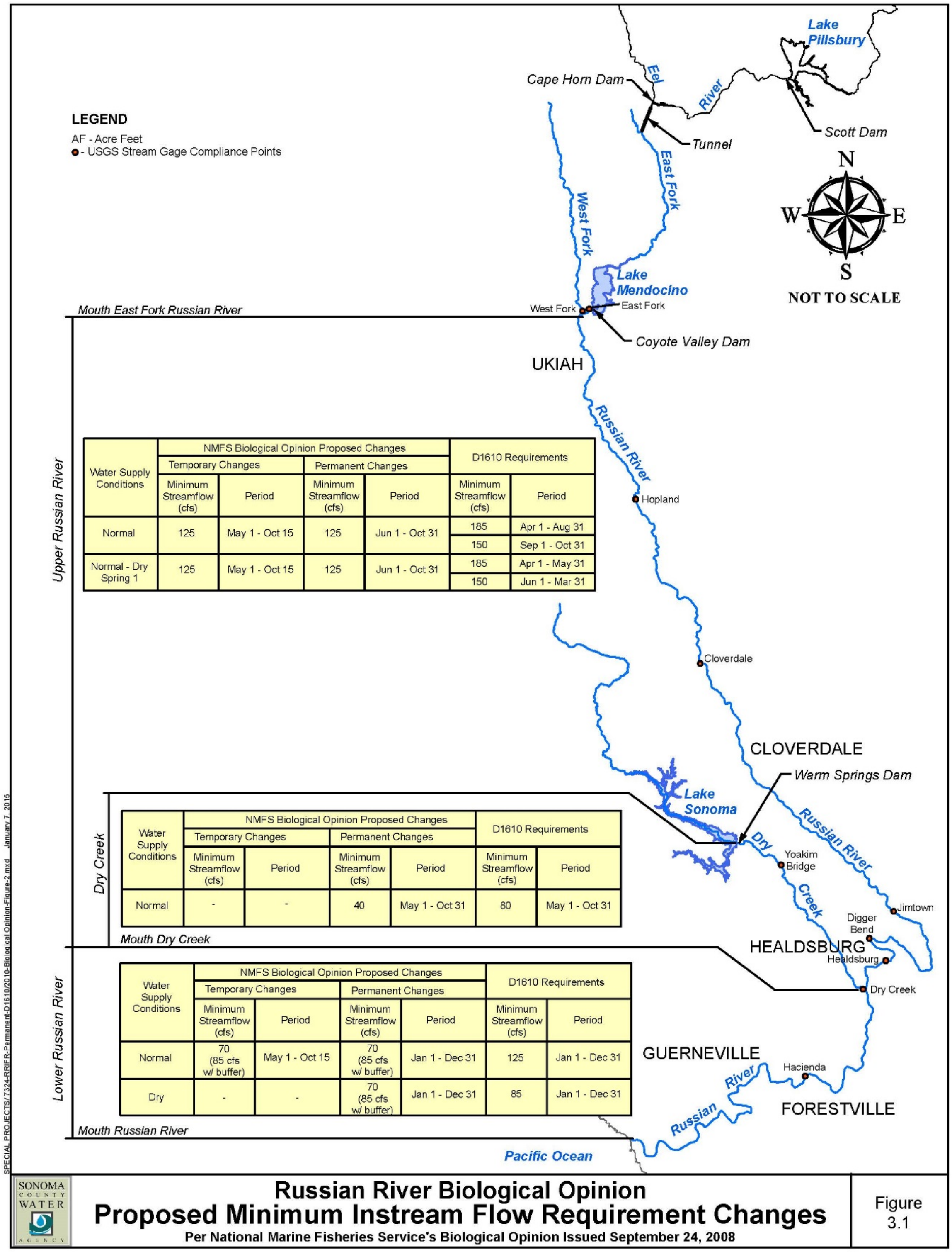
## Summary Status

The SWRCB issued a second amended public notice of Sonoma Water’s petition to modify Decision 1610 for public comment on March 29, 2010. Following filing of the petition to change Decision 1610, Sonoma Water issued a Notice of Preparation (NOP) of an Environmental Impact Report (EIR) for the Fish Habitat Flows and Water Rights Project (Fish Flow Project).

A Draft Environmental Impact Report (EIR) was released for public review on August 19, 2016. The public comment period closed on March 10, 2017, after extending the comment period to allow additional time to review an errata released on January 26, 2017. Sonoma Water staff worked on responding to comments received on the Draft EIR in 2018.

# Temporary Changes

Until the SWRCB issues an order on the petition to permanently modify Decision 1610, the minimum instream flow requirements specified in Decision 1610 (with the resulting adverse impacts to listed salmonids) will remain in effect, unless temporary changes to these requirements are made by the SWRCB. The Russian River Biological Opinion requires that Sonoma Water petition the SWRCB for temporary changes to the Decision 1610 minimum instream flow requirements beginning in 2010 and for each year until the SWRCB issues an




Upper Russian River

| Water Supply Conditions | NMFS Biological Opinion Proposed Changes: Temporary Changes – Minimum Streamflow (cfs) | Temporary Changes – Period | Permanent Changes – Minimum Streamflow (cfs) | Permanent Changes – Period | D1610 Requirements – Minimum Streamflow (cfs) | D1610 Requirements – Period |
|---|---|---|---|---|---|---|
| Normal | 125 | May 1 - Oct 15 | 125 | Jun 1 - Oct 31 | 185 | Apr 1 - Aug 31 |
| | | | | | 150 | Sep 1 - Oct 31 |
| Normal - Dry Spring 1 | 125 | May 1 - Oct 15 | 125 | Jun 1 - Oct 31 | 185 | Apr 1 - May 31 |
| | | | | | 150 | Jun 1 - Mar 31 |

Dry Creek

| Water Supply Conditions | NMFS Biological Opinion Proposed Changes: Temporary Changes – Minimum Streamflow (cfs) | Temporary Changes – Period | Permanent Changes – Minimum Streamflow (cfs) | Permanent Changes – Period | D1610 Requirements – Minimum Streamflow (cfs) | D1610 Requirements – Period |
|---|---|---|---|---|---|---|
| Normal | - | - | 40 | May 1 - Oct 31 | 80 | May 1 - Oct 31 |

Lower Russian River

| Water Supply Conditions | NMFS Biological Opinion Proposed Changes: Temporary Changes – Minimum Streamflow (cfs) | Temporary Changes – Period | Permanent Changes – Minimum Streamflow (cfs) | Permanent Changes – Period | D1610 Requirements – Minimum Streamflow (cfs) | D1610 Requirements – Period |
|---|---|---|---|---|---|---|
| Normal | 70 (85 cfs w/ buffer) | May 1 - Oct 15 | 70 (85 cfs w/ buffer) | Jan 1 - Dec 31 | 125 | Jan 1 - Dec 31 |
| Dry | - | - | 70 (85 cfs w/ buffer) | Jan 1 - Dec 31 | 85 | Jan 1 - Dec 31 |

**Figure 3.1. A summary of the permanent and temporary changes to Decision 1610 minimum instream flow requirements specified by NMFS in the Russian River Biological Opinion.**

order on Sonoma Water's petition for the permanent changes to these requirements. NMFS' Russian River Biological Opinion only requires that petitions for temporary changes "request that minimum bypass flows of 70 cfs be implemented at the USGS gage at the Hacienda Bridge between May 1 and October 15, with the understanding that for compliance purposes SCWA will typically maintain about 85 cfs at the Hacienda gage. For purposes of enhancing steelhead rearing habitats between the East Branch and Hopland, these petitions will request a minimum bypass flow of 125 cfs at the Healdsburg gage between May 1 and October 15."

## Summary Status

Water supply conditions on June 1, 2018, changed from *Normal* to *Dry*, therefore Sonoma Water did not submit a Temporary Urgency Change Petition to the SWRCB as the Russian River minimum instream flow requirements under Decision 1610 met the recommendations in the Russian River Biological Opinion.

# References

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation District in the Russian River Watershed. September 24, 2008.

# CHAPTER 4 Estuary Management

The Russian River estuary (Estuary) is located approximately 97 kilometers (km; 60 miles) northwest of San Francisco in Jenner, Sonoma County, California. The Estuary extends from the mouth of the Russian River upstream approximately 10 to 11 km (6 to 7 miles) between Austin Creek and the community of Duncans Mills (Heckel 1994). When a barrier beach forms and closes the river mouth, a lagoon forms behind the beach and reaches up to Vacation Beach.

The Estuary may close throughout the year as a result of a barrier beach forming across the mouth of the Russian River. The mouth is located at Goat Rock State Beach (California Department of Parks and Recreation). Although closures may occur at any time of the year, the mouth usually closes during the spring, summer, and fall (Heckel 1994; Merritt Smith Consulting 1997, 1998, 1999, 2000; Sonoma County Sonoma Water and Merritt Smith Consulting 2001). Closures result in ponding of the Russian River behind the barrier beach and, as water surface levels rise in the Estuary, flooding may occur. The barrier beach has been artificially breached for decades; first by local citizens, then the County of Sonoma Public Works Department, and, since 1995, by the Sonoma Water. The Sonoma Water's artificial breaching activities are conducted in accordance with the Russian River Estuary Management Plan recommended in the Heckel (1994) study. The purpose of artificially breaching the barrier beach is to alleviate potential flooding of low-lying properties along the Estuary.

The National Marine Fisheries Service's (NMFS) Russian River Biological Opinion (NMFS 2008) found that artificially elevated inflows to the Russian River estuary during the low flow season (May through October) and historic artificial breaching practices have significant adverse effects on the Russian River's estuarine rearing habitat for steelhead, coho salmon, and Chinook salmon. The historical method of artificial sandbar breaching, which is done in response to rising water levels behind the barrier beach, adversely affects the Estuary's water quality and freshwater depths. The historical artificial breaching practices create a tidal marine environment with shallow depths and high salinity. Salinity stratification contributes to low dissolved oxygen at the bottom in some areas. The Biological Opinion (NMFS 2008) concludes that the combination of high inflows and breaching practices impact rearing habitat because they interfere with natural processes that cause a freshwater lagoon to form behind the barrier beach. Fresh or brackish water lagoons at the mouths of many streams in central and southern California often provide depths and water quality that are highly favorable to the survival of rearing salmon and steelhead.

The Biological Opinion's RPA 2, Alterations to Estuary Management, (NMFS 2008) requires the Sonoma Water to collaborate with NMFS and to modify Estuary water level management in order to reduce marine influence (high salinity and tidal inflow) and promote a higher water surface elevation in the Estuary (formation of a fresh or brackish lagoon) for purposes of enhancing the quality of rearing habitat for young-of-year and age 1+ juvenile (age 0+ and 1+) steelhead from May 15 to October 15 (referred to hereafter as the "lagoon management period"). A program of potential, incremental steps are prescribed to accomplish this, including adaptive management of a lagoon outlet channel on the barrier beach, study of the existing jetty and its potential influence on beach formation processes and salinity seepage through the barrier beach, and a feasibility study of alternative flood risk measures. RPA 2 also includes provisions for monitoring the response of water quality, invertebrate production, and salmonids in the Estuary to the management of water surface elevations during the lagoon management period.

The following section provides a summary of the Water Agency's estuary management actions required under the Russian River Biological Opinion RPA 2. These actions are also required by other regulatory permits issued for the Estuary Management Project, including the California Coastal Commission's Coastal Development Permit (CDP) and North Coast Regional Water Quality Control Board Clean Water Act Section 401 Water Quality Certification (Certification). References to the Biological Opinion's RPA are used to maintain consistency with previous annual reports.

# Barrier Beach Management

RPA 2 requires the Sonoma Water, in coordination with NMFS, California Department of Fish and Wildlife (CDFW), and the U.S. Army Corps of Engineers (USACE), to annually prepare barrier beach outlet channel design plans. Sonoma Water contracted with Environmental Science Associates (ESA) to prepare the Russian River Estuary Outlet Channel Adaptive Management Plan. The approach of the plan was to meet the objective of RPA 2 to the greatest extent feasible while staying within the constraints of existing regulatory permits and minimizing the impact to aesthetic, biological, and recreational resources of the site. The annual meeting with regulatory agency staff to discuss the prior year's beach management activities and preparation of the updated 2018 annual Outlet Channel Adaptive Management Plan Estuary management for 2018 was discussed at a meeting on April 5, 2018, that included representatives from NMFS and CDFW, as well as the Sonoma Water, University of California, Davis's Bodega Marine Laboratory (Bodega Marine Lab), the USACE, the North Coast Regional Water Quality Control Board (NCRWQCB), and ESA. Only minor updates to the prior year's plan were made in the 2018 plan, which includes a summary of physical processes from 2011 to 2017 as appendices to the plan.Outlet channel implementation has occurred once in 2010, twice in 2016, and twice in 2017 (summarized in Appendix F, L, and M of the 2018 Outlet Channel Adaptive Management Plan; Appendix 4.1). There were no beach management actions taken during the lagoon management period in 2018 since the mouth of the Estuary did not close until the last day of the season, October 15.

A monthly topographic survey of the beach at the mouth of the Russian River is also required under RPA 2. Topographic data was collected monthly in 2018 and provided to NMFS and CDFW. The March and April 2018 topographic surveys were cancelled due to the presence of neonate (less than 1 week old) harbor seals at the mouth of the Russian River. The beach topographic maps are provided in Appendix 4.2. The topographic maps provide documentation of changing beach widths and crest heights, which influence both flood risk and the need to respond to river mouth closures through beach management activities.

## 2018 Beach and River Mouth Conditions

A barrier beach formed six times in 2018. Sonoma Water conducted water level management activities at the barrier beach just once, on December 10, 2018, outside the management period (Table 4.1). All other closures ended in a self-breach (Table 4.2). The Russian River mouth was closed to the ocean for a total of 49 days (or 13%) in 2018, during the fall and winter months.

**Table 4.1. Summary of beach management activities at Goat Rock State Beach for the Russian River Estuary Management Project, 2018.**

| Closure Date | Beach Management Date | No. Days Closed | Activity Time[1] | Water Elevation (ft)[2] | Beach Management Activity[3] | Excavated Volume (CY)[4] |
|---|---|---|---|---|---|---|
| 6-Dec | 10-Dec | 4 | 2:32pm-3:09pm | 9.44 | Pilot Channel | 206 |

[1] Estimated period that excavator/bulldozer equipment was on the beach.

[2] Water surface elevation recorded at the Jenner gage located at the Jenner Visitor's Center.

[3] Beach management activity consists of a pilot channel to initiate an artificial breach of the barrier beach or outlet channel to form a lagoon.

[4] Estimated volume of sand excavated with heavy equipment during artificial breach or lagoon management activity.

**Table 4.2. Summary of river mouth closures in 2018 at the Russian River mouth (Goat Rock State Beach). Peak water level during the event was measured at the gage located at the Sonoma Coast State Park Visitor's Center in Jenner, CA.**

| Date mouth closed | Peak height (ft NGVD) | Date mouth opened | Management Activity |
|---|---|---|---|
| January 15 | 7.9 | January 17 | none |
| October 15 | 8.5 | November 13 | none |
| November 18 | 8.0 | November 24 | none |
| November 28 | 9.5 | November 30 | none |
| December 6 | 9.4 | December 10 | breach |
| December 14 | 10.9 | December 17 | none |

### Lagoon Management Period Closures, Outlet Channel Implementation, and Self-Breaches

Time series of Estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 4.1 for the entire 2018 management season (ESA 2019, Appendix 4.3). The lagoon water level time series (Figure 4.1a) summarizes the fully-tidal conditions in the Estuary throughout summer, and also shows the closure events that occurred later in the fall. During the management period, Russian River flows were lower than during the wet 2017 conditions, and similar to the dry years of 2013-2015. As shown in Figure 4.1d, flows at Hacienda temporarily dropped below 100 cubic feet per second (cfs) in late June, and were

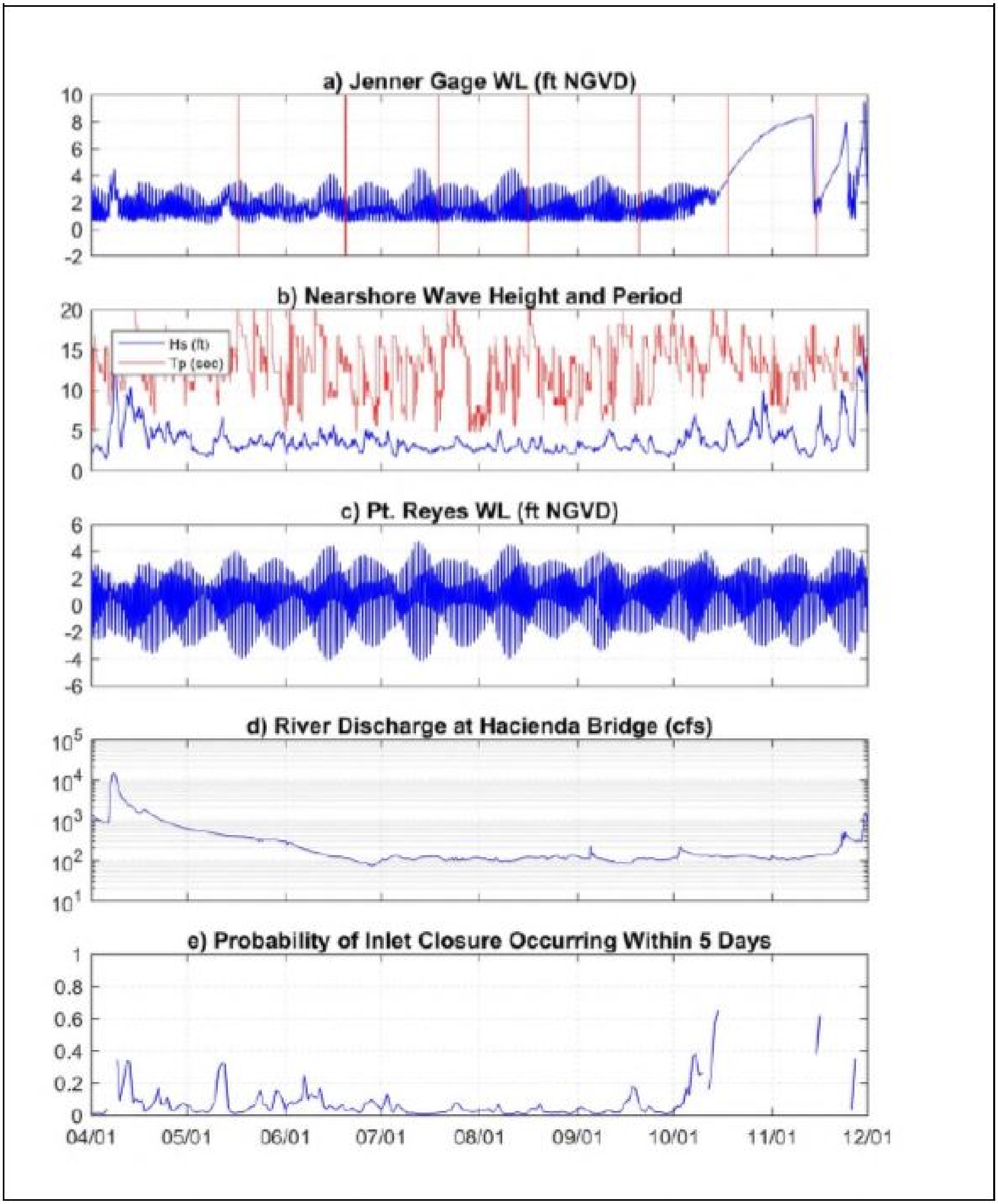



**Figure 4.1. Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2018.**

otherwise between 100 and 150 cfs for most of the period from July to late November. As in prior years, wave heights declined in May and June and were lowest through July, August, and September (Figure 4.1b). Although there were swell events during the summer, most were associated with wave heights less than 5 feet, and did not appear to result in significant deposition in the inlet. The location of the inlet next to the groin may have also played a role in limiting deposition within the inlet. However, beginning in October, when wave heights began to frequently exceed 5 feet and have periods of 12 seconds or more, the inlet began to experience shallowing and closure (ESA 2019).

During the 2018 lagoon management period, Sonoma Water staff regularly monitored current and forecasted estuary water surface elevations, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. Unlike the wet winter of 2016/2017, the winter of 2017/2018 was comparatively dry, with peak flows at the USGS Hacienda Bridge gage only achieving peak flows of roughly 15,000 cf). As a result of these winter flow conditions, the river mouth never migrated to the north end of Goat Rock State Beach and remained adjacent to the jetty's groin for the entire season. The river mouth did not close during the 2018 lagoon management period, until the last day of the season on October 15, despite the dry conditions (Figure 4.1). During a high wave event in early May coincident with neap oceanic tides, the river mouth nearly closed. For several days, the accumulation of sand in the mouth reduced the tide range in the estuary to about 1 foot, but the mouth scoured once the ocean tide range subsequently increased (Figure 4.2).

Appendix N of the 2019 Russian River Estuary Outlet Channel Adaptive Management Plan (ESA 2019) (Appendix 4.3) offers lessons learned based on 2018 observations of the Estuary, associated physical processes, and Sonoma Water's planning for outlet channel management. These are summarized here and may be found in Appendix 4.3 of this report for fuller context:

- As observed in similarly dry years from 2012 to 2015, peak 2018 winter flows of less than 40,000 cfs limited the inlet's northward excursion, and the inlet remained near the groin for the entire lagoon management period.
- Ocean waves with sufficient power to move sand are needed to close the river mouth. These wave conditions occur predominantly in the early part of the management period and again in the fall at the end of the season.

## Artificial Breaching

Outside of the management period, there were six mouth closures in 2018. Several inlet closure events occurred in the fall, beginning on October 15, the last day of the management period (Table 4.2, Figure 4.3). Although these occurred too late in the season to allow for beach management action to enhance habitat, they were notable for several reasons: the first event coincided with low runoff conditions and lasted for nearly 30 days (October 15 to November 13), and the events in late November and mid-December coincided with exceptionally high wave events that made artificial breaching difficult and led to water levels approaching or just exceeding flood stage in the Estuary.

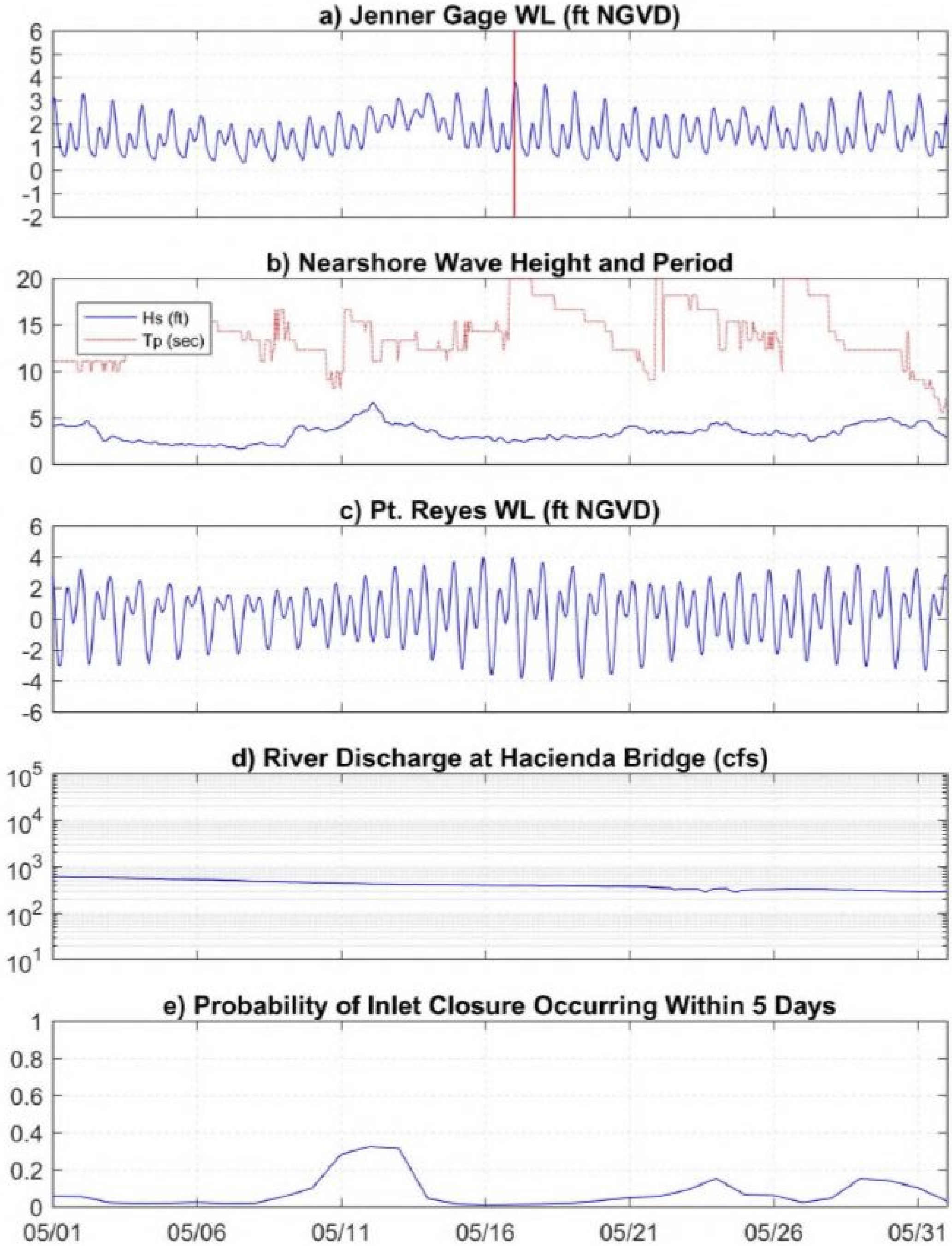



**Figure 4.2. Estuary, Ocean, and River Conditions Compared with Closure Probability: May 2018.**

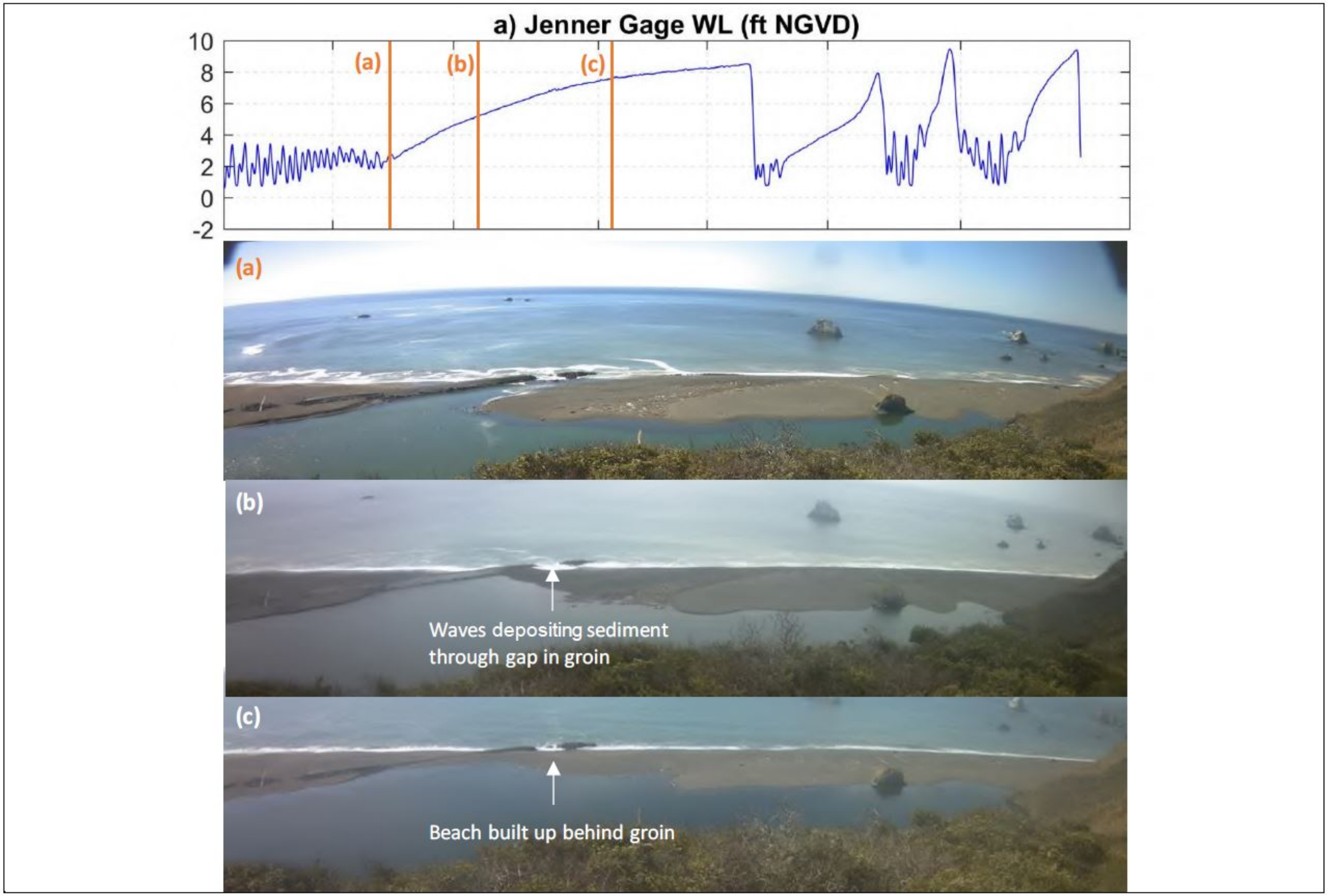



**Figure 4.3. Russian River mouth a) prior to closure on October 15, 2018; b) immediately after closure, showing wave transmission through a gap in the jetty groin; and c) after several weeks of closure.**

A moderate swell wave event from October 6 to 9 brought significant wave heights (Hs) of 5 to 6 feet and periods of roughly 15 to 17 seconds. Although this is not a particularly strong wave event, it was sufficient to deposit enough sand in the mouth to begin to mute the tide range in the Estuary to less than 2 feet. Following this, swell waves with periods of 17 to 20 seconds arrived the following week and closed the mouth on October 15. Even though the inlet had been located next to the groin, the swell waves were nonetheless able to close the inlet. The time lapse camera shows waves pushing through the gap at the offshore end of the jetty groin and probably contributing sand to build the beach (Figure 4.3). The October closure event coincided with low discharge at the USGS Hacienda gauge (less than 110 cfs), which slowed the rise of water levels. The mouth self-breached on November 13th at an elevation of 8.5 feet NGVD.

Sonoma Water artificially breached the barrier beach at the Russian River mouth outside the lagoon management period once in 2018 (Table 4.1, Figures 4.4 and 4.5). Time series photographs of the December 10 event are shown in Figure 4.5. The breaching was necessary to minimize flood risk to low-lying structures, which occurs at or above an elevation of approximately 9 feet NGVD at the Jenner gage located at State Parks' Jenner visitor center. The December 10 breaching event was a result of closure of the river mouth on December 6. Water surface elevations within the lagoon increased quickly, exceeding the 9 foot flood stage within a few days. Water surface elevation in the lagoon reached 9.44 ft at the time of artificial breaching. No artificial breaching activities occurred during the lagoon management period (May 15 – October 15).

The last closure of 2018 occurred on December 14. High waves during the last closure prevented crews and equipment from safely accessing the beach. Water levels in the estuary peaked at 10.92 feet NGVD on December 17 at the time that the barrier beach self-breached. As in previous years such as 2015 and 2017, these kind of event demonstrates that during the fall and winter, high wave conditions can contribute to inability to access the beach and increase potential for flooding in a short time period, particularly when combined with high discharges of river flows into the Estuary.

## Flood Risk Management Study

The Russian River Biological Opinion, RPA 2, includes a Flood Risk Reduction step if it proves difficult to reliably achieve raised water surface elevation targets based on implementation of a lagoon outlet channel or modification of the existing jetty. Should those actions be unsuccessful in meeting estuarine water surface elevation goals, RPA 2 states that the Sonoma Water "will evaluate, in coordination with NMFS and other appropriate public agencies, the feasibility of actions to avoid or mitigate damages to structures in the town of Jenner and low-lying properties along the Estuary that are currently threatened with flooding and prolonged inundation when the barrier beach closes and the Estuary's water surface elevation rises above 9 feet. Such actions may include, but are not limited to, elevating structures to avoid flooding or inundation."


**Figure 4.4. Location of beach management activity in 2018 at the Russian River mouth, Goat Rock State Beach. Line crossing the barrier beach is the location of a pilot channel for artificial breaching (red). Self-breach events are not shown.**

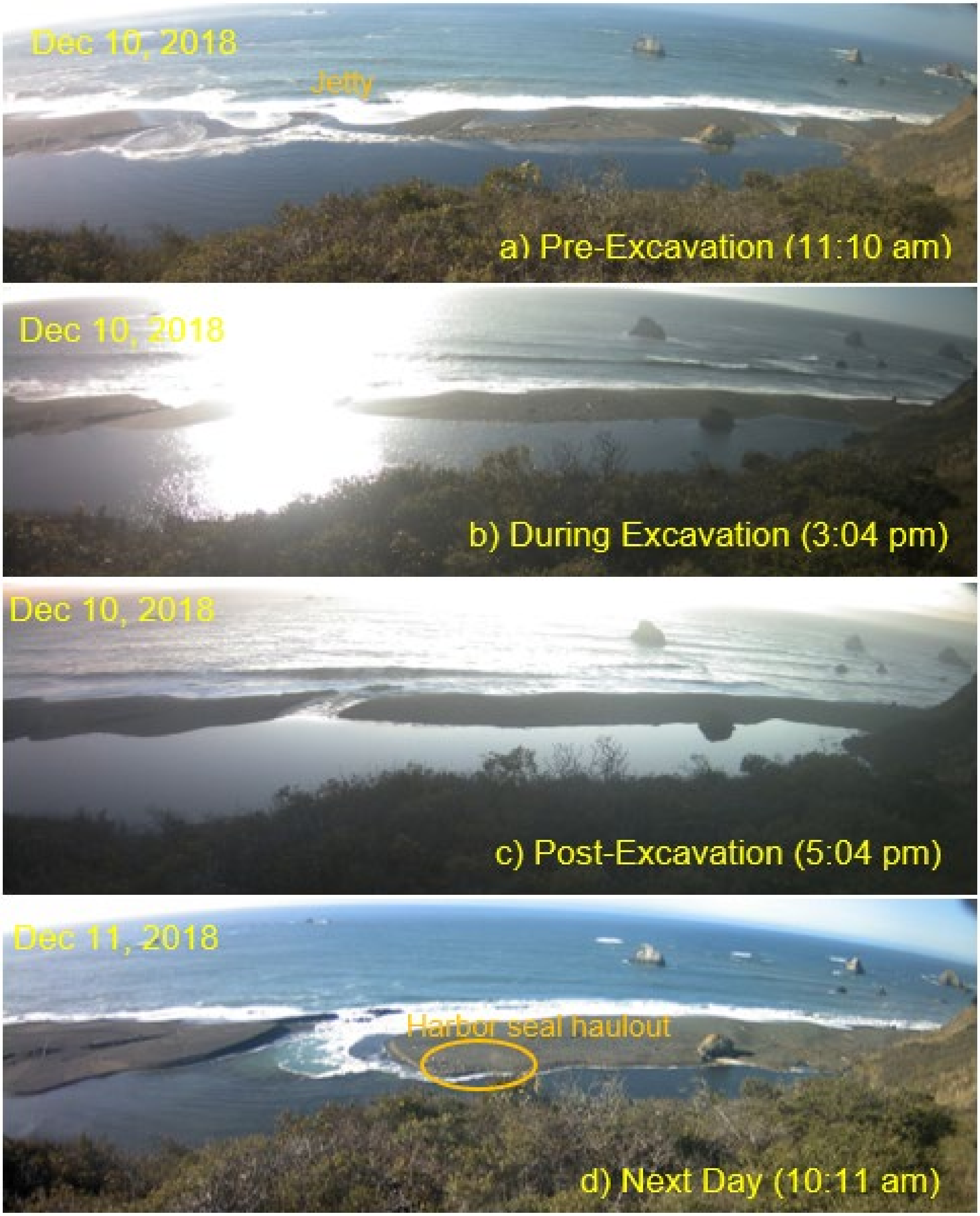



**Figure 4.5. Artificial breaching at the mouth of the Russian River Estuary, December 10, 2018. Large waves and high tide delayed excavation until late afternoon and the image of excavation is obscured by sun glare (second from top panel). Photographs show pre-management through next day conditions.**

As described in earlier annual reports, the first effort to address flood risk management feasibility was compilation of a preliminary list of structures, properties, and infrastructure that would be subject to flooding/inundation as the result of sandbar formation and if the Estuary were allowed to naturally breach. As required by RPA 2, the Sonoma Water submitted a preliminary list of properties, structures, and infrastructure that may be subject to inundation if the barrier beach at the mouth of the Russian River was allowed to naturally breach. This preliminary list was updated for the California Coastal Commission Coastal Development Permit application process. Allowing Estuary water surface elevations to rise to between 10 and 12 feet NGVD (the estimated water surface elevation if the barrier beach was allowed to naturally breach per consultation with NMFS) may potentially inundate portions of properties.

As described in previous reports, the Sonoma Water was awarded federal funding from the National Oceanic and Atmospheric Administration (NOAA) under its Habitat Blueprint framework to provide funds to the United States Geological Survey (USGS) expansion of its sea level rise model (the Coast Storm Modeling System or CoSMoS) from Bodega Bay north along the Sonoma Coast to Point Area, including the Russian River Estuary up to Duncans Mills, to be used to inform adaptation planning and Estuary management efforts (model included both open and closed river mouth conditions). These model scenarios were incorporated into the Our Coast, Our Future (OCOF) web platform by Point Blue Conservation Science (https://ourcoastourfuture.org/case-studies/). Sonoma Water hopes to use the CoSMoS and OCOF information to inform future flood risk feasibility studies of sea level rise and climate change effects on estuary flood risk and habitat management. In 2018, Sonoma Water began identifying next steps for the flood risk scope of work and plan to meet with resource agencies in 2019 to more fully develop the work to be completed.

# Pinniped Annual Monitoring

In addition to the Flood Management, Water Quality, and Habitat Conditions monitoring summarized in this report, Sonoma Water also monitors pinnipeds at the mouth of the Russian River.

An Incidental Harassment Authorization Letter of Authorization (LOA) was issued by the NMFS pursuant to Section 101(a)(5)(A) of the Marine Mammal Protection Act (16 U.S.C 1371(a)(5)(A)) to take small numbers of marine mammals, by Level B harassment, incidental to the Sonoma Water's Estuary Management Project (issued April 21, 2017, NMFS LOA). A summary of the results of 2018 pinniped monitoring as reported in the *Russian River Estuary Management Project, Marine Mammal Protection Act Incidental Harassment Authorization, Report of Activities and Monitoring Results – January 1 to December 31, 2018* (SCWA 2019; Appendix 4.4) are provided below.

Harbor seals (*Phoca vitulina richardsi*) regularly haul out at the mouth of the Russian River (Jenner haul-out). California sea lions (*Zalophus californianus*) and northern elephant seals (*Mirounga angustirostris*) are occasionally observed at the haul-out. There are also several known resting areas in the river at logs and rock piles.

Pinniped monitoring was performed in accordance with the requirements of the NMFS LOA issued April 21, 2017, and the Russian River Estuary Management Activities Pinniped Monitoring Plan (Sonoma County Sonoma Water and Stewards of the Coast and Redwoods 2016). Baseline monitoring was performed to gather additional information about the population of harbor seals utilizing the Jenner haul-out including population trends, patterns in seasonal abundance and the influence of barrier beach condition on harbor seal abundance. Pinniped monitoring was also conducted in relation to Sonoma Water water level management events (lagoon outlet channel implementation and artificial breaching). Estuary management monitoring occurred during the Sonoma Water's monthly topographic surveys of the barrier beach and biological and physical monitoring of the Estuary.

The purpose of the Russian River Estuary Management Project Pinniped Monitoring Plan (Sonoma County Sonoma Water and Stewards of the Coast and Redwoods 2016) is to detect the response of pinnipeds to estuary management activities at the Russian River estuary. Specifically, the following questions are of interest: 1) Under what conditions do pinnipeds haul out at the Russian River estuary mouth at Jenner?; 2) How do seals at the Jenner haul-out respond to activities associated with the construction and maintenance of the lagoon outlet channel and artificial breaching activities?; 3) Does the number of seals at the Jenner haul-out significantly differ from historic averages with formation of a summer (May 15th to October 15th) lagoon in the Russian River estuary?; and 4) Are seals at the Jenner haul-out displaced to nearby river and coastal haul-outs when the mouth remains closed in the summer?

The Estuary management and monitoring activities in 2018 resulted in incidental harassment (Level B harassment) of 1,441 harbor seals and one northern elephant seal, well under the total allowed by NMFS LOA. The Russian River estuary management activities in 2017, 2016, 2014, 2013, 2012, 2011 and 2010 resulted in incidental harassment (Level B harassment) of 1,290, 1,915, 2,383, 2,121, 1,351, 208, 42 and 290 harbor seals, respectively.

Harbor seals are found at the mouth of the Russian River (Jenner haul-out) throughout the year. They are observed on the beach throughout the tidal cycle and at any time of day. Our baseline pinniped monitoring concluded that tidal state and time of day influenced harbor seal abundance at the Jenner haul-out, with seals less abundant in the early morning and at high tide (SCWA 2012). Harbor seals were most abundant on the Jenner haul-out in July during their annual molt (SCWA 2012), with these same trends being observed in subsequent years (SCWA 2013, 2014, 2016). Seasonal variation in the abundance of harbor seals at their haul-out locations is commonly observed throughout their range (Allen et al. 1989, Stewart and Yochem 1994, Gemmer 2002). The variation in their abundance can mostly be explained by changes in their biological and physiological requirements throughout the year.

Peak seal abundance, as measured by the single greatest count of harbor seals at the Jenner haul-out, was on April 17 (356 seals). Using the average number of seals hauled out by month, seal abundance at Jenner was greatest in July compared to all other months except April and June. Seal abundance was lowest in November.

Harbor seals will use the beach when there is an open channel or when a barrier beach has formed, however, the number of seals at Jenner was influenced by river mouth condition. Fewer seals were present during closed conditions (mean = 48 ± 13.9 s.e., n =39) compared to open conditions (mean = 147 ± 5.7 s.e., n=349; ANOVA p<0.001). However, the overall trend was an increase in seal abundance compared to earlier years.

The response of harbor seals at the Jenner haul-out to water level management activities in 2018 was similar to the responses observed in previous years of monitoring (Merritt Smith Consulting 1997, 1998, 1999, 2000; Sonoma County Sonoma Water and Merritt Smith Consulting 2001; SCWA 2011, 2012, 2013, 2014, 2015,  2016, and 2018). Harbor seals alerted to the sound of equipment on the beach and left the haul-out as the crew and equipment approached closer on the beach. Harbor seals returned to the beach within 2 hours after the breach. Most often seals will remain off the haul-out throughout the observation period but will have returned to the haul-out before the start of the post activity monitoring the following day. On some occasions seals that are hauled out north of the beach management activity do not vacate the haul-out.

# 4.1 Water Quality Monitoring

Water quality monitoring was conducted in the lower, middle, and upper reaches of the Russian River Estuary, including two tributaries and the Maximum Backwater Area (MBA), between the mouth of the river at Jenner and Vacation Beach near Guerneville. Sonoma Water staff continued to collect data to establish baseline information on water quality in the Estuary, gain a better understanding of the longitudinal and vertical water quality profile during the ebb and flow of the tide, and track changes to the water quality profile that may occur during periods of barrier beach closure, partial or full lagoon formation, lagoon outlet channel implementation, and sandbar breach.

Saline water is denser than freshwater and a salinity “wedge” (halocline) forms in the Estuary as freshwater outflow passes over the denser tidal inflow. During the Lagoon Management Period, the lower and middle reaches of the Estuary up to Sheephouse Creek are predominantly saline environments with a thin freshwater layer that flows over the denser saltwater. The upper reach of the Estuary transitions to a predominantly freshwater environment, which is periodically underlain by a denser, saltwater layer that migrates upstream to Duncans Mills during summer low flow conditions and barrier beach closure. Additionally, river flows, tides, topography, and wind action affect the amount of mixing of the water column at various longitudinal and vertical positions within the reaches of the Estuary. The Maximum Backwater Area encompasses the area of the river between Duncans Mills and Vacation Beach that is generally outside the influence of saline water, but within the upper extent of inundation and backwatering that can occur during tidal cycles and lagoon formation.

## Methods

### Continuous Multi-Parameter Monitoring

Water quality was monitored using YSI Series 6600 multi-parameter datasondes. Hourly salinity (parts per thousand), water temperature (degrees Celsius), dissolved oxygen (percent saturation), dissolved oxygen (milligrams per liter), and pH (hydrogen ion) data were collected. Datasondes were cleaned and recalibrated periodically following the YSI User Manual procedures, and data was downloaded during each calibration event.

Six (6) stations were established for continuous water quality monitoring, including three stations in the mainstem Estuary, two tributary stations, and one station in the MBA near Villa Grande (Figure 4.1.1). One mainstem Estuary station was located in the middle reach at Patty’s Rock upstream of Penny Island (Patty’s Rock Station). One tributary station was located in the mouth of Willow Creek, which flows into the middle reach of the Estuary (Willow Creek Station). Two mainstem Estuary stations were located in the upper reach; downstream of Freezeout Creek in Duncans Mills (Freezeout Creek Station) and downstream of Austin Creek in Brown’s Pool (Brown’s Pool Station). The other tributary station was located downstream of the first steel bridge in lower Austin Creek, which flows into the mainstem Russian River above Brown’s Pool Station. Finally, one mainstem station was located in the MBA: in a pool across from Patterson Point in Villa Grande (Patterson Point Station). A seventh and eighth station were established in the middle reach at Sheephouse Creek and the MBA at Monte Rio, however due to equipment malfunctions no data was collected at these stations in 2018.

The rationale for choosing mainstem Estuary sites, including the Brown's Pool station, was to locate the deepest holes at various points throughout the Estuary to obtain the fullest vertical profiles possible and to monitor salinity circulation and stratification, hypoxic and/or anoxic events, and temperature stratification. Sondes were located near the mouths of Willow and Austin creeks to collect baseline water quality conditions and monitor potential changes to water quality (e.g. salinity intrusion) resulting from tidal cycling or inundation during partial or full lagoon formation. The Patterson Point station was established to monitor potential changes to water quality conditions (including potential salinity migration) in the MBA while inundated during lagoon formation (Figure 4.1.1).

Mainstem Estuary and MBA monitoring stations up to Patterson Point were comprised of a concrete anchor attached to a steel cable suspended from the surface by a large buoy (Figure 4.1.2).

The Patty's Rock, Freezeout Creek, Brown's Pool, and Patterson Point stations had a vertical array of two datasondes to collect water quality profiles. The Patty's Rock station, located in the middle reach of the Estuary, is predominantly saline and had sondes placed near the surface at approximately 1 meter depth (~1m), and at the mid-depth (~3-4m) portion of the water column. Stations in the upper reach of the Estuary, where the halocline is deeper and the water is predominantly fresh to brackish, had sondes placed at the bottom (~6-11m) and mid-depth (~3-7m) portions of the water column. The Patterson Point monitoring station, located in the MBA, also had datasondes placed at the bottom (~10-11m) and mid-depth (~6-7m) portions of the water column (Figure 4.1.2). Sondes were located in this manner to track vertical and longitudinal changes in water quality characteristics during periods of tidal circulation, barrier beach closure, lagoon formation, lagoon outlet channel implementation, and sandbar breach.

The monitoring stations in Austin Creek and Willow Creek consisted of one datasonde suspended at approximately mid-depth (~1-2m during open conditions) in the thalweg at each respective site.

The Patty's Rock, Brown's Pool, and Patterson Point stations were deployed from May to November. The Willow Creek sonde was deployed from April to November. The Freezeout Creek station was deployed from May to September. The Austin Creek sonde was deployed from April to August when a lack of flow and adequate water depth required equipment removal for the remainder of the season.

## Grab Sample Collection

In 2018, Sonoma Water staff continued to conduct nutrient and indicator bacteria grab sampling at three stations in the freshwater segment of the Russian River Estuary referred to as the MBA, including one station established in 2010 just downstream of the Monte Rio Bridge (Monte Rio Station). The 2018 grab sampling effort represented the fifth year of collecting samples at Patterson Point in Villa Grande (Patterson Point Station); and just downstream of the Vacation Beach summer dam (Vacation Beach station). Refer to Figure 4.1.1 for grab sampling locations.

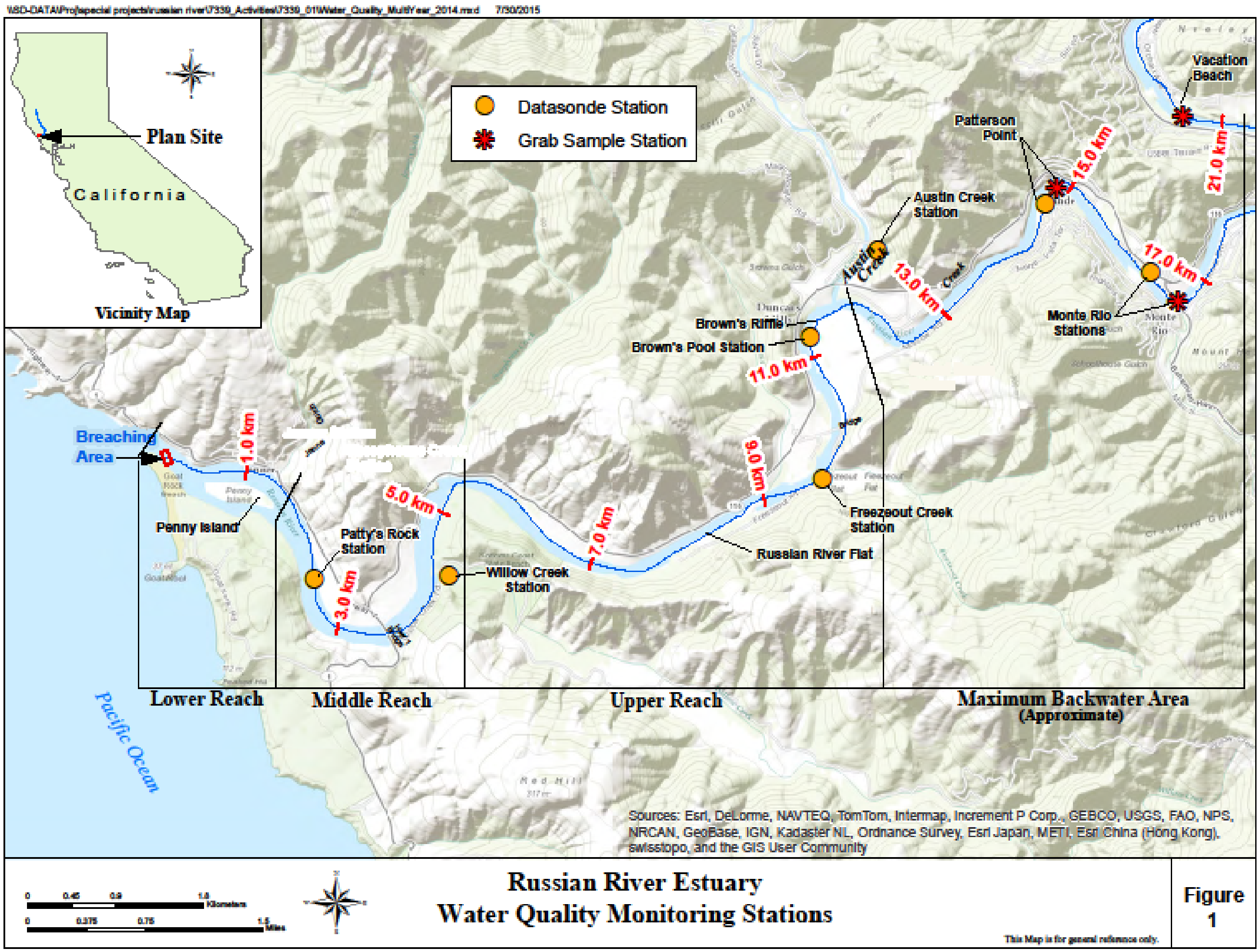



**Figure 4.1.1. 2018 Russian River Estuary water quality monitoring stations.**

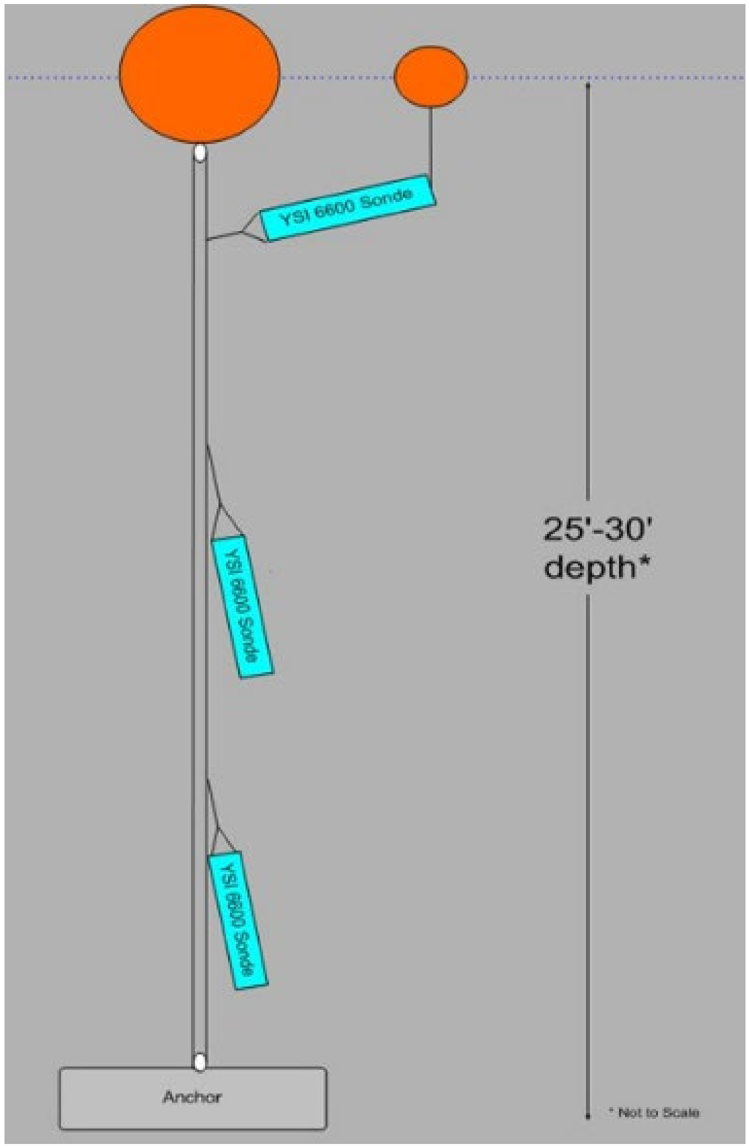



**Figure 4.1.2. Typical Russian River Estuary monitoring station datasonde array.**

Sonoma Water staff collected grab samples weekly from May 15 to October 16. Additional focused sampling (collecting three samples over a ten day period) was conducted following or during specific river management and operational events including removal of summer recreational dams.

Nutrient sampling was conducted for total organic nitrogen, ammonia, unionized ammonia, nitrate, nitrite, total Kjeldahl nitrogen, total nitrogen, total phosphorus, total orthophosphate, dissolved and total organic carbon, total dissolved solids, and turbidity, as well as for *Chlorophyll a*, which is a measurable parameter of algal growth that can be tied to excessive nutrient concentrations and reflect a biostimulatory response. Grab samples were also collected for the presence of indicator bacteria including total coliforms, *Escherichia coli* (E. coli) and

Enterococcus. These bacteria are considered indicators of water quality conditions that may be a concern for water contact recreation and public health.

Nutrients, organic carbon, total dissolved solids, turbidity, and chlorophyll a grab samples were analyzed at Alpha Analytical Labs in Ukiah, and bacterial grab samples were analyzed at the Sonoma County Department of Health Services (DHS) lab in Santa Rosa.

The sampling results for total nitrogen, total phosphorus, turbidity, *Chlorophyll a*, and bacterial indicators are analyzed and discussed below. Sampling results for other nutrient components, dissolved and total organic carbon, and total dissolved solids are included in Appendix 4.5; however, an analysis and discussion of these constituents is not included in this report. Temperature, dissolved oxygen, pH, salinity, specific conductance, and turbidity values were recorded using a YSI 6600 datasonde during grab sampling events.

## Results

Water quality conditions in 2018 were similar to trends observed in sampling from 2004 to 2017. The lower and middle reaches are predominantly saline environments with a thin freshwater layer that flows over the denser saltwater layer. The upper reach transitions to a predominantly freshwater environment, which is periodically underlain by a denser, saltwater layer that migrates up and downstream and appears to be affected in part by freshwater inflow rates, tidal inundation, barrier beach closure, and subsequent tidal cycles following reopening of the barrier beach. The river upstream of Brown's Pool is considered predominantly freshwater habitat. The lower and middle reaches of the Estuary are subject to tidally-influenced fluctuations in water depth during open conditions and inundation during barrier beach closure, as is the upper reach and the MBA to a lesser degree.

Table 4.1.1 presents a summary of minimum, mean, and maximum values for temperature, depth, DO, pH, and salinity recorded at the various datasonde monitoring stations. Data associated with malfunctioning datasonde equipment has been removed from the data sets, resulting in the data gaps observed in the graphs presented as Figures 4.1.3 through 4.1.26. These data gaps may affect minimum, mean, and maximum values of the various constituents monitored in 2018, including temperature, dissolved oxygen, pH, and salinity at Freezeout Creek bottom sonde from mid-June to the end of the season; temperature, dissolved oxygen, and salinity at the Brown's Pool bottom sonde from Mid-September to the end of the season; and pH at the Freezeout Creek mid-depth sonde and both Patty's Rock sondes from June to the end of the season. Sondes were not placed at Sheephouse Creek or Monte Rio in 2018 due to a shortage of properly functioning datasondes.

Although gaps exist in the 2018 data that affect sample statistics, Sonoma Water staff has collected long time-series data on an hourly frequency for several years at most of these stations, and it is unlikely that the missing data appreciably affected the broader understanding of water quality conditions within the estuary. The following sections provide a brief discussion of the results observed for each parameter monitored.

**Table 4.1.1. Russian River Estuary 2018 water quality monitoring results. Minimum, mean, and maximum values for temperature (degrees Celsius), depth (meters), dissolved oxygen (percent) saturation, dissolved oxygen concentration (milligrams per Liter), hydrogen ion (pH units), and salinity (parts per thousand).**

| Monitoring Station | Temperature | Depth | Dissolved Oxygen | Dissolved Oxygen | Hydrogen Ion | Salinity |
|---|---|---|---|---|---|---|
| ***Sonde*** | (°C) | (m) | (mg/L) | (%) saturation | (pH) | (ppt) |
| **Patty's Rock** | | | | | | |
| ***Surface*** | | | | | | |
| May 10, 2018 - November 19, 2018 | | | | | | |
| Min | 10.0 | 0.8 | 1.5 | 17.8 | 7.7 | 0.5 |
| Mean | 15.6 | 1.2 | 9.6 | 109.0 | 8.1 | 18.8 |
| **Max** | **22.7** | **2.0** | **22.6** | **259.8** | **9.0** | **30.7** |
| | | | | | | |
| ***Mid-Depth*** | | | | | | |
| May 10, 2018 - September 14, 2018 | | | | | | |
| Min | 10.6 | 3.2 | 2.8 | 30.5 | 7.7 | 14.5 |
| Mean | 12.9 | 3.3 | 9.2 | 101.7 | 7.9 | 25.1 |
| **Max** | **17.1** | **3.4** | **15.8** | **177.2** | **8.4** | **33.3** |
| | | | | | | |
| **Willow Creek** | | | | | | |
| ***Mid-Depth*** | | | | | | |
| April 3, 2018 - November 30, 2018 | | | | | | |
| **Min** | 7.9 | 0.0 | 0.1 | 0.4 | 6.3 | 0.0 |
| **Mean** | 16.7 | 0.6 | 7.3 | 80.4 | 7.7 | 11.7 |
| **Max** | **25.3** | **2.7** | **14.1** | **172.6** | **8.7** | **29.5** |
| | | | | | | |
| **Freezeout Creek** | | | | | | |
| ***Mid-Depth*** | | | | | | |
| May 10, 2018 - September 27, 2018 | | | | | | |
| **Min** | 16.9 | 4.2 | 4.4 | 48.7 | 7.4 | 0.1 |
| **Mean** | 21.3 | 4.3 | 8.9 | 100.2 | 7.8 | 0.2 |
| **Max** | **25.0** | **4.4** | **13.0** | **143.8** | **8.3** | **3.2** |
| | | | | | | |
| **Bottom** | | | | | | |
| May 10, 2018 - June 15, 2018 | | | | | | |
| **Min** | 17.0 | 6.2 | 3.4 | 38.5 | 7.8 | 0.1 |
| **Mean** | 20.3 | 6.5 | 8.8 | 97.6 | 8.1 | 0.2 |
| **Max** | **23.0** | **7.0** | **12.6** | **140.4** | **8.6** | **0.7** |
| | | | | | | |

## Salinity

Full strength seawater has a salinity of approximately 35 parts per thousand (ppt), with salinity decreasing from the ocean to the upstream limit of the Estuary, which is considered freshwater at approximately 0.5 ppt (Horne, 1994). The Patty's Rock mid-depth sonde in the middle reach was located in a predominantly saline environment, whereas the surface sonde was located at the saltwater-freshwater interface (halocline or salt wedge) and recorded both freshwater and saltwater conditions. In the lower and middle reaches of the Estuary, salinities can range as high as 30 ppt in the saltwater layer, with brackish conditions prevailing at the upper end of the salt wedge, to less than 1 ppt in the freshwater layer on the surface. The Willow Creek sonde was located just upstream of the confluence with the Russian River, where predominantly freshwater conditions observed in the creek during higher springtime flows transitioned to a brackish environment during lower dry season flows.

In the Upper Reach, the Estuary typically transitions from predominantly saline conditions to brackish and freshwater conditions in the Heron Rookery area. Upstream, the Freezeout Creek station is located in a predominantly freshwater environment; however, brackish conditions can occur in the lower half of the water column during open estuary conditions with lower in-stream flows, as well as during barrier beach closure or perched conditions. The Brown's Pool station is located in predominantly freshwater habitat in the upper reach of the Estuary, just downstream of the confluence with Austin Creek and the beginning of the MBA.

The Austin Creek, Patterson Point and Monte Rio stations are located in the MBA in freshwater habitat that can become inundated during high tides, barrier beach closures, perched conditions, and lagoon formation. Elevated salinity levels were not observed at any of the stations in the MBA during either open river mouth or closed barrier beach conditions in 2018.

### *Lower and Middle Reach Salinity*

The Patty's Rock station is located at River Kilometer 2.5 (RK 2.5), which is approximately 2.5 km upstream from the river mouth. The surface sonde at the Patty's Rock station was suspended at a depth of approximately 1 meter, and experienced frequent hourly fluctuations in salinity during open conditions. These fluctuations are influenced by freshwater inflows, tidal movement and expansion and contraction of the salt wedge. The freshwater layer was observed to deepen and become more persistent at the surface sonde during closed barrier beach conditions (Figure 4.1.3). Concentrations ranged from 0.5 to 30.7 ppt at the Patty's Rock surface sonde with a mean salinity value of 18.8 ppt (Table 4.1.1).

The mid-depth sonde at the Patty's Rock station was suspended at a depth of approximately 3 meters, and also experienced frequent fluctuations in salinity during open and closed conditions, though to a lesser degree than the surface sonde. Concentrations ranged from 14.5 to 33.3 ppt at the Patty's Rock mid-depth sonde with a mean salinity value of 25.1 ppt (Table 4.1.1).

The Estuary experienced five closures following the 2018 management period, including one closure that lasted 29 days between 15 October and 13 November (Figure 4.1.3). Declines in salinity during barrier beach closure and lagoon formation were due to a combination of freshwater inflows increasing the depth of the freshwater layer over the salt layer, a reduction in

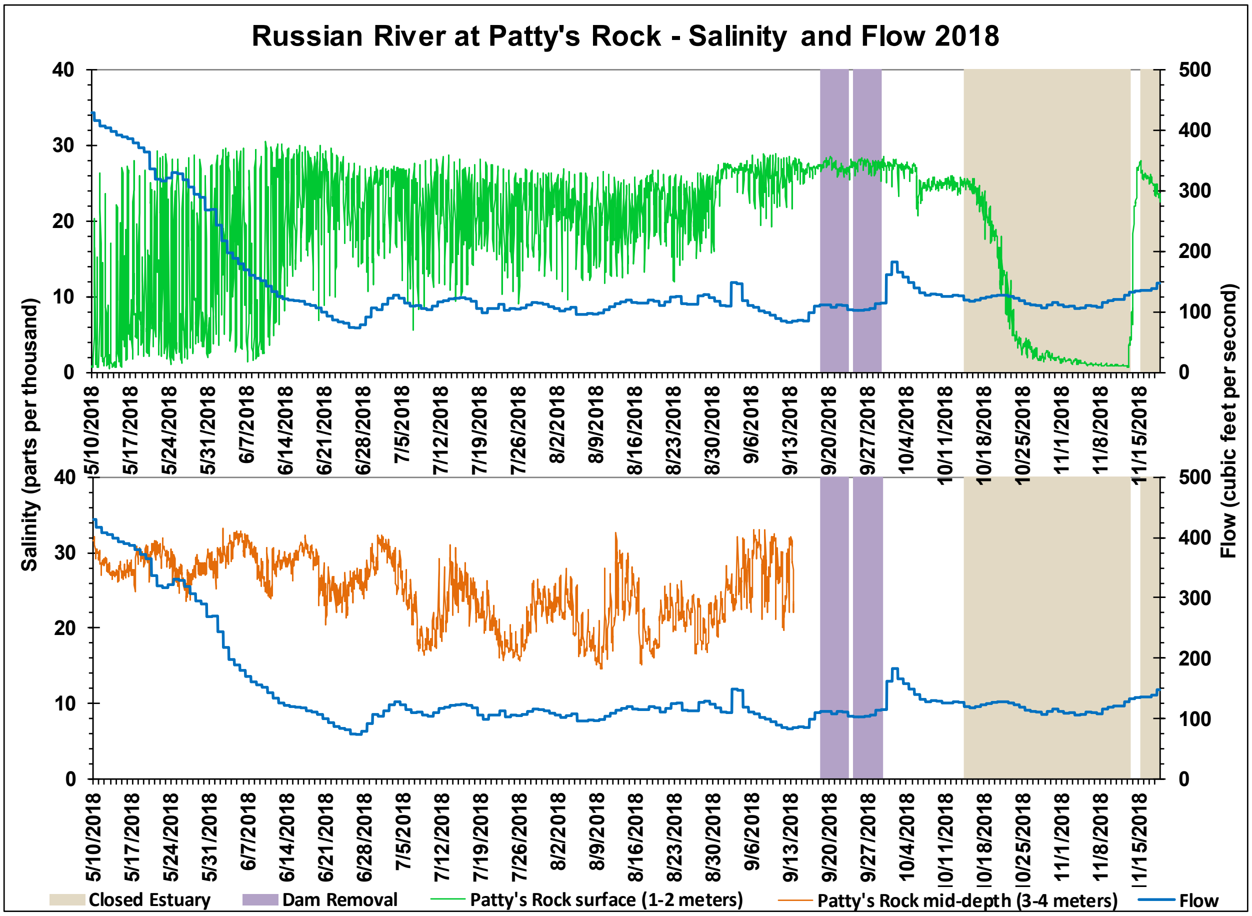



**Figure 4.1.3. 2018 Russian River at Patty's Rock salinity and flow graph.**

tidal inflow, the compression and leveling out of the salt layer, and seepage of saline water through the barrier beach. Salinity returned to pre-closure levels within a few hours after the barrier beach reopened, although the time required to return to pre-closure conditions can vary between closure events. This variability is related to the strength of subsequent tidal cycles, freshwater inflow rates, topography, relative location within the Estuary, and to a lesser degree, wind mixing.

The Willow Creek station is located approximately 300 meters upstream from the confluence of Willow Creek with the mainstem Russian River, which occurs at RK 4.2. The Willow Creek station was located in predominantly freshwater habitat until June when declining spring flows and increasing tidal action allowed saline water to migrate to this station during open conditions.

Salinity was observed to generally remain brackish through the rest of the monitoring season, including during late season closures (Figure 4.1.4). However, salinity concentrations were also observed to fluctuate significantly at times during open and closed barrier beach conditions. The mean salinity concentration observed at the Willow Creek station was 11.7 ppt, with a minimum concentration of 0.0 ppt, and a maximum concentration of 29.5 ppt (Table 4.1.1).

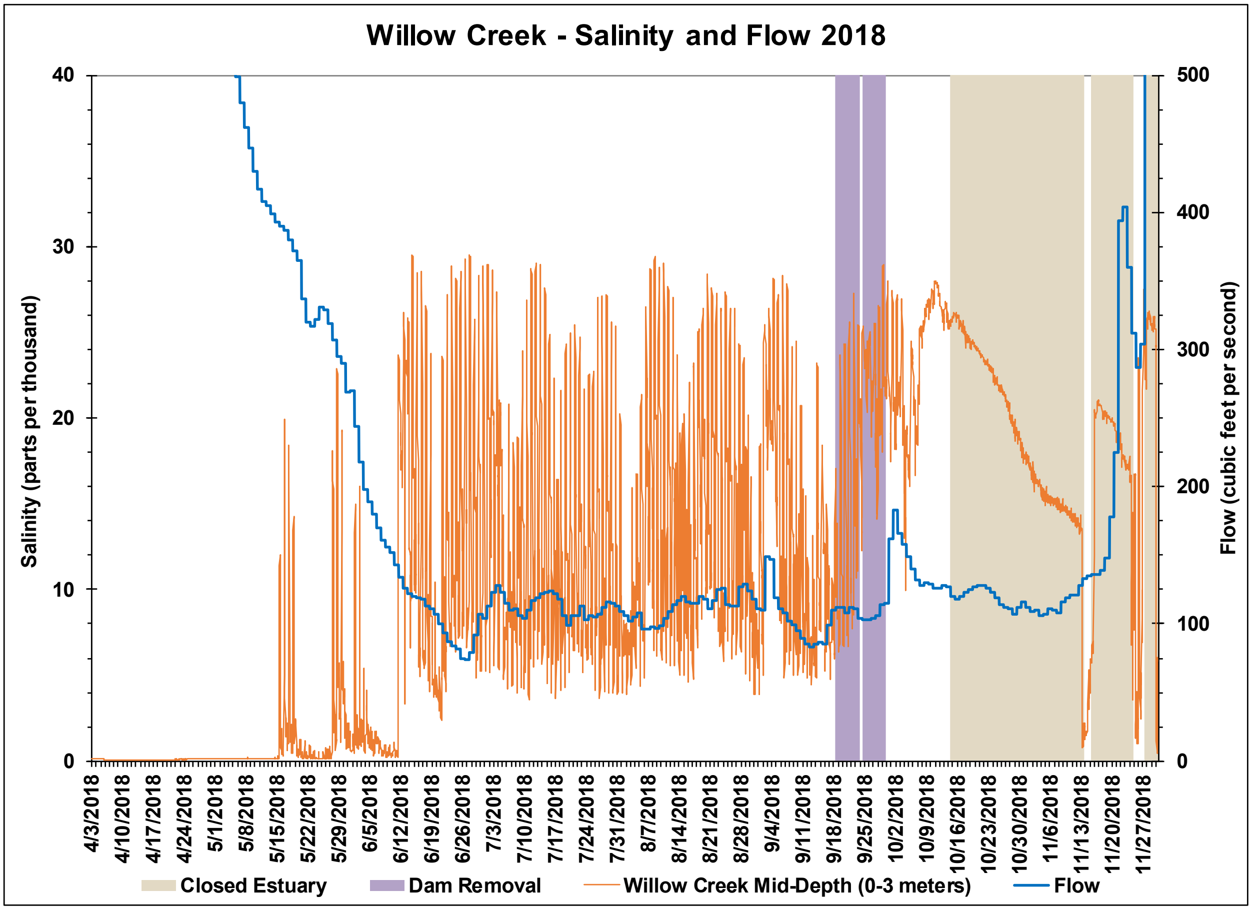



**Figure 4.1.4. 2018 Willow Creek salinity and Russian River flow graph.**

### *Upper Reach Salinity*

Two stations were monitored in the upper reach in 2018: Freezeout Creek and Brown's Pool. Both stations included a bottom sonde and a mid-depth sonde, however the bottom sonde at the Freezeout Creek station malfunctioned in mid-June and did not collect data after that. Sondes were located in this manner to track changes in the presence and concentration of salinity in the water column as well as the presence of thermal refugia for salmonids.

The Freezeout Creek station is located at River Kilometer 9.5 (RK 9.5) in a pool approximately 300 meters downstream of the confluence of Freezeout Creek and the mainstem of the river. This station was located in a predominantly freshwater habitat that was subject to elevated salinity levels as the salt wedge migrated up the Estuary during open conditions (Figure 4.1.5). The bottom sonde at Freezeout Creek had a mean salinity concentration of 0.2 ppt, and salinity levels that ranged from 0.1 to 0.7 ppt during the one month of operation (Table 4.1.1). The mid-depth sonde at Freezeout Creek had a mean salinity concentration of 0.2 ppt, and salinity levels that ranged from 0.1 to 3.2 ppt..

The Brown's Pool station is located at RK 11.3 in a pool that is approximately 10m deep. Brown's Pool is located immediately downstream of Brown's Riffle (RK 11.4) and the confluence of Austin Creek and the mainstem Russian River, which is located at RK 11.65. Brown's Riffle is

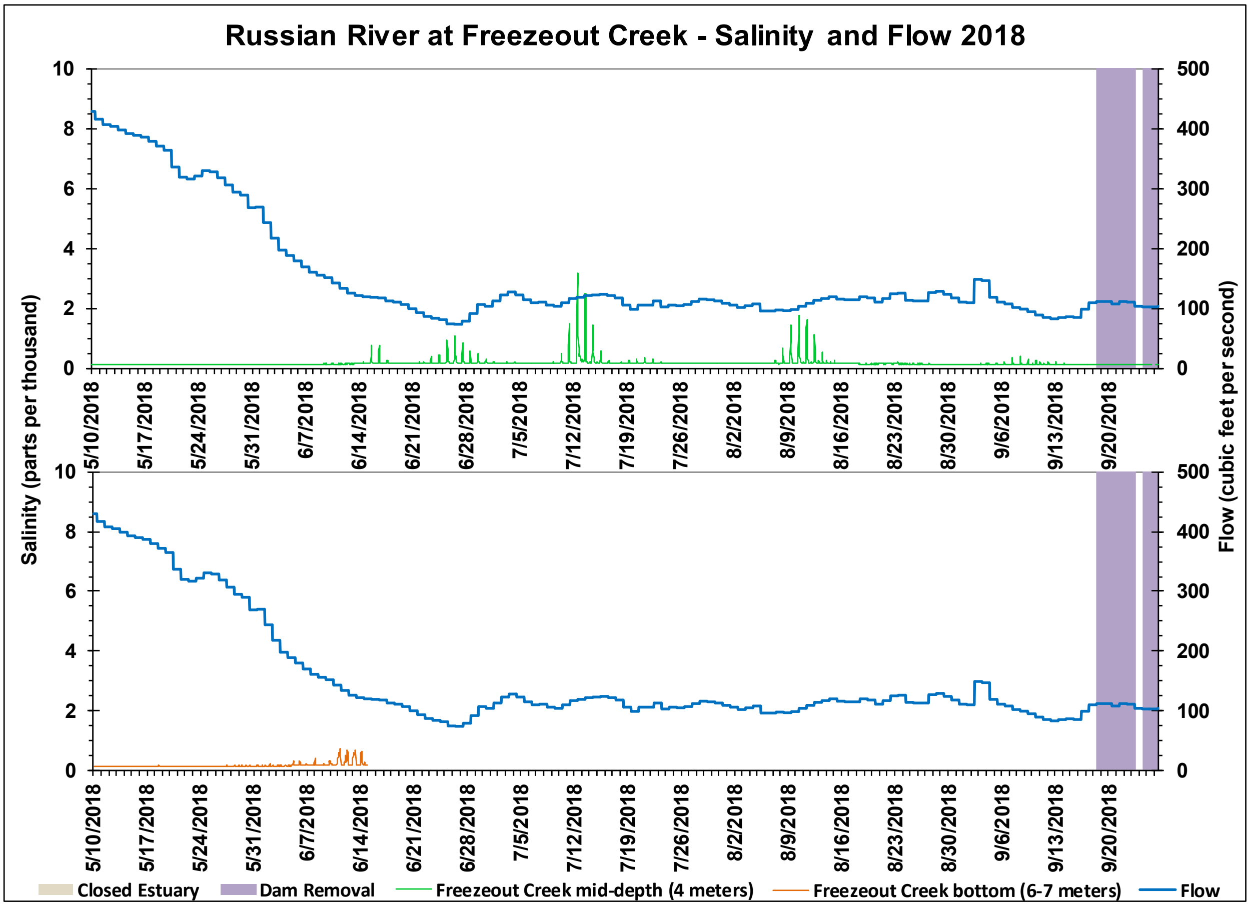



**Figure 4.1.5. 2018 Russian River at Freezeout Creek salinity and flow graph.**

generally considered the demarcation between the Estuary and the MBA, where salinity levels have not been observed to occur past this point.

This station did not experience any elevated salinity levels and remained freshwater habitat during the entire monitoring season of 2018 (Figure 4.1.6). The bottom sonde at Brown's Pool had a mean salinity concentration of 0.1 ppt, and salinity levels that ranged from 0.1 to 0.2 ppt (Table 4.1.1). The mid-depth sonde at Brown's Pool also had a mean salinity concentration of 0.1 ppt, and salinity levels that ranged from 0.1 to 0.2 ppt.

*Maximum Backwater Area Salinity*

Two stations were located in the MBA, including one tributary station in lower Austin Creek and one mainstem Russian River station located in Patterson Point (RK 14.9) (Figure 4.1.1). Neither of these stations were observed to have salinity levels above normal background conditions expected in freshwater habitats, during both open and closed barrier beach conditions (Figures 4.1.7 and 4.1.8).

The Austin Creek station had a mean salinity concentration of 0.1 ppt, with a minimum of 0.1 ppt and a maximum of 0.2 ppt. The Patterson Point bottom sonde had a mean salinity concentration of 0.1 ppt, a minimum concentration of 0.1 ppt, and a maximum concentration of 0.2 ppt. The

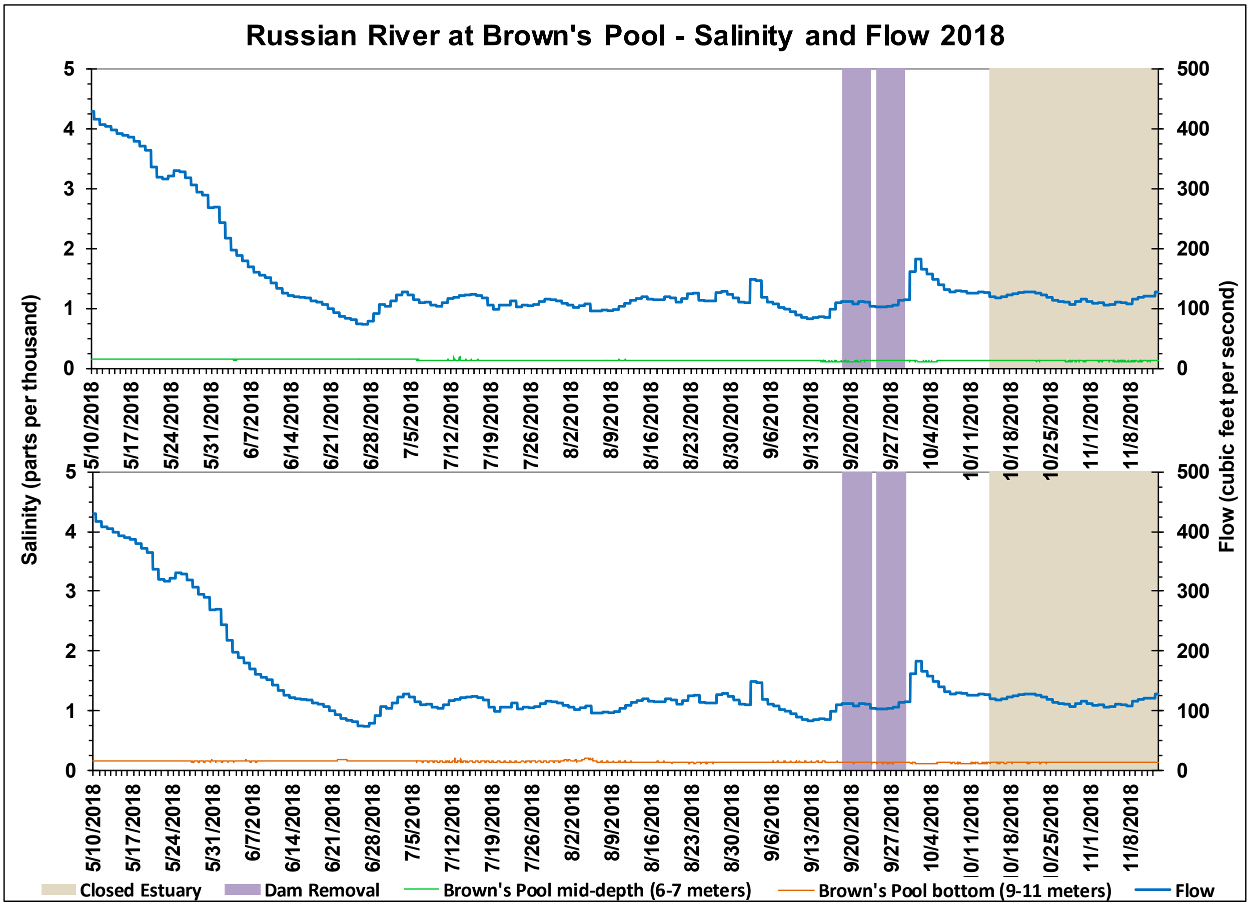



**Figure 4.1.6. 2018 Russian River at Brown's Pool salinity and flow graph.**

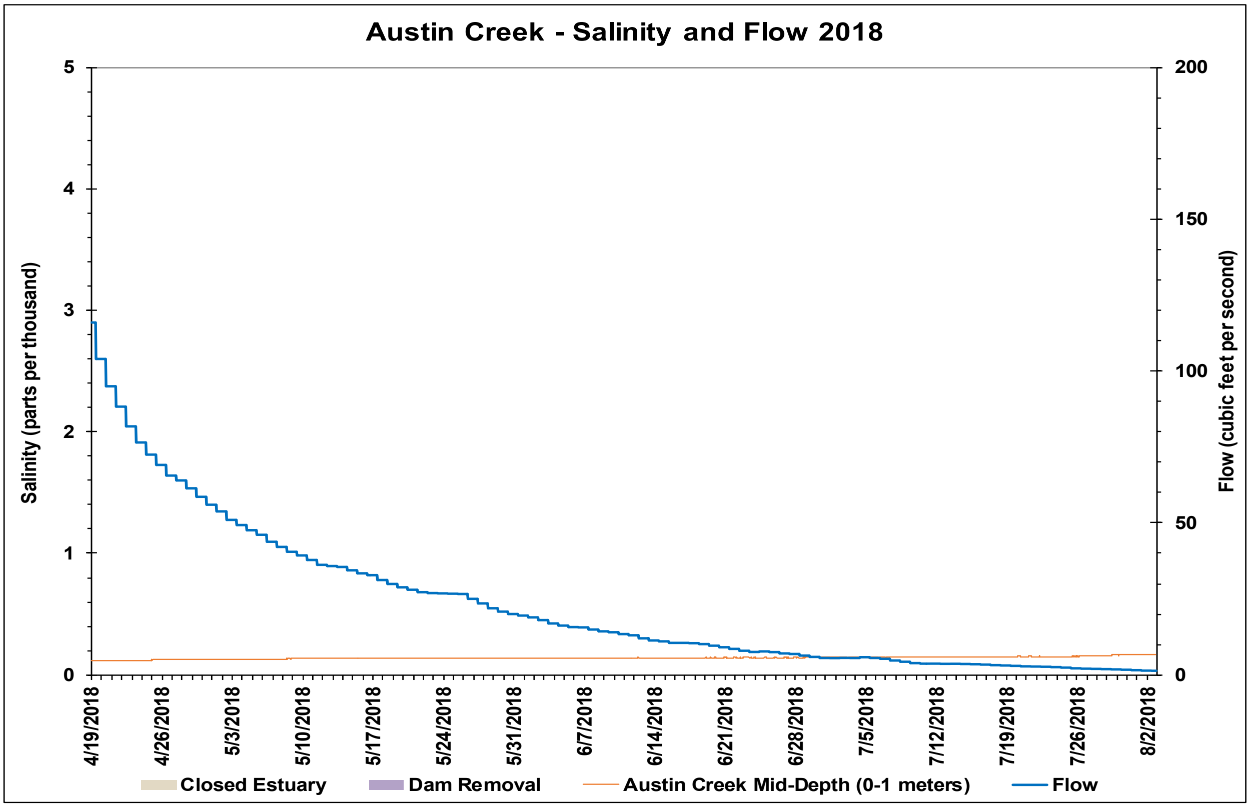



**Figure 4.1.7. 2018 Austin Creek salinity and flow graph.**

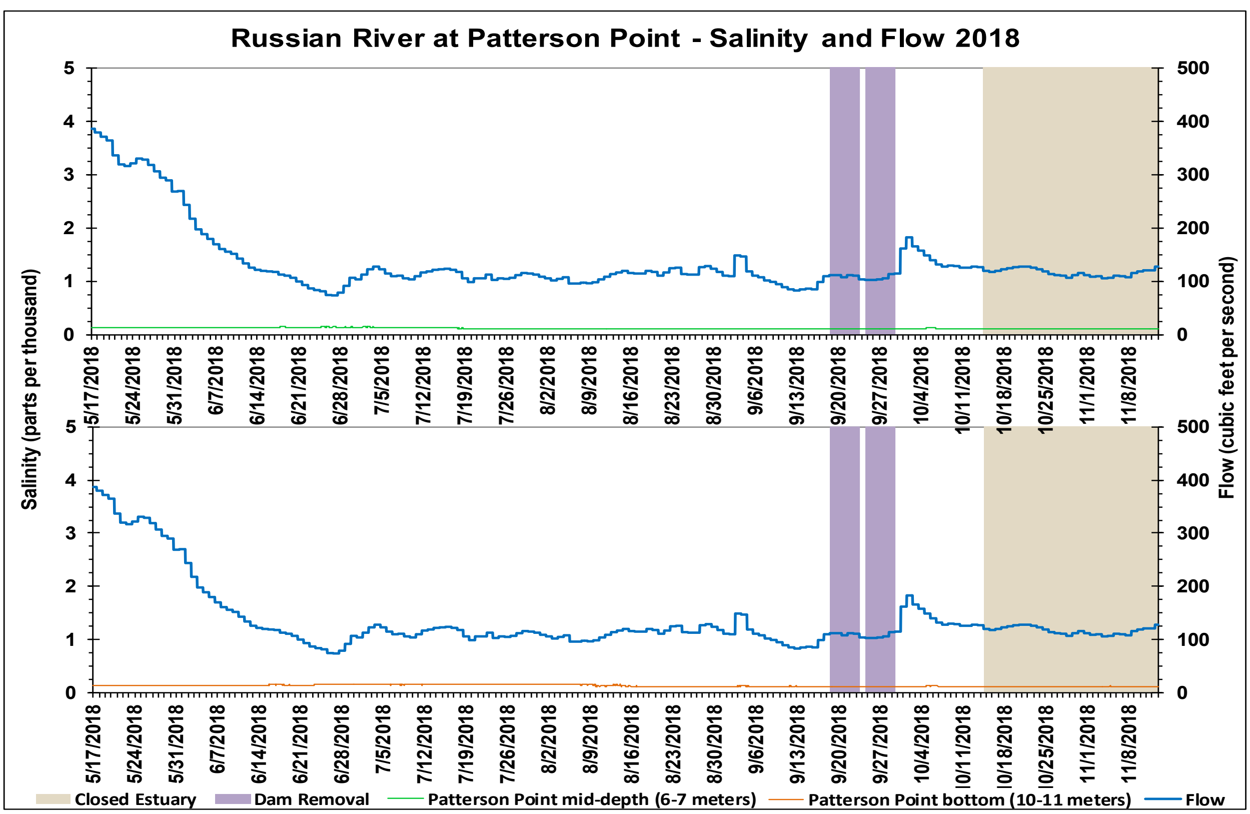



**Figure 4.1.8. 2018 Russian River at Patterson Point salinity and flow graph.**

Patterson Point mid-depth sonde had a mean salinity concentration of 0.1 ppt, a minimum concentration of 0.1 ppt, and a maximum concentration of 0.2 ppt.

## Temperature

During open estuary conditions, mainstem water temperatures were reflective of the halocline, with lower mean and maximum temperatures typically being observed in the saline layer at the bottom and mid-depth sondes compared to temperatures recorded in the freshwater layer at the mid-depth and surface sondes (Figures 4.1.9 through 4.1.13). The differences in temperatures between the underlying saline layer and the overlying freshwater layer can be attributed in part to the source of saline and fresh water. During open estuary conditions, the Pacific Ocean, where temperatures are typically around 10 degrees Celsius (°C), is the source of saltwater in the Estuary. Whereas, the mainstem Russian River, with water temperatures reaching as high as 27 °C in the interior valleys, is the primary source of freshwater in the Estuary.

Increasing temperatures associated with fresh/saltwater stratification were not observed to occur at the Patty's Rock station in 2018 in part because the first Estuary closure did not occur until mid-October when temperatures (and the effects of solar radiation) have begun to decline for the season (Figure 4.1.9). Density and temperature gradients between freshwater and saltwater play a role in stratification and serve to prevent/minimize mixing of the freshwater and saline layers. During the hot summer months, when the estuary is closed or the river mouth is perched and the supply of cool tidal inflow is reduced, solar radiation heats the underlying saline layer. The overlying freshwater surface layer restricts the release of this heat, which can result in higher water temperatures in the underlying saline layer than in the overlying freshwater layer. Stratification based heating has also been observed to result in higher temperatures in the mid-depth saline layer compared to the bottom layer in deep pools, forming a three layered system. This stratification based heating can also contribute to higher seasonal mean temperatures in the saline layer than would be expected to occur under open conditions.

### *Lower and Middle Reach Temperature*

The Patty's Rock surface sonde was located at the freshwater/saltwater interface and was observed to have a maximum temperature of 22.7 °C (Table 4.1.1). Whereas, the mid-depth sonde was located primarily in saltwater and had a maximum temperature of 17.1 °C. Maximum temperatures were observed to occur in brackish to saline water during open river mouth conditions (Figures 4.1.3 and 4.1.9). The Patty's Rock surface sonde had a mean temperature of 15.6 °C and a minimum temperature of 10.0 °C. The mid-depth sonde had a mean temperature of 12.9 °C and a minimum temperature of 10.6 °C.

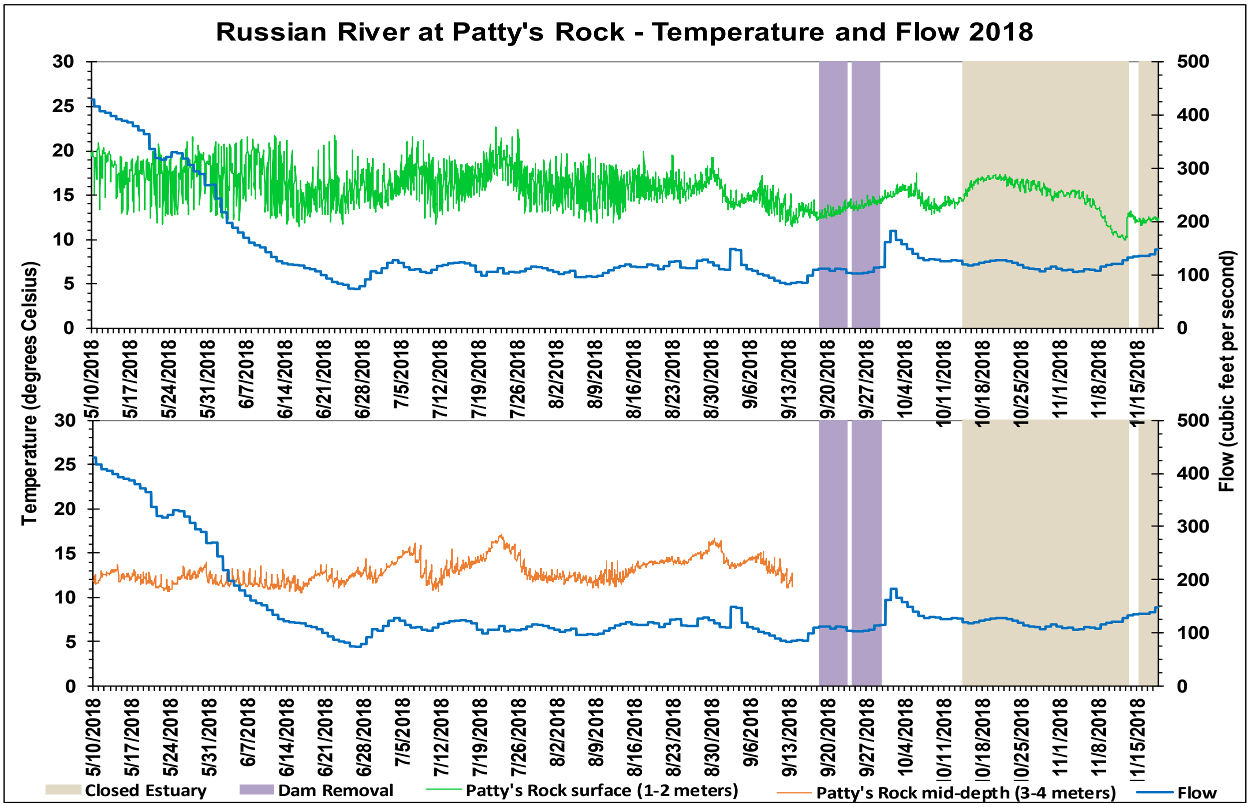



Figure 4.1.9. 2018 Russian River at Patty's Rock temperature and flow graph.

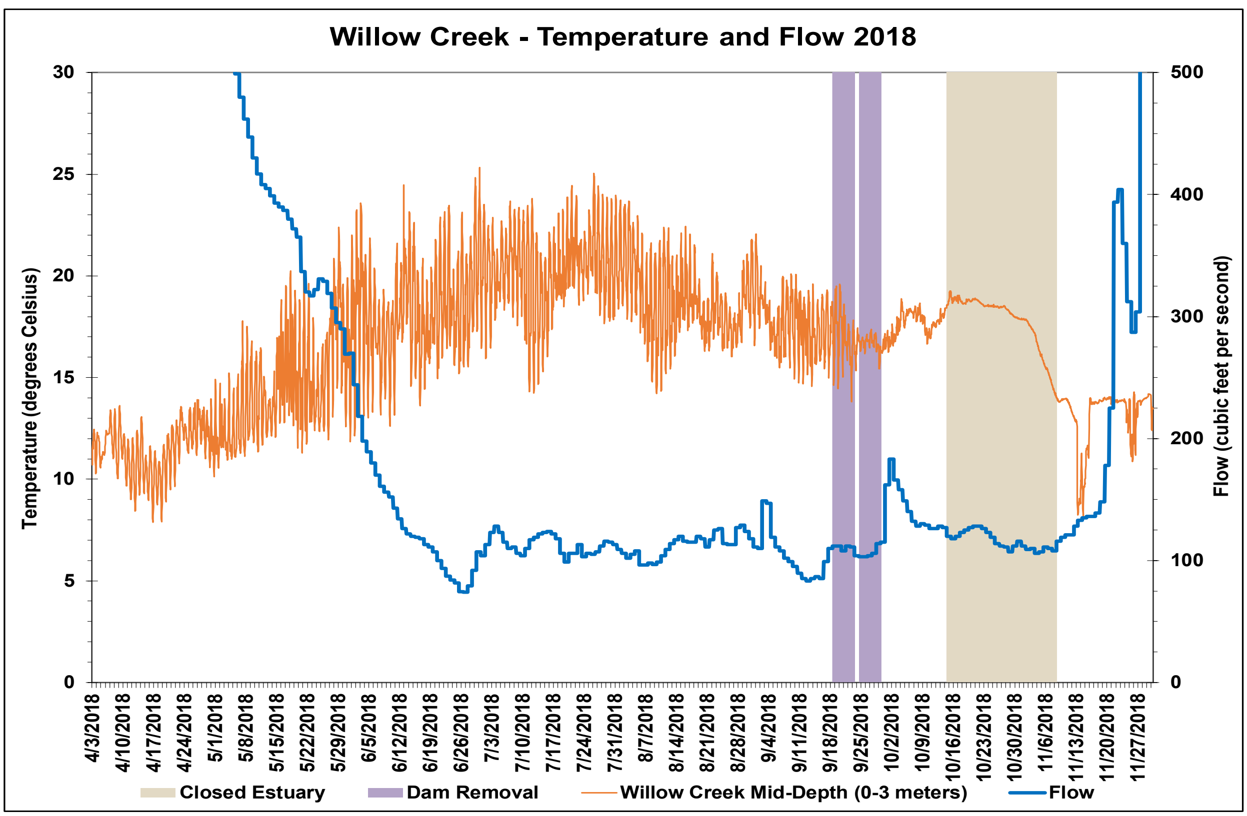



Figure 4.1.10. 2018 Willow Creek temperature with Russian River flow graph.

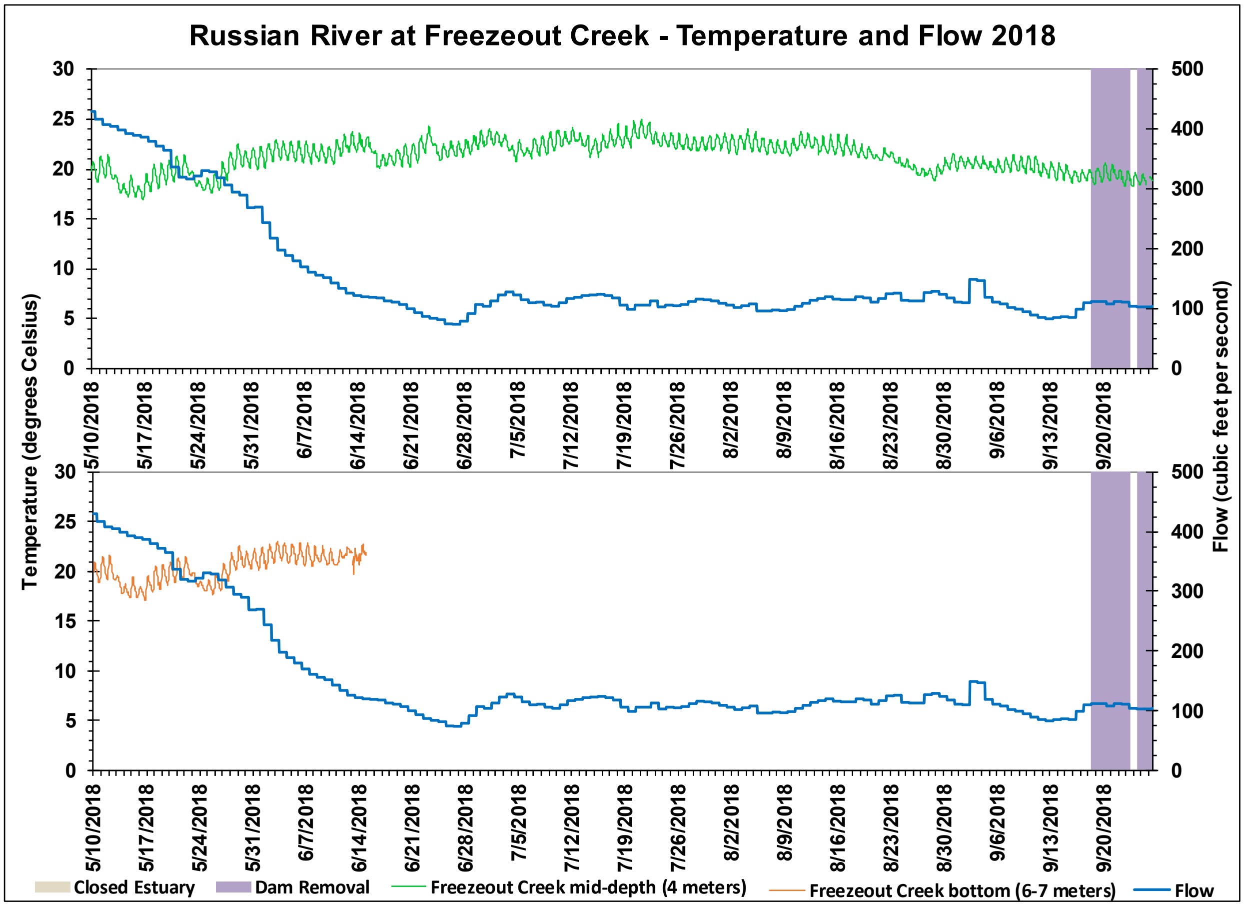



**Figure 4.1.11. 2018 Russian River at Freezeout Creek temperature and flow graph.**

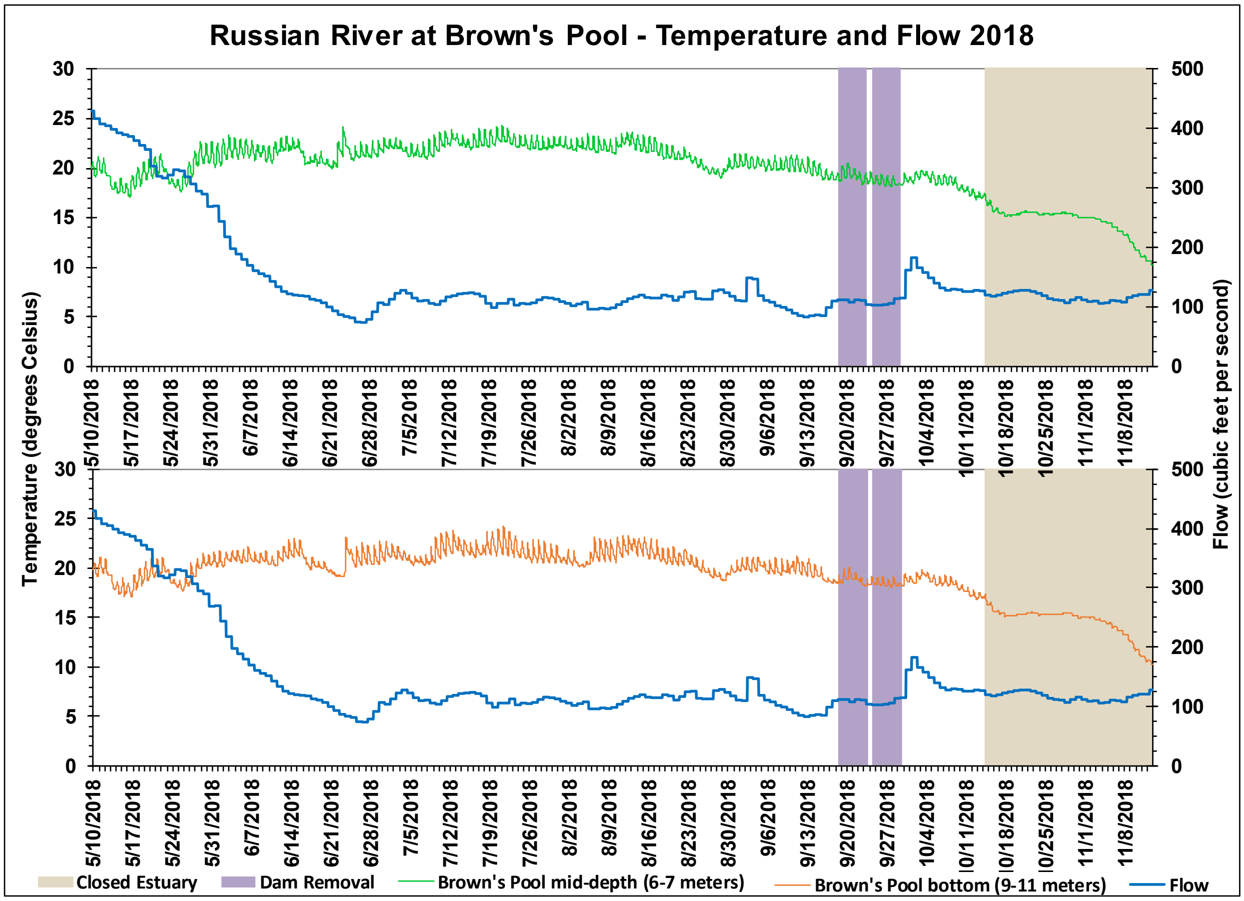



**Figure 4.1.12. 2018 Russian River at Brown's Pool temperature and flow graph.**

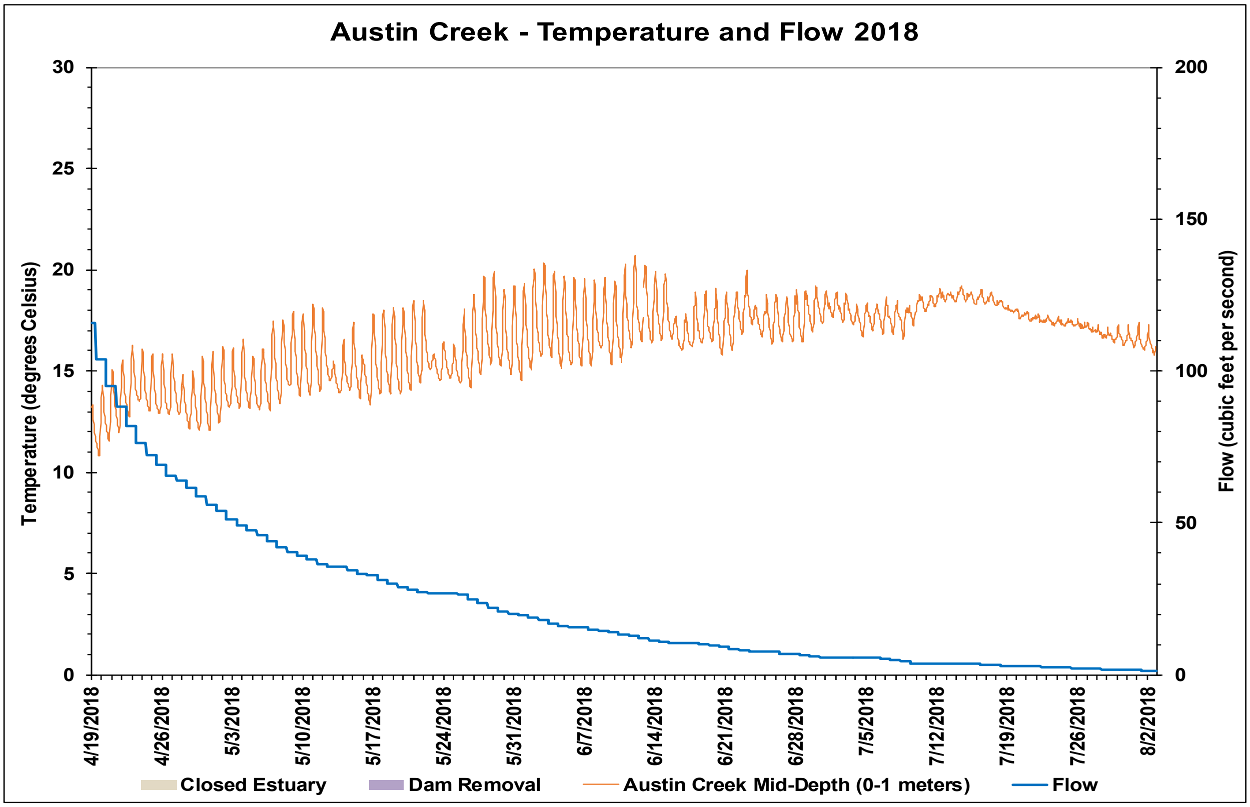



**Figure 4.1.13. 2018 Austin Creek temperature and flow graph.**

The Willow Creek station had a maximum temperature of 25.3 °C, which occurred on 30 June in brackish to saline water and open conditions (Figures 4.1.10 and 4.1.4). The mean temperature was 16.7 °C, and the minimum temperature was 7.9 °C. Elevated salinity was periodically observed in May with mainstem flows dropping below 400 cfs (Figure 4.1.4). However, the station became predominantly brackish to saline by mid-June and remained that way through the management period. Salinity concentrations were observed to stabilize and decline over time during closed Estuary conditions (Figure 4.1.4). Temperatures were observed to fluctuate with the movement of saline water into and out of the station, resulting in both heating and cooling during open and closed Estuary conditions (Figure 4.1.10).

### *Upper Reach Temperature*

Overall estuarine temperatures in both the saline layer and freshwater layer were typically hottest at the upper reach stations, as observed at Freezeout Creek and Brown's Pool, and became progressively cooler as the water flowed downstream, closer to the cooling effects of the coast and ocean.

The Freezeout Creek bottom sonde had a maximum temperature of 23.0 °C, a mean temperature of 20.3 °C, and a minimum temperature of 17.0 °C during the one month the sonde was in operation (Table 4.1.1). The Freezeout Creek mid-depth sonde had a maximum temperature of 25.0 °C, a mean temperature of 21.3 °C, and a minimum temperature of 16.9 °C. Minimum temperatures occured in freshwater during open conditions in May (Figure 4.1.11).

The maximum temperatures were observed to occur in freshwater conditions during open estuary conditions in July (Figures 4.1.11 and 4.1.5).

The Brown's Pool bottom sonde had a maximum temperature of 24.2 °C, a mean temperature of 19.4 °C, and a minimum temperature of 10.2 °C (Table 4.1.1). The Brown's Pool mid-depth sonde had a maximum temperature of 24.3 °C, a mean temperature of 19.8 °C, and a minimum temperature of 10.2 °C. Minimum temperatures at the Brown's Pool station were observed in freshwater habitat during closed conditions in November (Figures 4.1.12 and 4.1.6).

*Maximum Backwater Area Temperature*
Austin Creek had a maximum temperature of 21.5 °C, a mean temperature of 16.6 °C, and a minimum temperature of 10.8 °C (Table 4.1.1). A gradual increase in temperature through the summer months of the estuary management period coincided with increases in air temperatures (Figure 4.1.13).

The Patterson Point bottom sonde had a maximum temperature of 22.6 °C, a mean temperature of 18.3 °C, and a minimum temperature of 9.1 °C (Table 4.1.1). The Patterson Point mid-depth sonde had a maximum temperature of 23.6 °C, a mean temperature of 19.9 °C, and a minimum temperature of 9.3 °C. Under open and closed conditions, daily temperatures were often lower at Patterson Point than at Brown's Pool, which suggests that thermal stratification may be occurring at depth (Figure 4.1.14). It is also possible that a groundwater source could be contributing colder water at depth, or it could a combination of both effects occurring in tandem. Temperatures continued to decline with atmospheric temperatures through the end of the season and did not appear to be affected by the extended closures (Figure 4.1.14).

## Dissolved Oxygen

Dissolved oxygen (DO) levels in the Estuary, including the MBA, depend upon factors such as the extent of diffusion from surrounding air and water movement, including freshwater inflow. DO is affected by salinity and temperature stratification, tidal and wind mixing, abundance of aquatic plants, and presence of decomposing organic matter. DO affects fish growth rates, embryonic development, metabolic activity, and under severe conditions, stress and mortality. Cold water has a higher saturation point than warmer water; therefore cold water is capable of carrying higher levels of oxygen.

DO levels are also a function of nutrients, which can accumulate in water and promote plant and algal growth that both consume and produce DO during photosynthesis and respiration. Estuaries tend to be naturally eutrophic because land-derived nutrients are concentrated where runoff enters the marine environment in a confined channel[1]. Upwelling in coastal systems also promotes increased productivity by conveying deep, nutrient-rich waters to the surface, where the nutrients can be assimilated by algae. Excessive nutrient concentrations and plant, algal, and bacterial growth can overwhelm eutrophic systems and lead to a reduction in DO levels that can affect the overall ecological health of the Estuary.

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[1] National Estuarine Eutrophication Assessment by NOAA National Centers for Coastal Ocean Science (NCCOS) and the Integration and Application Network (IAN), 1999.

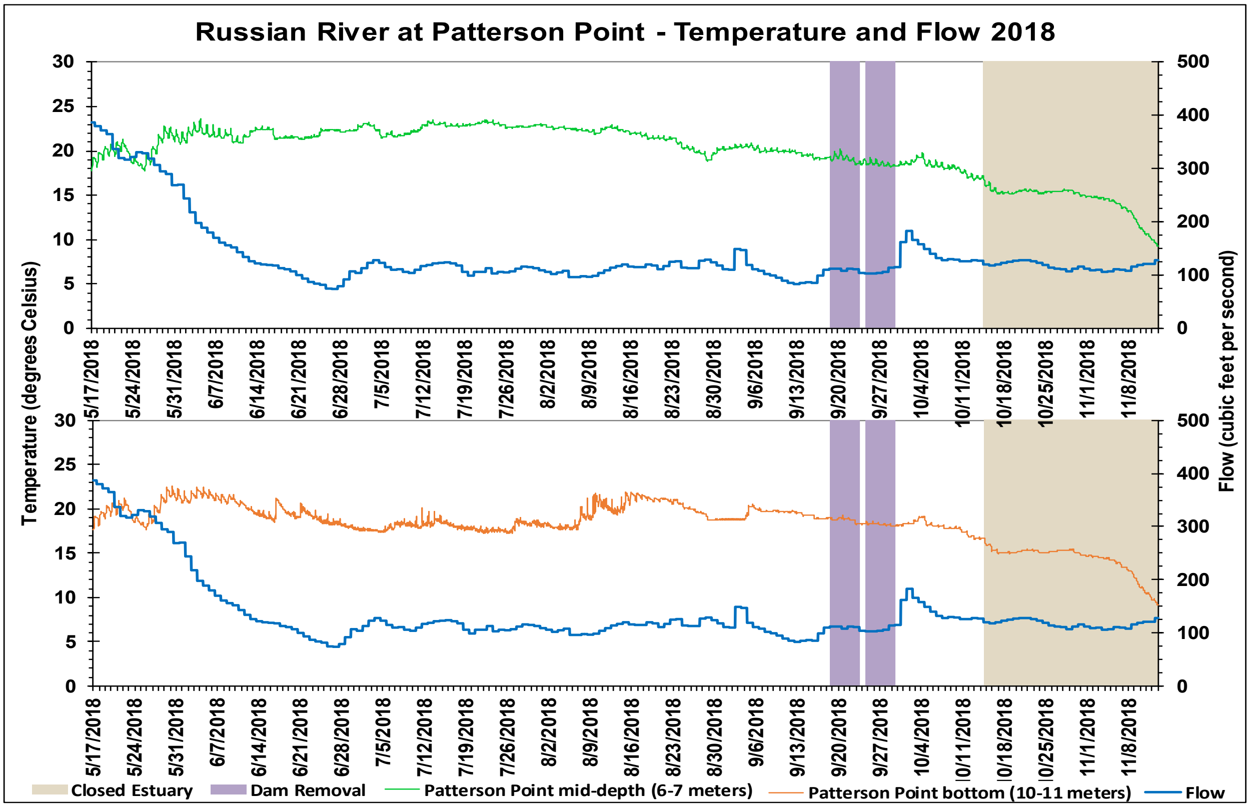



**Figure 4.1.14. 2018 Russian River at Patterson Point temperature and flow graph.**

### *Lower and Middle Reach Dissolved Oxygen*

Mean dissolved oxygen concentrations at Patty's Rock were generally higher at the surface sonde compared to the mid-depth sonde. Whereas the Patty's Rock surface sonde had a mean DO concentration of 9.6 mg/L, the mid-depth sonde had a mean DO concentration of 9.2 mg/L (Table 4.1.1). The mid-depth and surface sondes were both observed to experience supersaturation conditions, and occasional hypoxic conditions. These supersaturation and hypoxic events were observed during open and closed conditions (Figure 4.1.15).

The effect of closed conditions at the surface sonde was variable as DO concentrations were observed to increase to supersaturation conditions before declining to normal concentrations during the October closure, as well as decrease to hypoxic conditions during the November closure (Figure 4.1.15). The Patty's Rock surface sonde had a minimum DO concentration of 1.5 mg/L (Table 4.1.1). Minimum concentrations were observed to occur in brackish water following the transition from closed to open barrier beach conditions (Figures 4.1.15 and 4.1.3).

DO concentrations were observed to become hypoxic at the Patty's Rock mid-depth sonde during open conditions (Figure 4.1.15). The minimum DO concentration at the mid-depth sonde was 2.8 mg/L (Table 4.1.1).

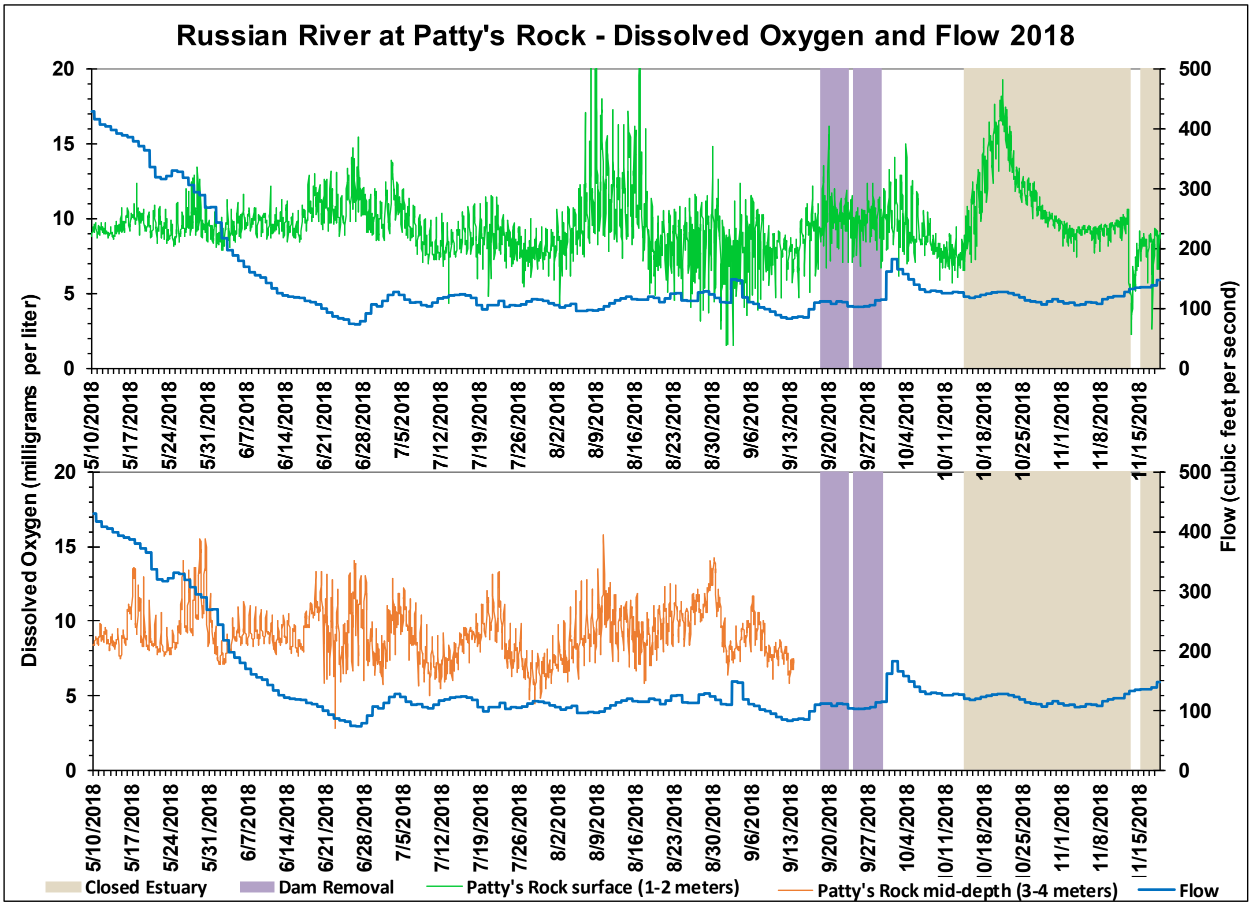



**Figure 4.1.15. 2018 Russian River at Patty's Rock dissolved oxygen and flow graph.**

The Patty's Rock surface sonde, and mid-depth sonde to a lesser degree, experienced hourly fluctuating supersaturation events. Supersaturation events were observed at the surface and mid-depth sondes during open and closed estuary conditions (Figure 4.1.15). At times when oxygen production exceeds the diffusion of oxygen out of the system, supersaturation may occur (Horne, 1994). DO concentrations exceeding 100% saturation in the water column are considered supersaturated conditions. Because the ability of water to hold oxygen changes with temperature, there are a range of concentration values that correspond to 100% saturation. For instance, at sea level, 100% saturation is equivalent to approximately 11 mg/L at 10 °C, but only 8.2 mg/L at 24 °C. Consequently, these two temperature values roughly represent the range of temperatures typically observed in the Estuary.

The Patty's Rock surface sonde had a maximum DO concentration of 22.6 mg/L, which corresponded to 260% saturation (Table 4.1.1). The maximum DO concentration at the mid-depth sonde was 15.8 mg/L, which corresponded to 177% saturation (Table 4.1.1).

Dissolved oxygen concentrations in Willow Creek were observed to fluctuate in response to a variety of events including tidal water movement, saline intrusion, and open or closed Estuary conditions. Large diurnal swings in dissolved oxygen concentrations were observed to occur with frequent supersaturation events in both brackish and freshwater during open barrier beach conditions in the first half of the monitoring season (Figure 4.1.16). Whereas, DO concentrations were observed to steadily decline over a period of days during barrier beach closures in both brackish and freshwater conditions. However, DO concentrations were observed to recover between and after closures as oxygenated saline water or freshwater migrated back into the station (Figure 4.1.16).

The Willow Creek sonde had a minimum DO concentration of 0.1 mg/L, a mean DO concentration of 7.3 mg/L, and a maximum DO concentration of 14.1 mg/L (173%) (Table 4.1.1).

*Upper Reach Dissolved Oxygen*
Dissolved oxygen concentrations in the upper reach were influenced by the presence or absence of salinity, with lower minimum and mean DO concentrations observed in brackish water and higher minimum and mean concentrations observed in freshwater, especially during closed conditions. Although the bottom sonde at Freezeout Creek malfunctioned in June and salinity concentrations were not tracked at the bottom of the station after that, the mid-depth sonde remained a predominantly freshwater habitat that was periodically subject to elevated salinity levels during the season as the salt wedge migrated up the Estuary during open conditions (Figure 4.1.5). Whereas, the Brown’s Pool station remained a freshwater habitat during the entire monitoring season with no elevated salinity levels recorded in 2018 (Figure 4.1.6). Depressed oxygen concentrations approaching hypoxic levels were observed to occur at both sondes at the Freezeout Creek station in brackish and freshwater habitat during open Estuary conditions (Figure 4.1.17). Whereas, hypoxic and anoxic conditions were observed to occur in freshwater habitat during open conditions at the bottom of the Brown’s Pool station, but not at the mid-depth sonde (Figure 4.1.18).

The Freezeout Creek mid-depth sonde had a minimum concentration of 4.4 mg/L, a mean DO concentration of 8.9 mg/L, and a maximum concentration of 13.0 mg/L (144%) (Table 4.1.1).

The Freezeout Creek bottom sonde malfunctioned in June and no data were recorded after that. During the time it was functional, the Freezeout Creek bottom sonde had a minimum concentration of 3.4 mg/L, a mean DO concentration of 8.8 mg/L, and a maximum concentration of 12.6 mg/L (140%) (Table 4.1.1).

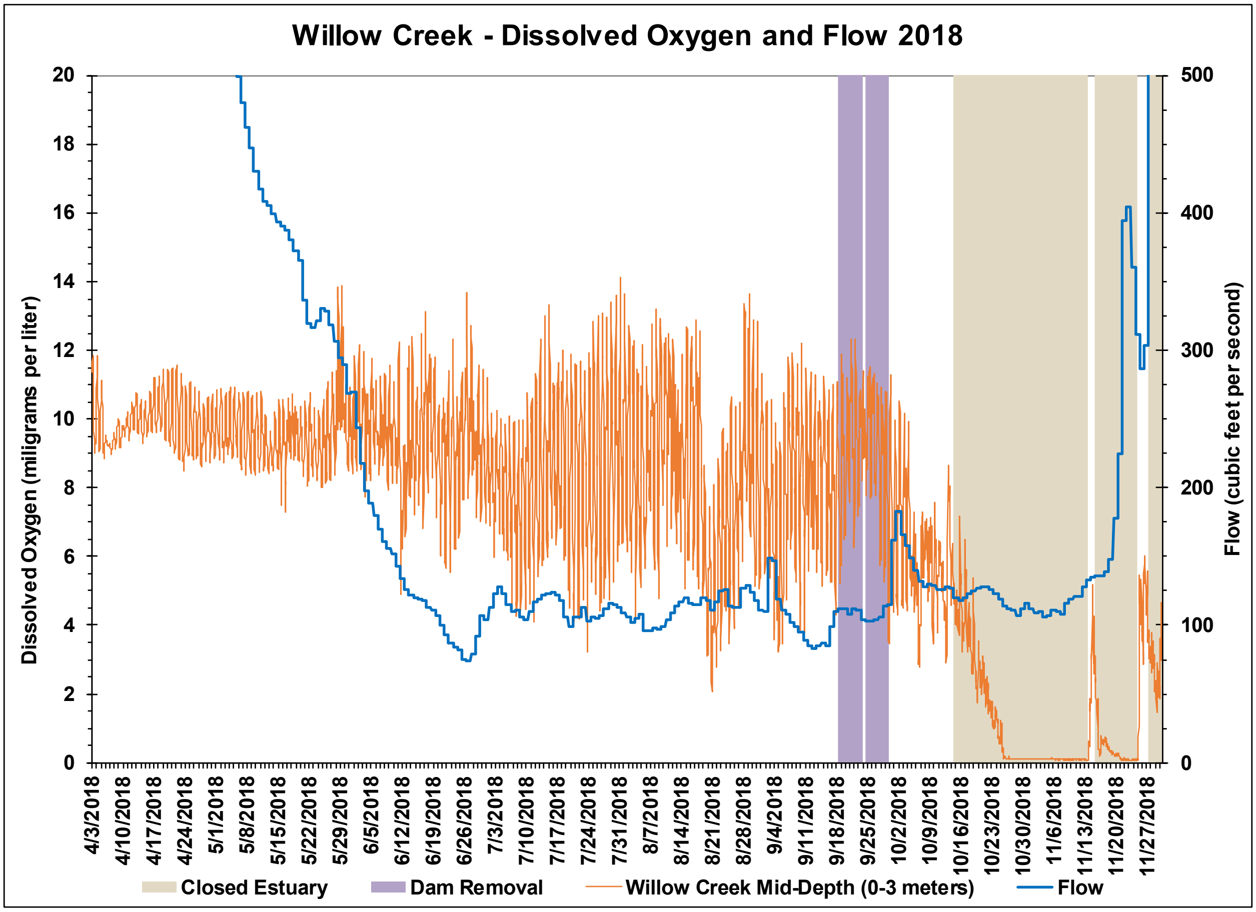



**Figure 4.1.16. 2018 Willow Creek dissolved oxygen and Russian River flow graph.**

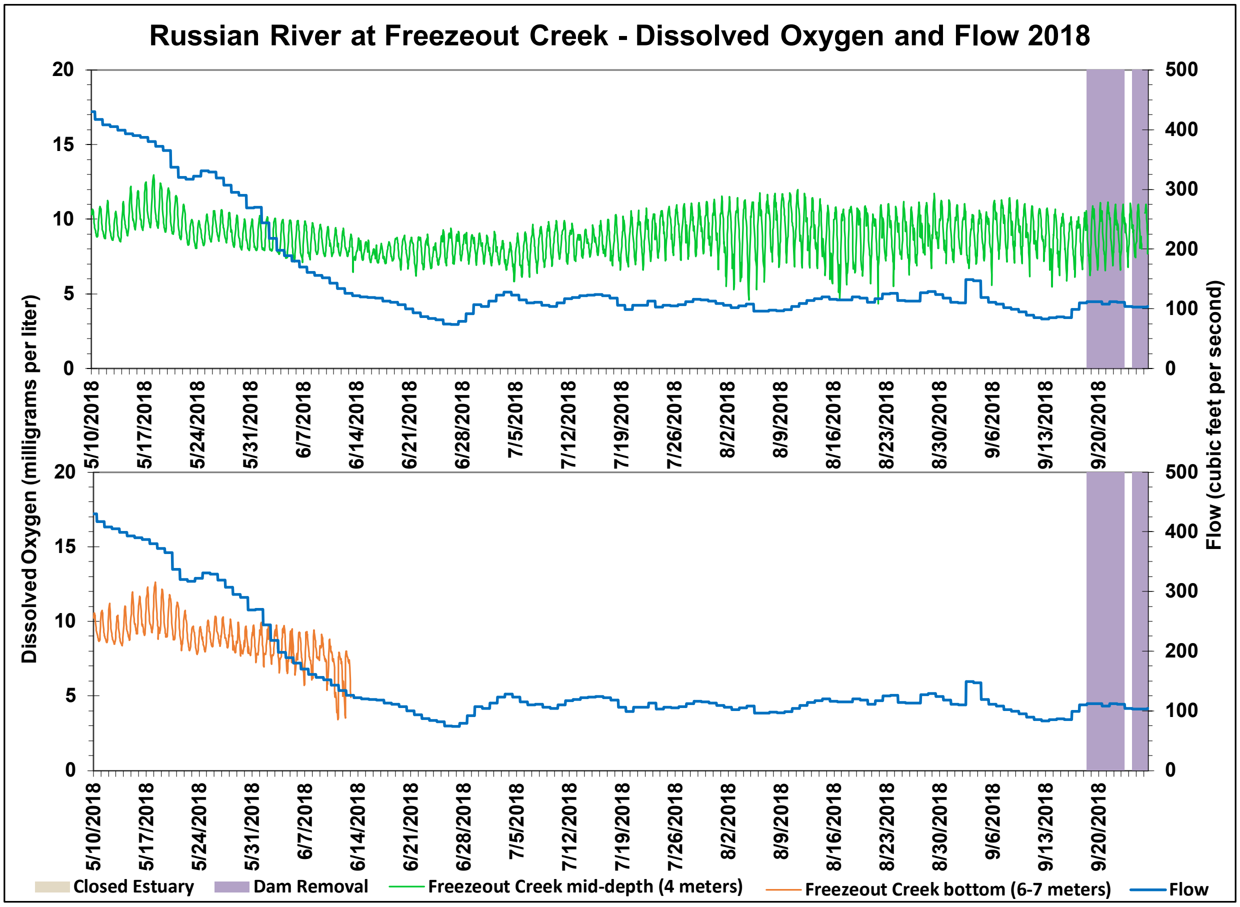



**Figure 4.1.17. 2018 Russian River at Freezeout Creek dissolved oxygen and flow graph.**

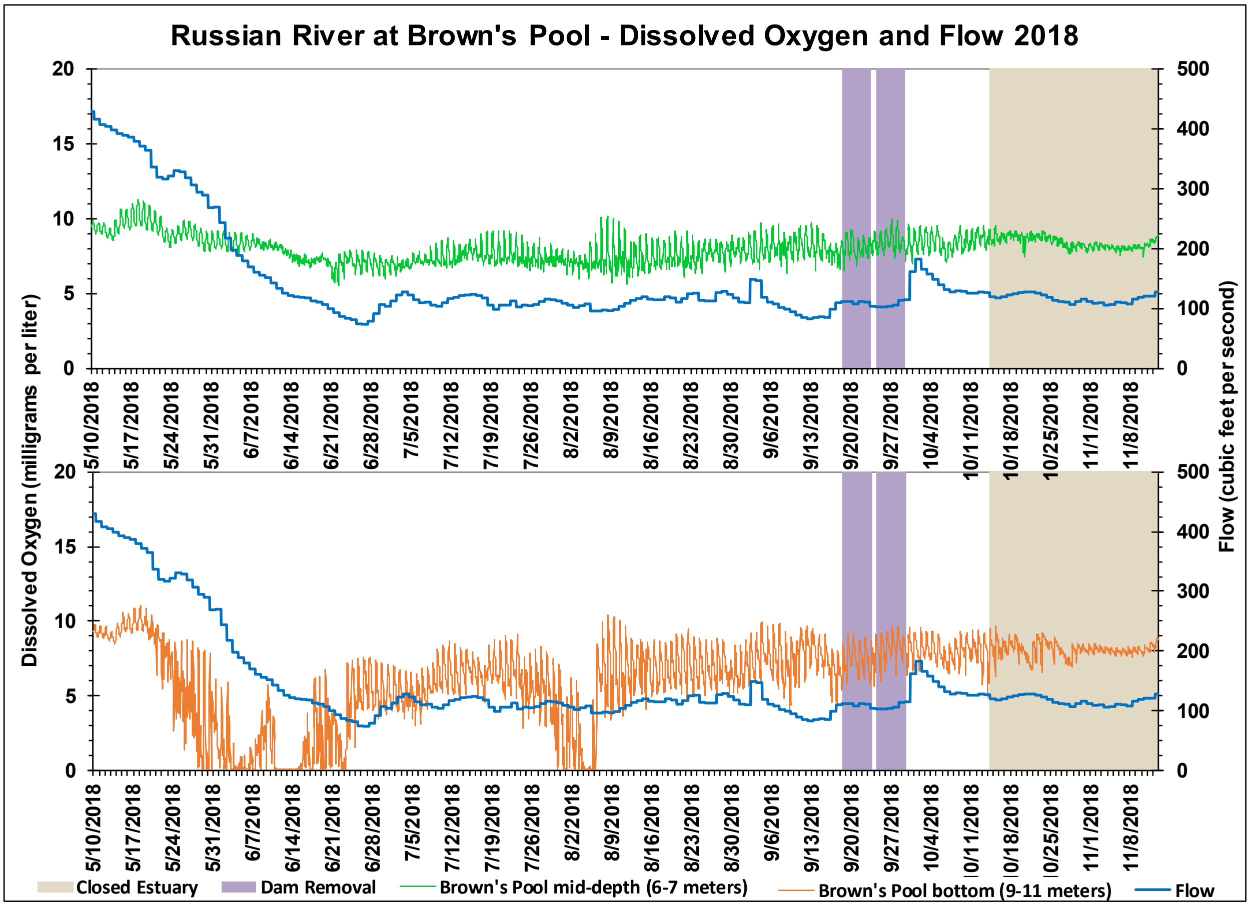



**Figure 4.1.18. 2018 Russian River at Brown's Pool dissolved oxygen and flow graph.**

The Brown's Pool mid-depth sonde had a minimum concentration of 5.6 mg/L, a mean DO concentration of 8.0 mg/L, and a maximum concentration of 11.3 mg/L (125%) (Table 4.1.1). The Brown's Pool bottom sonde was observed to have a minimum DO concentration of 0.1 mg/L, a mean concentration of 6.3 mg/L, and a maximum concentration of 11.1 mg/L (122%) (Table 4.1.1).

The bottom of Brown's Pool remained freshwater during the entire monitoring season in open and closed conditions (Figure 4.1.6). DO concentrations were observed to remain relatively stable in freshwater conditions, however depressed concentrations as low as 0.1 mg/L were observed during estuary closure in August (Figure 4.1.18).

*Maximum Backwater Area Dissolved Oxygen*

The Austin Creek sonde was deployed from May to August when a lack of flow and adequate water depth required equipment removal for the remainder of the season. During that period, the Austin Creek station had a minimum DO concentration of 0.6 mg/L, a mean concentration of 7.2 mg/L, and a maximum concentration of 10.9 mg/L (106%) (Table 4.1.1).

Minimum concentrations at Austin Creek were observed when flows dropped below 2 cfs in early August (Figure 4.1.19).

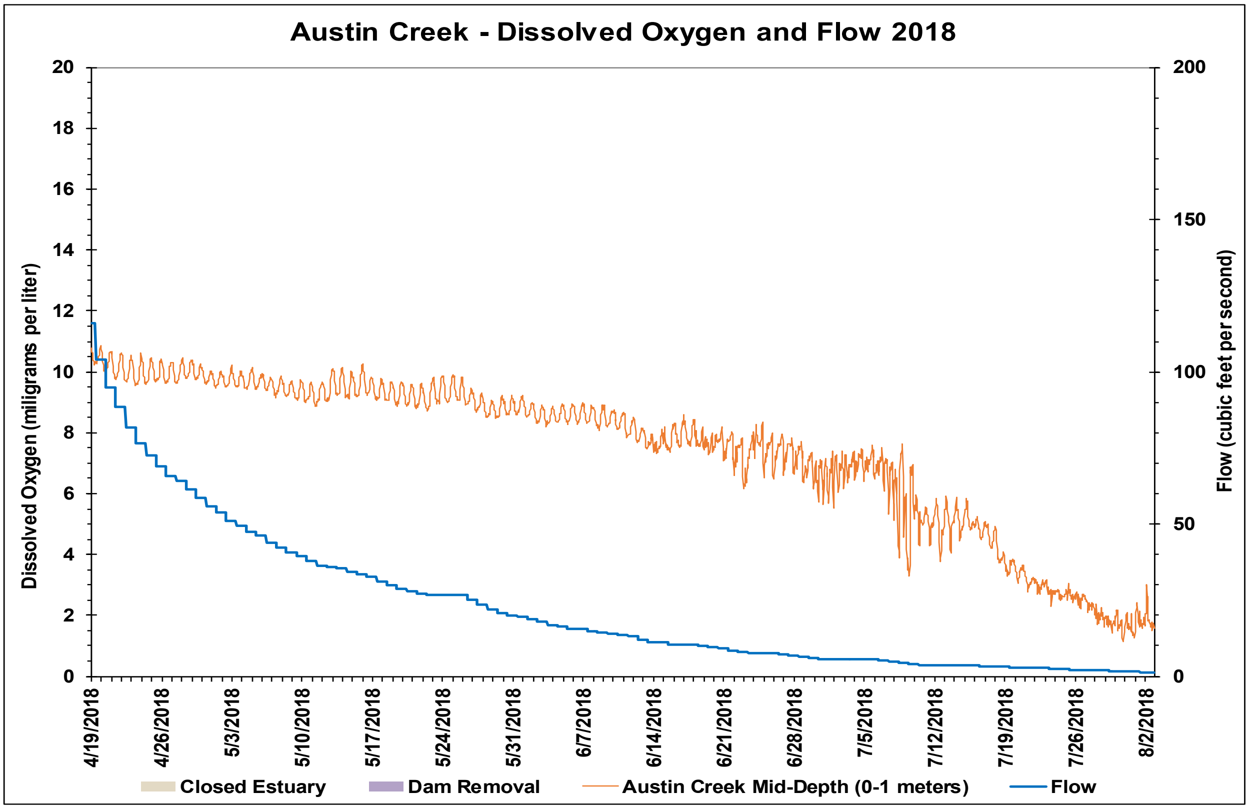



**Figure 4.1.19. 2018 Austin Creek Dissolved Oxygen and Flow Graph.**

The Patterson Point bottom sonde had a minimum DO concentration of 0.1 mg/L, a mean concentration of 5.1 mg/L, and a maximum concentration of 11.1 mg/L (121%). The bottom sonde remained predominantly hypoxic to anoxic from June through August under open conditions before recovering for the rest of the season, including during closed conditions (Figure 4.1.20).

The Patterson Point mid-depth sonde had minimum, mean, and maximum DO concentrations of 3.9, 7.8, and 11.1 mg/L (122%), respectively (Table 4.1.1). DO concentrations were observed to remain relatively stable in freshwater conditions, with depressed concentrations as low as 3.9 mg/L being observed to briefly occur during open conditions in late June and early July (Figure 4.1.20).

## Hydrogen Ion (pH)

The acidity or alkalinity of water is measured in units called pH, an exponential scale of 1 to 14 (Horne, 1994). Acidity is controlled by the hydrogen ion H+, and pH is defined as the negative log of the hydrogen ion concentration. A pH value of 7 is considered neutral, freshwater streams generally remain at a pH between 6 and 9, and ocean derived salt water is usually at a pH between 8 and 9. When the pH falls below 6 over the long term, there is a noticeable reduction in the abundance of many species, including snails, amphibians, crustacean zooplankton, and fish such as salmon and some trout species (Horne 1994).

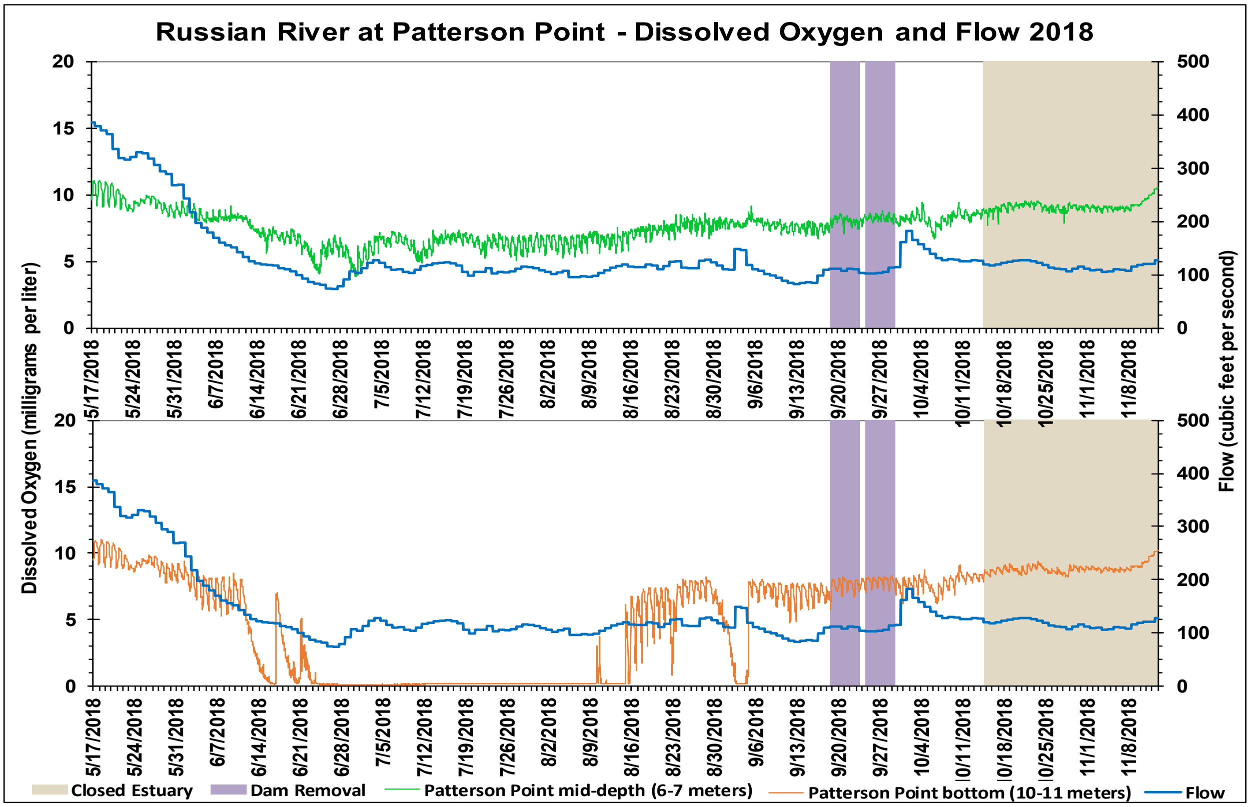



**Figure 4.1.20. 2018 Russian River at Patterson Point Dissolved Oxygen and Flow Graph.**

### *Lower and Middle Reach pH*

Both sondes at the Patty's Rock station experienced malfunctioning pH sensors in late May and early June. During the time they were in operation, the Patty's Rock surface sonde had a minimum pH value of 7.7, a mean pH value of 8.1, and a maximum pH value of 9.0 pH (Table 4.1.1, Figure 4.1.21). The Patty's Rock mid-depth sonde had a minimum pH value of 7.7, a mean pH value of 7.9, and a maximum pH value of 8.4 pH.

The Willow Creek station had a minimum pH value of 6.3, a mean pH value of 7.7, and a maximum pH value of 8.7 (Table 4.1.1). The Willow Creek station also had pH values that were observed to vary with increases and decreases of DO concentrations, as well as with fluctuations in salinity associated with reduced freshwater flows, tidal influence, and Estuary closures (Figures 4.1.16 and 4.1.22).

### *Upper Reach pH*

Both sondes at the Freezeout Creek station experienced malfunctioning pH sensors in late May and late June. During the time they were in operation, the Freezeout Creek mid-depth sonde recorded a minimum pH value of 7.4, a mean pH value of 7.8, and a maximum pH value of 8.3 (Table 4.1.1 and Figure 4.1.23). The Freezeout Creek bottom sonde recorded a minimum pH value of 7.8, a mean pH value of 8.1, and a maximum pH value of 8.6 (Table 4.1.1).

The Brown's Pool mid-depth sonde had a minimum pH value of 7.7, a mean pH value of 8.0, and a maximum pH value of 8.7 (Table 4.1.1). The Brown's Pool bottom sonde had a minimum

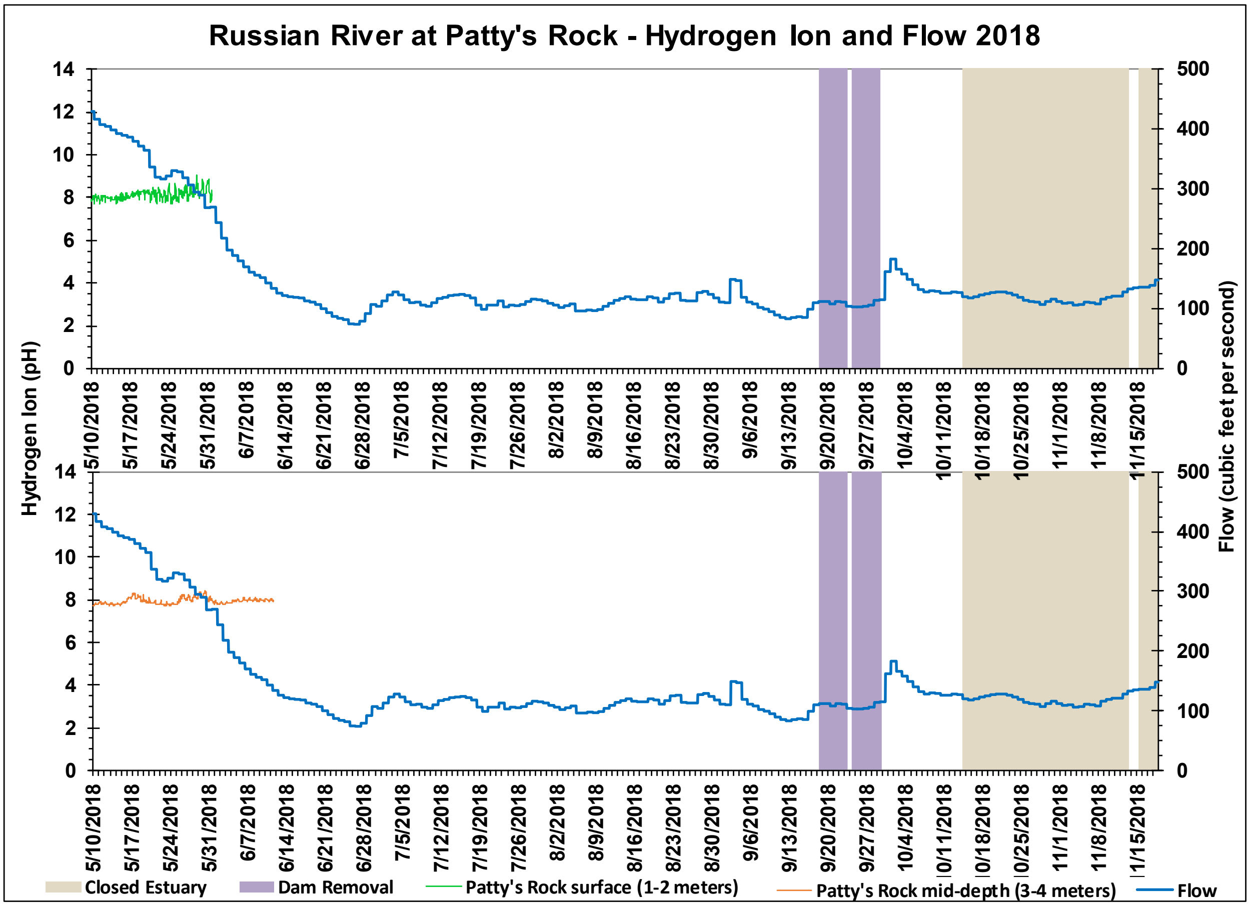



**Figure 4.1.21. 2018 Russian River at Patty's Rock Hydrogen Ion and Flow Graph**

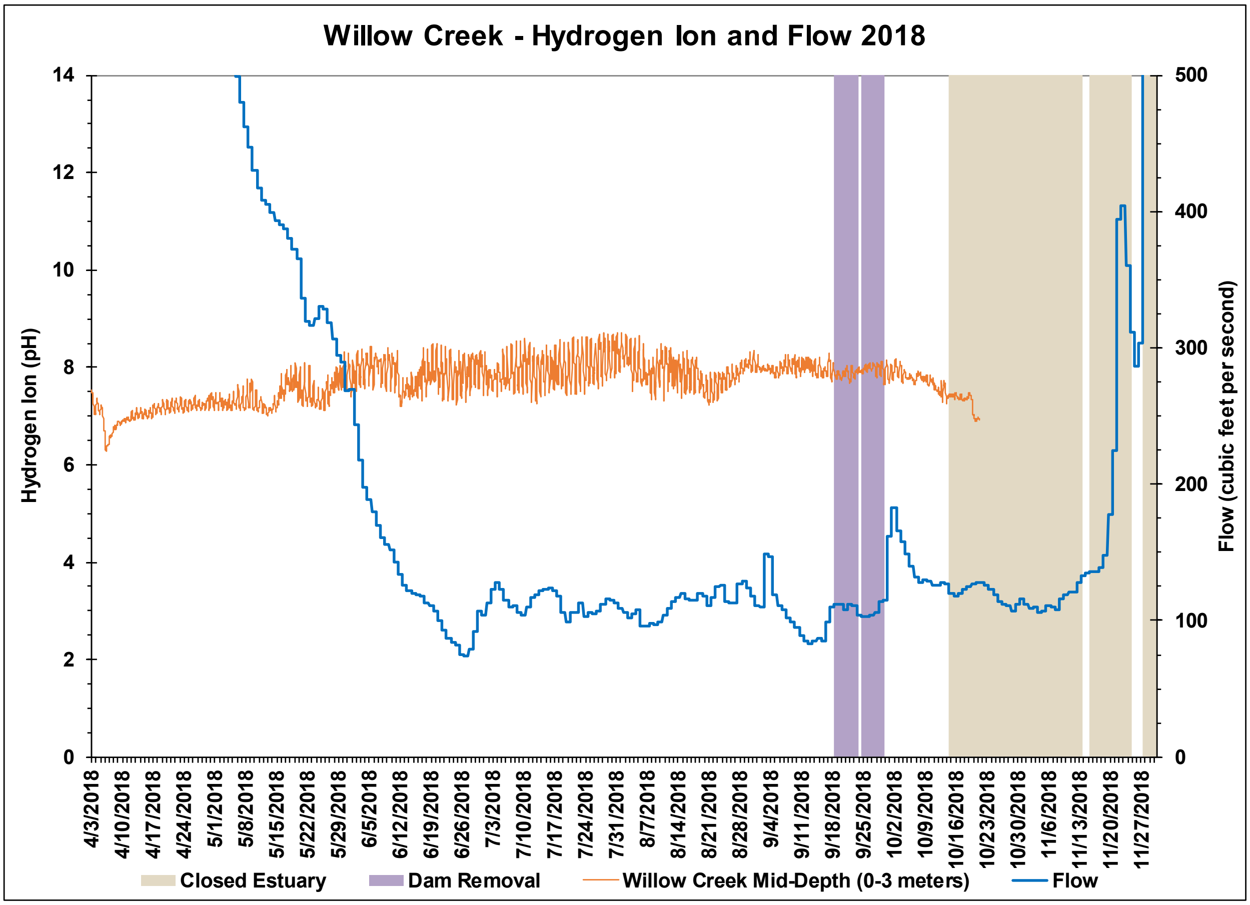



**Figure 4.1.22. 2018 Willow Creek Hydrogen Ion and Russian River Flow Graph**

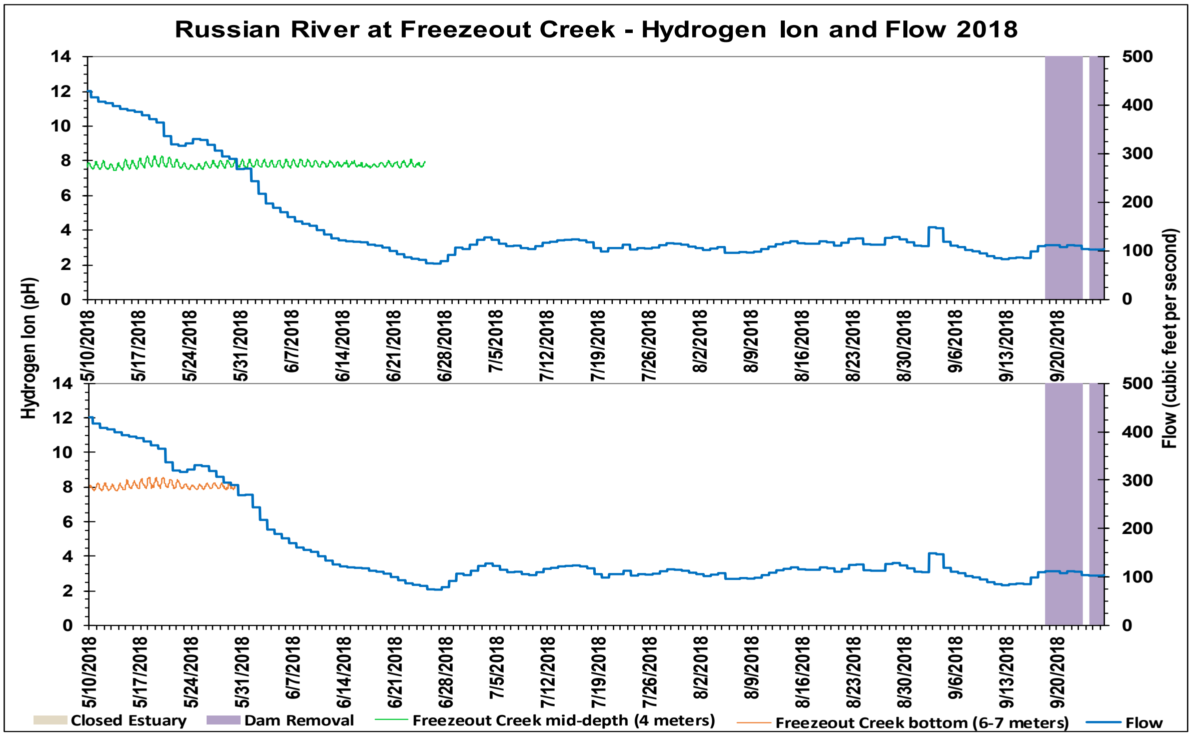



**Figure 4.1.23. 2018 Russian River at Freezeout Creek Hydrogen Ion and Flow Graph**

pH value of 6.5, a mean pH value of 7.8, and a maximum pH value of 8.7 (Table 4.1.1). Minimum pH values occurred at the bottom sonde in freshwater during anoxic conditions when the Estuary was open (Figures 4.1.18 and 4.1.24).

### *Maximum Backwater Area pH*

The Austin Creek sonde had a minimum pH value of 6.5, a mean pH value of 7.4, and a maximum pH value of 8.0 (Table 4.1.1). The Austin Creek sonde also had pH values that were generally observed to vary with increases and decreases of DO concentrations, though not as significantly as some of the mainstem stations (Figures 4.1.19 and 4.1.25).

The Patterson Point mid-depth sonde had a minimum pH value of 7.5, a mean pH value of 7.8, and a maximum pH value of 8.4 (Table 4.1.1). The Patterson Point bottom sonde had a minimum pH value of 6.7, a mean pH value of 7.5, and a maximum pH value of 8.3 (Table 4.1.1). The Patterson Point sondes also had pH values that were generally observed to vary with increases and decreases of DO concentrations (Figures 4.1.20 and 4.1.26). Minimum pH values were observed during hypoxic and anoxic DO concentrations when the Estuary was open.

## Grab Sampling

Sonoma Water staff conducted weekly grab sampling from May 15 to October 16 at three freshwater stations in the mainstem of the lower river including Patterson Point, Monte Rio, and Vacation Beach (Figure 4.1.1). Additional focused sampling was conducted during and after summer dam removal in late September, where Sonoma Water staff would collect three samples in ten days (Tables 4.1.2 through 4.1.4). Samples collected and analyzed for nutrients,

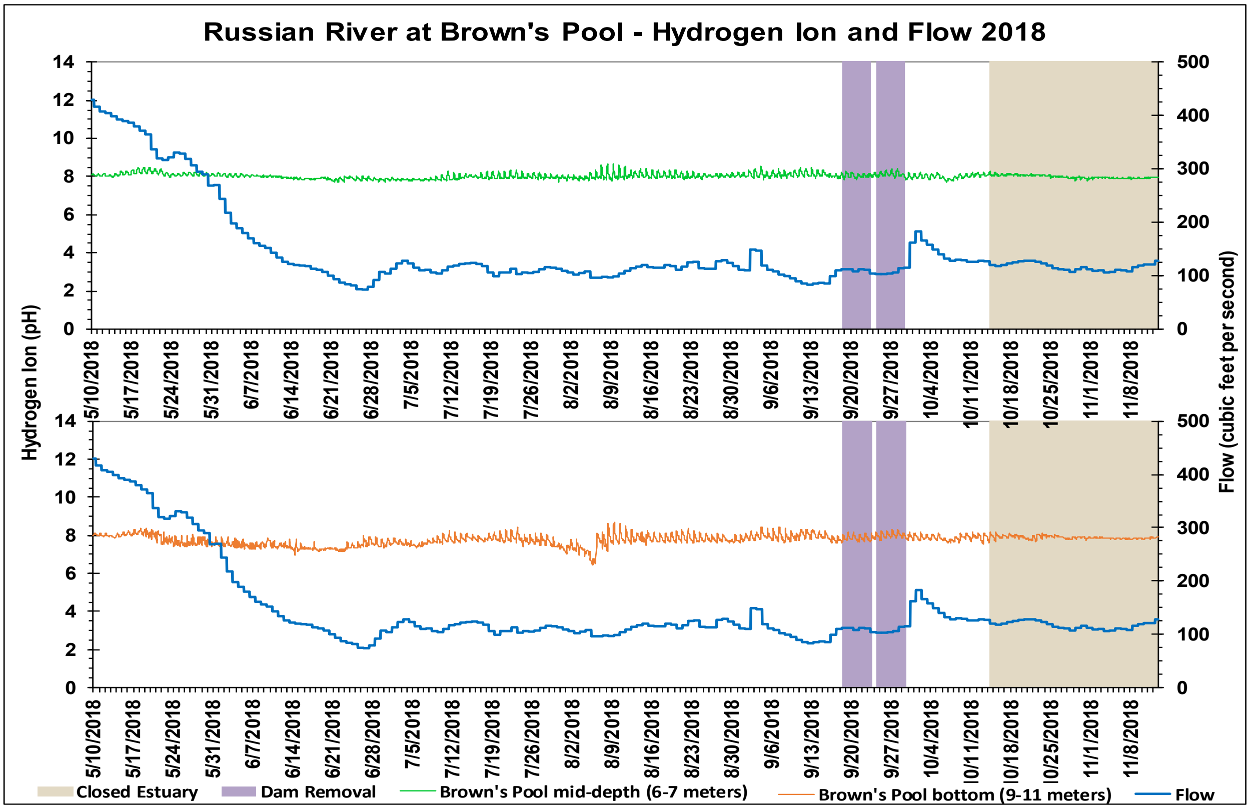



**Figure 4.1.24. 2018 Russian River at Brown's Pool hydrogen ion and flow graph.**

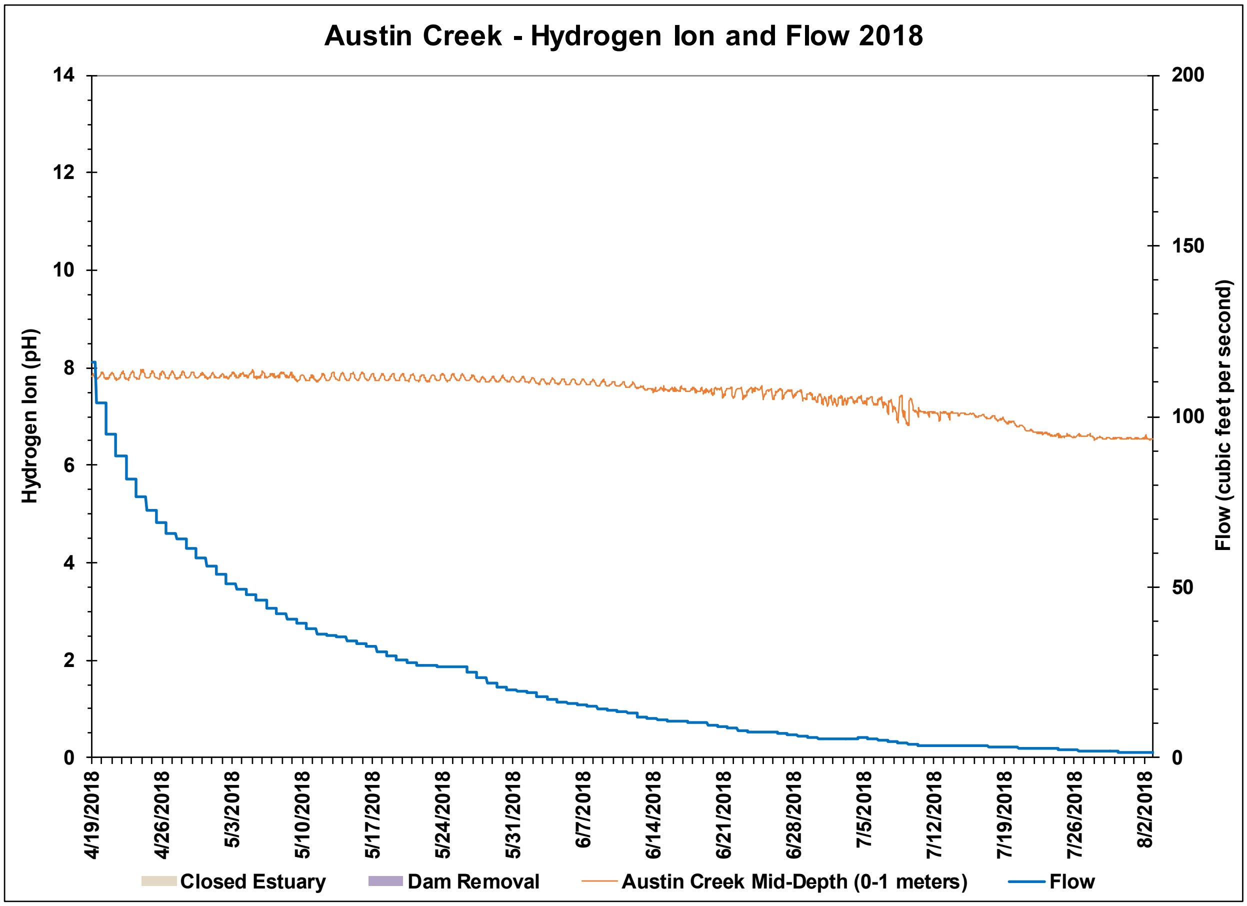



**Figure 4.1.25. 2018 Austin Creek hydrogen ion and flow graph.**

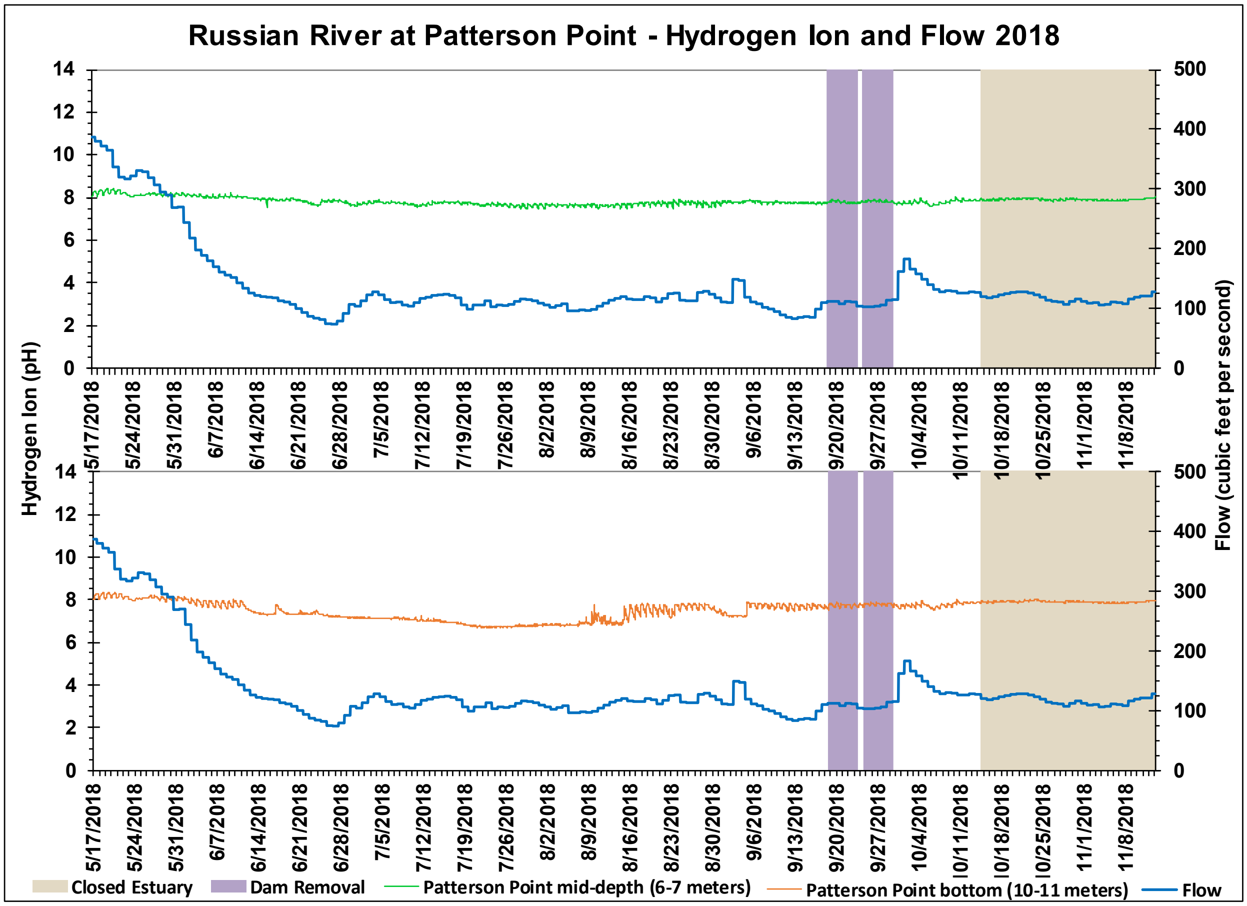



**Figure 4.1.26. 2018 Russian River at Patterson Point hydrogen ion and flow graph.**

## Table 4.1.2. 2018 Russian River at Patterson Point station grab sample results.

| Patterson Point* | Temperature | Total Nitrogen*** | Total Phosphorus | Turbidity | Chlorophyll-a | Total Coliforms (Collilert) | Total Coliforms Diluted 1:10 (Collilert) | E. coli (Collilert) | E. coli Diluted 1:10 (Collilert) | Enterococcus (Enterolert) | USGS 11467000 RR near Guerneville (Hacienda)*** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MDL** | | | 0.020 | 0.020 | 0.000050 | 2 | 20 | 2 | 20 | 2 | Flow Rate | Estuary | Jenner |
| Date | °C | mg/L | mg/L | NTU | mg/L | MPN/100mL | MPN/100mL | MPN/100mL | MPN/100mL | MPN/100mL | (cfs) | Condition | Gauge (ft) |
| 5/15/2018 | 17.4 | 0.26 | **0.039** | 2.2 | **0.0028** | 629.4 | 512 | 6.2 | 10 | 5.2 | 399 | open | 0.97 |
| 5/22/2018 | 19.9 | 0.20 | **0.031** | 1.1 | 0.0016 | 727.0 | 708 | 6.3 | <10.0 | 3.1 | 337 | open | 1.05 |
| 5/29/2018 | 20.8 | 0.21 | **0.031** | 1.4 | **0.0020** | 648.8 | 521 | 9.7 | 20 | 3.1 | 307 | open | 0.84 |
| 6/5/2018 | 23.1 | 0.044 | **0.036** | 1.6 | **0.0025** | 866.4 | 880 | 20.1 | 41 | <1.0 | 198 | open | 0.59 |
| 6/12/2018 | 21.5 | 0.14 | **0.035** | 1.6 | **0.0039** | 1299.7 | 888 | 34.1 | 20 | 1.0 | 143 | open | 1.32 |
| 6/19/2018 | 21.7 | 0.24 | **0.053** | **2.6** | 0.0013 | 1986.3 | 1935 | 30.5 | 31 | 12.2 | 113 | open | 0.93 |
| 6/25/2018 | 23.3 | 0.21 | **0.059** | 2 | **0.0023** | >2419.6 | 2613 | 28.8 | 52 | 17.5 | 83.9 | open | 1.26 |
| 7/3/2018 | 22.8 | **0.47** | **0.066** | **2.5** | 0.0017 | >2419.8 | 9208 | 14.8 | <10 | 18.9 | 113 | open | 0.76 |
| 7/10/2018 | 22.7 | 0.24 | **0.046** | **2.4** | **0.0037** | >2419.6 | 2613 | 38.9 | 20 | 11.0 | 106 | open | 0.72 |
| 7/17/2018 | 22.7 | 0.071 | **0.041** | 1.7 | **0.0020** | 1986.3 | 2149 | 10.9 | 10 | 8.4 | 124 | open | 0.59 |
| 7/24/2018 | 23.2 | 0.10 | **0.045** | 1.4 | **0.0018** | 2419.6 | 1607 | 46.4 | 86 | 7.4 | 113 | open | 0.8 |
| 7/31/2018 | 22.9 | 0.10 | **0.043** | 1.8 | 0.0013 | 1299.7 | 1483 | 26.9 | <10 | 10 | 115 | open | 0.5 |
| 8/7/2018 | 22.4 | 0.035 | **0.038** | 1.4 | 0.0012 | 1413.6 | 1211 | 39.9 | 75 | 18.1 | 96.2 | open | 1.35 |
| 8/14/2018 | 22.2 | 0.14 | **0.032** | 0.88 | 0.001 | 1203.3 | 1374 | 12.2 | <10 | **110** | 114 | open | 0.63 |
| 8/21/2018 | 21.4 | 0.14 | **0.031** | 0.78 | 0.0012 | 1299.7 | 697 | 9.7 | <10 | 2.0 | 118 | open | 1.64 |
| 8/28/2018 | 19.6 | 0.07 | **0.024** | 1.4 | ND | 866.4 | 473 | 14.5 | <10 | 4.1 | 113 | open | 0.59 |
| 9/4/2018 | 20.2 | 0.16 | **0.027** | 1.2 | ND | 613.1 | 432 | 13.4 | 41 | 5.2 | 149 | open | 1.77 |
| 9/11/2018 | 19.9 | 0.13 | **0.027** | 0.57 | ND | 1119.9 | 1054 | 12.2 | 20 | 6.2 | 95.0 | open | 0.55 |
| 9/18/2018 | 19.2 | 0.20 | **0.024** | 0.84 | ND | 1046.2 | 689 | 7.5 | 10 | 10.8 | 99.1 | open | 1.52 |
| 9/20/2018 | 19.0 | 0.10 | 0.020 | 0.76 | **--** | 770.1 | 882 | 49.6 | 20 | 28.2 | 112 | open | 1.81 |
| 9/25/2018 | 18.4 | 0.17 | **0.023** | 1.4 | ND | 920.8 | 738 | 58.3 | 74 | 32.3 | 104 | open | 0.72 |
| 9/27/2018 | 18.2 | 0.35 | **0.031** | 1.3 | ND | 727.0 | 683 | 25.3 | 31 | 8.6 | 103 | open | 0.72 |
| 10/2/2018 | 18.3 | 0.14 | **0.025** | 1 | **0.0020** | >2419.6 | 8664 | 222.4 | 223 | **107.1** | 162 | open | 1.81 |
| 10/9/2018 | 17.9 | 0.21 | **0.040** | 0.84 | ND | 613.1 | 465 | 18.9 | 10 | 8.4 | 128 | open | 1.98 |
| 10/16/2018 | 15.0 | 0.24 | **0.039** | 1.2 | ND | 365.4 | 487 | 17.5 | 41 | 7.4 | 120 | closed | 3.12 |

* All results are preliminary and subject to final revision

** Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors.

*** Total nitrogen is calculated through the summation of the different components of total nitrogen:
organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN) and nitrate/nitrite nitrogen.

**** United States Geological Survey (USGS) Continuous-Record Gaging Station ( Flow rates are preliminary and subject to final revision by USGS).

**Recommended EPA Criteria based on Aggregate Ecoregion III**

Total Phosporus: 0.02188 mg/L (21.88 ug/L) ≈ 0.022 mg/L

Total Nitrogen: 0.38 mg/L

Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L) ≈ 0.0018 mg/L

Turbidity: 2.34 FTU/NTU

**CDPH Draft Guidance for Fresh Water Beaches - Single Sample Values:**

Beach posting is recommended when indicator organisms exceed any of the following levels:

Total coliforms: 10,000 per 100 ml

*E. coli:* 235 per 100 ml

Enterococcus: 61 per 100 ml

## Table 4.1.3. 2018 Russian River at Monte Rio Station grab sample results.

| Monte Rio* | Temperature | Total Nitrogen*** | Total Phosphorus | Turbidity | Chlorophyll-a | Total Coliforms (Colilert) | Total Coliforms Diluted 1:10 (Colilert) | E. coli (Colilert) | E. coli Diluted 1:10 (Colilert) | Enterococcus (Enterolert) | USGS 11467000 RR near Guerneville (Hacienda)**** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MDL** | | | 0.020 | 0.020 | 0.000050 | 2 | 20 | 2 | 20 | 2 | Flow Rate | Estuary | Jenner |
| Date | °C | mg/L | mg/L | NTU | mg/L | MPN/100mL | MPN/100mL | MPN/100mL | MPN/100mL | MPN/100mL | (cfs) | Condition | Gauge (ft) |
| 5/15/2018 | 17.2 | 0.30 | **0.038** | **2.7** | **0.0046** | 686.7 | 676 | 13.4 | 20 | 5.2 | 399 | open | 0.97 |
| 5/22/2018 | 19.9 | 0.27 | **0.038** | 1.3 | **0.0031** | 579.4 | 650 | 5.2 | <10.0 | 3.0 | 337 | open | 0.88 |
| 5/29/2018 | 21.1 | 0.17 | **0.034** | 1.5 | **0.0022** | 770.1 | 613 | 5.2 | 10 | 5.2 | 307 | open | 0.97 |
| 6/5/2018 | 23.0 | 0.28 | **0.037** | 1.8 | **0.0025** | 1046.2 | 882 | 14.5 | 10 | 2.0 | 198 | open | 0.5 |
| 6/12/2018 | 22.5 | 0.18 | **0.038** | 1.4 | **0.0041** | 866.4 | 727 | 21.8 | 20 | <1.0 | 143 | open | 1.47 |
| 6/19/2018 | 22.0 | 0.24 | **0.048** | 2.1 | ND | 1119.9 | 1274 | 21.3 | 75 | 14.6 | 113 | open | 0.72 |
| 6/25/2018 | 23.3 | 0.071 | **0.059** | **2.4** | **0.0024** | >2419.6 | 3873 | 27.2 | 97 | 30.1 | 83.9 | open | 1.52 |
| 7/3/2018 | 23.7 | 0.070 | **0.058** | 1.4 | **0.0019** | >2419.8 | 7701 | 24.3 | 20 | 16.9 | 113 | open | 0.72 |
| 7/10/2018 | 23.4 | **0.56** | **0.043** | 2.1 | **0.0029** | >2419.6 | 3873 | 6.3 | <10 | 16.9 | 106 | open | 1.31 |
| 7/17/2018 | 23.4 | 0.10 | **0.042** | 1.0 | 0.0015 | 2419.6 | 2143 | 7.5 | 10 | 1.0 | 124 | open | 0.55 |
| 7/24/2018 | 23.7 | 0.18 | **0.040** | 1.2 | **0.0021** | 1119.4 | 1334 | 29.5 | 20 | 6.3 | 113 | open | 1.43 |
| 7/31/2018 | 23.8 | 0.18 | **0.038** | 1.9 | 0.0016 | 1046.2 | 1081 | 23.1 | 20 | 31 | 115 | open | 0.46 |
| 8/7/2018 | 23.3 | 0.10 | **0.036** | 1.4 | 0.0010 | 1119.9 | 1162 | 14.6 | 10 | 9.7 | 96.2 | open | 1.47 |
| 8/14/2018 | 22.7 | 0.14 | **0.031** | 1.0 | **0.0024** | 920.8 | 959 | 5.1 | 30 | **75** | 114 | open | 0.63 |
| 8/21/2018 | 21.6 | 0.14 | **0.027** | 1.4 | 0.0015 | 816.4 | 697 | 36.4 | 63 | 5.2 | 118 | open | 1.73 |
| 8/28/2018 | 19.8 | 0.10 | 0.021 | 1.4 | ND | 579.4 | 368 | 14.5 | <10 | 4.1 | 113 | open | 0.59 |
| 9/4/2018 | 20.5 | 0.20 | **0.024** | 1.0 | 0.0013 | 461.1 | 441 | 22.3 | 20 | 5.2 | 149 | open | 1.6 |
| 9/11/2018 | 20.5 | 0.10 | **0.036** | 0.74 | ND | 1203.3 | 789 | 16.1 | <10 | 6.3 | 95.0 | open | 0.63 |
| 9/18/2018 | 19.6 | 0.21 | **0.024** | 0.88 | 0.0014 | 1046.2 | 644 | 16.1 | 20 | 5.1 | 99.1 | open | 1.43 |
| 9/20/2018 | 19.2 | 0.24 | **0.022** | **2.4** | | 579.4 | 733 | 36.4 | 10 | 7.4 | 112 | open | 1.85 |
| 9/25/2018 | 18.7 | 0.17 | **0.024** | 1.6 | ND | 613.1 | 512 | 14.5 | 10 | 6.3 | 104 | open | 1.35 |
| 9/27/2018 | 18.6 | 0.14 | 0.021 | 1.4 | ND | 547.5 | 417 | 20.3 | 30 | 10 | 103 | open | 1.52 |
| 10/2/2018 | 18.3 | **0.61** | **0.026** | 0.84 | ND | >2419.6 | 4106 | 123.6 | 86 | **122.3** | 162 | open | 1.81 |
| 10/9/2018 | 17.7 | 0.21 | **0.035** | 0.73 | ND | 435.2 | 644 | 14.6 | 41 | 11.9 | 128 | open | 2.27 |
| 10/16/2018 | 14.5 | 0.24 | **0.039** | 1.1 | ND | 387.3 | 318 | 18.3 | 10 | 13.4 | 120 | closed | 3.12 |

* All results are preliminary and subject to final revision

** Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors.

*** Total nitrogen is calculated through the summation of the different components of total nitrogen:
organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN) and nitrate/nitrite nitrogen.

**** United States Geological Survey (USGS) Continuous-Record Gaging Station ( Flow rates are preliminary and subject to final revision by USGS).

**Recommended EPA Criteria based on Aggregate Ecoregion III**

Total Phosporus: 0.02188 mg/L (21.88 ug/L) ≈ 0.022 mg/L

Total Nitrogen: 0.38 mg/L

Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L) ≈ 0.0018 mg/L

Turbidity: 2.34 FTU/NTU

**CDPH Draft Guidance for Fresh Water Beaches - Single Sample Values:**

Beach posting is recommended when indicator organisms exceed any of the following levels:

Total coliforms: 10,000 per 100 ml

*E. coli:* 235 per 100 ml

Enterococcus: 61 per 100 ml

**Table 4.1.4. 2018 Russian River at Vacation Beach Station grab sample results.**

| Vacation Beach* | Temperature | Total Nitrogen*** | Total Phosphorus | Turbidity | Chlorophyll-a | Total Coliforms (Colilert) | Total Coliforms Diluted 1:10 (Colilert) | E. coli (Colilert) | E. coli Diluted 1:10 (Colilert) | Enterococcus (Enterolert) | USGS 11467000 RR near Guerneville (Hacienda)**** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MDL** | | | 0.020 | 0.020 | 0.000050 | 2 | 20 | 2 | 20 | 2 | Flow Rate | Estuary | Jenner |
| Date | °C | mg/L | mg/L | NTU | mg/L | MPN/100mL | MPN/100mL | MPN/100mL | MPN/100mL | MPN/100mL | (cfs) | Condition | Gauge (ft) |
| 5/15/2018 | 17.0 | 0.36 | **0.042** | 2.3 | ND | 579.4 | 644 | 9.6 | 10 | 6.3 | 399 | open | 1.05 |
| 5/22/2018 | 19.8 | 0.21 | **0.033** | 1.3 | **0.0038** | 410.6 | 521 | 9.8 | 10 | <1.0 | 337 | open | 0.76 |
| 5/29/2018 | 21.2 | 0.11 | **0.034** | 1.8 | **0.0026** | 435.2 | 691 | 2 | 10 | 2.0 | 307 | open | 1.26 |
| 6/5/2018 | 22.7 | 0.22 | **0.036** | 2 | **0.0026** | 1986.3 | 1314 | 14.6 | 10 | 6.1 | 198 | open | 0.5 |
| 6/12/2018 | 22.0 | 0.18 | **0.039** | 1 | **0.0026** | 1553.1 | 1616 | 32.3 | 52 | 1.0 | 143 | open | 1.47 |
| 6/19/2018 | 21.9 | 0.27 | **0.043** | 1.9 | 0.0011 | 2419.6 | 1054 | 43.5 | <10.0 | 35.4 | 113 | open | 0.72 |
| 6/25/2018 | 23.4 | 0.17 | **0.046** | 1.9 | **0.0031** | >2419.6 | 3076 | 35.9 | 30 | 28.5 | 83.9 | open | 1.52 |
| 7/3/2018 | 23.5 | 0.14 | **0.049** | 1.8 | 0.0011 | >2419.8 | 2489 | 14.8 | 20 | 59.1 | 113 | open | 0.63 |
| 7/10/2018 | 23.4 | 0.18 | **0.045** | 1.6 | **0.0019** | 1986.3 | 1935 | 9.6 | <10 | 4.1 | 106 | open | 1.31 |
| 7/17/2018 | 23.4 | 0.10 | **0.035** | 1.3 | **0.0020** | >2419.6 | 1500 | 10.9 | 10 | 5.1 | 124 | open | 0.5 |
| 7/24/2018 | 23.9 | 0.18 | **0.038** | 1.8 | | 1413.6 | 1450 | 7.5 | 10 | 7.4 | 113 | open | 1.43 |
| 7/31/2018 | 23.6 | 0.10 | **0.034** | 1.6 | 0.0014 | 1119.9 | 1421 | 12.1 | 20 | 52.0 | 115 | open | 0.46 |
| 8/7/2018 | 23.2 | 0.035 | **0.035** | 1.8 | 0.0016 | 1553.1 | 1467 | 3.1 | 20 | 6.3 | 96.2 | open | 1.47 |
| 8/14/2018 | 22.9 | 0.10 | **0.030** | 1.8 | 0.0015 | 1732.9 | 1178 | 36.4 | 31 | **108** | 114 | open | 0.59 |
| 8/21/2018 | 21.5 | 0.070 | **0.025** | 1.1 | 0.0013 | 770.1 | 1137 | 20.6 | <10 | 6.2 | 118 | open | 1.73 |
| 8/28/2018 | 19.9 | 0.10 | **0.023** | 1.6 | 0.0010 | 517.2 | 609 | 2 | 20 | 6.3 | 113 | open | 0.63 |
| 9/4/2018 | 20.6 | 0.13 | **0.26** | 0.82 | 0.0010 | 1413.6 | 727 | 8.6 | <10 | 6.3 | 149 | open | 1.6 |
| 9/11/2018 | 20.5 | 0.10 | **0.025** | 0.64 | ND | 613.1 | 408 | 4.1 | <10 | 4.1 | 95 | open | 0.63 |
| 9/18/2018 | 19.9 | 0.18 | 0.021 | 1.1 | 0.0013 | 648.8 | 776 | 2 | 20 | 8.5 | 99.1 | open | 1.43 |
| 9/20/2018 | 19.4 | 0.20 | **0.023** | 0.66 | | 920.8 | 884 | 10.8 | 63 | 7.3 | 112 | open | 1.68 |
| 9/25/2018 | 19.1 | 0.20 | 0.020 | **3.3** | ND | 816.4 | 480 | 9.7 | 10 | 13.5 | 104 | open | 1.81 |
| 9/27/2018 | 18.7 | 0.24 | **0.026** | 1.6 | ND | 816.4 | 657 | 41.4 | 20 | 8.6 | 103 | open | 2.02 |
| 10/2/2018 | 17.9 | **0.64** | **0.032** | 1.4 | 0.0017 | >2419.6 | 8664 | **435.2** | **383** | **435.2** | 162 | open | 1.68 |
| 10/9/2018 | 17.7 | 0.27 | **0.030** | 1.4 | ND | 980.4 | 754 | 46.4 | 74 | 25.9 | 128 | open | 2.27 |
| 10/16/2018 | 14.7 | 0.21 | **0.035** | 1.5 | ND | 579.4 | 309 | 14.5 | 10 | 12.0 | 120 | closed | 3.12 |

* All results are preliminary and subject to final revision
** Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors.
*** Total nitrogen is calculated through the summation of the different components of total nitrogen:
organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN) and nitrate/nitrite nitrogen.
**** United States Geological Survey (USGS) Continuous-Record Gaging Station ( Flow rates are preliminary and subject to final revision by USGS).

**Recommended EPA Criteria based on Aggregate Ecoregion III**
Total Phosporus: 0.02188 mg/L (21.88 ug/L) ≈ 0.022 mg/L
Total Nitrogen: 0.38 mg/L
Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L) ≈ 0.0018 mg/L
Turbidity: 2.34 FTU/NTU

**CDPH Draft Guidance for Fresh Water Beaches - Single Sample Values:**
Beach posting is recommended when indicator organisms exceed any of the following levels:
Total coliforms: 10,000 per 100 ml
*E. coli:* 235 per 100 ml
Enterococcus: 61 per 100 ml

turbidity, *chlorophyll a*, and indicator bacteria are discussed below. Other sample results including organic carbon, and dissolved solids are not discussed, but are included as an appendix to the report.

### *Nutrients*

The United States Environmental Protection Agency (USEPA) has established section 304(a) nutrient criteria across 14 major ecoregions of the United States. The Russian River was designated in Aggregate Ecoregion III (USEPA, 2013a). USEPA's section 304(a) criteria are intended to provide for the protection of aquatic life and human health (USEPA, 2013b). The following discussion of nutrients compares sampling results to these USEPA criteria. However, it is important to note that these criteria are established for freshwater systems, and as such, are only applicable to the freshwater portions of the Estuary. Currently, there are no numeric nutrient criteria established specifically for estuaries.

The USEPA desired goal for total nitrogen in Aggregate Ecoregion III is 0.38 mg/L for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). Calculating total nitrogen values requires the summation of the different components of total nitrogen; organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN), and nitrate/nitrite nitrogen (Appendix 4.5).

Total nitrogen concentrations were observed to exceed the recommended USEPA levels once each at the Patterson Point and Monte Rio stations, and twice at the Vacation Beach station (Tables 4.1.2 through 4.1.4). Two exceedances occurred in early July during open conditions with flows over 100 cfs, and two more occurred following summer dam removal in early October during open conditions (Figure 4.1.27). Whereas some of the lowest total nitrogen values observed at the freshwater stations occurred during open conditions in August when flows were just below 100 cfs (Tables 4.1.2 through 4.1.4). Overall, total nitrogen exceedances constituted 5.3% of all samples collected (Figure 4.1.27).

The maximum total nitrogen concentration observed at Patterson Point was 0.47 mg/L on July 3 during open conditions with a flow of approximately 113 cfs (Table 4.1.2). The mean concentration at Patterson Point was 0.17 mg/L. The minimum concentration at Patterson Point was 0.035 mg/L, which occurred on August 7 during open conditions with a flow of approximately 96 cfs. Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on June 25 with a concentration of 0.21 mg/L (Table 4.1.2).

The maximum total nitrogen concentration observed at Monte Rio was 0.61 mg/L on October 2 following summer dam removal and during open conditions with a flow of approximately 162 cfs (Table 4.1.3). The mean concentration at Monte Rio was 0.21 mg/L. The minimum concentration at Monte Rio was 0.070 mg/L, which occurred on July 3 during open conditions with a flow of approximately 113 cfs. Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on June 25 with a concentration of 0.071 mg/L (Table 4.1.3).

The maximum total nitrogen concentration observed at Vacation Beach was 0.64 mg/L on 2 October following summer dam removal and during open conditions with a flow of approximately 162 cfs (Table 4.1.4). The mean concentration at Vacation Beach was 0.19 mg/L. The minimum concentration at Vacation Beach was 0.035 mg/L, which occurred on August 7 during open conditions and a flow of approximately 96 cfs. Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on June 25 with a concentration of 0.17 mg/L (Table 4.1.4).

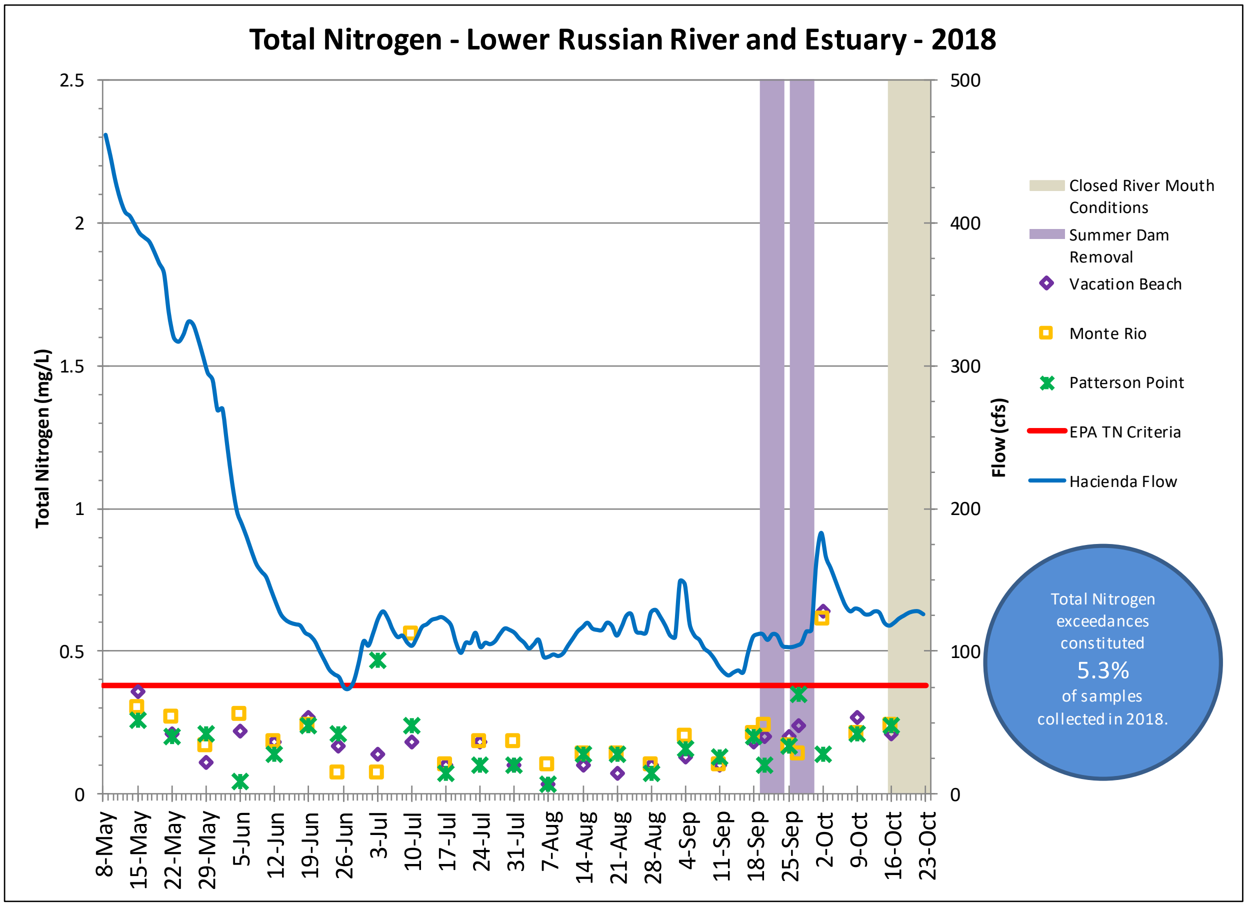



**Figure 4.1.27. 2018 Russian River grab sampling results for total nitrogen.**

The USEPA's desired goal for total phosphates as phosphorus in Aggregate Ecoregion III has been established as 21.88 micrograms per liter (µg/L), or approximately 0.022 mg/L, for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). Total phosphorus concentrations at the freshwater monitoring stations exceeded the U.S. EPA criteria approximately 93.3% of the time, continuing a trend of consistent exceedances observed in previous years (Figure 4.1.28).

Exceedances occurred during open and closed Estuary conditions, and in river flows ranging from 84 cfs to 399 cfs. Total phosphorus values were observed to generally be higher in the spring and early summer, trending downward through the rest of the season (Figure 4.1.28).

The maximum total phosphorus concentration observed at Patterson Point was 0.066 mg/L on July 3 during open conditions with a flow of approximately 113 cfs (Table 4.1.2). The mean concentration at Patterson Point was 0.036 mg/L. The minimum concentration at Patterson Point was 0.020 mg/L, which occurred September 20 during open conditions with a flow of approximately 112 cfs. Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on June 25, with a concentration of 0.059 mg/L (Table 4.1.2).

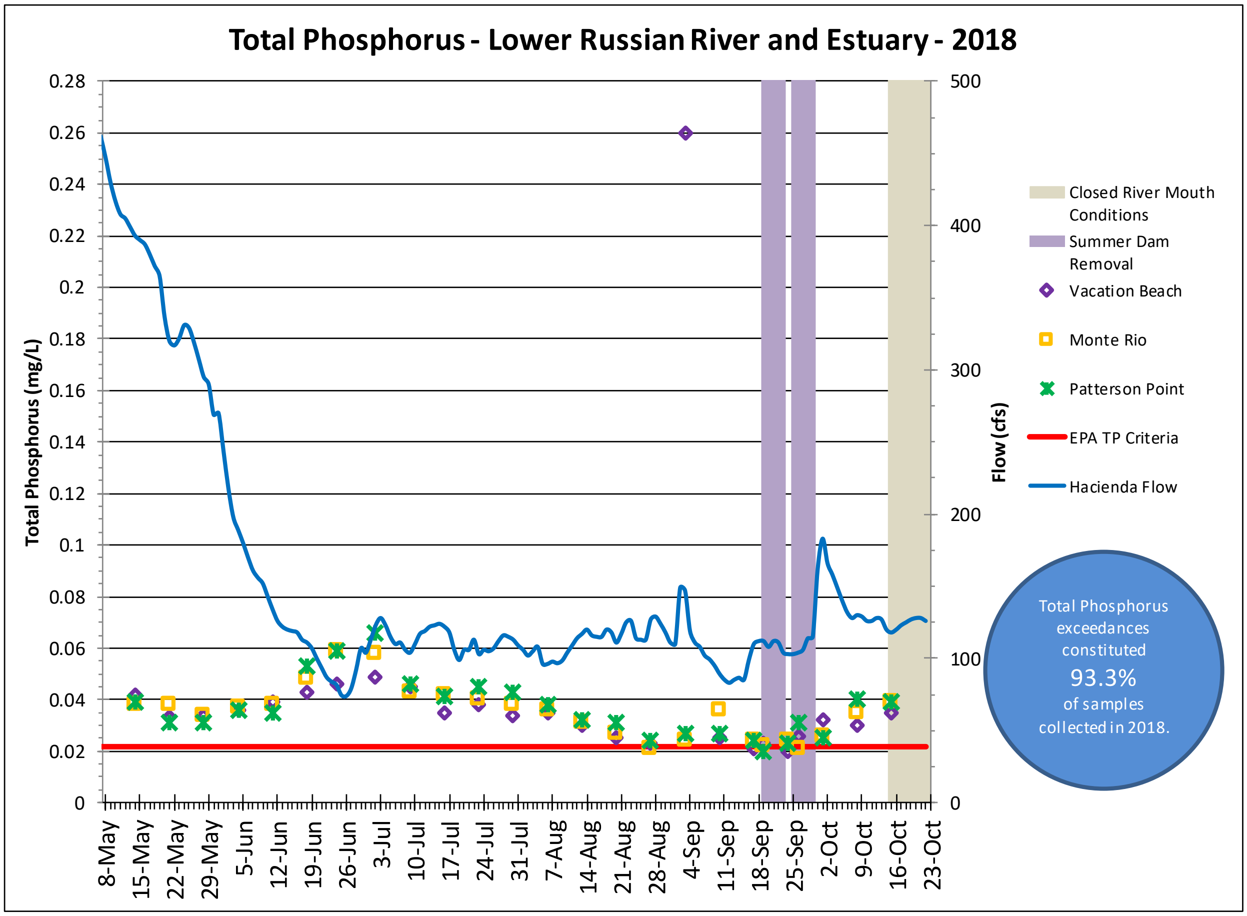



**Figure 4.1.28. 2018 Russian River grab sampling results for total phosphorus.**

The maximum total phosphorus concentration observed at Monte Rio was 0.059 mg/L on June 25 during open conditions with a flow of approximately 84 cfs, which was the lowest flow recorded during sampling events (Table 4.1.3). The mean concentration at Monte Rio was 0.035 mg/L. The minimum concentration at Monte Rio was 0.021 mg/L, which occurred twice; first on August 28 during open conditions with a flow of approximately 113 cfs, and again on September 27 during open conditions with a flow of approximately 103 cfs.

The maximum total phosphorus concentration observed at Vacation Beach was 0.26 mg/L on September 4 during open conditions with a flow of approximately 149 cfs (Table 4.1.4). The mean concentration at Vacation Beach was 0.042 mg/L. The minimum concentration at Vacation Beach was 0.020 mg/L, which occurred on 25 September during open conditions and a flow of approximately 104 cfs (Table 4.1.4). Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on 25 June, with a concentration of 0.046 mg/L (Table 4.1.3).

### *Turbidity*

There were three (3) exceedances of the Turbidity EPA criteria at Patterson Point, three (3) exceedances at Monte Rio, and one (1) exeedance at Vacation Beach (Figure 4.1.29). These exceedances of the Turbidity criteria occurred approximately 9.3% of the time under open

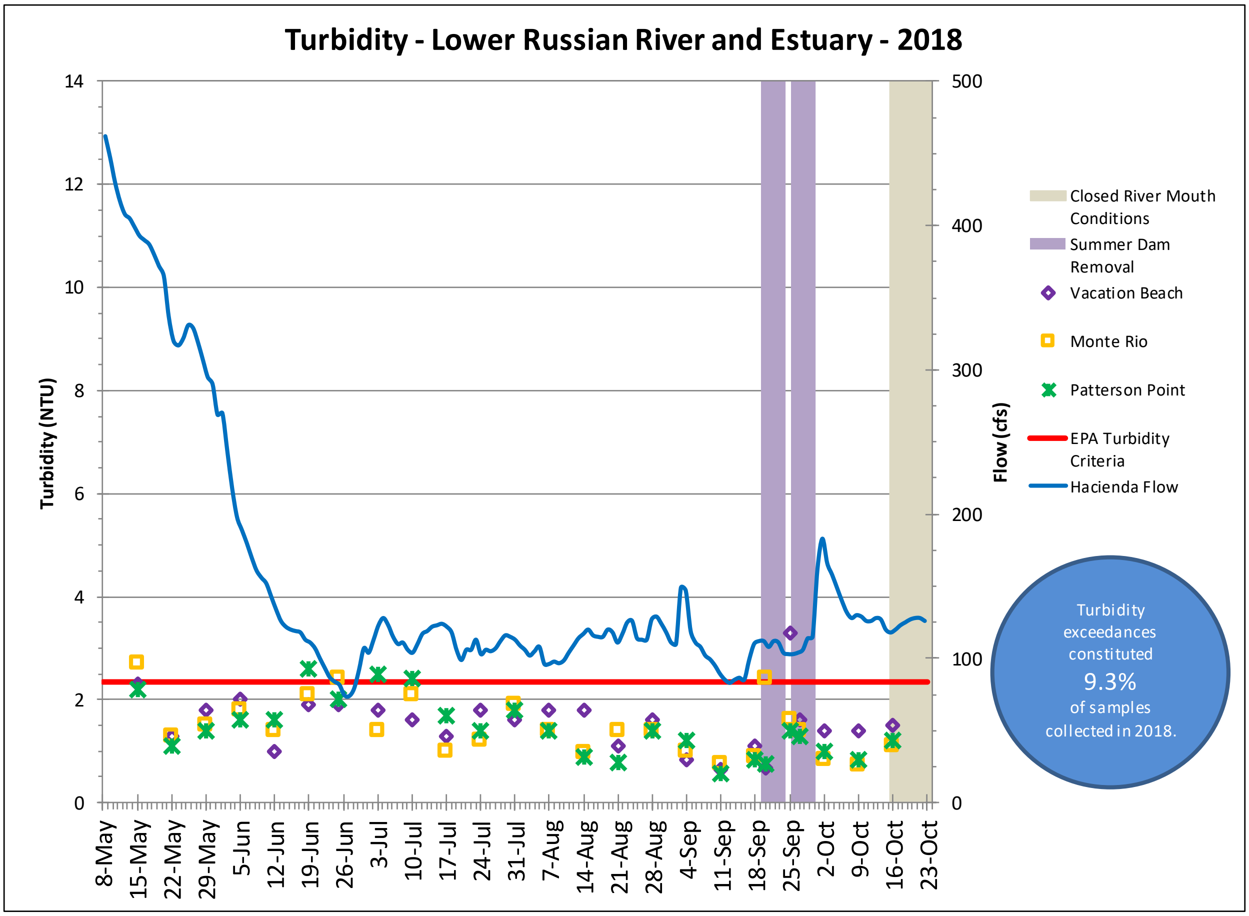



**Figure 4.1.29. 2018 Russian River grab sampling results for turbidity.**

conditions in flows that ranged from 84 cfs to 399 cfs. Although Vacation Beach can be subject to elevated turbidity from the effects of the summer dam over flow and fish ladder outflow occurring just upstream from the station, there was only one exceedance recorded in 2018.

The maximum turbidity value observed at Patterson Point was 2.6 NTU on June 19 during open conditions with a flow of approximately 113 cfs (Table 4.1.2). The mean value at Patterson Point was 1.4 NTU. The minimum value at Patterson Point was 0.57 NTU, which occurred on September 11 during open conditions with a flow of approximately 95 cfs. Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on June 25, with a value of 2.0 NTU (Table 4.1.2).

The maximum turbidity value observed at Monte Rio was 2.7 NTU on May 15 during open conditions with a flow of approximately 399 cfs (Table 4.1.3). The mean value at Monte Rio was 1.5 NTU. The minimum value at Monte Rio was 0.73 NTU, which occurred on October 9 during open conditions with a flow of approximately 128 cfs. Finally, the lowest flow recorded during the sampling events was 84 cfs, which occurred on June 25, with a value of 2.3 NTU (Table 4.1.3).

The maximum turbidity value observed at Vacation Beach was 3.3 NTU on September 25 during open conditions with a flow of approximately 104 cfs (Table 4.1.4). The mean value at Vacation Beach was 1.6 NTU. The minimum value at Vacation Beach was 0.64 NTU, which occurred on September 11 during open conditions and a flow of approximately 95 cfs. Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on June 25, with a value of 1.9 NTU (Table 4.1.4).

*Chlorophyll a*

In the process of photosynthesis, *Chlorophyll a* - a green pigment in plants, absorbs sunlight and combines carbon dioxide and water to produce sugar and oxygen. *Chlorophyll a* can therefore serve as a measureable parameter of algal growth. Qualitative assessment of primary production on water quality can be based on *Chlorophyll a* concentrations. A U.C. Davis report on the Klamath River (1999) assessing potential water quality and quantity regulations for restoration and protection of anadromous fish in the Klamath River includes a discussion of *Chlorophyll a* and how it can affect water quality. The report characterizes the effects of *Chlorophyll a* in terms of different levels of discoloration (e.g., no discoloration to some, deep, or very deep discoloration). The report indicated that less than 10 µg/L (or 0.01 mg/L) of *Chlorophyll a* exhibits no discoloration (Deas and Orlob, 1999). Additionally, the USEPA criterion for *Chlorophyll a* in Aggregate Ecoregion III is 1.78 µg/L, or approximately 0.0018 mg/L for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). However, it is important to note that the EPA criterion is established for freshwater systems, and as such, is only applicable to the freshwater portions of the Estuary. Currently, there are no numeric *Chlorophyll a* criteria established specifically for estuaries.

*Chlorophyll a* concentrations did not exceed 0.01 mg/L during the monitoring period, the level recommended to prevent discoloration of surface waters (Tables 4.1.2 through 4.1.4). However, *Chlorophyll a* concentrations exceeded the EPA criteria of 0.0018 mg/L approximately 36.6% of the time at the stations throughout the season under open Estuary conditions, and during flows ranging from approximately 84 cfs to 399 cfs (Figure 4.1.30). Similar to the trend for total phosphorus, *Chlorophyll a* values were observed to generally be higher in the spring and early summer, trending downward through the rest of the season (Figure 4.1.30).

The maximum *Chlorophyll a* concentration observed at Patterson Point was 0.0046 mg/L on May 15 during open conditions with a flow of approximately 399 cfs (Table 4.1.2). The mean value at Patterson Point was 0.0022 mg/L. The minimum value at Patterson Point was ND, which occurred on October 17 during closed conditions with a flow of approximately 189 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a value of 0.0013 mg/L (Table 4.1.2).

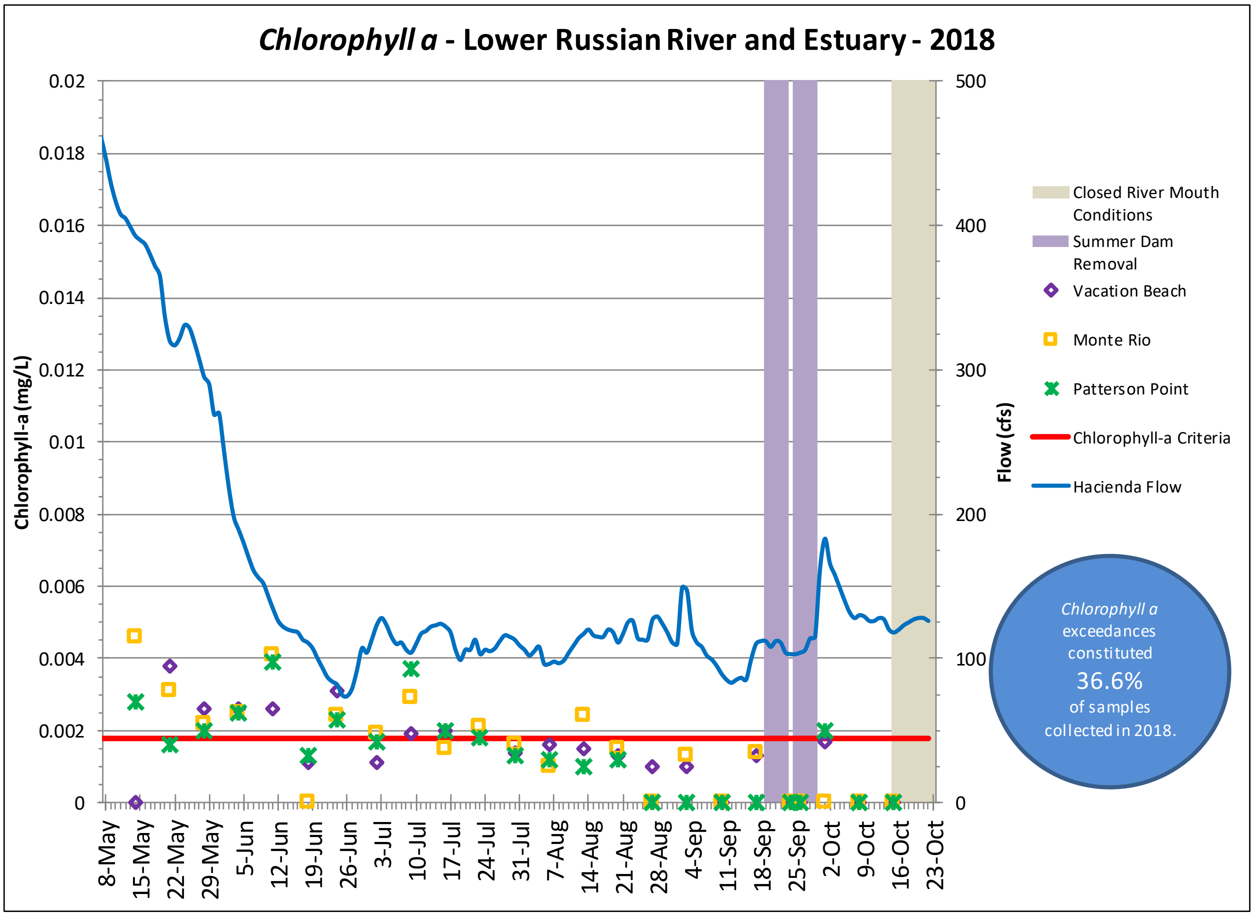



**Figure 4.1.30. 2018 Russian River grab sampling results for *Chlorophyll a.***

The maximum *Chlorophyll a* concentration observed at Monte Rio was 0.0046 mg/L on 15 May during open conditions with a flow of approximately 399 cfs (Table 4.1.3). The mean value at Monte Rio was 0.0017 mg/L. The minimum value at Monte Rio was ND, which occurred seven (7) times in the latter half of the season during open and closed conditions with flows that ranged from 95 to 162 cfs. Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on June 25, with a value of 0.0024 mg/L (Table 4.1.3).

The maximum *Chlorophyll a* concentration observed at Vacation Beach was 0.0038 mg/L on 22 May during open conditions with a flow of approximately 337 cfs (Table 4.1.4). The mean value at Vacation Beach was 0.0016 mg/L. The minimum value at Vacation Beach was ND, which occurred five (5) times in the latter half of the season during open and closed conditions with flows that ranged from 95 to 128 cfs. Finally, the lowest flow recorded during the sampling events was approximately 84 cfs, which occurred on 25 June, with a value of 0.0031 mg/L (Table 4.1.4).

### *Indicator Bacteria*

The California Department of Public Health (CDPH) developed the "Draft Guidance for Fresh Water Beaches," which describes bacteria levels that, if exceeded, may require posted warning signs in order to protect public health (CDPH 2011). The CDPH draft guideline for single sample maximum concentrations is: 10,000 most probable numbers (MPN) per 100 milliliters (ml) for total coliform, 235 MPN per 100 ml for E. coli, and 61 MPN per 100 ml for Enterococcus. In 2012, the United States Environmental Protection Agency (EPA) issued Clean Water Act (CWA) §304(a) Recreational Water Quality Criteria (RWQC) for States (EPA 2012). The RWQC recommends using two criteria for assessing water quality relating to fecal indicator bacteria: the geometric mean (GM) of the dataset, and changing the single sample maximum (SSM) to a Statistical Threshold Value (STV) representing the 75$^{th}$ percentile of an acceptable water-quality distribution. However, the EPA recommends using STV values as SSM values for potential recreational beach posting and those values are provided in this report for comparative purposes. It must be emphasized that these are draft guidelines and criteria, not adopted standards, and are therefore both subject to change (if it is determined that the guidelines and/or criteria are not accurate indicators) and are not currently enforceable.

Samples were collected during the monitoring season for diluted and undiluted analysis of E. coli and total coliform for comparative purposes and the results are included in Tables 4.1.2 through 4.1.4 and Figures 4.1.31 and 4.1.32. Samples collected for Enterococcus were undiluted only and results are included in Tables 4.1.2 through 4.1.4 and Figure 4.1.32. The Sonoma Water submitted samples to the Sonoma County DHS Public Health Division Lab in Santa Rosa for bacteria analysis. E. coli and total coliform were analyzed using the Colilert method and Enterococcus was analyzed using the Enterolert method. Samples for all other constituents were submitted to Alpha Labs in Ukiah for analysis. E. coli and total coliform data presented in Figures 4.1.31 and 4.1.32 utilize undiluted sample results unless the reporting limit has been exceeded, at which point the diluted results are utilized.

In 2014, staff at the NCRWQCB indicated that Enterococcus was not being utilized as a fecal indicator bacteria due to uncertainty in the validity of the lab analysis to produce accurate results, as well as evidence that Enterococcus colonies can be persistent in the water column and therefore its presence at a given site may not always be associated with a fecal source. Sonoma Water staff will continue to collect Enterococcus samples and record and report the data however, Enterococcus results will not be relied upon when coordinating with the NCRWQCB and Sonoma County DHS about potentially posting warning signs at freshwater beach sites or to discuss potential adaptive management actions including artificial breaching of the sandbar to address potential threats to public health.

There was one exceedance of the RWQC for E. coli during the 2018 monitoring season, representing 1.3% of the total samples collected (Figure 4.1.31). Vacation Beach had a value of 435.2 MPN recorded on October 2 during open conditions with a flow of 162 cfs. Summer dam removal may have had an effect on E. coli, as values were observed to increase following removal of the Johnson's Beach summer dam (Table 4.1.3). Increasing flows may have also had an effect as flows were observed to increase from approximately 120 cfs to 162 cfs during this same time period (Figure 4.1.31).

There were no exceedances of the RWQC for total coliform recorded during the 2018 monitoring season, representing 0% of the total samples collected (Figure 4.1.32).

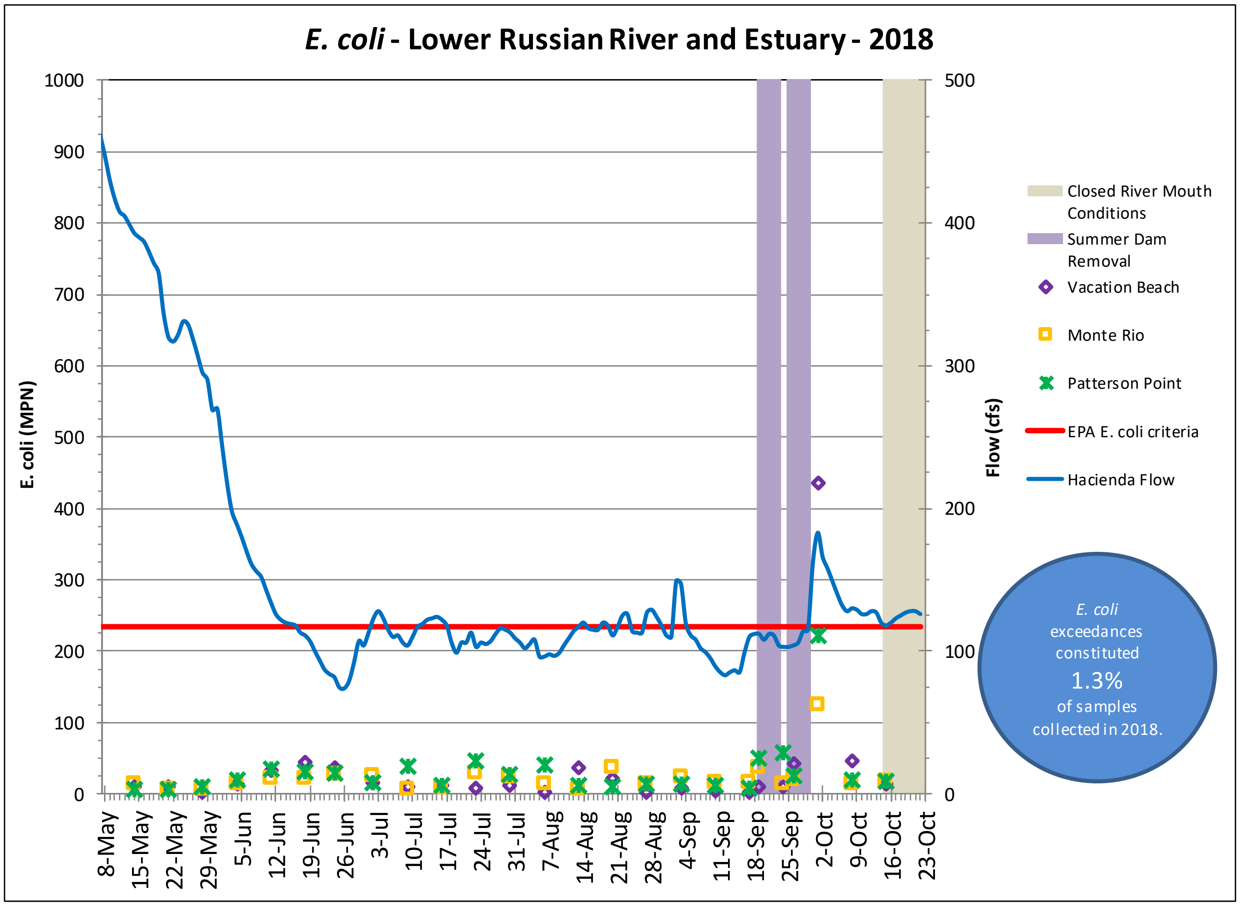



**Figure 4.1.31. 2018 Russian River grab sampling results for E. coli.**

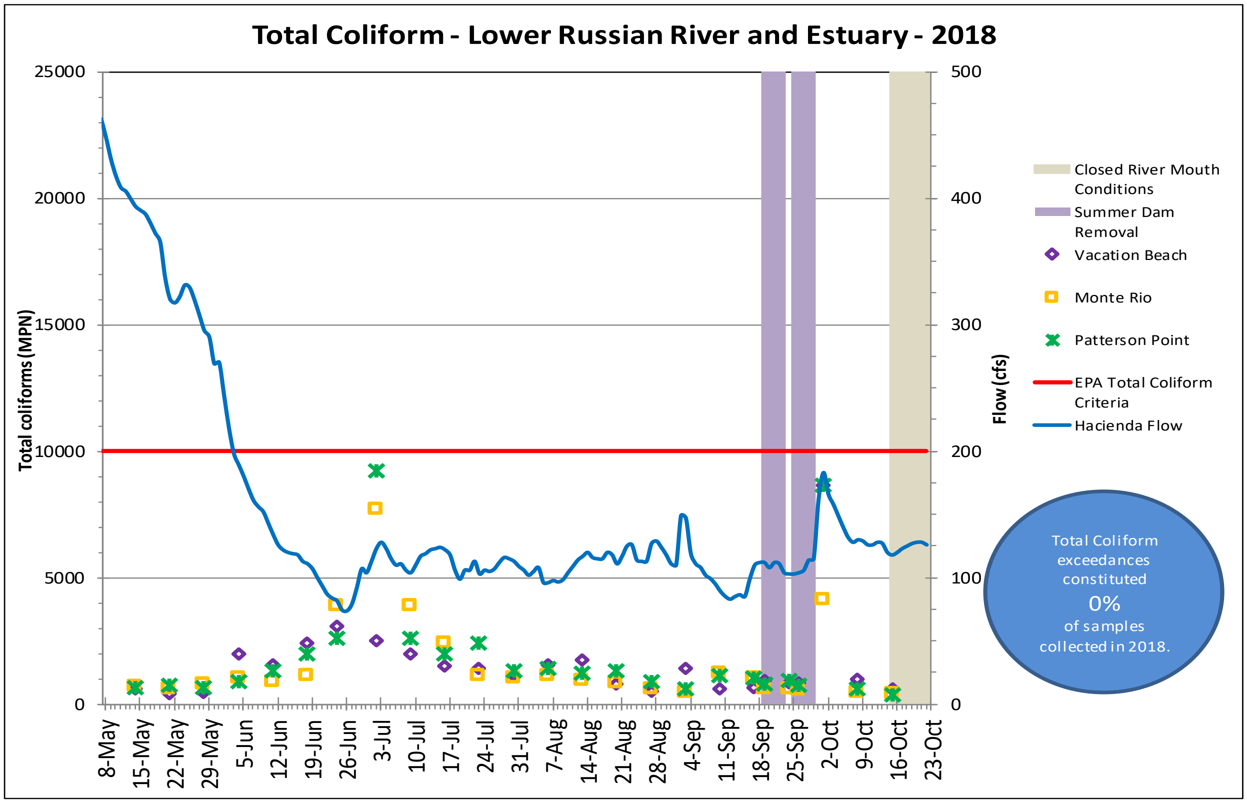



**Figure 4.1.32. 2018 Russian River grab sampling results for total coliform.**

Summer dam removal may have had an effect on total coliform as values were observed to increase following removal of the Johnson's Beach dam at the end of September. These increases may have also been affected by increased recreational activity as they were observed during and following the Fourth of July holiday.

There were two exceedances each of the recommended Enterococcus RWQC for fresh water beaches at Patterson Point, Monte Rio, and Vacation Beach representing 8.0% of the total samples collected (Figure 4.1.33). Summer dam removal may have had an effect as values were observed to increase during removal of the Johnson's Beach summer dam, including a concentration of 435.2 MPN that occurred at the Vacation Beach station on October 2 (Figure 4.1.33).

# Conclusions and Recommendations

## Continuous Water Quality Monitoring Conclusions

Water quality conditions observed during the 2018 monitoring season were similar to conditions observed during previous monitoring seasons, and similar to the dynamic conditions associated with an estuarine river system. The differing physical properties associated with freshwater versus those of saltwater play a pivotal role in the stratification that is common in the Russian River Estuary. Since the saltwater is denser than the freshwater inflow, the saltwater layer is observed below the freshwater layer, and the slope of the temperature and density gradients is

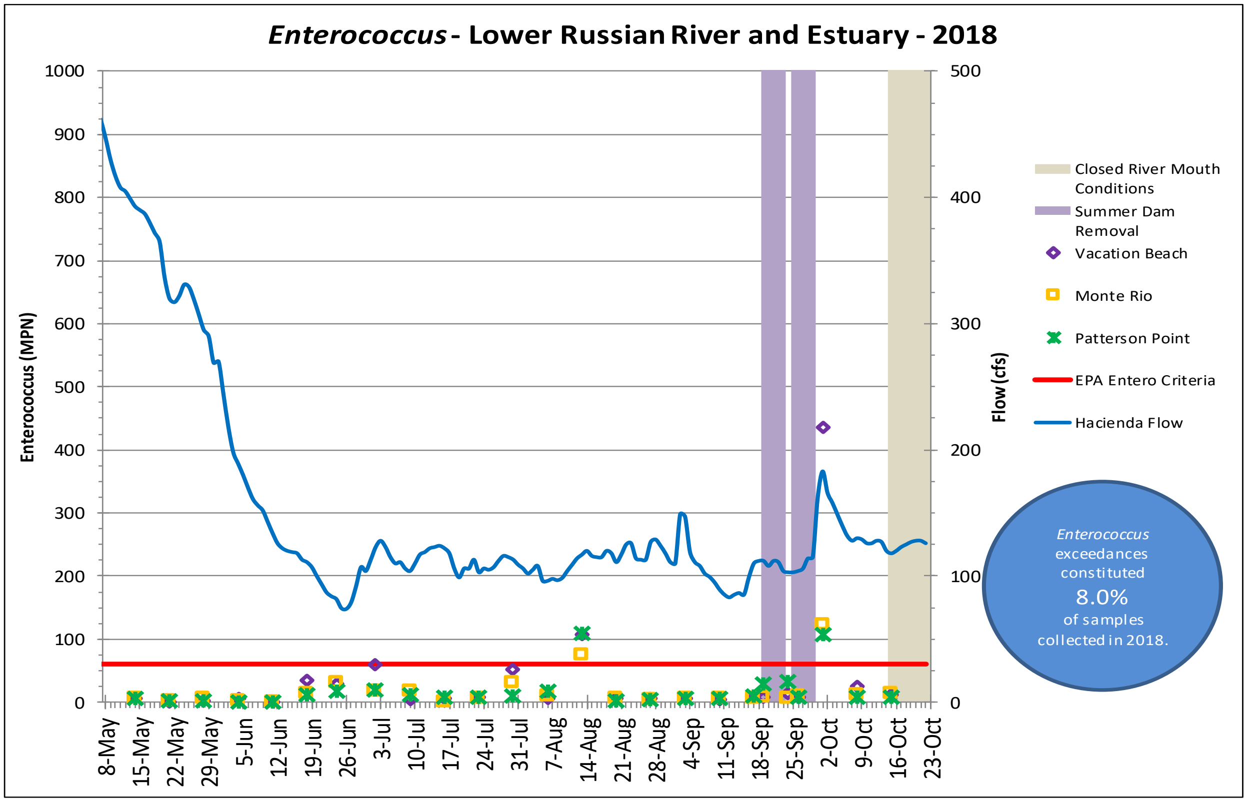



**Figure 4.1.33. 2018 Russian River grab sampling results for Enterococcus.**

typically steepest at the halocline. While this relationship is a key player in what shapes the water quality conditions in the estuary, there are other influences at work in the Estuary as well, including wind mixing, river inflow, tidal influence, shape and size of the river mouth, air temperatures, and others.

There were no beach management actions taken during the lagoon management period in 2018 since the mouth of the Estuary did not close until the last day of the season, October 15. That barrier beach closure lasted for a period of twenty-nine (29) days until unidentified individuals appeared to dig a pilot channel that breached the barrier beach on November 13. The barrier beach closed for six (6) days from November 18 to November 24 before breaching naturally. The barrier beach closed on November 28 and remained closed for two (2) days before breaching naturally on November 30. The barrier beach closed again on December 6 and remained closed for four (4) days before Sonoma Water staff artificially breached the barrier beach on December 10 to prevent flooding of low-lying structures.The barrier beach closed for the last time of the calendar year on December 14 before breaching naturally on December 17.

Consequently, there was no opportunity for Sonoma Water staff to assess the availability of suitable aquatic habitat for rearing salmonids in comparison to closed and open Estuary conditions. Although staff were unable to assess the merits of the Lagoon Outlet Channel project, staff were still able to collect data that provides a fuller understanding of salinity migration in the Upper Reach of the Estuary.

As freshwater flows in the Russian River decrease through spring, the salt layer typically migrates upstream. Mainstem Russian River flows decreased later in the 2018 season compared to the drought years of 2013 through 2015, but were similar to declining flows in the non-drought years of 2016 and 2017. Flows dropped below 200 cfs in mid-June 2016 and early July in 2017. In 2018, mainstem flows were observed to drop below 200 cfs in mid-June, whereas mainstem flows decreased below 200 cfs in mid-May during the drought years.

Although salinity migration patterns in the upper reach of the Estuary were fairly similar to prior monitoring years, the Brown's Pool (RK 11.3) station was observed to remain entirely freshwater during the 2018 management period, similar to 2017. Whereas the bottom of Brown's Pool became predominantly brackish during open and closed conditions throughout the 2016 monitoring season with concentrations as high as 6.5 ppt during the management period and 10.7 ppt in late-October (Martini-Lamb and Manning, 2017).

Brackish water had not been observed at Brown's Pool prior to the 2013 monitoring season, however Sonoma Water staff had only previously deployed a continuously monitoring sonde at this station in the 2011 season (Manning and Martini-Lamb, 2012). Even so, it is not unreasonable to expect salinity migration to periodically occur in this area, given the proximity of the Brown's Pool station to Moscow Road Bridge (RK 10.15), where brackish water has been observed to occur.

Monitoring conducted in the MBA at the bottom of the Patterson Point station in Villa Grande continued to show freshwater conditions with a maximum salinity value of approximately 0.2 ppt. Water is considered fresh at approximately 0.5 ppt. These results correspond with the data collected in the Upper Reach of the Estuary and the MBA since 2010 and further supports the theory that Brown's Riffle and the confluence of Austin Creek provide a significant hydrologic barrier to salinity migration in the mainstem Russian River.

Temperature, pH, and dissolved oxygen patterns during the 2018 monitoring season were also similar to those observed in previous monitoring years. While the Russian River Estuary is a dynamic estuarine system, the seasonal changes during the monitoring seasons have largely followed similar patterns each year since the implementation of the Biological Opinion in 2009.

To further illustrate the extent of salinity migration, a graphical representation of the maximum salinity levels recorded at various stations in the Russian River Estuary between 2009 and 2018 is being presented (Figure 4.1.34). The sondes chosen for this graph were situated in the lower portion of the water column at each station, where saline water would be expected to occur. This corresponds to approximately three to four meter depths for the Mouth, Patty's Rock, and Sheephouse Creek stations, six to nine meter depths at the Heron Rookery station, six to seven meter depths at the Freezeout Creek station, eight to 11 meter depths at the Brown's Pool station, six to eight meter depths at Villa Grande, nine to 11 meters depth at Patterson Point, and one to two meters at the Monte Rio station. In the upper reaches of the Estuary and MBA, the sondes are located on the bottom of the river because the salt layer is typically thin when it occurs at these river locations. Excluding the depth variations, the graph depicts the decrease in salinity the further upstream in the Estuary and MBA the monitoring station is located.

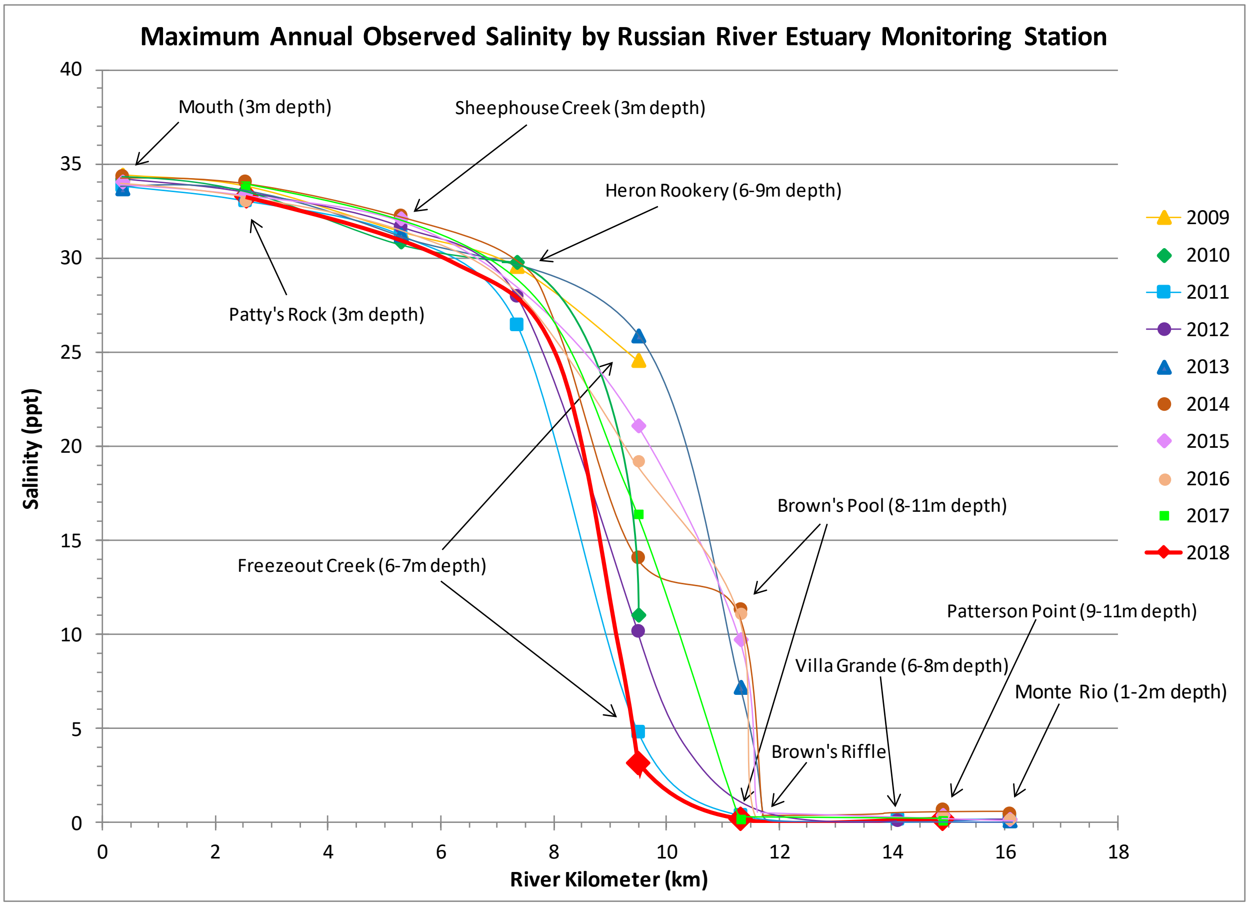



**Figure 4.1.34. The maximum salinities at monitoring stations throughout the Russian River Estuary and Maximum Backwater Area between the years of 2009 and 2018.**

The graph also illustrates the variable nature of salinity levels in the Upper Estuary. For instance, in 2014 and 2016, the maximum salinity concentrations observed at Brown's Pool were nearly identical at approximately 11 ppt, whereas in 2017 and 2018 the maximum salinity concentration was 0.2 ppt.

Brown's Pool has been observed to have maximum salinity concentrations that range from lows of 0.2 ppt in 2017 and 2018, to a high of 11.3 ppt in 2014. Likewise, the maximum salinity concentrations observed at Freezeout Creek range from a low of 4.8 ppt in 2011 to a high of 25.9 ppt in 2013. In 2018, maximum salinity concentrations at Freezeout Creek were only 3.2 ppt; however, this was recorded at the mid-depth sonde that typically has a lower concentration than the bottom sonde, which began malfunctioning in June.

Note that there are no elevated salinity levels recorded in the Maximum Backwater Area for any monitoring seasons. As was mentioned above, it is possible that saline water does not migrate past the riffle between Brown's Pool and the confluence of Austin Creek due to hydrologic and/or geologic conditions that serve to define a transition from the Russian River Estuary and the beginning of the Maximum Backwater Area.

## Water Quality Grab Sampling Conclusions

The 2018 grab sampling effort in the Russian River Estuary continued to collect a robust set of data similar in effort to the 2012 through 2017 monitoring seasons. Additional focused sampling was conducted during summer dam removal in late September. Table 4.1.5 shows the total yearly number of sampling trips and the total number of samples collected within the freshwater portions of the Russian River Estuary and Maximum Backwater Area during each monitoring season since the implementation of the Biological Opinion in 2009.

The 2018 grab sampling effort observed Total Phosphorus exceedances in 93.3% of all samples collected (Table 4.1.6). This is not uncommon in the Russian River Estuary, and similar percentages of the samples analyzed for Total Phosphorus were in exceedance during previous monitoring seasons. Table 4.1.6 shows the percentage of samples that were in exceedance each season since 2009.

The Total Nitrogen and *Chlorophyll a* exceedances for samples taken during 2018 were also similar to percentages observed in previous monitoring years (Table 4.1.6). Year to year variability in the percentage of exceedances for these three constituents can be attributed in part to: the frequency and timing of storm events, fluctuating freshwater inflow rates, the frequency and timing of barrier beach closures, the strength of tidal cycles, summer dam removal, topography, relative location within the Estuary, and wind mixing.

The percentage of E. coli exceedances since the implementation of the BO in 2009 until 2018 can be seen in Table 4.1.7. However, E. coli was not sampled for in 2010, with sampling being conducted for fecal coliforms instead. Samples collected in 2009 were analyzed using the multiple tube fermentation technique, whereas samples collected from 2011 through 2018 were analyzed using the Colilert Quanti-Tray method. Percentages for total coliform samples are not shown here since values were not quantified above 1600 MPN for 2010 and a portion of 2011, or above >2419.6 MPN for 2012, 2013 and a portion of the 2014 season. Both levels are below CDPH Guidelines, therefore it is impossible to establish percent criteria exceedances in this case.

Data collected through the grab sampling effort in 2018 appear consistent with data collected between 2009 and 2017. Further analysis could elucidate any trends that may exist temporally or longitudinally through the Russian River Estuary and guide water quality monitoring efforts in the future.

Time series trend analyses of the grab sampling data collected could prove useful in the future. Trend analyses could determine if there have been changes over time for any of the constituents collected under this project. Certain trend tests are used for non-parametric data analysis such as water quality data, including the Sen Slope test, the Kendall-Theil test, the Seasonal Kendall test, or a variety of other suitable statistical tests. Analyses of this nature require both time and expert knowledge of environmental statistical analysis. As such, they are difficult to run and outside the scope of this project at this time. In the future, allocating resources to analyses of this nature, on these data, would likely give a better understanding of the existence, or absence, of trends in the data.

**Table 4.1.5. The total number of grab sampling trips per monitoring season and the total number of samples taken in the freshwater portion of the Russian River Estuary and Maximum Backwater Area per monitoring season. Note: duplicate and triplicate samples were counted as separate samples during the same sampling trip.**

| Estuary Monitoring Season | Total Number of Sampling Trips | Total Number of Samples |
|---|---|---|
| **2009** | 7 | 7 |
| **2010** | 13 | 39 |
| **2011** | 13 | 52 |
| **2012** | 18 | 72-90 |
| **2013** | 33 | 98 |
| **2014** | 26-31 | 104-111 |
| **2015** | 26-27 | 104-106 |
| **2016** | 29-30 | 87-90 |
| **2017** | 26 | 75 |
| **2018** | 25 | 75 |

**Table 4.1.6. The percentages of freshwater samples taken that were in exceedance of U.S. EPA water quality criteria for Total Phosphorus, Total Nitrogen, and Chlorophyll a. Note; Chlorophyll a was not quantified below 0.01 mg/L in 2009, and as such, cannot be verified against the U.S. EPA criteria of 0.00178 mg/L. Also, the Total Nitrogen values in 2009 were not quantified sufficiently against the criteria to make comparisons. The U.S. EPA criteria for Total Nitrogen is 0.38 mg/L, and the criteria for Total Phosphorus is 0.02188 mg/L.**

| Estuary Monitoring Season | Percentage of Total Phosphorus Samples in Exceedance | Percentage of Total Nitrogen Samples in Exceedance | Percentage of Total *Chlorophyll a* Samples in Exceedance |
|---|---|---|---|
| **2009** | 100 | N/A | N/A |
| **2010** | 84.6 | 15.4 | 18.0 |
| **2011** | 92.3 | 30.8 | 23.7 |
| **2012** | 61.5 | 6.9 | 11.5 |
| **2013** | 99.0 | 15.3 | 44.9 |
| **2014** | 100 | 14.4 | 23.1 |
| **2015** | 86.5 | 1.9 | 26.0 |
| **2016** | 83.9 | 8.1 | 39.1 |
| **2017** | 97.3 | 9.3 | 54.7 |
| **2018** | 93.3 | 5.3 | 36.6 |

**Table 4.1.7. The percentages of freshwater samples taken that were in exceedance of CDPH Guidelines for E. coli for the sampling years 2009 through 2018. Note that for 2009, the analyzing method was multiple tube fermentation, and for 2011-2018 the method was Colilert Quanti-Tray.**

| Estuary Monitoring Season | Percentage of Total E. coli Samples in Exceedance |
|---|---|
| **2009** | 0 |
| **2010** | N/A |
| **2011** | 0 |
| **2012** | 0 |
| **2013** | 1.0 |
| **2014** | 6.3 |
| **2015** | 1.9 |
| **2016** | 2.2 |
| **2017** | 1.3 |
| **2018** | 1.3 |

## 4.2 Invertebrate Prey Monitoring, Salmonid Diet Analysis and Juvenile Steelhead Behavior

The Russian River Biological Opinion requires the Sonoma Water to "monitor the effects of alternative water level management scenarios and resulting changes in depths and water quality (primarily salinity, dissolved oxygen concentration, temperature, and pH) on the productivity of invertebrates that would likely serve as the principal forage base of juvenile salmonids in the Russian River Estuary (NMFS 2008). Specifically, the Sonoma Water is determining the temporal and spatial distribution, composition (species richness and diversity), and relative abundance of potential prey items for juvenile salmonids in the Estuary, and evaluating invertebrate community response to changes in sandbar management strategies, inflow, estuarine water circulation patterns (stratification), and water quality. The monitoring of invertebrate productivity in the Estuary focuses primarily on epibenthic and benthic marine and aquatic arthropods within the classes Crustacea and Insecta, the primary invertebrate taxa that serve as prey for juvenile salmonids, especially steelhead (*Oncorhynhus mykiss*) that may be particularly characteristic of conditions unique to estuarine lagoons for which steelhead may be adapted in intermittent estuaries near the southern region of their distribution (Hayes and Kocik 2014). The monitoring effort will involve systematic sampling and analysis of zooplankton, epibenthic, and benthic invertebrate species" (NMFS 2008, page 254).

Commensurate with assessment of potential responses to Estuary conditions by the macroinvertebrate prey of juvenile salmonids, the Sonoma Water is also monitoring juvenile salmonid diet composition and behavior. Based on the hypothesis that both diet and behavior of juvenile salmonids will vary as a function of increased water level and rearing space when the mouth of the Estuary is closed, the potentially differential effects of density-dependent interactions on diet composition and consumption rate are being compared between open and closed Estuary conditions. To facilitate the synthesis of this information with more precise information on juvenile salmonid exposure to variability in Estuary salinity and thermal regime, the Sonoma Water is supporting hydroacoustic telemetry of their position, behavior and residence as a function of Estuary conditions. The purpose of this effort is to determine for juvenile steelhead in the Estuary between June-September the variation under different Estuary open-closure conditions in: (1) the Estuary's water quality environment and the specific water quality conditions experienced by the juvenile steelhead; (2) their behavior in terms of estuarine habitat, reach occupancy and intra-estuarine movement patterns; (3) diet composition; (4) potential (modeled) and empirical growth. These will be used to refine parameters used in the Seghesio (2011) bioenergetics model to generate more empirically-based potential growth estimates during juvenile steelhead response to changing conditions in this intermittent Estuary.

The Sonoma Water entered into an agreement with the University of Washington, School of Aquatic and Fishery Sciences' Wetland Ecosystem Team (UW-WET) to conduct studies of the ecological response of the Estuary to natural and alternative management actions associated with the opening and closure of the Estuary mouth. This component of the study is designed to evaluate how different natural and managed barrier beach conditions in the Estuary affect juvenile salmon foraging and their potential prey resources over different temporal and spatial scales. Systematic sampling is intended to capture the natural ecological responses (prey composition and consumption rate) of juvenile salmon and availability of their prey resources (insect, benthic and epibenthic macroinvertebrates, zooplankton) under naturally variable, seasonal changes in water level, salinity, temperature and dissolved oxygen conditions. A second approach, event sampling, was originally proposed in 2009 to contrast juvenile salmonid foraging and prey availability changes over Estuary closure and re-opening events. The hydroacoustic telemetry component was particularly adaptable and targeted for the event sampling.

Based on prior data on the foraging of juvenile salmonids in the region's estuaries, the dominant prey of juvenile steelhead can be generally classified as invertebrate organisms that are epibenthic and benthic infauna. All of these prey sources are vulnerable to the variable conditions imposed by river mouth conditions, but taxa composition, relative abundance and production may vary as a function of both longitudinal axis (reach) of the estuary and cross-channel distribution. Another potential invertebrate component, pelagic zooplankton, has not appeared in juvenile salmon diets in either open or closed estuary conditions. Epibenthic, benthic, and zooplankton invertebrate sampling has been conducted monthly from May to October since 2010. Most of these sampling events were completed during open river mouth, tidal conditions in the estuary providing a robust baseline dataset. The composition and abundance of invertebrates was consistent among monthly sampling and among years indicating that the current dataset is adequate to characterize the invertebrate fauna of the estuary. The main gap in data is sampling during prolonged lagoon conditions in the estuary, which is the continuing focus of the on-going research. The methods and results presented in the following sections focus on the overall lessons of monitoring invertebrates in the Russian River Estuary through 2018.

## Methods

As a result of greater focus on changes in epibenthic and benthic prey availability during estuary closures, the Sonoma Water- UW-WET invertebrate monitoring protocols were revised in 2016 and were followed in 2018:

> *Monthly Estuary Surveys :*During years when no prolonged lagoon forms invertebrate surveys will be collected during May, June, and September. Under prolonged lagoon conditions surveys would be conducted monthly from May to October. This sampling schedule would be consistent with the Estuary fish seining schedule. There would be no change in the monthly number of epibenthic, benthic, and zooplankton invertebrate samples collected.
>
> *Mouth Closure Event Surveys:* Monitoring protocols will not change during estuary closure events. Samples would be collected approximately seven and 14 days after a river mouth closure and monthly during prolonged lagoon conditions.
>
> *Lab Processing:* The focus of invertebrate processing in the lab would include the primary steelhead prey taxa (based on years' results, approximately 12-15 taxa). These dominant prey would be sorted and enumerated in epibenthic and benthic samples.

Zooplankton are not an important prey group and samples would not be processed. All invertebrates from epibenthic, benthic, and zooplankton samples would be archived for further analysis if deemed important.

## Sampling Sites

Sampling for fish diet and prey availability is designed to coincide with established Sonoma Water and other related sampling sites distributed in the lower, middle, and upper reaches of the Estuary during the Lagoon Management Period (May 15 to October 15). Since 2009, salmonid diet samples have been coincident with beach seining at 11 primary sites (Figure 4.2.1; modified from Largier and Behrens 2010) sampled for juvenile salmon by the Sonoma Water – (1) Lower Reach: River Mouth, Penny's Point and Jenner Gulch; (2) Middle Reach: Patty's Rock, Bridgehaven and Willow Creek; and, (3) Upper Reach: Sheephouse Creek, Heron Rookery, Freezeout Bar, Moscow Bridge and Casini Ranch. When possible, samples are specifically selected for diet analysis from the overall beach seine collections at Jenner Gulch to represent the lower Estuary reach, Bridgehaven to represent the middle reach and Casini Ranch, Freezeout Bar and Sheephouse Creek to represent the upper reach. Incidental steelhead diet samples also originated from Penny Point (lower), Willow Creek (middle), and Casini Ranch (upper) sites when there are not sufficient samples from the preferred reach sites. These locations also overlap with sites established by water quality measurements—dissolved oxygen, temperature and salinity.

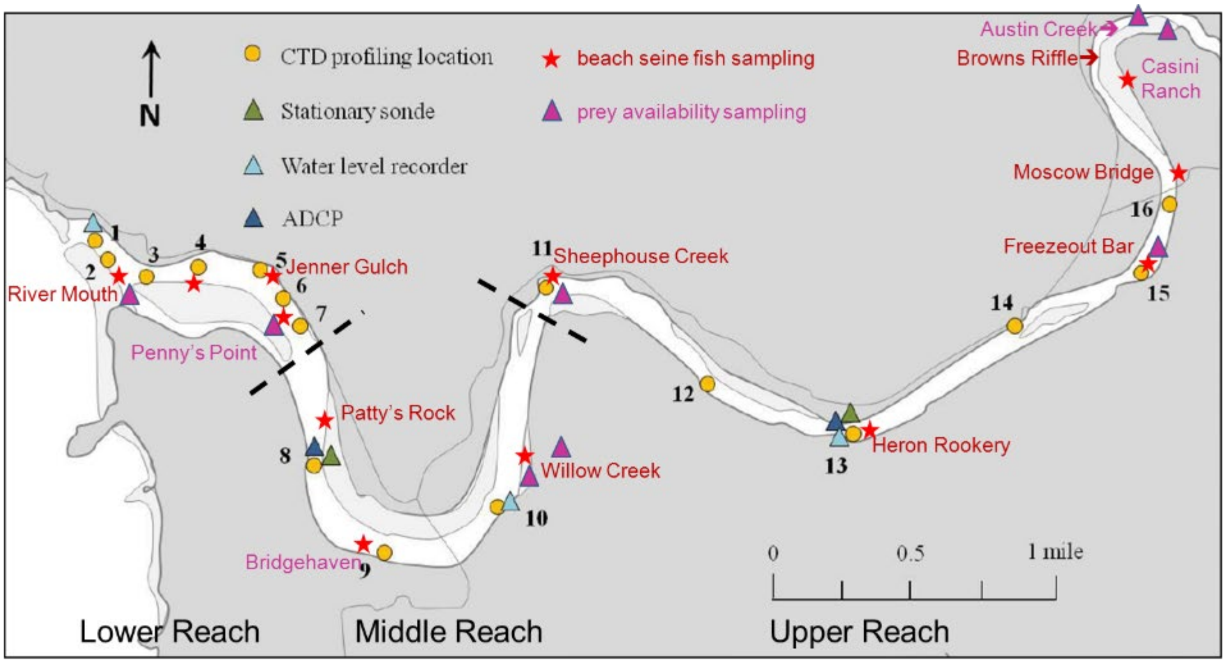



**Figure 4.2.1. Locations of sampling stations for juvenile salmon diet (seining location) and prey resource availability (benthic infauna, epibenthos, zooplankton) in three reaches of the Russian River Estuary.**

Prey resource availability sampling occurs at four sites distributed through the three estuarine reaches (Figure 4.2.1): Lower Reach—River Mouth and Penny Point; Middle Reach—Willow Creek; and Upper Reach—Freezeout Bar. Each of the sites includes three, lateral transects across the Estuary over which four sampling methods were deployed to sample availability of juvenile steelhead prey (Figures 4.2.2 - 4.2.7 for more specific locations by different sampling methods).

## Juvenile Salmon Diet Composition

Systematic sampling of the diets of five or more ($n \geq 5$) juvenile steelhead ≥55 mm FL are derived, when available, from the beach seine sampling during the lagoon management period between May 15 and October 15. All fish designated for diet analysis are handled, gastric lavaged and released according to the University of Washington animal care protocols. If resources are available and sample sizes are less than five individual fish (n=<5) during systematic sampling, event sampling around scheduled beach management at the barrier beach are coordinated with Sonoma Water fisheries monitoring and physical measurements of estuarine response.

Stomach lavage follows Foster (1977) and Light et al (1983). Diet contents are preserved in 10% Formalin for later laboratory processing. As per Sonoma Water fisheries protocols, fork lengths and weights are taken from each fish. Each fish is scanned for a passive integrated transponder (PIT) tag and tagged if no previous PIT tag was detected.

## Prey Resource Availability

Benthic infauna and epibenthos prey resource sampling are conducted once per month in the lagoon management period during open, tidal (baseline) conditions. If barrier beach conditions result in a closure, epibenthos and benthic infauna are sampled seven and 14 days after closure. Following an extended closure of 14 days or more, prey resource availability sampling of benthic infauna, epibenthos, and zooplankton begins at day 14 and continue every three weeks after until the Estuary opens. Since the Russian River Estuary experienced only a single mouth closure in 2018 on the last day of the lagoon management period samples were collected during May, June, and September. As demonstrated in diet composition documented throughout this study since 2009, juvenile steelhead occupying the Russian River Estuary tend to feed somewhat specifically on a limited suite of epibenthic crustaceans and aquatic insects. These prey, dominated by two species of epibenthic gammarid amphipods, tubicolous *Americorophium* spp. (*A. spinicorne; A. stimpsoni*) and *E. confervicolus*, the epibenthic isopod *G. insulare*, and aquatic insects of the hemipteran family Corixidae (water boatmen), also occur consistently in the diets of juvenile steelhead sampled in other estuaries along the northeastern Pacific, including other intermittent systems (Needham 1940; Shapovalov Taft 1954; Meyer et al. 1981; Martin 1995; Salamunovich and Ridenhour 1990; Daly et al. 2014).

**Figure 4.2.2 . Distribution of juvenile salmonid prey resource availability in three reaches of the Russian River Estuary.**

**Figure 4.2.3. Distribution of juvenile salmonid prey availability sampling transects and techniques at the River Mouth site in the Russian River Estuary.**

Figure 4.2.4. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Penny Point site in the Russian River Estuary.

Figure 4.2.5. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Willow Creek site in the Russian River Estuary.


**Figure 4.2.6. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Freezeout Bar site in the Russian River Estuary.**


**Figure 4.2.7. Modification of sampling techniques during closed conditions for distribution of juvenile salmonid prey availability sampling transects and techniques at Willow Creek site in the Russian River Estuary. The grey area is the inundation of area during closed conditions.**

### *Benthic Infauna*

Replicate core samples (0.0024-$m^2$ PVC core inserted 10 cm in to the sediment) are taken at each transect of each site. The location of each core sample is consistent with each epibenthic sled and epibenthic net to shore sample, but no core samples are taken in between transects. This sample is repeated four times per transect (twelve times per site). Additional samples would be added along the transect with increasing water level (inundation of the shoreline) during closure or outlet channel implementation. The sediment cores are preserved in 10% buffered Formalin for laboratory analysis.

### *Epibenthos*

Epibenthic organisms at the sediment-water interface are sampled with two methods: 1) epibenthic net (net to shore); and, 2) epibenthic (channel) sled. The epibenthic net is a 0.5-m x 0.25-m rectangular net, equipped with 106-µm Nitex mesh that is designed to ride along the surface of the Estuary bottom substrate. It is deployed 10 m from shore and then pulled along the bottom perpendicular back to shore by an individual onshore. This is replicated five times per site (once at each transect and then once between Transects 1 and 2 and also between Transects 2 and 3). The epibenthic sled is equipped with a 0.125-$m^2$ opening, 1-m long 500-µm Nitex mesh net towed behind the boat against the current. The sled is dropped off of the bow of the boat and allowed to sink to the bottom. Once the boat has finished towing the sled (in reverse) 10 m against the current, it will be retrieved back onto the boat. This is replicated five times per site (once at each transect and then once between Transects 1 and 2 and also between Transects 2 and 3). The sled is used to obtain three samples per transect (nine per site under open conditions). Additional samples would be added along the shoreward margin of the transect with increasing water level (inundation of the shoreline) during closure or outlet channel implementation (Figure 4.2.7). Captured organisms are preserved in 10% buffered Formalin for laboratory analysis.

## Sample Processing and Analyses

Stomach contents from juvenile salmon are identified to the species level if possible under a dissecting microscope. Invertebrates found in the diets of steelhead and collected in the prey resource samples are identified to species level, except for insects which are identified to family level. Any invertebrate collected during prey sampling and not found to be part of the steelhead diet is identified to order or family level. Each of the identified prey taxa are counted (for numerical composition) and weighed (for gravimetric [biomass] composition) and the frequency of occurrence. The state of total stomach content biomass is normalized by individual fish weight to provide an additional index of relative consumption rate (“instantaneous” ration), which is the total biomass of prey found in individual fish stomach contents relative to the biomass of the fish expressed as $g\ g^{-1}$. It is recognized that this is only a short-term index of consumption, and will vary by fish size, time of day and other factors influencing foraging behavior. If fish are captured under the same general conditions, this index can provide an indication of differences in feeding performance. Under some conditions, the instantaneous ration can be used to develop an estimate of daily ration that can be used in bioenergetic modeling of potential growth. For further details regarding methods for other calculated indices, see previous project annual reports.

# Results

## Estuary Conditions

There were no beach management actions taken during the lagoon management period in 2018 since the mouth of the Estuary did not close until the last day of the season, October 15. Samples were collected during May, June, and September. Sampling results for juvenile steelhead diet composition and prey availability were consistent with results from previous years' efforts during the lagoon management period. The results presented here provide a summary of current understanding of juvenile steelhead diet composition and prey availability in the Russian River Estuary based on monitoring results from 2009 to 2018.

## Juvenile Steelhead Diet Composition

Overall, the diet of juvenile steelhead in the Estuary is composed of few taxa and varied spatially. The diet composition did not differ between the Middle and Lower reaches, but the Upper Reach was significantly different from the other two, lower reaches (Matsubu, in prep). The diets in the Lower and Middle reaches of the Estuary were mainly composed of epibenthic crustaceans—the gammarid amphipods *Eogammarus confervicolus* and *Americorophium* spp., and the isopod *Gnorimosphaeroma insulare.* In addition to these epibenthic crustaceans observed in the diets from the lower estuary, the Upper Reach was more diverse with adult and aquatic life stages of insects including Chironomidae, Ephemeroptera, and Corixidae.

## Prey Availability

UW-WET found that the abundance and compositions of macroinvertebrates varied between open and closed mouth states. Furthermore, they found expansive aggregations of mobile epibenthic and less mobile benthic macroinvertebrates in habitats only inundated when the mouth was closed. As water elevation rises during a closure event, the epibenthic net to shore samples organisms expand (numerical response) or migrate (distributional response) into the recently inundated shallow water margin. Most taxa appear adapted to the changing conditions in the Russian River estuary (Matsubu, in prep). As a result, key food web macroinvertebrates are likely to be resilient to management activities in the Russian River Estuary.

As has been reported in previous reports, the prominent macroinvertebrates (>95%) were comprised of just a few taxa, varying by sampling type and site. Overall, Nematoda was the most abundant taxa at the lower sites in the benthos (>30%), and main channel samples (>20%) while Ostracoda (35%) and Hydrobiidae (23.1%) dominated the margin samples (Matsubu, in prep). In the benthic samples, the distribution of dominant taxa became more equally distributed further upstream, with decreased proportional contributions of Nematoda and increased contributions of *Americorophium* spp. and *G. insulare* at the upstream sites. Comparisons between open and closed mouth states across epibenthic sampling types indicated shifts in the proportional distribution of taxa. For example, the proportion of *G. insulare* at Willow Creek increased in the margin samples when the mouth was closed but decreased in the main channel samples. Similarly, at Freezeout Bar in the Upper Reach of the Estuary, proportions of Corixidae in the margin habitat increased when the mouth was closed and decreased in the main channel.

Macroinvertebrates that are essential to the food web were relatively abundant in the Estuary (Matsubu, in prep). The abundance of specific food web taxa varied across the sites, but differences in the total abundance of taxa were less severe due to averaging across the individual taxa. The differences in abundance across sites reflected the tolerance of individual taxa to salinity, with less euryhaline species, including Corixidae, Ephemeroptera, and Chironomidae most abundant at Freezeout Bar, the most freshwater site. The additional sampling of the newly flooded habitats during river mouth closures detected large aggregations of food web taxa. When compared with the main channel samples, the total densities of the key food web taxa were higher in the closure-inundated, shallow littoral habitat at the Penny Point, Willow Creek, and Freezeout Bar sites. The most substantial changes were attributed to higher densities of Hydrobiidae snails (up to 100x) and *Americorophium* spp. (up to 20X) at Penny Point and Willow Creek, and Corixidae (30x) at Freezeout Bar.

## Conclusions and Recommendations

Invertebrate monitoring from 2009 to 2018 found that the community of macroinvertebrates in the Estuary is primarily composed of taxa that can tolerate the abiotic variability in intermittently closed estuaries, such as the Russian River Estuary, either physiologically or behaviorally. As a result, changes to the river mouth condition had limited impacts on the assemblages and abundance of macroinvertebrates. Similar to permanently open systems, taxa were distributed relatively consistently along the salinity gradient under open and closed states, with the least euryhaline taxa most common in the tidal freshwater sites (Matsubu, in prep).

Macroinvertebrates that are essential to the food web were relatively abundant in the Estuary (Matsubu, in prep). There is a consistent estuarine prey community available for juvenile steelhead despite some variability in the occurrence and duration of freshwater outflow and estuary closure events. Overall, the primary macroinvertebrate taxa found in the Estuary are able to withstand the varying conditions due to their ability to adapt to varying salinities (euryhaline) or mobile abilities. The combination of euryhaline and freshwater taxa important to the food web suggest that the assemblage is adapted for either river mouth state, whether it be saline/brackish when the mouth is open or primarily freshwater. Furthermore, some taxa, including tuberous *Americorophium* spp., have life history characteristics and behaviours that may mediate unpredictable environmental disturbances. These amphipods are euryhaline and have unique life history and ecology characteristics, as they live in “U” shaped tubes in the substrate (Eriksen, 1968; Thiel and Watling, 2015). These tubes may provide a refuge from deleterious conditions but would likely dry out after an abrupt opening. The Hydrobiidae snails found in the Estuary have an operculum that can seal off the snail from changes in physical conditions although they are not very mobile. Other key food web taxa, including *G. insulare*, *E. confervicolus*, and *N. mercedis*, are all very motile and euryhaline and can not only avoid deleterious conditions, but can also take advantage of increased resources, including detritus in newly inundated habitat. (Stimpson, 1856; Heuback, 1969; Bousfield, 1979; Tomikawa et al., 2006).

As demonstrated in diet composition documented throughout this study since 2009, juvenile steelhead occupying the Russian River Estuary tend to feed somewhat specifically on a limited suite of epibenthic crustaceans and aquatic insects. These prey, dominated by two species of epibenthic gammarid amphipods, tubicolous *Americorophium* spp. (*A. spinicorne; A. stimpsoni*) and *E. confervicolus*, the epibenthic isopod *G. insulare*, and aquatic insects of the hemipteran family Corixidae (water boatmen), also occur consistently in the diets of juvenile steelhead sampled in other estuaries along the northeastern Pacific, including other intermittent systems (Needham 1940; Shapovalov Taft 1954; Meyer et al. 1981; Martin 1995; Salamunovich and Ridenhour 1990; Daly et al. 2014).

Expansive aggregations of mobile epibenthic and less mobile benthic macroinvertebrates in habitats only inundated when the mouth was closed provide benefits to foraging juvenile steelhead. As water elevation rises during a closure event, the epibenthic net to shore samples organisms expand or migrate into the recently inundated shallow water margin.

Comparisons between open and closed mouth states across epibenthic sampling types indicated shifts in the proportional distribution of taxa (Matsubu, in prep). For example, the proportion of *G. insulare* at Willow Creek increased in the margin samples when the mouth was closed, but decreased in the main channel samples. Similarly, at Freezeout Bar in the Upper Reach of the Estuary, proportions of Corixidae in the margin habitat increased when the mouth was closed and decreased in the main channel. The increase in prey, primarily amphipods, detected with sampling in newly flooded habitat, is possibly attributed to new availability of food resources, such as detritus, for macroinvertebrates that could mobilize to occupy the new intertidal habitat or food resource and other conditions that would facilitate productive increase in their populations.

The expansion of prey into newly flooded shoreline habitat provides additional foraging habitat for juvenile steelhead in areas that generally have lower salinity (fresh or brackish water) and higher dissolved oxygen, conditions that are more suitable for juvenile steelhead (primarily young of the year and age 1+).

Juvenile steelhead would benefit from closed mouth conditions by an increased capability to move longitudinally and the ability to occupy thermal refugia, smaller individuals have more access to deeper depths (decreased avian predation and increased access to prey, and expansive aggregations of prey taxa would lead to more efficient foraging for juvenile steelhead (Matsubus, in prep).

# 4.3 Fish Sampling – Beach Seining

Sonoma Water has been sampling fish in the Russian River Estuary since 2004 - prior to issuance of the Biological Opinion. An Estuary fish survey methods study was completed in 2003 (Cook 2004). To provide context to data collected in 2018, we present and discuss previous years of data in this report. Although survey techniques have been similar since 2004, some survey locations and the sampling extensity changed in 2010 as required in the Biological Opinion. The distribution and abundance of fish in the Estuary are summarized below. In addition to steelhead, coho salmon, and Chinook salmon, we describe the catch of several common species to help characterize fisheries habitat conditions in the Estuary.

## Methods

### Study Area

The Estuary fisheries monitoring area included the tidally-influenced section of the Russian River and extended from the sandbar at the Pacific Ocean to Duncans Mills, located 9.8 km (6.1 mi) upstream from the coast (Figure 4.3.1).

#### *Fish Sampling*

A beach-deployed seine was used to sample fish species, including salmonids, and determine their relative abundances and distributions within the Estuary. The rectangular seine consisted of 5 mm (¼ inch) mesh netting with pull ropes attached to the four corners. Floats on the top and weights on the bottom positioned the net vertically in the water. From 2004 to 2006, a 30 m (100 ft) long by 3 m (10 ft) deep purse seine was used. From 2007 to 2014 a conventional seine 46 m (150 ft) long by 4 m (14 ft) deep was used. Then in 2015 a 46 m by 3 m seine with a 3 m square pocket located in the center of the net was employed. The seine was deployed with a boat to pull an end offshore and then around in a half-circle while the other end was held onshore. The net was then hauled onshore by hand. Fish were placed in aerated buckets for sorting, identification, and counting prior to release.

Salmonids were anesthetized with Alka-Seltzer tablets or MS-222 and then measured, weighed, and examined for general condition, including life stage (i.e., parr, smolt). All salmonids were scanned for passive integrated transponder (PIT) tags or other marks. Steelhead and coho salmon were identified as wild or hatchery stock by a clipped adipose fin. Hatchery coho salmon were no longer clipped after spring 2013 and were either marked with a coded wire tag or PIT tag. Unmarked juvenile steelhead caught in the Estuary greater than 60 mm fork length were

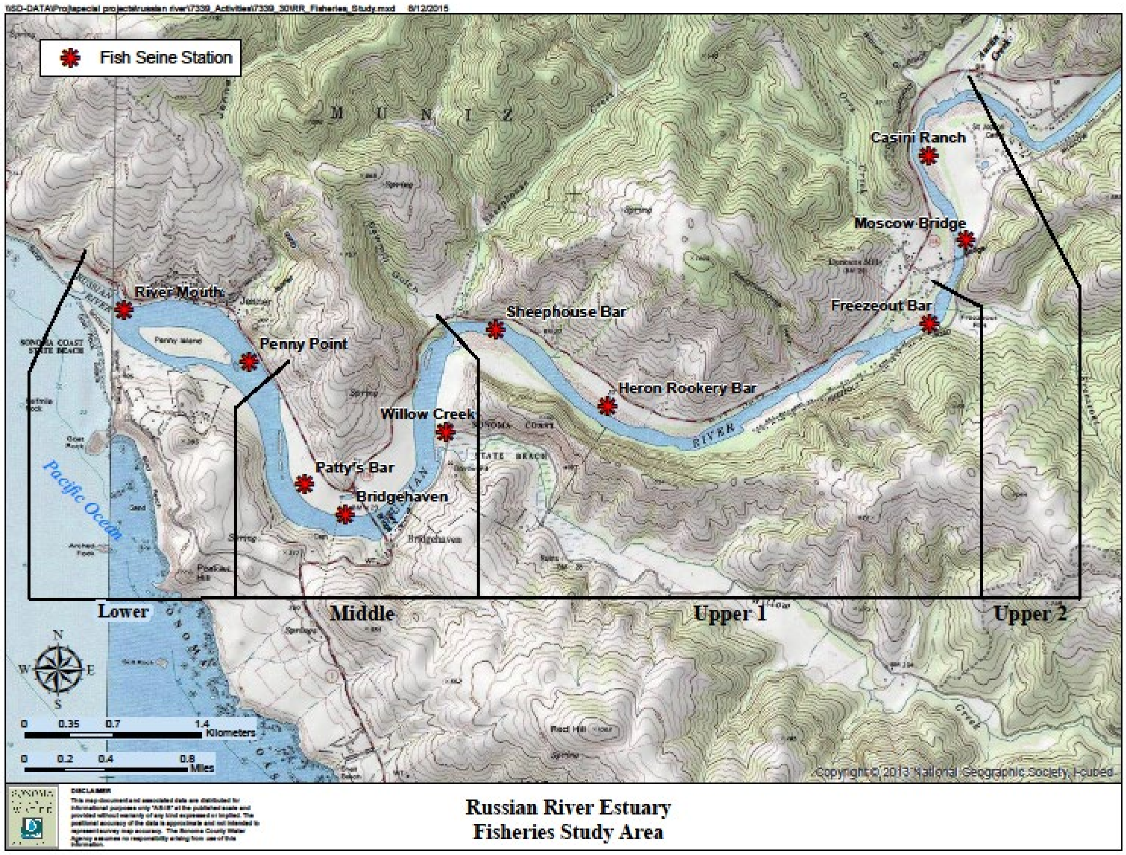



**Figure 4.3.1. Russian River Estuary fisheries seining study reaches and sample sites, 2018.**

surgically implanted with a PIT tag. Fish were allowed to recover in aerated buckets prior to release.

From 2004 to 2009, eight seining stations were located throughout the Estuary in a variety of habitats based on substrate type (i.e., mud, sand, and gravel), depth, tidal, and creek tributary influences. Three seine sets adjacent to each other were deployed at each station totaling 24 seine sets per sampling event. Stations were surveyed approximately every 3 weeks from late May through September or October. Total annual seine pulls ranged from 96 to 168 sets.

Starting in 2010 fish seining sampling was doubled in effort with 300 sets completed for the season. Surveys were conducted monthly from May to October. Between 3 and 7 seine sets where deployed at 10 stations for a total of 50 sets for each sampling event. Twenty-five sets were in the lower and middle Estuary and 25 in the upper Estuary. Since 2014, seining was reduced to three events in May, June, and September if the river mouth condition remained open (tidal) during the lagoon management period (May 15 to October 15). If a prolonged closure occurred or a lagoon outlet channel was successfully installed forming a freshwater lagoon seine events occur monthly from May to June. In 2017, four seining events were completed in May, June, late-August, and late-September. Also, in 2014 seining was conducted in October.

For data analysis the Estuary study area was divided into three reaches, including Lower, Middle, and Upper, which is consistent with study areas for water quality and invertebrate studies. For the fish seining study, the Upper Reach of the Estuary was divided into Upper1 and Upper2 sub-reaches to improve clarity on fish patterns. Fish seining stations were located in areas that could be sampled during open and closed river mouth conditions. Suitable seining sites are limited during closed mouth conditions due to flooded shorelines. Catch per unit effort (CPUE), defined as the number of fish captured per seine set (fish/set), was used to compare the relative abundance of fish among Estuary reaches and study years.

The habitat characteristics and locations of study reaches, fish seining stations, and number of monthly seining sets are below:

- Lower Estuary
  - River Mouth (7 seine sets): sandbar separating the Russian River from the Pacific Ocean, sandy substrate with a low to steep slope, high tidal influence.
  - Penny Point (3 seine sets): shallow water with a mud and gravel substrate, high tidal influence.
- Middle Estuary
  - Patty's Bar (3 seine sets): large gravel and sand bar with moderate slope, moderate tidal influence.
  - Bridgehaven (7 seine sets): large gravel and sand bar with moderate to steep slope, moderate tidal influence.
  - Willow Creek (5 seine sets): shallow waters near the confluence with Willow Creek, gravel and mud substrate, aquatic vegetation common, moderate tidal influence.
- Upper Estuary

  *Upper1 Sub-Reach*
  - Sheephouse Bar (5 seine sets): opposite shore from Sheephouse Creek, large bar with gravel substrate and moderate to steep slope, low to moderate tidal influence
  - Heron Rookery Bar (5 seine sets): gravel bank adjacent to deep water, low to moderate tidal influence.
  - Freezeout Bar (5 seine sets): opposite shore from Freezeout Creek, gravel substrate with a moderate slope, low tidal influence.

  *Upper2 Sub-Reach*
  - Moscow Bridge (5 seine sets): steep to moderate gravel/sand/mud bank adjacent to shallow to deep water, aquatic vegetation common, low tidal influence.
  - Casini Ranch (5 seine sets): moderate slope gravel/sand bank adjacent to shallow to deep water, upper end of Estuary at riffle, very low tidal influence.

# Results

## Fish Distribution and Abundance

Fish captures from seine surveys in the Russian River Estuary for 2018 are summarized in Table 4.3.1. During the 15 years of study over 50 fish species were caught in the Estuary. In 2018, seine captures consisted of 11,806 fish comprised of 35 species.

The distribution of fish in the Estuary is, in part, based on a species preference for or tolerance to salinity (Figure 4.3.2). In general, the influence of cold seawater from the ocean under open mouth conditions results in high salinity levels and cool temperatures in the Lower Reach transitioning to warmer freshwater in the Upper Reach from river inflows (Figure 4.3.3). The water column is usually stratified with freshwater flowing over the denser seawater.

Fish commonly found in the Lower Reach were marine and estuarine species including topsmelt (*Atherinops affinis*), surf smelt (*Hypomesus pretiosus*), and staghorn sculpin (*Leptocottus armatus*). The Middle Reach had a broad range of salinities and a diversity of fish tolerant of these conditions. Common fish in the Middle Reach included those found in the Lower Reach and shiner surfperch (*Cymatogaster aggregata*) and bay pipefish (*Syngnathus leptorhynchus*). Freshwater dependent species, such as the Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow (*Ptychocheilus grandis*), and Russian River tule perch (*Hysterocarpus traskii pomo*) were predominantly distributed in the Upper Reach. Anadromous fish, such as steelhead (*Oncorhynchus mykiss*) and American shad (*Alosa sapidissima*), which can tolerate a broad range of salinities, occurred throughout the Estuary. Habitat generalists, such as threespine stickleback (*Gasterosteus aculeatus*) and prickly sculpin (*Cottus asper*), occurred in abundance in the Estuary, except within full strength seawater in the Lower Reach.

### *Steelhead*

During 2018, a total of 65 steelhead were captured (Table 4.3.1) in 150 seine sets. These steelhead were wild, except for two hatchery fish. The resulting CPUE was 0.43 fish/set (Figure 4.3.4). In comparison, during 2017, a total of 22 steelhead were captured in 200 seine sets for a CPUE of 0.11 fish/set. There has been an overall decline in steelhead abundance since 2008 when the CPUE was 1.32 fish/set, although the steelhead capture rate in 2018 is the highest since 2013. The seasonal abundance of steelhead captures varied annually in the Estuary (Figure 4.3.5). Juvenile steelhead were captured during all three survey events in 2018. The highest steelhead abundances are typically in June and August. During 2018, steelhead captures were highest during May at 0.84 fish/set followed by June at 0.38 fish/set. The highest capture abundance among all study years was in August at 4.3 fish/set and June at 4.2 fish/set in 2008. Since seining surveys began in 2004, steelhead appear to have a patchy distribution and vary in abundance in the Estuary (Figure 4.3.6). Overall years surveyed, captures were typically highest in the Upper Reach with a high of 6.9 fish/set in the Upper1 Sub-Reach in 2008.

**Table 4.3.1. Total fish caught by beach seine in the Russian River Estuary, 2018. Each station was sampled monthly during May, June, and September for a total of 150 seine sets for all sites. Monthly seine sets per station are shown in parentheses.**

| | | Seining Station | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Life History** | **Species** | **River Mouth (7)** | **Penny Point (3)** | **Patty's Bar (3)** | **Bridge-haven (7)** | **Willow Creek (5)** | **Sheep-house Bar (5)** | **Heron Rookery Bar (6)** | **Freeze-out Bar (4)** | **Moscow Bridge (5)** | **Casini Ranch (5)** | **Total** |
| Anadromous | American shad | | | | | 3 | | 4 | | 28 | 79 | 114 |
| | Chinook salmon | 3 | 8 | | 16 | 2 | | 1 | | 9 | 1 | 40 |
| | coho salmon | 2 | 1 | 2 | 1 | | | | 1 | 3 | 7 | 17 |
| | steelhead | | | | 5 | 1 | | 1 | 1 | | 57 | 65 |
| Freshwater | bluegill | | | | | | | 1 | 2 | 3 | | 6 |
| | California roach | | | | | | | | | 17 | | 17 |
| | common carp | | | | | | | | 5 | | | 5 |
| | cyprinid sp | | | | | | | 8 | 3 | | | 11 |
| | hardhead | | | | | | | | | 1 | | 1 |
| | hitch | | | | | | | 4 | 6 | 14 | | 24 |
| | largemouth bass | | | | | | 1 | 1 | 92 | 176 | 7 | 277 |
| | redear sunfish | | | | | | | | 3 | | | 3 |
| | Russian River tule perch | | 20 | | 6 | | 1 | 25 | 981 | 611 | 1 | 1645 |
| | Sacramento pikeminnow | | 1 | | 4 | 2 | 36 | 228 | | 76 | 26 | 373 |
| | Sacramento sucker | | | | 2 | | 365 | 174 | 607 | 530 | 385 | 2063 |
| | white catfish | | | | | | | | 1 | 2 | | 3 |
| Estuarine | bay pipefish | 5 | 6 | 7 | 15 | 5 | 1 | | | | | 39 |
| | shiner surfperch | 7 | 98 | 84 | 104 | 10 | 16 | | | | | 319 |
| | staghorn sculpin | 23 | 135 | 27 | 62 | 7 | 10 | 7 | | | | 271 |
| | starry flounder | 11 | 64 | 4 | 18 | 6 | 2 | 2 | 16 | 9 | 39 | 171 |
| | topsmelt | | 4 | 28 | 2 | 30 | | | | | | 64 |
| Marine | cabezon | 17 | | | | | | | | | | 17 |
| | English sole | 1 | | | | | | | | | | 1 |
| | lingcod | 35 | | | | | | | | | | 35 |
| | northern anchovy | | | 4 | 1 | | | | | | | 5 |
| | Pacific herring | 13 | | | | | | | | | | 13 |
| | Pacific sanddab | 1 | | | | | | | | | | 1 |
| | redtail surfperch | | | | 1 | | | | | | | 1 |
| | saddleback gunnel | 1 | | 1 | 1 | | | | | | | 3 |
| | sebastes sp. (rockfish) | 10 | 3 | | | | | | | | | 13 |

| Life History | Species | Seining Station River Mouth (7) | Penny Point (3) | Patty's Bar (3) | Bridge-haven (7) | Willow Creek (5) | Sheep-house Bar (5) | Heron Rookery Bar (6) | Freeze-out Bar (4) | Moscow Bridge (5) | Casini Ranch (5) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | sharpnose sculpin | 1 | 2 | | | | | | | | | 3 |
| | striped surfperch | 1 | | | | | | | | | | 1 |
| | surf smelt | 786 | 122 | | 2 | | | | | | | 910 |
| Generalist | prickly sculpin | 50 | 49 | 137 | 209 | 37 | 31 | 57 | 18 | 45 | 5 | 638 |
| | threespine stickleback | 2 | 373 | 374 | 803 | 205 | 272 | 1765 | 512 | 320 | 11 | 4637 |
| | **Total** | **969** | **886** | **668** | **1252** | **308** | **735** | **2278** | **2248** | **1844** | **618** | **11806** |

*Prickly Sculpin counts may include small numbers of the freshwater-resident Coast Range sculpin (*Cottus aleuticus*) and riffle sculpin (*Cottus gulosus*), although neither of these species has been reported from the Estuary.

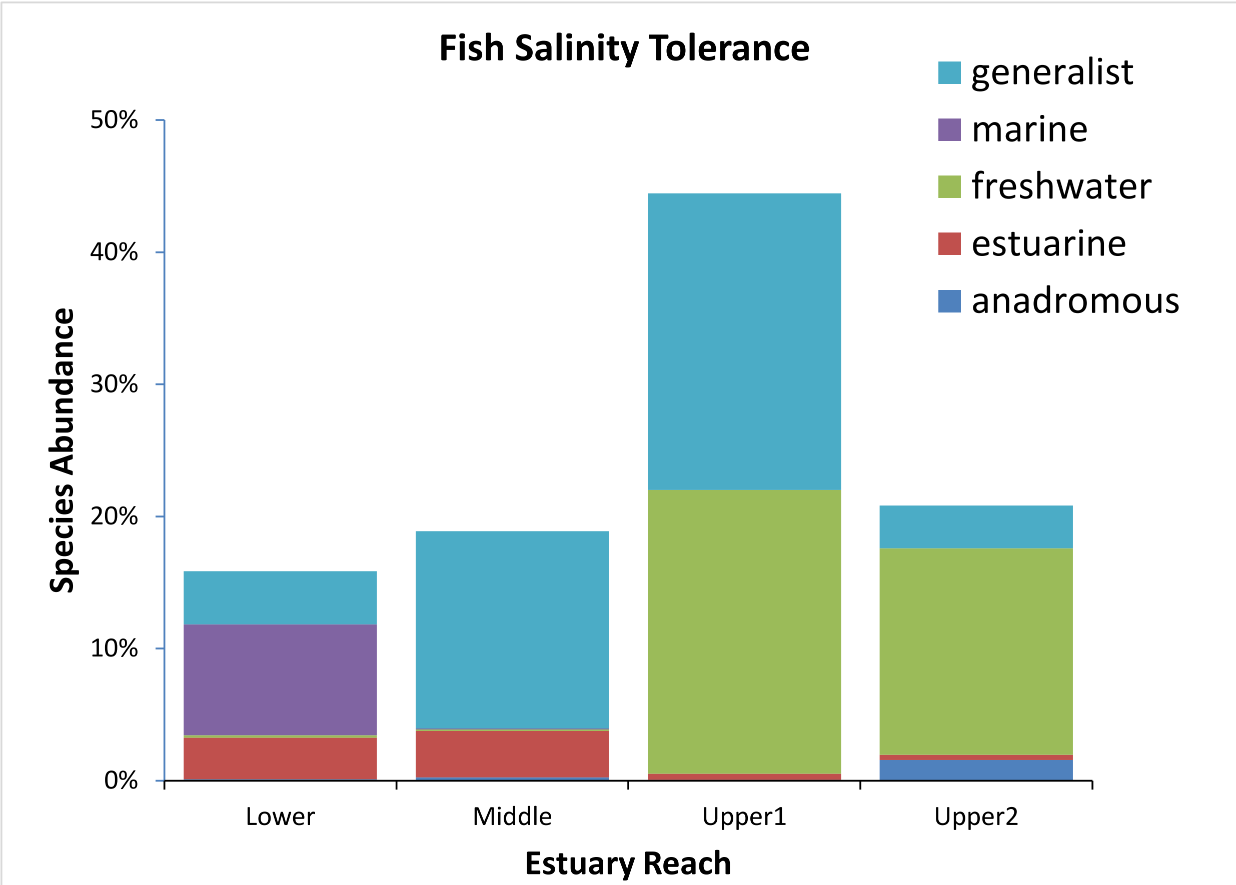



**Figure 4.3.2. Distribution of fish in the Russian River Estuary based on salinity tolerance and life history, 2018. Data is from monthly seining during May, June, and September. Groups include: generalist species that occur in a broad range of habitats; species that are primarily anadromous; freshwater resident species; brackish-tolerant species that complete their lifecycle in estuaries; and species that are predominantly marine residents. See Table 4.3.1 for a list of species in each group.**

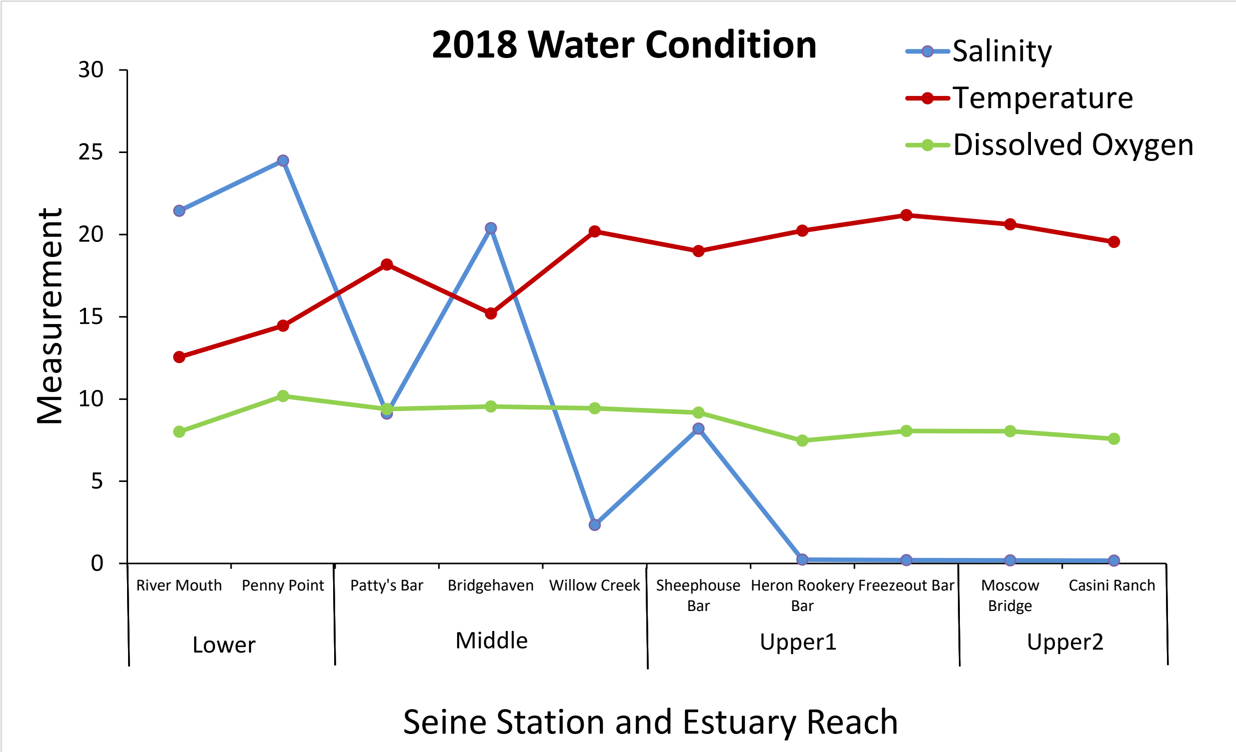



**Figure 4.3.3. Generalized water conditions at fish seining stations in the Russian River Estuary, 2018. Values are averages collected at 0.5 m intervals in the water column during beach seining events from May, June, and September during primarily open mouth conditions. Water measurements are salinity in parts per thousand (ppt), dissolved oxygen in milligrams per liter (mg/L), and temperature in Celsius (C).**

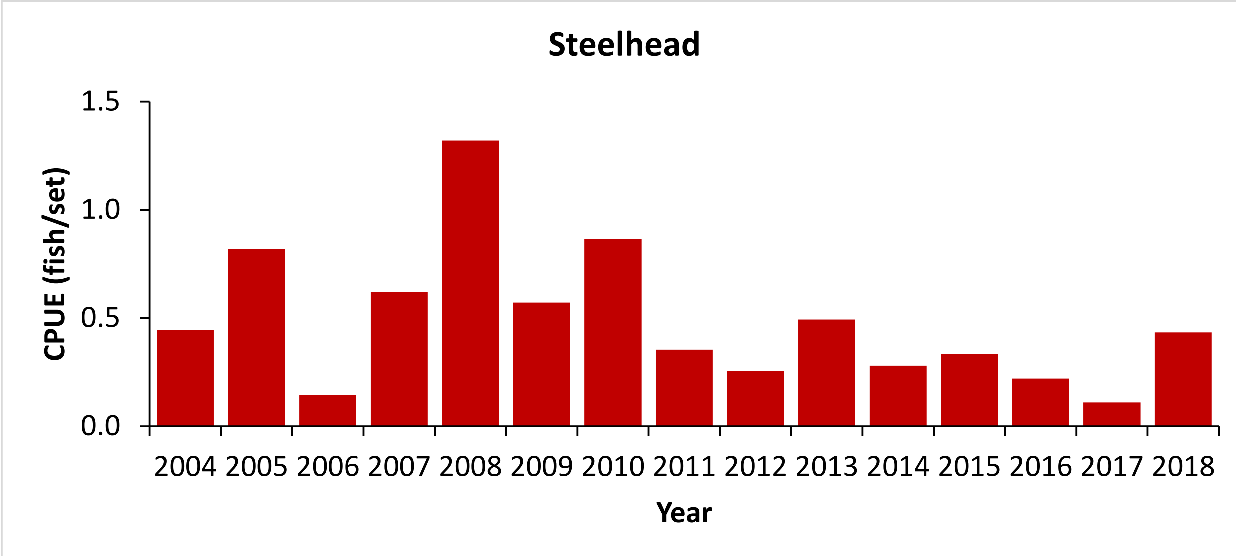



**Figure 4.3.4. Annual abundance of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2018. Samples are from 96 to 300 seine sets conducted yearly from May to October.**

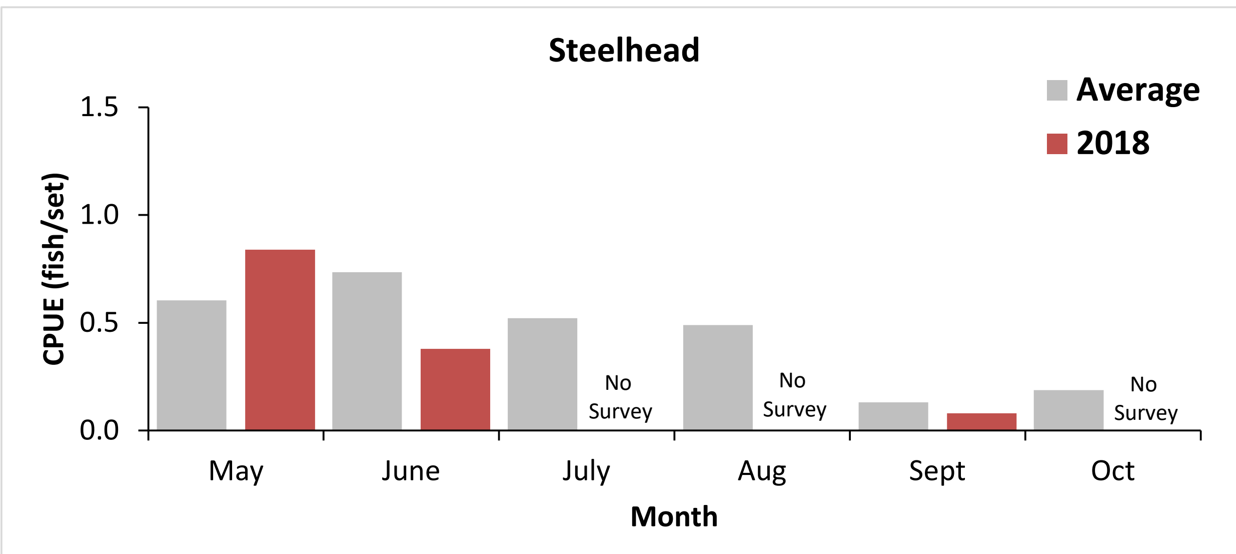



**Figure 4.3.5. Seasonal abundance of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2018. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010.**

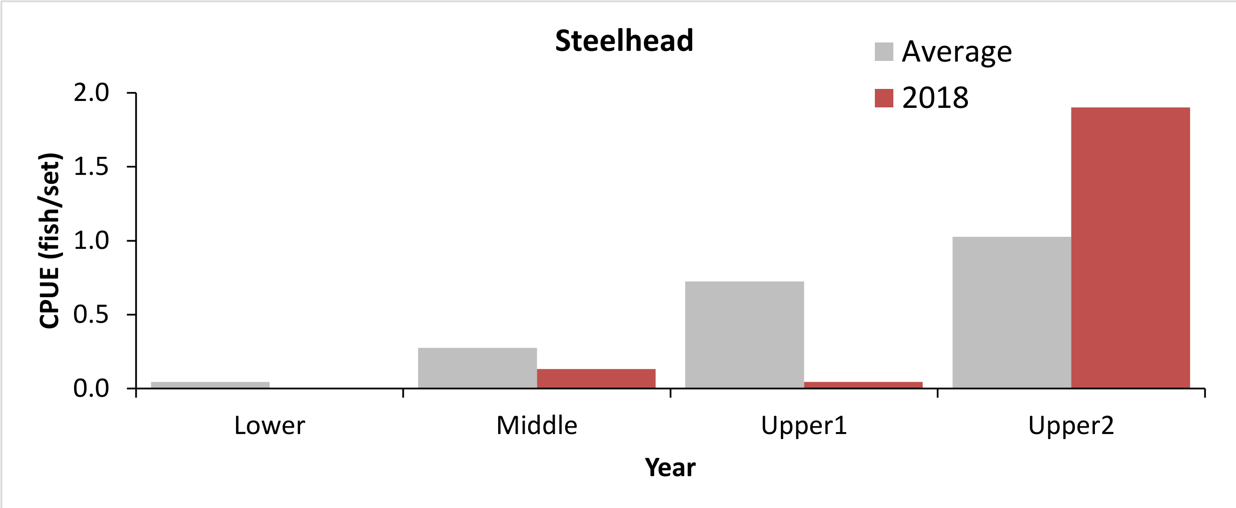



**Figure 4.3.6. Distribution of juvenile steelhead in the Russian River Estuary, 2004-2018. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2018 were averaged.**

Overall, there were few steelhead found in the Estuary in 2018, which limited the temporal and spatial evaluation of steelhead in the Estuary (Figure 4.3.7). The typical pattern observed in previous study years consisted of relatively large numbers of juveniles in the upper Estuary in May and June, these fish found in the middle Estuary in mid-summer, then most steelhead found in the lower Estuary in September. Spring captures are typically parr that are residing in freshwater in the upper Estuary. Then by late summer the steelhead are mainly smolts residing to the brackish water of the lower Estuary. The pattern observed in 2018 consisted of parr steelhead in the Upper Estuary in May and June and a few smolts in September. There were a few steelhead captured in the Middle Estuary and none in the Lower Estuary. Most juvenile steelhead captured in 2018 were age 0+ parr or age 1+ smolts and ranged in size from 70 mm to 400 mm fork length (Figure 4.3.8).

In 2018, 60 juvenile steelhead captured during Estuary seining surveys were implanted with PIT tags. In addition, 917 juvenile steelhead where PIT-tagged during downstream migrant trapping studies in the Russian River and tributaries upstream of the Estuary. There were no PIT-tagged steelhead recaptured in the Estuary during 2018 seining.

*Chinook Salmon*

A total of 40 Chinook salmon smolts were captured by beach seine in the Estuary during 2018 (Table 4.3.1). The abundance of smolts in the Estuary has varied since studies began in 2004 (Figure 4.3.9). The highest abundance of Chinook salmon smolts was in 2008 at 5.2 fish/set. The lowest abundance of Chinook smolts was in 2016 and 2018 at 0.3 fish/set. Chinook salmon smolts are usually most abundant during May and June (Figure 4.3.10) and rarely encountered after July. Monthly smolt captures in 2018 were highest during May at 0.7 fish/set. Chinook salmon smolts were distributed throughout the Estuary with captures at most sample stations and reaches annually (Figure 4.3.11).

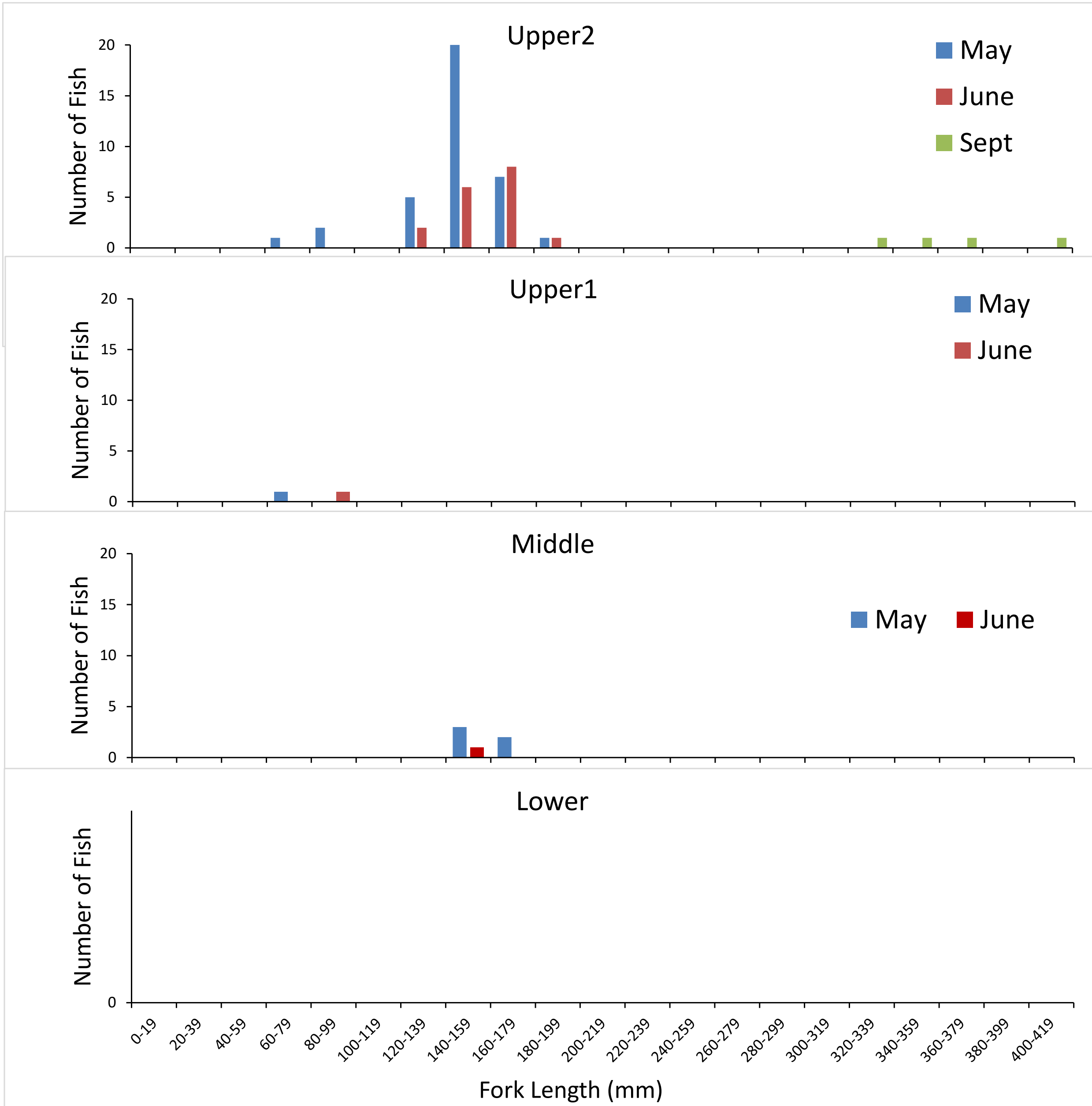



**Figure 4.3.7. Length frequency of juvenile steelhead captured by beach seine in the Russian River Estuary, 2018. Fish captures are grouped by Estuary reach and month.**

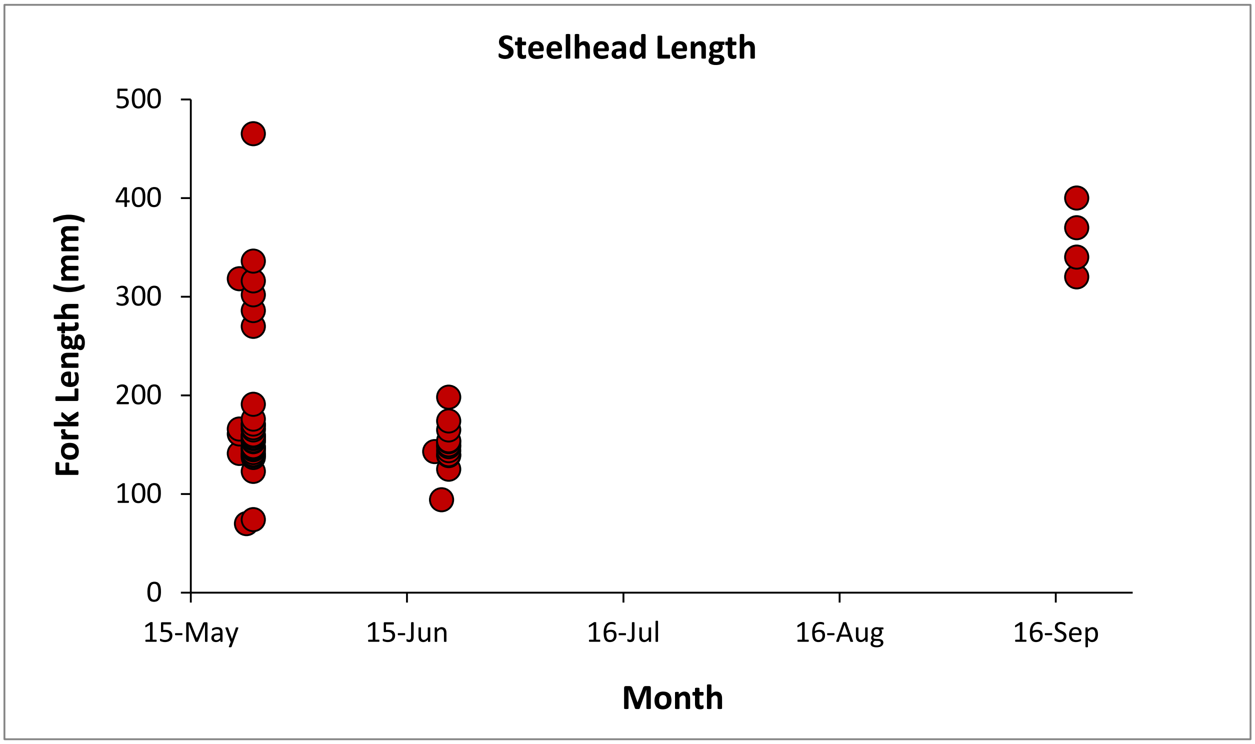



**Figure 4.3.8. Juvenile steelhead sizes captured by beach seine in the Russian River Estuary, 2018.**

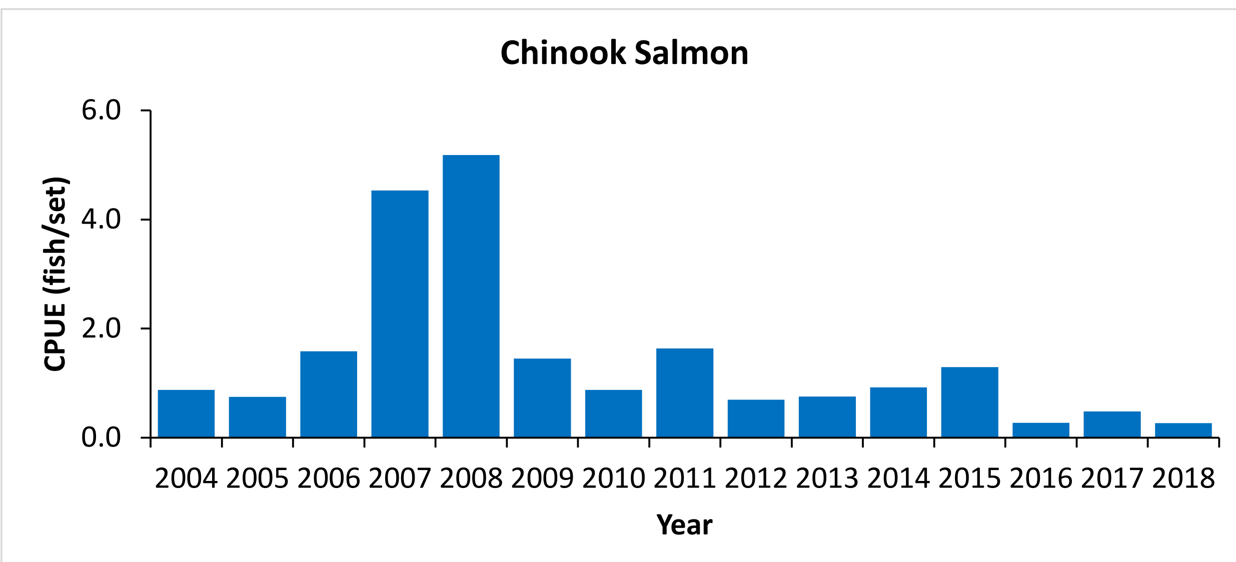



**Figure 4.3.9. Annual abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2018. Samples are from 96 to 300 seine sets yearly from May to October.**

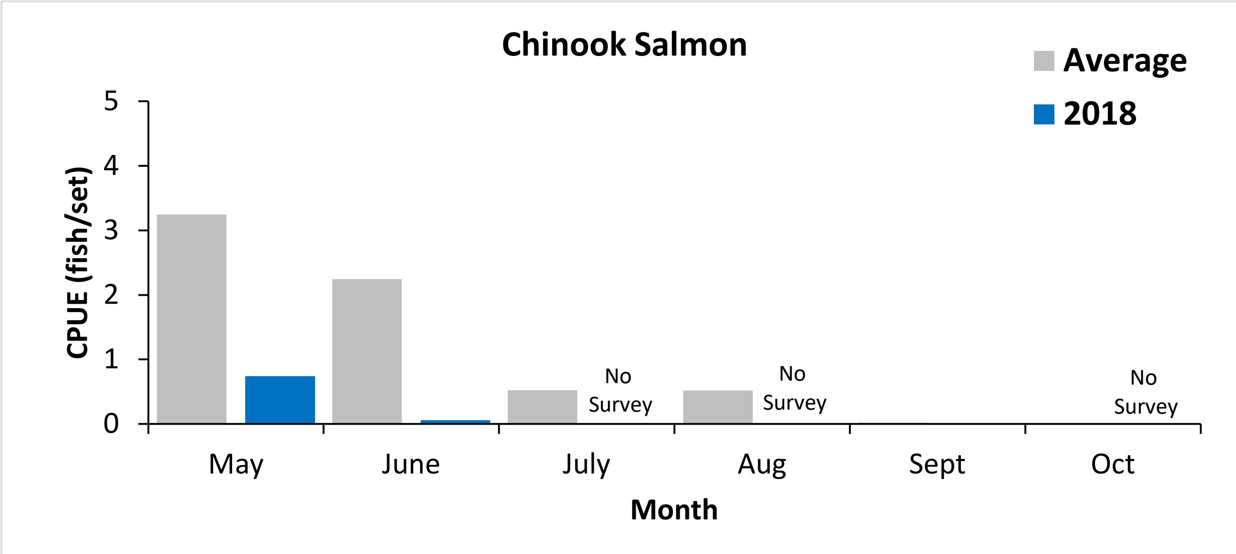



**Figure 4.3.10. Seasonal abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2018. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2018 were averaged.**

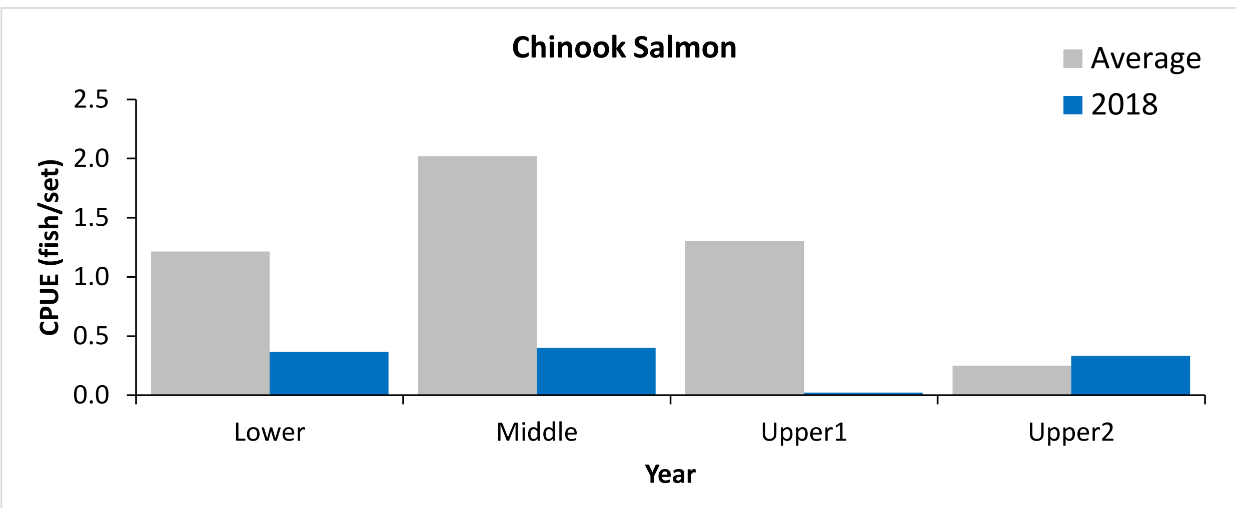



**Figure 4.3.11. Spatial distribution of Chinook salmon smolts in the Russian River Estuary, 2004-2018. Fish were sampled by beach seine consisting of 96 to 300 sets annually. Data from 2004 to 2018 were averaged. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009.**

There were 3,741 Chinook smolts PIT-tagged at several downstream migrant trap sites in the Russian River and tributaries during spring 2018. Two of these smolts were recaptured in the Estuary in the middle reach. Both fish were tagged in the Russian River at the Wohler-Mirabel downstream migrant trap near Forestville on May 16 at fork lengths of 88 mm. These smolts were recaptured in the Estuary 5 to 6 days later at the Penny Point and Bridgehaven seining stations and had grown 1-2 mm. These smolts migrated quickly through the lower Russian River and grew very little.

### *Coho Salmon*

There have been relatively few coho salmon smolts captured in the Estuary during our beach seining surveys (Figure 4.3.12). The first coho salmon smolt captured in the Estuary was a single fish in 2006. In 2011 and 2015 there were marked increases in abundances of coho smolts with a CPUE of 0.9 and 0.7 fish/set, respectively. During 2018 the total capture of coho was 17 smolts at a CPUE of 0.11 fish/set. One smolt was not marked and presumed wild. The remaining smolts were hatchery raised. Nearly all coho salmon smolts are captured by June and smolts in 2018 were captured in May and June (Figure 4.3.13). The spatial distribution of coho smolts has varied annually (Figure 4.3.14). Coho salmon were captured in all reaches in 2018, with the highest abundance in Upper2 Sub-Reach.

All hatchery coho are implanted with a coded wire tag and a portion are also implanted with a PIT tag. In 2018 there were 2,475 hatchery coho PIT-tagged. Three of these coho were recaptured in the Estuary. The history of these coho are shown in Table 4.3.2. These fish were initially released in three tributaries of the Russian River, including Mill (tributary to Dry Creek), Dutch Bill, and Willow creeks. Two parr coho were stocked in fall 2017 in tributaries, were detected moving downstream in spring 2018, and captured as smolts in the Estuary 9 to 10 days later. The third fish was a smolt released in Dutch Bill Creek on May 23, 2018, and recaptured in the upper Estuary one day later.

### *American Shad*

American shad is an anadromous sportfish, native to the Atlantic coast. It was introduced to the Sacramento River in 1871 and within two decades was abundant locally and had established populations from Alaska to Mexico (Moyle 2002). Adults spend from 3 to 5 years in the ocean before migrating upstream to spawn in the main channels of rivers. Juveniles spend the first year or two rearing in rivers or estuaries. The abundance of American shad in the Estuary during 2018 was low at 0.8 fish/set (Figure 4.3.15). This low abundance may have been influenced by the reduced seining effort in 2018 where no surveys were conducted during July and August. Typically, juvenile American shad first appear in relatively large numbers in July and the catch usually peaks in August. Shad are typically distributed throughout the Estuary, although in 2018 they were found mostly in the Upper2 Sub-reach (Figure 4.3.16).

### *Topsmelt*

Topsmelt are one of the most abundant fish in California estuaries (Baxter et al. 1999) and can tolerate a broad range of salinities and temperatures, but are seldom found in freshwater (Moyle 2002). They form schools and are often found near the water surface in shallow water. Sexual maturity is reached in 1 to 3 years and individuals can live as long as 7 to 8 years. Estuaries are used as nursery and spawning grounds and adults spawn in late spring to summer.

Topsmelt is a common fish in the Russian River Estuary. However, the abundance of topsmelt in the Estuary has varied substantially since 2004. There were peaks in abundance in 2006 and 2014 with a CPUE up to 17.9 and abundances below 0.3 fish/set in 2016 and 2017 (Figure 4.3.17). Also, the abundance of topsmelt in 2015 and 2016 may be an underestimate because no seining was conducted in July and August when the catch of topsmelt usually peaks. Topsmelt abundance in 2018 was low at 0.4 fish/set. Topsmelt are mainly distributed in the Lower and Middle Reaches in the Estuary (Figure 4.3.18).

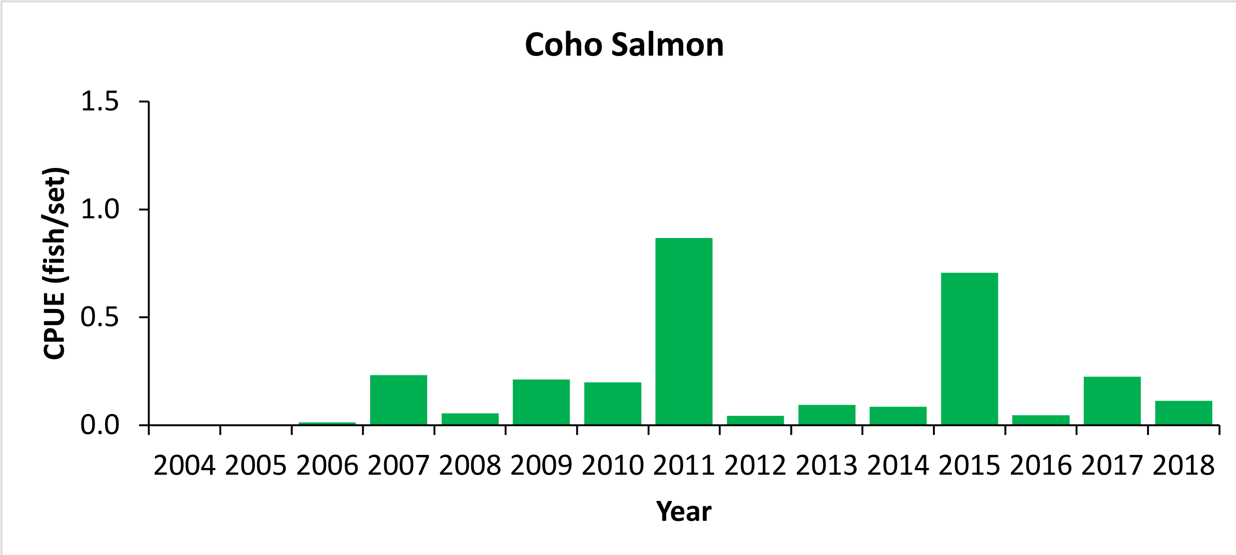



**Figure 4.3.12. Annual abundance of coho salmon smolts captured by beach seine in the Russian River Estuary, 2004-2018. Samples are from 96 to 300 seine sets yearly from May to October.**

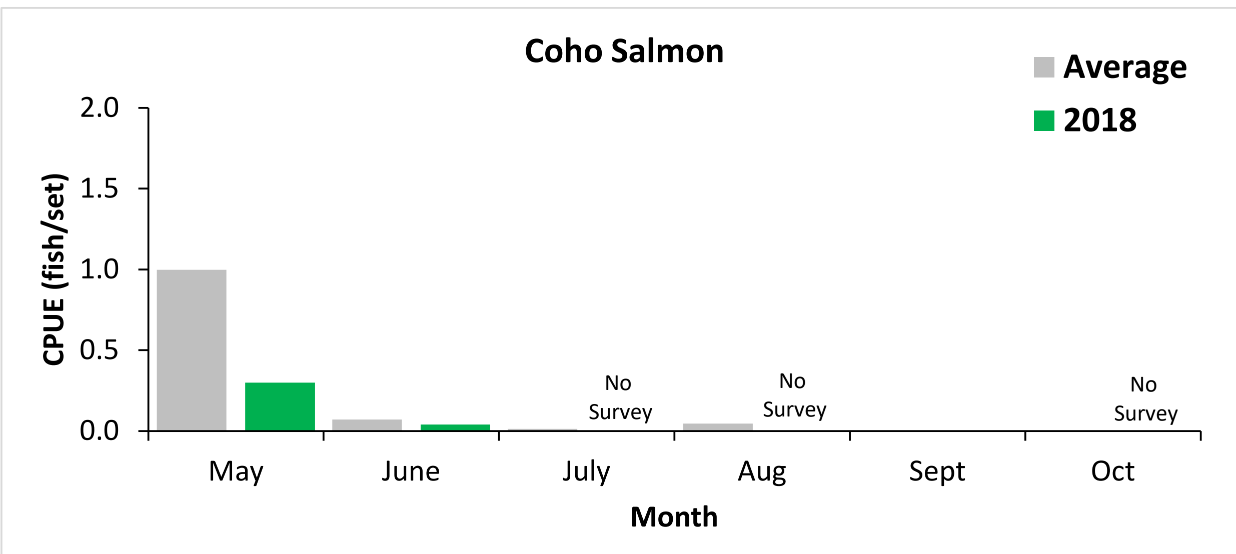



**Figure 4.3.13. Seasonal abundance of coho salmon smolts captured by beach seine in the Russian River Estuary, 2004-2018. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2018 were averaged.**

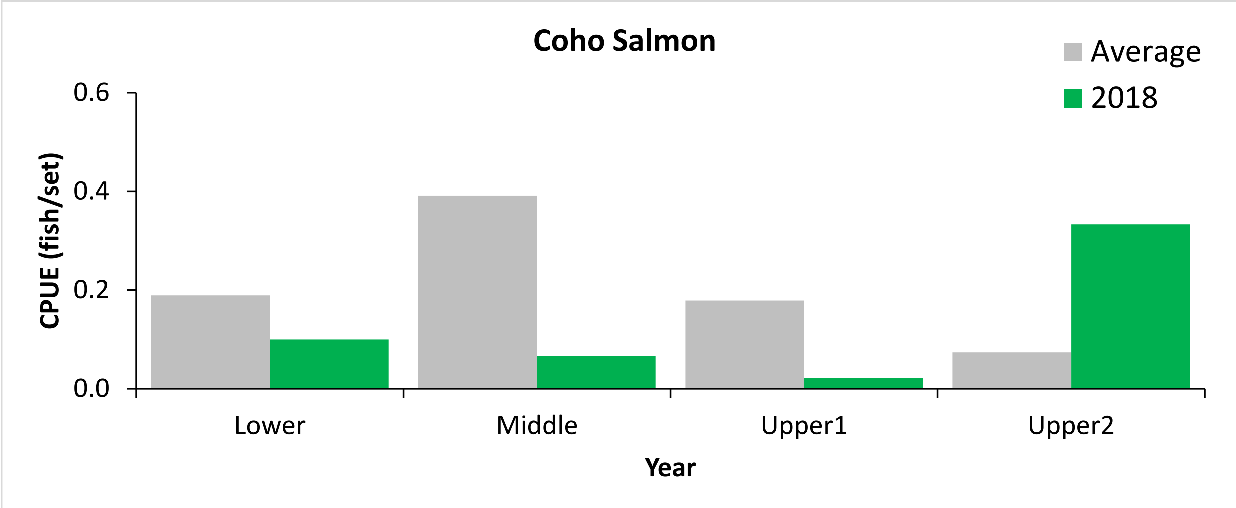



**Figure 4.3.14. Spatial distribution of coho salmon smolts in the Russian River Estuary, 2004-2018. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2018 were averaged.**

**Table 4.3.2. Hatchery coho salmon detection sites and seasons captured in the Russian River Estuary in 2018. Coho were either stocked in creeks or captured at downstream migrant traps. Fish are from the coho salmon broodstock program at Warm Springs Fish Hatchery.**

| PIT Tag | Release/Capture Site | Date | Fork Length (mm) | Estuary Recapture Location | Date | Fork Length (mm) |
|---|---|---|---|---|---|---|
| 3DD.003BF2217C | Mill Creek (tag-released) | 11/16/17 | 68 | -- | -- | -- |
| | Mill Creek (antenna) | 5/15/18 | -- | -- | -- | -- |
| | -- | -- | -- | Casini Ranch | 5/24/18 | 110 |
| 3DD.003BF23306 | Willow Creek (tag-released) | 11/22/17 | 75 | -- | -- | -- |
| | Willow Creek (trap) | 6/15/18 | 89 | -- | -- | -- |
| | | | | River Mouth | 6/25/18 | 92 |
| 3DD.003BF25888 | Dutch Bill Creek (tag-released) | 5/23/18 | 128 | -- | -- | -- |
| | -- | -- | -- | Moscow Bridge | 5/24/18 | 131 |

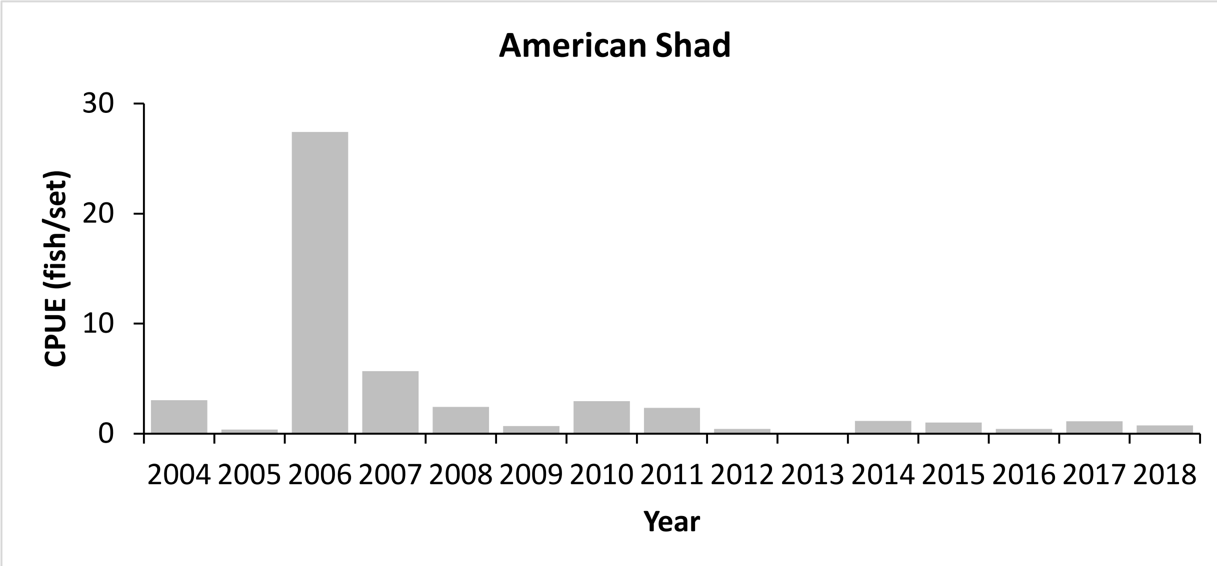



**Figure 4.3.15**. **Annual abundance of juvenile American shad captured by beach seine in the Russian River Estuary, 2004-2018. Samples are from 96 to 300 seine sets yearly from May to October.**

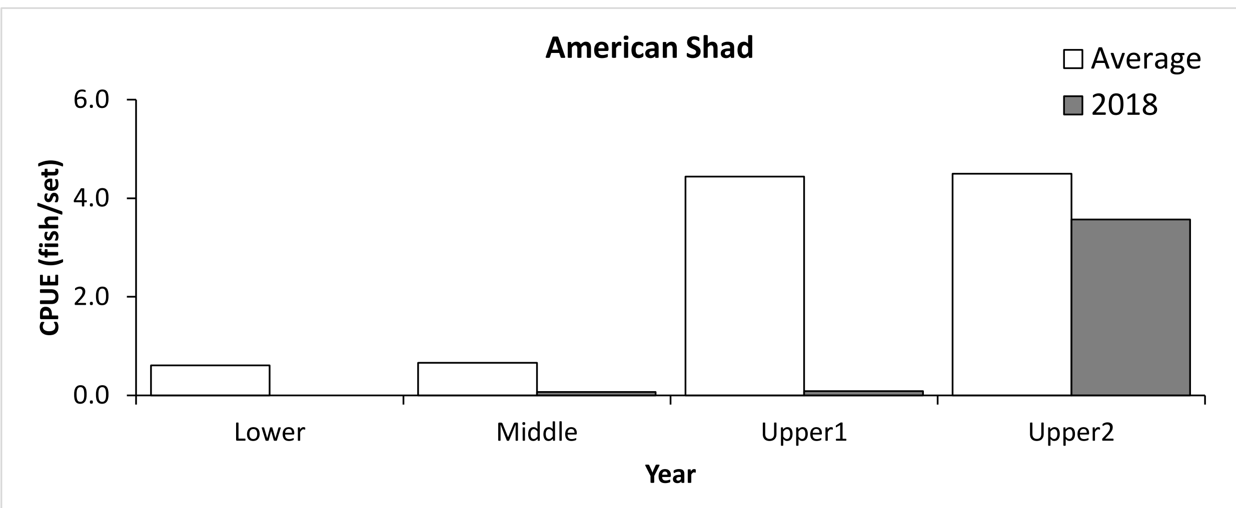



**Figure 4.3.16. Spatial distribution of juvenile American shad in the Russian River Estuary, 2004-2018. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Reach during 2004 and 2009. Data from 2004 to 2018 were averaged. Whiskers indicate minimum and maximum values.**

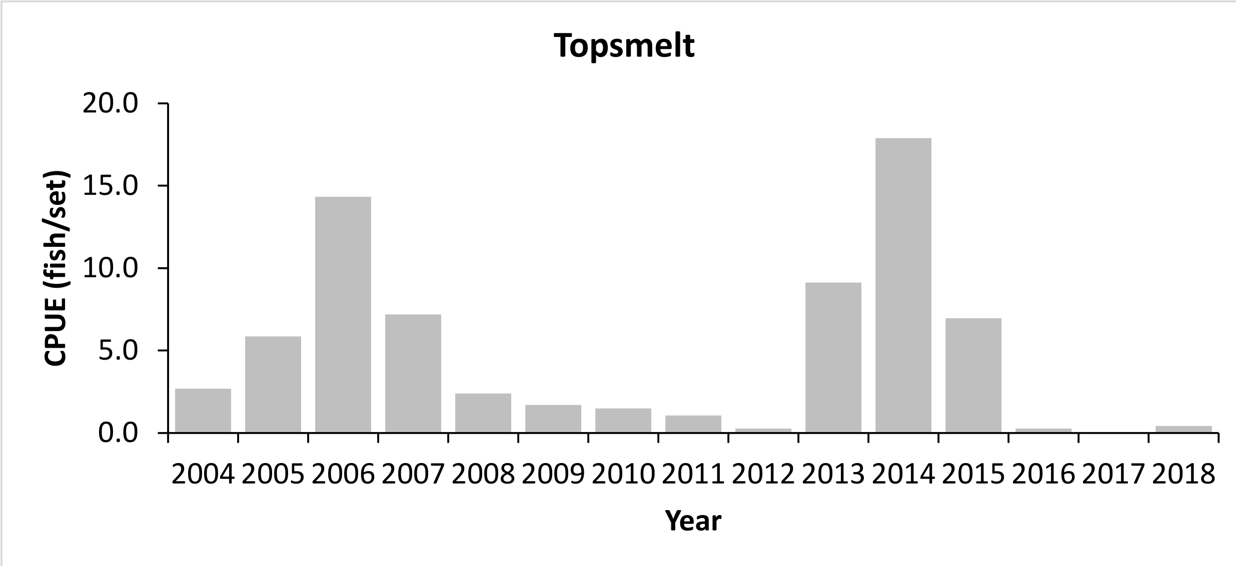



**Figure 4.3.17. Annual abundance of topsmelt captured by beach seine in the Russian River Estuary, 2004-2018. Samples are from 96 to 300 seine sets yearly from May to October.**

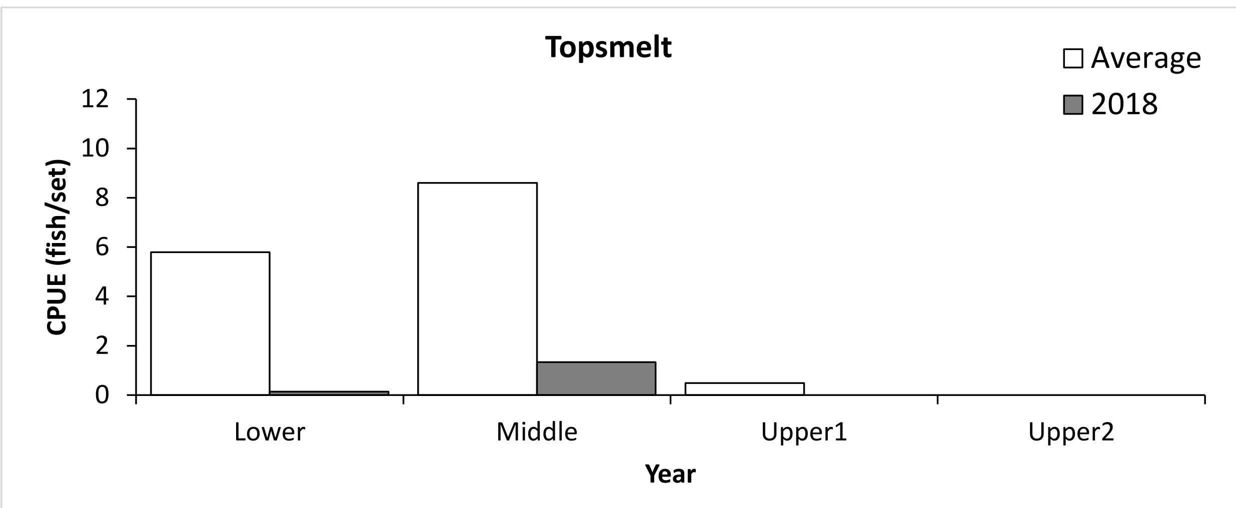



**Figure 4.3.18. Spatial distribution of topsmelt in the Russian River Estuary, 2004-2018. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach during 2004 and 2009. Data from 2004 to 2018 were averaged.**

### *Starry Flounder*

Starry flounder range from Japan and Alaska to Santa Barbara in coastal marine and estuarine environments. In California, they are common in bays and estuaries (Moyle 2002). This flatfish is usually found dwelling on muddy or sandy bottoms. Males mature during their second year and females mature at age 3 or 4 (Baxter et al. 1999). Spawning occurs during winter along the coast, often near the mouths of estuaries. Young flounders spend at least their first year rearing in estuaries. They move into estuaries during the spring and generally prefer warm, low-salinity water or freshwater. As young grow, they shift to using brackish waters.

The abundance of juvenile starry flounder in the Estuary has varied since studies began in 2004 (Figure 4.3.19). Juvenile flounder were relatively abundant in 2004-2005 and 2016-2017 with CPUEs greater than 8 fish/set. In 2018 this flounder had the fourth highest abundance at 1.1 fish/set. During the decade period from 2006 to 2015 abundances of flounder were below 2 fish/set. The Estuary appears to be utilized primarily by young-of- the-year fish as most flounder captures are less than 100 mm fork length. The seasonal occurrence of starry flounder was typically highest in May and June, and then gradually decreased through September and October when few were caught. Starry flounder were distributed throughout the Estuary ranging from the River Mouth in the Lower Reach, with cool seawater conditions, to the Upper Reach, with warm freshwater (Figure 4.3.20). Starry flounder have been detected as far as Austin Creek at the upstream end of the Estuary (Cook 2006).

## Conclusions and Recommendations

The results of Estuary fish surveys from 2004 to 2018 found over 50 fish species from marine, estuarine, and riverine origins. The distribution of species was strongly influenced by the salinity gradient in the Estuary that is typically cool seawater near the mouth of the Russian River and transitions to warmer freshwater at the upstream end. Exceptions to this distribution pattern were anadromous and generalist fish that occurred throughout the Estuary regardless of salinity levels. The 2018 fish studies contribute to the 15-year dataset of existing conditions and our knowledge of a tidal brackish system. This baseline data will be used to compare with a closed mouth lagoon system.

All three salmonid species in the Russian River watershed were detected in the Russian River Estuary at the parr and/or smolt lifestages. Chinook salmon and coho smolts were not detected after June suggesting limited rearing occurred in the Estuary before migrating to the ocean. In comparison, juvenile steelhead were found during the entire summer and were often found in the Upper Reach of the Estuary.

The fluctuation in abundance of steelhead annually is likely attributed to the variability in adult spawner population size (i.e. cohort abundance), residence time of young steelhead before out-migration, and schooling behavior that affects susceptibility to capture by seining. A prolonged and severe drought that began in 2013 likely contributed to the low abundance of steelhead and salmon in the Russian River Estuary in 2018.

Although beach seining is widely used in estuarine fish studies, beach seines are only effective near shore in relatively open water habitats free of large debris and obstructions that can foul or snag the net. Consequently, there is inherent bias in seine surveys (Steele et al. 2006). By design, our seining stations were located in areas with few underwater obstructions (i.e., large rocks, woody debris, etc.) and this likely influenced our assessment of fish abundance and habitat use. However, the spatial and temporal aspects of our sampling do allow quantitative comparisons among reaches and years.

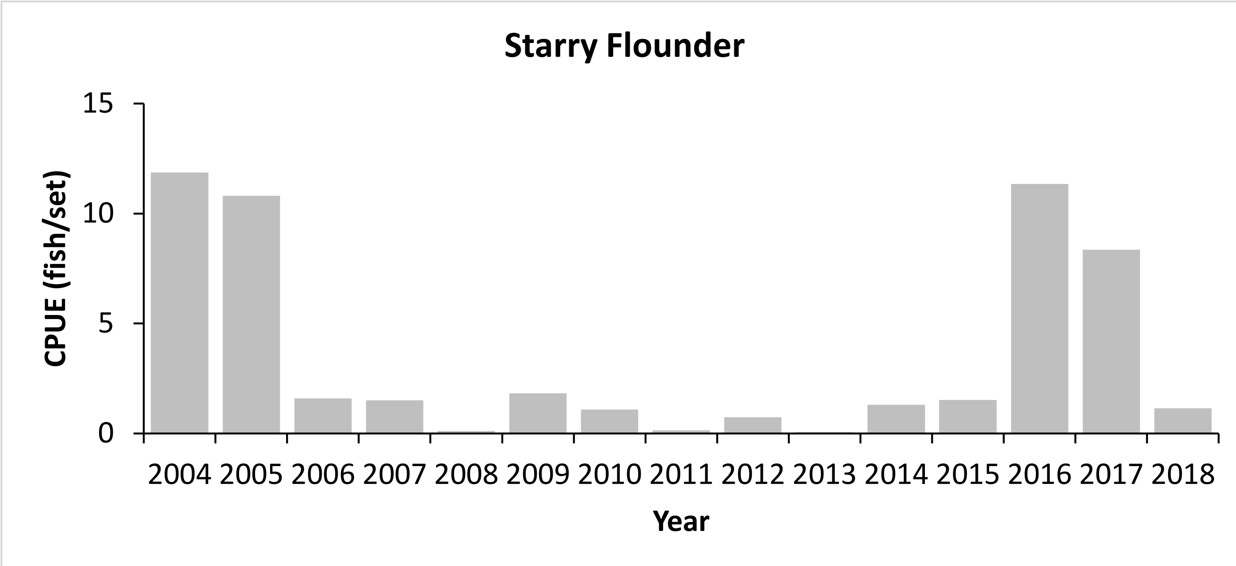



**Figure 4.3.19. Annual abundance of juvenile starry flounder captured by beach seine in the Russian River Estuary, 2004-2018. Samples are from 96 to 300 seine sets yearly from May to October.**

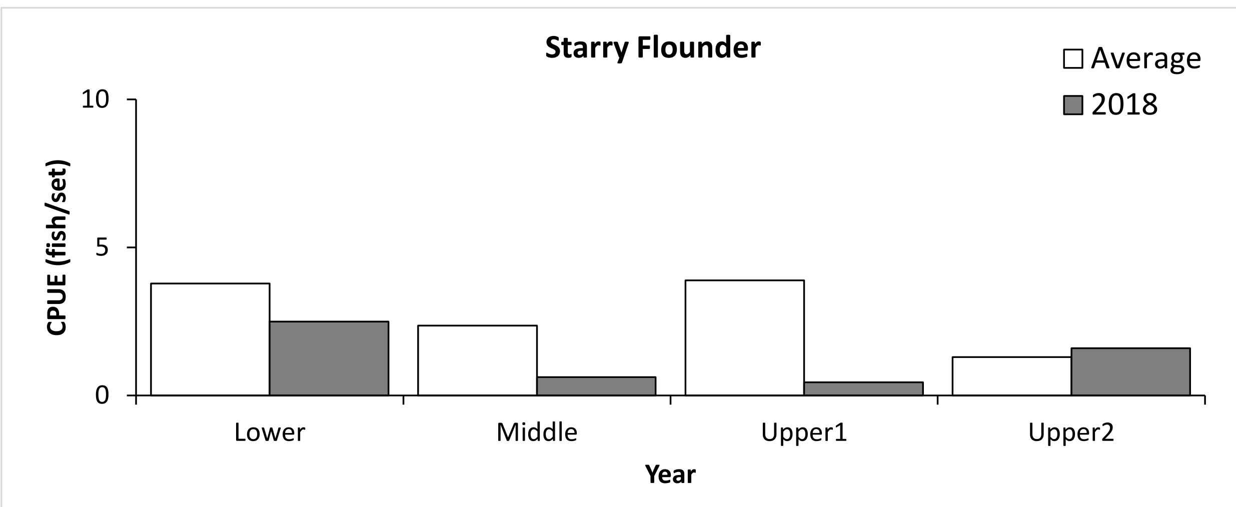



**Figure 4.3.20. Spatial distribution of juvenile starry flounder in the Russian River Estuary, 2004-2018. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach during 2004 and 2009. Data from 2004 to 2018 were averaged.**

## 4.4 Downstream Migrant Trapping

The Reasonable and Prudent Alternative (RPA) in the Russian River Biological Opinion compels Sonoma Water to provide information about the timing of downstream movements of juvenile steelhead, their relative abundance and the size/age structure of the population as related to the implementation of an adaptive management approach to promote formation of a perched freshwater lagoon. The sampling design implemented by Sonoma Water and described in this section specifically targets the detection and capture of anadromous salmonid young-of-the-year (YOY, age-0) and parr (≥age-1) (collectively referred to as juveniles) as well as smolts. In order to help accomplish the objectives listed above, Sonoma Water undertook fish capture and PIT-tagging activities at selected trapping sites upstream of the Estuary (Figure 4.4.1):

- Dry Creek (capture only)
- Mainstem Russian River at Mirabel
- Mark West Creek
- Dutch Bill Creek
- Austin Creek

Stationary PIT antenna arrays were operated in the following locations:

- Upstream end of the Russian River estuary in Duncans Mills (river km 10.46)
- Near the mouth of Austin Creek (river km 0.5)

Implementation of the monitoring activities described here are the result of a continually-evolving process of evaluating and improving on past monitoring approaches. Descriptions and data from other fish trapping operations in Dry Creek are presented in Chapter 5 of this report.

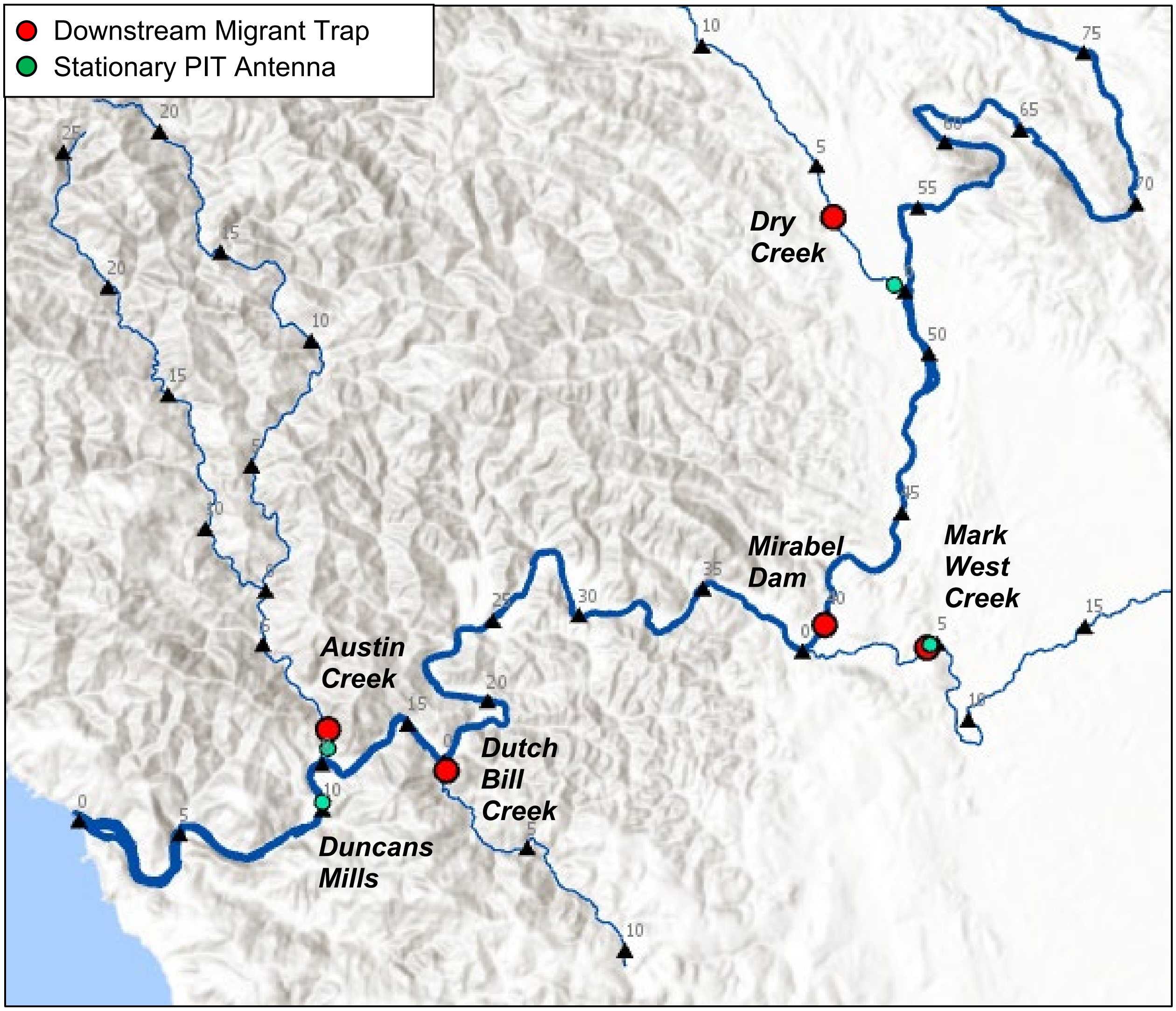



**Figure 4.4.1. Map of downstream migrant detection sites in the lower Russian River, 2018. Numbered symbols along stream courses represent distance (km) from the mouth of each stream.**

## Methods

In 2018 Sonoma Water again relied on downstream migrant traps and stationary PIT antenna arrays at lower-Russian River basin trap sites to address the objectives in the RPA. Similar to 2010 through 2017, fish were physically captured at downstream migrant traps (rotary screw trap, funnel trap or pipe trap depending on the site), sampled for biological data and released. PIT tags were applied to a subset of age-0 steelhead captured at trap sites and fish were subject to detection at downstream PIT antenna arrays if they moved downstream into the Estuary. In the sections that follow, the sampling methods and analyses conducted for data collected at each site are described.

### Estuary/Lagoon PIT antenna systems

Two antenna arrays with multiple flat plate antennas (antennas designed to lay flat on the stream bottom) were installed in the upper Russian River estuary near the town of Duncans

Mills (river km 10.44, 10.46) to detect PIT-tagged fish entering the Estuary (Figure 4.4.2). Generally, 12 antennas were operated continuously throughout the year. The orientation of the antennas consisted of 2 rows of antennas with one row slightly upstream of the other. Each row contained 6 antennas placed side by starting at the west river bank and extending out into the channel.


**Figure 4.4.2. Flat plate antenna arrays at Duncans Mills (river km 10.44 and 10.46). Rectangles represent individual flat plate antennas.**

## Lower River Fish Trapping and PIT tagging

Following consultation with NMFS and CDFW, Sonoma Water identified three lower Russian River tributaries (Mark West Creek, Dutch Bill Creek and Austin Creek, Figure 4.4.1) in which to operate fish traps as a way to supplement data collected from the Duncans Mills PIT antenna array and during sampling by beach seining throughout the Estuary (Figure 4.4.1). Sonoma Water operated three types of downstream migrant traps in 2018: rotary screw trap, funnel trap and pipe trap depending on the stream, water depth, and velocity (Figure 4.4.3). Fish traps were checked daily by Sonoma Water staff during the trapping season (March through July). Captured fish were enumerated and identified to species and life stage at all traps. All PIT-tagged fish were measured for fork length (±1 mm) and weighed (±0.1 g). Additionally, a subset of all non-PIT-tagged individuals were measured and weighed each day. PIT tags were implanted in a portion of the total number of steelhead YOY and parr captured that were ≥60 mm in fork length.

Mark West Creek: Rotary screw trap (fished 4/25-6/4) switched to pipe trap (fished 6/5-6/19).

Dutch Bill Creek: Funnel net (3/9-4/25) switched to a pipe trap (fished 4/26-6/19).

Austin Creek: Rotary screw trap (fished 4/18-5/22) switched to a funnel trap (fished 5/23-7/12).

**Figure 4.4.3. Photographs of downstream migrant traps operated by Sonoma Water (Mark West, Dutch Bill and Austin Creeks) in 2018. See Chapter 5 for details regarding operation of the Dry Creek trap.**

### *Mainstem Russian River at Mirabel and Dry Creek at Westside Road*

Typically, two rotary screw traps (one 5 foot and one 8 foot) adjacent to one another are operated on the mainstem Russian River immediately downstream of Sonoma Water's inflatable dam site at Mirabel (approximately 38.7 km upstream of the river mouth in Jenner) (Table 4.4.1). Sonoma Water also operates a rotary screw trap at Dry Creek. The purpose of trapping at these locations was to fulfill a broader set of objectives than the timing of salmonid entrance into the Estuary and more information can be found in Chapter 5 of this report.

### *Mark West Creek*

A five foot rotary screw trap was installed on Mark West Creek approximately 4.8 km upstream of the mouth on April 25. On June 4 the rotary screw trap was removed and replaced with a pipe trap because of low water velocities. The pipe trap was removed and all trapping operations were suspended on June 19 when fish captures dropped off rapidly (Table 4.4.1).

### *Dutch Bill Creek*

A pipe trap was installed on Dutch Bill Creek adjacent to the park in downtown Monte Rio (approximately 0.3 km upstream of the creek mouth) on March 9. The funnel net was removed and replaced with a pipe trap on April 24 because of low water velocity. The pipe trap was fished until the completion of trapping operations on June 19 when stream flow in lower Dutch Bill Creek became disconnected (Table 4.4.1).

### *Austin Creek*

A rotary screw trap was installed in Austin Creek on April 18. Due to low water velocity this trap was changed to a funnel trap May 22. The funnel trap consisted of wood-frame/plastic-mesh weir panels, a funnel net and a wooden live box. Trapping continued until July 12 when surface flow in lower Austin Creek was no longer contiguous and daily catches of steelhead dropped to zero (Table 4.4.1).

Steelhead parr were marked with PIT tags and released upstream of the trap in order to measure trap efficiency and estimate population size of fish passing the trap site. We operated a dual PIT antenna array approximately 0.2 km downstream of the funnel trap and approximately 0.5 km upstream from the mouth of Austin Creek in order to detect PIT-tagged steelhead moving out of Austin Creek (Figure 4.4.4). The PIT antenna array was located at the upstream extent of the area that can be inundated by the Russian River during closure of the barrier beach; therefore, we assumed that once fish passed the antenna array they had effectively entered the estuary/lagoon. A second PIT tag antenna array located in the Russian River estuary at Duncans Mills (approximately 1.5 km downstream) was used to calculate antenna efficiency for the PIT antenna array located in Austin Creek.

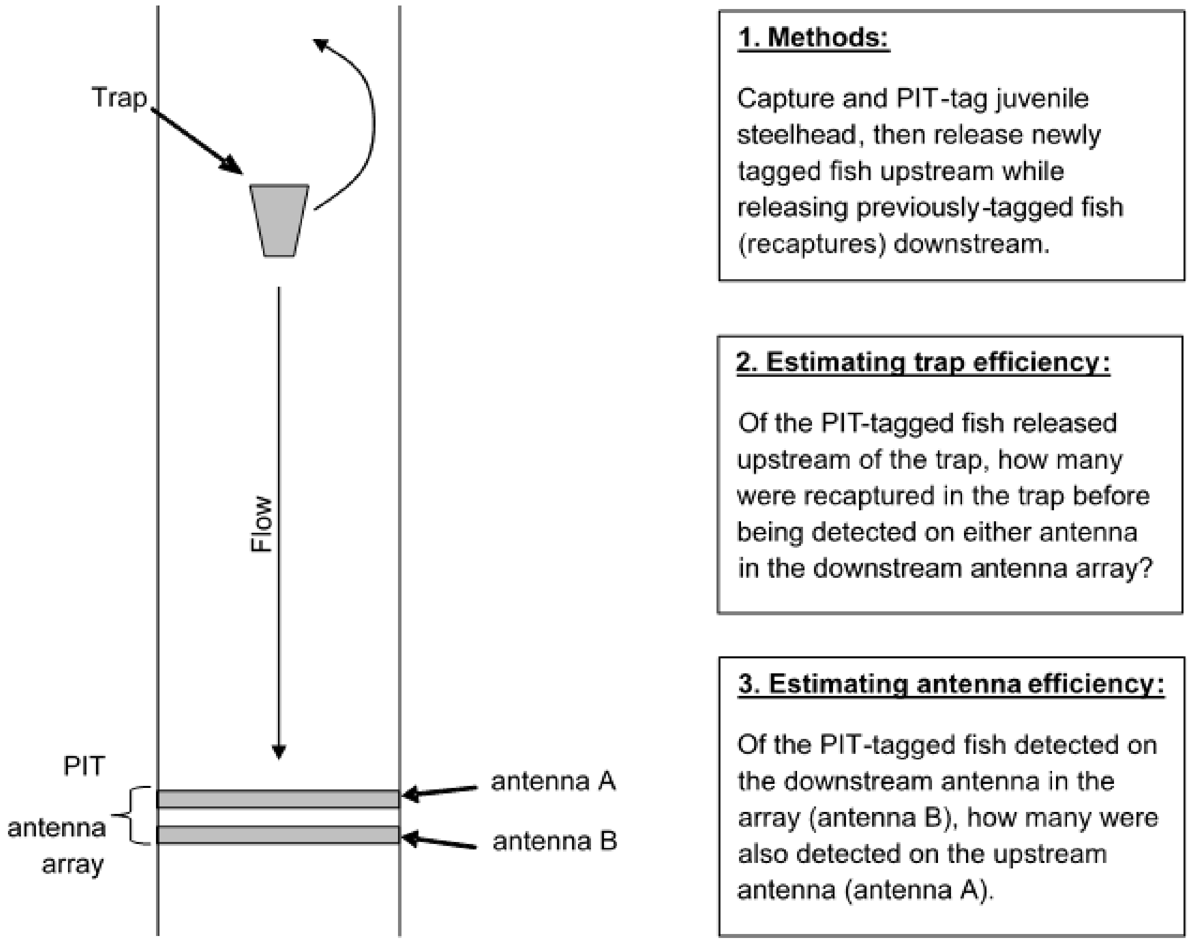



**Figure 4.4.4. Diagram illustrating the relative location of the downstream migrant trap and PIT antenna array operated on Austin Creek and outline of how antenna efficiency was estimated.**

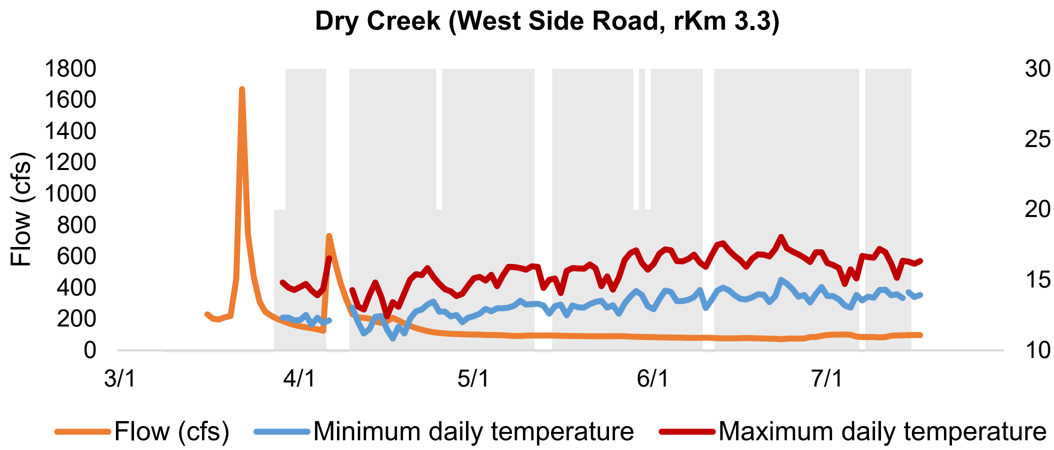
**Table 4.4.1. Installation and removal dates, and total number of days fished for lower Russian River monitoring sites operated by Sonoma Water in 2018. The mainstem site is located at Mirabel on the Russian River.**

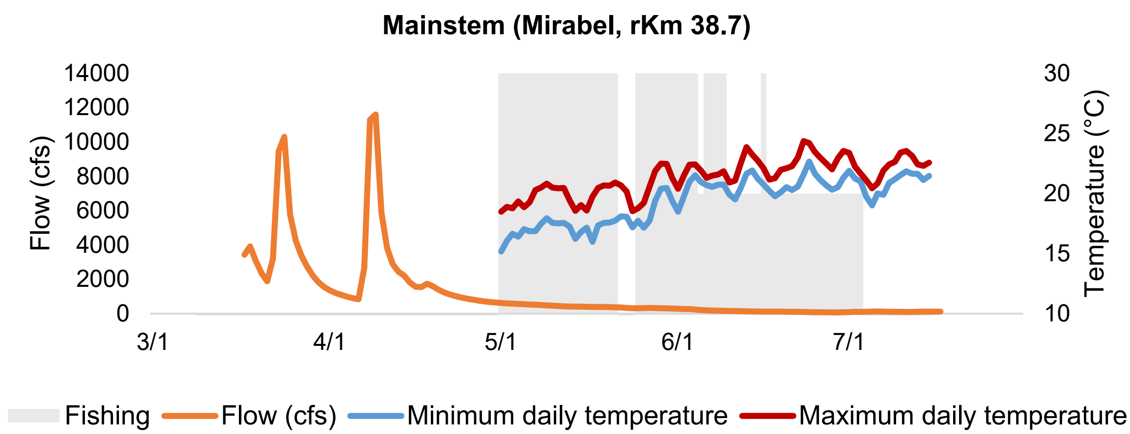
| Monitoring site (gear type) | Installation date | Removal date | Number of days fished |
|---|---|---|---|
| Dry Creek (DSMT) | 3/28 | 7/31 | 94 |
| Mainstem (DSMT) | 5/1 | 7/3 | 61 |
| Mark West Creek (DSMT) | 4/25 | 6/19 | 54 |
| Dutch Bill Creek (DSMT) | 3/9 | 6/19 | 80 |
| Austin Creek (DSMT) | 4/18 | 7/12 | 85 |
| Duncans Mills (PIT antenna array)[1] | continuous (not removed) | continuous (not removed) | entire downstream migration season |

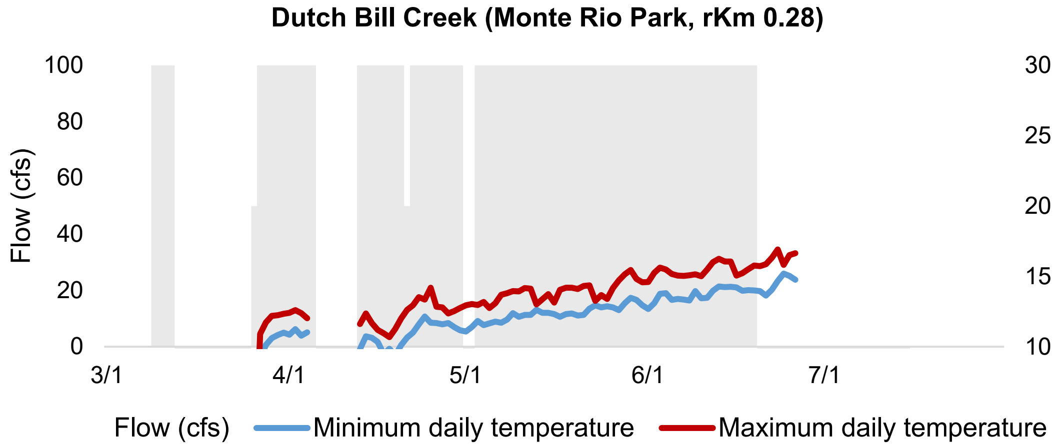
[1]See text for details on changes to PIT antenna array throughout the season.

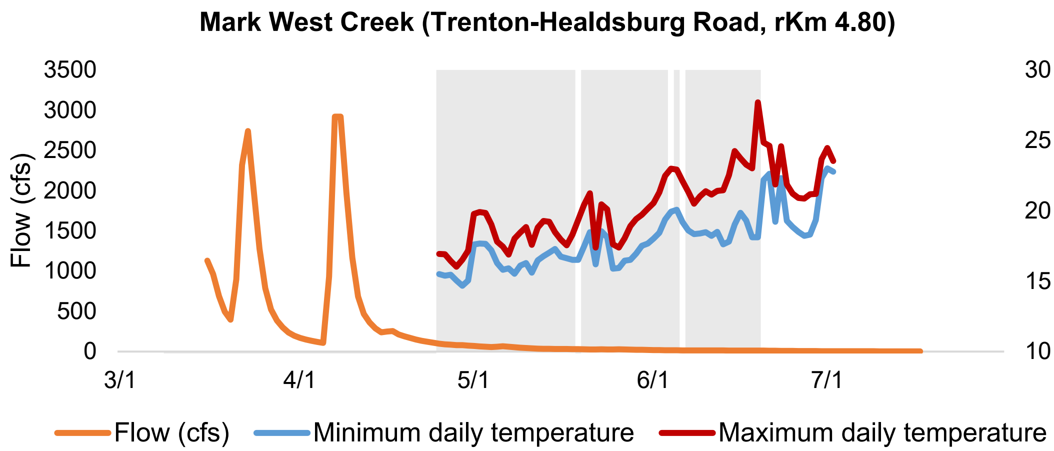
# Results

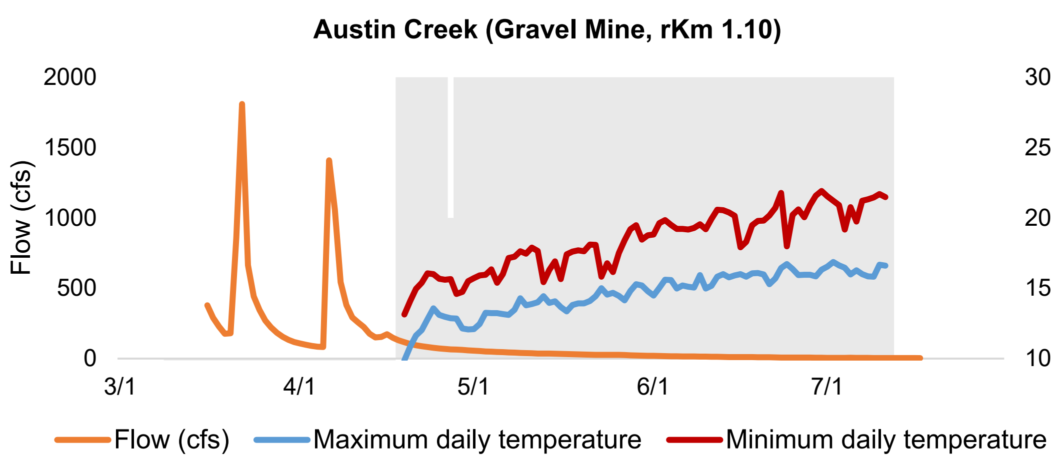
Stream flow largely dictates when downstream migrant traps can be installed (Figure 4.4.5). Our sampling period most likely encompassed a high portion of the juvenile steelhead movement period but we probably missed a substantial portion of the steelhead smolt migration due to the early run time of steelhead smolts.




Dutch Bill Creek (Monte Rio Park, rKm 0.28)
Flow (cfs)
Temperature (°C)
100
80
60
40
20
0
30
25
20
15
10
3/1
4/1
5/1
6/1
7/1
Flow (cfs)
Minimum daily temperature
Maximum daily temperature


Mark West Creek (Trenton-Healdsburg Road, rKm 4.80)
Flow (cfs)
Temperature (°C)
3500
3000
2500
2000
1500
1000
500
0
30
25
20
15
10
3/1
4/1
5/1
6/1
7/1
Flow (cfs)
Minimum daily temperature
Maximum daily temperature


Austin Creek (Gravel Mine, rKm 1.10)
Flow (cfs)
Temperature (°C)
2000
1500
1000
500
0
30
25
20
15
10
3/1
4/1
5/1
6/1
7/1
Flow (cfs)
Maximum daily temperature
Minimum daily temperature

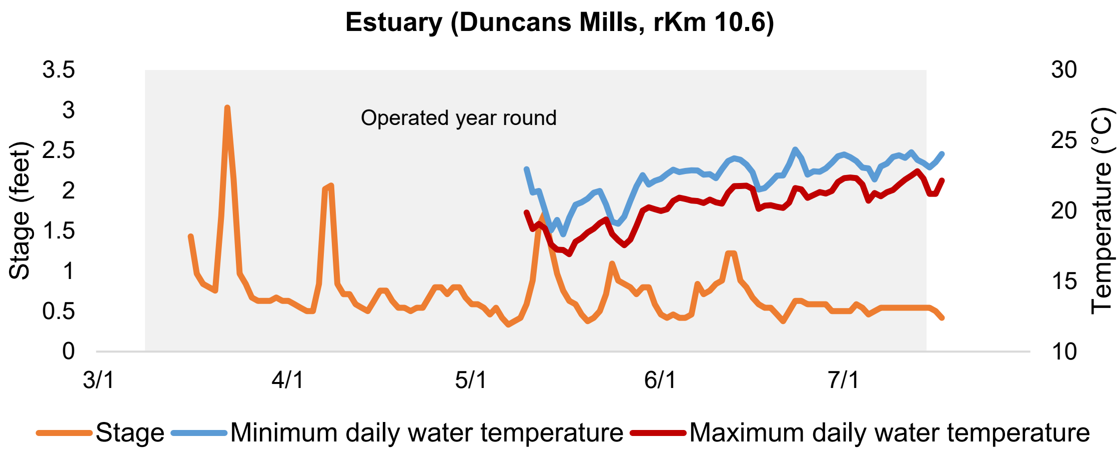



**Figure 4.4.5. Environmental conditions at downstream migrant detection sites from March 1 to July 31. Gray shading indicates the proportion of each day that each trap was operated. Discharge data are from the USGS gage at Healdsburg (mainstem Russian, 11464000), the USGS gage at Trenton-Healdsburg Road (Mark West Creek, 11466800), a gage operated by CMAR on Dutch Bill Creek (data unavailable in 2018) and the USGS gauge at Cazadero (Austin Creek, 11467200). Stage data for the estuary are from the Jenner gage. Temperature data are from the data loggers operated by the Sonoma Water at each monitoring site.**

## Estuary/Lagoon PIT antenna systems

### *Steelhead*

Steelhead were most frequently encountered at Dry Creek than any other trap. In total 3,741 YOY and parr, and 126 smolts were captured at the Dry Creek trap. In Austin Creek 2,345 juveniles and 48 smolts were captured while only 22 juvenile and 1 smolt steelhead were captured in Dutch Bill Creek. At Mark West Creek 82 YOY and parr, and 104 smolts were captured (Figure 4.4.6.). Of the 917 juvenile steelhead that were PIT-tagged in downstream migrant traps in 2018, 75 (8.3%) were detected on the PIT antenna array at Duncans Mills (Table 4.4.2 and Table 4.4.3). Reasons for non-detection include an unknown number of fish that simply did not move into the Estuary as well as fish that moved into the tidal portion of the Estuary but were not detected due to imperfect PIT antenna array detection efficiency at Duncans Mills.

**Table 4.4.2. Number of steelhead juveniles PIT-tagged at downstream migrant traps, 2009-2018 (N.T. indicates that tagging steelhead was not part of the protocol for that year, a dash indicates the trap was not operated). The mainstem site is located at Mirabel on the Russian River.**

| Site | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dry Creek | N.T. | N.T. | N.T. | N.T. | 2,703 | 1,348 | N.T. | N.T. | N.T. | N.T. |
| Mainstem | 5 | 96 | 99 | 315 | 100 | 101 | - | - | 1 | 63 |
| Mark West Creek | - | - | - | 43 | 135 | 18 | 19 | 546 | 49 | 62 |
| Dutch Bill Creek | - | 46 | 22 | 6 | 12 | 21 | 7 | 46 | 377 | 12 |
| Austin Creek | - | 996 | 500 | 1,636 | 1,749 | 590 | 107 | 1,205 | 359 | 780 |
| **Total** | **5** | **1,138** | **621** | **2,000** | **4,699** | **2,078** | **133** | **1,797** | **791** | **917** |

**Table 4.4.3. The number of steelhead (parr+smolt) captured at downstream migrant traps, the number PIT tagged and the number (proportion) detected on the Duncans Mills PIT tag detection systems before October 15, 2018. The mainstem site is located at Mirabel on the Russian River.**

| Site | Number Captured | Number PIT- Tagged | Number (proportion) Detected at Duncans Mills |
|---|---|---|---|
| Mainstem | 241 | 63 | 0 (0.0%) |
| Mark West Creek | 186 | 62 | 0 (0.0%) |
| Dutch Bill Creek | 23 | 12 | 1 (8.3%) |
| Austin Creek | 2,393 | 780 | 74 (9.4%) |
| **Total** | **2,978** | **906** | **75 (8.3%)** |

Many steelhead juveniles were captured in Austin Creek in 2018. Over the course of the season, 2,393 steelhead were captured of which 2,239 were YOY (1,267 of the 2,239 YOY were ≥60 mm, Figure 4.4.12). Although PIT tags were applied to 780 total individuals (YOY+parr), it is estimated that, based on their size, 719 of these PIT-tagged fish were YOY. In total, 774 PIT-tagged steelhead were released upstream of the trap and 6 were released downstream of the trap (Table 4.4.4). Because 291 of the 719 PIT-tagged YOY were detected on the PIT antenna array downstream of the trap in Austin Creek, there is high certainty that at least 40% (291/719) moved downstream into the estuary/lagoon. Because of imperfect antenna detection efficiency, we expanded those minimum counts that were based only on PIT-tagged YOY were expanded to the entire population of YOY in the vicinity of the Austin Creek trap (both tagged and untagged) as follows.

Of the 75 PIT tagged individuals (YOY+parr) detected on the downstream antenna in the array (Duncans Mills), 60 were also detected on the upstream antenna array (Austin Creek) resulting in an estimated antenna efficiency of 80% (60/75). In order to estimate the number of YOY out of the original 719 that actually moved downstream of the Austin Creek antenna array, this proportion was used to expand the 293 detections to 366 (293/80%).

Sixty one YOY were released upstream of the trap, detected on the downstream PIT antenna arrays and recaptured in the trap resulting in a trap efficiency of 21%. Based on this trap efficiency the 2,239 steelhead YOY captured at the trap was expanded to a population estimate of 10,661. Using the percentage of emigrants from the PIT tagged population it is estimated that 4,318 steelhead YOY (40.5% of the 10,661 steelhead YOY trap estimate) emigrated from Austin Creek to the Estuary.

**Table 4.4.4. PIT tag and trap capture metrics and values for YOY steelhead in Austin Creek. Note that 2010 numbers differ from Martini-Lamb and Manning (2011) because they have been adjusted to only include YOY.**

| Metric | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number PIT-tagged YOY released upstream of trap | 765 | 324 | 1,356 | 0 | 214 | 101 | 1,132 | 244 | 719 |
| Number PIT-tagged YOY released downstream of trap | 195 | 2 | 162 | 1,746 | 269 | 6 | 73 | 2 | 6 |
| Number PIT-tagged YOY detected on antenna array that were tagged in Austin Creek | 547 | 131 | 574 | 1,335 | 275 | 13 | 193 | 80 | 291 |
| Number PIT-tagged YOY released upstream & detected on antenna array | 389 | 131 | 486 | 0 | 57 | 13 | 151 | 80 | 291 |
| Number released upstream & recaptured in trap & detected on antenna | 47 | 8 | 196 | 0 | 2 | 0 | 60 | 0 | 61 |
| **ESTIMATED TRAP EFFICIENCY** | **12.1%** | **6.1%** | **40.3%** | **N/A** | **N/A** | **N/A** | **39.7%** | **N/A** | **21.0%** |
| Number YOY+parr detected on both antennas in array | 241 | 93 | 85 | 399 | 129 | 34 | 76 | 52 | 60 |
| Number YOY+parr detected on downstream antenna only | 288 | 178 | 129 | 463 | 162 | 35 | 205 | 55 | 75 |
| **ESTIMATED ANTENNA EFFICIENCY** | **83.6%** | **52.2%** | **65.9%**[1] | **86.2%**[1] | **79.6%**[1] | **97.1%** | **37.1%**[1] | **94.5%** | **80%**[1] |
| Number YOY captured and PIT-tagged | 960 | 324 | 1,518 | 1,746 | 483 | 42 | 993 | 319 | 719 |
| Total number of YOY captured (≥60 mm only) | 2,617 | 453 | 2,341 | 4,216 | 541 | 42 | 2,427 | 319 | 2,239 |
| **ESTIMATED NUMBER OF PIT-TAGGED YOY EMIGRANTS (≥60 mm only)** | **632** | **251** | **759** | **1,549** | **325** | **32** | **520** | **55** | **93** |
| **ESTIMATED PROPORTION OF PIT-TAGGED YOY THAT EMIGRATED (≥60 mm only)** | **65.8%** | **77.5%** | **50%** | **88.5%** | **67.3%** | **76.2%** | **46.0%** | **17.2%** | **40.5%** |
| **ESTIMATED POPULATION SIZE OF YOY AT TRAP** | **21,628** | **7,426** | **5,804** | **N/A** | **N/A** | **N/A** | **6,113** | **N/A** | **10,661** |
| **ESTIMATED NUMBER OF YOY IN POPULATION THAT EMIGRATED** | **14,231** | **5,755** | **2,901** | **N/A** | **N/A** | **N/A** | **2,812** | **N/A** | **4,318** |

[1]Efficiency is based on detections of PIT-tagged fish at Duncans Mills.

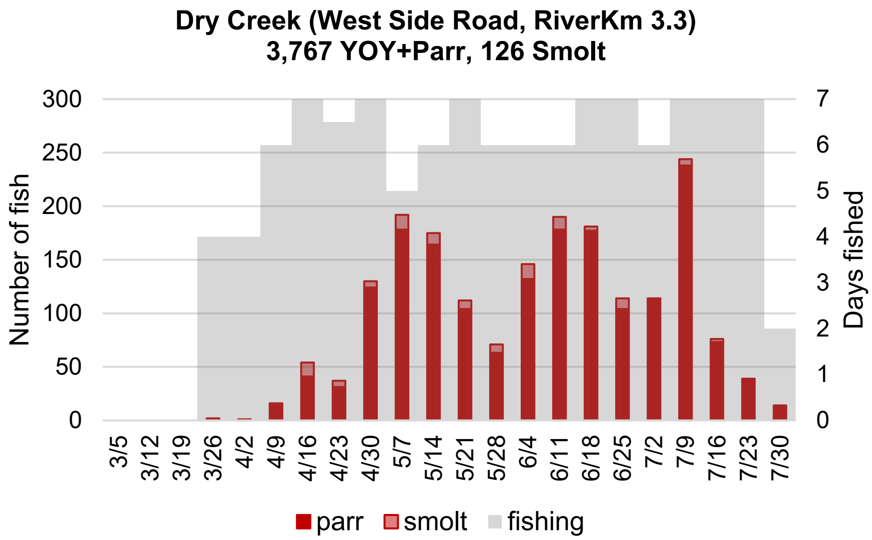
When compared to Austin and Dry Creeks fewer numbers of juvenile steelhead were captured at the mainstem Russian River, Mark West and Dutch Bill creeks (Figure 4.4.6), meaning that fewer numbers of juvenile steelhead were PIT-tagged at these locations (Table 4.4.3). Fork lengths of fish caught at these traps show at least 3 year classes with steelhead YOY present at each of the trapping locations (Figure 4.4.7). As in other years, it is assumed that the few steelhead smolts captured at any of the trap sites was likely due to a large portion of the smolt outmigration occurring before trap installation and the generally low trap efficiencies for steelhead smolts that is well-documented in the Russian River and elsewhere. The season total catches of steelhead have been variable over the course of this study (Figure 4.4.8 through Figure 4.4.12).

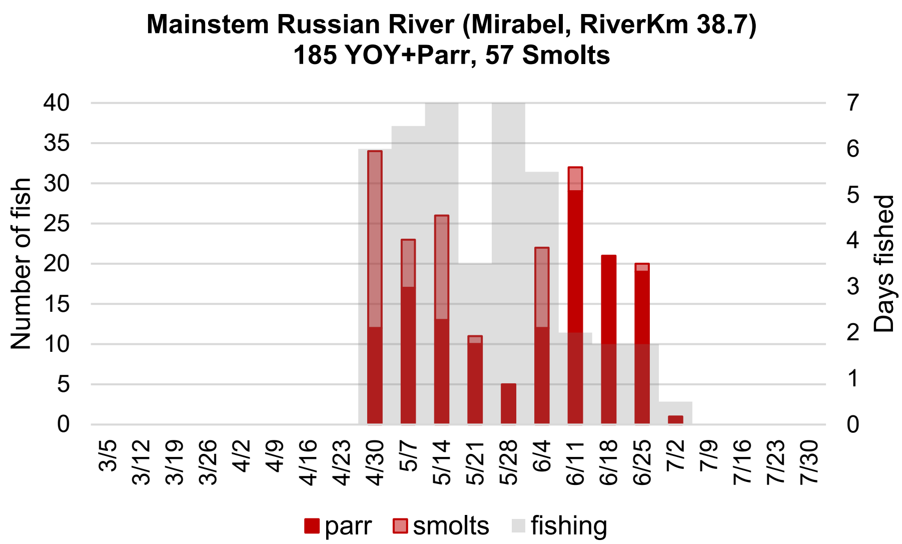
*Coho Salmon*

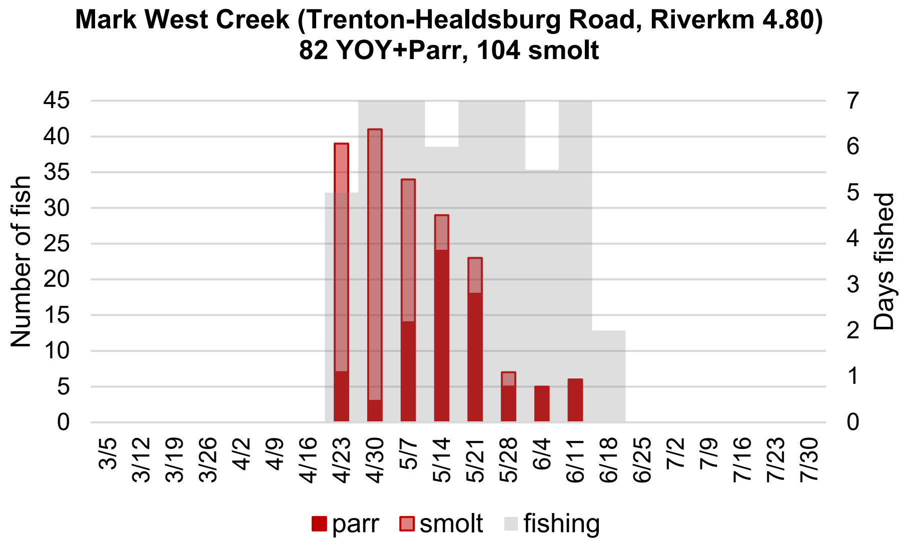
At Dry Creek 19 hatchery smolts, 83 wild smolts, 2 smolts of unknown origin, 1 YOY of unknown origin and 5 wild YOY Coho Salmon were detected at the trap (Figure 4.4.8 and Figure 4.4.13). At Mark West Creek, 23 hatchery smolts, 1 smolts of unknown origin, and 50 wild YOY/parr Coho Salmon were detected at the trap (Figure 4.4.10 and Figure 4.4.13). A total of 1,220 hatchery smolts, 16 smolt of unknown origin, 40 wild smolts, 3 YOY/parr Coho Salmon of unknown origin were captured at the Dutch Bill Creek trap (Figure 4.4.11and Figure 4.4.13). At Austin Creek, 916 hatchery smolts, 25 smolts of unknown origin, 55 wild smolts, and 24 YOY/parr of unknown origin, and 24 wild YOY/parr Coho Salmon were captured (Figure 4.4.12 and Figure 4.4.13). Based on length data collected at the lower river traps, there were at least two age groups (YOY: age-0 and parr/smolt: ≥age-1) of Coho Salmon captured (Figure 4.4.14). For a more detailed analysis of downstream migrant trapping catches of Coho Salmon from other Russian River streams see UCCE Coho Salmon Monitoring Program results for 2018 (California Sea Grant. 2019).

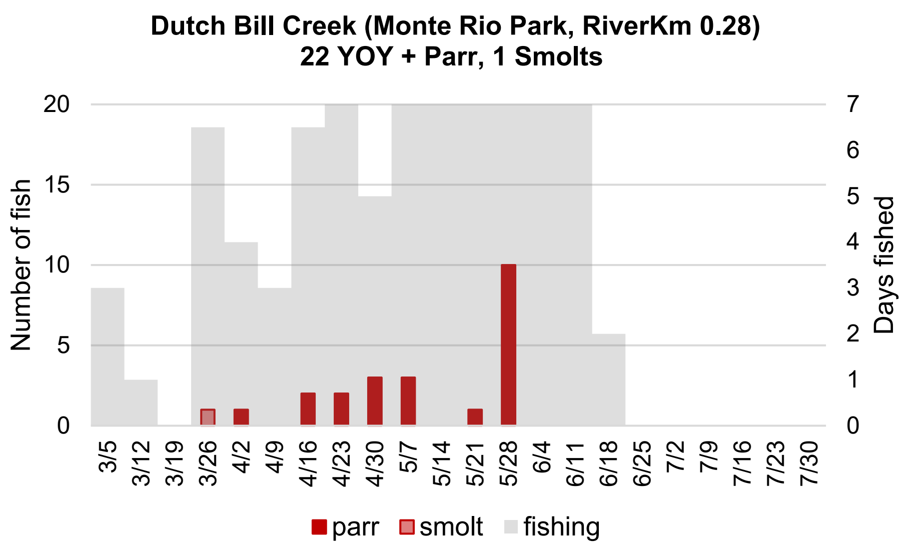
*Chinook Salmon*

In 2018, relatively few Chinook smolts were captured in Austin Creek, Dutch Bill Creek, and Mark West Creek (15, 8 and 777 respectively). In the mainstem Russian River, 2,523 Chinook smolts where captured (Figure 4.4.15 and Figure 4.4.16). Fork lengths of Chinooks smolts captured at the mainstem Russian River trap increased over the course of the trapping seasons (Figure 4.4.17). A total of 1,484 Chinook Salmon smolts were marked with either PIT tags or fin clips and released upstream of the dam. Of these, 132 (8.9 percent) were recaptured. Based on the Darroch Analysis with Rank-Reduction (DARR) estimator (Bjorkstedt 2005), mark-recapture estimate was 49,666 (+/-21,535) juvenile Chinook Salmon migrating past the trapping site during the mark-recapture study. For more details on characteristics of Chinook smolts captured at Dry Creek see Chapter 5 of this report.


Dry Creek (West Side Road, RiverKm 3.3)
3,767 YOY+Parr, 126 Smolt
Number of fish
Days fished
300
250
200
150
100
50
0
7
6
5
4
3
2
1
0
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
parr
smolt
fishing


Mainstem Russian River (Mirabel, RiverKm 38.7)
185 YOY+Parr, 57 Smolts
Number of fish
Days fished
40
35
30
25
20
15
10
5
0
7
6
5
4
3
2
1
0
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
parr
smolts
fishing


Mark West Creek (Trenton-Healdsburg Road, Riverkm 4.80)
82 YOY+Parr, 104 smolt
Number of fish
Days fished
0
5
10
15
20
25
30
35
40
45
0
1
2
3
4
5
6
7
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
parr
smolt
fishing


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
22 YOY + Parr, 1 Smolts
Number of fish
Days fished
0
5
10
15
20
0
1
2
3
4
5
6
7
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
parr
smolt
fishing

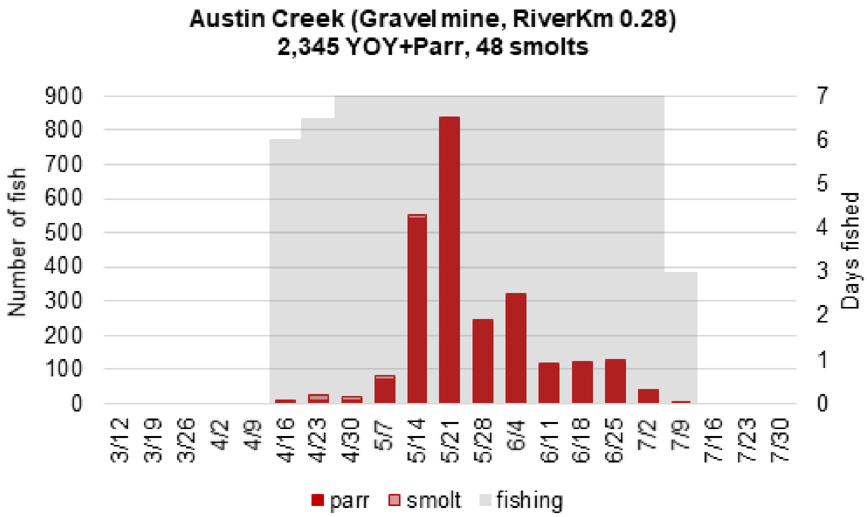
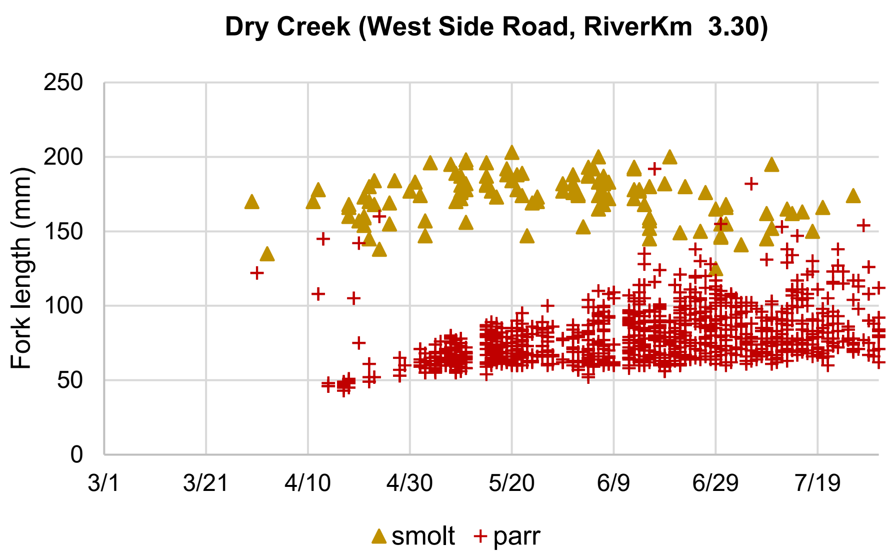
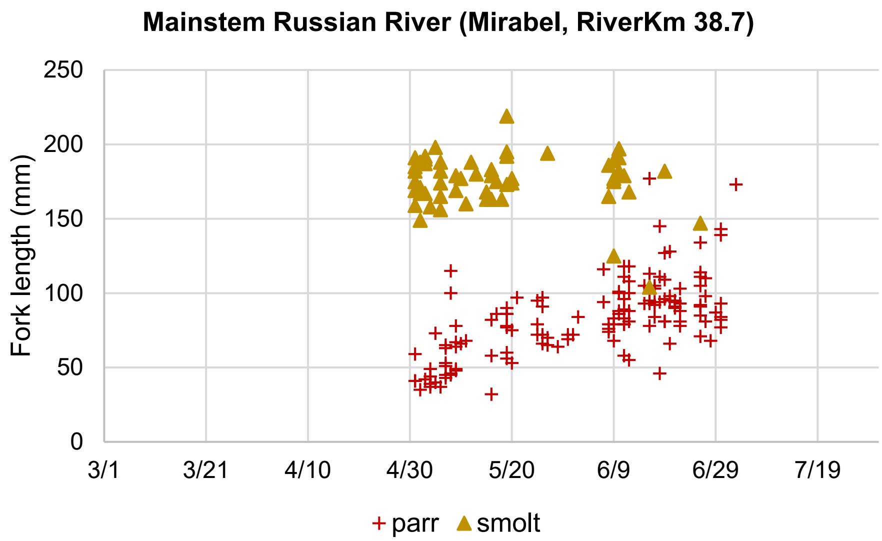
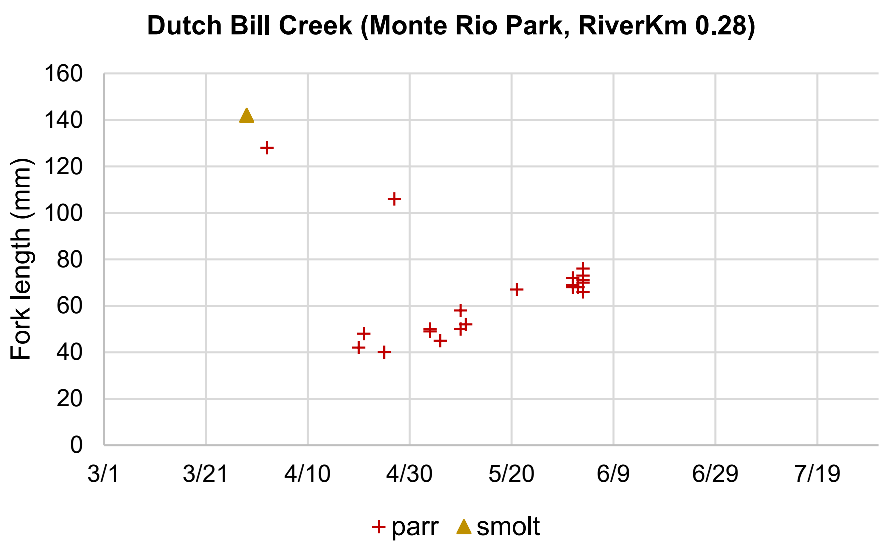
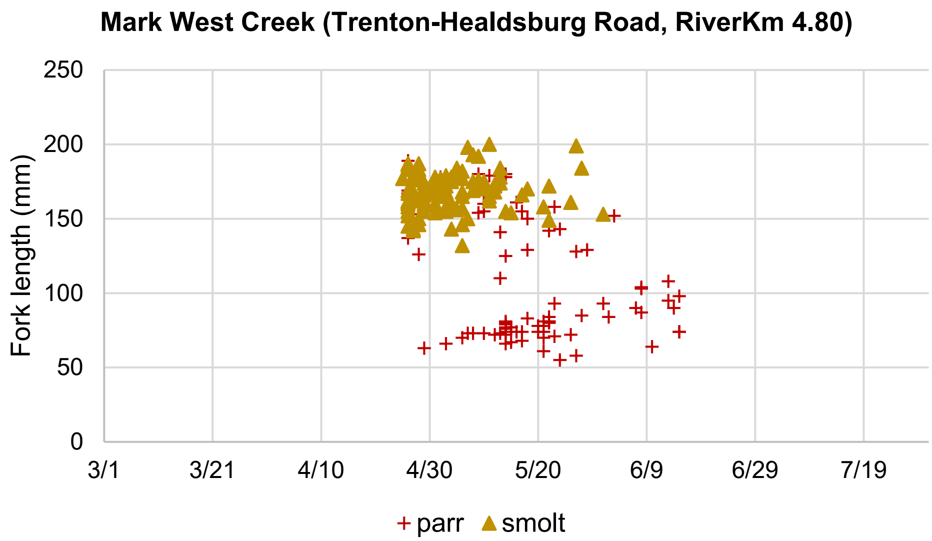



**Figure 4.4.6. Weekly capture of steelhead by life stage at lower Russian River downstream migrant trapping sites, 2018. Gray shading indicates portion of each week trap was fishing. Note the different vertical scale among plots for each site.**




Mainstem Russian River (Mirabel, RiverKm 38.7)
Fork length (mm)
250
200
150
100
50
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
parr
smolt


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
Fork length (mm)
160
140
120
100
80
60
40
20
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
parr
smolt



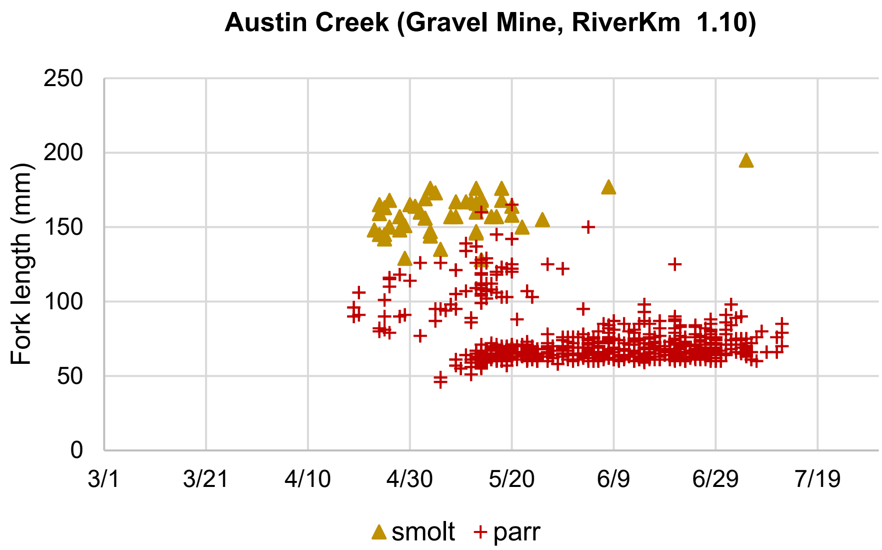
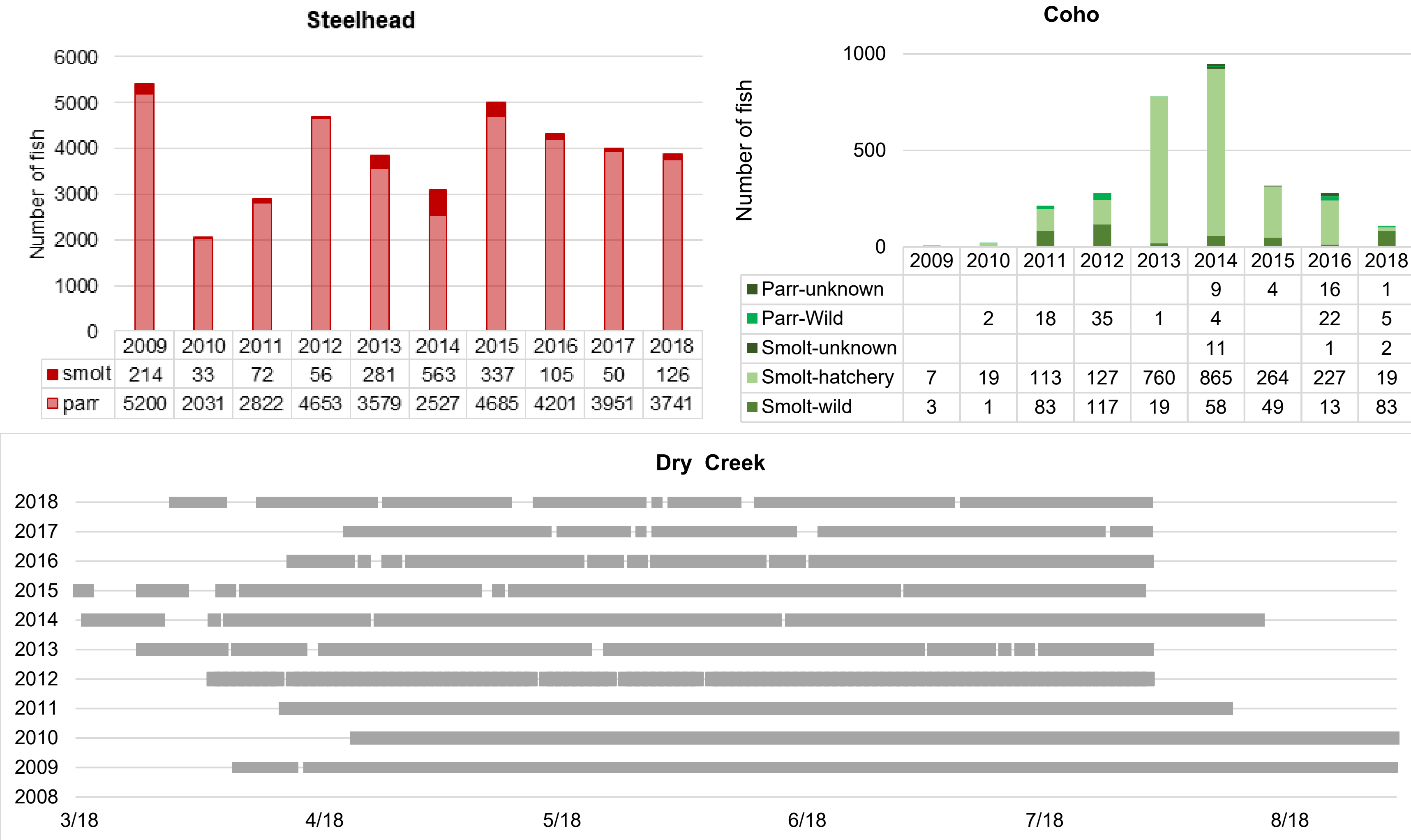



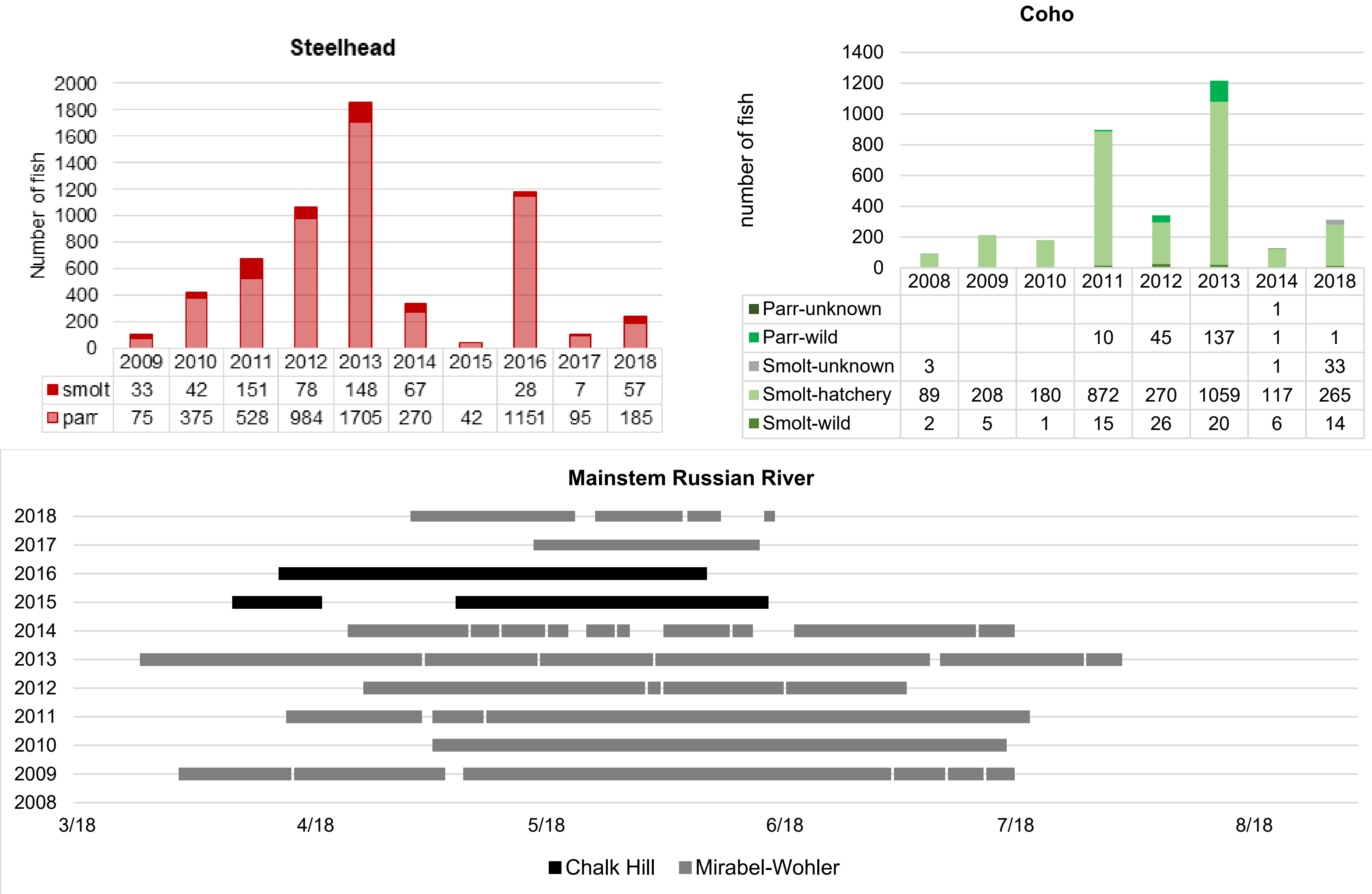

**Figure 4.4.7. Weekly fork lengths of steelhead captured at lower Russian River downstream migrant trap sites, 2018.**




| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| smolt | 214 | 33 | 72 | 56 | 281 | 563 | 337 | 105 | 50 | 126 |
| parr | 5200 | 2031 | 2822 | 4653 | 3579 | 2527 | 4685 | 4201 | 3951 | 3741 |

| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| Parr-unknown | | | | | | 9 | 4 | 16 | 1 |
| Parr-Wild | | 2 | 18 | 35 | 1 | 4 | | 22 | 5 |
| Smolt-unknown | | | | | | 11 | | 1 | 2 |
| Smolt-hatchery | 7 | 19 | 113 | 127 | 760 | 865 | 264 | 227 | 19 |
| Smolt-wild | 3 | 1 | 83 | 117 | 19 | 58 | 49 | 13 | 83 |

**Figure 4.4.8. Number of steelhead and Coho Salmon captured by life stage and origin at the Dry Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2018.**




| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| smolt | 33 | 42 | 151 | 78 | 148 | 67 | | 28 | 7 | 57 |
| parr | 75 | 375 | 528 | 984 | 1705 | 270 | 42 | 1151 | 95 | 185 |

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Parr-unknown | | | | | | | 1 | |
| Parr-wild | | | | 10 | 45 | 137 | 1 | 1 |
| Smolt-unknown | 3 | | | | | | 1 | 33 |
| Smolt-hatchery | 89 | 208 | 180 | 872 | 270 | 1059 | 117 | 265 |
| Smolt-wild | 2 | 5 | 1 | 15 | 26 | 20 | 6 | 14 |

**Figure 4.4.9. Number of steelhead and Coho Salmon captured by life stage and origin at the mainstem Russian River at Chalk Hill and Mirabel-Wohler downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2018.**

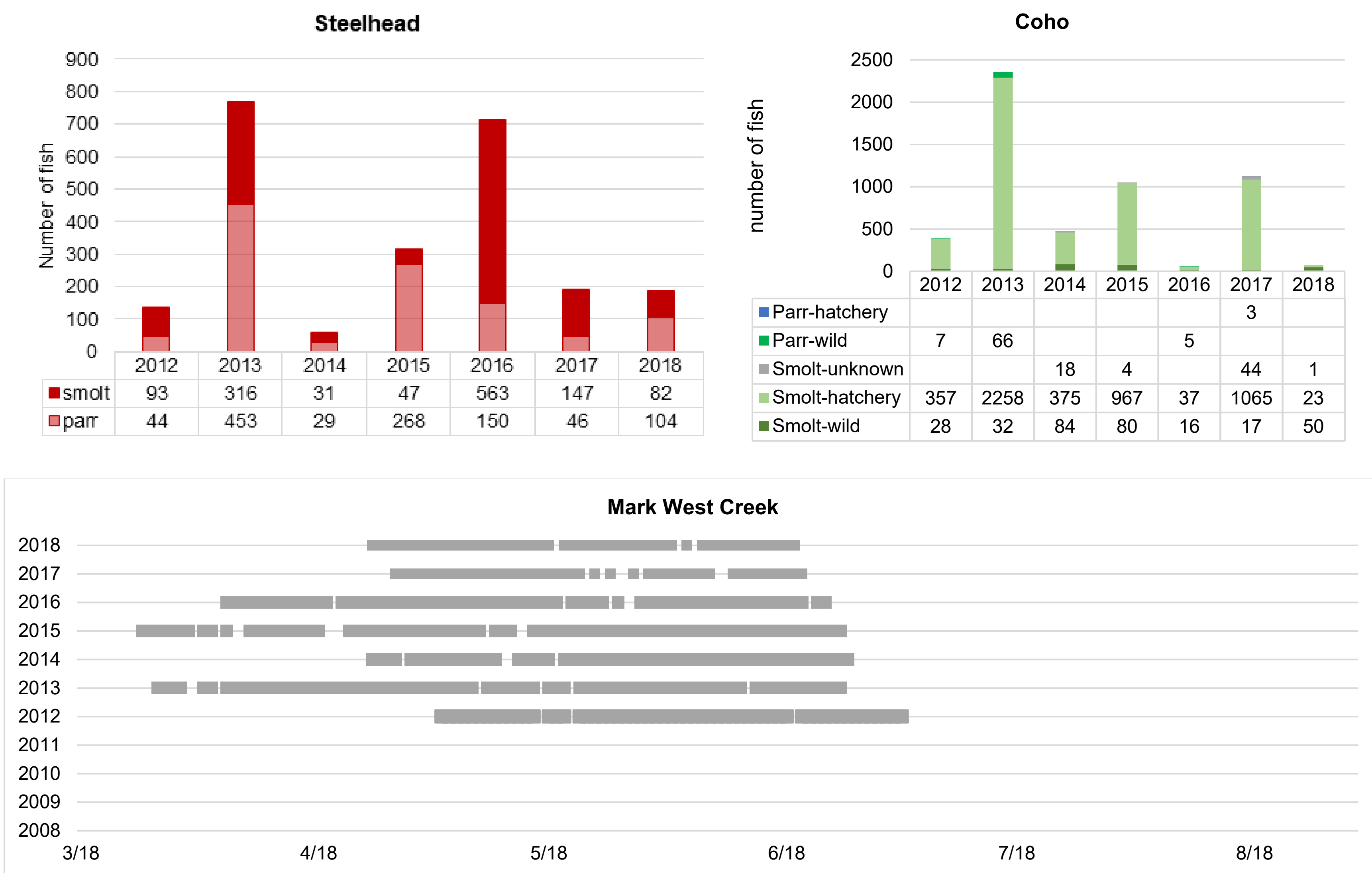
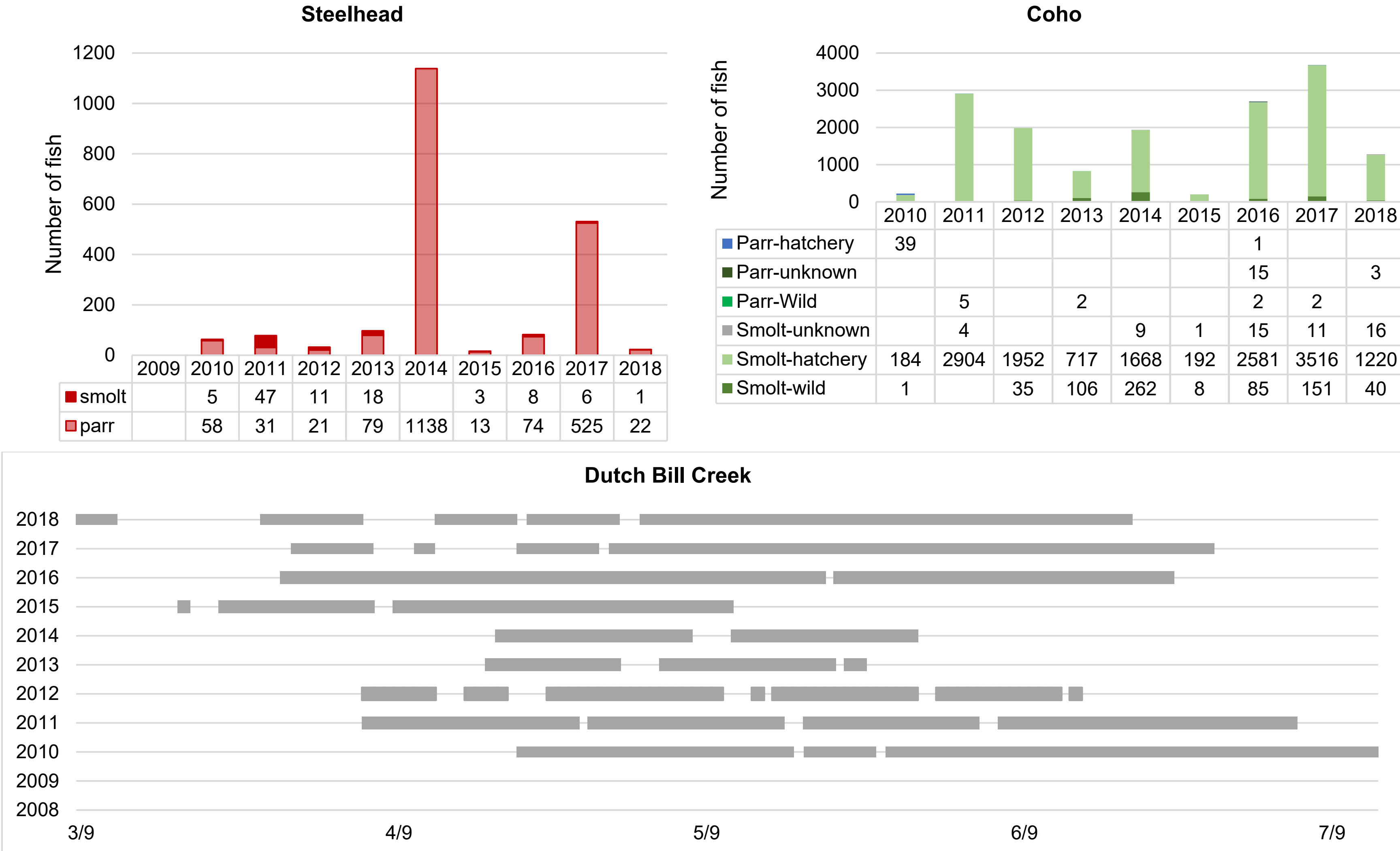



**Figure 4.4.10. Number of steelhead and Coho Salmon captured by life stage and origin at the Mark West Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2018.**

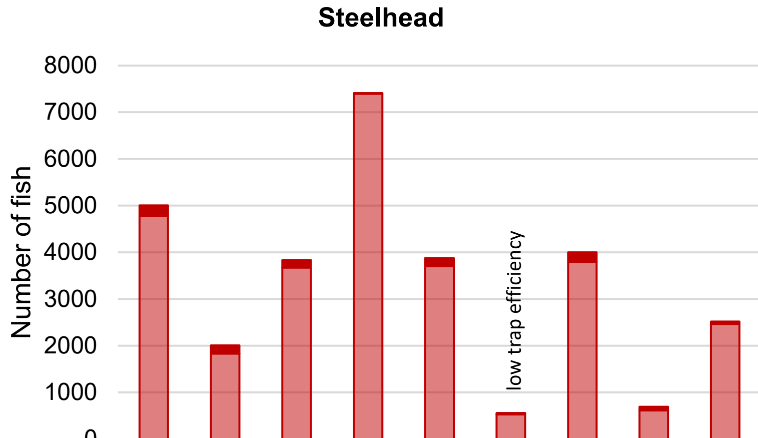



| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| smolt | | 5 | 47 | 11 | 18 | | 3 | 8 | 6 | 1 |
| parr | | 58 | 31 | 21 | 79 | 1138 | 13 | 74 | 525 | 22 |

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| Parr-hatchery | 39 | | | | | | 1 | | |
| Parr-unknown | | | | | | | 15 | | 3 |
| Parr-Wild | | 5 | | 2 | | | 2 | 2 | |
| Smolt-unknown | | 4 | | | 9 | 1 | 15 | 11 | 16 |
| Smolt-hatchery | 184 | 2904 | 1952 | 717 | 1668 | 192 | 2581 | 3516 | 1220 |
| Smolt-wild | 1 | | 35 | 106 | 262 | 8 | 85 | 151 | 40 |

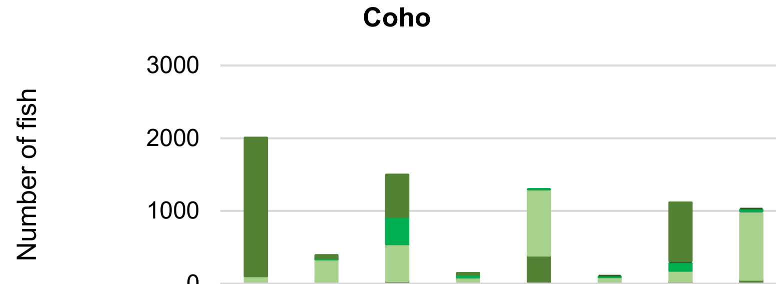
**Figure 4.4.11. Number of steelhead and Coho Salmon captured by life stage and origin at the Dutch Bill Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2018.**

## Steelhead




| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| smolt | 232 | 175 | 164 | 14 | 173 | 30 | 201 | 79 | 50 |
| parr | 4774 | 1829 | 3672 | 7397 | 3702 | 527 | 3798 | 611 | 2466 |

## Coho




| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Parr-hatchery | 1906 | 45 | 584 | 24 | | | 809 | |
| Parr-unknown | | | | | 3 | 26 | 25 | 24 |
| Parr-Wild | | 14 | 372 | 38 | 1 | 9 | 105 | 24 |
| Smolt-unknown | | | | | 13 | | 3 | 25 |
| Smolt-Hatchery | 103 | 335 | 507 | 74 | 899 | 80 | 144 | 916 |
| Smolt-wild | | | 37 | 12 | 386 | 9 | 32 | 55 |

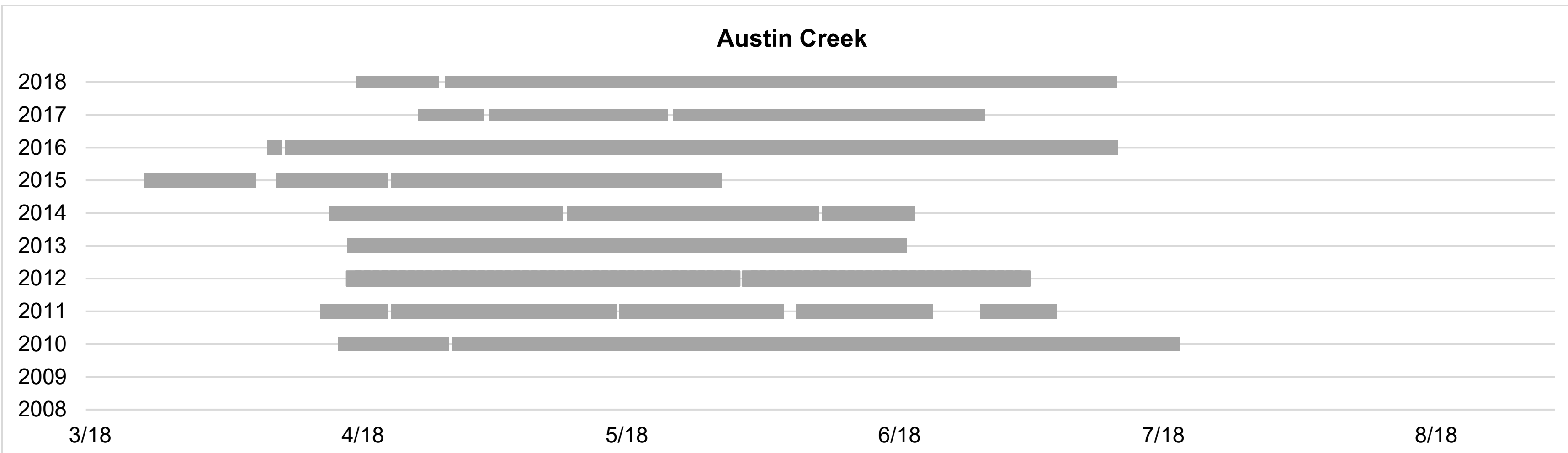
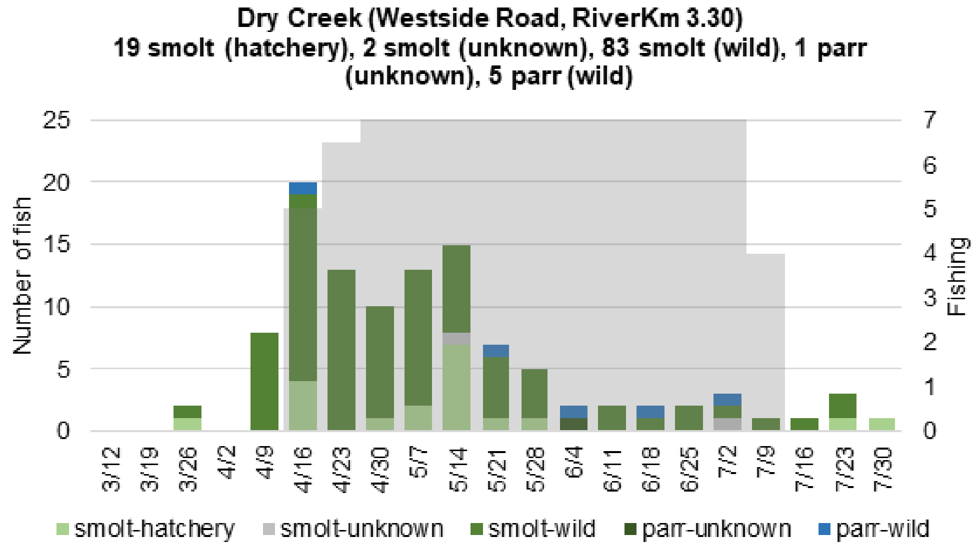
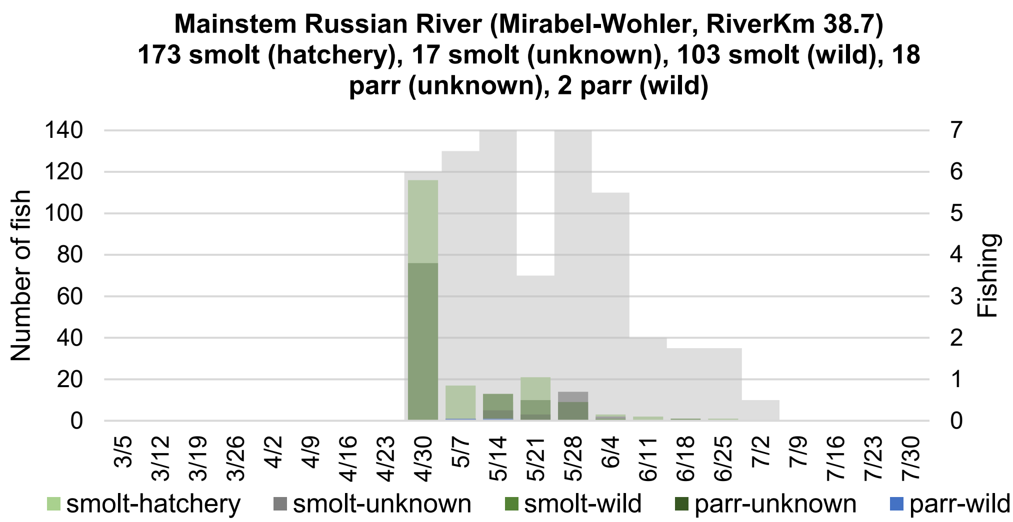
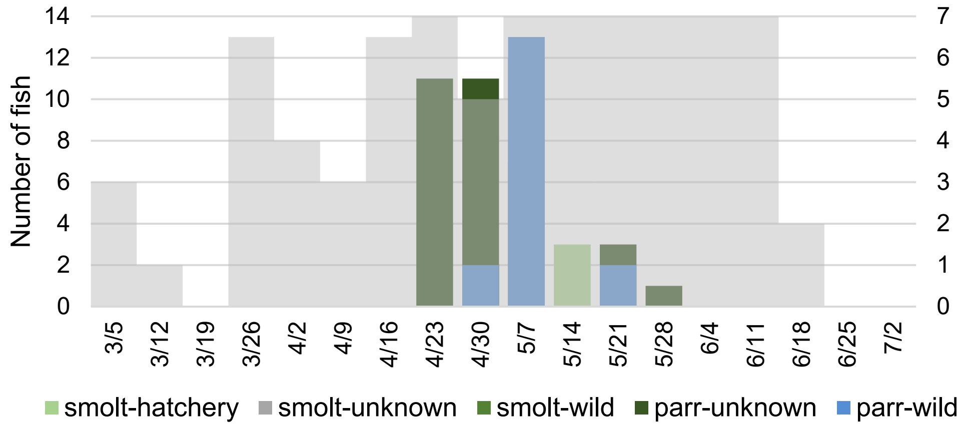



**Figure 4.4.12. Number of steelhead and Coho Salmon captured by life stage and origin at the Austin Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2018.**

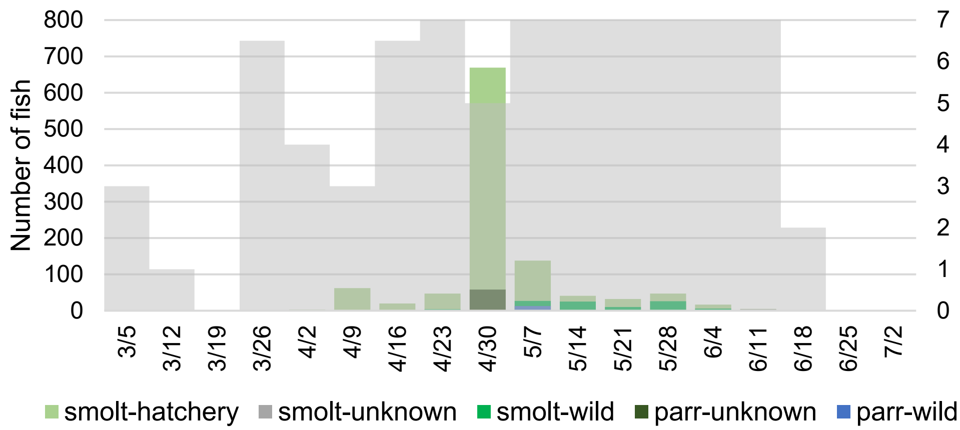

Dry Creek (Westside Road, RiverKm 3.30)
19 smolt (hatchery), 2 smolt (unknown), 83 smolt (wild), 1 parr (unknown), 5 parr (wild)
Number of fish
Fishing
25
20
15
10
5
0
7
6
5
4
3
2
1
0
3/12 3/19 3/26 4/2 4/9 4/16 4/23 4/30 5/7 5/14 5/21 5/28 6/4 6/11 6/18 6/25 7/2 7/9 7/16 7/23 7/30
smolt-hatchery
smolt-unknown
smolt-wild
parr-unknown
parr-wild


Mainstem Russian River (Mirabel-Wohler, RiverKm 38.7)
173 smolt (hatchery), 17 smolt (unknown), 103 smolt (wild), 18 parr (unknown), 2 parr (wild)
Number of fish
Fishing
140
120
100
80
60
40
20
0
7
6
5
4
3
2
1
0
3/5 3/12 3/19 3/26 4/2 4/9 4/16 4/23 4/30 5/7 5/14 5/21 5/28 6/4 6/11 6/18 6/25 7/2 7/9 7/16 7/23 7/30
smolt-hatchery
smolt-unknown
smolt-wild
parr-unknown
parr-wild

**Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)**
**678 smolt (hatchery), 52 smolt (unknown), 249 smolt (wild), 47 parr (unknown), 25 parr (wild)**




**Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)**
**139 smolt (hatchery), 1 smolt (unknown), 47 smolt (wild), 8 parr (unknown), 6 parr (wild)**



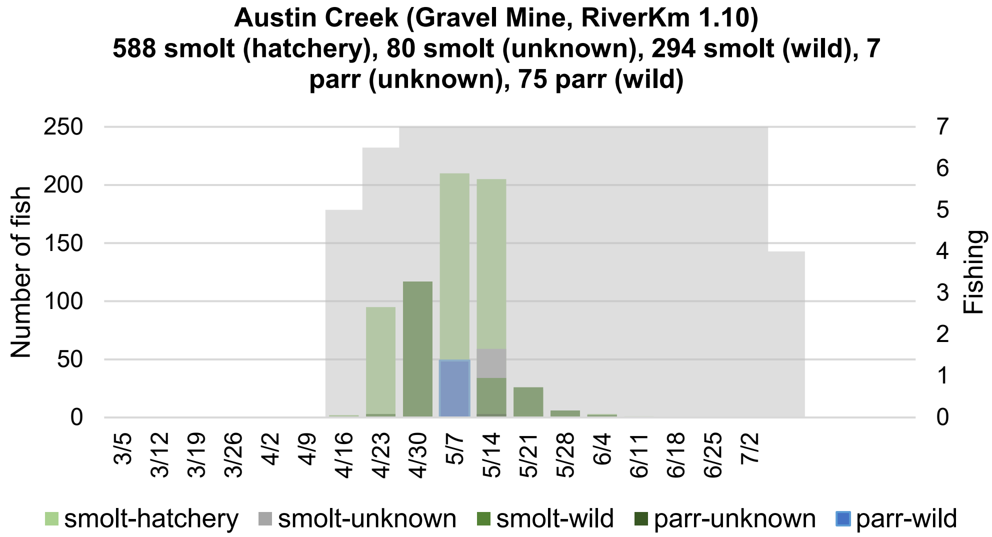
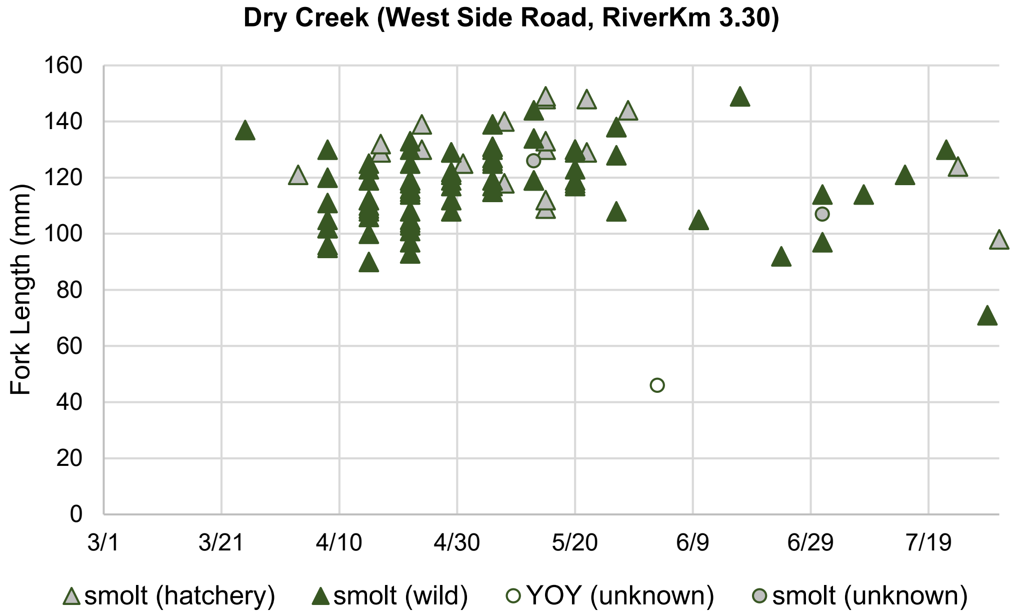
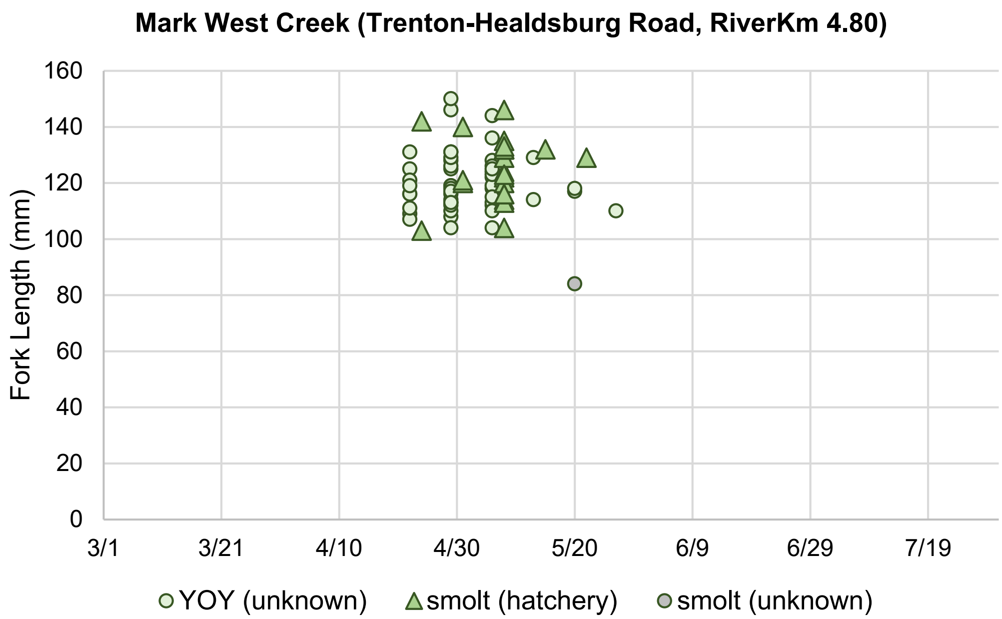
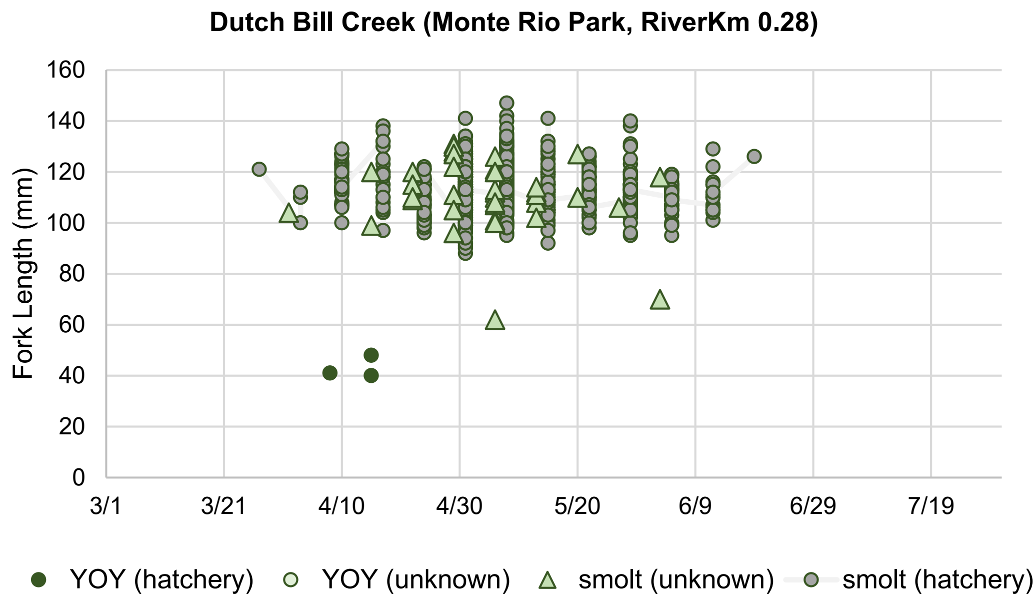
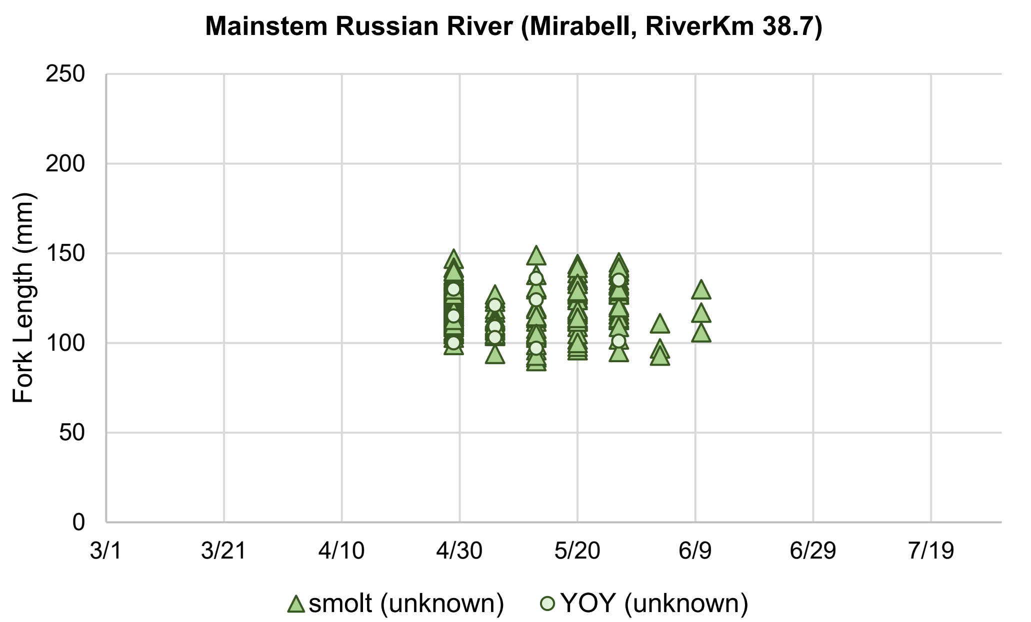



**Figure 4.4.13. Weekly capture of Coho Salmon by life stage at lower Russian River downstream migrant trapping sites, 2018. Gray shading indicates portion of each week trap was fishing. Note the different vertical scale among plots for each site.**


Dry Creek (West Side Road, RiverKm 3.30)
Fork Length (mm)
160
140
120
100
80
60
40
20
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
smolt (hatchery)
smolt (wild)
YOY (unknown)
smolt (unknown)


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
Fork Length (mm)
160
140
120
100
80
60
40
20
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
YOY (unknown)
smolt (hatchery)
smolt (unknown)


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
Fork Length (mm)
160
140
120
100
80
60
40
20
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
YOY (hatchery)
YOY (unknown)
smolt (unknown)
smolt (hatchery)


Mainstem Russian River (Mirabell, RiverKm 38.7)
Fork Length (mm)
250
200
150
100
50
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
smolt (unknown)
YOY (unknown)

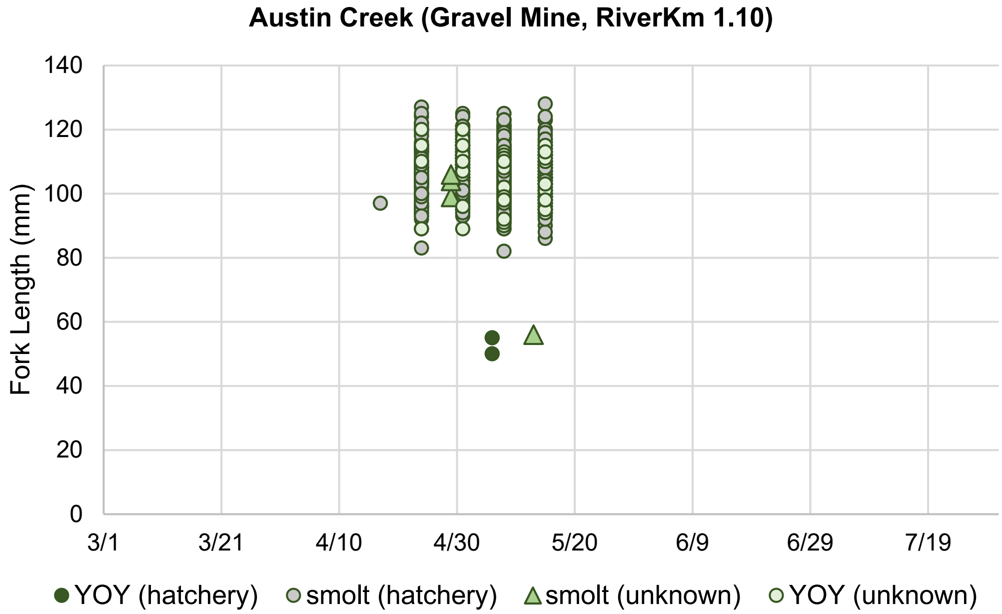



**Figure 4.4.14. Weekly fork lengths of Coho Salmon captured at lower Russian River downstream migrant trap sites, 2018.**

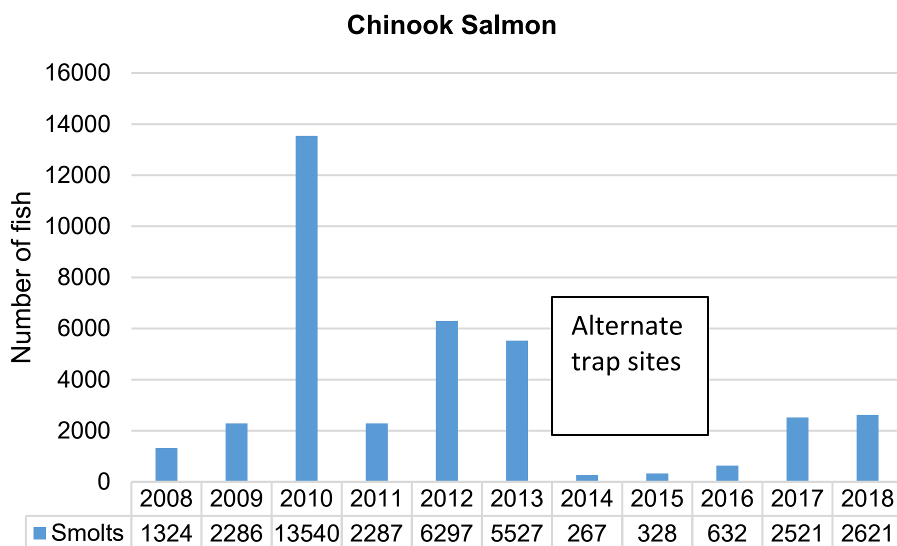



**Figure 4.4.15. Number Chinook Salmon smolts captured in the mainstem Russian River downstream migrant trap.**

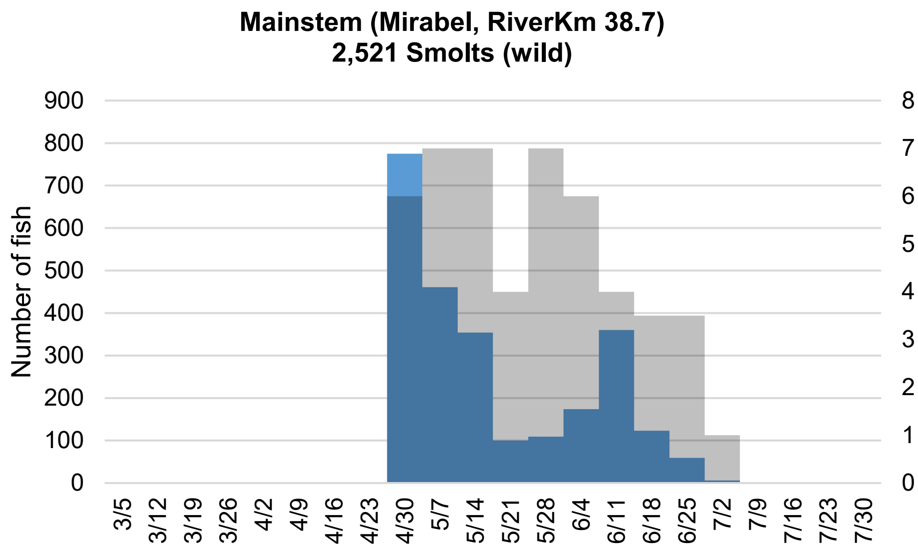



**Figure 4.4.16. Weekly capture of Chinook Salmon smolts at the Mirabel fish ladder on the mainstem Russian River, 2018. Gray shading indicates portion of each week trap was fishing. Note the different vertical scale among plots for each site.**

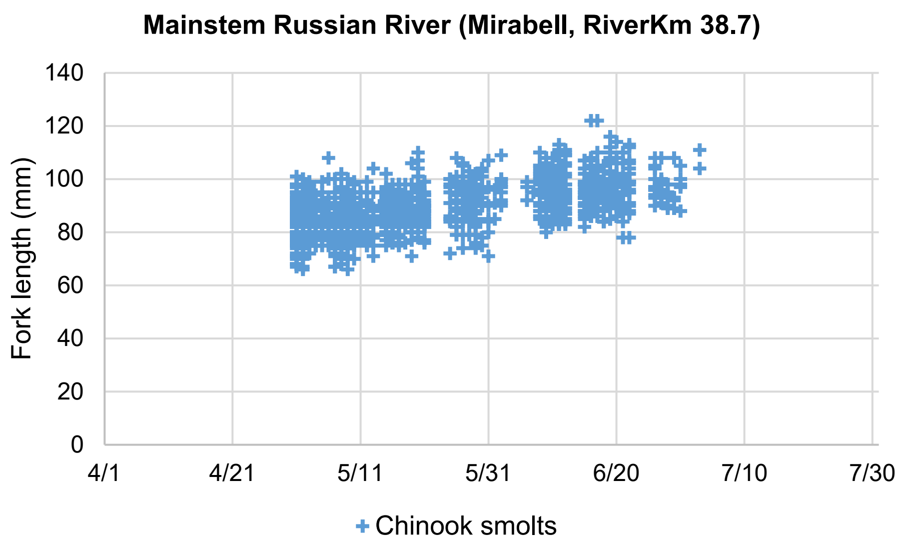



**Figure 4.4.17. Weekly fork lengths of Chinook Salmon captured at the Wohler Mirabel trap site on the mainstream Russian River downstream migrant trap sites, 2018.**

## Conclusions and Recommendations

Russian River Biological Opinion objectives regarding the timing of Estuary entry are partially met by using PIT tag detections from the paired antenna array in lower Austin Creek where antenna efficiency estimates are possible and where fish moving past that array have effectively entered the Estuary. In 2018, as in past years, many steelhead YOY were detected leaving Austin Creek and entering the Estuary. This same pattern was not seen at the other tributary monitoring sites.

While the PIT tag antenna at Duncans Mills spanned much of the Russian River for the 2018 outmigration season, detections of PIT-tagged fish were not guaranteed because there are sections between antennas where fish could pass undetected.  Fish orientation, and multiple PIT-tagged fish in the detection field of the same antenna at the same time, can also affect detection probability. Brackish water occasionally occurs at the antenna site, which causes decreases in antenna read range, and water depths may exceed the detection field of some antennas.  Collectively, these limitations all result in decreases in overall antenna efficiency; however, they are non-issues as long as detection efficiency can be estimated for use in expanding the number of fish detected.  Unfortunately, efficiency estimates at Duncans Mills have not been possible because of the lack of a second antenna array in close proximity to the first (e.g., as is the case in Austin Creek, Figure 4.4.4).  Regardless of these issues, PIT-tagging steelhead YOY at upstream locations and detecting those individuals if and when they move into the Estuary (along with beach seining in the Estuary itself) remain as the only viable method we know of for addressing the fish monitoring objectives in the Russian River Biological Opinion.  Attempts continue to measure antenna efficiency so that expanded counts of PIT-tagged individuals passing the antenna array can be constructed in future years.

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# Chapter 5: Dry Creek Habitat Enhancement, Planning, and Monitoring

## Introduction

The Biological Opinion contains a timeline that prescribes a series of projects to improve summer and winter rearing habitat for juvenile Coho Salmon and steelhead in Dry Creek (Figure 5.1). During the initial three years of implementation, 2008 to 2011, Sonoma Water was charged with improving fish passage and habitat in selected tributaries to Dry Creek and the lower Russian River. The status of those efforts is described in previous reports (Martini-Lamb and Manning 2020). For the mainstem of Dry Creek, during this initial period, Sonoma Water was directed to perform fisheries monitoring, develop a detailed adaptive management plan, and conduct feasibility studies for large-scale habitat enhancement and a potential water supply bypass pipeline. The pipeline feasibility study was completed in 2011 and is reported in Martini-Lamb and Manning 2011.

In 2012, Sonoma Water began construction of the first phase of the Dry Creek Habitat Enhancement Demonstration Project. A second phase of the Dry Creek Habitat Enhancement Demonstration Project was constructed in 2013 with a third and final phase of the Demonstration Project constructed in 2014. The Dry Creek Habitat Enhancement Demonstration Project consists of a variety of habitat enhancement projects along a section of Dry Creek a little over one mile in length in the area centered around Lambert Bridge. Concurrently, the U.S. Army Corps of Engineers completed construction in 2013 of a habitat enhancement project on U.S. Army Corps of Engineers owned property just below Warm Springs Dam (Reach 15). In 2016, Sonoma Water began construction on the Dry Creek Habitat Enhancement Project: Phase 2, Part 1 (centered approximately a mile upstream of the Demonstration Project) and the Dry Creek Habitat Enhancement Project: Phase 3, Part 1 (centered in a lower reach area of Dry Creek just below the Westside Road Bridge crossing of Dry Creek). Construction activities for both the Phase 2, Part 1 and Phase 3, Part 1 projects were completed during the 2017 construction season. Phase 2, Part 2 (Reach 14) construction started in the 2018 construction season at two of the Reach 14 sites (Corps of Engineers/Weinstock property site and Vala property site) by Sonoma Water. A third site (Gallo property) in Reach 14 is expected to be completed during the 2019 construction season. Phase 3, Part 2 (Reach 4a) was constructed during the 2018 construction season by the USACE. Phase 3, Part 3 (Reach 5) will likely be constructed during the 2020 construction season by Sonoma Water. Additional sites in reaches 1, 2, 4, 10, and 13 are in design for tentative construction at a future date.

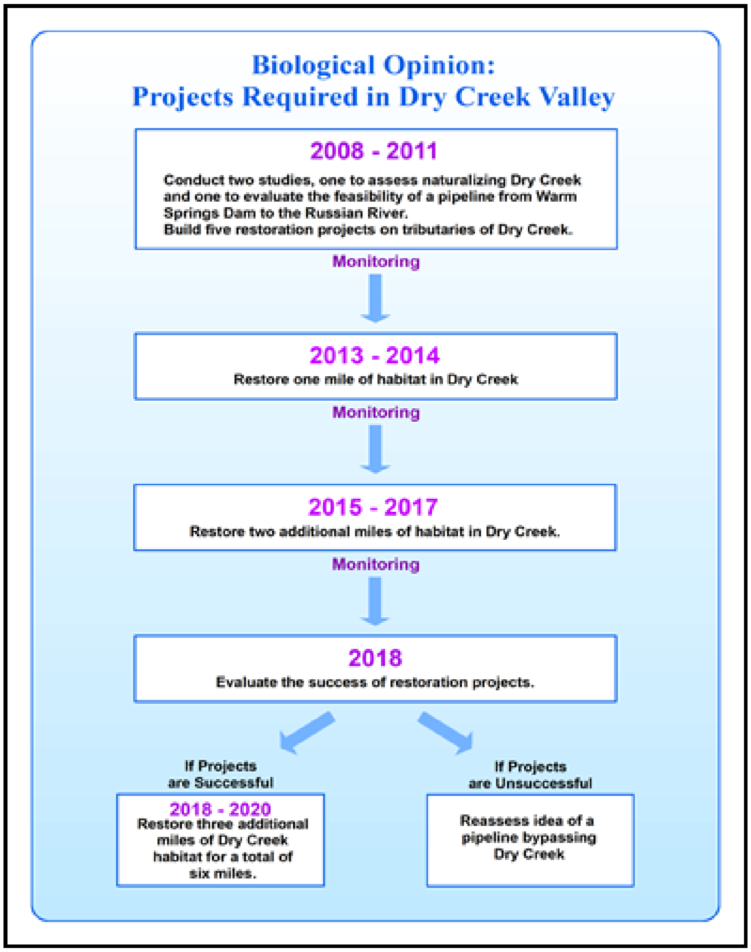


**Figure 5.1. Timeline for implementation of Biological Opinion projects on Dry Creek.**

## 2018 Habitat Enhancement Overview

In 2018 construction was completed in two new reaches: Reach 14 and Reach 4a (Ferrari-Carano, Olson). In Reach 14 two sites were constructed (Army Corps Reach 14 and Weinstock). A third site in Reach 14 (Gallo) is expected to be completed in 2019. We conducted pre- and post-enhancement monitoring in these two reaches (no post-enhancement monitoring in Gallo) as well as post-effective flow monitoring in previously completed reaches (Truett Hurst, Meyer, Carlson Lonestar, City of Healdsburg Yard, and Geyser Peak (Figure 5.2)).

Of the number of habitat enhancement reaches implemented to date (13), monitoring data resulted in 7 reaches rated good-excellent, 3 rated fair, and 3 have not yet been fully monitored (Table 5.1). Two reaches previously rated poor were upgraded to good (Truett Hurst) and fair (Geyser Peak) ratings after subsequent monitoring in 2018. Several large storms in the winter of 2016-2017, followed by sustained flood control releases from Warm Springs Dam led to substantial aggradation in Truett Hurst, Meyer, and Geyser Peak enhancement reaches. Sonoma Water repaired and modified these enhancement reaches in October 2017 and the 2018 ratings for these reaches reflect the post-repair conditions.

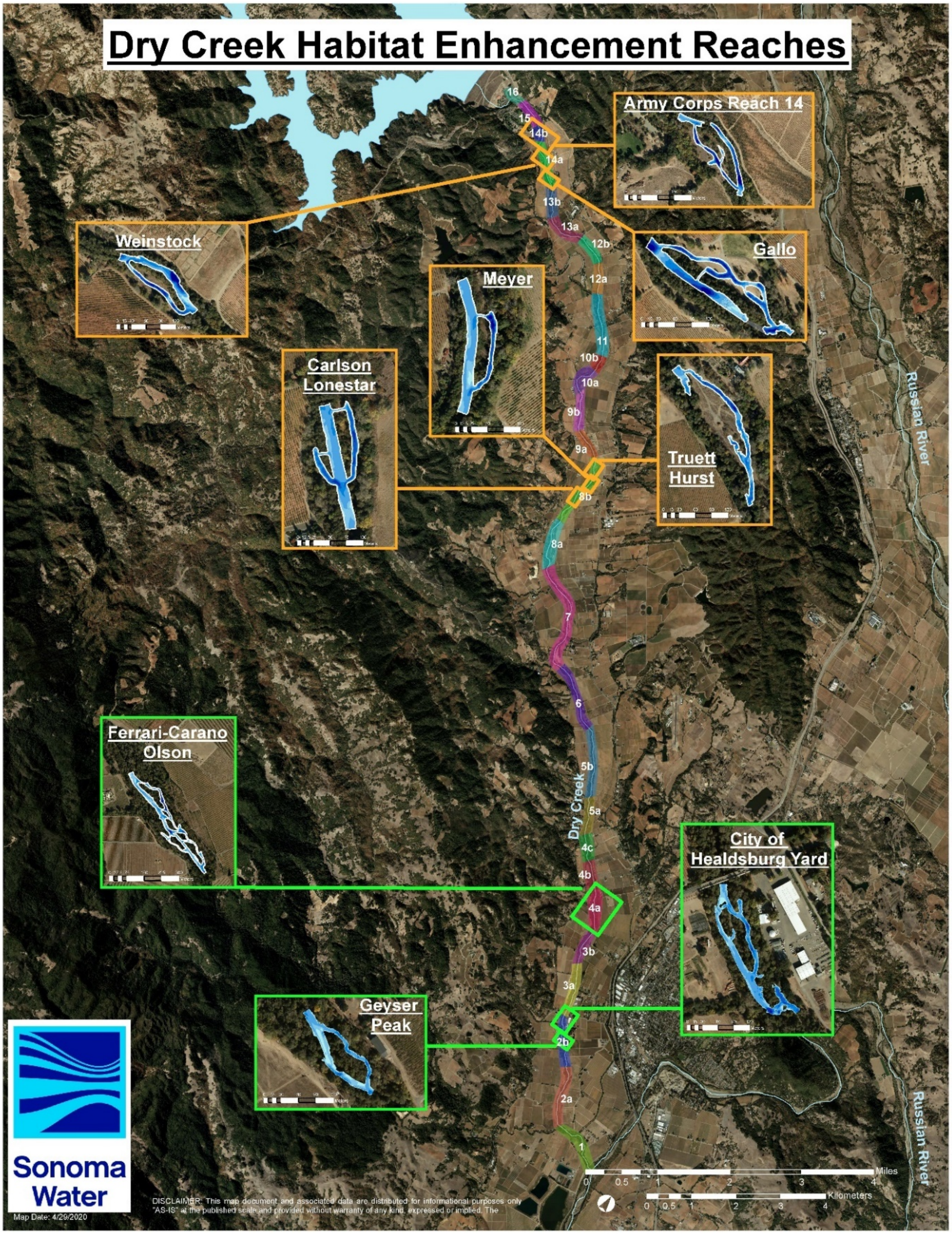


**Figure 5. 2. Location of Dry Creek habitat enhancement reaches monitored for effectiveness in 2018.**

**Table 5. 1. Dry Creek enhancement reaches monitored, year(s) of post-effective flow effectiveness monitoring and effectiveness rating, and latest overall rating. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River).**

| Enhancement Reach | 2015 | 2016 | 2017 | 2018 | Overall Rating |
|---|---|---|---|---|---|
| Army Corps Reach 15 | | Excellent | | | Excellent |
| Army Corps Reach 14 | | | | | -- |
| Weinstock | | | | | -- |
| Quivira | | Excellent | | | Excellent |
| Van Alyea | | | Good | | Good |
| Farrow Wallace | | | Fair | | Fair |
| Rued | Good | | | | Good |
| Truett Hurst | | | Poor | Good | Good |
| Meyer | | | Fair | Fair | Fair |
| Ferrari-Carano, Olson | | | | | -- |
| Carlson, Lonestar | | | | Good | Good |
| City of Healdsburg Yard | | | | Good | Good |
| Geyser Peak | | | Poor | Fair | Fair |

## Dry Creek Adaptive Management Plan

In 2014, an Adaptive Management Plan (AMP) to guide the process for evaluating habitat enhancement projects in Dry Creek was completed (Porter et al. 2014). Development of the Dry Creek AMP was facilitated by ESSA Technologies Ltd. (an independent consulting firm from Vancouver Canada) and it represented the culmination of a 3-year process including NMFS, CDFW, Sonoma Water, USACE, and Inter-Fluve (the design contractor for the initial phase of habitat enhancement). Enhancement projects were designed and implemented with the objective of addressing the lack of low water velocity areas with adequate cover and appropriate water depth that limit habitat suitability for juvenile salmonids in general and juvenile Coho Salmon in particular (NMFS 2008).

The Dry Creek AMP is based on the concept of adaptive management which involves synthesizing existing knowledge, exploring alternative actions, making explicit predictions of their outcomes, selecting one or more actions to implement, monitoring to see if the actual outcomes match those predicted, and then using these results to learn and adjust future management plans and policy (see Porter et al. 2014 and references therein). Sonoma Water's and USACE's level of compliance with the RPA for Dry Creek will involve examination of data from implementation, effectiveness and, to a lesser extent, validation monitoring. The process of combining monitoring data stems from first selecting a stream reach for enhancement then developing enhancement designs given geomorphic and landowner constraints. Once these designs are agreed to by parties to NMFS' Russian River Biological Opinion and enhancement projects are implemented, monitoring begins (Figure 5.3).

Prior to construction of a given enhancement project, but following reach selection and approval of construction design, pre-enhancement effectiveness monitoring is conducted. The objective of pre-enhancement monitoring is to rate existing habitat local to the intended enhancement project. Once construction of the project is complete, implementation monitoring is conducted to determine if the habitat enhancement was implemented according to the approved design. If it was, post-enhancement effectiveness monitoring is conducted following a geomorphically effective flow or within three years (whichever comes first). Validation monitoring aimed at assessing whether the habitat enhancement is achieving intended biological objectives is conducted after project implementation and can occur before, during or after post-enhancement effectiveness monitoring.

Enhancement project success is primarily based on the results of effectiveness monitoring and, in particular, post-enhancement effectiveness data. Importantly, however, implementation monitoring not only triggers post-enhancement effectiveness monitoring by addressing the question of whether the habitat enhancement was implemented according to the approved design, but it also builds a template for conducting that monitoring. Though less important for evaluating overall project success, validation monitoring can be key in tipping the overall project rating but only in a positive direction (Figure 5.3).

The specific quantitative data collected for effectiveness monitoring vary depending on aspects of the habitat being evaluated. Regardless, however, the aim is to evaluate habitat in light of those factors deemed in the RPA as most significantly impacting juvenile salmonid rearing habitat in Dry Creek (current velocity, depth, cover, habitat complexity). The RPA recognizes validation monitoring as being important given the complexity of major habitat enhancements and influences of uncontrollable factors such as major flood events. For both types of monitoring, the AMP lists “primary metrics” and outlines how data collection to evaluate against these metrics will occur (see Effectiveness Monitoring and Validation Monitoring sections). In some cases, data on “secondary metrics” which may inform habitat-related questions in Dry Creek as well as (potentially) beyond Dry Creek.

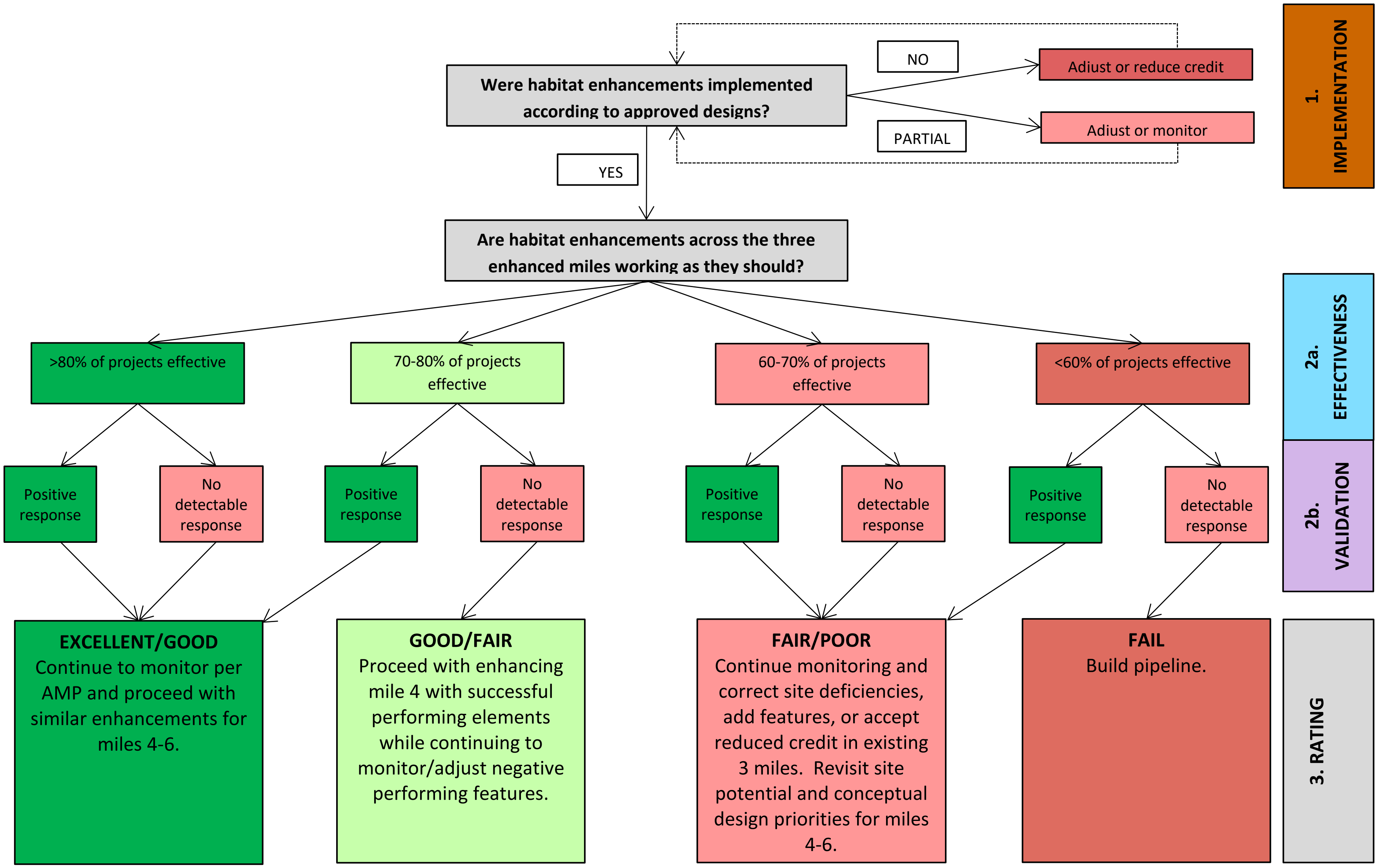


**Figure 5. 3. Process for determining course of action after the first three miles of Dry Creek have been enhanced. Ratings will be based on an objective evaluation in a step-wise phased monitoring approach which includes physical and biological quantitative measurements which lead to qualitative ratings (Porter et al. 2014).**

## Data Roll-up

Implementation monitoring is based solely on qualitative data at the habitat feature scale (i.e., was the feature installed in the approved location in the approved manner?) while effectiveness and validation monitoring are based on collecting quantitative data at one scale (i.e., the feature, site, enhancement reach scale) then qualitatively “rolling-up” those results to the next broader spatial scale (Figure 5.4).

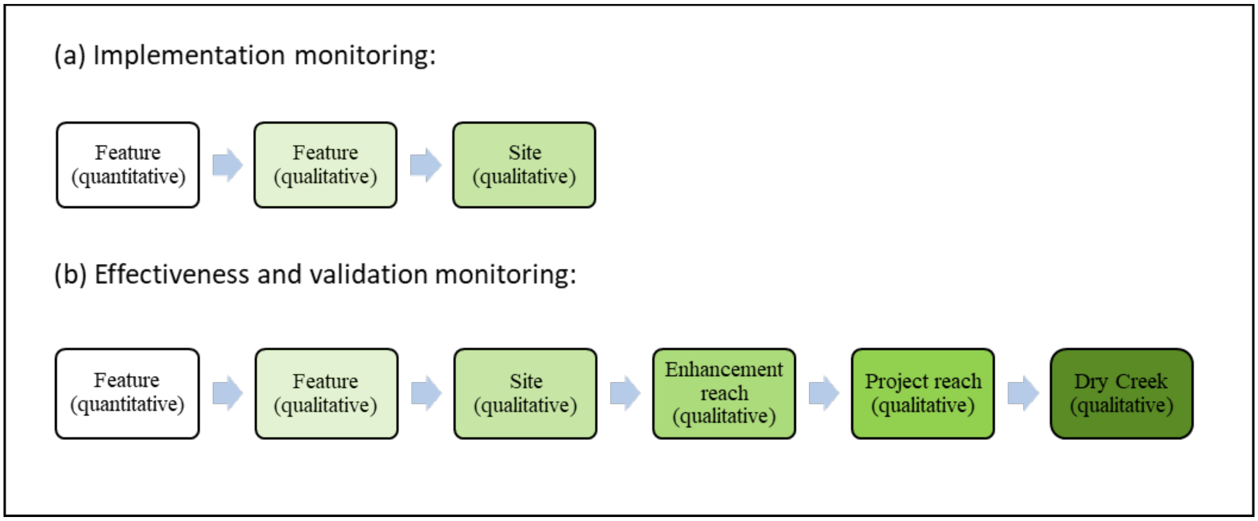


**Figure 5. 4. Illustration of the rollup concept for (a) implementation and (b) effectiveness and validation monitoring (from Porter et al. 2014).**

In the sections that follow, definition of the following terms is necessary (from Porter et al. 2014):

- **Features:** Individually engineered elements (e.g., large woody debris accumulation, riffle, pool, side channel, alcove, boulder cluster, etc.) that will individually or in composite make up a habitat enhancement site (see definition for Site below). Features can in some cases represent complete habitat units (see definition for Habitat Unit below), while in other cases they represent only structural components within a habitat unit (e.g., large wood placement).
- **Site:** One or more engineered habitat features (see definition for Features above) that have been designed to work in combination to enhance a stream reach.
- **Enhancement reach:** A specified collection of enhancement sites (see definition for site above) that are implemented in close proximity to one another.
- **Project reach:** A specified collection of enhancement reaches (see definition for Enhancement Reach above).

The qualitative rating derived for a given group of features within a site, sites within an enhancement reach or enhancement reaches within a project reach represent the basis for overall rating of habitat enhancements. These overall ratings will influence crediting toward the total length of habitat enhanced in Dry Creek (Figure 5.3).

- Excellent-Good: >80% rated Good or Excellent
- Fair-Poor: 60-80% rated Good or Excellent
- Fail: <60% rated Good or Excellent

# 5.1 Habitat Enhancement Implementation

## Phase 2 and 3

Beyond the completion of the Demonstration Project (Reach 7) work and the USACE's Reach 15 work, Sonoma Water has continued to make progress towards the construction of the next two miles of habitat enhancement. These next two miles have been designated as Phase 2 and 3, with each of these phases to be constructed in parts. Figure 5.1.1 shows completed project areas (including the Demonstration Project and Reach 15), along with other areas in construction or under design. Construction of Phase 2, Part 1 (Reach 8) and Phase 3, Part 1 (Reach 2) was completed in 2017. Phase 2, Part 2 (Reach 14) construction started in 2018 and is expected to be completed in 2019. The construction management for Phase 2, Part 2 is being overseen by Sonoma Water. Phase 3, Part 2 (Reach 4a) was constructed in 2018 by the USACE.

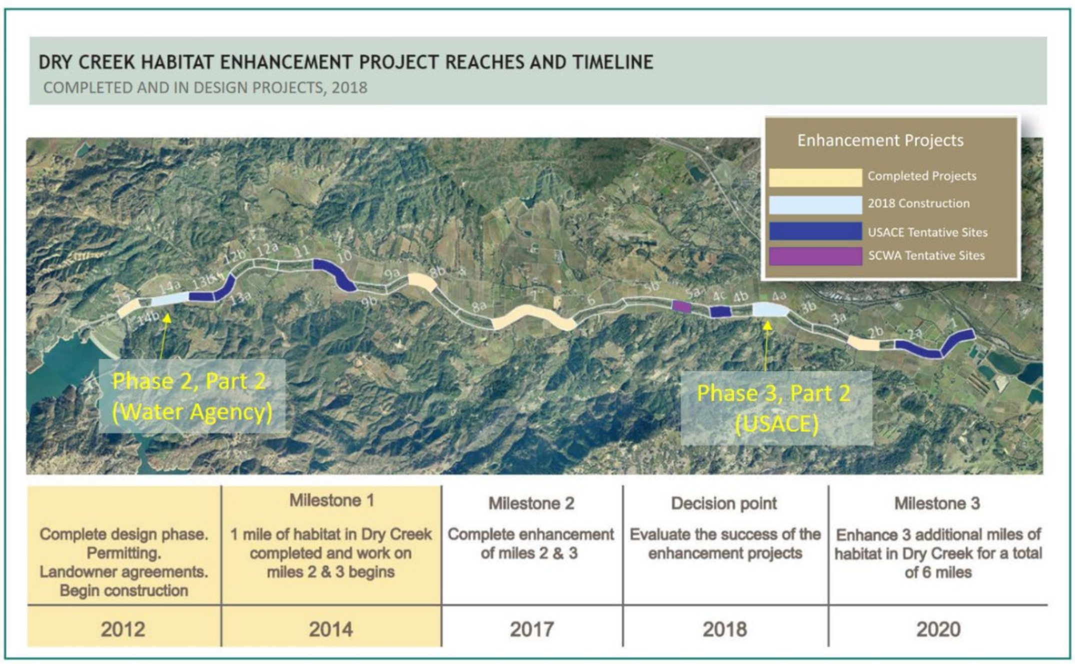


**Figure 5.1.1. Projects along Dry Creek that have been completed and projects that are being designed.**

### Phase 2, Part 2

The Phase 2, Part 2 project area is along approximately 4,000 feet of Dry Creek in the Reach 14 area of Dry Creek just below Warm Springs Dam. This site originally consisted of five different sites, labeled Areas G, H, I, J, and K in the design drawings (Figure 5.1.2). Areas H (Army Corps Reach 14) and J (Weinstock) were constructed during the 2018 construction season. Area G (Gallo) will be constructed in 2019. Areas I and K unfortunately had to be dropped from the project because an agreement to construct the project could not be reached with the landowners of these two sites.

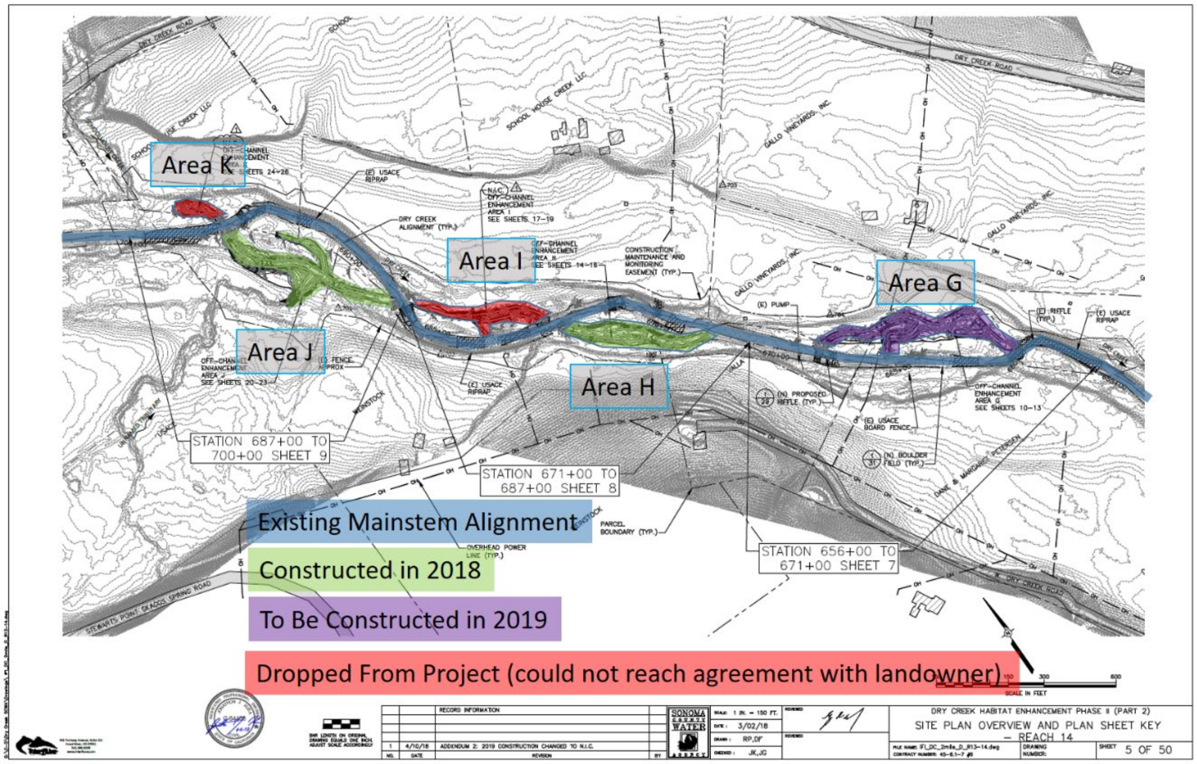


**Figure 5.1.2. This figure shows the work area for the Dry Creek Habitat Enhancement Project, Phase 2, Part 2, constructed in 2018 and portion expected to be completed in 2019.**

**Photo 5.1.1. Dry Creek Enhancement Project Phase 2, Part 2, Army Corps Reach 14 (Area J) looking upstream from downstream end of site during construction. August 7, 2018.**

**Photo 5.1.2. Dry Creek Enhancement Project Phase 2, Part 2, Army Corps Reach 14 (Area J) upstream inlet under construction. Installed logs visible on the left, sheet pile isolating the work area from Dry Creek is visible in the center of the photo, and the active flow of Dry Creek is on the right. August 7, 2018.**

**Photo 5.1.3. Dry Creek Enhancement Project Phase 2, Part 2, Army Corps Reach 14 (Area J) completed inlet at upstream end of the site. September 12, 2018.**

**Photo 5.1.4. Dry Creek Enhancement Project Phase 2, Part 2, Weinstock (Area H), view of completed side channel looking upstream from the downstream end of the site. October 3, 2018.**

## Phase 3, Part 2

The Phase 3, Part 2 project area is along approximately 1,700 feet of Dry Creek in the Reach 4a area (Ferrari-Carano, Olson) of Dry Creek about a mile upstream of the Westside Road bridge over Dry Creek (Figure 5.1.3). The construction of this site was managed by the USACE and was completed in 2018.

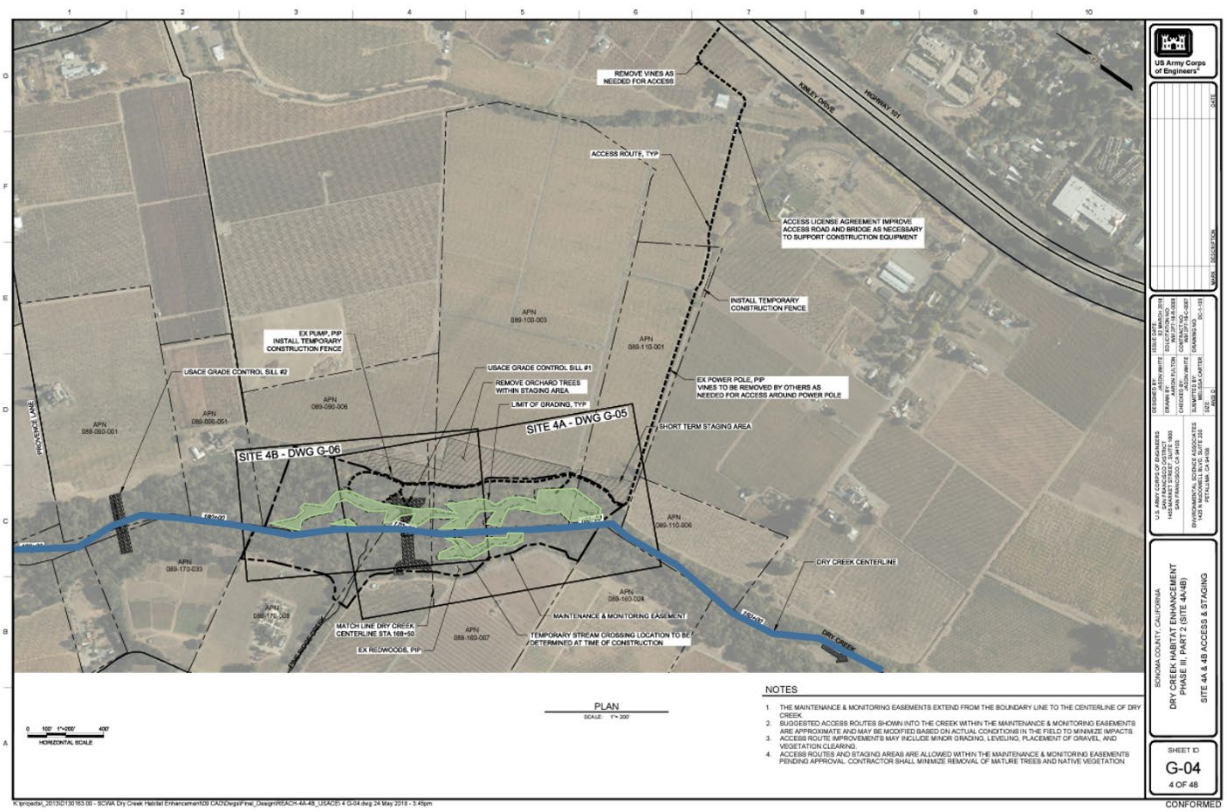


**Figure 5.1.3. This figure shows the work area for the Dry Creek Habitat Enhancement Project, Phase 3, Part 2 (Ferrari-Carano, Olson), constructed in 2018.**

**Photo 5.1.5. Dry Creek Enhancement Project Phase 3, Part 2, Ferrari-Carano, Olson, temporary crossing of Dry Creek during construction. July 26, 2018.**


**Photo 5.1.6. Dry Creek Enhancement Project Phase 3, Part 2, Ferrari-Carano, Olson, construction underway. August 30, 2018.**


**Photo 5.1.7. Dry Creek Enhancement Project Phase 3, Part 2, Ferrari-Carano, Olson, aerial view of completed project. November 19, 2018.**

# 5.2 Effectiveness monitoring

## Performance Measures

Effectiveness monitoring focuses on the physical response of Dry Creek to habitat enhancements and determines "whether habitat enhancement is having the intended effect on physical habitat quality" in Dry Creek (NMFS 2008, pg. 266). NMFS (2008) concluded that sub-optimal water velocity, depth, and instream cover limit juvenile Coho Salmon and steelhead and suggested optimal values for water velocity depth, and cover as part of the Reasonable and Prudent Alternative (NMFS 2008). The Joint Monitoring Team, consisting of representatives from NMFS, CDFW, USACE, and Sonoma Water, refined these values within the Dry Creek Adaptive Management Plan (AMP) (Porter et al. 2014) and developed primary performance metrics linked to the optimal values of water velocity, depth, and cover by which to evaluate the effectiveness of habitat features, sites, and reaches (Table 5.2.1). The Joint Monitoring Team also identified secondary performance metrics that help determine the effectiveness of habitat enhancements to influence non-target, ancillary conditions (e.g., water temperature, dissolved oxygen concentration). The AMP also suggested target flows to represent seasonal variation critical to each life stage (Porter et al. 2014).

**Table 5.2. 1. Primary and secondary performance measures from the Dry Creek Adaptive Management Plan.**

| Type of Performance Measure | Performance Measure | Life Stage | Spring Flow[1] | Summer Flow[2] | Winter Flow[3] |
|---|---|---|---|---|---|
| **Primary** | Velocity (ft/sec) | fry | 0-0.5 ft/s | n/a | n/a |
| | Depth (ft) | fry | 0.5-2.0 ft | n/a | n/a |
| | Velocity (ft/sec) | Summer/winter parr | 0-0.5 ft/s | 0-0.5 ft/s | 0-0.5ft/s |
| | Depth (ft) | Summer/winter parr | 2-4 ft | 2-4 ft | 2-4 ft |
| | Shelter value | Juvenile | ≥80 | ≥80 | ≥80 |
| | Pool: Riffle ratio | Juvenile | n/a | 1:2 to 2:1 | n/a |
| **Secondary** | Temperature (°C) | Juvenile | n/a | 8-16° C | n/a |
| | Dissolved oxygen (mg/l) | Juvenile | n/a | 6-10 mg/l | n/a |
| | Canopy (%) | Juvenile | 80 % | | |
| | Quiet water (< 0.5 ft/s) (%) | Juvenile | n/a | n/a | ≥ 25% |
| | Off-channel access (off-ramps) (ft/sec) | Juvenile | Approx. 1.5 – 1.8 cm/s (Ucrit);<br>Approx. 3.3 ft/s (burst speed) | | |
| | Connectivity of habitats | Juvenile | Undefined | | |
| | Substrate particle size (in.) | Adult | n/a | n/a | 0.25-2.5 in. |
| | Depth (ft) | Adult | n/a | n/a | 0.5-1.6 ft |

[1] Target coho life stage during spring is newly emerged feeding fry which use shallower depths than would be preferred later in the summer and winter when fish would be larger. Target spring flow (discharge within the enhancement reach) is 200 cfs (approximately double the summer "base" flow).

[2] Target summer flow is 105 cfs

[3] Target winter flow is 1000 cfs

## Spatial Scales

Data collection to evaluate the effectiveness of the Dry Creek Habitat Enhancement Project occurred across several increasingly broad spatial scales that nest within each other as they increase in size:

- Feature: Individually engineered elements (e.g., large woody debris accumulation, riffle, pool, side channel, alcove, boulder cluster).

- Habitat unit: A designation within a habitat classification system (e.g., Flosi et al. 2010) that allows stratification (based on natural patterns of variation) when attempting to quantify physical attributes of a stream.

- Site: An engineered portion of stream channel (e.g., side channel or alcove) constructed within an enhancement reach (see definition below), or a portion of stream channel adjacent to engineered portions of stream channel (e.g., a mainstem portion of channel adjacent to a constructed side channel). Sites typically contain several features and habitat units, but in some cases may contain no features and a single habitat unit (e.g., a mainstem portion of channel with no features adjacent to constructed side channel). Sites may also contain several features, but no habitat unit, such as floodplain sites that are dry during the summer.

- Enhancement reach: A collection of sites implemented in close proximity to one another.

- Project reach: A collection of enhancement reaches implemented during the same project phase

Quantitative and qualitative data collected at the feature and habitat unit-scale provide the basis to inform evaluation of progressively larger sites, enhancement reaches, and project reaches. This integration, or spatial rollup, allows a robust evaluation of individual project elements across multiple spatial scales.

## Effectiveness Ratings

Within the AMP, the Joint Monitoring Team developed checklists to evaluate and rate the physical effectiveness of the Dry Creek Habitat Enhancement Project (See Porter et al [2014], pp. 40-45). The Joint Monitoring Team expanded existing checklists developed by Harris (2004) by incorporating additional quantitative metrics outlined in the RPA. The checklists integrate hydraulic (water depth and velocity) and shelter (shelter value, percent cover, shelter score) data to evaluate project performance relative to primary metrics (Table 5.2.1), and qualitative observations of features. The ratings of features and habitat units inform ratings of sites, enhancement reaches, and project reaches, which occur at increasingly broader spatial scales. Quantitative data collected to evaluate project performance support qualitative ratings that provide the basis for evaluating the overall effectiveness of habitat enhancement measures (see Methods, below). The qualitative ratings determine relative success of habitat enhancement measures within sites and habitat enhancement reaches and determine potential future outcomes (management actions) (Table 5.2.2).

**Table 5.2. 2. Potential enhancement reach ratings, criteria, and future outcomes (actions). From Porter et al. 2014.**

| Rating | Objectives | Criteria | Unintended Effects | Future Outcome |
|---|---|---|---|---|
| **Excellent-Good** | Achieved all or most stated reach design objectives. | All or most sites/ enhancement reaches meet or exceed targeted values. (>80% of sites rated Good or Excellent) | None or minimal negative unintended effects. Unintended positive effects may outweigh failure to achieve a targeted value. | Continue to monitor according to adaptive management plan. |
| **Fair-Poor** | Partially achieved most reach design objectives, or objectives not achieved were beyond reach capacity | Some sites / enhancement reaches did not meet targeted values (60-80% of sites/ enhancement reaches rated Good or Excellent) | May have minor or major unintended negative effects that partially offset objectives or negates a targeted gain. | Develop and implement plans to correct site or metric deficiencies, add sites/features or reduce total project habitat credit. Step up monitoring on sites and features exhibiting negative performance. |
| **Fail** | Many sites achieved no goals; objectives not achieved were the fault of the feature; sites/feature may be completely gone. | Many sites/ enhancement reaches did not meet targeted values (<60% of sites/ enhancement reaches rated Good or Excellent). | Few positive effects and/or unintended negative effects may be degrading the habitat and outweigh achieved objectives. | Reduce total project habitat credit, and abandon use of failed features. Revisit site potential and conceptual design priorities |

# Methods

## Performance Measures

Performance measure data collection focuses on data to assess the Dry Creek Habitat Enhancement Project against the primary performance measures of water depth (0.5-2 or 2-4 ft) and velocity (<0.5 ft/s), pool to riffle ratio, and amount of instream cover (shelter score) from the AMP (Porter et al. 2014) (Table 5.2.1). Depth, velocity, pool to riffle ratio, and shelter score also provide a means to directly assess against optimal habitat values suggested as part of the RPA in the BO (NMFS 2008). We collected data from April to September during summer baseflow conditions. Daily average discharge ranged from 110 to 135 cfs over the monitoring period (as measured at the Dry Creek below Lambert Bridge near Geyserville USGS gage [gage #11465240]), and monitoring did not occur at discharges above 135 cfs to ensure accuracy and consistency when measuring depth and velocity, determining habitat types, and evaluating cover.

### Depth and velocity

The AMP suggested collecting water depth and velocity at points along transects placed within constructed backwaters and main channel portions of Dry Creek, and "habitat feature mapping" near selected habitat enhancements (logjams, boulder fields). Habitat feature mapping would result in two-dimensional depictions of depth and velocity around habitat features and allow quantification of optimal habitat area adjacent to features. Upon consultation with NMFS, and through field experimentation with several mapping and survey tools (auto-level, differential global positioning system, total station), Sonoma Water developed a robust habitat feature mapping method to characterize all portions of the Dry Creek channel, not just adjacent to enhancement features, obviating the need to collect cross-sectional data.

Field crews collected water depth and velocity at points across the streambed using handheld flow meters and a total station. At each point, we collected geographic location (latitude, longitude, elevation), and water depth and velocity by aiming the total station at a USGS topset rod fit with a survey prism and a flow meter (Figure 5.2.1). The technique allowed simultaneous collection of spatially accurate topographic and hydraulic data (water depth and velocity) that enabled comparison to future conditions. Field crews focused point collection on breaks in slope and breaks in water velocity, and at a minimum collected points at the top of each bank, water surface elevation, toe of bank, thalweg, and at least two points between toe of bank and thalweg.

We processed the data within a Geographic Information System (GIS) to create detailed maps of hydraulic conditions (water depth and velocity) to spatially characterize habitat conditions and quantify optimal fry and juvenile habitat. We processed spatial data to create raster (grid) based digital elevation models (DEMs) that classified hydraulic habitat conditions according to the primary metrics from the AMP (depth [0.5-2 ft or 2-4 ft], depending on life stage and velocity [<0.5 ft/s]) to identify the location of habitat falling within optimal depth, velocity, and depth and velocity ranges as polygons (Figure 5.2.2). Generating polygons within a GIS also allowed us to quantify the areas of optimal habitat.


**Figure 5.2. 1. Dry Creek effectiveness monitoring. At each data point, we collected geographic location (latitude, longitude, elevation), and water depth and velocity by aiming the total station at a USGS topset rod fit with a survey prism and a flow meter**

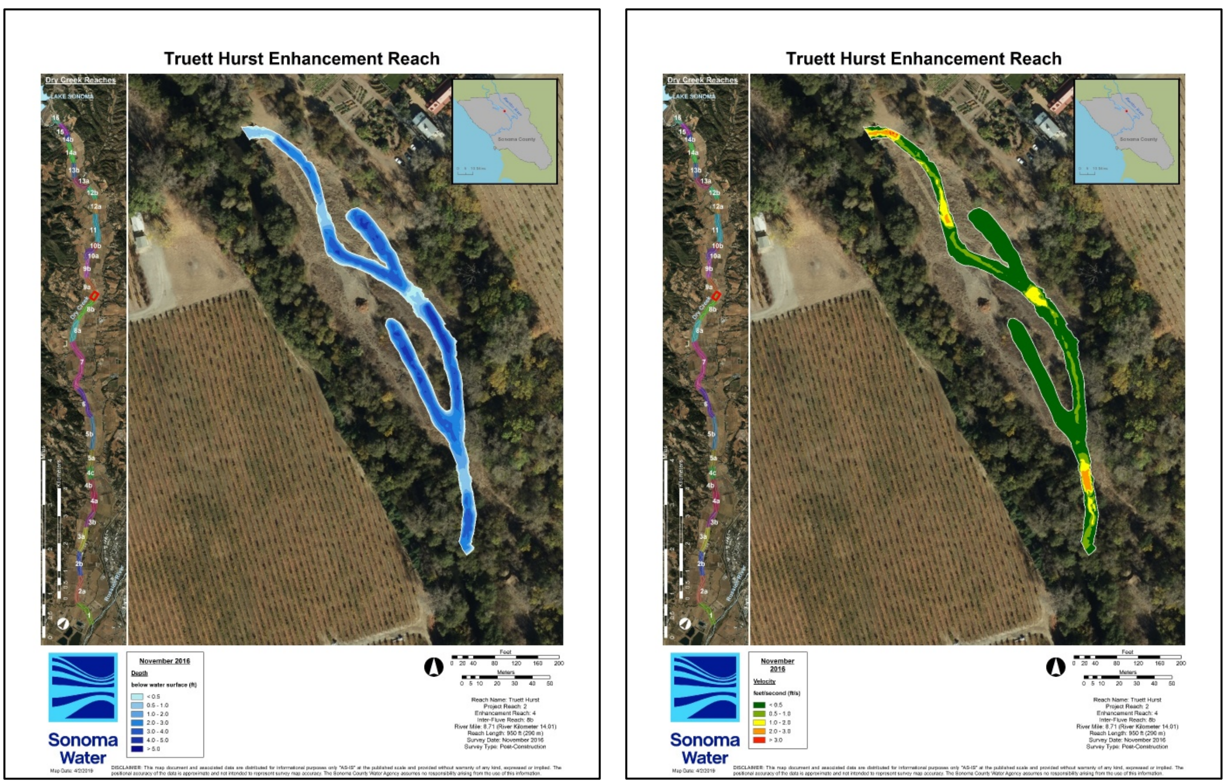


**Figure 5.2. 2. Digital elevation models (DEMs) created from spatially referenced depth and velocity points.**

## Habitat Types, Pool to Riffle Ratio, and Shelter Scores

We inventoried instream habitat units using descriptions from the California Salmonid Habitat Restoration Manual (Flosi et al. 2010). Differences in local channel gradient, water velocity, depth, and substrate size distinguish habitat types. Flosi et al. (2010) use four hierarchical levels to describe physical fish habitat, with each successive level providing greater detail. The most elementary descriptions (Levels 1 and 2) break stream channels into pool, riffle, or flatwater habitat types Successive levels differentiate habitat types by location within the stream channel (e.g., mid-channel pools, Level 3) or by cause or agent of formation (e.g., lateral-scour, log-formed pools, Level 4). In this survey, we inventoried habitat types to Level 2 and delineated upstream and downstream boundaries with nail spikes on the right and left bank. We surveyed the location of the nail spikes with a total station and processed the data within a GIS to create polygons of habitat types (Figure 5.2.3). After the inventory, we determined pool: riffle ratio to compare against the performance metric of 1:2 (0.5) to 2:1 (2.0) (Figure 5.2.3) (Porter et al. 2014).

Field crews determined the shelter value of individual habitat units within each enhancement site. Flosi et al. (2010) rates instream shelter by multiplying the complexity of available cover (0 = no shelter, 3 = highly complex shelter) by the overhead area occupied by that cover (0 = 0% of overhead area covered, 100 = 100% of overhead area covered) The maximum shelter value is 300 (3 [complexity of available cover within a habitat unit] * 100 [area of habitat unit covered]), with a score of ≥80 considered optimal within the AMP (Porter et al. 2014) (Figure 5.2.3).

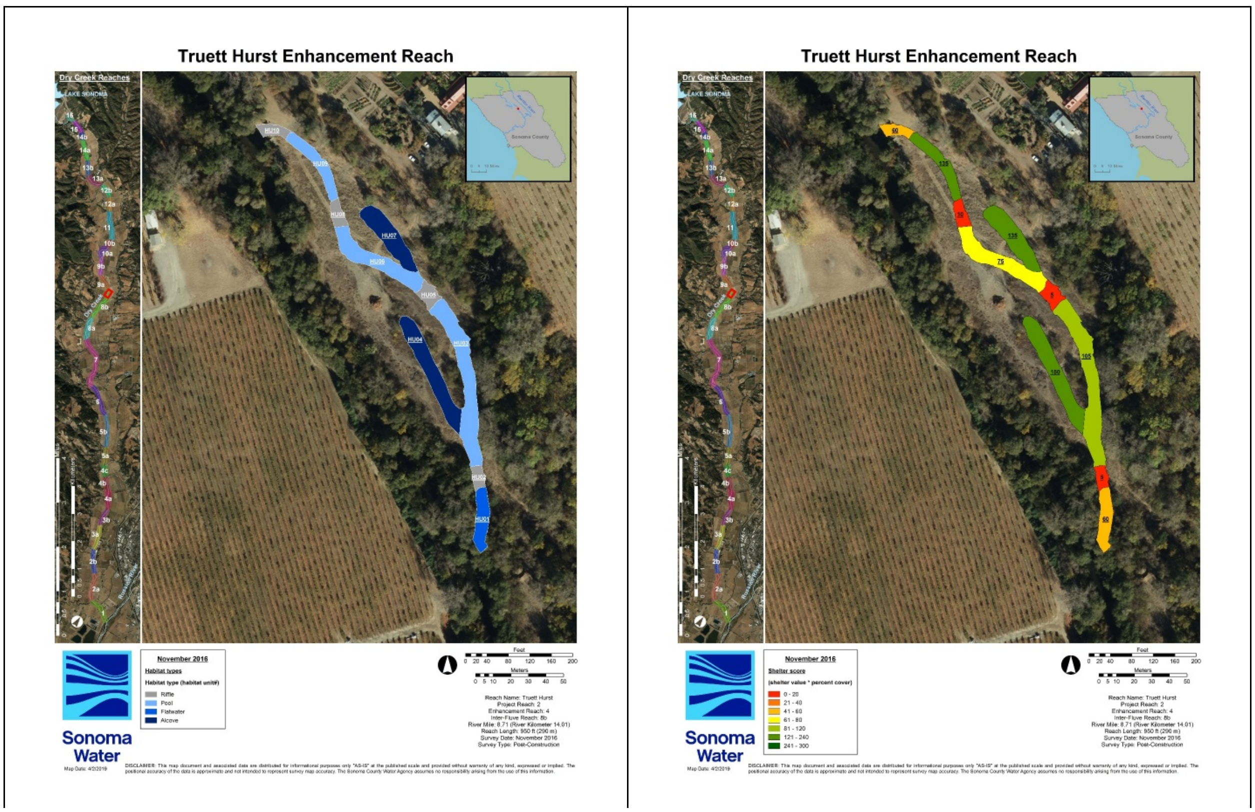


**Figure 5.2. 3. Example of inventoried habitat types and estimated shelter values within a Dry Creek habitat enhancement reach.**

## Effectiveness Ratings

We used modified monitoring checklists from the AMP to quantitatively and qualitatively evaluate enhancement features, habitat units, sites, and reaches. As noted above, the Joint Monitoring Team expanded checklists from Harris (2004) by incorporating quantitative metrics outlined in the RPA and to allow spatial rollup of the evaluation of project performance. The AMP included pre- and post-enhancement checklists for off-channel, in-channel, and areas along the bank for a total of six individual checklists (See Porter et al [2014], pp. 40-45). We modified off-channel and in-channel checklists to include bank areas, obviating the need for a bank stabilization checklist, and used the same checklists for pre-and post-enhancement, for a total of two individual checklists (Table 5.2.3 and Table 5.2.4). We standardized each checklist to ask the same number of questions, albeit with slightly different questions for off- and in-channel areas).

We retained the general order of the AMP checklist, but reclassified questions into spatially explicit data categories. The original AMP checklists ordered and grouped questions into several data categories (feature, depth/habitat, shelter, channel, velocity, and other) that included observations at multiple spatial scales (Table 5.2.3 and Table 5.2.4; see question 7: Current level II habitat type? [habitat unit scale]) and question 8: If an objective, did the feature create the targeted instream habitat type? [feature-scale]) are both in the depth/habitat category). We reclassified questions into data categories that evaluated enhancement features (feature data) or habitat units through hydraulic data and shelter data (habitat unit data) (Table 5.2.3 and Table 5.2.4). Grouping the questions facilitated the rollup from feature and habitat unit data into site and reach ratings.

**Table 5.2. 3. Off-channel effectiveness monitoring checklist showing original data category from the AMP (left column) and modified data category (right column).**

| ORIGINAL DATA CATEGORY | # | QUESTION | MODIFIED DATA CATEGORY |
|---|---|---|---|
| FEATURE | 1. | LENGTH OF TARGETED TREATMENT (FT) | FEATURE DATA |
| | 2. | WIDTH OF TARGETED TREATMENT: (FT) | FEATURE DATA |
| | 3. | ESTIMATE AREA OF THE TARGETED FEATURE: ($FT^2$) | FEATURE DATA |
| | 4. | STRUCTURAL CONDITION OF FEATURE: EXCL, GOOD, FAIR, POOR, FAIL | FEATURE DATA |
| | 5a | ARE PROBLEMS WITH THE FEATURE VISIBLE? | FEATURE DATA |
| | 5b | TYPES: ANC, BBB, CRF, MAT, SHF, STR, SWA, UND, UNS, WSH, OTH | FEATURE DATA |
| | 6a | IS THE FEATURE STILL IN ITS ORIGINAL LOCATION? | FEATURE DATA |
| | 6b | IS THE FEATURE STILL IN ITS ORIGINAL POSITION? | FEATURE DATA |
| | 6c | IF YES: LBK, MDC, RBK, SPN, OTH | FEATURE DATA |
| | 6d | IS THE FEATURE STILL IN ITS ORIGINAL ORIENTATON? | FEATURE DATA |
| | 6e | IF YES: DNS, MUL, PRL, PRP, UPS, OTH | FEATURE DATA |
| DEPTH/HABITAT | 7. | CURRENT LEVEL II HABITAT UNIT TYPE: FLT, POO, RIF, DRY, ALC, OTH | HABITAT UNIT (SHELTER) DATA |
| | 8. | IF AN OBJECTIVE, DID THE FEATURE CREATE THE TARGETED INSTREAM HABITAT TYPE? | FEATURE DATA |
| | 9. | WERE THERE ANY UNINTENDED EFFECTS BY THE FEATURE ON THE HABITAT TYPE? IF Y, COMMENT. | FEATURE DATA |
| | 10. | MEAN WATER DEPTH IN HABITAT UNIT: FT | HABITAT UNIT (HYDRAULIC) DATA |
| | 11a | MAXIMUM WATER DEPTH IN HABITAT UNIT: FT | HABITAT UNIT (HYDRAULIC) DATA |
| | 11b | AREA OF HABITAT UNIT WITHIN 0.5 -2.0 FT DEPTH: (FT2) | HABITAT UNIT (HYDRAULIC) DATA |
| | 11c | AREA OF HABITAT UNIT WITHIN 2.0 -4.0 FT DEPTH: (FT2) | HABITAT UNIT (HYDRAULIC) DATA |
| | 11d | AREA OF HABITAT UNIT WITHIN 0.5-4.0 FT DEPTH: (FT2) | HABITAT UNIT (HYDRAULIC) DATA |
| | 11e | % AREA OF HABITAT UNIT WITHIN 0.5 -2.0 FT DEPTH | HABITAT UNIT (HYDRAULIC) DATA |
| | 11f | % AREA OF HABITAT UNIT WITHIN 2.0 -4.0 FT DEPTH | HABITAT UNIT (HYDRAULIC) DATA |
| | 11g | % AREA OF HABITAT UNIT WITHIN 0.5-4.0 FT DEPTH | HABITAT UNIT (HYDRAULIC) DATA |
| | 11h | IF AN OBJECTIVE, DID THE FEATURE INCREASE/DECREASE WATER DEPTH IN THE TREATMENT AREA? | FEATURE DATA |
| SHELTER | 12a | TARGETED DEPTH OR RANGE (FT) IN HABITAT UNIT | HABITAT UNIT (SHELTER) DATA |
| | 12b | ESTIMATE AREA OF FEATURE WITHIN TARGETED DEPTH OR RANGE $FT^2$: | FEATURE DATA |
| | 13. | WERE THERE ANY UNINTENDED EFFECTS OF THE FEATURE ON THE WATER DEPTH? IF Y, COMMENT. | FEATURE DATA |
| | 14. | INSTREAM SHELTER VALUE IN THE HABITAT UNIT: 0, 1, 2, 3 | HABITAT UNIT (SHELTER) DATA |
| | 15. | PERCENT OF HABITAT UNIT COVERED BY SHELTER: % | HABITAT UNIT (SHELTER) DATA |
| | 16a | 1ST DOMINANT COVER IN HABITAT UNIT: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH | HABITAT UNIT (SHELTER) DATA |
| | 16b | 2ND DOMINANT IN HABITAT UNIT: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH | HABITAT UNIT (SHELTER) DATA |
| | 17a | IF AN OBJECTIVE, DID THE FEATURE INCREASE INSTREAM SHELTER RATING? | FEATURE DATA |
| | 17b | A. CALCULATE THE SHELTER RATING FOR THE HABITAT UNIT: 0-300 | HABITAT UNIT (SHELTER) DATA |
| | 18a | LARGE WOODY DEBRIS COUNT IN HABITAT UNIT: D >1', L 6-20' | HABITAT UNIT (SHELTER) DATA |
| | 18b | LARGE WOODY DEBRIS COUNT IN HABITAT UNIT: D >1', L >20' | HABITAT UNIT (SHELTER) DATA |
| | 19a | IF AN OBJECTIVE, DID THE FEATURE INCREASE LWD COUNT IN THE HABITAT UNIT? | FEATURE DATA |
| | 19b | LWD RECRUITMENT MECHANISMS IN HABITAT UNIT: ANC, EXC, EXH, INT, RPR, UNA, OTH | HABITAT UNIT (SHELTER) DATA |
| CHANNEL | 20. | CURRENT STREAM CHANNEL PROBLEMS IN THE HABITAT UNIT: AGG, BRD, FLO, GRC, HDC, INC, NAR, SCU, STT, WID, NON, OTH | HABITAT UNIT (SHELTER) DATA |
| | 21a | IF AN OBJECTIVE, DID THE FEATURE LEAD TO THE TARGETED CHANNEL CONDITIONS? | FEATURE DATA |
| | 21b | OVERALL OFFCHANNEL CONDITION (SITE): AGG, FPD, GRC, INC, NAR, SIN, STB, TOG, WID, OTH | FEATURE DATA |
| | 21c | OUTLET CONDITIONS (SITE): AGG, FPD, GRC, INC, NAR, SIN, STB, TOG, WID, OTH | FEATURE DATA |
| | 21d | INLET CONDITIONS (SITE): AGG, FPD, GRC, INC, NAR, SIN, STB, TOG, WID, OTH | FEATURE DATA |
| | 22. | WERE THERE ANY UNINTENDED EFFECTS ON THE STREAM CHANNEL AT THE FEATURE? IF Y, COMMENT. | FEATURE DATA |
| VELOCITY | 23. | IF AN OBJECTIVE, DID THE FEATURE DECREASE/INCREASE VELOCITY IN THE TREATMENT AREA? | FEATURE DATA |
| | 24. | TARGETED VELOCITY/RANGE IN THE HABITAT UNIT: (FT/SEC) | HABITAT UNIT (SHELTER) DATA |
| | 25. | DID THE FEATURE ACHIEVE THE TARGETED VELOCITY? | FEATURE DATA |
| | 26a | MEASURED MINIMUM VELOCITY (FT/SEC) IN HABITAT UNIT | HABITAT UNIT (HYDRAULIC) DATA |
| | 26b | MEASURED MAX VELOCITY (FT/SEC) IN HABITAT UNIT | HABITAT UNIT (HYDRAULIC) DATA |
| | 26c | MEASURED MEAN VELOCITY (FT/SEC) IN HABITAT UNIT | HABITAT UNIT (HYDRAULIC) DATA |
| | 27. | AREA OF HABITAT UNIT WITHIN TARGETED VELOCITY: ($FT^2$) | HABITAT UNIT (HYDRAULIC) DATA |
| | 28. | PERCENT OF HABITAT UNIT WITHIN TARGETED VELOCITY (SEE ABOVE): (%) | HABITAT UNIT (HYDRAULIC) DATA |
| | 29. | WERE THERE ANY UNINTENDED EFFECTS OF FEATURE ON VELOCITY IF Y, COMMENT. | FEATURE DATA |
| OTHER | 30a | 1ST/2ND DOMINANT SUBSTRATE IN HABITAT UNIT: BED, BOL, COB, GRV, SND, SLC, OTH | HABITAT UNIT (SHELTER) DATA |
| | 30b | 2ND DOMINANT SUBSTRATE IN HABITAT UNIT: BED, BOL, COB, GRV, SND, SLC, OTH | HABITAT UNIT (SHELTER) DATA |
| | 31. | IF AN OBJECTIVE, DID THE FEATURE ACHIEVE THE TARGETED SUBSTRATE COMPOSITION? | FEATURE DATA |
| | 32. | % CANOPY MEASUREMENT: | HABITAT UNIT (SHELTER) DATA |
| | 33. | PHOTOPOINT DATA COLLECTED: YES /NO | HABITAT UNIT (SHELTER) DATA |
| | 34. | TEMPERATURE PROFILE: YES /NO | HABITAT UNIT (SHELTER) DATA |
| | 35. | DISSOLVED OXYGEN PROFILE: YES/NO | HABITAT UNIT (SHELTER) DATA |
| RATING | 36a | TOTAL HABITAT UNIT AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36b | TOTAL HABITAT UNIT AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36c | TOTAL HABITAT UNIT AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36d | % HABITAT UNIT AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36e | % HABITAT UNIT AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36f | % HABITAT UNIT AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 37. | DOES THIS FEATURE NEED: DEC, ENH, MNT, REP, NON, OTH | FEATURE DATA |
| | 38. | ARE ADDITIONAL RESTORATION TREATMENTS RECOMMENDED AT THIS LOCATION? | FEATURE DATA |

## Table 5.2. 4. In-channel effectiveness monitoring checklist showing original data category from the AMP (left column) and modified data category (right column).

| ORIGINAL DATA CATEGORY | # | QUESTION | MODIFIED DATA CATEGORY |
|---|---|---|---|
| FEATURE | 1. | LENGTH OF TARGETED TREATMENT (FT) | FEATURE DATA |
| | 2. | WIDTH OF TARGETED TREATMENT: (FT) | FEATURE DATA |
| | 3. | ESTIMATE AREA OF THE TARGETED **FEATURE**: ($FT^2$) | FEATURE DATA |
| | 4. | STRUCTURAL CONDITION OF **FEATURE**: EXCL, GOOD, FAIR, POOR, FAIL | FEATURE DATA |
| | 5a | ARE PROBLEMS WITH THE **FEATURE** VISIBLE? | FEATURE DATA |
| | 5b | TYPES: ANC, BBB, CRF, MAT, SHF, STR, SWA, UND, UNS, WSH, OTH | FEATURE DATA |
| | 6a | IS THE **FEATURE** STILL IN ITS ORIGINAL LOCATION? | FEATURE DATA |
| | 6b | IS THE **FEATURE** STILL IN ITS ORIGINAL POSITION? | FEATURE DATA |
| | 6c | IF YES: LBK, MDC, RBK, SPN, OTH | FEATURE DATA |
| | 6d | IS THE **FEATURE** STILL IN ITS ORIGINAL ORIENTATON? | FEATURE DATA |
| | 6e | IF YES: DNS, MUL, PRL, PRP, UPS, OTH | FEATURE DATA |
| DEPTH/HABITAT | 7. | CURRENT LEVEL II HABITAT TYPE: FLT, POO, RIF, DRY, ALC, OTH | HABITAT UNIT (SHELTER) DATA |
| | 8. | IF AN OBJECTIVE, DID THE **FEATURE** CREATE THE TARGETED INSTREAM HABITAT TYPE? | FEATURE DATA |
| | 9. | WERE THERE ANY UNINTENDED EFFECTS BY THE **FEATURE** ON THE HABITAT TYPE? IF Y, COMMENT. | FEATURE DATA |
| | 10. | MEAN WATER DEPTH IN **HABITAT UNIT**: FT | HABITAT UNIT (HYDRAULIC) DATA |
| | 11a | MAXIMUM WATER DEPTH IN **HABITAT UNIT**: FT | HABITAT UNIT (HYDRAULIC) DATA |
| | 11b | AREA OF **HABITAT UNIT** WITHIN 0.5 -2.0 FT DEPTH: (FT2) | HABITAT UNIT (HYDRAULIC) DATA |
| | 11c | AREA OF **HABITAT UNIT** WITHIN 2.0 -4.0 FT DEPTH: (FT2) | HABITAT UNIT (HYDRAULIC) DATA |
| | 11d | AREA OF **HABITAT UNIT** WITHIN 0.5-4.0 FT DEPTH: (FT2) | HABITAT UNIT (HYDRAULIC) DATA |
| | 11e | % AREA OF **HABITAT UNIT** WITHIN 0.5 -2.0 FT DEPTH | HABITAT UNIT (HYDRAULIC) DATA |
| | 11f | % AREA OF **HABITAT UNIT** WITHIN 2.0 -4.0 FT DEPTH | HABITAT UNIT (HYDRAULIC) DATA |
| | 11g | % AREA OF **HABITAT** UNIT WITHIN 0.5-4.0 FT DEPTH | HABITAT UNIT (HYDRAULIC) DATA |
| | 11h | IF AN OBJECTIVE, DID THE **FEATURE** INCREASE/DECREASE WATER DEPTH IN THE TREATMENT AREA? | FEATURE DATA |
| SHELTER | 12a | TARGETED DEPTH OR RANGE (FT) IN **HABITAT UNIT** | HABITAT UNIT (SHELTER) DATA |
| | 12b | ESTIMATE AREA OF **FEATURE** WITHIN TARGETED DEPTH OR RANGE $FT^2$: | FEATURE DATA |
| | 13. | WERE THERE ANY UNINTENDED EFFECTS OF THE **FEATURE** ON THE WATER DEPTH? IF Y, COMMENT. | FEATURE DATA |
| | 14. | INSTREAM SHELTER VALUE IN THE **HABITAT UNIT**: 0, 1, 2, 3 | HABITAT UNIT (SHELTER) DATA |
| | 15. | PERCENT OF **HABITAT UNIT** COVERED BY SHELTER: % | HABITAT UNIT (SHELTER) DATA |
| | 16a | 1ST DOMINANT COVER IN **HABITAT UNI**T: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH | HABITAT UNIT (SHELTER) DATA |
| | 16b | 2ND DOMINANT IN **HABITAT UNIT**: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH | HABITAT UNIT (SHELTER) DATA |
| | 17a | IF AN OBJECTIVE, DID THE **FEATURE** INCREASE INSTREAM SHELTER RATING? | FEATURE DATA |
| | 17b | A. CALCULATE THE SHELTER RATING FOR THE **HABITAT UNIT**: 0-300 | HABITAT UNIT (SHELTER) DATA |
| | 18a | LARGE WOODY DEBRIS COUNT IN **HABITAT UNIT**: D >1', L 6-20' | HABITAT UNIT (SHELTER) DATA |
| | 18b | LARGE WOODY DEBRIS COUNT IN **HABITAT UNIT**: D >1', L >20' | HABITAT UNIT (SHELTER) DATA |
| | 19a | IF AN OBJECTIVE, DID THE **FEATURE** INCREASE LWD COUNT IN THE **HABITAT UNIT**? | FEATURE DATA |
| | 19b | LWD RECRUITMENT MECHANISMS IN **HABITAT UNIT**: ANC, EXC, EXH, INT, RPR, UNA, OTH | HABITAT UNIT (SHELTER) DATA |
| CHANNEL | 20. | CURRENT STREAM CHANNEL PROBLEMS IN THE **HABITAT UNIT**: AGG, BRD, FLO, GRC, HDC, INC, NAR, SCU, STT, WID, NON, OTH | HABITAT UNIT (SHELTER) DATA |
| | 21a | IF AN OBJECTIVE, DID THE **FEATURE** LEAD TO THE TARGETED CHANNEL CONDITIONS? | FEATURE DATA |
| | 21b | CONDITIONS AT THE **FEATURE**: AGG, FPD, GRC, INC, NAR, SIN, STB, TOG, WID, OTH | FEATURE DATA |
| | 22. | WERE THERE ANY UNINTENDED EFFECTS ON THE STREAM CHANNEL AT THE **FEATURE**? IF Y, COMMENT. | FEATURE DATA |
| VELOCITY | 23. | IF AN OBJECTIVE, DID THE **FEATURE** DECREASE/INCREASE VELOCITY IN THE TREATMENT AREA? | FEATURE DATA |
| | 24. | TARGETED VELOCITY/RANGE IN THE **HABITAT UNIT**: (FT/SEC) | HABITAT UNIT (SHELTER) DATA |
| | 25. | DID THE **FEATURE** ACHIEVE THE TARGETED VELOCITY? | FEATURE DATA |
| | 26a | MEASURED MINIMUM VELOCITY (FT/SEC) IN **HABITAT UNIT** | HABITAT UNIT (HYDRAULIC) DATA |
| | 26b | MEASURED MAX VELOCITY (FT/SEC) IN **HABITAT UNIT** | HABITAT UNIT (HYDRAULIC) DATA |
| | 26c | MEASURED MEAN VELOCITY (FT/SEC) IN **HABITAT UNIT** | HABITAT UNIT (HYDRAULIC) DATA |
| | 27. | AREA OF **HABITAT UNIT** WITHIN TARGETED VELOCITY: ($FT^2$) | HABITAT UNIT (HYDRAULIC) DATA |
| | 28. | PERCENT OF **HABITAT UNIT** WITHIN TARGETED VELOCITY (SEE ABOVE): (%) | HABITAT UNIT (HYDRAULIC) DATA |
| | 29. | WERE THERE ANY UNINTENDED EFFECTS OF **FEATURE** ON VELOCITY IF Y, COMMENT. | FEATURE DATA |
| OTHER | 30a | 1ST/2ND DOMINANT SUBSTRATE IN **HABITAT UNIT**: BED, BOL, COB, GRV, SND, SLC, OTH | HABITAT UNIT (SHELTER) DATA |
| | 30b | 2ND DOMINANT SUBSTRATE IN **HABITAT UNIT**: BED, BOL, COB, GRV, SND, SLC, OTH | HABITAT UNIT (SHELTER) DATA |
| | 31. | IF AN OBJECTIVE, DID THE **FEATURE** ACHIEVE THE TARGETED SUBSTRATE COMPOSITION? | FEATURE DATA |
| | 32. | % CANOPY MEASUREMENT: | HABITAT UNIT (SHELTER) DATA |
| | 33. | PHOTOPOINT DATA COLLECTED: YES /NO | HABITAT UNIT (SHELTER) DATA |
| | 34. | TEMPERATURE PROFILE: YES /NO | HABITAT UNIT (SHELTER) DATA |
| | 35. | DISSOLVED OXYGEN PROFILE: YES/NO | HABITAT UNIT (SHELTER) DATA |
| RATING | 36a | TOTAL **HABITAT UNIT** AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36b | TOTAL **HABITAT UNIT** AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36c | TOTAL **HABITAT UNIT** AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36d | % **HABITAT UNIT** AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36e | % **HABITAT UNIT** AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 36f | % **HABITAT UNIT** AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP | HABITAT UNIT (HYDRAULIC) DATA |
| | 37. | DOES THIS **FEATURE** NEED: DEC, ENH, MNT, REP, NON, OTH | FEATURE DATA |
| | 38. | ARE ADDITIONAL RESTORATION TREATMENTS RECOMMENDED AT THIS LOCATION? | FEATURE DATA |

## Feature Ratings

From the modified checklists, we reduced the number of questions used to rate each enhancement feature to focus on feature condition, function, and apparent effect on habitat. The modified checklists for off- and in-channel areas contain up to 30 questions in the feature data category, including questions with multiple parts (e.g., Question 21; Table 5.2.3 and Table 5.2.4). We reduced the list to 11 questions with each response assigned a numeric score (Table 5.2.5). The sum of the numeric scores for each feature (up to 15 points) corresponds to a qualitative rating ranging from excellent to fail. We used the reduced list to score and rate each feature, but still answered the full list of questions for each feature (see completed checklists in Appendices). The full list provides ancillary qualitative information beyond the reduced list, but the reduced list directly evaluates feature condition, function, and effect on habitat, and is more efficient given the number of features in the Dry Creek Habitat Enhancement Project (>500 as of August 2019) and the number of feature data questions in the original and modified AMP checklists.

## Habitat Unit Ratings

We also reduced the number of questions used to rate habitat units to focus on area of hydraulic habitat and shelter data and to directly evaluate performance relative to primary performance measures (Table 5.2.6). The modified checklists for off- and in-channel areas each contain 40 habitat unit data questions, including questions with multiple parts (e.g., Question 16; Table 5.2.3 and Table 5.2.4). The reduced list of habitat unit data questions includes shelter value, percent overhead cover, and the calculated shelter score, with each response assigned a numeric score (Table 5.2.6). The reduced list of habitat unit data questions also includes the percent area of a habitat unit within optimal depth (0.5–2.0 ft; 2.0–4.0 ft) and velocity (≤0.5 ft/s) ranges, both singly and in combination, as specified in the BO and AMP, each assigned a numeric score (Table 5.2.6). The sum of the numeric scores for habitat units (up to 35 points) determines a qualitative rating ranging from excellent to fail. As with feature data, we still answered the full list of questions for each habitat unit (see completed checklists in Appendix 5.1). But, the reduced list directly evaluates habitat unit shelter and hydraulic habitat, which are primary performance measures in the AMP, and is more efficient given the number of habitat units evaluated for the Dry Creek Habitat Enhancement Project (>700 as of August 2019) and the number of habitat unit data questions in the original and modified AMP checklists.

**Table 5.2. 5. Feature data questions used to rate each enhancement feature, the highest numerical score assigned to each response, and the qualitative rating assigned to the range of quantitative ratings.**

| Question # | Question | Highest possible score |
|---|---|---|
| 4. | Structural condition of feature[a] | 5 |
| 5a | Are problems with the feature visible?[b] | 1 |
| 6a | Is the feature still in its original location?[c] | 1 |
| 6b | Is the feature still in its original position?[c] | 1 |
| 6d | Is the feature still in its original orientation?[c] | 1 |
| 8. | Did the feature create the targeted instream habitat type?[c] | 1 |
| 9. | Were there any unintended effects by the feature on the habitat type?[b] | 1 |
| 17a | Did the feature increase instream shelter rating?[c] | 1 |
| 19a | Did the feature increase LWD count in the habitat unit?[c] | 1 |
| 21a | Did the feature lead to the targeted channel conditions?[c] | 1 |
| 25. | Did the feature achieve the targeted velocity?[c] | 1 |
| **Feature quantitative rating** | **(sum of above)** | **15** |
| **Feature qualitative rating: Excellent (≥12), Good (≥9), Fair (≥6), Poor (≥3), Fail (<3)** | | **Excellent** |

[a]Excellent = 5 points; Good = 4 point; Fair = 3 points; Poor = 2 points; Fail = 1 point
[b]Yes = 0 points; No = 1 point
[c]Yes = 1 point; No = 0 points

**Table 5.2. 6. Habitat unit data questions used to rate each habitat unit, the highest numerical score assigned to each response, and the qualitative rating assigned to the range of quantitative ratings.**

| Question # | Question | Highest possible score |
|---|---|---|
| 11e | % Area of **habitat unit** within 0.5 -2.0 ft depth[a] | 4 |
| 11f | % Area of **habitat unit** within 2.0 -4.0 ft depth[a] | 4 |
| 14. | Instream shelter value in the **habitat unit**: 0, 1, 2, 3[b] | 5 |
| 15. | Percent of **habitat unit** covered by shelter: %[c] | 5 |
| 17b | a. Calculate the shelter rating for the **habitat unit**: 0-300[d] | 5 |
| 28. | Percent of **habitat unit** within targeted velocity (see above): (%)[a] | 4 |
| 36e | % **habitat unit** area where < 0.5 f/s; 0.5 to 2 ft and shelter criteria overlap[a] | 4 |
| 36f | % **habitat unit** area where < 0.5 f/s; 2 to 4 ft and shelter criteria overlap[a] | 4 |
| **Habitat unit quantitative rating (out of 35)** | **(sum of above)** | **35** |
| **Habitat unit qualitative rating: Excellent (>=28), Good (>=21), Fair (>=14), Poor (>=7), Fail (<7)** | | **Excellent** |

[a]≥40% = 4 points; ≥30% = 3 points; ≥20% = 2 points; ≥10% = 1 point, ; ≥5% = 0 points
[b]3 = 5 points; 2 = 4 points, 1 = 3 points, 0 = 0 points
[c]≥80% = 5 points; ≥60% = 4 points; ≥40% = 3 points; ≥20% = 2 points; ≥10% = 1 point; <10% = 0 points
[d]≥140 = 5 points; ≥100 = 4 points; ≥80 = 3 points; ≥60 = 2 points; ≥40 = 1 point; <40 = 0 points

## Site and Enhancement Reach Ratings

Data collected at the feature and habitat unit scale provide the basis to evaluate and rate sites and enhancement reaches (Table 5.2.7). The sum of the site average feature and site average habitat unit ratings determines the site quantitative rating (up to 50 points), which is converted to a site qualitative rating, ranging from excellent to fail, similar to ratings for features and habitat units. Following the upward progression of spatial scales, the average of all sites within an enhancement reach determines the enhancement reach quantitative and qualitative ratings (Table 5.2.7).

**Table 5.2. 7. Spatial roll-up of site average feature and habitat unit ratings into site and enhancement reach rating using an enhancement reach with three sites as an example. The sum of the site average feature and habitat unit ratings determine the site quantitative and qualitative rating. The average of site ratings determines the enhancement reach quantitative and qualitative rating.**

| | **Site number** | **1** | **2** | **3** |
|---|---|---|---|---|
| **Site average feature rating** | Site average feature quantitative rating[a] | 15 | 15 | 15 |
| | Site average feature qualitative rating[a] | Excellent | Excellent | Excellent |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 35 | 35 | 35 |
| | Site average qualitative rating[b] | Excellent | Excellent | Excellent |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | 50 | 50 | 50 |
| | Site qualitative rating[c]: | Excellent | Excellent | Excellent |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[c] | 50 | | |
| | Enhancement reach qualitative rating[c]: | Excellent | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

## Monitoring Frequency

The AMP recommended monitoring sites at three different time periods: prior to enhancement (pre-enhancement), just after enhancement (post-enhancement), and following a geomorphically effective flow (post-effective flow) (Porter et al. 2014). Pre-enhancement surveys include depth, velocity, habitat type and shelter value, but do not include feature data, as feature installation occurs during construction. Accordingly, pre-enhancement site and enhancement reach ratings do not include feature ratings. Post-enhancement surveys occur after construction and include quantitative ratings and qualitative ratings of all spatial scales (feature, habitat unit, site, and enhancement reach). The AMP also recommends collecting data after a geomorphically effective flow (the flow [discharge] responsible for transporting the largest volume of sediment in a river or stream over the long-term). In the absence of a geomorphically effective discharge, the AMP recommends collecting data within three years after construction (Porter et al. 2014). Inter-Fluve (2013) found that the geomorphically effective flow in Dry Creek occurred at a return period of less than one year (i.e., annually or sub-annually). Following this, post-effective flow surveys typically occurred the following spring or summer after construction. After the initial post-effective flow survey, Sonoma Water surveys each site every three years.

We also added a post-repair monitoring time-period. The AMP recommends future outcomes (actions) for enhancement reaches receiving low ratings (fair to fail) that range from corrective action (repair or modification) to a reduction in potential habitat credit, to abandonment of features, sites, or enhancement reaches (Table 5.2.2). If Sonoma Water repaired or modified a site, we conducted post-repair effectiveness monitoring shortly after repairs or modifications. We added post-repair to the monitoring frequency categories to differentiate from post-enhancement monitoring that occurs after a site is newly constructed. We will include this category as necessary in future monitoring reports.

# Results

During the summer and fall 2018, Sonoma Water effectiveness monitored seven enhancement reaches totaling over 800,000 $ft^2$ on mainstem Dry Creek, side channels, and alcoves (Table 5.2.8, Figure 5.2.4). Fields crews collected over 25,000 depth and velocity points, evaluated 490 features for their condition, and evaluated 158 habitat units for their hydraulic (depth and velocity) and shelter characteristics. The monitored enhancement reaches stretch from Reach 2b (as defined by Inter-Fluve 2012, River Mile [RM] 1.67) to Reach 14b (RM 12.00) (Figure 5.2.4). We monitored and rated the pre- and post-enhancement conditions of three newly constructed enhancement reaches (Army Corps Reach 14, Weinstock, and Ferrari, Carano-Olson; see Pre-Enhancement and Post-enhancement results below), monitored and rated the pre-enhancement condition of the Gallo enhancement reach, scheduled for construction in 2019 (see Pre-Enhancement results below), and monitored and rated five enhancement reaches post-effective flow (Truett-Hurst, Meyer, Carlson, Lonestar, City of Healdsburg, and Geyser Peak; see Post-effective flow results below). Sonoma Water constructed the Carlson, Lonestar and City of Healdsburg enhancement reaches in 2017 and this is the first post-effective flow effectiveness monitoring survey for both enhancement reaches. Sonoma Water constructed the Truett Hurst, Meyer, and Geyser Peak enhancement reaches in 2016. Several large storms in 2016/2017, followed by sustained flood control releases from Warm Springs Dam led to substantial aggradation in Truett Hurst, Meyer, and Geyser Peak enhancement reaches and fair to poor enhancement reach ratings (see 2017 report for results). Sonoma Water repaired and modified these enhancement reaches in October 2017, and crews monitored and rated the enhancement reaches shortly after (see 2017 report for results). The 2018 post-effective flow results for Truett Hurst, Meyer, and Geyser Peak enhancement reaches summarize habitat conditions post-2017 repairs.

The results below summarize effectiveness monitoring results for each monitoring time period (pre- and post-enhancement, and post-effective flow; we did not conduct any post-repair monitoring) by enhancement reach. Each summary describes the amount of habitat monitored within each main and side channel area, the area and percent of the enhancement reach meeting depth and velocity criteria, habitat types, shelter scores, and pool to riffle ratio. We also summarize the feature and habitat unit ratings that inform the site ratings, and the roll-up of site ratings into the enhancement reach rating.

**Table 5.2. 8. Creek enhancement reaches monitored in 2018, type of monitoring conducted, and area of aquatic habitat monitored. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River) (-- indicates monitoring not conducted).**

| Enhancement reach | Pre-enhancement ($ft^2$) | Post-enhancement ($ft^2$) | Post-effective Flow ($ft^2$) | Post-repair ($ft^2$) |
|---|---|---|---|---|
| Army Corps Reach 14 | 52,393 | 77,783 | -- | -- |
| Weinstock | 42,134 | 46,693 | -- | -- |
| Gallo | 49,138 | -- | -- | -- |
| Truett Hurst | -- | -- | 84,943 | -- |
| Meyer | -- | -- | 47,569 | -- |
| Carlson Lonestar | -- | -- | 56,120 | -- |
| Ferrari-Carano Olson | 96,264 | 151,027 | -- | -- |
| City of Healdsburg Yard | -- | -- | 70,852 | -- |
| Geyser Peak | -- | -- | 35,758 | -- |
| **TOTAL ($ft^2$)** | **239,930** | **275,502** | **295,242** | -- |
| **GRAND TOTAL ($ft^2$)** | **810,674** | | | |

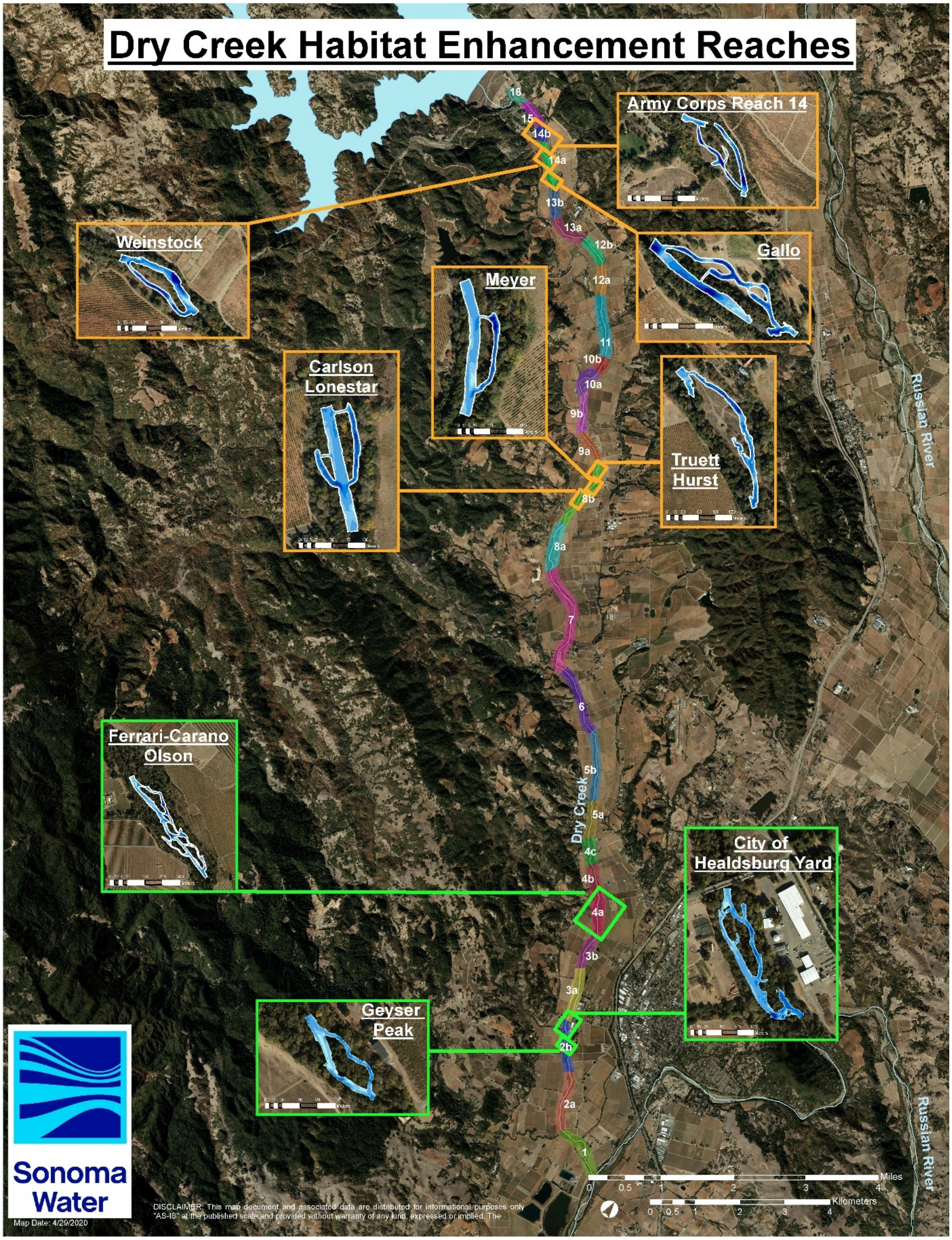


**Figure 5.2.1. Location of Dry Creek habitat enhancement reaches monitored in 2018.**

# Pre-enhancement

## Summary

Sonoma Water monitored the pre-enhancement condition of the Army Corps Reach 14, Weinstock, Gallo, and Ferrari-Carano, Olson reaches in 2018 (Table 5.2.8, Figure 5.2.4). Overall, the pre-enhanced reaches covered 239,930 $ft^2$ within the main channel of Dry Creek, with 20% meeting the optimal depth and velocity criteria (Table 5.2.9). Crews recorded 31 habitat units across all enhancement reaches with a total pool to riffle ratio of 14:9 (1.55) and a total average shelter score of 69 (Table 5.2.10). Alcove average shelter score exceeded (85) the optimum shelter value of 80, but no other habitat unit averaged or exceeded the optimum shelter value. Pre-enhancement, all enhancement reaches monitored in 2018 rated fair (Table 5.2.11; see below for individual enhancement reach summaries and Appendix 5.1 for all measured values, scores, and ratings).

### *Depth and velocity*

**Table 5.2. 9. Pre-enhancement areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches constructed in 2018.**

| Dry Creek enhancement reach | Wetted area | Optimal depth 0.5 – 2.0 ft | Optimal depth 2.0 – 4.0 ft | Optimal depth Total | Optimal velocity < 0.5 ft/s | Optimal habitat 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 239,930 $ft^2$ | 119,756 $ft^2$ | 52,885 $ft^2$ | 172,641 $ft^2$ | 83,565 $ft^2$ | 34,211 $ft^2$ | 14,163 $ft^2$ | 48,374 $ft^2$ |
| Main channel % of wetted area | 100% | 50% | 22% | 72% | 35% | 14% | 6% | 20% |

### *Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 10. Pre-enhancement habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches constructed in 2018.**

| Habitat Type | # of Habitat Units | Shelter Score |
|---|---|---|
| Riffle | 9 | 52 |
| Pool | 14 | 83 |
| Flatwater | 6 | 58 |
| Alcove | 2 | 85 |
| **Pool: riffle** | **14:9 (1.55)** | **Avg = 69** |

### *Reach ratings*

**Table 5.2. 11. Pre-enhancement ratings for Carlson, Lonestar and City of Healdsburg Yard enhancement reaches in 2018.**

| Enhancement Reach | Pre-enhancement Rating |
|---|---|
| Army Corps Reach 14 | Fair |
| Weinstock | Fair |
| Gallo | Fair |
| Ferrari, Carano, Olson | Fair |

## Army Corps Reach 14 Enhancement Reach

Sonoma Water monitored the pre-enhancement condition of the Army Corps Reach 15 enhancement reach in May 2018. The reach covered 52,393 ft$^2$ within the main channel of Dry Creek, with 18% meeting optimal depth and velocity criteria, mostly along the channel margins (Table 5.2.12, Figure 5.2.5). Seven habitat units made up the enhancement reach, with a pool to riffle ratio of 3:3 (1.00) and an average shelter score of 56 (Table 5.2.13, Figure 5.2.6, Figure 5.2.7). One habitat unit [HU05, riffle] met or exceeded the optimal shelter value of 80. The reach comprised one mainstem enhancement site with fair habitat unit ratings and fair overall reach rating (Table 5.2.14, Figure 5.2.8, Figure 5.2.9; see Appendix 5.1 for all measured values, scores, and ratings).

### *Depth and velocity*

**Table 5.2. 12. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Army Corps Reach 14 enhancement reach, May 2018.**

| Army Corps Reach 14 Pre-enhancement May 2018 | Wetted area | Optimal depth 0.5 – 2.0 ft | Optimal depth 2.0 – 4.0 ft | Optimal depth Total | Optimal velocity < 0.5 ft/s | Optimal habitat 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 52,393 ft$^2$ | 24,797 ft$^2$ | 14,689 ft$^2$ | 39,486 ft$^2$ | 17,958 ft$^2$ | 5,212 ft$^2$ | 3,959 ft$^2$ | 9,171 ft$^2$ |
| Main channel % of wetted area | 100% | 47% | 28% | 75% | 34% | 10% | 8% | 18% |

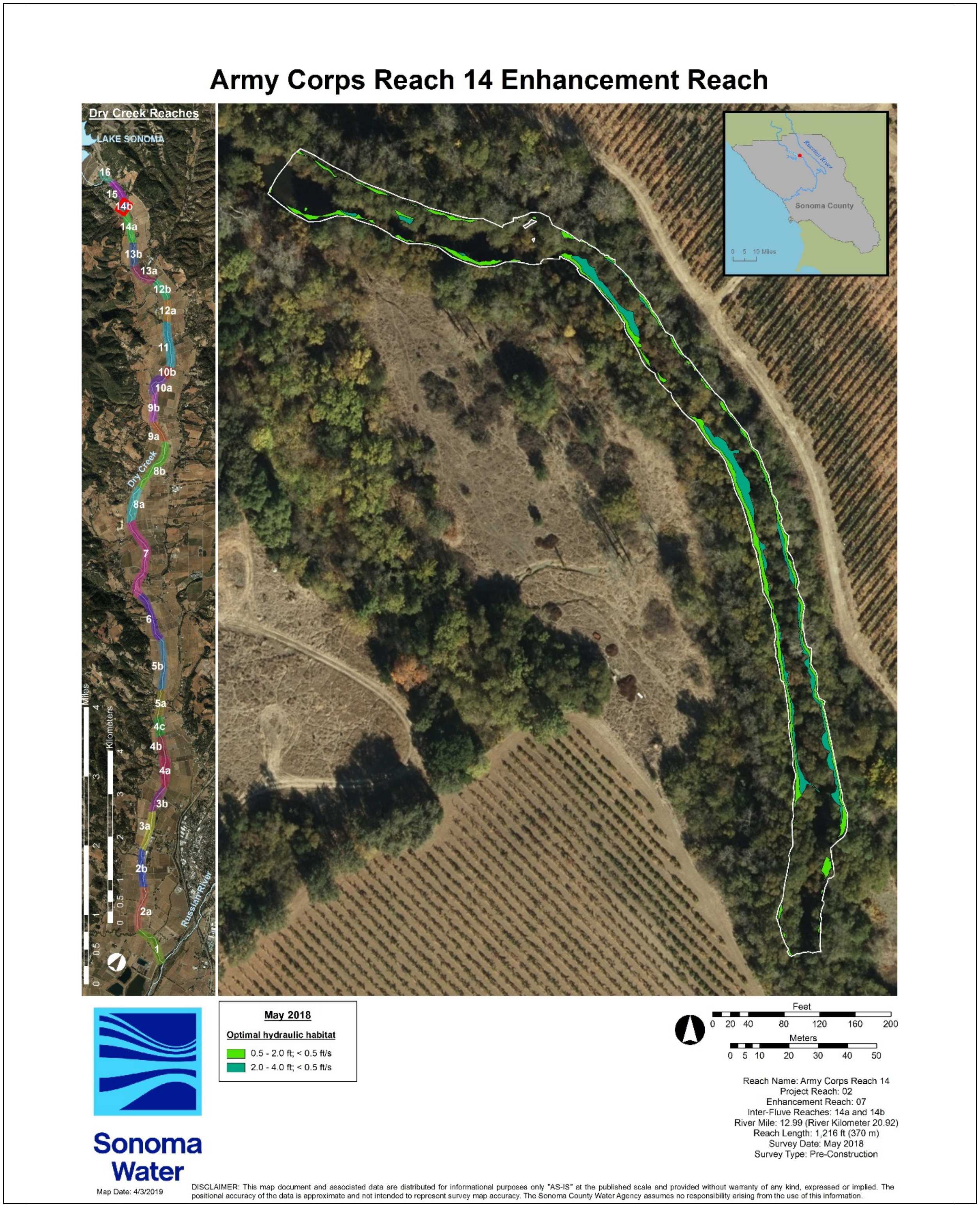


**Figure 5.2.2. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Army Corps Reach 14 enhancement reach, May 2018.**

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 13. Habitat, types, shelter score, percent cover, and shelter value for main channel habitat units within the Army Corps Reach 14 enhancement reach, May 2018, pre-enhancement.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Riffle | 2 | 15 | 30 |
| HU02 | Pool | 3 | 20 | 60 |
| HU03 | Riffle | 1 | 10 | 10 |
| HU04 | Pool | 3 | 25 | 75 |
| HU05 | Riffle | 3 | 40 | 120 |
| HU06 | Pool | 3 | 15 | 45 |
| HU07 | Flatwater | 2 | 25 | 50 |
| **Pool: riffle** | **3: 3 (1.00)** | | | **Avg = 56** |

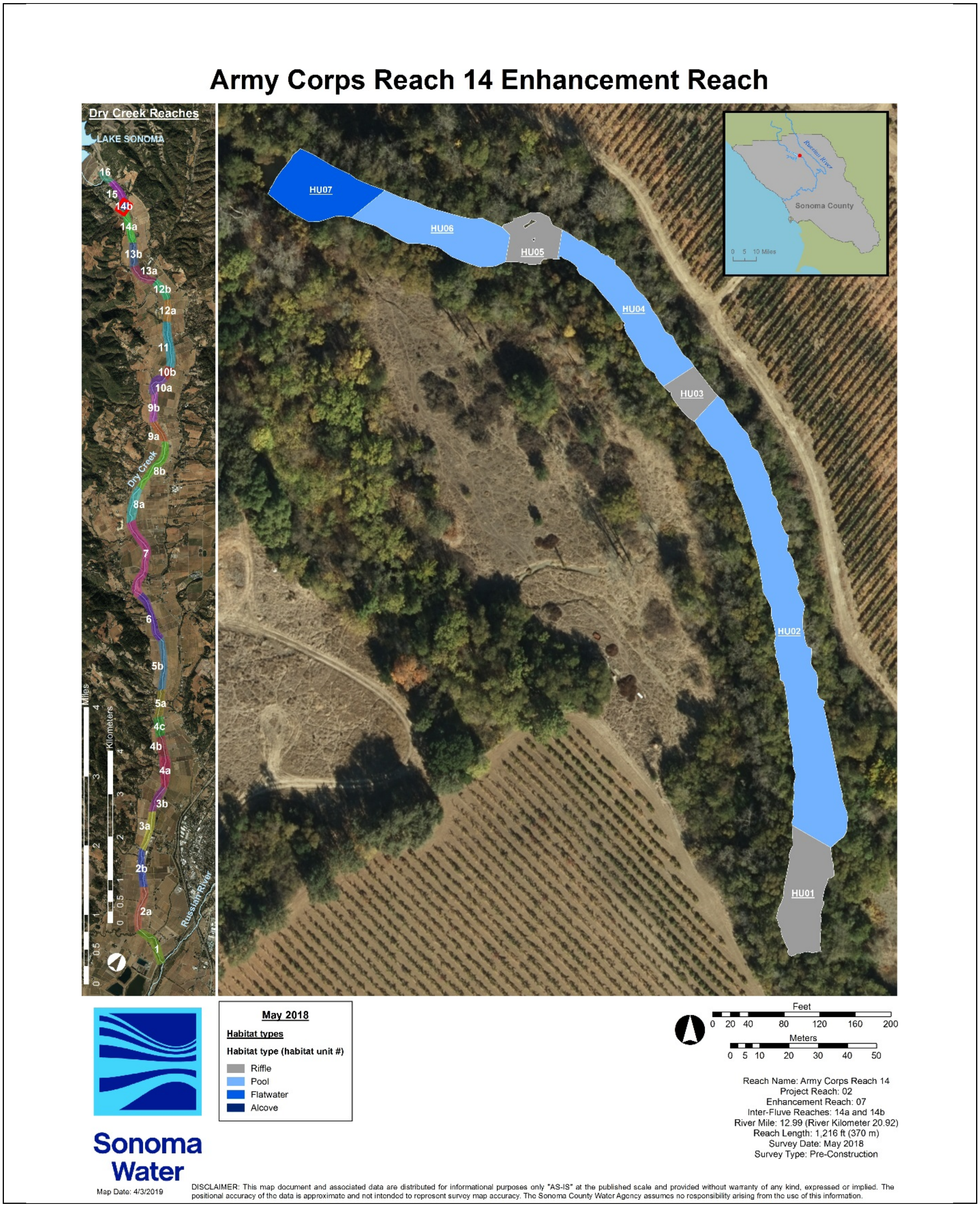


**Figure 5.2.3. Habitat unit number and type within the Army Corps Reach 14 enhancement reach, May 2018.**

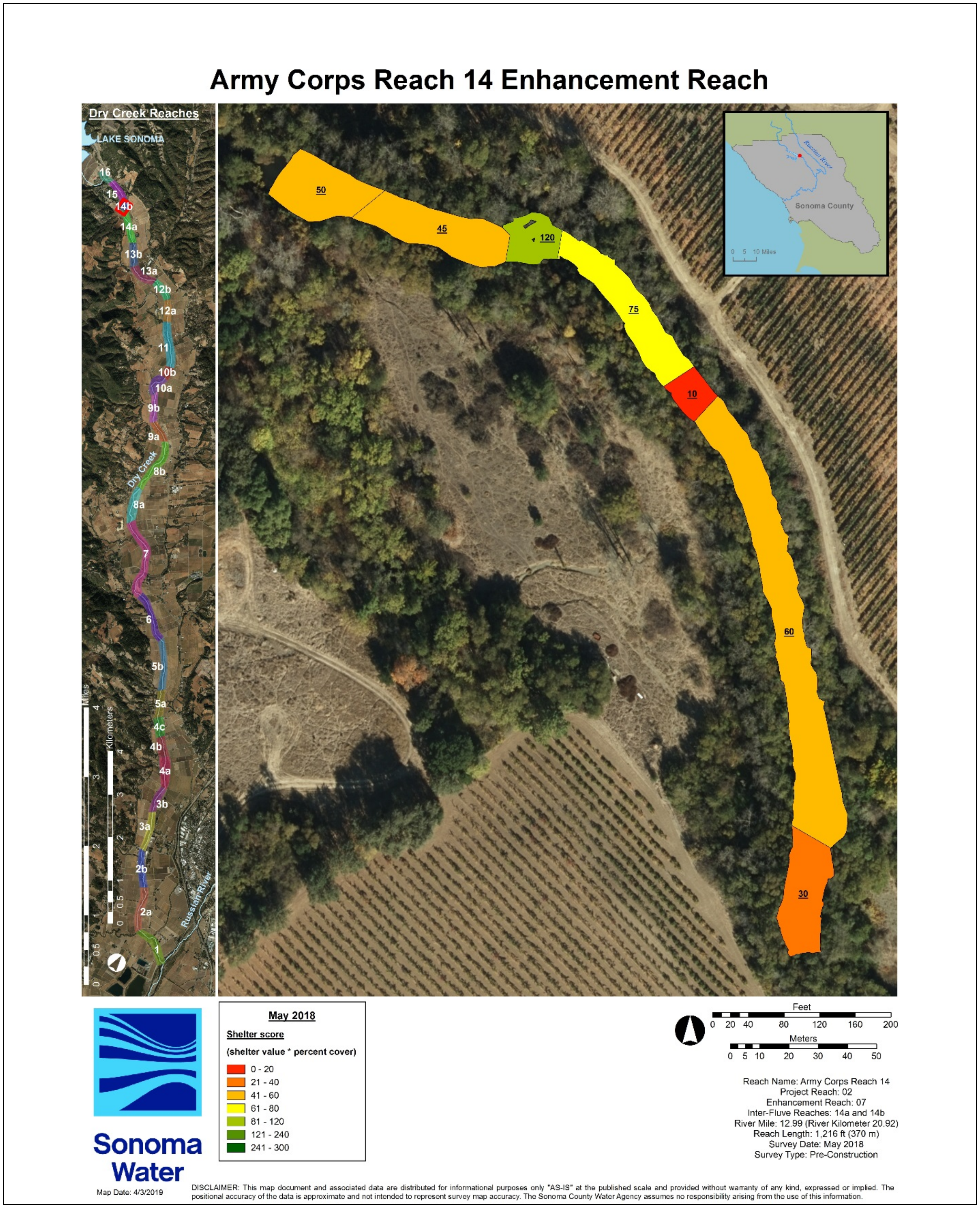


**Figure 5.2.4. Habitat unit shelter values within the Army Corps Reach 14 enhancement reach, May 2018.**

*Habitat unit, site, and reach ratings*

**Table 5.2. 14. Pre-enhancement average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the for the Army Corps Reach 14 enhancement reach, May 2018.**

| **Site number** | | **1** | | | |
|---|---|---|---|---|---|
| **Site type** | | Main channel | | | |
| **Site average feature rating** | Site average feature quantitative rating[a] | 0 | | | |
| | Site average feature qualitative rating[a] | Not rated | | | |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 15 | | | |
| | Site average qualitative rating[b] | Fair | | | |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | **15** | | | |
| | Site qualitative rating[c] | Fair | | | |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[c] | 15 | | | |
| | Enhancement reach qualitative rating[c]: | Fair | | | |

[a]not included in rating
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)

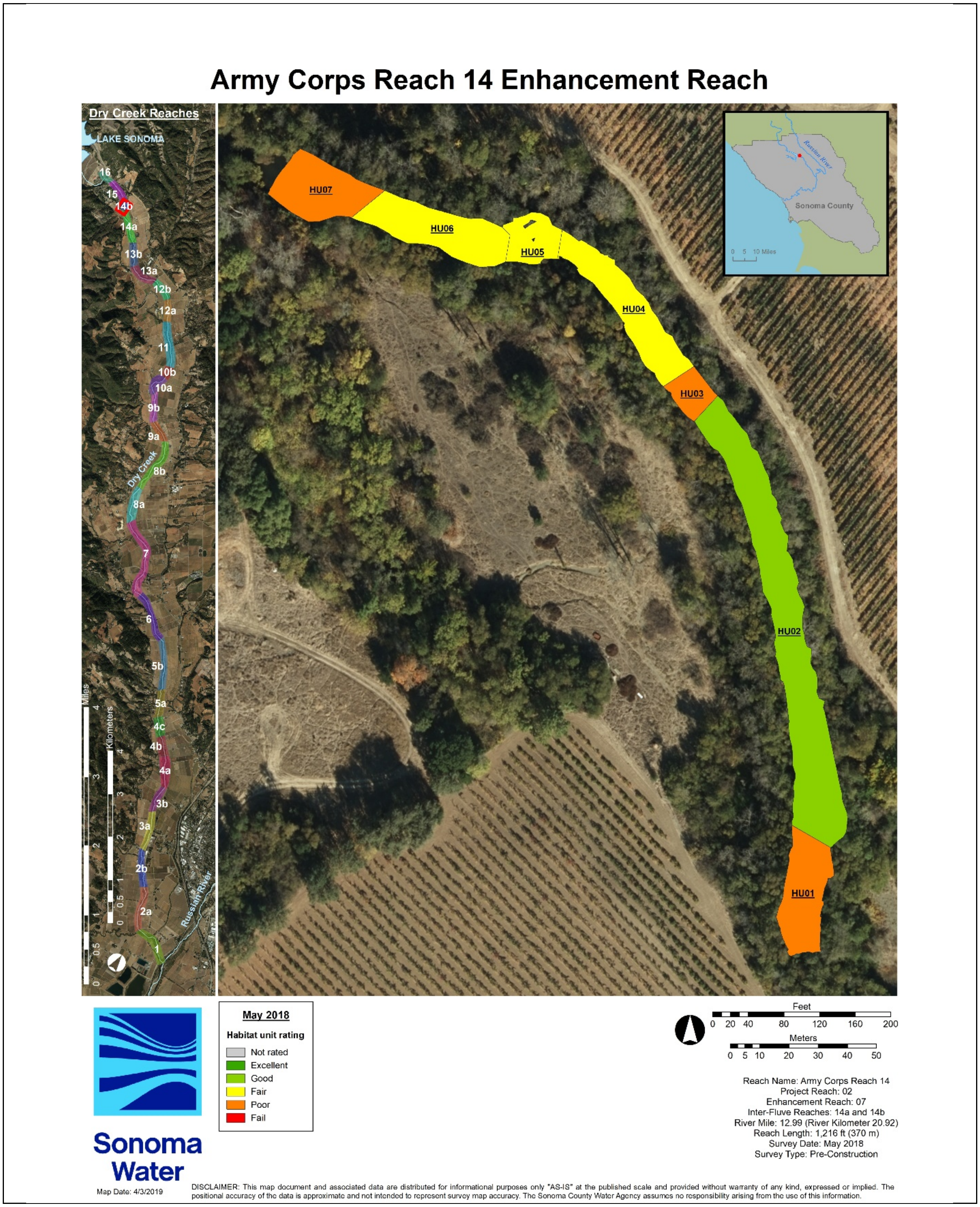


**Figure 5.2.5. Habitat unit ratings for the Army Corps Reach 14 enhancement reach, May 2018.**

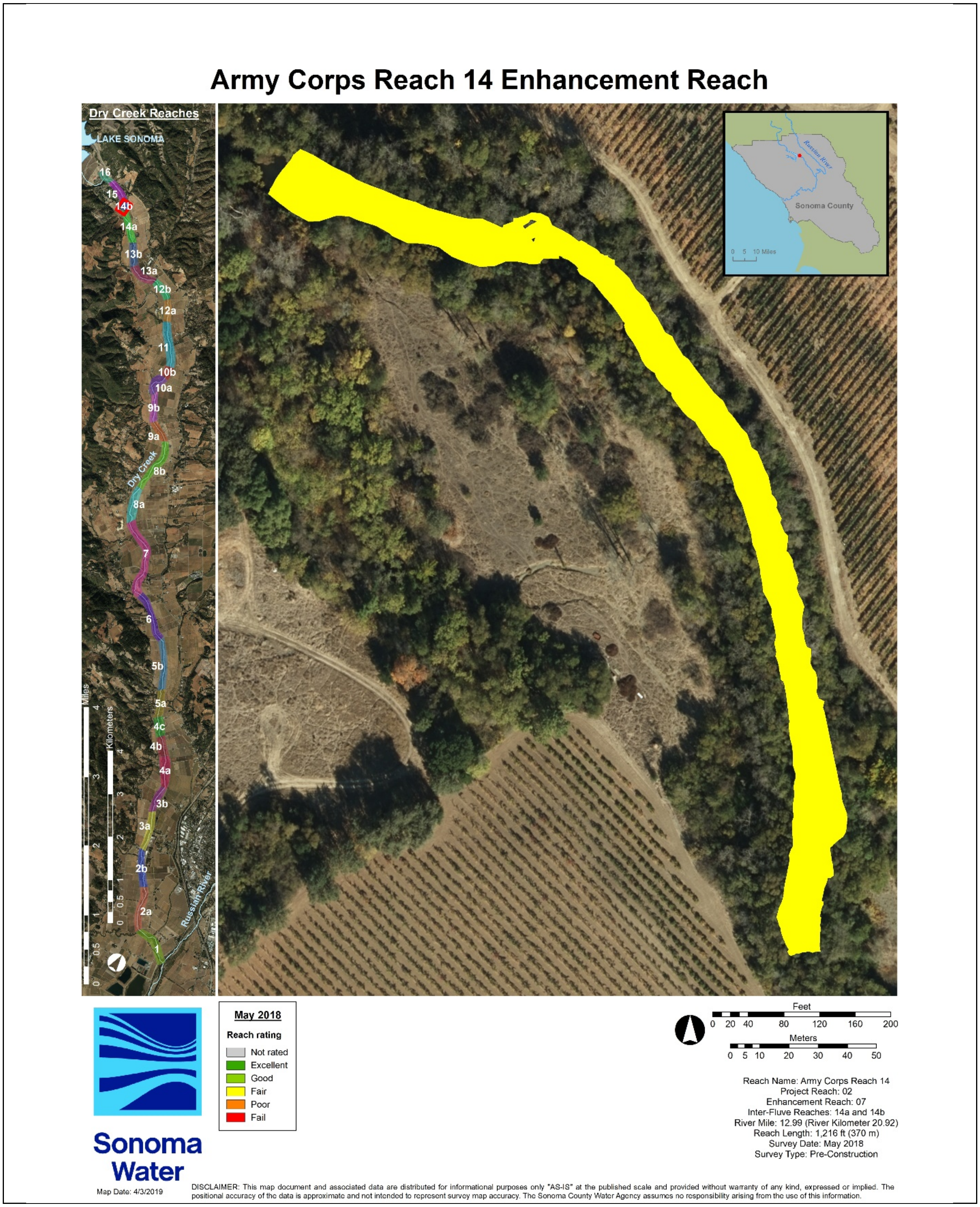


**Figure 5.2.6. Pre-enhancement site and reach rating for the Army Corps Reach 14 enhancement reach May 2018.**

## Weinstock Enhancement Reach

Sonoma Water monitored the pre-enhancement condition of the Weinstock enhancement reach in July 2018. The reach covered 42,134 $ft^2$ within the main channel of Dry Creek, with 24% meeting optimal depth and velocity criteria, mostly along the channel margins (Table 5.2.15, Figure 5.2.10). Six habitat units made up the enhancement reach, with a pool to riffle ratio of 4: 1 (4.00) and an average shelter score of 58 (Table 5.2.16, Figure 5.2.11, Figure 5.2.12). Two habitat units met or exceeded the optimal shelter score of 80. The enhancement reach comprised a main channel enhancement site with fair habitat unit ratings and a fair overall enhancement reach rating (Table 5.2.17, Figure 5.2.13, Figure 5.2.14; see Appendix 5.1 for all measured values, scores, and ratings).

### *Depth and velocity*

**Table 5.2. 15. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Weinstock enhancement reach, July 2018.**

| Weinstock Pre-enhancement July 2018 | Wetted area | Optimal depth 0.5 – 2.0 ft | Optimal depth 2.0 – 4.0 ft | Optimal depth Total | Optimal velocity < 0.5 ft/s | Optimal habitat 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 42,134 $ft^2$ | 17,161 $ft^2$ | 16,899 $ft^2$ | 34,059 $ft^2$ | 15,795 $ft^2$ | 6,735 $ft^2$ | 3,518 $ft^2$ | 10,253 $ft^2$ |
| Main channel % of wetted area | 100% | 41% | 40% | 81% | 37% | 16% | 8% | 24% |

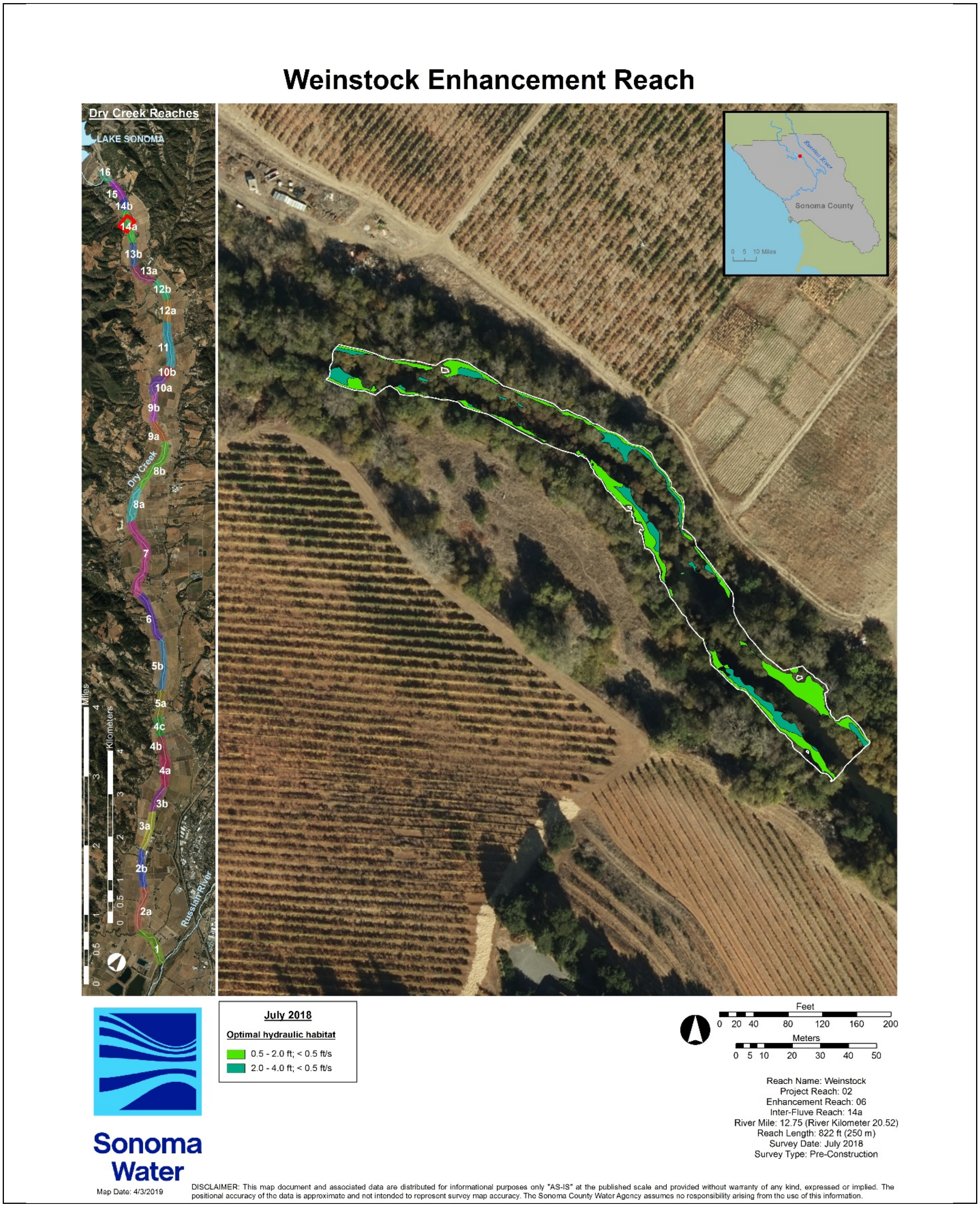


**Figure 5.2.7. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Weinstock enhancement reach, July 2018.**

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 16. Habitat, types, shelter score, percent cover, and shelter value for main channel habitat units within the Weinstock enhancement reach, July 2018, pre-enhancement.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Pool | 1 | 15 | 15 |
| HU02 | Riffle | 2 | 35 | 70 |
| HU03 | Pool | 3 | 40 | 120 |
| HU04 | Flatwater | 2 | 20 | 40 |
| HU05 | Pool | 3 | 30 | 90 |
| HU06 | Pool | 1 | 15 | 15 |
| **Pool: riffle** | **4: 1 (4.00)** | | | **Avg = 58** |

# Weinstock Enhancement Reach

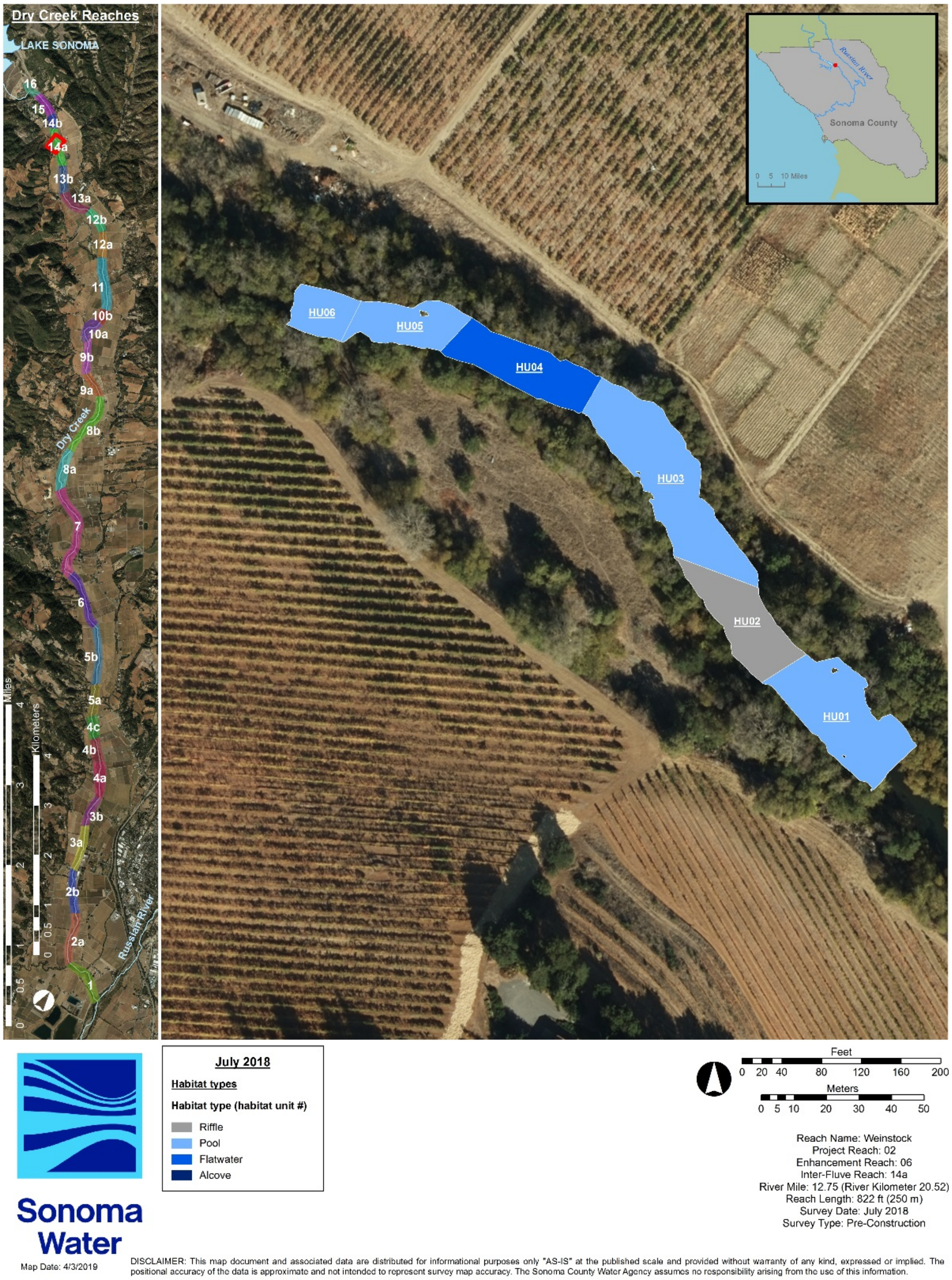


**Figure 5.2.8. Habitat unit number and type within the Weinstock enhancement reach, July 2018.**

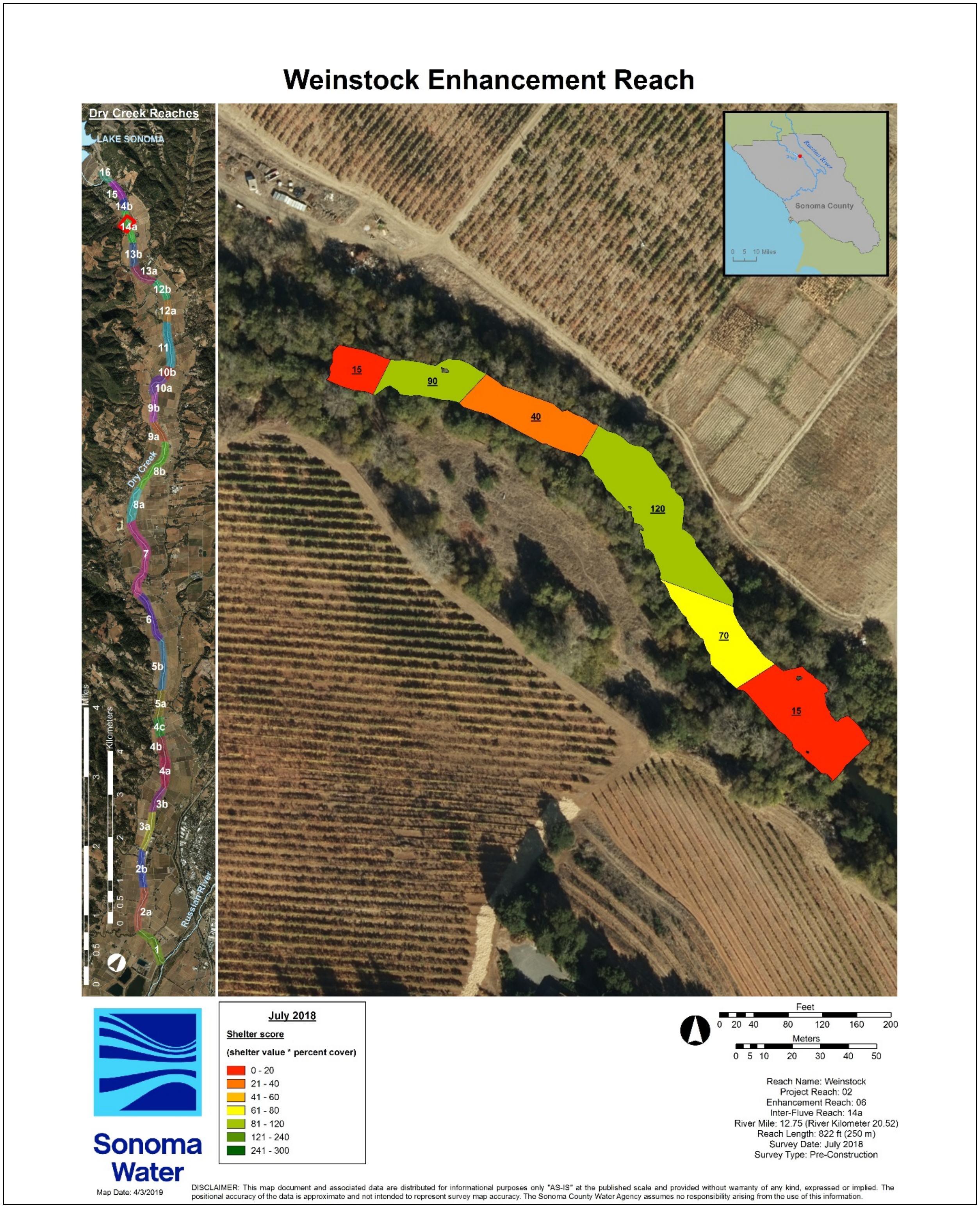


**Figure 5.2.9. Habitat unit shelter values within the Weinstock enhancement reach, July 2018.**

*Habitat unit, site, and reach ratings*

**Table 5.2. 17. Pre-enhancement average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the for the Weinstock enhancement reach, July 2018.**

| Site number | | **1** | | | |
|---|---|---|---|---|---|
| **Site type** | | Main channel | | | |
| **Site average feature rating** | Site average feature quantitative rating[a] | 0 | | | |
| | Site average feature qualitative rating[a] | Not rated | | | |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 18 | | | |
| | Site average qualitative rating[b] | Fair | | | |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | **18** | | | |
| | Site qualitative rating[c] | Fair | | | |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[c] | 18 | | | |
| | Enhancement reach qualitative rating[c]: | Fair | | | |

[a]not included in rating
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)

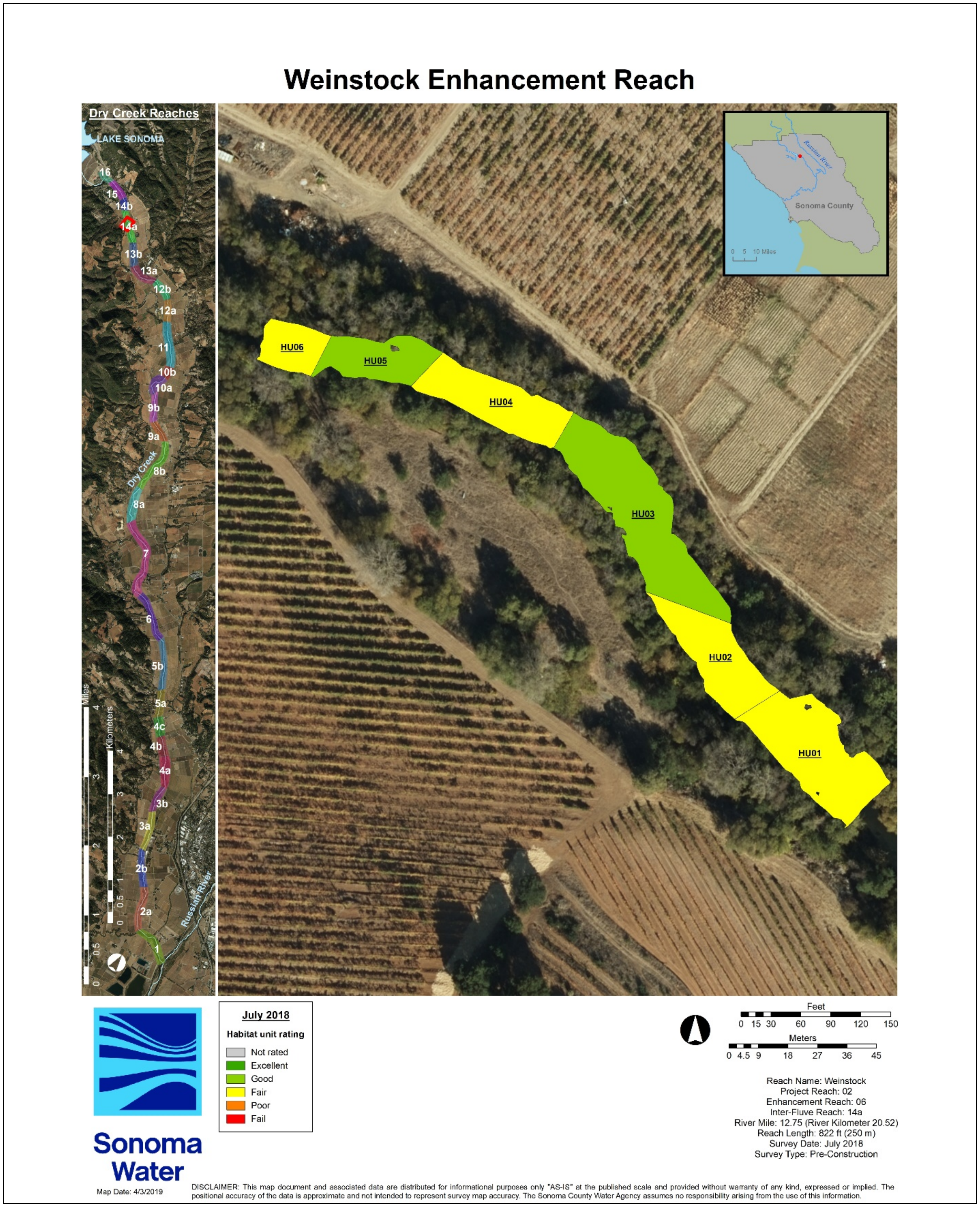


**Figure 5.2.10. Habitat unit ratings for the Weinstock enhancement reach, July 2018.**

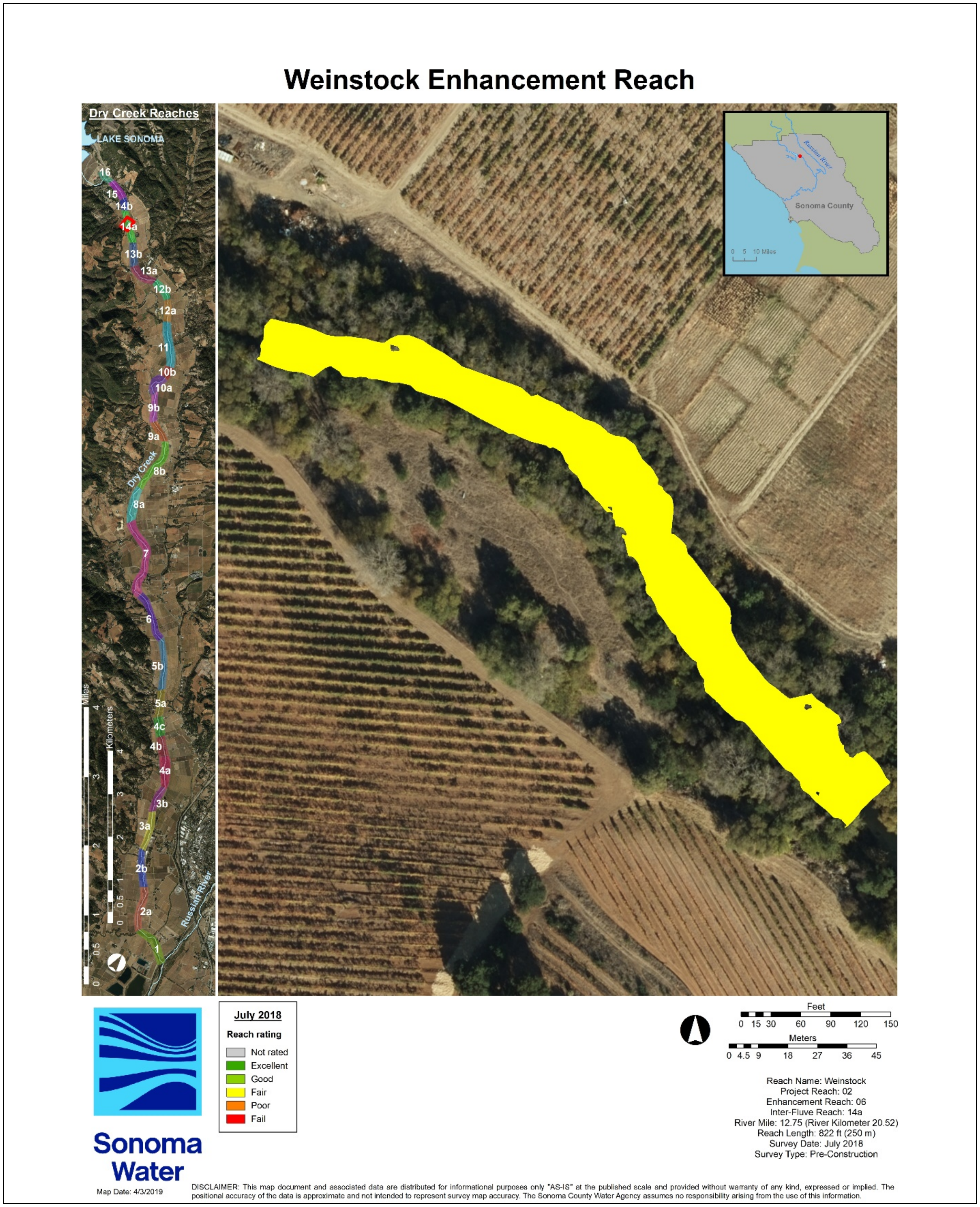


**Figure 5.2.11. Pre-enhancement site and reach rating for the Weinstock enhancement reach July 2018.**

## Gallo Enhancement Reach

Sonoma Water monitored the pre-enhancement condition of the Gallo enhancement reach in June 2018. The reach covered 48,099 $ft^2$ within the main channel of Dry Creek, with 23% meeting optimal depth and velocity criteria, mostly along the channel margins (Table 5.2.18, Figure 5.2.15). Six habitat units made up the enhancement reach, with a pool to riffle ratio of 2:2 (1.00) and an average shelter score of 73 (Table 5.2.19, Figure 5.2.16, Figure 5.2.17). Two habitat units met or exceeded the optimal shelter score of 80. The enhancement reach comprised a main channel enhancement site with fair habitat unit ratings and a fair overall enhancement reach rating (Table 5.2.20, Figure 5.2.18, Figure 5.2.19; see Appendix 5.1 for all measured values, scores, and ratings).

### *Depth and velocity*

**Table 5.2. 18. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Gallo enhancement reach, June 2018.**

| Gallo Pre-enhancement June 2018 | Wetted area | Optimal depth 0.5 – 2.0 ft | Optimal depth 2.0 – 4.0 ft | Optimal depth Total | Optimal velocity < 0.5 ft/s | Optimal habitat 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 48,099 $ft^2$ | 20,535 $ft^2$ | 17,877 $ft^2$ | 38,412 $ft^2$ | 17,484 $ft^2$ | 6,566 $ft^2$ | 4,557 $ft^2$ | 11,123 $ft^2$ |
| Main channel % of wetted area | 100% | 43% | 37% | 80% | 36% | 14% | 9% | 23% |

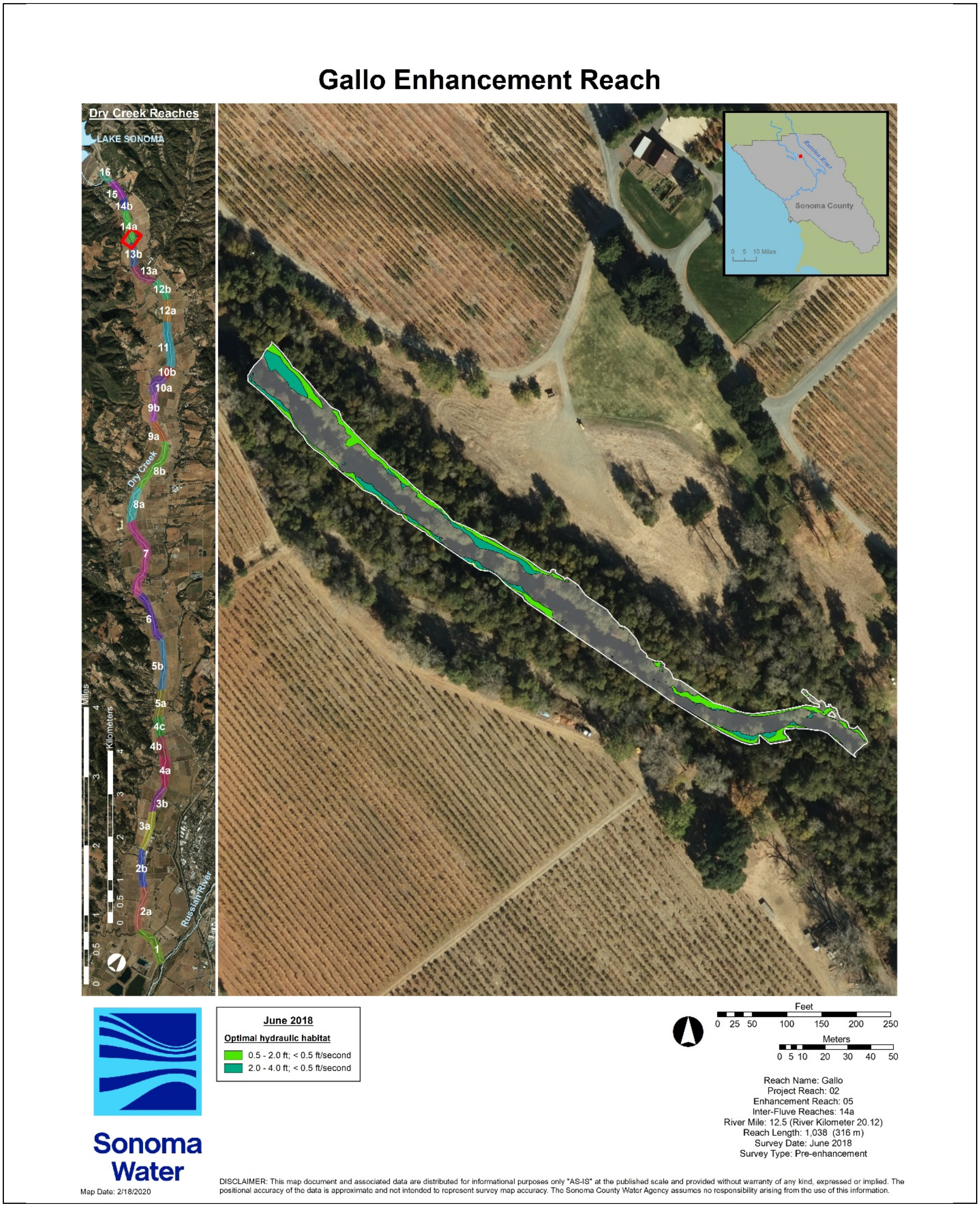


**Figure 5.2.12. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Gallo enhancement reach, June 2018.**

### *Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 19. Habitat, types, shelter value, percent cover, and shelter score for main channel habitat units within the Gallo enhancement reach, June 2018, pre-enhancement.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Riffle | 2 | 20 | 40 |
| HU02 | Alcove | 1 | 90 | 90 |
| HU03 | Pool | 3 | 50 | 150 |
| HU04 | Riffle | 2 | 25 | 50 |
| HU05 | Pool | 3 | 25 | 75 |
| HU06 | Pool | 2 | 15 | 30 |
| **Pool: riffle** | **2:2 (1.00)** | | | **Avg = 73** |

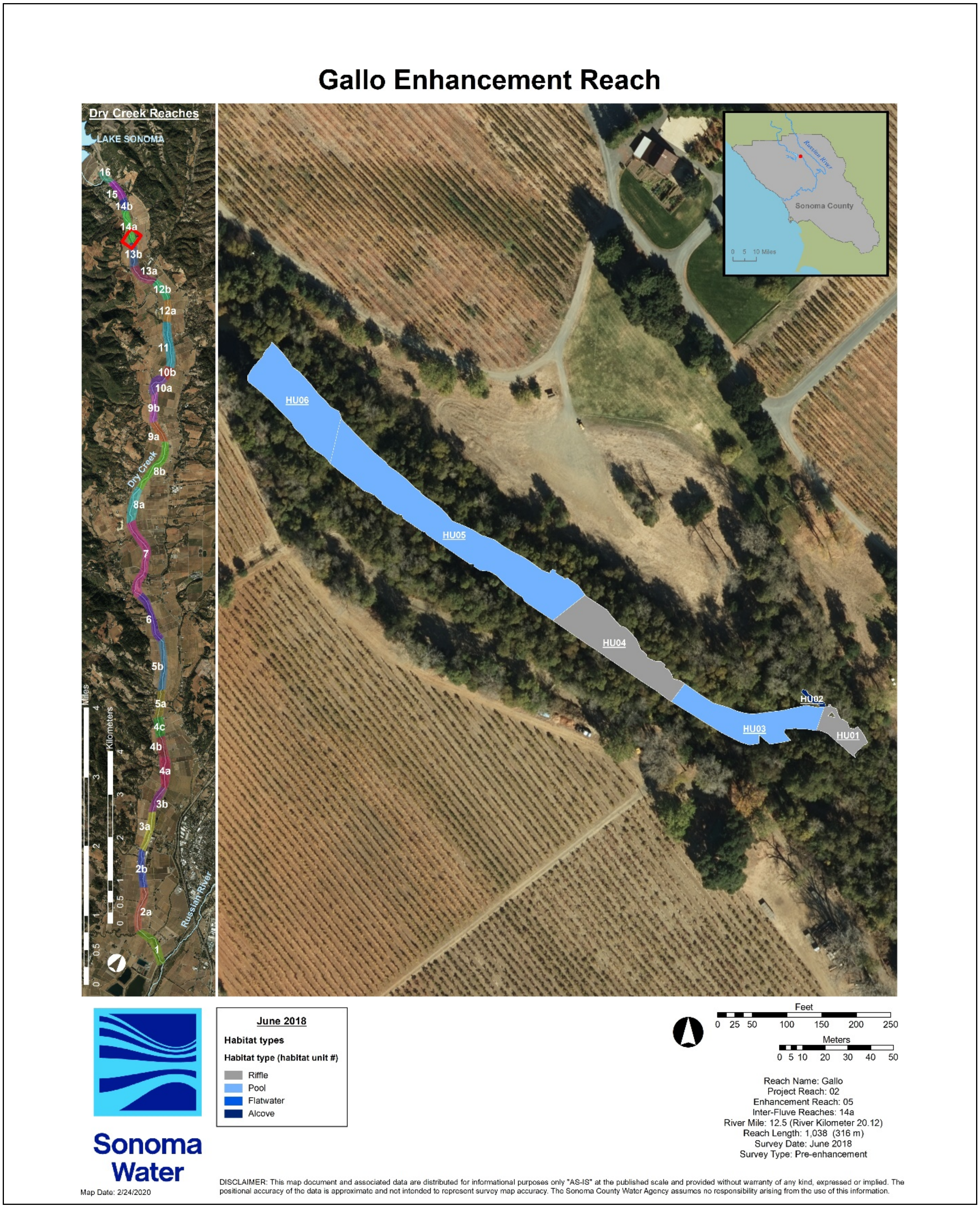


**Figure 5.2.13. Habitat unit number and type within the Gallo enhancement reach, June 2018.**

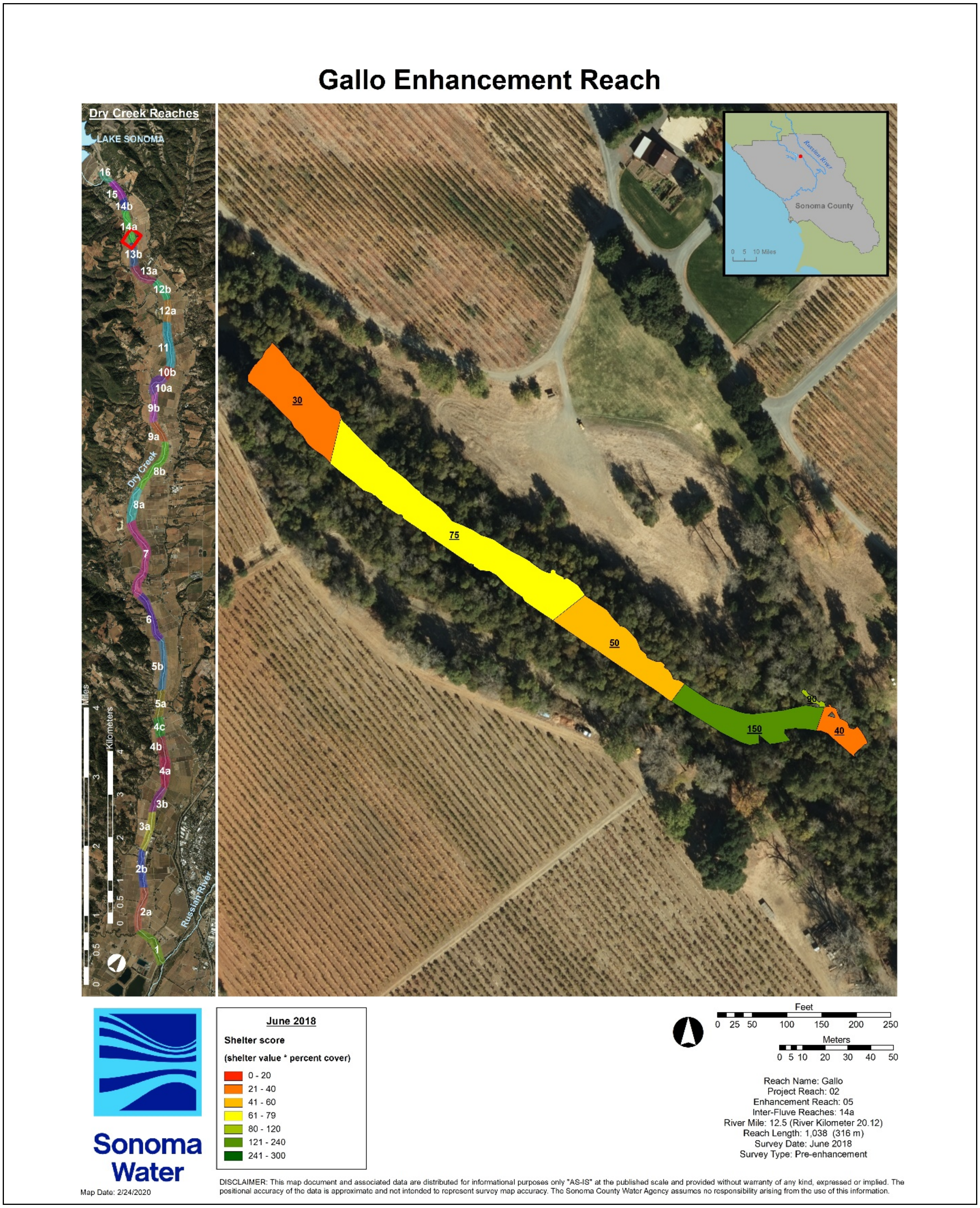


**Figure 5.2.14. Habitat unit shelter scores within the Gallo enhancement reach, June 2018.**

*Habitat unit, site, and reach ratings*

**Table 5.2. 20. Pre-enhancement average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the for the Gallo enhancement reach, June 2018.**

| | | | | | |
|---|---|---|---|---|---|
| **Site number** | | **1** | | | |
| **Site type** | | Main channel | | | |
| **Site average feature rating** | Site average feature quantitative rating[a] | 0 | | | |
| | Site average feature qualitative rating[a] | Not rated | | | |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 15 | | | |
| | Site average qualitative rating[b] | Fair | | | |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | 15 | | | |
| | Site qualitative rating[c] | Fair | | | |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[c] | 15 | | | |
| | Enhancement reach qualitative rating[c]: | Fair | | | |

[a]not included in rating
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)

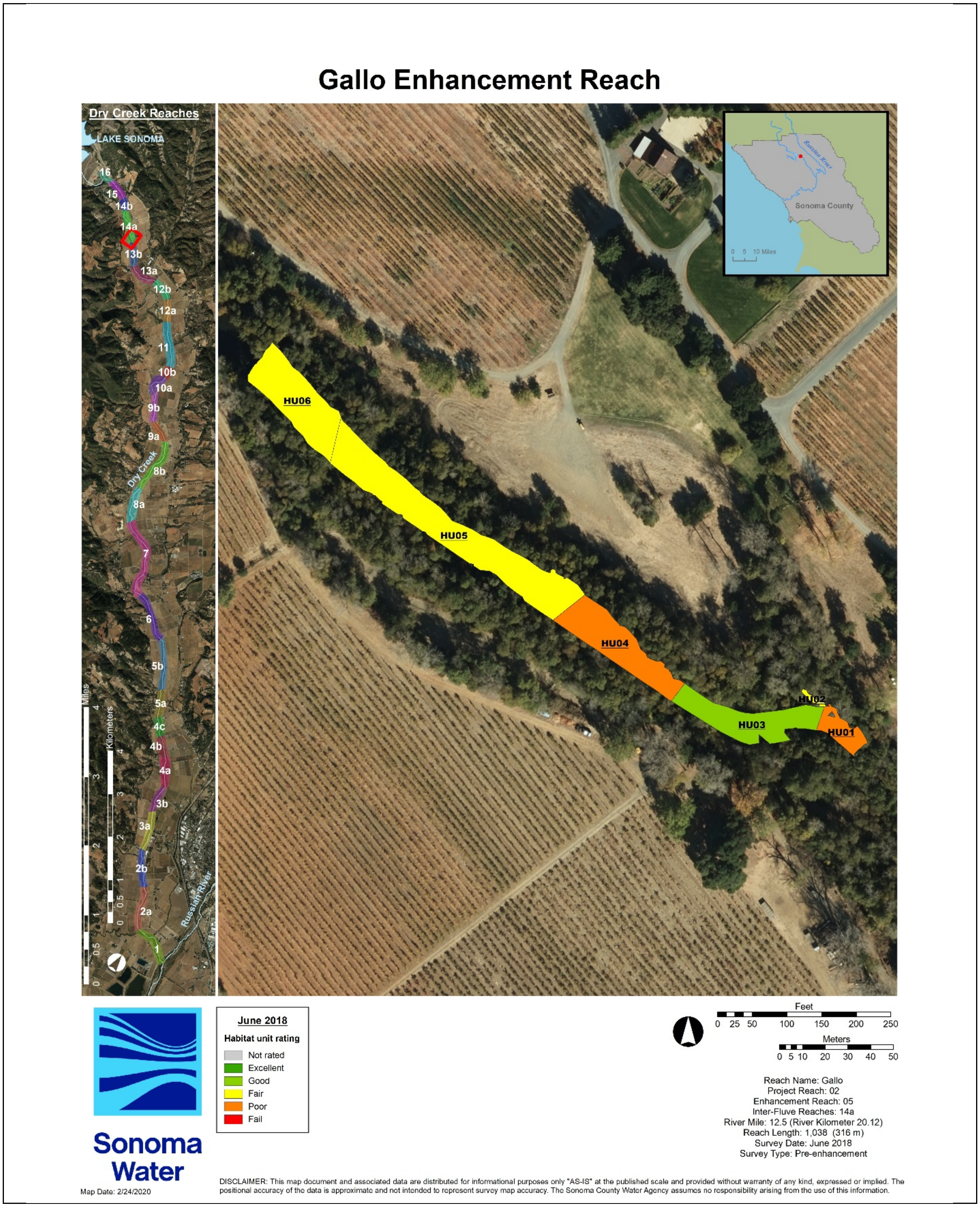


**Figure 5.2.15. Habitat unit ratings for the Gallo enhancement reach, June 2018.**

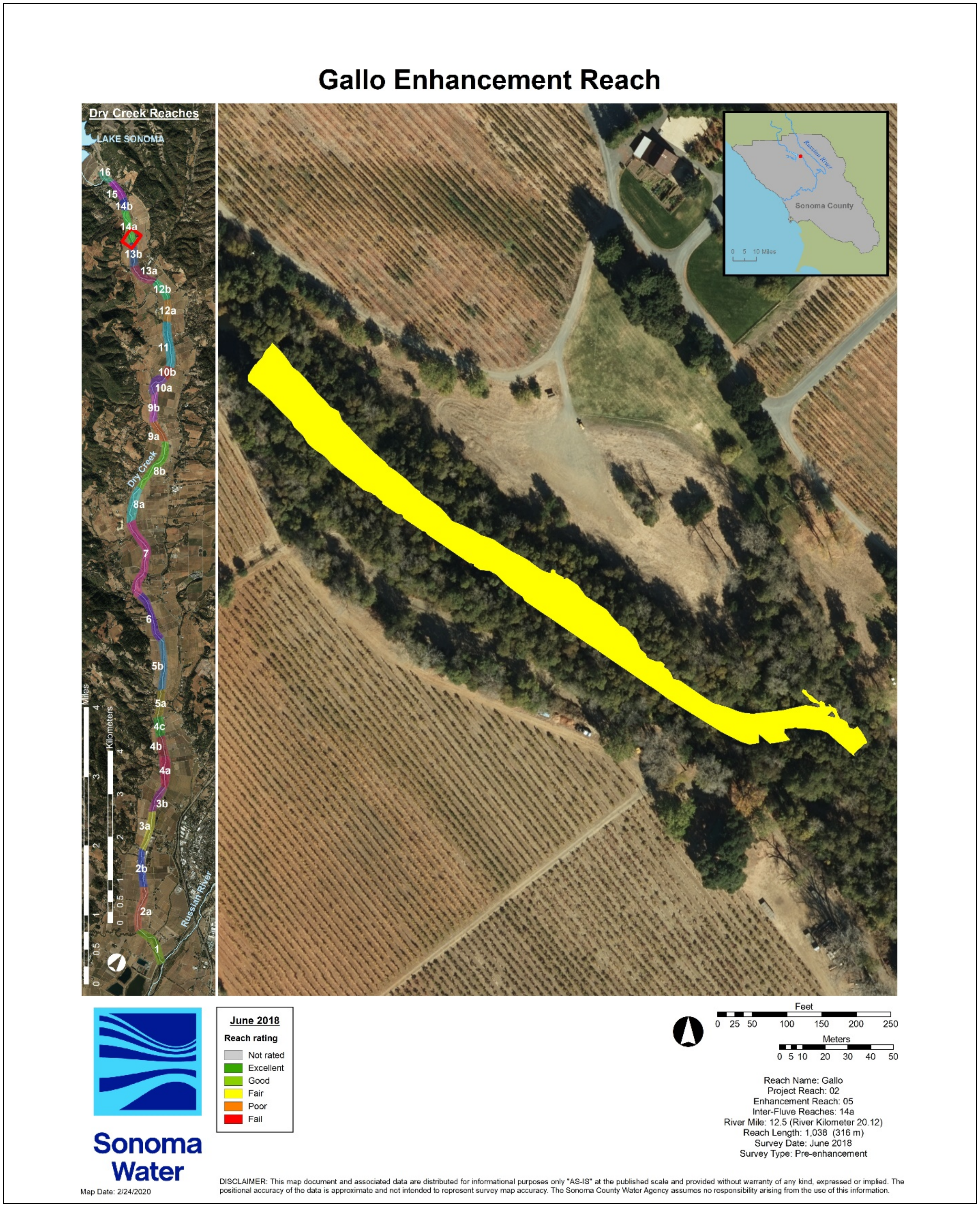


**Figure 5.2.16. Pre-enhancement site and reach rating for the Gallo enhancement reach June 2018.**

## Ferrari-Carano, Olson Enhancement Reach

Sonoma Water monitored the pre-enhancement condition of the Ferrari-Carano, Olson enhancement reach in May 2018. The reach covered 96,264 $ft^2$ within the main channel of Dry Creek, with 19% meeting optimal depth and velocity criteria, mostly along the channel margins (Table 5.2.21, Figure 5.2.20). Twelve habitat units made up the enhancement reach, with a pool to riffle ratio of 4:3 (1.33) and an average shelter score of 81 (Table 5.2.22, Figure 5.2.21, Figure 5.2.22). Four habitat units met or exceeded the optimal shelter score of 80. The enhancement reach comprised a main channel enhancement site with fair habitat unit ratings and a fair overall enhancement reach rating (Table 5.2.23, Figure 5.2.23, Figure 5.2.24; see Appendix 5.1 for all measured values, scores, and ratings).

### *Depth and velocity*

**Table 5.2. 21. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Ferrari-Carano, Olson enhancement reach, May 2018.**

| Ferrari-Carano, Olson Pre-enhancement May 2018 | Wetted area | Optimal depth 0.5 – 2.0 ft | Optimal depth 2.0 – 4.0 ft | Optimal depth Total | Optimal velocity < 0.5 ft/s | Optimal habitat 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 96,264 $ft^2$ | 60,100 $ft^2$ | 16,148 $ft^2$ | 76,248 $ft^2$ | 32,427 $ft^2$ | 15,586 $ft^2$ | 2,289 $ft^2$ | 17,875 $ft^2$ |
| Main channel % of wetted area | 100% | 62% | 17% | 79% | 34% | 16% | 2% | 19% |

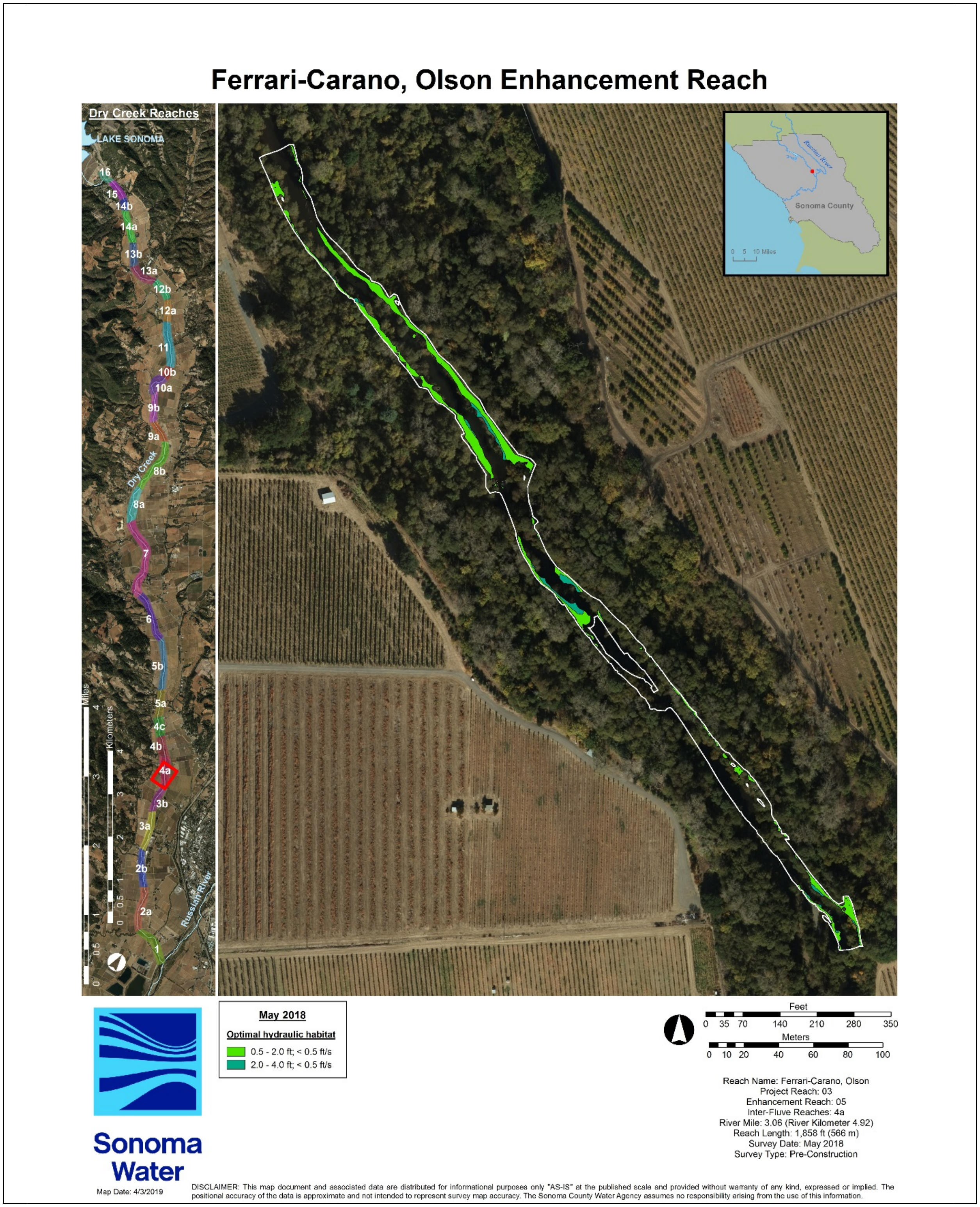


**Figure 5.2.17. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Ferrari-Carano, Olson enhancement reach, May 2018.**

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 22. Habitat, types, shelter value, percent cover, and shelter score within the Ferrari-Carano, Olson enhancement reach, May 2018, pre-enhancement.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Pool | 3 | 75 | 225 |
| HU02 | Pool | 2 | 60 | 120 |
| HU03 | Alcove | 2 | 40 | 80 |
| HU04 | Riffle | 3 | 25 | 75 |
| HU05 | Flatwater | 3 | 25 | 75 |
| HU06 | Flatwater | 2 | 15 | 30 |
| HU07 | Riffle | 3 | 15 | 45 |
| HU08 | Flatwater | 3 | 30 | 90 |
| HU09 | Pool | 3 | 25 | 75 |
| HU10 | Riffle | 3 | 10 | 30 |
| HU11 | Pool | 2 | 35 | 70 |
| HU12 | Flatwater | 2 | 30 | 60 |
| **Pool: riffle** | **4: 3 (1.33)** | | | **Avg = 81** |

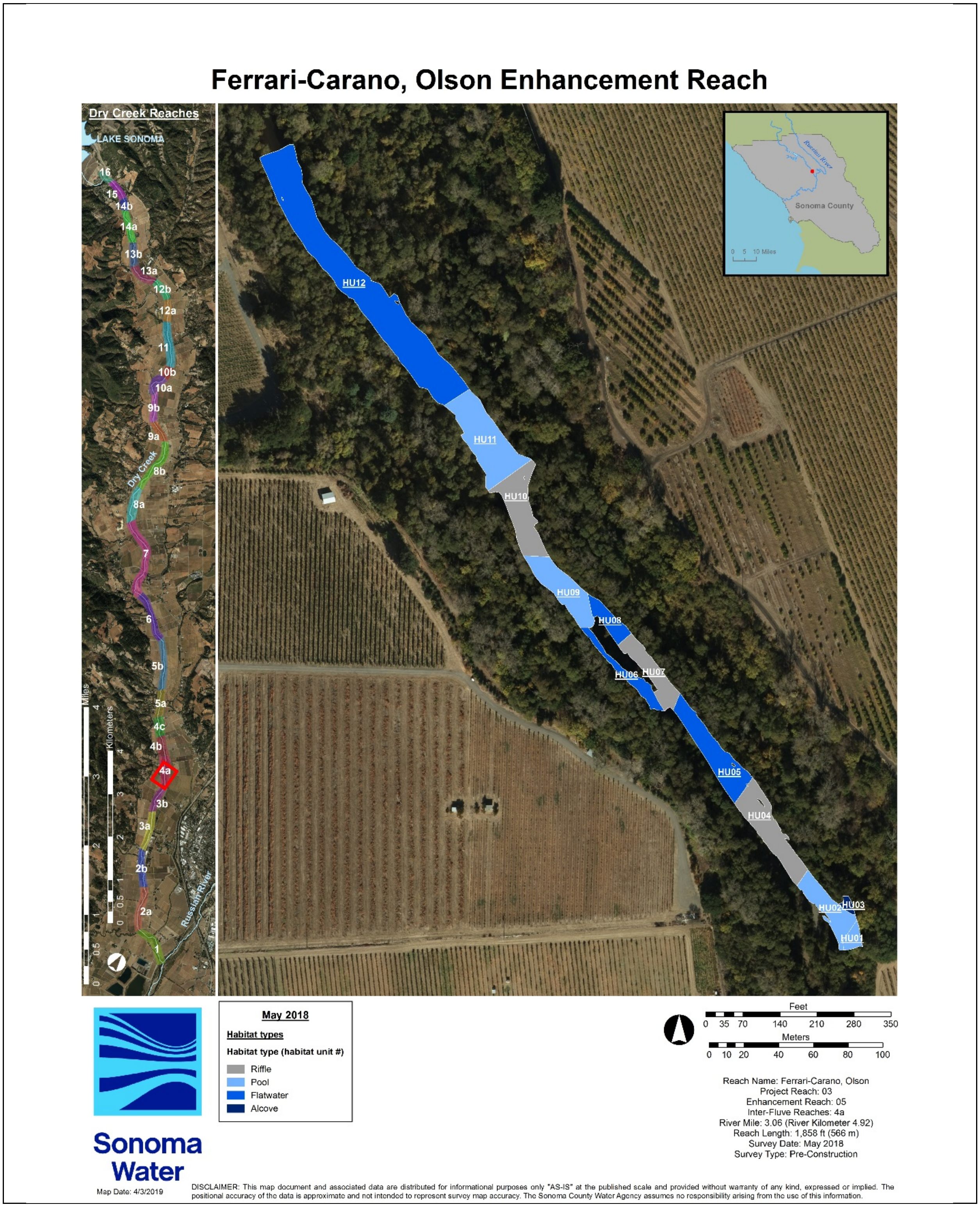


**Figure 5.2.18. Habitat unit number and type within the Ferrari-Carano, Olson enhancement reach, May 2018.**

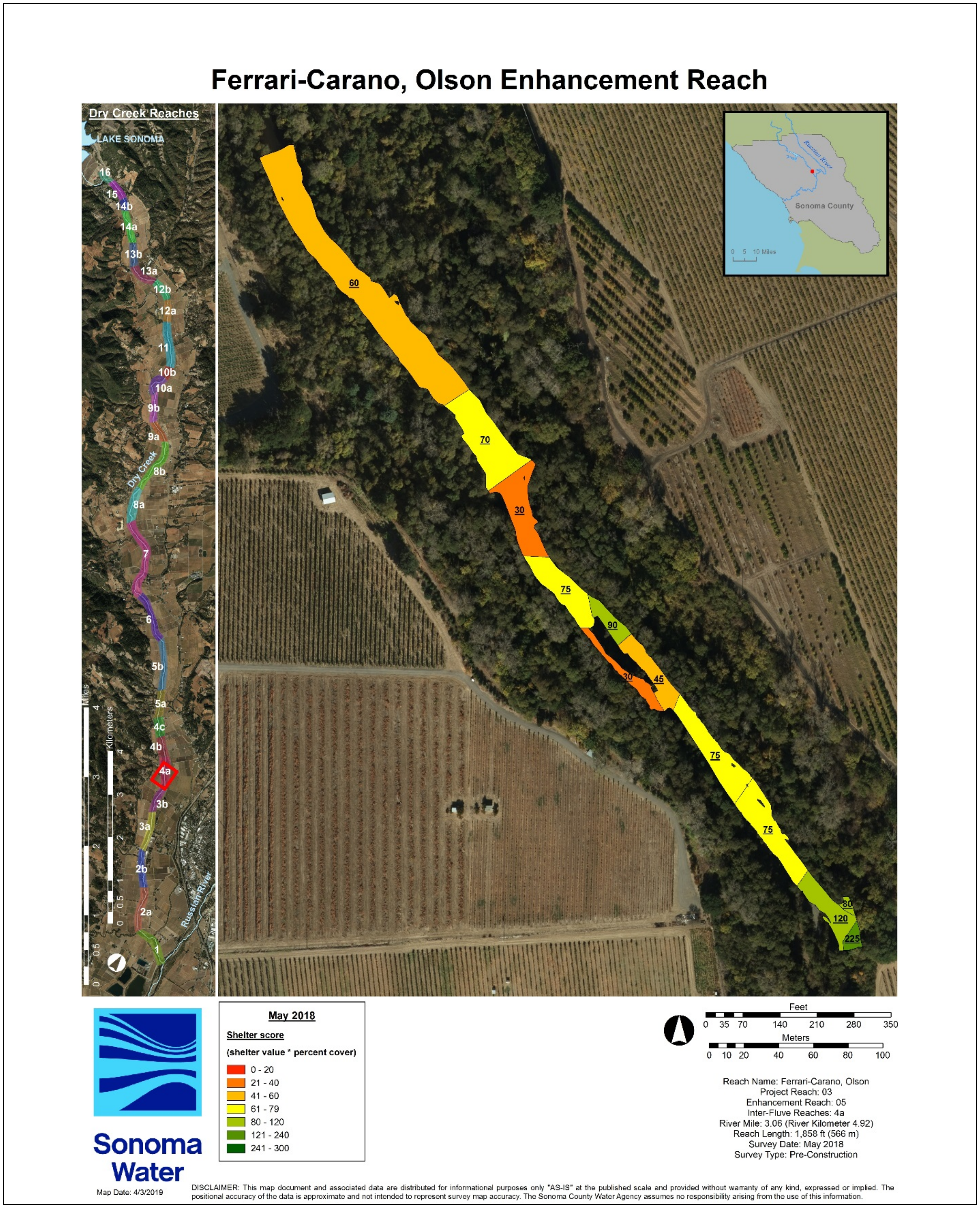


**Figure 5.2.19. Habitat unit shelter scores within the Ferrari-Carano, Olson enhancement reach, May 2018.**

### *Habitat unit, site, and reach ratings*

**Table 5.2. 23. Pre-enhancement average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Ferrari-Carano, Olson enhancement reach, May 2018.**

| Site number | | 1 | 2 | 3 | |
|---|---|---|---|---|---|
| Site type | | Main channel | | | |
| **Site average feature rating** | Site average feature quantitative rating[a] | 0 | | | |
| | Site average feature qualitative rating[a] | Not rated | | | |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 18 | | | |
| | Site average qualitative rating[b] | Fair | | | |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | **18** | | | |
| | Site qualitative rating[c] | Fair | | | |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[c] | 18 | | | |
| | Enhancement reach qualitative rating[c]: | Fair | | | |

[a]not included in rating
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)

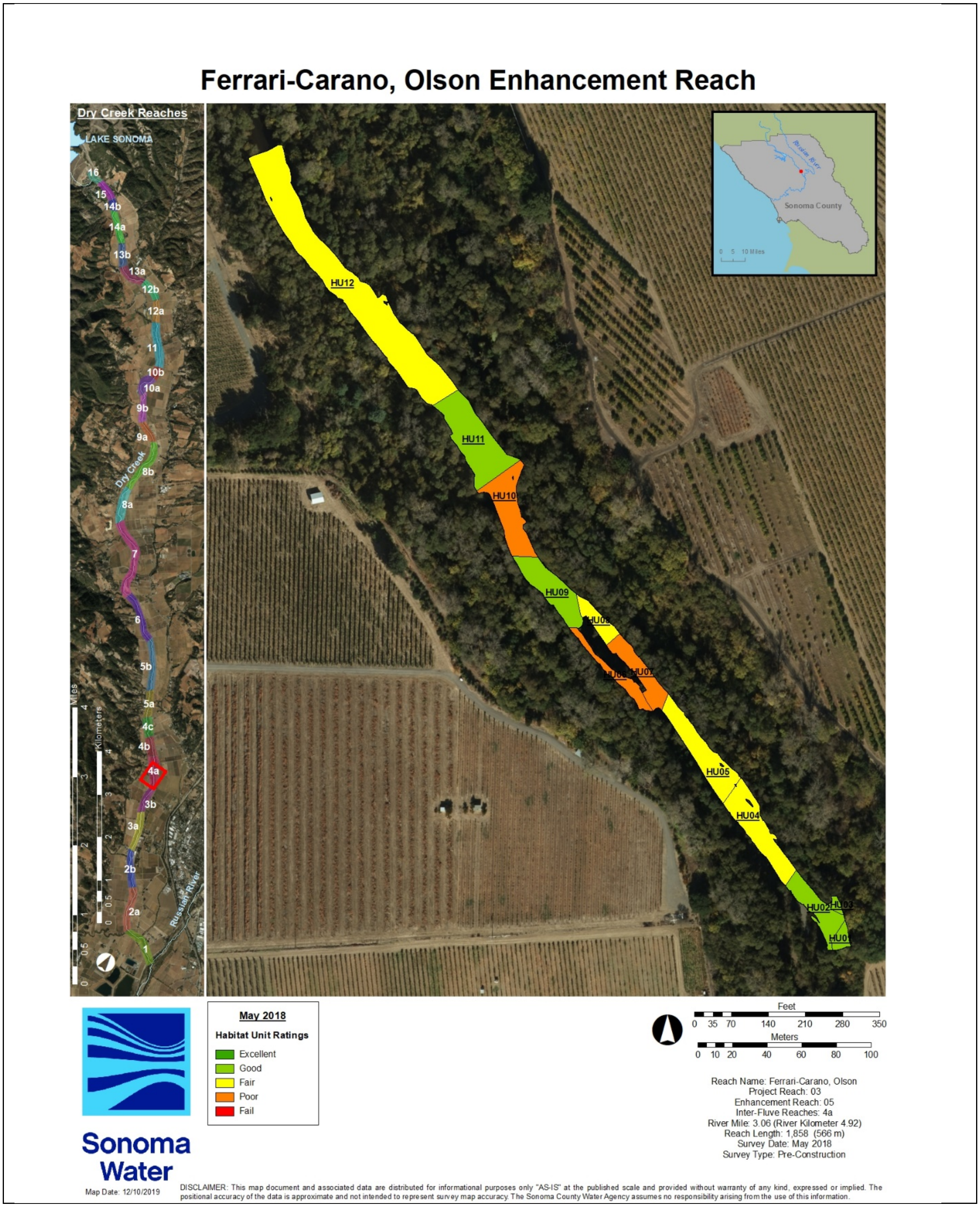


**Figure 5.2.20. Habitat unit ratings for the Ferrari-Carrano, Olson enhancement site May, 2018.**

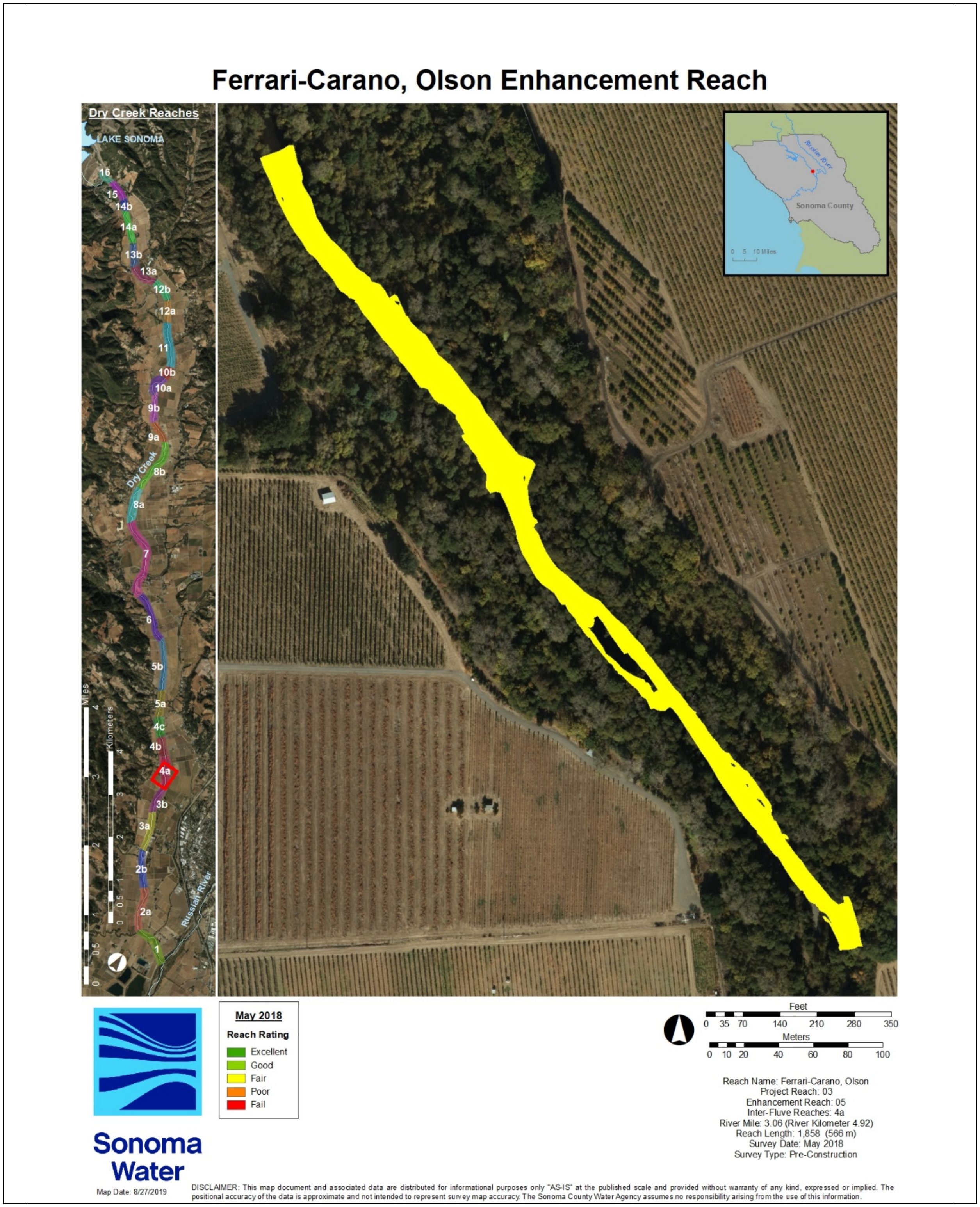


**Figure 5.2.21. Pre-enhancement site and reach rating for the Ferrari-Carano, Olson enhancement reach, May 2018.**

# Post-enhancement

## Summary

Sonoma Water monitored the post-enhancement conditions of the Army Corps Reach 14, Weinstock, and Ferrari-Carano, Olson enhancement reaches in 2018 (Table 5.2.8, Figure 5.2.4). Overall, the enhanced portion of the reaches covered 275,502 $ft^2$ within main- and off-channel areas of Dry Creek, with 33% meeting the optimal depth and velocity criteria (Table 5.2.24). The enhancement added 129,359 $ft^2$ of off-channel and alcove area, of which 42% met optimal depth and velocity criteria, compared to 146,143 $ft^2$ and 25% in the main channel. Crews recorded 59 habitat units across both enhancement reaches with a total pool to riffle ratio of 18:16 (1.13) and a total average shelter score of 65. Average alcove shelter score (83) and pool average shelter score (84) exceeded the optimum shelter score of 80, followed by flatwaters (68) and riffles (33) (Table 5.2.25). Post-enhancement, all enhancement reaches monitored in 2018 received a good rating (Table 5.2.26; see below for individual enhancement reach summaries and Appendix 5.1 for all measured values, scores, and ratings).

*Depth and velocity*

**Table 5.2. 24. Post-enhancement areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches constructed in 2018.**

| Dry Creek Post-enhancement 2018 | Wetted area ($ft^2$) | Optimal depth ($ft^2$) 0.5 – 2.0 ft | Optimal depth ($ft^2$) 2.0 – 4.0 ft | Optimal depth ($ft^2$) Total | Optimal velocity ($ft^2$) < 0.5 ft/s | Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 146,143 | 77,813 | 32,087 | 109,900 | 60,632 | 23,102 | 13,383 | 36,485 |
| Off channel area | 129,359 | 53,784 | 43,496 | 97,280 | 78,740 | 30,484 | 23,597 | 54,081 |
| **Total area** | 275,502 | 131,597 | 75,583 | 207,181 | 139,372 | 53,586 | 36,980 | 90,565 |
| Main channel % of wetted area | 53% | 53% | 22% | 75% | 41% | 16% | 9% | 25% |
| Off channel % of wetted area | 47% | 42% | 34% | 75% | 61% | 24% | 18% | 42% |
| **Total % of wetted area** | **100%** | **48%** | **27%** | **75%** | **51%** | **19%** | **13%** | **33%** |

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 25. Post-enhancement habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches constructed in 2018, post-enhancement.**

| Habitat Type | # of Habitat Units | Shelter Score |
|---|---|---|
| Riffle | 16 | 33 |
| Pool | 18 | 84 |
| Flatwater | 19 | 68 |
| Alcove | 6 | 83 |
| **Pool: riffle** | **18: 16 (1.13)** | **Avg = 65** |

*Reach ratings*

**Table 5.2. 26. Post-enhancement ratings for Dry Creek enhancement reaches constructed in 2018.**

| Enhancement Reach | Post- -enhancement Rating |
|---|---|
| Army Corps Reach 14 | Good |
| Weinstock | Good |
| Ferrari-Carano, Olson | Good |

## Army Corps Reach 14 Enhancement Reach

Sonoma Water monitored the post-enhancement condition of the Army Corps Reach 14 enhancement reach in October 2018. The enhancement reach encompassed 77,783 $ft^2$ within main- and off channel areas of Dry Creek, with 35% meeting optimal depth and velocity criteria (Table 5.2.27 and Figure 5.2.25). The enhancement added 30,751 $ft^2$ of off-channel alcove and off- channel area, of which 79% and 36% met optimal depth and velocity criteria, compared to 29% in the main channel. Fifteen habitat units composed the enhancement reach, with a pool to riffle ratio of 6:6 (1.00) and an average shelter value of 51 (Table 5.2.28, Figure 5.2.26, Figure 5.2.27). Four habitat units (three pools and one riffle) met or exceeded the optimum shelter score of 80. The reach comprised four enhancement sites (one main channel, one side channel, two alcoves; Figure 5.2.28) with excellent site average feature ratings (site 1 contained no features and did not receive a feature rating) and poor to good site average habitat unit ratings (Table 5.2.29, Figure 5.2.29, Figure 5.2.30). Site ratings ranged from poor to good, with the main channel site scoring lower due to poor site average habitat unit ratings compared to good site average habitat unit ratings for side channel and alcove sites (Table 5.2.29, Figure 5.2.31). Overall, the Army Corps Reach 14 enhancement reach, post-enhancement, received a good effectiveness monitoring rating (Table 5.2.29, Figure 5.2.32; see Appendix 5.1 for all measured values, scores, and ratings).

*Depth and velocity*

**Table 5.2. 27. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Army Corps Reach 14 enhancement reach, October 2018.**

| **Army Corps Reach 14 Post-enhancement 2018** | **Wetted area ($ft^2$)** | **Optimal depth ($ft^2$) 0.5 – 2.0 ft** | **Optimal depth ($ft^2$) 2.0 – 4.0 ft** | **Optimal depth ($ft^2$) Total** | **Optimal velocity ($ft^2$) < 0.5 ft/s** | **Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s** | **Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s** | **Optimal habitat ($ft^2$) Total** |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 47,031 | 19,100 | 13,983 | 33,083 | 22,033 | 6,249 | 7,273 | 13,522 |
| Off channel alcove area | 5,952 | 3,010 | 1,710 | 4,720 | 5,952 | 3,010 | 1,710 | 4,720 |
| Off channel area | 24,799 | 6,702 | 8,493 | 15,194 | 14,944 | 4,252 | 4,753 | 9,005 |
| **Total area** | **77,783** | **28,812** | **24,185** | **52,997** | **42,929** | **13,512** | **13,736** | **27,247** |
| Main channel % of wetted area | 60% | 41% | 30% | 70% | 47% | 13% | 15% | 29% |
| Side channel alcove % of wetted area | 8% | 51% | 29% | 79% | 100% | 51% | 29% | 79% |
| Side channel % of wetted area | 60% | 27% | 34% | 61% | 60% | 17% | 19% | 36% |
| **Total % of wetted area** | **32%** | **37%** | **31%** | **68%** | **55%** | **17%** | **18%** | **35%** |

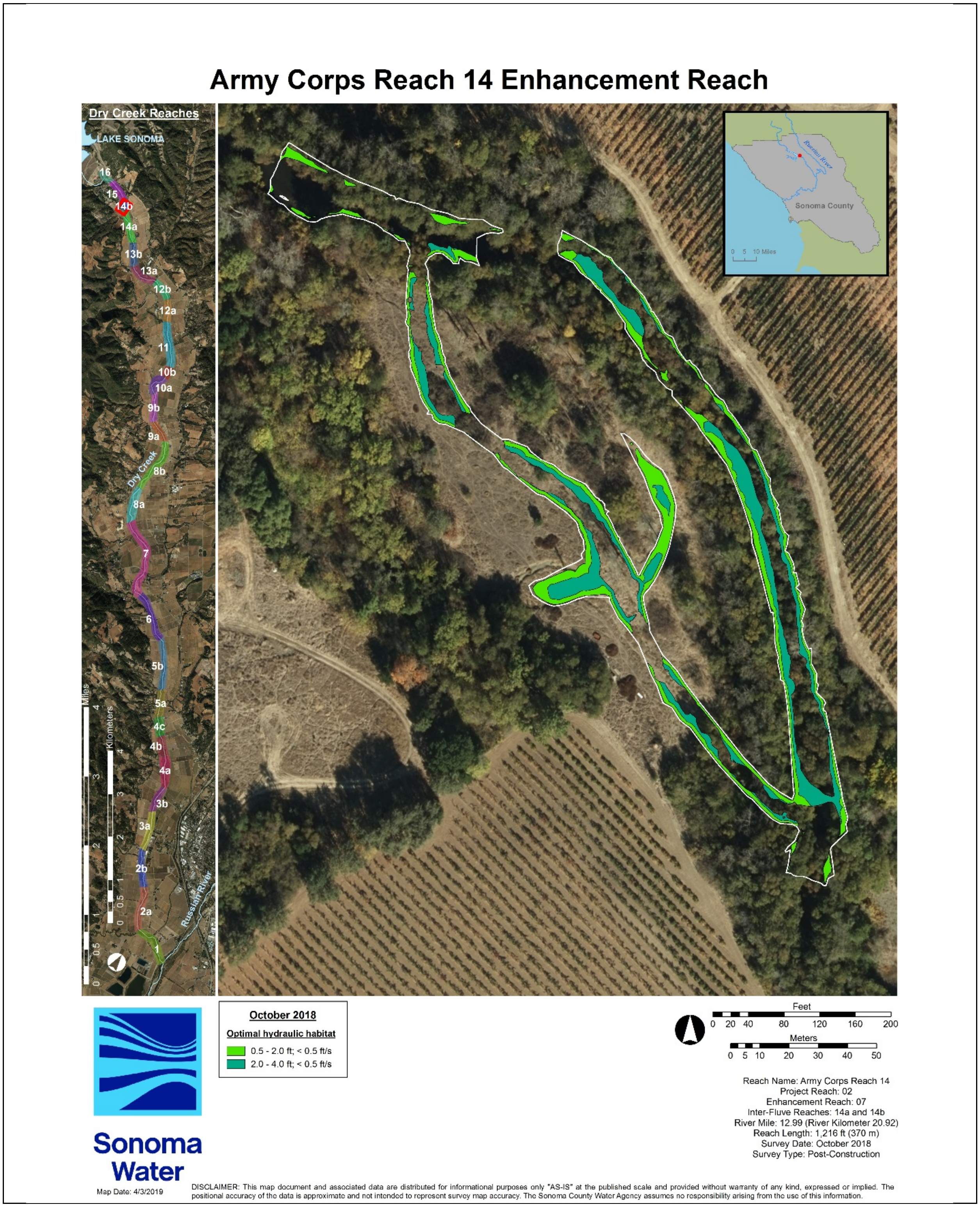


**Figure 5.2.22. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Army Corps Reach 14 enhancement reach, October 2018.**

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 28. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Army Corps Reach 14 enhancement reach, October 2018, post-enhancement.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Riffle | 3 | 10 | 30 |
| HU02 | Pool | 3 | 15 | 45 |
| HU03 | Riffle | 1 | 5 | 5 |
| HU04 | Pool | 1 | 5 | 5 |
| HU05 | Riffle | 2 | 30 | 60 |
| HU06 | Pool | 3 | 20 | 60 |
| HU07 | Pool | 3 | 30 | 90 |
| HU08 | Riffle | 2 | 5 | 10 |
| HU09 | Pool | 3 | 35 | 105 |
| HU10 | Alcove | 3 | 15 | 45 |
| HU11 | Alcove | 3 | 10 | 30 |
| HU12 | Riffle | 1 | 5 | 5 |
| HU13 | Pool | 3 | 40 | 120 |
| HU14 | Riffle | 3 | 45 | 135 |
| HU15 | Flatwater | 1 | 20 | 20 |
| **Pool: riffle** | **6: 6 (1.00)** | | | **Avg = 51** |

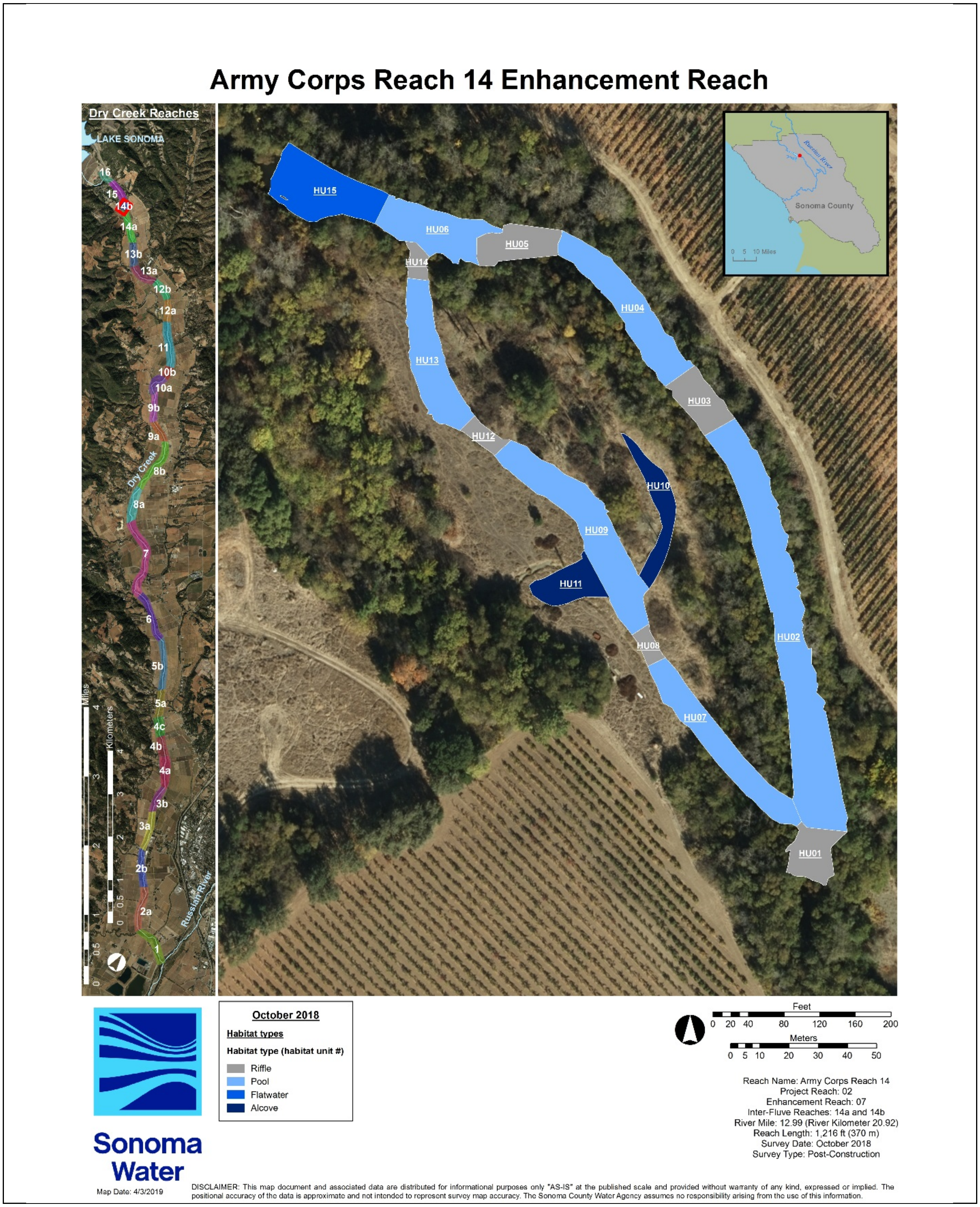


**Figure 5.2.23. Habitat unit number and type within the Army Corps Reach 14 enhancement reach, October 2018.**

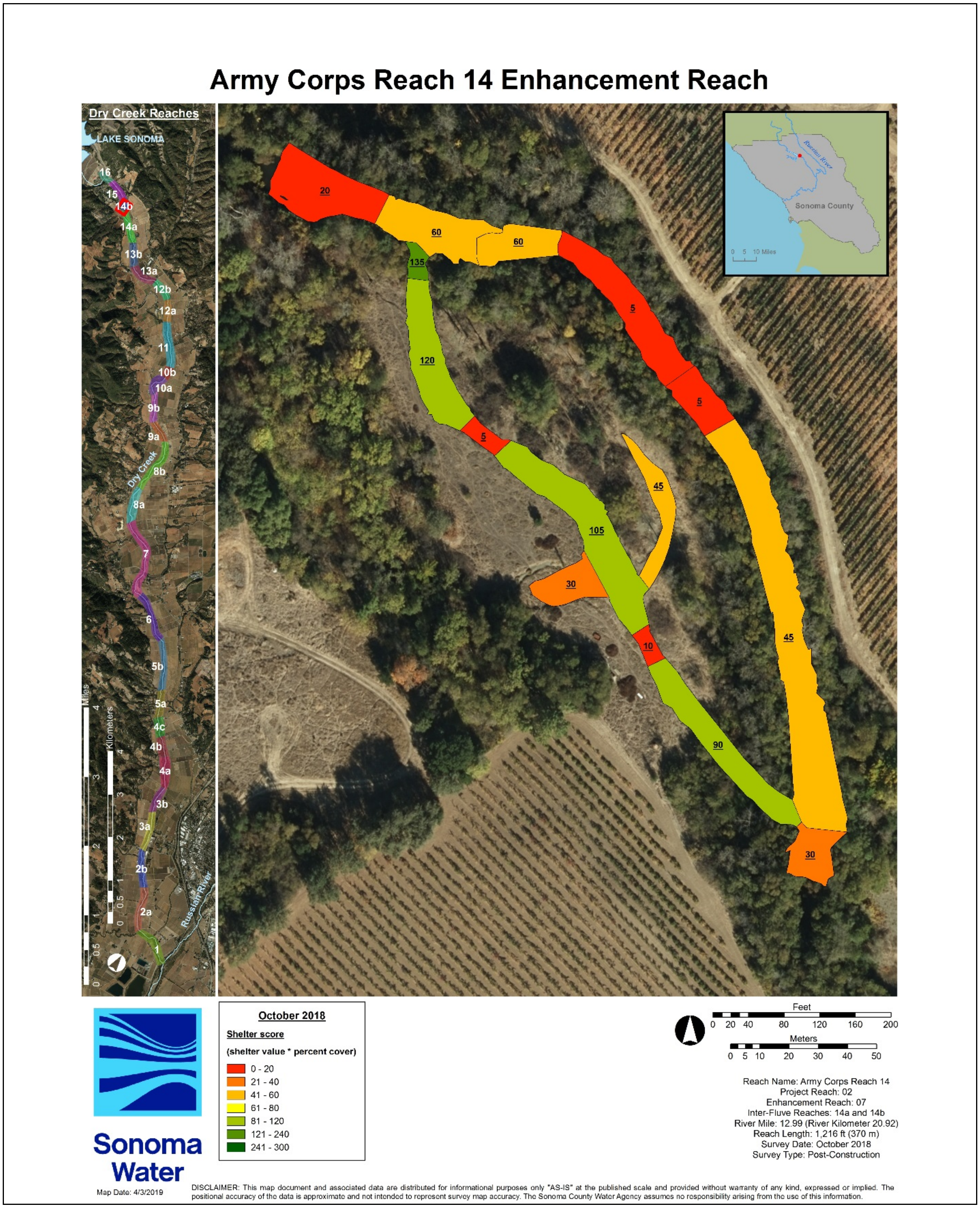


**Figure 5.2.24. Habitat unit shelter values within the Army Corps Reach 14 enhancement reach, October 2018.**

*Feature, habitat unit, site, and reach ratings*

**Table 5.2. 29. Post-enhancement average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Army Corps Reach 14 enhancement reach, October 2018.**

| Site number | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Site type** | | Main channel | Side channel | Alcove | **Alcove** |
| **Site average feature rating** | Site average feature quantitative rating[a] | 0 | 14 | 14 | 14 |
| | Site average feature qualitative rating[a] | Not rated | Excellent | Excellent | Excellent |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 14 | 17 | 21 | 24 |
| | Site average qualitative rating[b] | Poor | Fair | Good | Good |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | 14[b] | 31[c] | 35[c] | 38[c] |
| | Site qualitative rating | Poor[b] | Good[c] | Good[c] | Good[c] |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[d] | 29 | | | |
| | Enhancement reach qualitative rating[d]: | Good | | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)
[d]out of 46; Excellent (>=37), Good (>=28), Fair (>=19), Poor (>=9), Fail (<9)

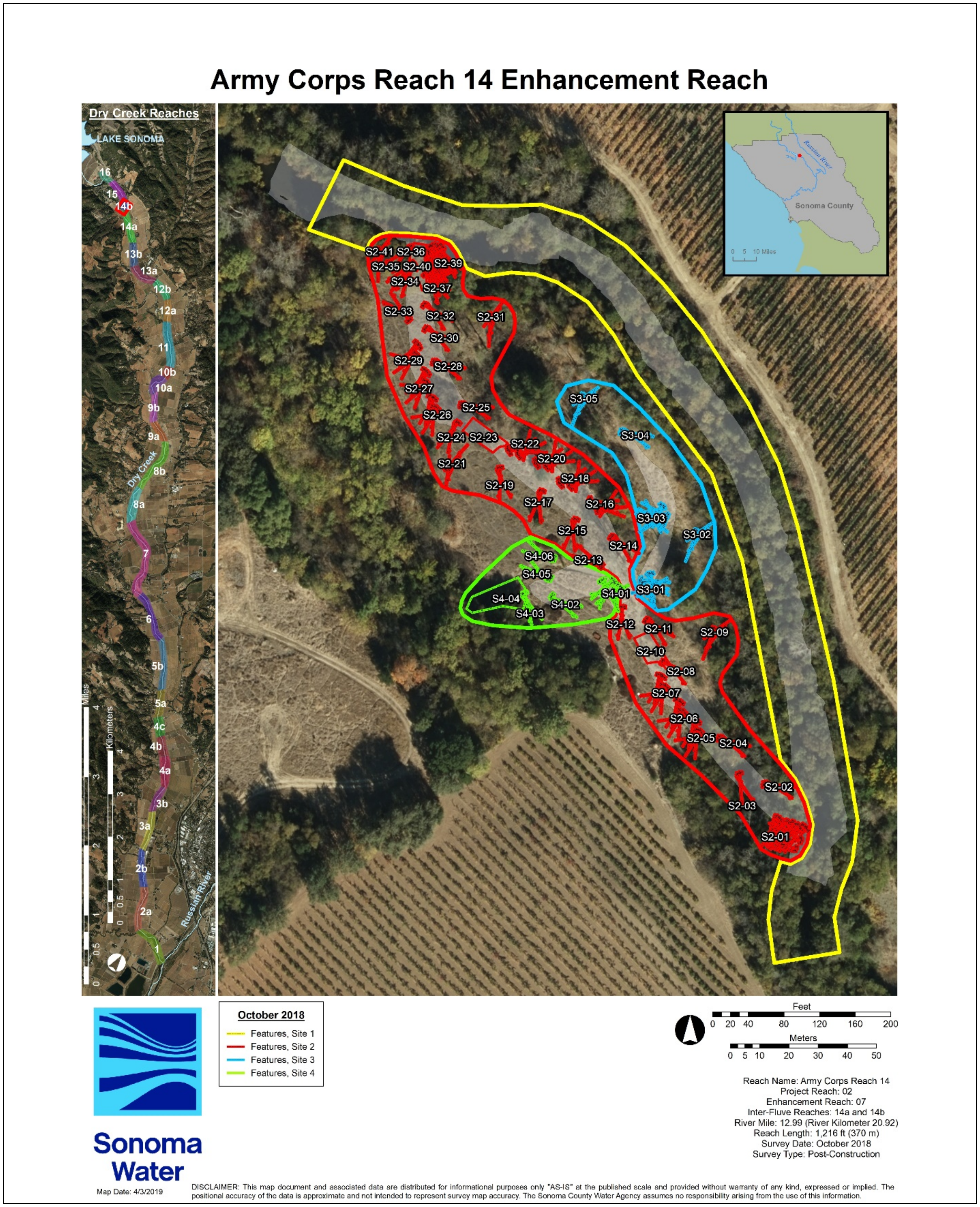


**Figure 5.2.25. Enhancement sites and features within the Army Corps Reach 14 enhancement reach, October 2018.**

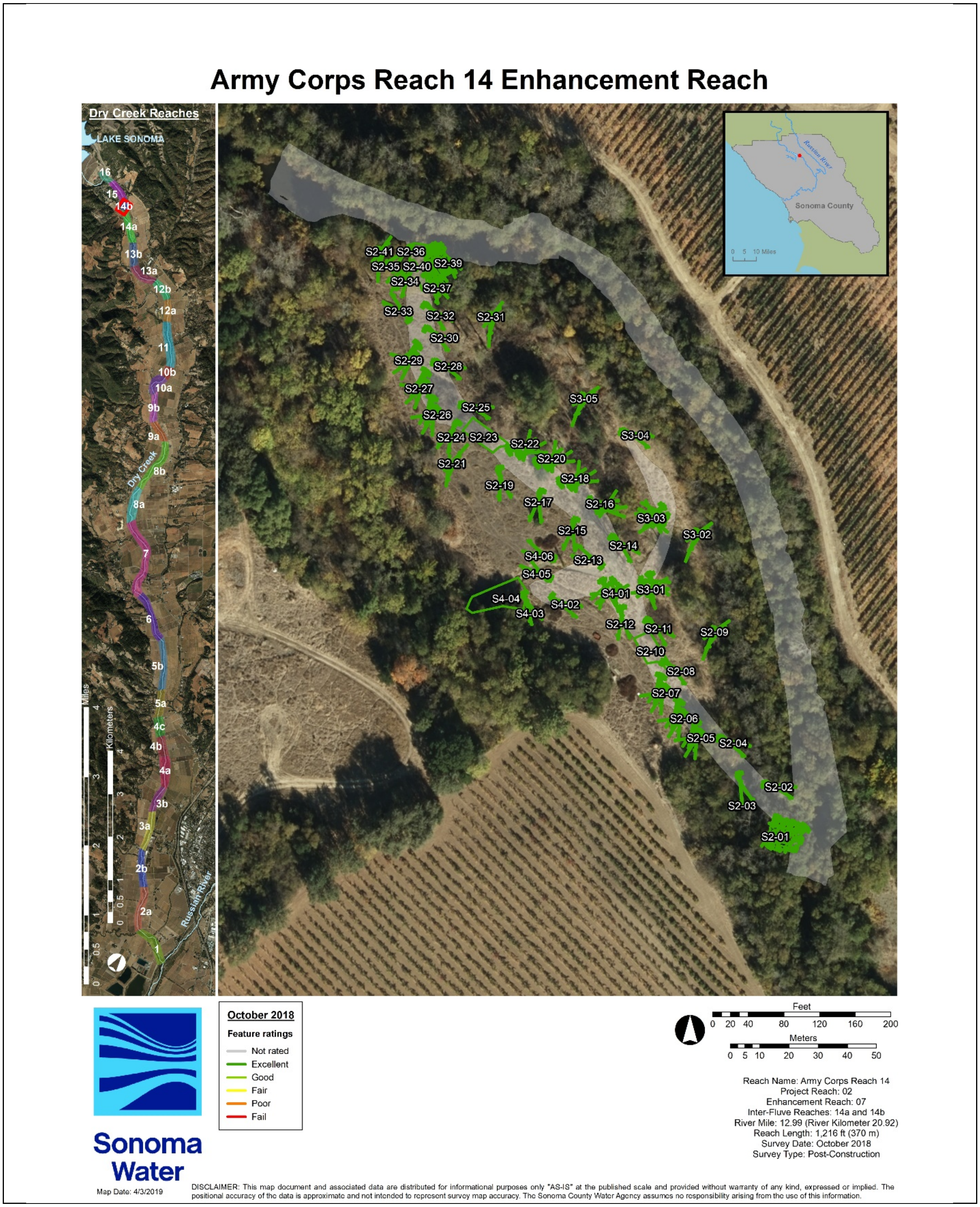


**Figure 5.2.26. Feature ratings for the Army Corps Reach 14 enhancement reach, October 2018.**

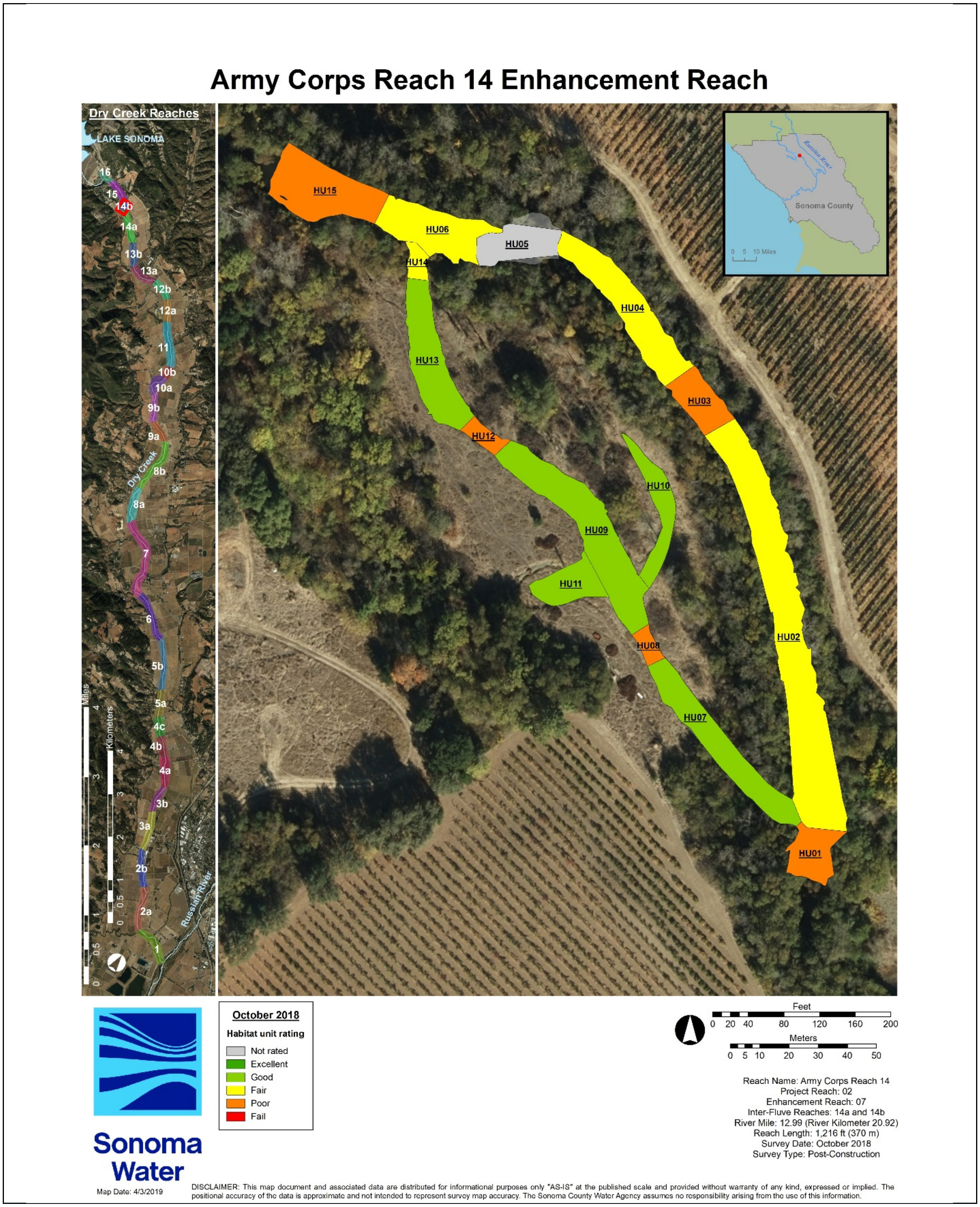


**Figure 5.2.27. Habitat unit ratings for the Army Corps Reach 14 enhancement reach, October 2018.**

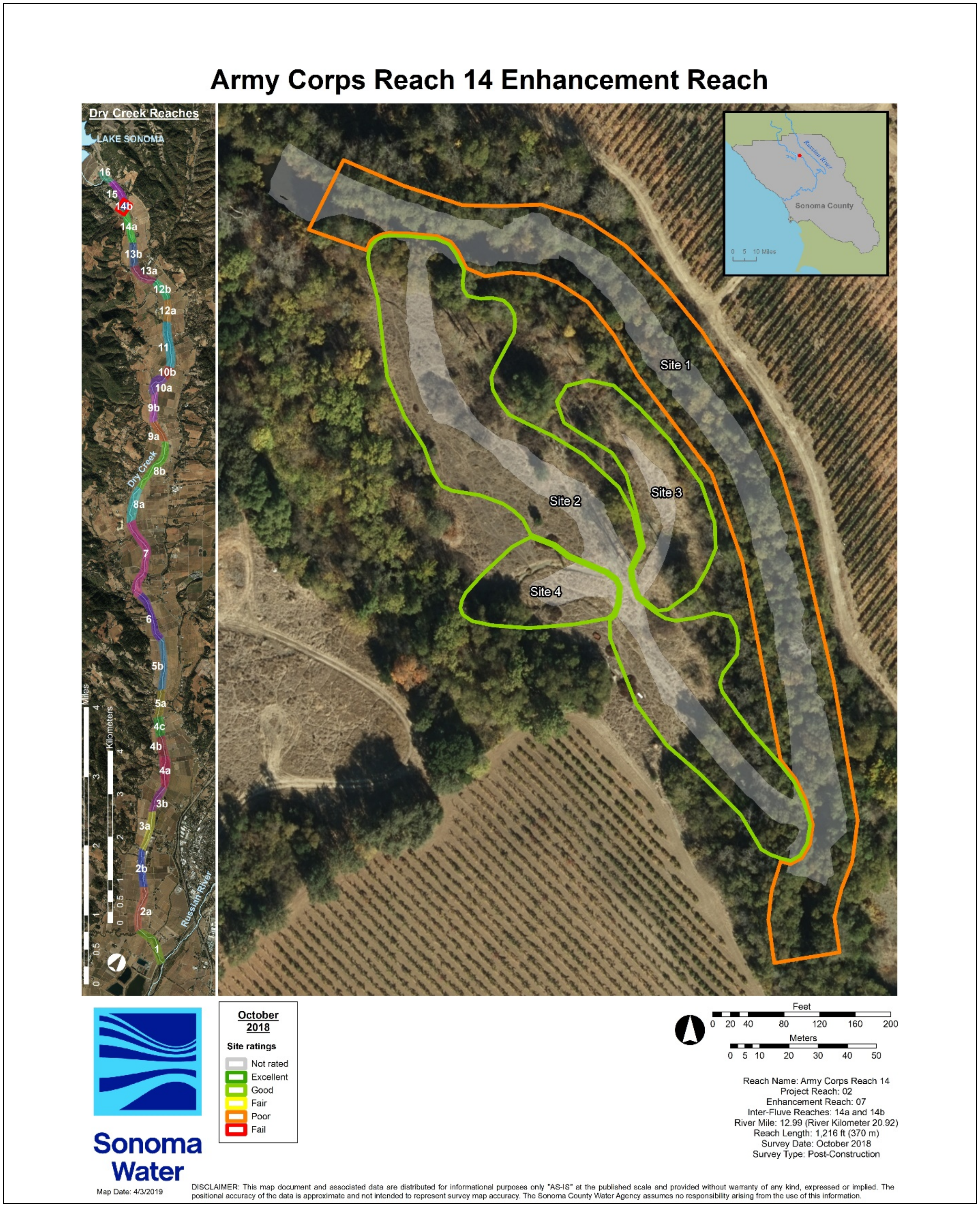


**Figure 5.2.28. Post enhancement site ratings for the Army Corps Reach 14 enhancement reach, October 2018.**

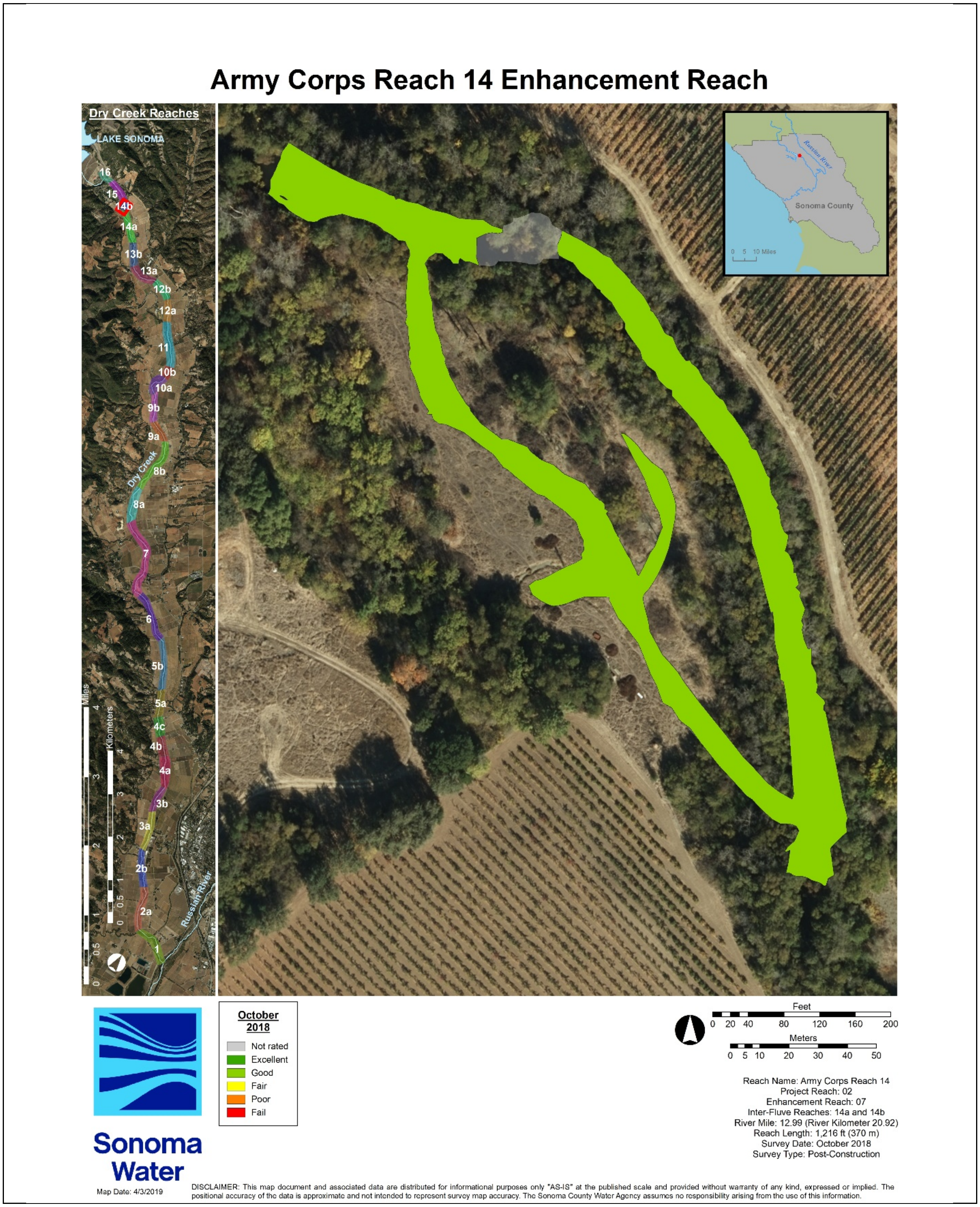


**Figure 5.2.29. Post-enhancement reach rating for the Army Corps Reach 14 enhancement reach, October 2018.**

## Weinstock Enhancement Reach

Sonoma Water monitored the post-enhancement condition of the Weinstock enhancement reach in October 2018. The enhanced reach encompassed 46,693 $ft^2$ within main- and off-channel areas of Dry Creek with 30% of the total area meeting optimal depth and velocity criteria (Table 5.2.30, Figure 5.2.33). The enhancement added 14.775 $ft^2$ of off-channel area, of which 38% met optimal depth and velocity criteria, compared to 27% in the main channel. Eleven habitat units composed the enhancement reach, with a pool to riffle ratio of 3:3 (1.00) and average shelter score of 75 (Table 5.2.31, Figure 5.2.34, Figure 5.2.35). Five habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised two enhancement sites (one main channel, one side channel; Figure 5.2.36), with excellent site average feature ratings, and fair site average habitat unit ratings (Table 5.2.32, Figure 5.2.37, Figure 5.2.38). Both enhancement sites received good ratings (Table 5.2.32, Figure 5.2.39). Overall, the Weinstock enhancement reach received a good effectiveness monitoring rating (Table 5.2.32, Figure 5.2.40; see Appendix 5.1 for all measured values, scores, and ratings).

### *Depth and Velocity*

**Table 5.2. 30. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Weinstock enhancement reach, October 2018.**

| Weinstock Post-enhancement 2018 | Wetted area ($ft^2$) | Optimal depth ($ft^2$) 0.5 – 2.0 ft | Optimal depth ($ft^2$) 2.0 – 4.0 ft | Optimal depth ($ft^2$) Total | Optimal velocity ($ft^2$) < 0.5 ft/s | Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 31,917 | 14,182 | 10,224 | 24,406 | 10,224 | 5,446 | 3,029 | 8,475 |
| Off channel area | 14,775 | 4,810 | 5,773 | 10,583 | 5,773 | 2,534 | 3,136 | 5,670 |
| **Total area** | **46,693** | **18,992** | **15,997** | **34,989** | **21,634** | **7,980** | **6,166** | **14,145** |
| Main channel % of wetted area | 68% | 44% | 32% | 76% | 42% | 17% | 9% | 27% |
| Off channel % of wetted area | 32% | 33% | 39% | 72% | 55% | 17% | 21% | 38% |
| **Total % of wetted area** | **100%** | **41%** | **34%** | **75%** | **46%** | **17%** | **13%** | **30%** |

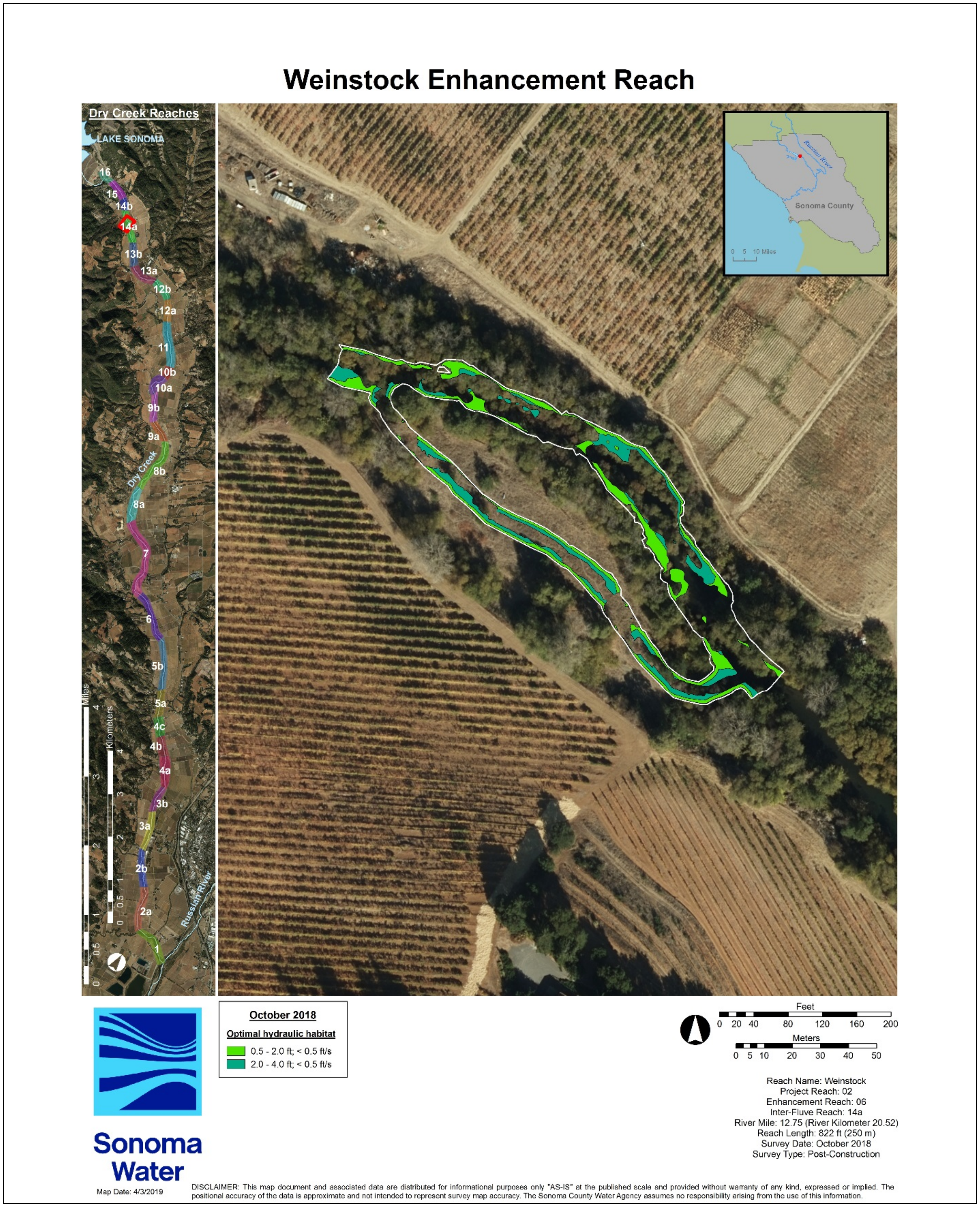


**Figure 5.2.30. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Weinstock enhancement reach, October 2018.**

### *Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 31. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Weinstock enhancement reach, October 2018, post-enhancement.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Flatwater | 2 | 25 | 50 |
| HU02 | Riffle | 2 | 30 | 60 |
| HU03 | Pool | 3 | 40 | 120 |
| HU04 | Flatwater | 2 | 20 | 40 |
| HU05 | Pool | 2 | 45 | 90 |
| HU06 | Flatwater | 3 | 15 | 45 |
| HU07 | Flatwater | 3 | 40 | 120 |
| HU08 | Riffle | 3 | 20 | 60 |
| HU09 | Flatwater | 3 | 30 | 90 |
| HU10 | Riffle | 2 | 20 | 40 |
| HU11 | Pool | 3 | 35 | 105 |
| **Pool: riffle** | **3: 3 (1.00)** | | | **Avg = 75** |

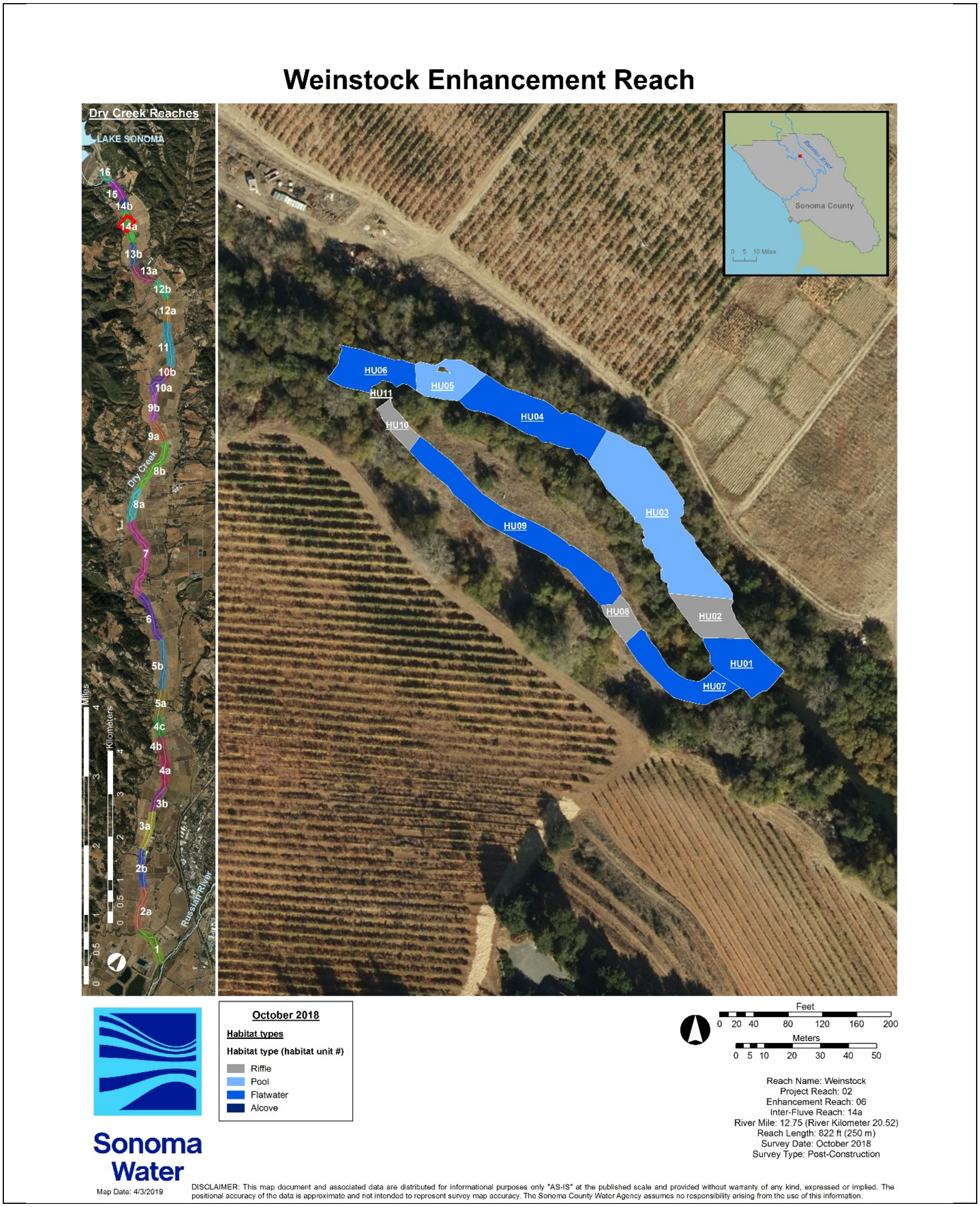


**Figure 5.2.31. Habitat unit number and type within the Weinstock enhancement reach, October 2018.**

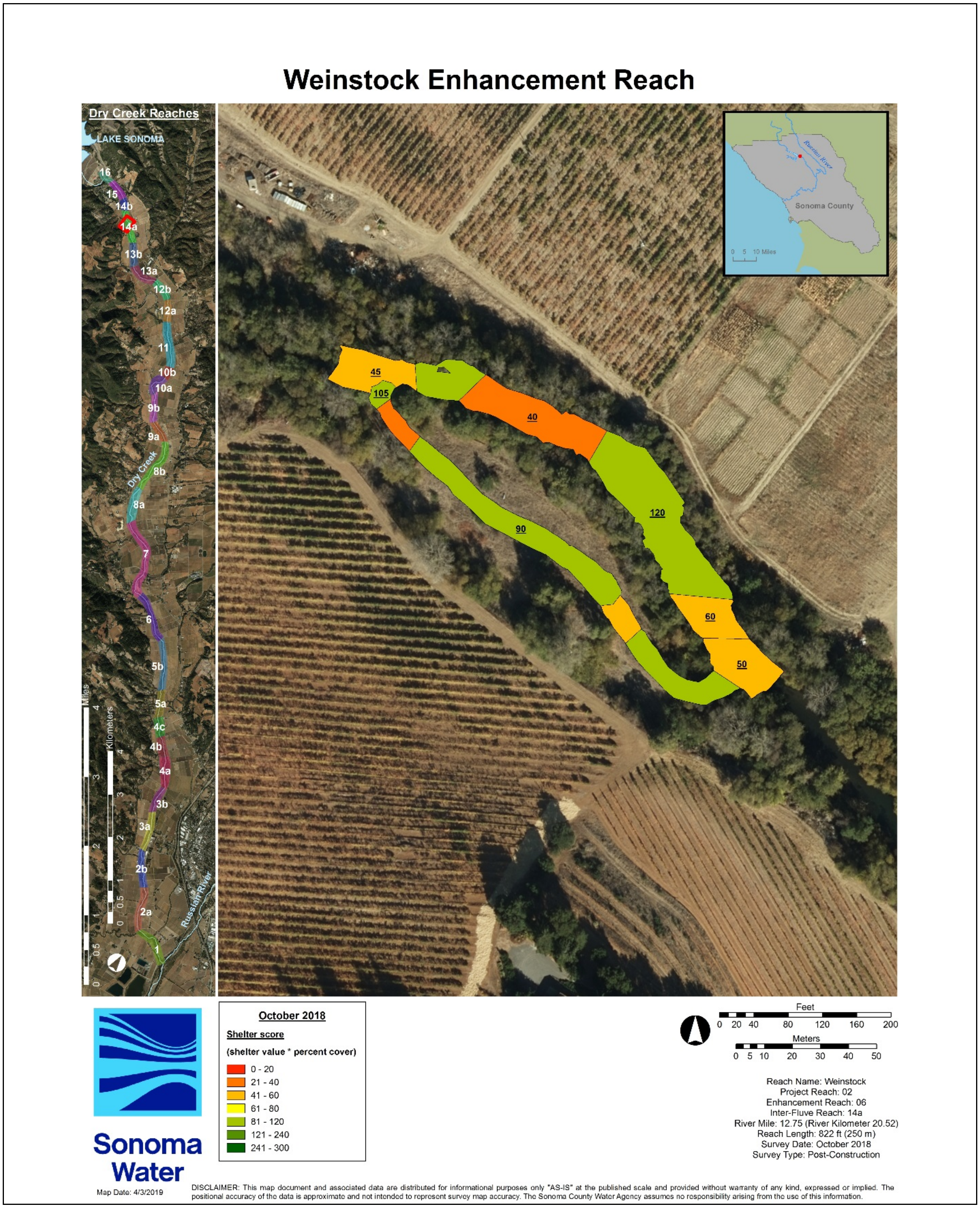


**Figure 5.2.32. Habitat unit shelter values within the Weinstock enhancement reach, October 2018.**

### *Feature, habitat unit, site, and reach ratings*

**Table 5.2. 32. Post-enhancement average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Weinstock enhancement reach, October 2018.**

| **Site number** | | **1** | **2** | | |
|---|---|---|---|---|---|
| **Site type** | | Main channel | Side channel | | |
| **Site average feature rating** | Site average feature quantitative rating[a] | 14 | 14 | | |
| | Site average feature qualitative rating[a] | Excellent | Excellent | | |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 19 | 20 | | |
| | Site average qualitative rating[b] | Fair | Fair | | |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | 33 | 34 | | |
| | Site qualitative rating[c] | Good | Good | | |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[c] | 34 | | | |
| | Enhancement reach qualitative rating[c]: | Good | | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

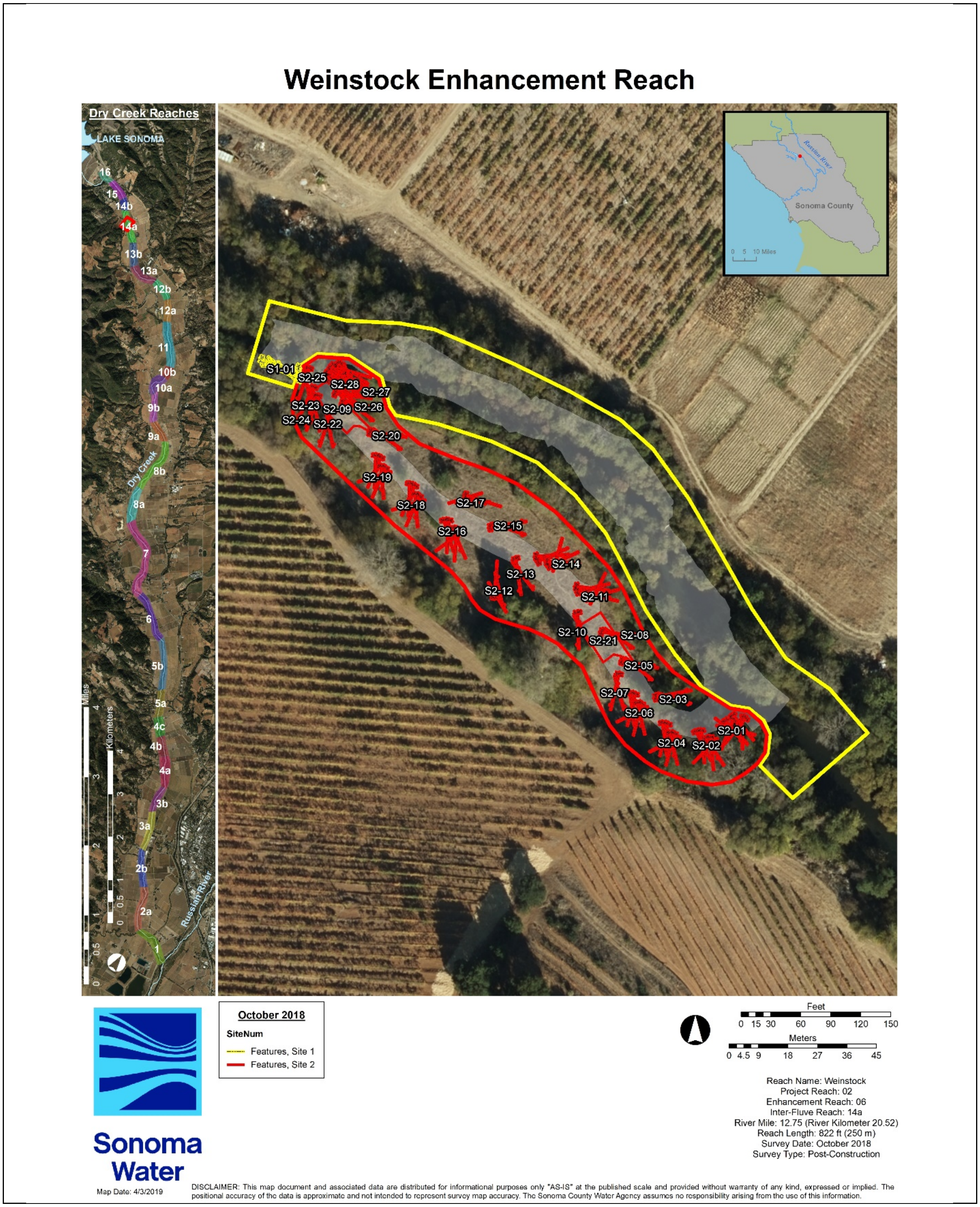


**Figure 5.2.33. Enhancement sites and features within the Weinstock enhancement reach, October 2018.**

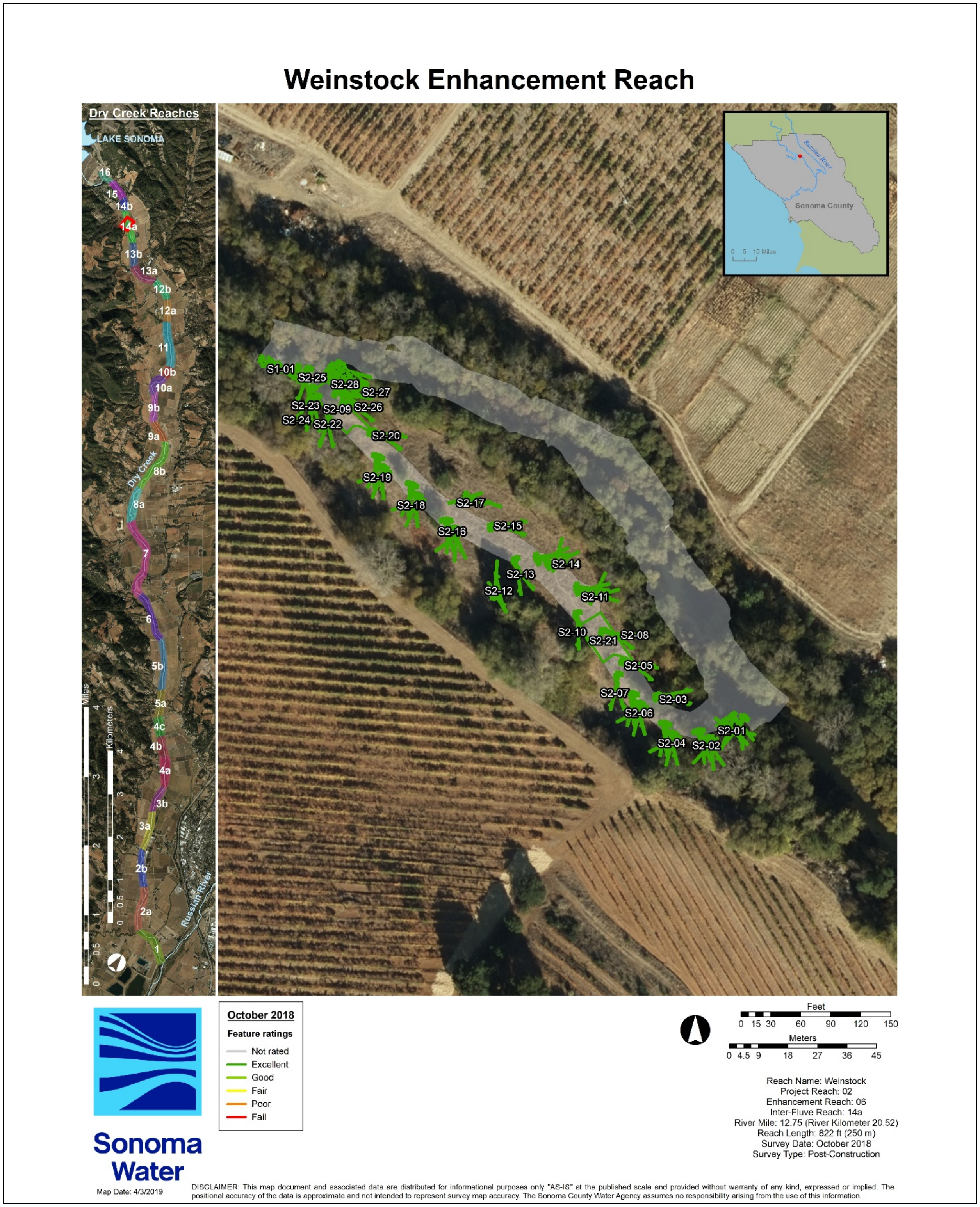


**Figure 5.2.34. Feature ratings for the Weinstock enhancement reach, October 2018.**

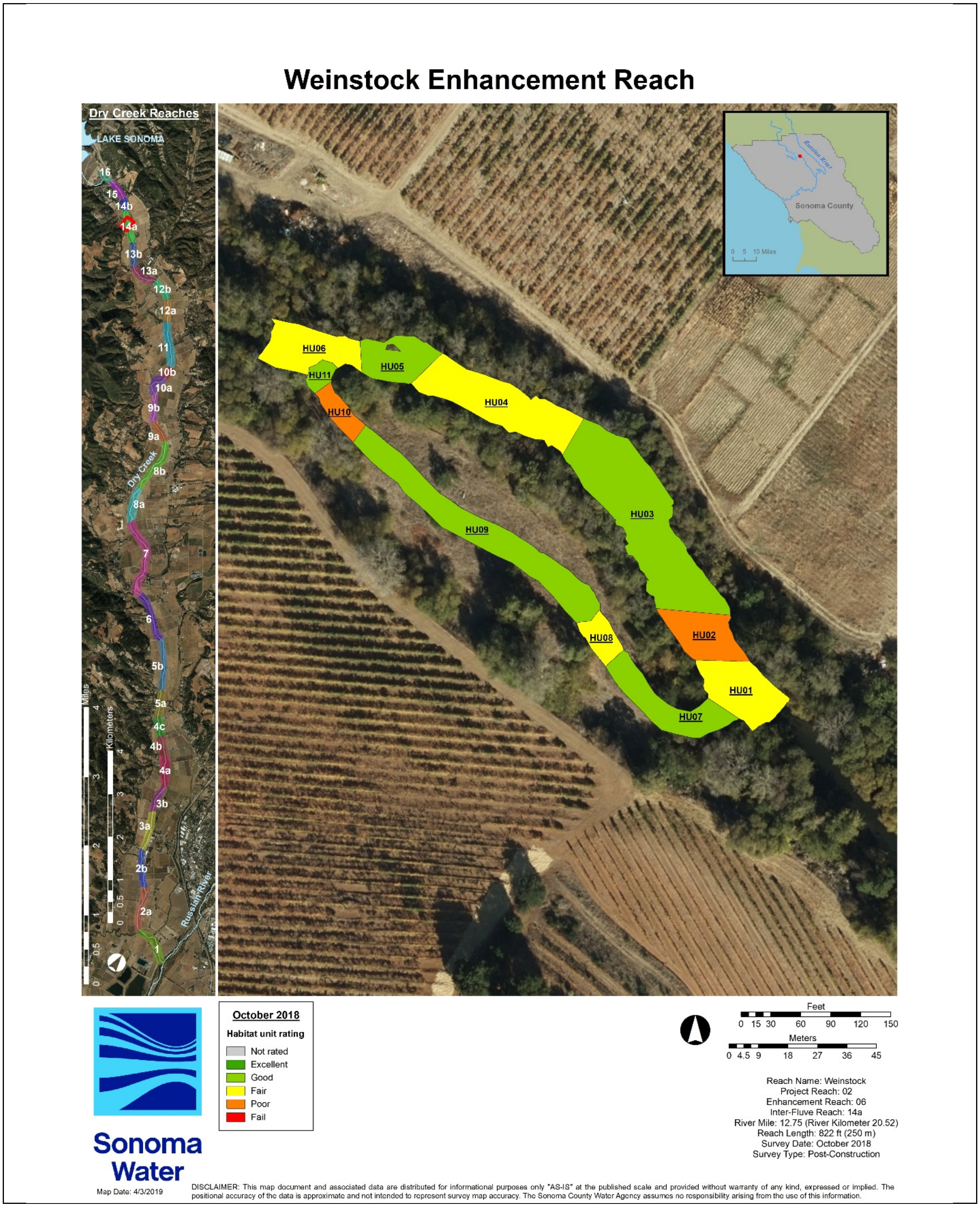


**Figure 5.2.35. Habitat unit ratings for the Weinstock enhancement reach, October 2018.**

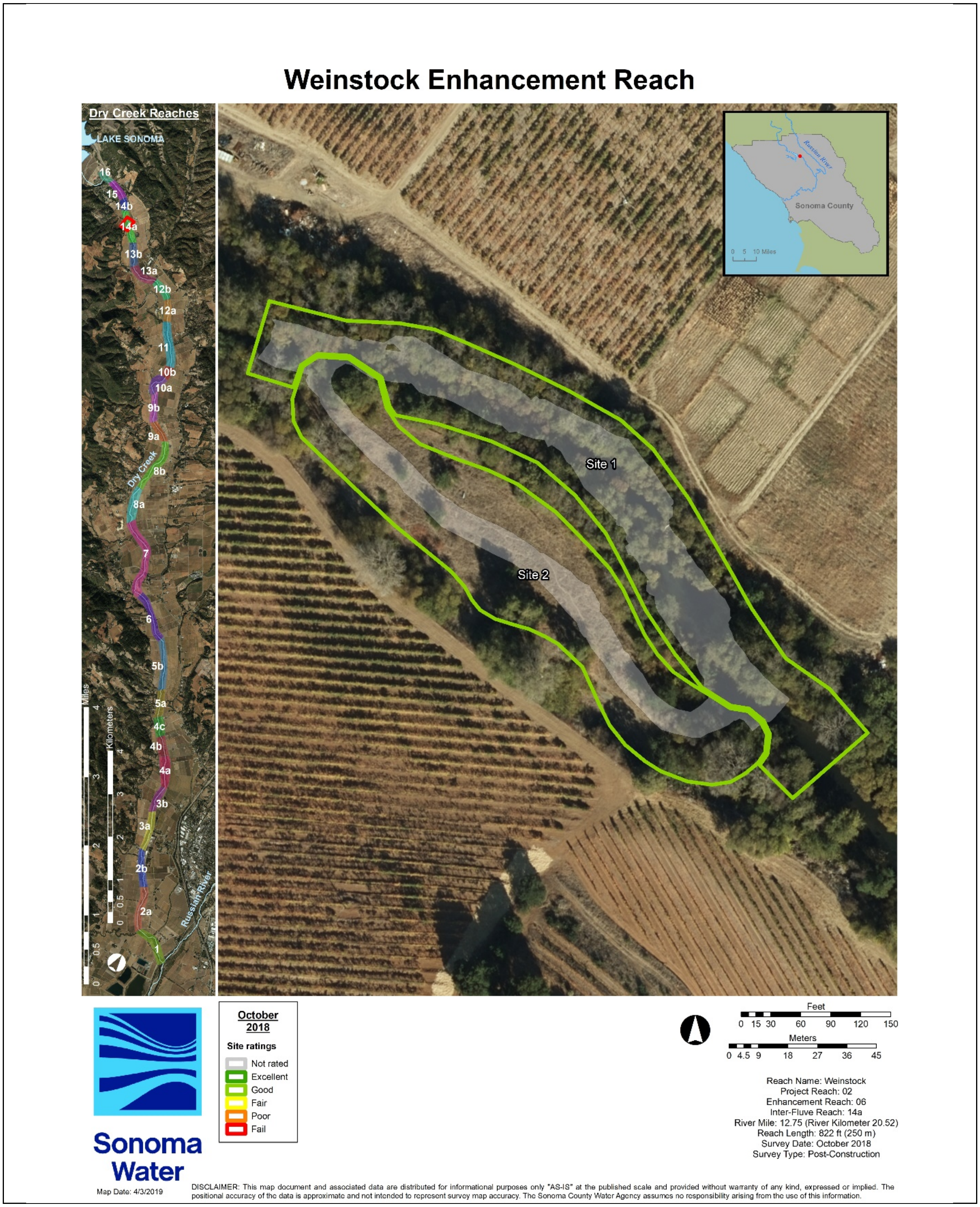


**Figure 5.2.36. Post enhancement site ratings for the Weinstock enhancement reach, October 2018.**

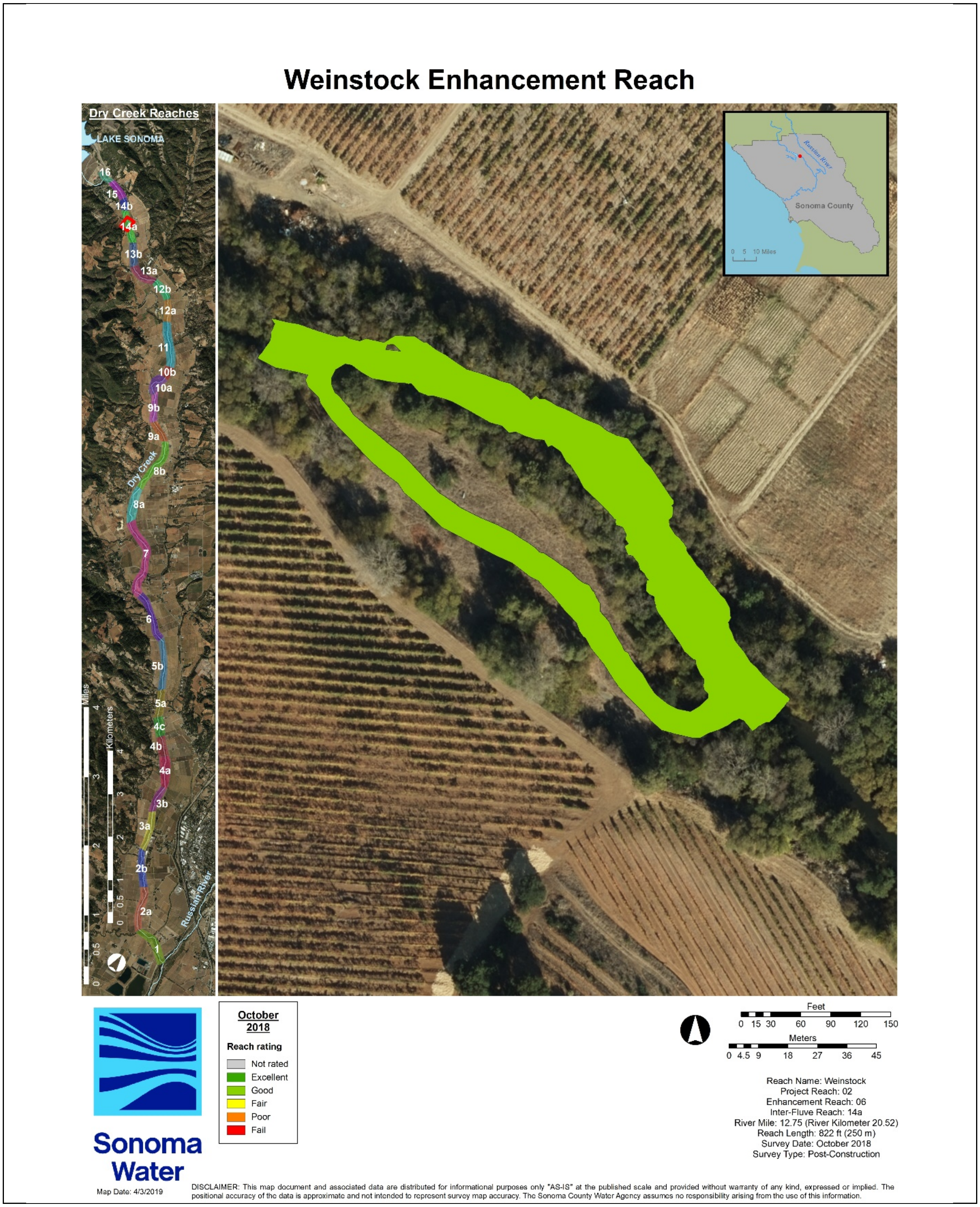


**Figure 5.2.37. Post-enhancement reach rating for the Weinstock enhancement reach, October 2018.**

## Ferrari-Carano, Olson Enhancement Reach

Sonoma Water monitored the post-enhancement condition of the Ferrari-Carano, Olson enhancement reach in October 2018. The enhanced reach encompassed 151,027 $ft^2$ within main- and off-channel areas of Dry Creek with 33% of the total area meeting optimal depth and velocity criteria (Table 5.2.33, Figure 5.2.41). The enhancement added 83,833 $ft^2$ of off-channel area, of which 41% met optimal depth and velocity criteria, compared to 22% in the main channel. Thirty-three habitat units composed the enhancement reach, with a pool to riffle ratio of 9:7 (1.29) and average shelter score of 68 (Table 5.2.34, Figure 5.2.42, Figure 5.2.43). Fourteen habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised three enhancement sites (one main-channel, two side channels; Table 5.2.35, Figure 5.2.44), with excellent site average feature ratings, and fair site average habitat unit ratings, likely driven by shelter scores (Table 5.2.35, Figure 5.2.45, Figure 5.2.46). Enhancement sites all received good ratings (Table 5.2.35, Figure 5.2.47). Overall, the Ferrari-Carano, Olson enhancement reach received a good effectiveness monitoring rating (Table 5.2.35, Figure 5.2.48; see Appendix 5.1 for all measured values, scores, and ratings).

### *Depth and velocity*

**Table 5.2. 33. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Ferrari-Carano, Olson enhancement reach, October 2018.**

| Ferrari-Carano, Olson Post-enhancement 2018 | Wetted area ($ft^2$) | Optimal depth ($ft^2$) 0.5 – 2.0 ft | Optimal depth ($ft^2$) 2.0 – 4.0 ft | Optimal depth ($ft^2$) Total | Optimal velocity ($ft^2$) < 0.5 ft/s | Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 67,194 | 44,531 | 7,880 | 52,411 | 25,139 | 11,407 | 3,080 | 14,487 |
| Off channel area | 83,833 | 40,377 | 26,860 | 67,237 | 49,655 | 20,614 | 14,062 | 34,676 |
| **Total area** | **151,027** | **84,908** | **34,740** | **119,648** | **74,793** | **32,021** | **17,142** | **49,163** |
| Main channel % of wetted area | 44% | 66% | 12% | 78% | 37% | 17% | 5% | 22% |
| Off channel % of wetted area | 56% | 48% | 32% | 80% | 59% | 25% | 17% | 41% |
| **Total % of wetted area** | **100%** | **56%** | **23%** | **79%** | **50%** | **21%** | **11%** | **33%** |

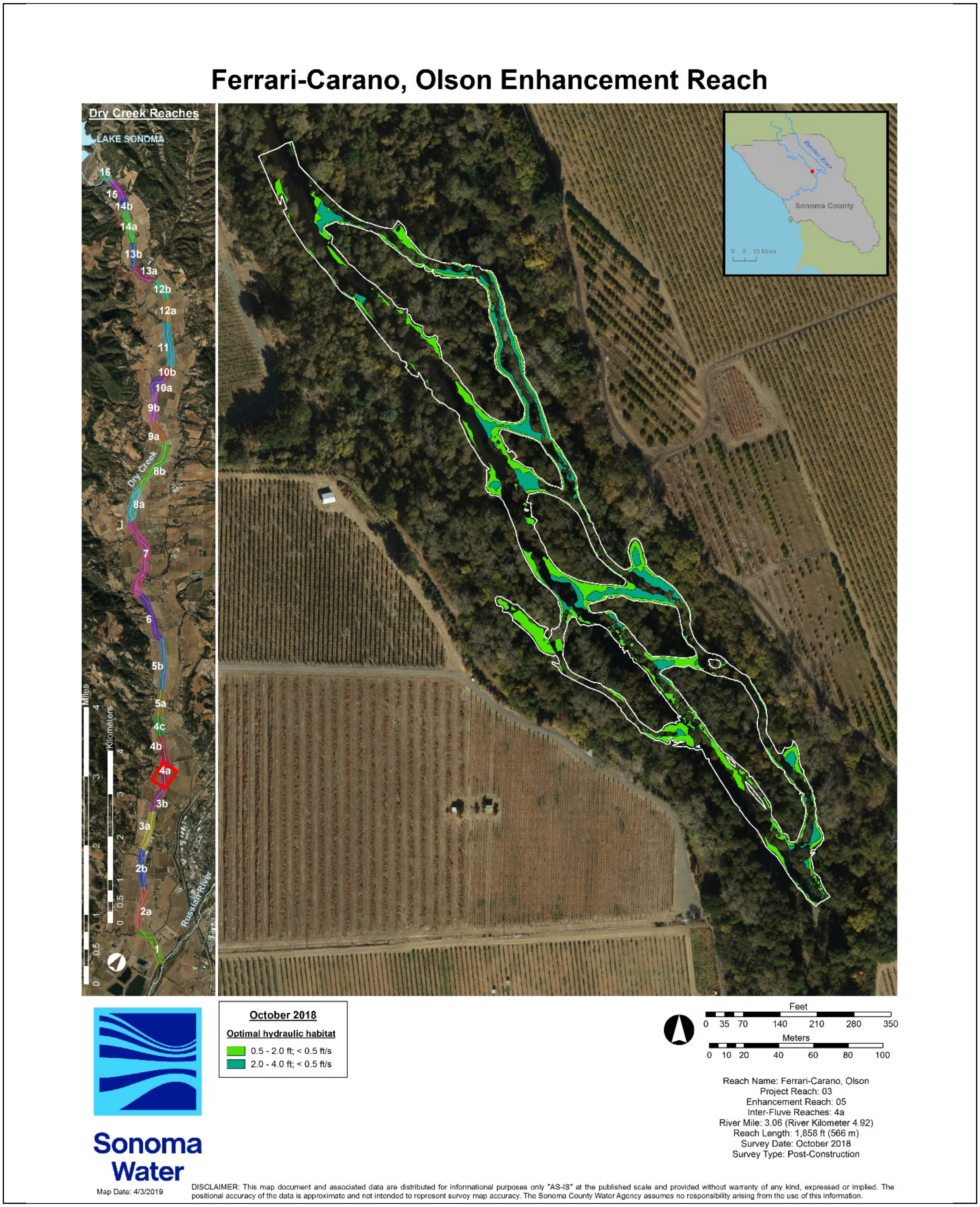


**Figure 5.2.38. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Ferrari-Carano, Olson enhancement reach, October 2018.**

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 34. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Ferrari-Carano, Olson enhancement reach, October 2018, post-enhancement.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Pool | 2 | 40 | 80 |
| HU03 | Flatwater | 3 | 35 | 105 |
| HU04 | Riffle | 1 | 30 | 30 |
| HU05 | Flatwater | 3 | 40 | 120 |
| HU06 | Pool | 3 | 20 | 60 |
| HU07 | Flatwater | 3 | 40 | 120 |
| HU08 | Pool | 3 | 20 | 60 |
| HU09 | Flatwater | 2 | 15 | 30 |
| HU10 | Pool | 3 | 35 | 105 |
| HU11 | Flatwater | 3 | 15 | 45 |
| HU12 | Alcove | 3 | 30 | 90 |
| HU13 | Riffle | 3 | 5 | 15 |
| HU14 | Pool | 3 | 40 | 120 |
| HU15 | Pool | 3 | 35 | 105 |
| HU16 | Alcove | 3 | 50 | 150 |
| HU17 | Pool | 3 | 30 | 90 |
| HU18 | Riffle | 0 | 0 | 0 |
| HU19 | Flatwater | 3 | 10 | 30 |
| HU20 | Alcove | 3 | 20 | 60 |
| HU21 | Riffle | 0 | 0 | 0 |
| HU22 | Riffle | 2 | 20 | 40 |
| HU23 | Flatwater | 3 | 20 | 60 |
| HU24 | Riffle | 3 | 5 | 15 |
| HU25 | Pool | 3 | 15 | 45 |
| HU26 | Flatwater | 3 | 20 | 60 |
| HU27 | Flatwater | 3 | 15 | 45 |
| HU28 | Flatwater | 3 | 35 | 105 |
| HU29 | Riffle | 2 | 10 | 20 |
| HU30 | Pool | 3 | 35 | 105 |
| HU31 | Flatwater | 3 | 40 | 120 |
| HU32 | Alcove | 3 | 40 | 120 |
| HU33 | Flatwater | 3 | 20 | 60 |
| HU34 | Flatwater | 3 | 10 | 30 |
| **Pool: riffle** | **9:7 (1.29)** | | | **Avg = 68** |

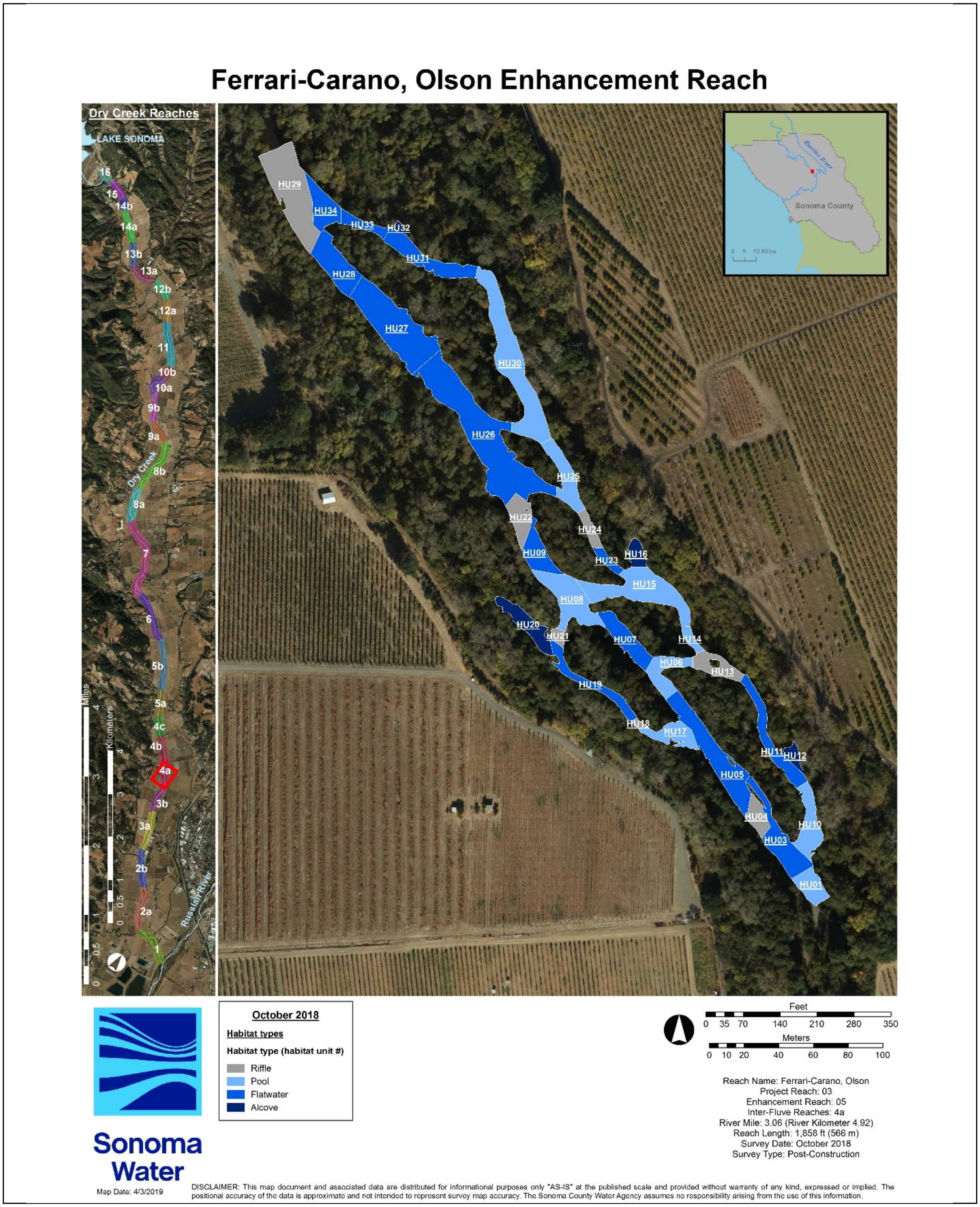


**Figure 5.2.39. Habitat unit number and type within the Ferrari-Carano, Olson enhancement reach, October 2018.**

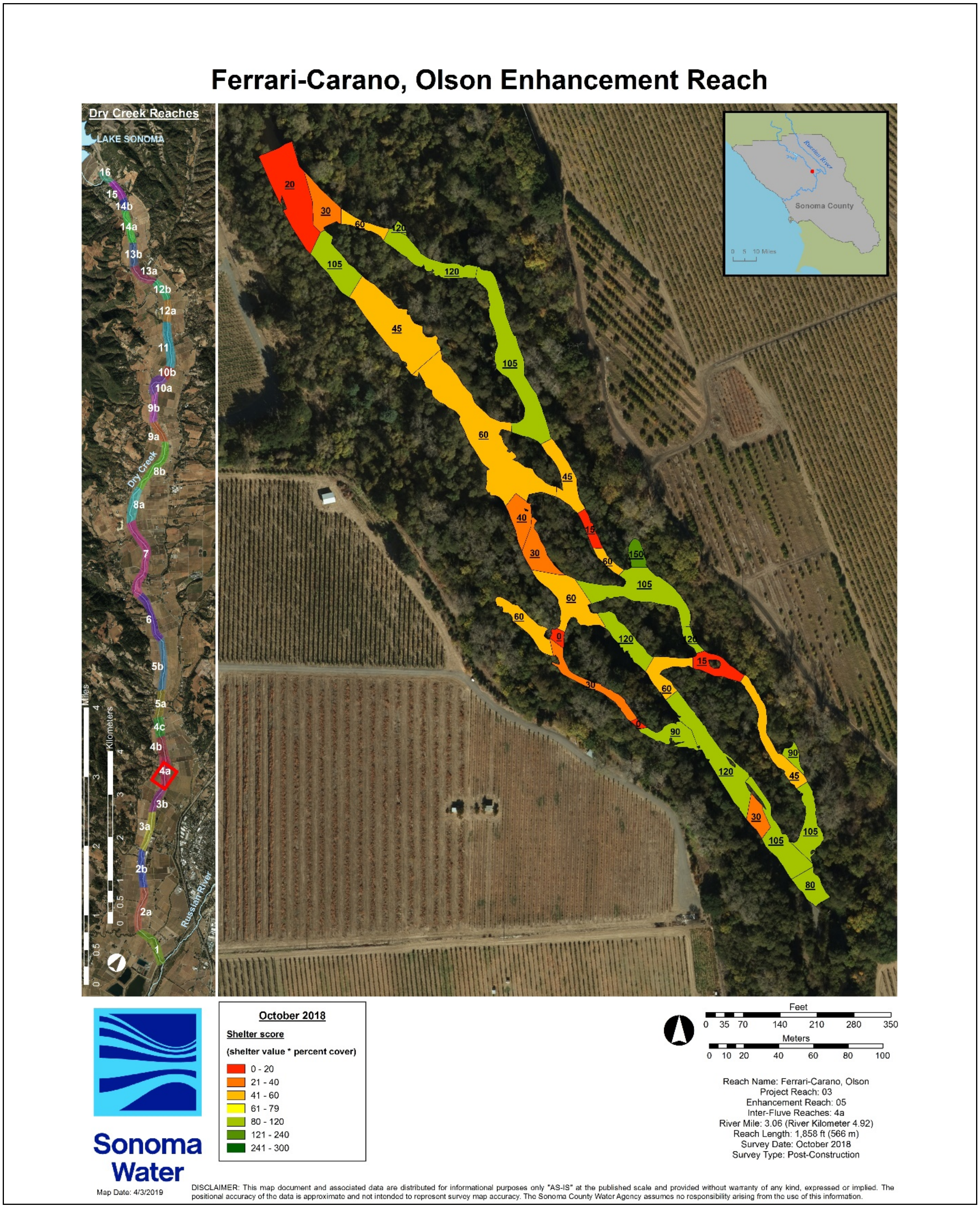


**Figure 5.2.40. Habitat unit shelter scores within the Ferrari-Carano, Olson enhancement reach, October 2018.**

*Feature, habitat unit, site, and reach ratings*

**Table 5.2. 35. Post-enhancement average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Ferrari-Carano, Olson enhancement reach, October 2018.**

| Site number | | 1 | 2 | 3 | |
|---|---|---|---|---|---|
| Site type | | Main channel | Side channel | Side channel | |
| Site average feature rating | Site average feature quantitative rating[a] | 14 | 13 | 13 | |
| | Site average feature qualitative rating[a] | Excellent | Excellent | Excellent | |
| Site average habitat unit rating | Site average habitat unit quantitative rating[b] | 19 | 22 | 16 | |
| | Site average qualitative rating[b] | Fair | Good | Fair | |
| Site rating | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | 32 | 36 | 29 | |
| | Site qualitative rating[c] | Good | Good | Fair | |
| Enhancement reach rating | Enhancement reach quantitative rating (average of site rating)[c] | 33 | | | |
| | Enhancement reach qualitative rating[c]: | Good | | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

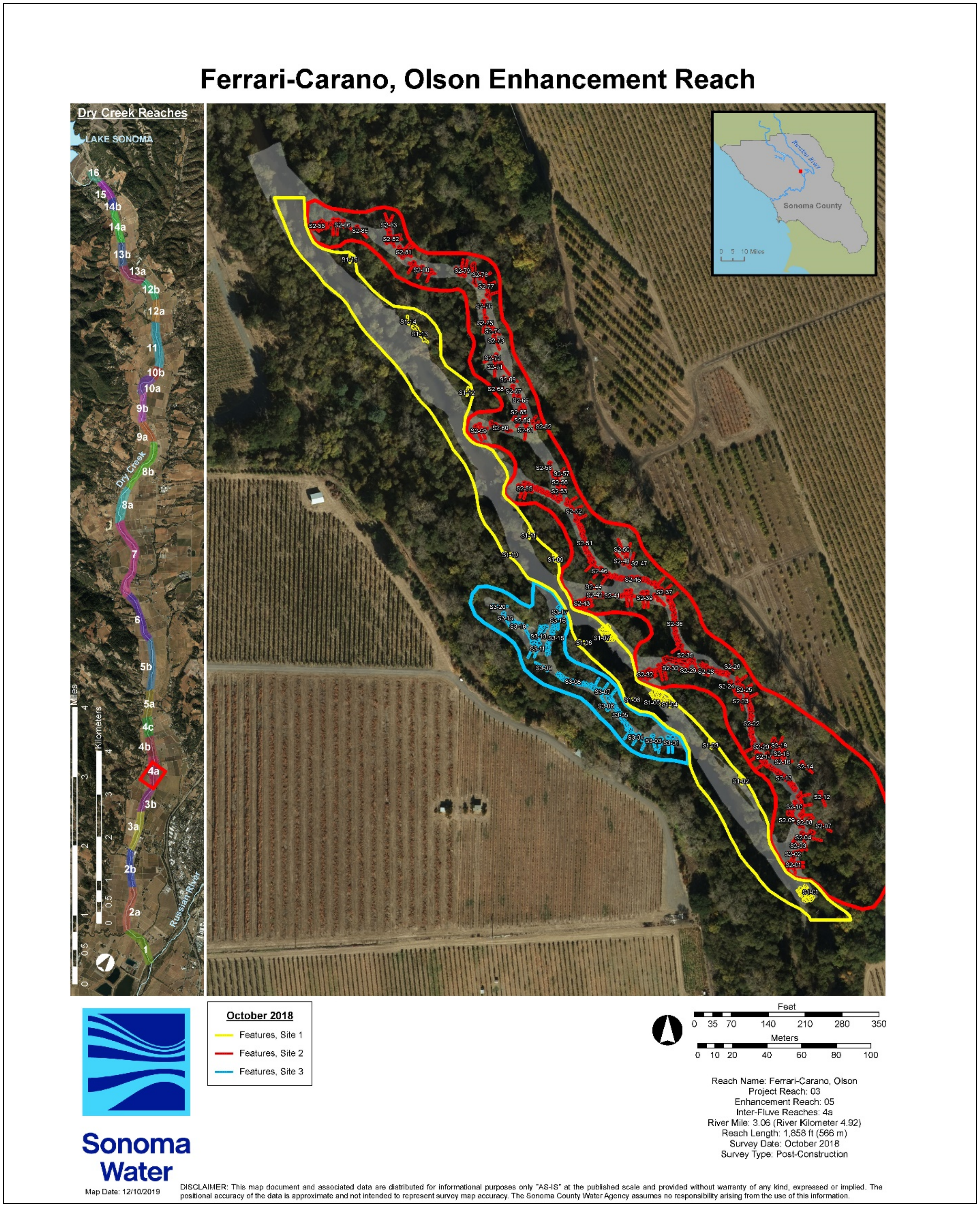


**Figure 5.2.41. Enhancement features within the Ferrari-Carrano, Olson enhancement, October 2018.**

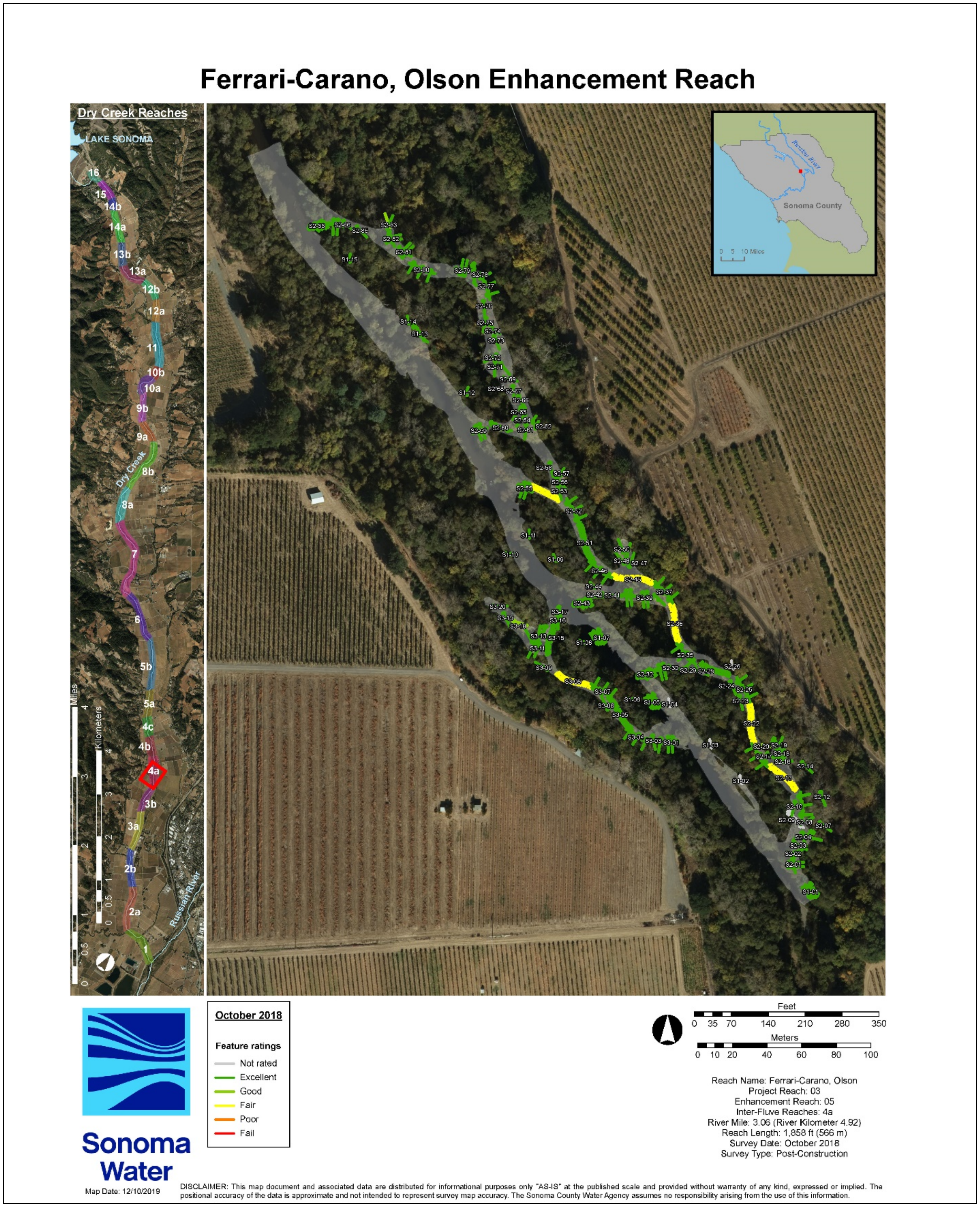


**Figure 5.2.42. Feature ratings for the Ferrari-Carrano, Olson enhancement reach October 2018.**

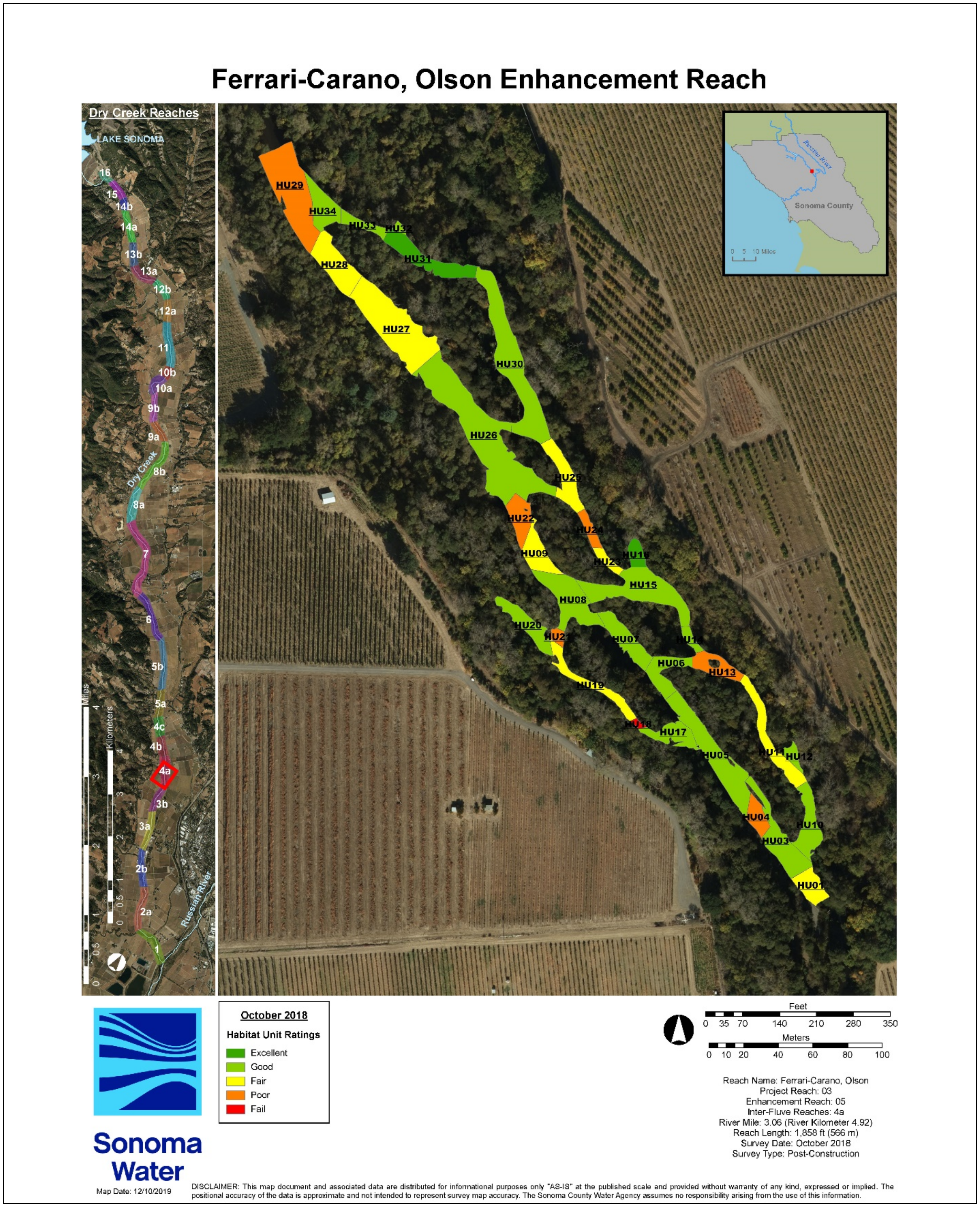


**Figure 5.2.43. Habitat unit ratings for the Ferrari-Carrano, Olson enhancement reach October 2018.**

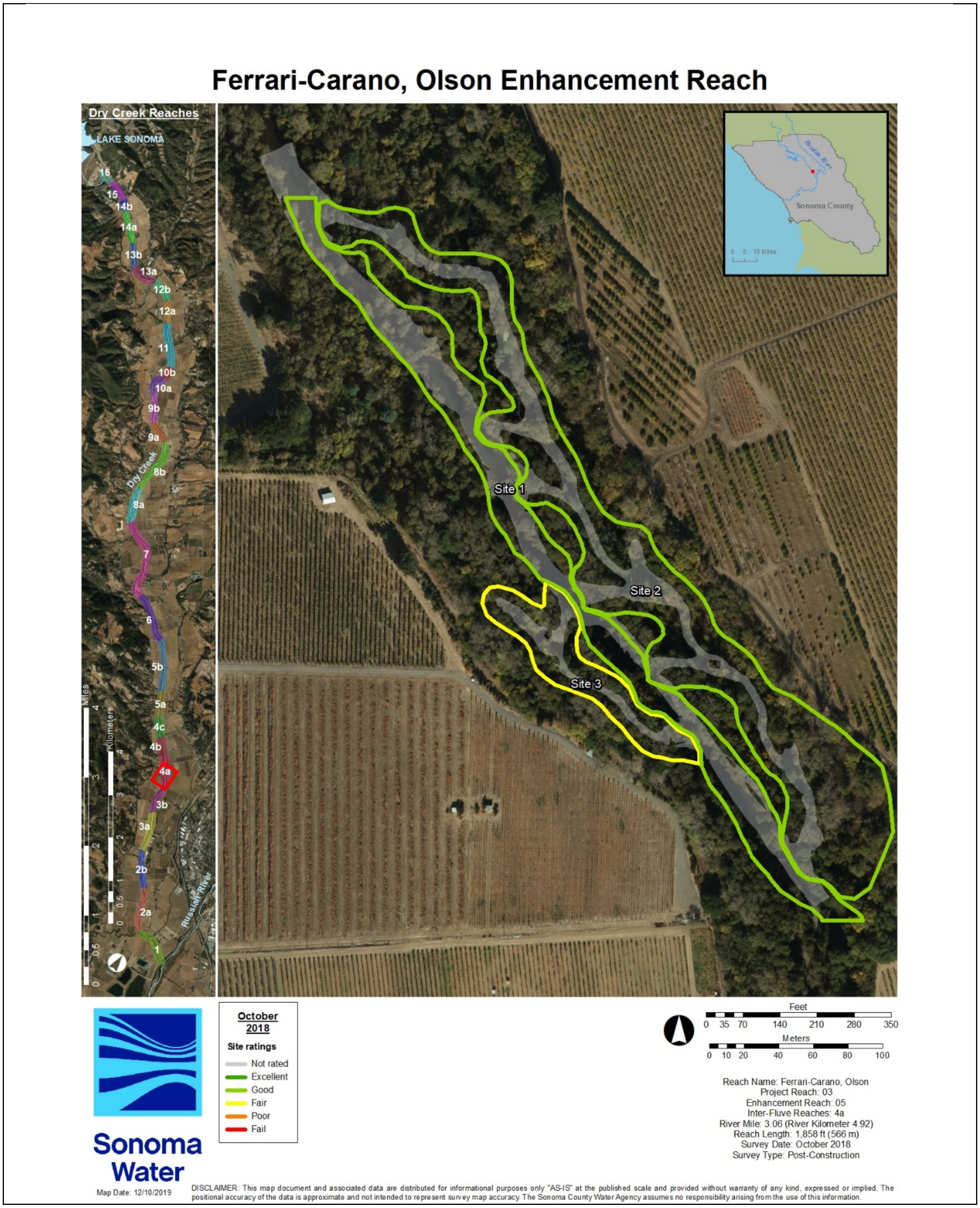


**Figure 5.2.44. Post-enhancement site ratings for the Ferrari-Carano, Olson enhancement reach, October 2018.**

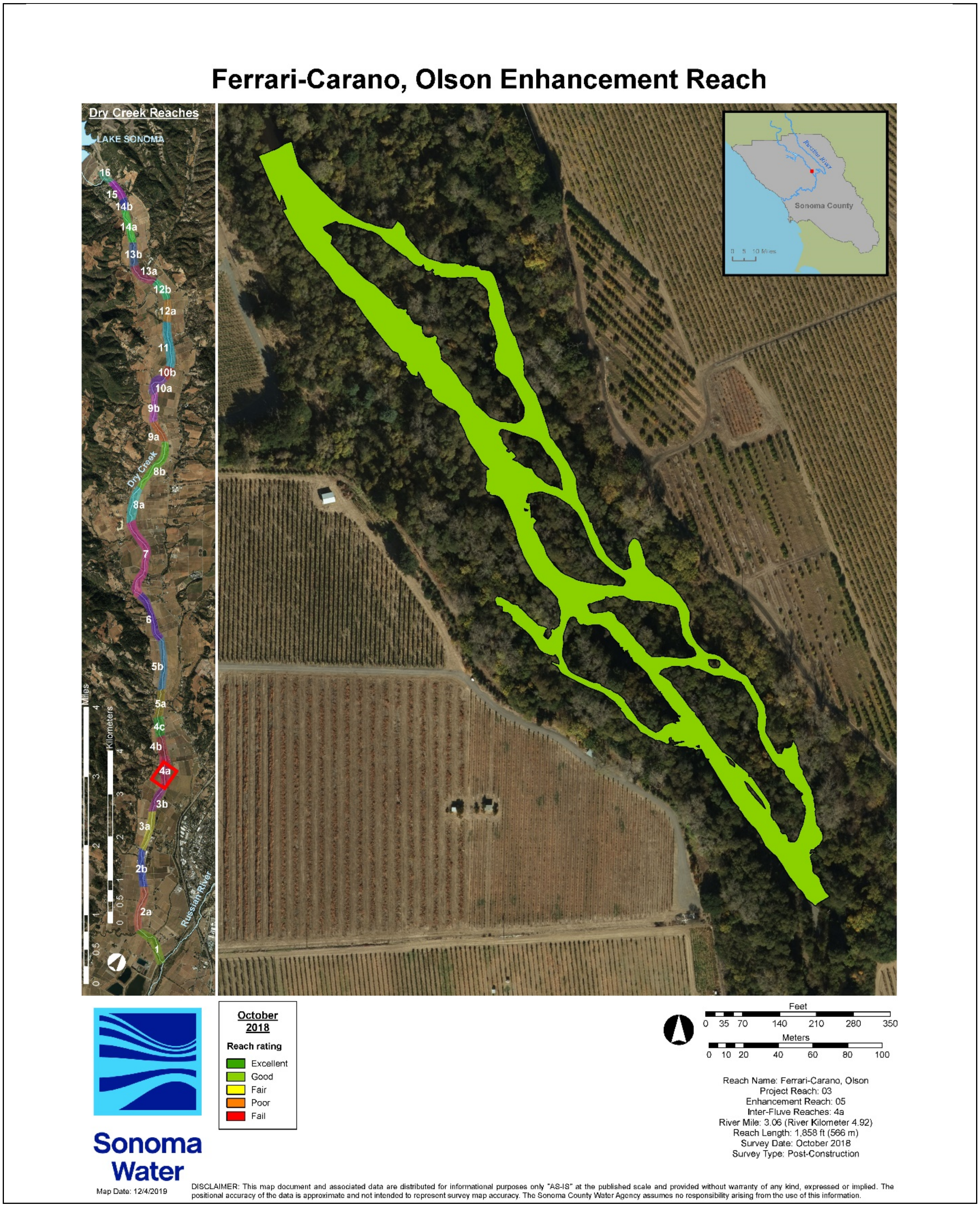


**Figure 5.2.45. Post-enhancement reach rating for the Ferrari-Carano, Olson enhancement reach, October 2018.**

# Post-effective Flow

## Summary

Sonoma Water monitored the post-effective flow conditions of the Truett Hurst, Meyer, Carlson, Lonestar, City of Healdsburg Yard, and Geyser Peak enhancement reaches in 2018 (Table 5.2.8, Figure 5.2.4). Overall, the enhancement reaches encompassed 295,242 $ft^2$ within main- and off-channel areas, with 24% of the total area meeting optimal depth and velocity criteria (Table 5.2.36). Monitoring examined 93,649 $ft^2$ of off-channel area, of which 44% met optimal depth and criteria, compared with 201,593 $ft^2$ and 15% in the main channel. Crews observed 68 habitat units across all enhancement reaches with a total pool to riffle ratio of 22:13 (1.69) and a total average shelter score of 95 (Table 5.2.37). Average alcove shelter score (239) and average pool shelter score (89) exceeded the optimum shelter score of 80, followed by riffles (62), and flatwaters (58). Post-effective flow, the Truett Hurst, Carlson, Lonestar, and City of Healdsburg enhancement reaches rated good, and Meyer and Geyser Peak rated fair (Table 5.2.38; see below for individual enhancement reach summaries and Appendix 5.1 for all measured values, scores, and ratings).

### *Depth and velocity*

**Table 5.2. 36. Post-effective flow areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement surveyed in 2018.**

| Dry Creek Post-effective Flow 2018 | Wetted area ($ft^2$) | Optimal depth ($ft^2$) 0.5 – 2.0 ft | Optimal depth ($ft^2$) 2.0 – 4.0 ft | Optimal depth ($ft^2$) Total | Optimal velocity ($ft^2$) < 0.5 ft/s | Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 201,593 | 143,001 | 24,938 | 167,938 | 51,176 | 23,126 | 7,319 | 30,444 |
| Off channel area | 93,649 | 41,650 | 36,249 | 77,899 | 54,012 | 21,868 | 19,503 | 41,370 |
| **Total area** | 295,242 | 184,651 | 61,187 | 245,838 | 105,188 | 44,993 | 26,821 | 71,815 |
| Main channel % of wetted area | 71% | 71% | 12% | 83% | 25% | 11% | 4% | 15% |
| Off channel % of wetted area | 29% | 44% | 39% | 83% | 58% | 23% | 21% | 44% |
| **Total % of wetted area** | **100%** | 63% | 21% | 83% | 36% | 15% | 9% | 24% |

### *Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 37. Post-enhancement habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches constructed in 2018, post-effective flow.**

| Habitat Type | # of Habitat Units | Shelter Score |
|---|---|---|
| Riffle | 13 | 62 |
| Pool | 22 | 89 |
| Flatwater | 23 | 58 |
| Alcove | 10 | 239 |
| **Pool: riffle** | **22:13 (1.69)** | **Avg: 95** |

### *Reach ratings*

**Table 5.2. 38. Post-enhancement ratings for Dry Creek enhancement reaches constructed in 2018.**

| Enhancement Reach | Post-effective Flow Rating |
|---|---|
| Truett Hurst | Good |
| Meyer | Fair |
| Carlson, Lonestar | Good |
| City of Healdsburg Yard | Good |
| Geyser Peak | Fair |

## Truett Hurst Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Truett Hurst enhancement reach in August 2018. Sonoma Water originally constructed the Truett Hurst enhancement reach in November 2016, but aggradation caused by large storms in winter 2016/2017 led to a poor effectiveness monitoring rating in July 2017 and repairs in summer 2017. Crews monitored again in October 2017 and the enhancement reach received a good post-repair rating (see 2017 report for results). The results below characterize the post effective flow, post-repair habitat condition of the Truett Hurst enhancement reach. The enhancement reach encompassed 84,943 $ft^2$ within main and off channel areas with 25% of the total area meeting optimal depth and velocity criteria (Table 5.2.39, Figure 5.2.49). The enhancement added 24,233 $ft^2$ of side channel and 7,509 $ft^2$ of side channel alcove area, of which 26% and 60%, respectively met optimal depth and velocity criteria, compared with 19% for the main channel area. Twenty one habitat units composed the enhancement reach post-effective flow, with a pool to riffle ratio of 7:5 (1.40) and an average shelter score of 83 (Table 5.2.39, Figure 5.2.50, Figure 5.2.51). Nine habitat units met or exceeded the optimal shelter value of 80. The enhancement reach comprised five enhancement sites (one main channel, a side channel, two alcoves, and a bank site; Table 5.2.41, Figure 5.2.52) that received good to excellent site average feature ratings (we did not rate enhancement site 1 as it contained no features), and fair to excellent site average habitat unit ratings (Figure 5.2.53, Figure 5.2.54). Enhancement site ratings ranged from poor to excellent, with the main channel site (site 1) receiving a poor rating, the two alcove sites receiving excellent ratings, and the side-channel and bank sites receiving good ratings (Table 5.2.41, Figure 5.2.55). Overall, the Truett Hurst enhancement reach, post-2017 repair, post effective flow received a good effectiveness monitoring rating (Figure 5.2.56, see Appendix 5.1 for all measured values, scores, and ratings).

*Depth and velocity*

**Table 5.2. 39. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Truett Hurst enhancement reach, August 2018.**

| **Truett Hurst Post-effective Flow 2018** | **Wetted area ($ft^2$)** | **Optimal depth ($ft^2$) 0.5 – 2.0 ft** | **Optimal depth ($ft^2$) 2.0 – 4.0 ft** | **Optimal depth ($ft^2$) Total** | **Optimal velocity ($ft^2$) < 0.5 ft/s** | **Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s** | **Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s** | **Optimal habitat ($ft^2$) Total** |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 53,201 | 32,915 | 9,753 | 42,667 | 17,792 | 7,123 | 2,828 | 9,952 |
| Off-channel area | 24,233 | 11,558 | 9,757 | 21,315 | 8,611 | 4,926 | 1,404 | 6,330 |
| Off- channel alcove area | 7,509 | 2,483 | 3,208 | 5,691 | 5,720 | 2,384 | 2,153 | 4,537 |
| **Total area** | **84,943** | **46,956** | **22,717** | **69,673** | **32,122** | **14,433** | **6,386** | **20,818** |
| Main channel % of wetted area | 62% | 62% | 18% | 80% | 33% | 13% | 5% | 19% |
| Side channel % of wetted area | 29% | 48% | 40% | 88% | 36% | 20% | 6% | 26% |
| Side channel alcove area % of wetted area | 9% | 33% | 43% | 76% | 76% | 32% | 29% | 60% |
| **Total % of wetted area** | **100%** | **55%** | **27%** | **82%** | **38%** | **17%** | **8%** | **25%** |

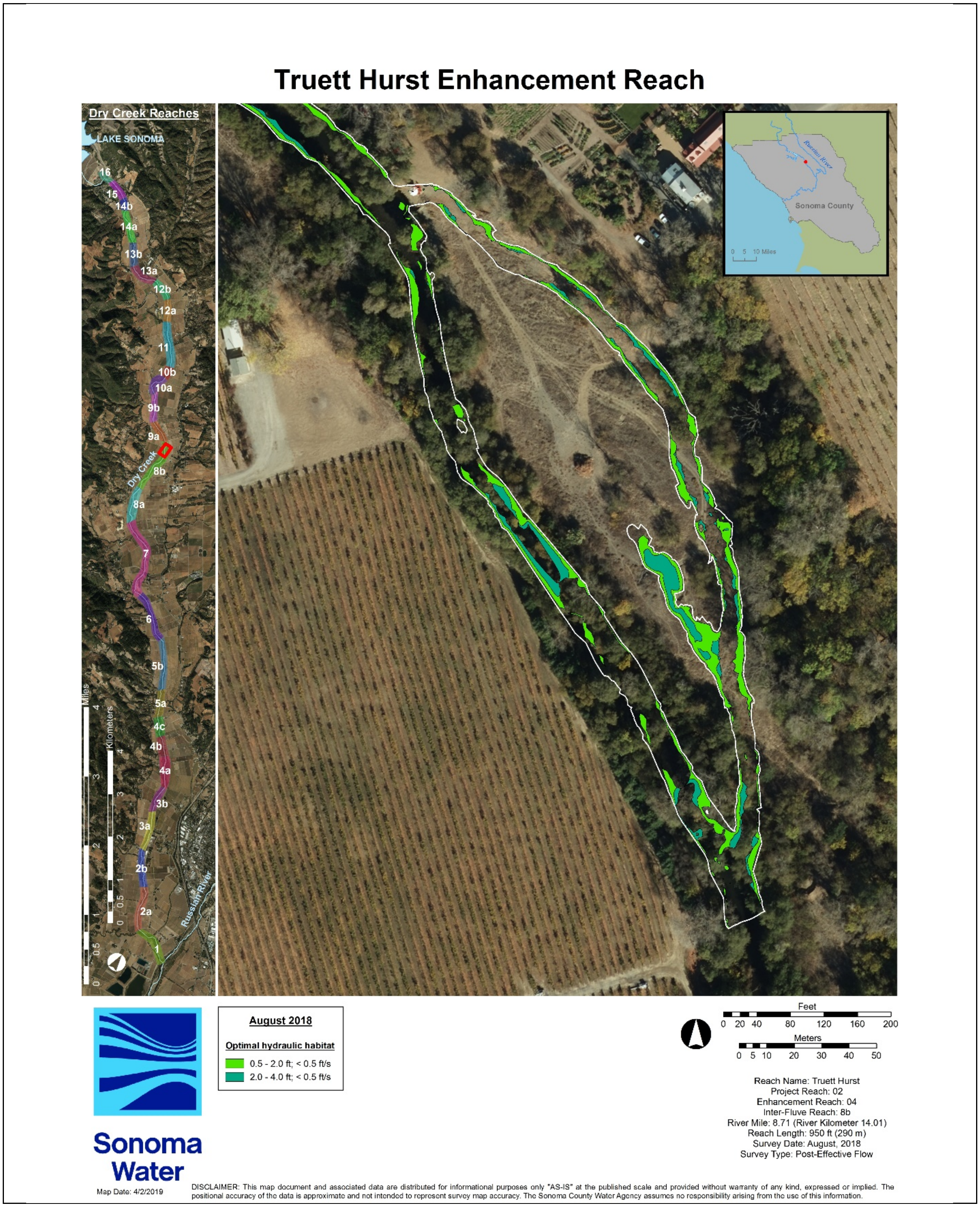


**Figure 5.2.46. Optimal hydraulic habitat for fry (<0.5 f/s, 0.5-2.0 ft) and parr (<0.5 f/s, 2.0-4.0 ft) within the Truett Hurst enhancement reach, August 2018.**

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 40. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Truett Hurst enhancement reach, August 2018, post-effective flow.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Pool | 3 | 20 | 60 |
| HU02 | Pool | 3 | 40 | 120 |
| HU03 | Flatwater | 2 | 20 | 40 |
| HU04 | Flatwater | 2 | 15 | 30 |
| HU05 | Pool | 3 | 50 | 150 |
| HU06 | Riffle | 3 | 10 | 30 |
| HU07 | Flatwater | 2 | 15 | 30 |
| HU08 | Riffle | 3 | 60 | 180 |
| HU09 | Flatwater | 3 | 35 | 105 |
| HU10 | Riffle | 2 | 10 | 20 |
| HU11 | Flatwater | 3 | 35 | 105 |
| HU12 | Pool | 3 | 40 | 120 |
| HU13 | Alcove | 3 | 95 | 285 |
| HU14 | Pool | 3 | 30 | 90 |
| HU15 | Flatwater | 3 | 10 | 30 |
| HU16 | Pool | 3 | 25 | 75 |
| HU17 | Flatwater | 3 | 25 | 75 |
| HU18 | Pool | 3 | 30 | 90 |
| HU19 | Riffle | 3 | 25 | 75 |
| HU20 | Flatwater | 2 | 10 | 20 |
| HU21 | Riffle | 1 | 5 | 5 |
| **Pool: riffle** | **7: 5 (1.40)** | | | **Avg = 83** |

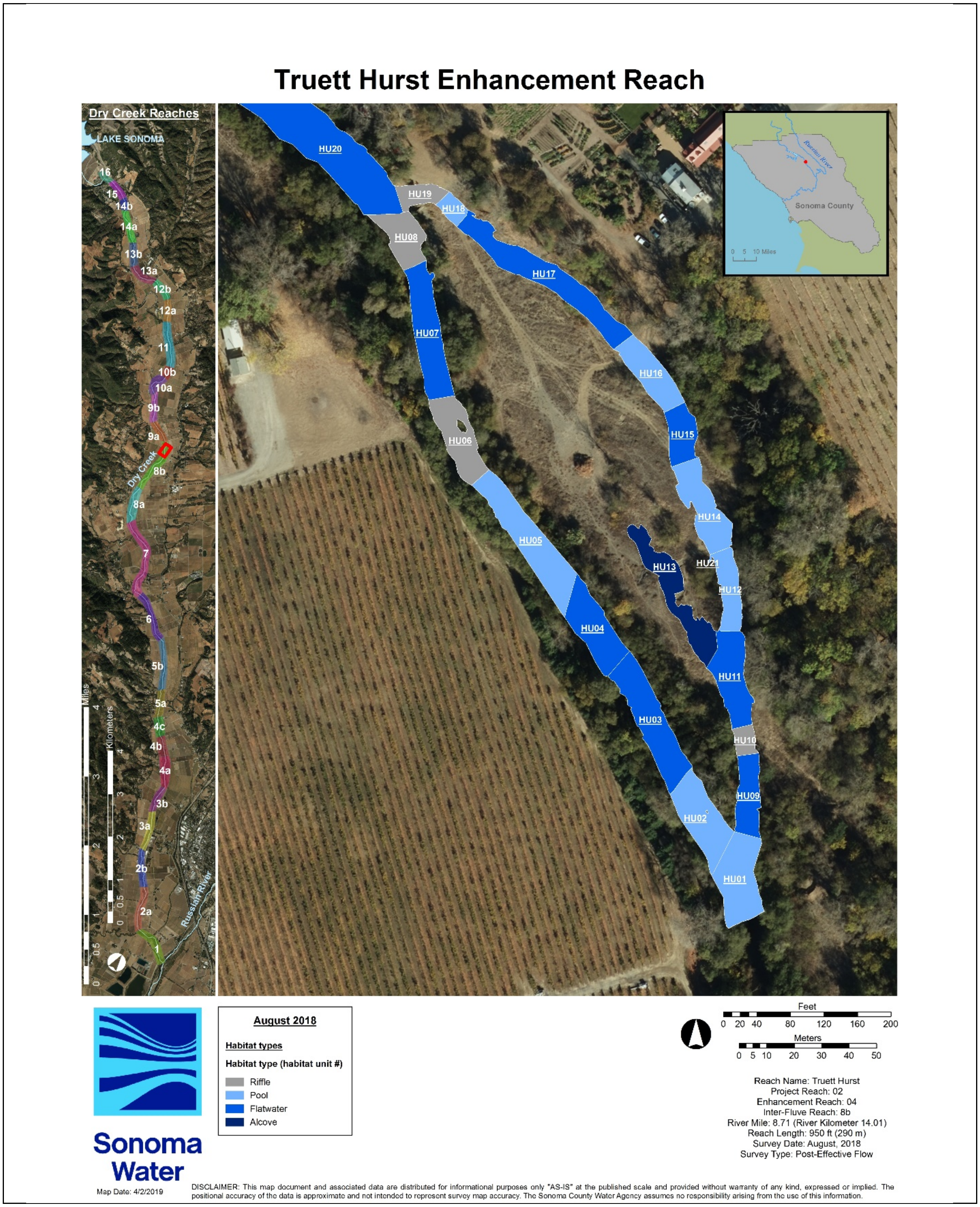


**Figure 5.2.47. Habitat unit number and type within the Truett Hurst enhancement reach, August 2018.**

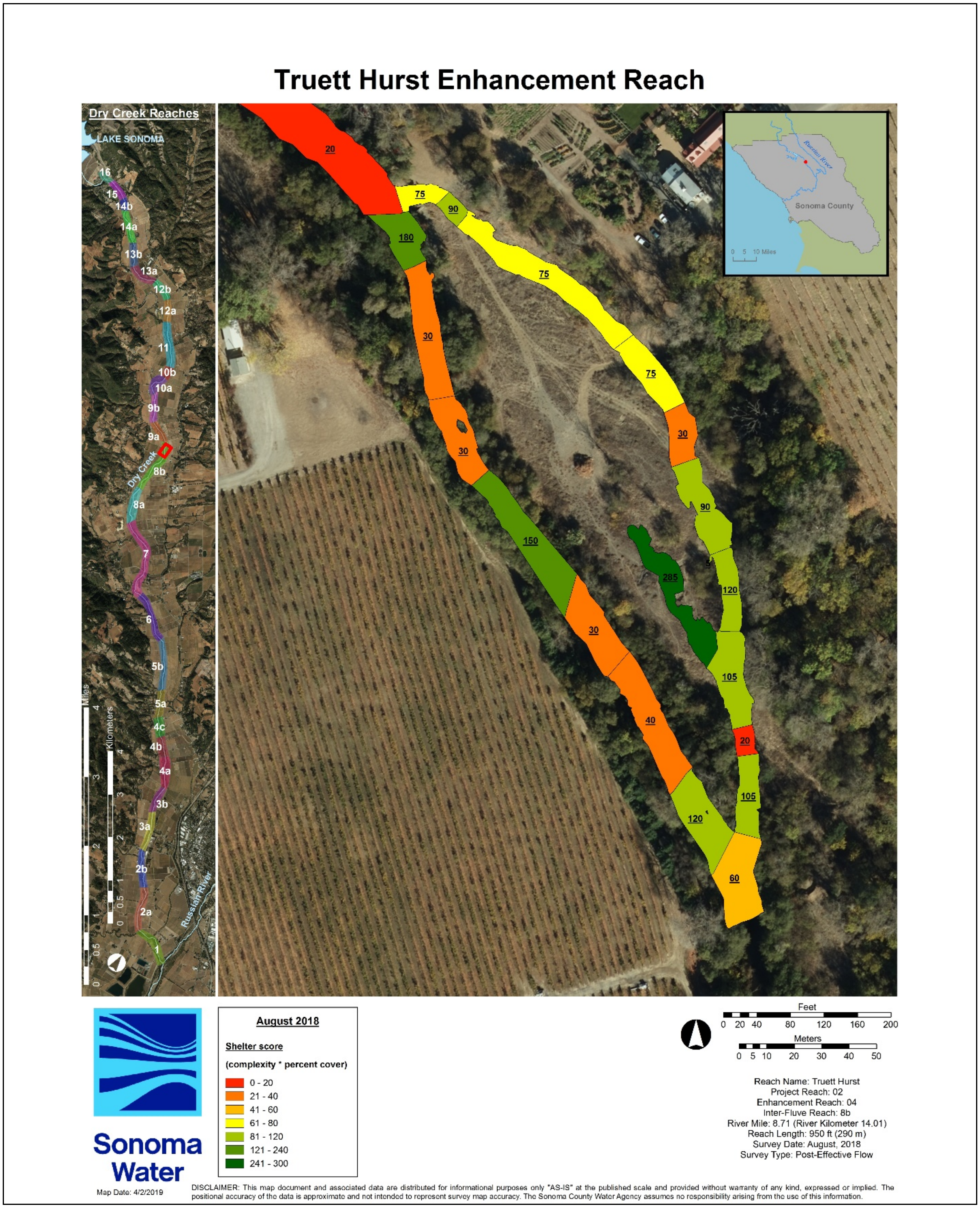


**Figure 5.2.48. Habitat unit shelter scores within the Truett Hurst enhancement reach, August 2018.**

### *Feature, habitat unit, site, and reach ratings*

**Table 5.2. 41. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Truett Hurst enhancement reach, August 2018.**

| Site number | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Site type | | Main channel | Side channel | Alcove | Alcove | Bank |
| **Site average feature rating** | Site average feature quantitative rating[a] | 0 | 14 | 12 | 9 | 12 |
| | Site average feature qualitative rating[a] | Not rated | Excellent | Good | Good | Good |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 17 | 20 | 33 | 21 | 19 |
| | Site average qualitative rating[b] | Fair | Fair | Excellent | Good | Fair |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | 17[b] | 34[c] | 45[c] | 30[c] | 31[c] |
| | Site qualitative rating[c] | Fair[b] | Good[c] | Excellent[c] | Good[c] | Good[c] |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[d] | 31 | | | | |
| | Enhancement reach qualitative rating[d]: | Good | | | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)
[d]out of 47: Excellent (>=38), Good (>=28), Fair(>=19), Poor (>=9), Fail (<9)

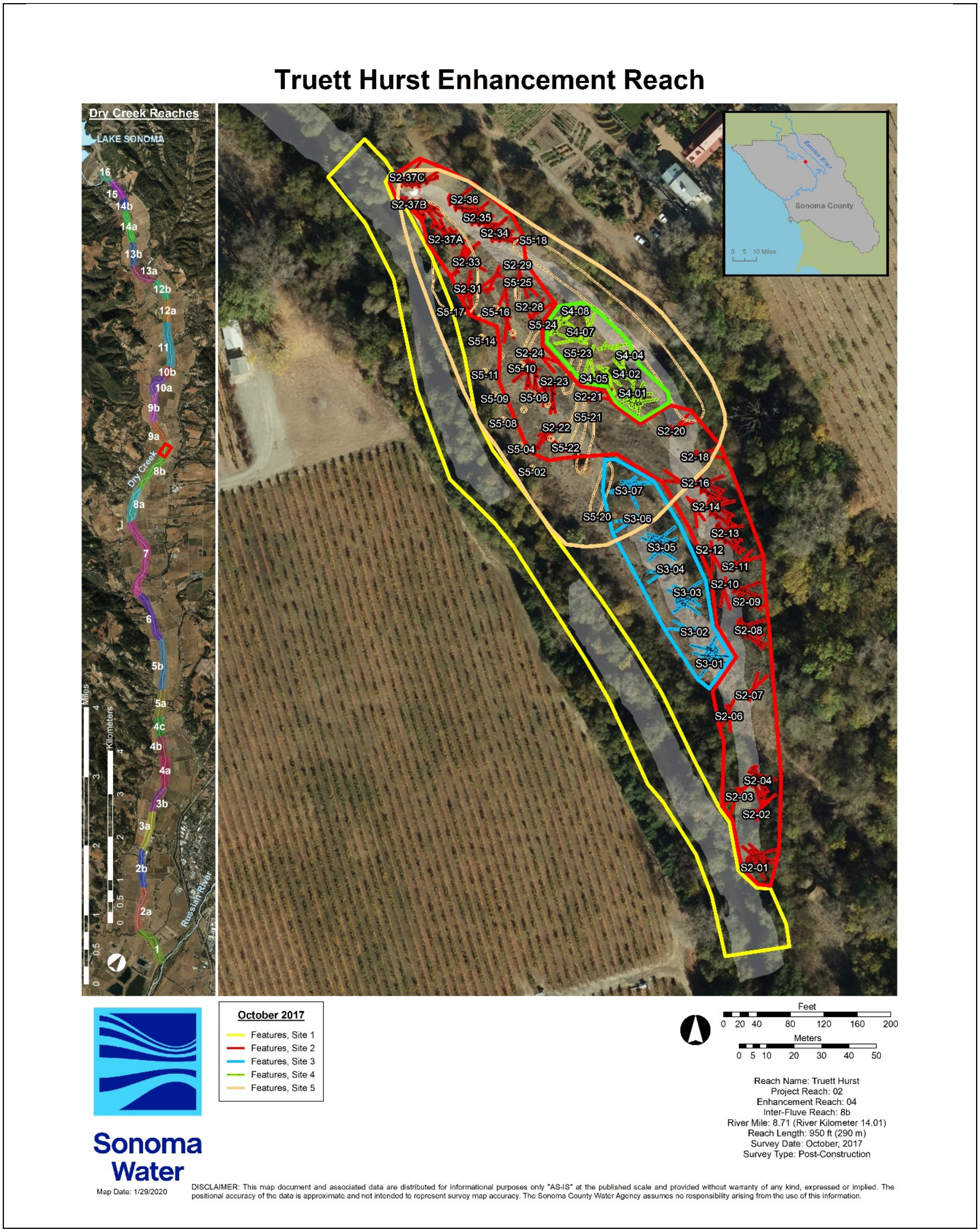


**Figure 5.2.49. Enhancement sites and features within the Truett Hurst enhancement reach, August 2018.**

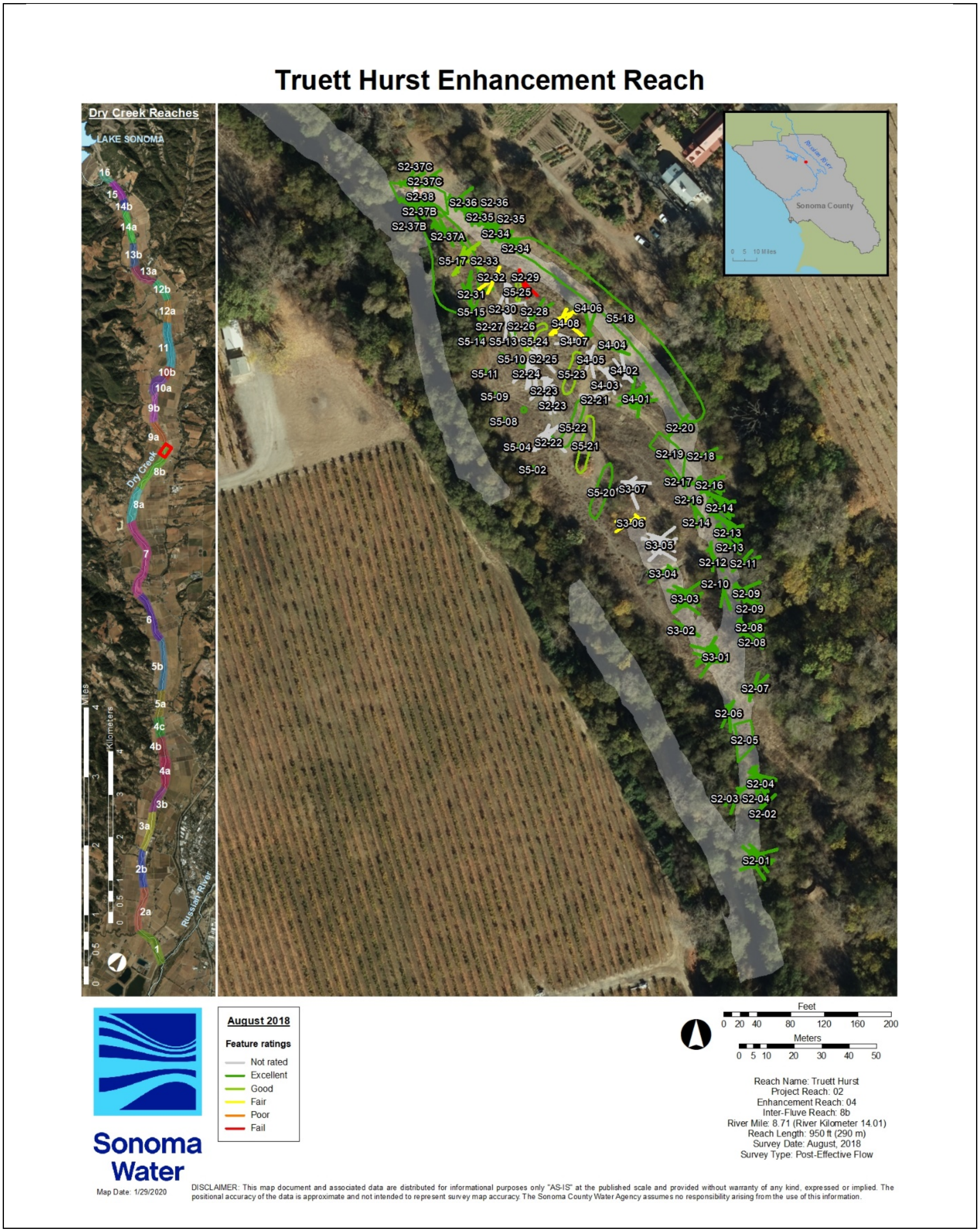


**Figure 5.2.50. Feature ratings for the Truett Hurst enhancement reach, August 2018.**

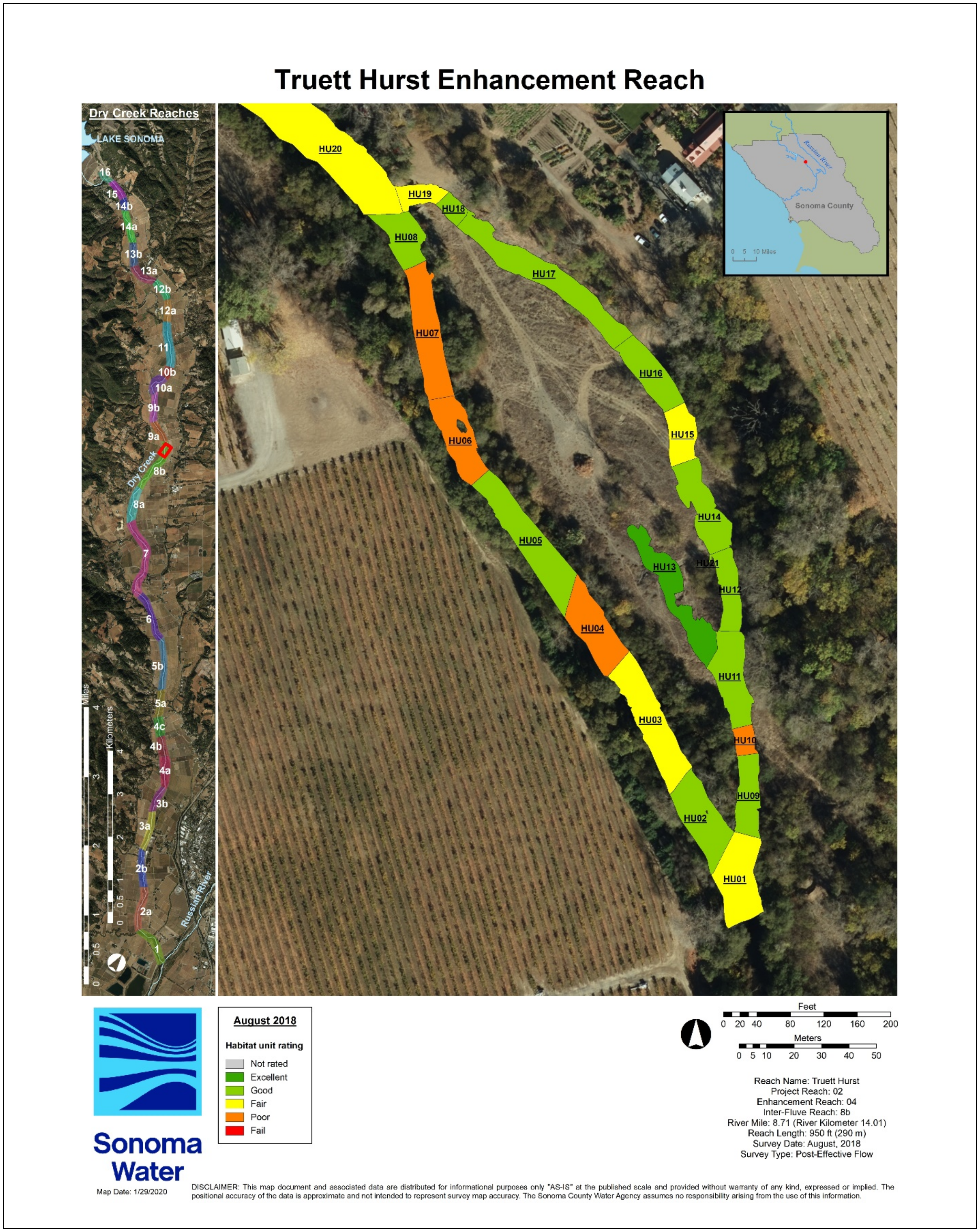


**Figure 5.2.51. Habitat unit ratings for the Truett Hurst enhancement reach, August 2018.**

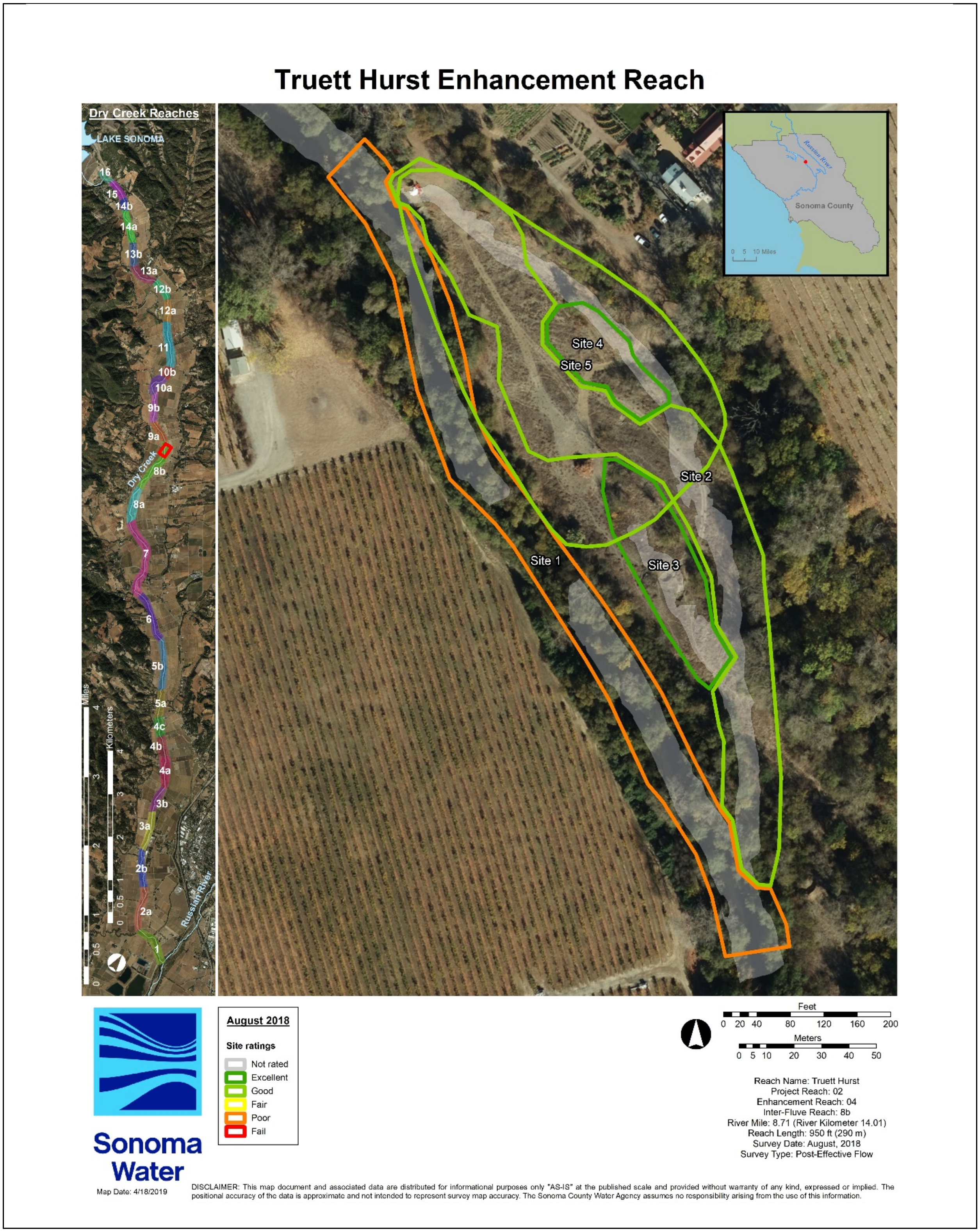


**Figure 5.2.52. Post-effective flow site ratings for the Truett Hurst enhancement reach, August 2018.**

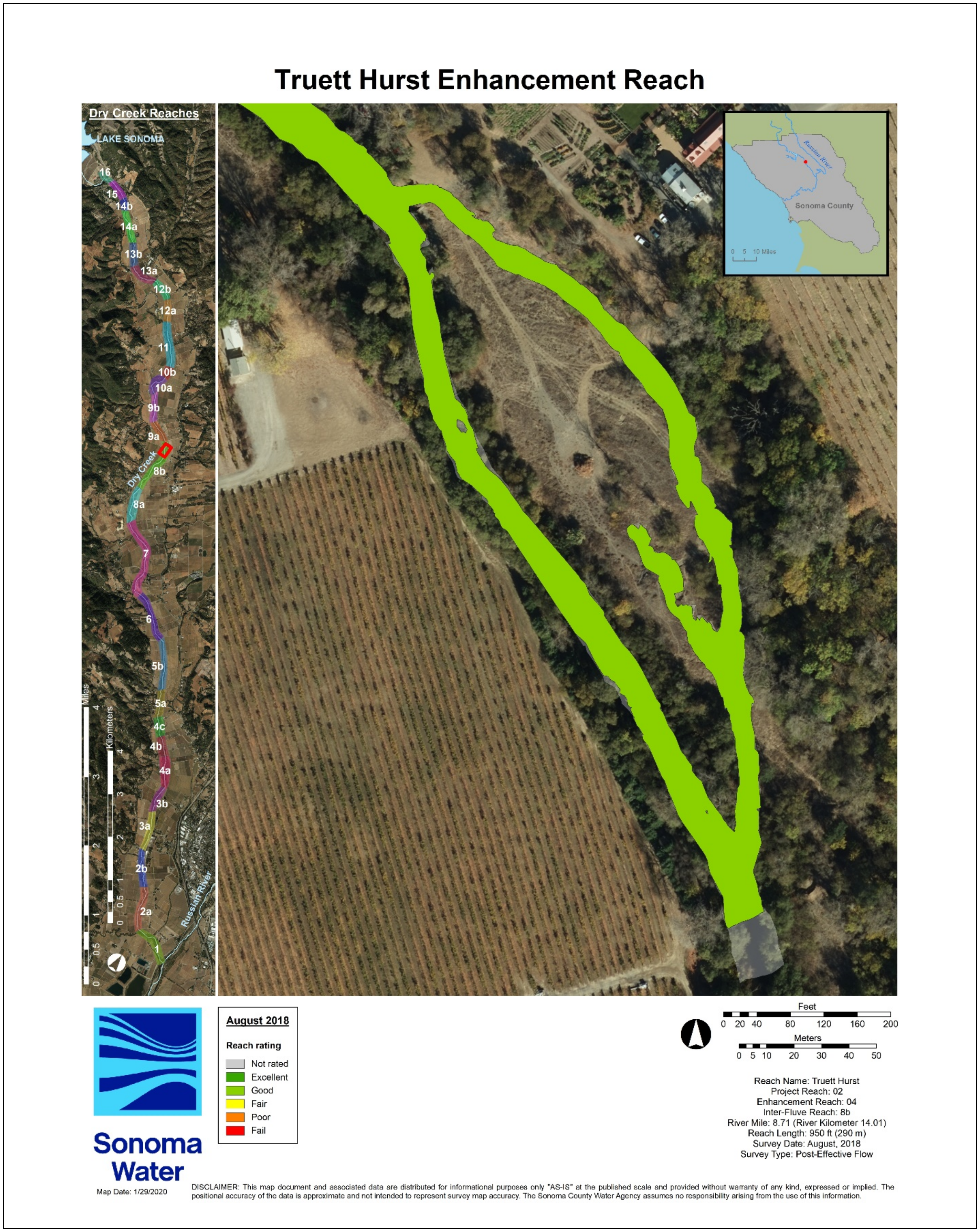


**Figure 5.2.53. Post-effective flow reach rating for the Truett Hurst enhancement reach, August 2018.**

## Meyer Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Meyer enhancement reach in August 2018. Sonoma Water originally constructed the Meyer enhancement reach in November 2016, but aggradation caused by large storms in winter 2016/2017 led to a fair effectiveness monitoring rating in July 2017 and repairs in summer 2017. Crews monitored again in October 2017 and the enhancement reach received a good post-repair rating (see 2017 report for results). The results below characterize the post effective flow, post-repair habitat condition of the Meyer enhancement reach. The enhancement reach encompassed 47,569 $ft^2$ within main- and off-channel areas with 22% of the total meeting optimum depth and velocity criteria (Table 5.2.42). The repair enhanced 12,122 $ft^2$ of off-channel area, of which 69% met optimal depth and velocity criteria, compared with 5% for the main channel (Table 5.2.42, Figure 5.2.57). Seven habitat units made up the enhancement reach post-effective flow, with a pool to riffle ratio of 3:3 (1.00) and an average shelter score of 104 (Table 5.2.43, Figure 5.2.58, Figure 5.2.59). Three habitat units exceeded the optimum shelter value of 80. The enhancement reach comprised three enhancement sites (one main channel and two side channels; Table 5.2.44, Figure 5.2.60) that received excellent site average feature rating (we did not rate enhancement site 1 as it contained no features), and poor to excellent site average habitat unit ratings (Table 5.2.44, Figure 5.2.61, Figure 5.2.62). Site 1 received a poor site average habitat unit rating due to a low amount of optimal depth and velocity area and low shelter scores. Enhancement site ratings ranged from poor to good, with the main channel site (site 1) receiving a poor rating, the two side channel sites receiving good and fair ratings (Figure 5.2.63). Site 3 (side channel) received slightly lower site average habitat unit rating, leading to a fair site rating. Overall, the Meyer enhancement reach received a fair effectiveness monitoring rating (Table 5.2.44, Figure 5.2.64; see Appendix 5.1 for all measured values, scores, and ratings).

*Depth and velocity*

**Table 5.2. 42. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Meyer enhancement reach, August 2018.**

| **Meyer Post-effective Flow 2018** | **Wetted area ($ft^2$)** | **Optimal depth ($ft^2$) 0.5 – 2.0 ft** | **Optimal depth ($ft^2$) 2.0 – 4.0 ft** | **Optimal depth ($ft^2$) Total** | **Optimal velocity ($ft^2$) < 0.5 ft/s** | **Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s** | **Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s** | **Optimal habitat ($ft^2$) Total** |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 35,447 | 29,463 | 1,179 | 30,641 | 4,514 | 1,734 | 204 | 1,939 |
| Off-channel area | 12,122 | 3,105 | 6,054 | 9,158 | 11,173 | 2,737 | 5,623 | 8,360 |
| **Total area** | **47,569** | **32,567** | **7,232** | **39,800** | **15,687** | **4,471** | **5,827** | **10,299** |
| Main channel % of wetted area | 75% | 83% | 3% | 86% | 13% | 5% | 1% | 5% |
| Off-channel % of wetted area | 25% | 26% | 50% | 76% | 92% | 23% | 46% | 69% |
| **Total % of wetted area** | **100%** | **68%** | **15%** | **84%** | **33%** | **9%** | **12%** | **22%** |

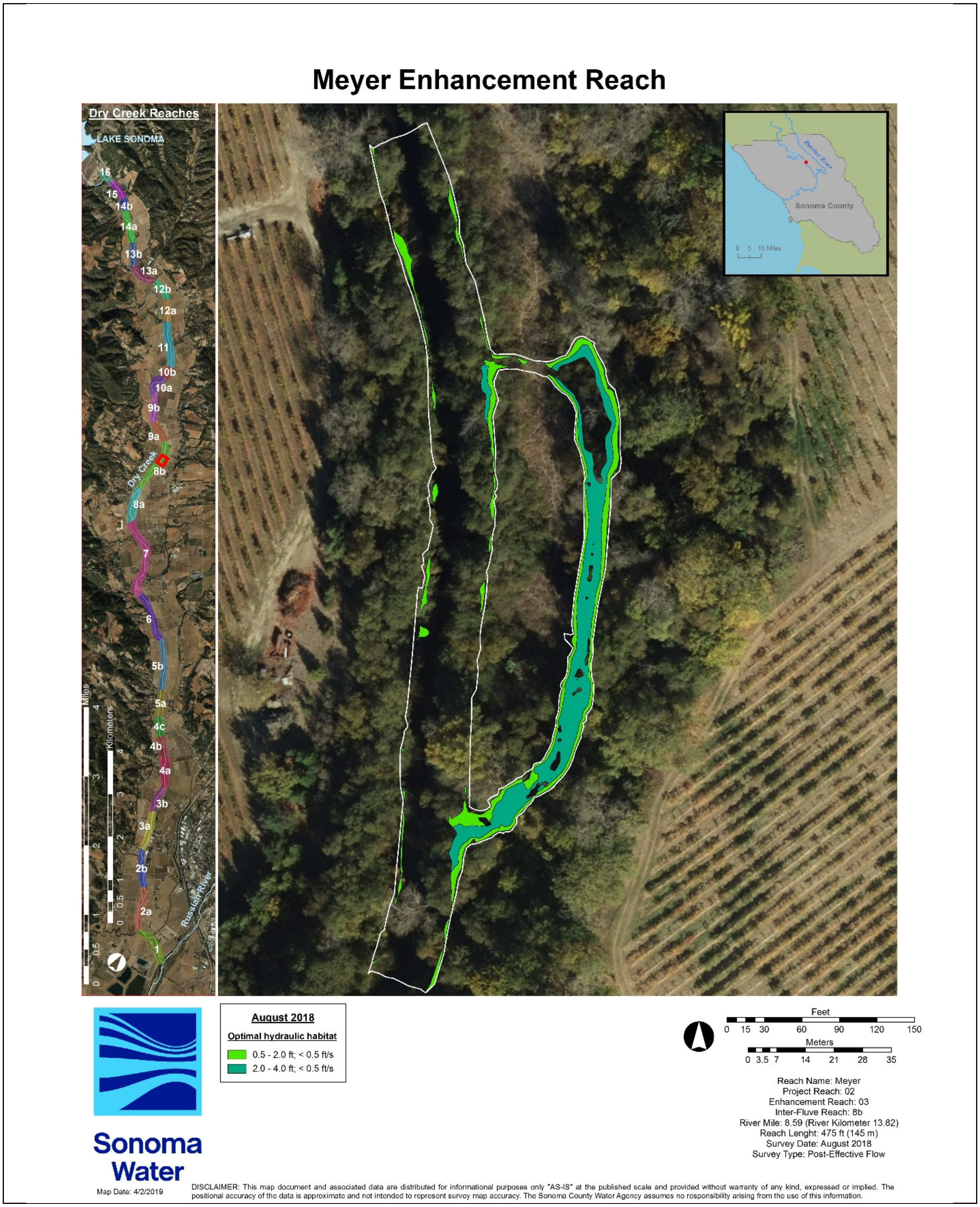


**Figure 5.2.54. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Meyer enhancement reach, August 2018.**

### *Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 43. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Meyer enhancement reach, August 2018, post-effective flow.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Riffle | 2 | 15 | 30 |
| HU02 | Pool | 3 | 20 | 60 |
| HU03 | Flatwater | 2 | 10 | 20 |
| HU04 | Pool | 3 | 35 | 105 |
| HU05 | Riffle | 3 | 10 | 30 |
| HU06 | Pool | 3 | 95 | 285 |
| HU07 | Riffle | 3 | 65 | 195 |
| **Pool: riffle** | **3: 3 (1.00)** | | | **Avg = 104** |

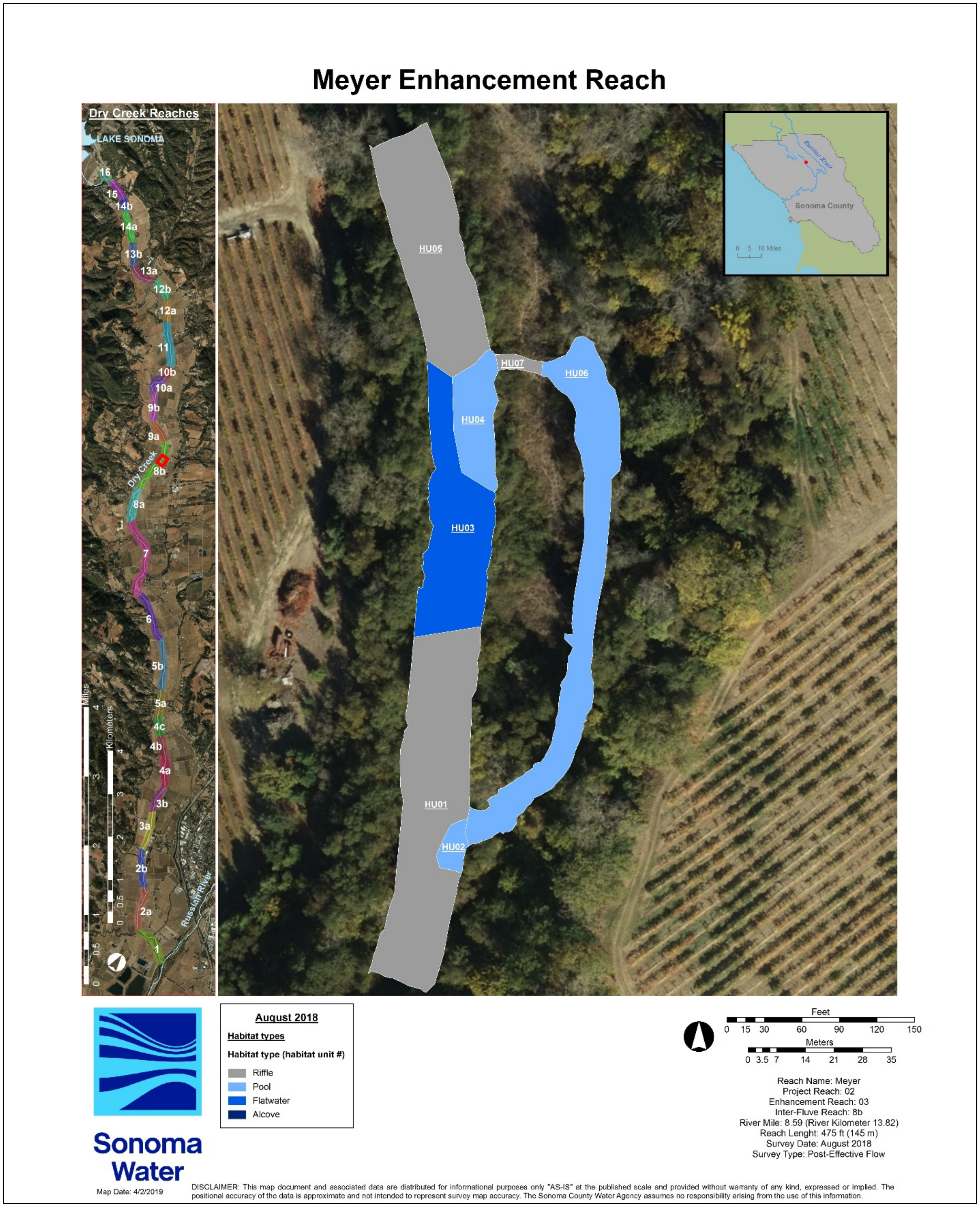


**Figure 5.2.55. Habitat unit number and type within the Meyer enhancement reach, August 2018.**

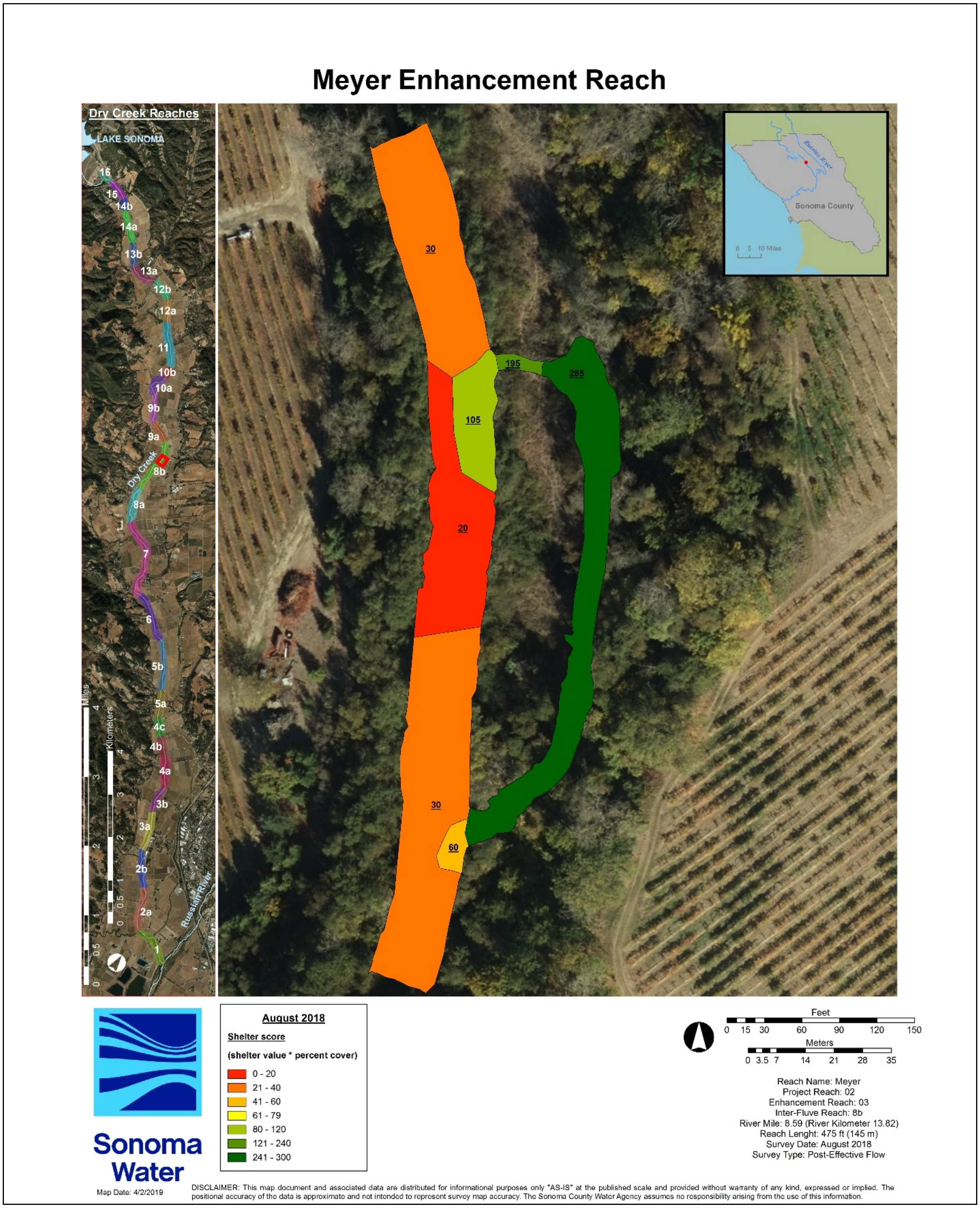


**Figure 5.2.56. Habitat unit shelter scores within the Meyer enhancement reach, August 2018.**

*Feature, habitat unit, site, and reach ratings*

**Table 5.2. 44. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Meyer enhancement reach, August 2018.**

| Site number | | 1 | 2 | 3 | |
|---|---|---|---|---|---|
| Site type | | Main channel | Side channel | Side channel | |
| Site average feature rating | Site average feature quantitative rating[a] | 0 | 13 | 14 | |
| | Site average feature qualitative rating[a] | Not rated | Excellent | Excellent | |
| Site average habitat unit rating | Site average habitat unit quantitative rating[b] | 13 | 19 | 14 | |
| | Site average qualitative rating[b] | Poor | Fair | Fair | |
| Site rating | Site quantitative rating (sum of site average feature and habitat unit rating) | 13[b] | 32[c] | 28[c] | |
| | Site qualitative rating | Poor[b] | Good[c] | Fair[c] | |
| Enhancement reach rating | Enhancement reach quantitative rating (average of site rating)[d] | 24 | | | |
| | Enhancement reach qualitative rating[d]: | Fair | | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair (>=14), Poor (>=7), Fail (<7)
[c]out 0f 50; Excellent (>=40), Good (>=30), Fair(>=20), Poor (>=10), Fail (<10)
[d]out of 45; Excellent (>=36), Good (>=27), Fair (>=18), Poor (>9), Fail (<9)

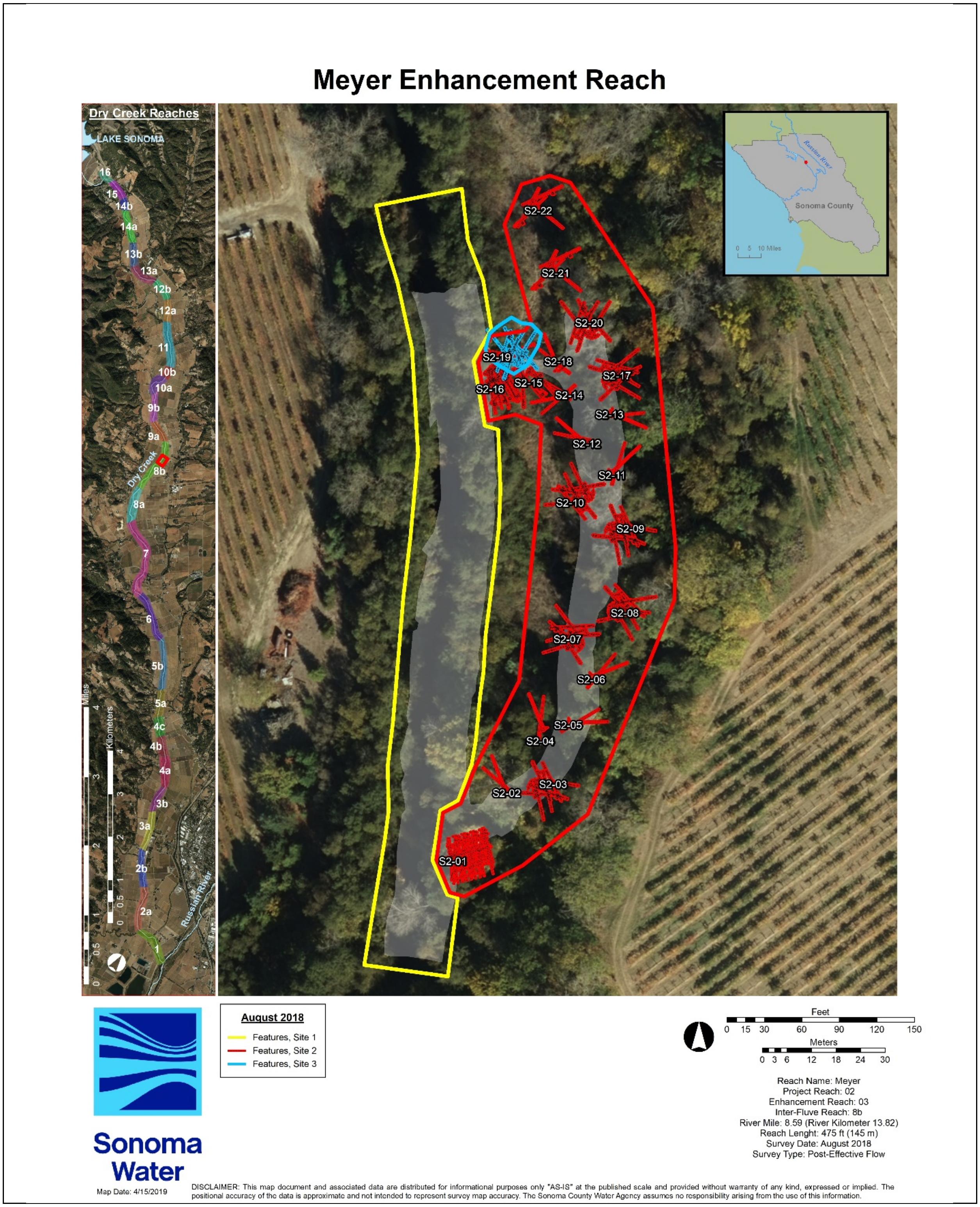


**Figure 5.2.57. Enhancement sites and features within the Meyer enhancement reach, August 2018.**

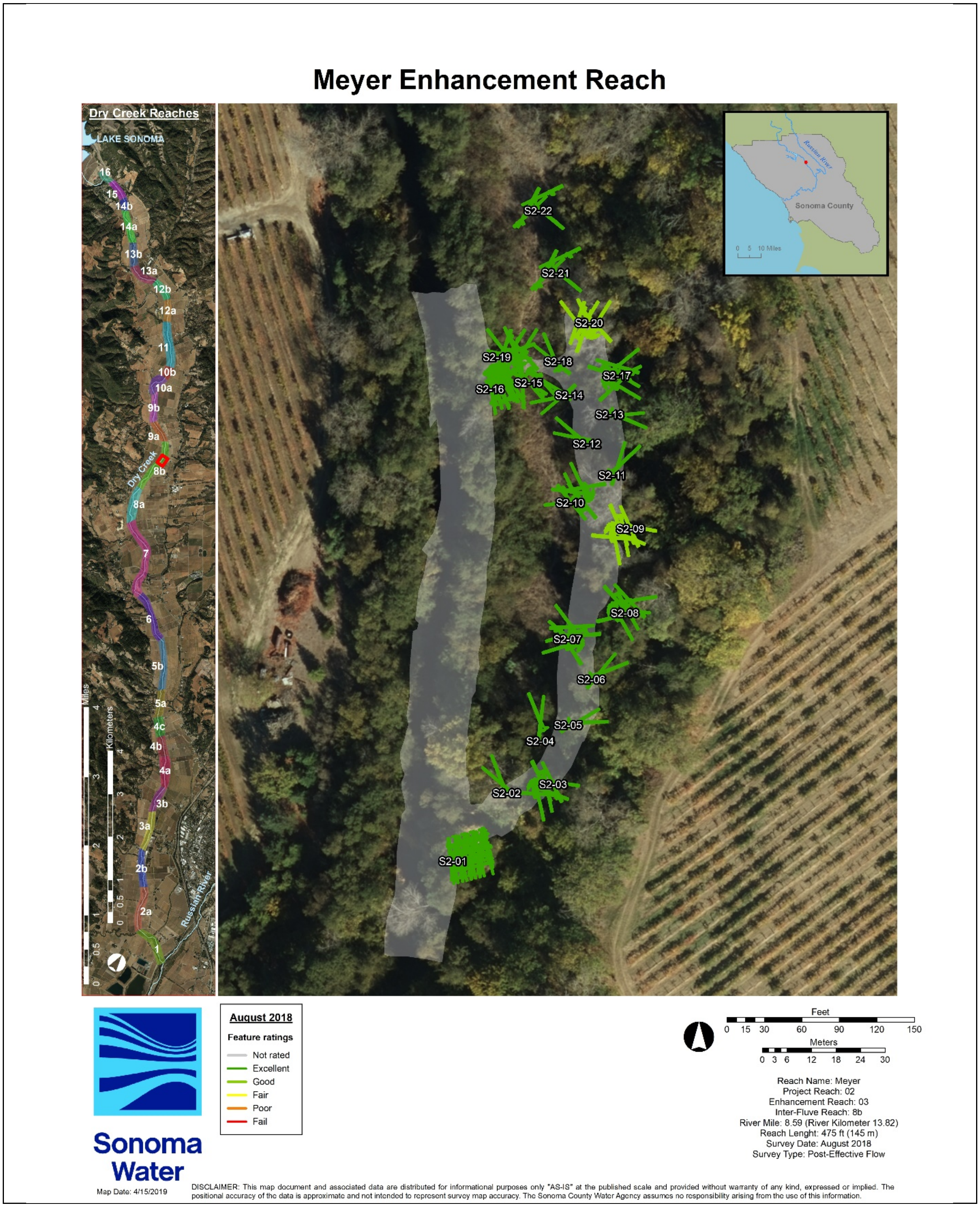


**Figure 5.2.58. Feature ratings for the Meyer enhancement reach, August 2018.**

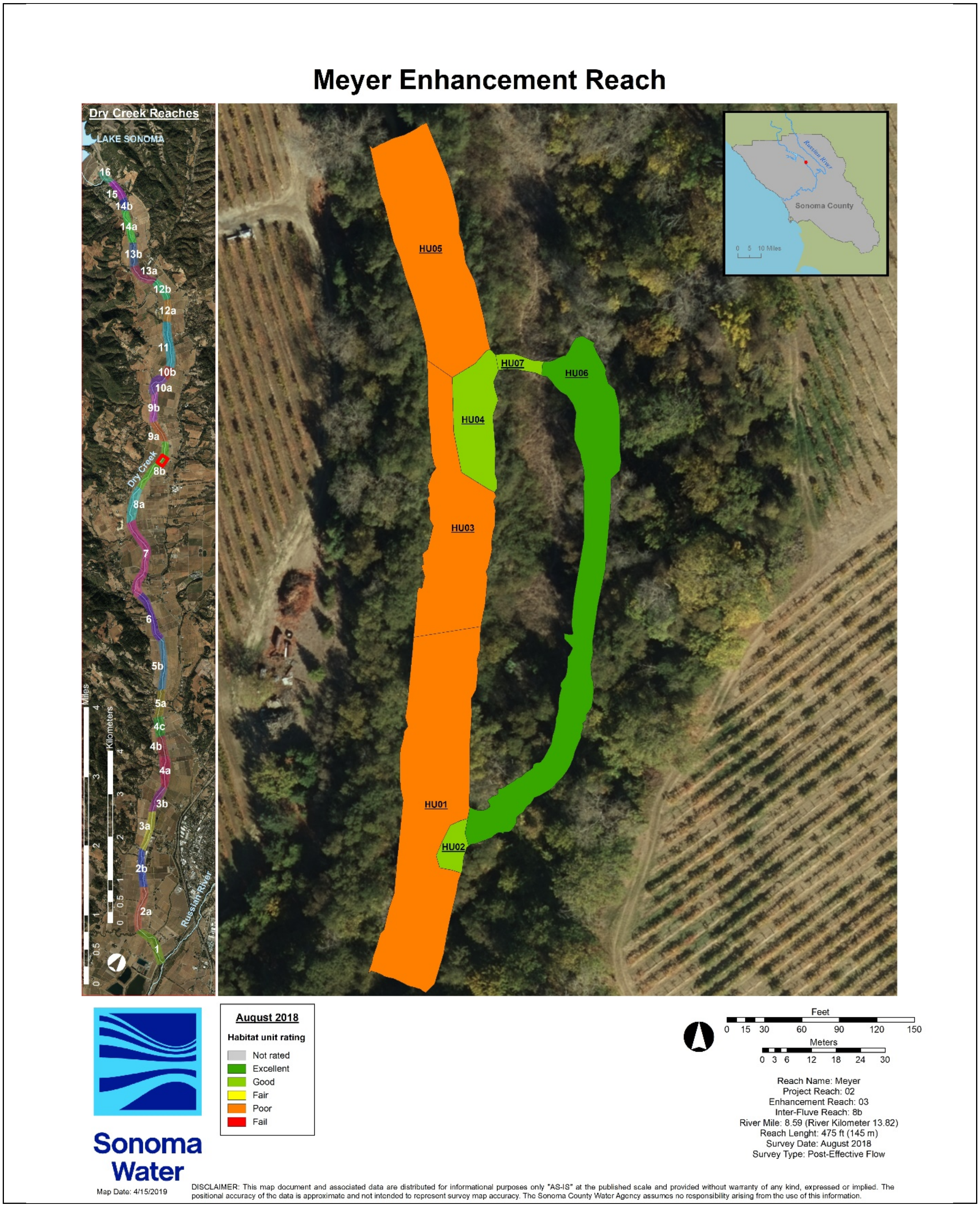


**Figure 5.2.59. Habitat unit ratings for the Meyer enhancement reach, August 2018.**

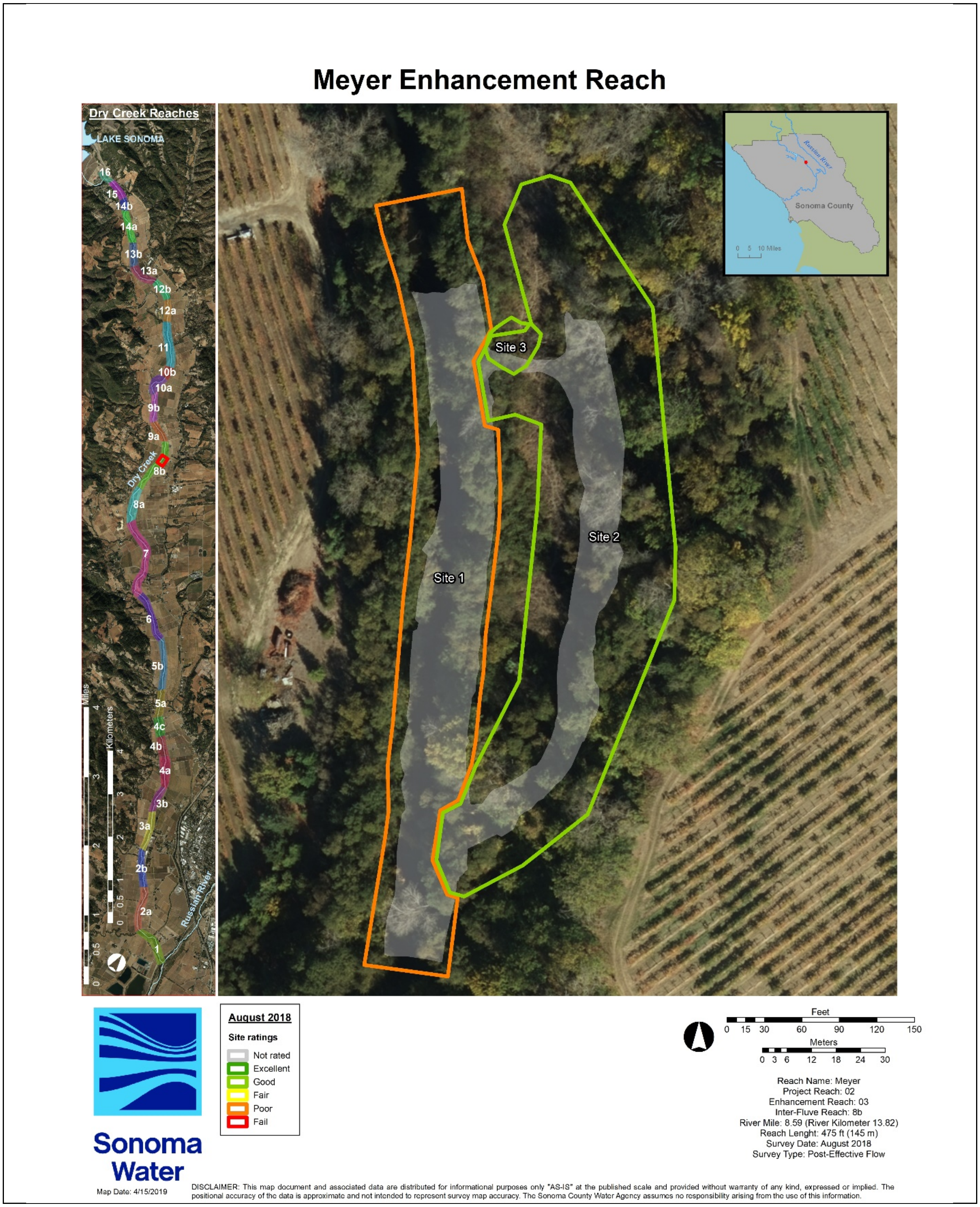


**Figure 5.2.60. Post-effective flow site ratings for the Meyer enhancement reach, August 2018.**

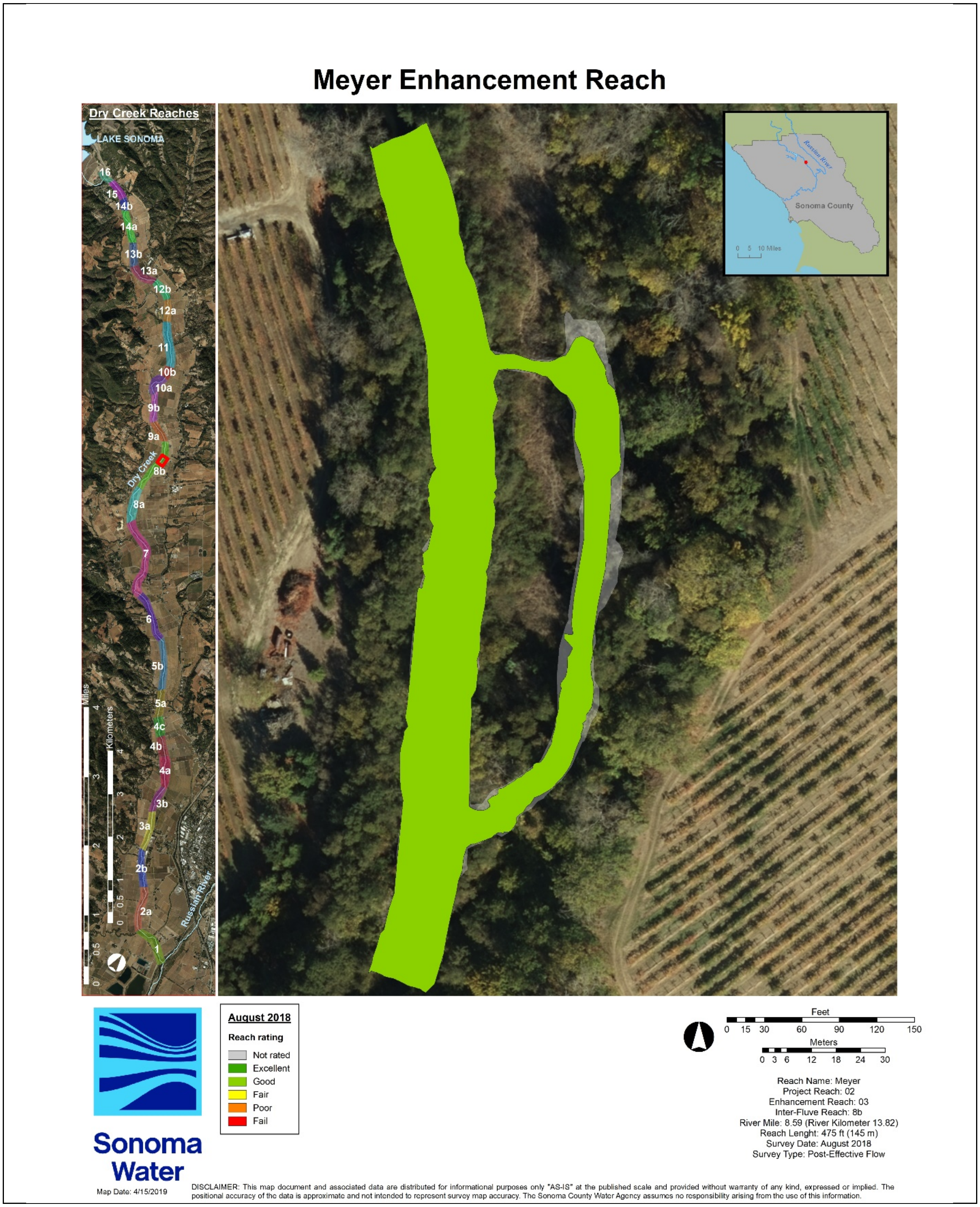


**Figure 5.2.61. Post-effective flow reach rating for the Meyer enhancement reach, August 2018.**

## Carlson, Lonestar Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Carlson, Lonestar enhancement reach in September 2018. Previous effectiveness monitoring surveys occurred in May 2017 (pre-enhancement) and September 2017 (post-enhancement) receiving fair and good ratings, respectively. The enhancement reach encompassed 56,120 $ft^2$ within main- and off-channel areas with 31% of the total meeting optimum depth and velocity criteria. Crews monitored 18,409 $ft^2$ of off-channel area, of which 80% met optimal depth and velocity criteria, compared with 8% for the main channel (Table 5.2.45, Figure 5.2.65). Seven habitat units made up the enhancement reach post-effective flow, with a pool to riffle ratio of 1:1 (1.00) and an average shelter score of 119 (Table 5.2.46, Figure 5.2.66, Figure 5.2.67). Four habitat units exceeded the optimum shelter value of 80. The enhancement reach comprised three enhancement sites (one main channel, two side channels; Table 5.2.47, Figure 5.2.68) that all received excellent site average feature ratings and poor to excellent site average habitat unit ratings (Table 5.2.47, Figure 5.2.69, Figure 5.2.70). The main channel site (site1) received the poor site average habitat unit rating, likely due to high velocities. All three enhancement sites received good qualitative ratings and similar numerical scores (Table 5.2.47, Figure 5.2.71). Overall, the Carlson, Lonestar enhancement reach received a good effectiveness monitoring score (Table 5.2.47; see Appendix 5.1 for all measured values, scores, and ratings).

*Depth and velocity*

**Table 5.2. 45. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Carlson, Lonestar enhancement reach, September 2018.**

| **Carlson, Lonestar Post-effective flow September 2018** | **Wetted area ($ft^2$)** | **Optimal depth ($ft^2$) 0.5 – 2.0 ft** | **Optimal depth ($ft^2$) 2.0 – 4.0 ft** | **Optimal depth ($ft^2$) Total** | **Optimal velocity ($ft^2$) < 0.5 ft/s** | **Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s** | **Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s** | **Optimal habitat ($ft^2$) Total** |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 37,711 | 29,705 | 4,122 | 33,827 | 5,614 | 2,419 | 504 | 2,923 |
| Off channel area | 18,409 | 6,417 | 8,989 | 15,406 | 17,714 | 5,735 | 8,979 | 14,714 |
| **Total area** | **56,120** | **36,122** | **13,111** | **49,233** | **23,328** | **8,154** | **9,483** | **17,637** |
| Main channel % of wetted area | 67% | 79% | 11% | 90% | 15% | 6% | 1% | 8% |
| Off channel % of wetted area | 33% | 35% | 49% | 84% | 96% | 31% | 49% | 80% |
| **Total % of wetted area** | **100%** | **64%** | **23%** | **88%** | **42%** | **15%** | **17%** | **31%** |

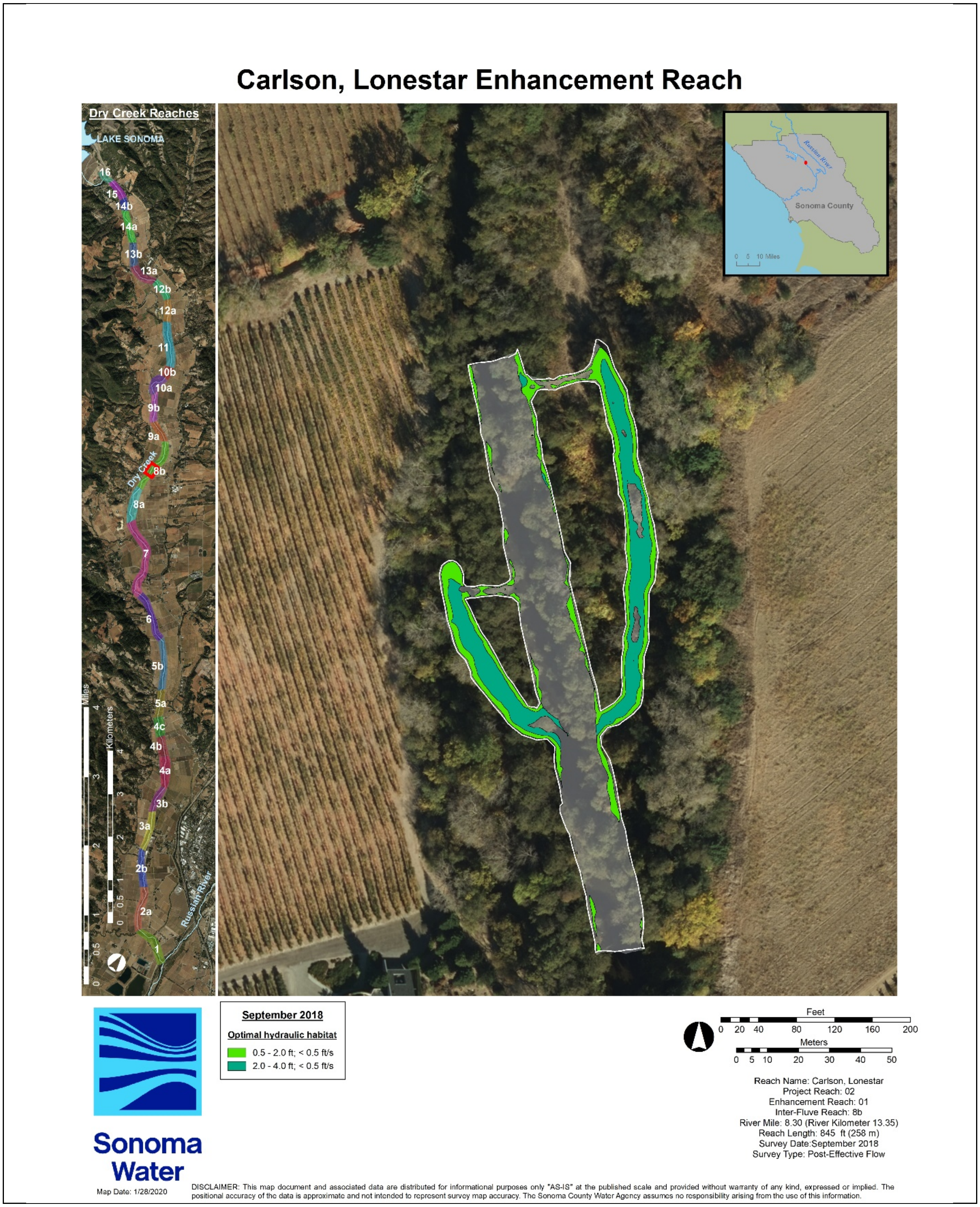


**Figure 5.2.62. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Carlson, Lonestar enhancement reach, September 2018.**

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 46. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Carlson, Lonestar enhancement reach, September 2018, post-effective flow.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Riffle | 1 | 10 | 10 |
| HU02 | Pool | 3 | 15 | 45 |
| HU03 | Flatwater | 3 | 5 | 15 |
| HU04 | Flatwater | 3 | 15 | 45 |
| HU05 | Alcove | 3 | 75 | 225 |
| HU06 | Flatwater | 3 | 70 | 210 |
| HU07 | Alcove | 3 | 75 | 225 |
| HU08 | Flatwater | 3 | 60 | 180 |
| **Pool: riffle** | **1: 1 (1.00)** | | | **Avg = 119** |

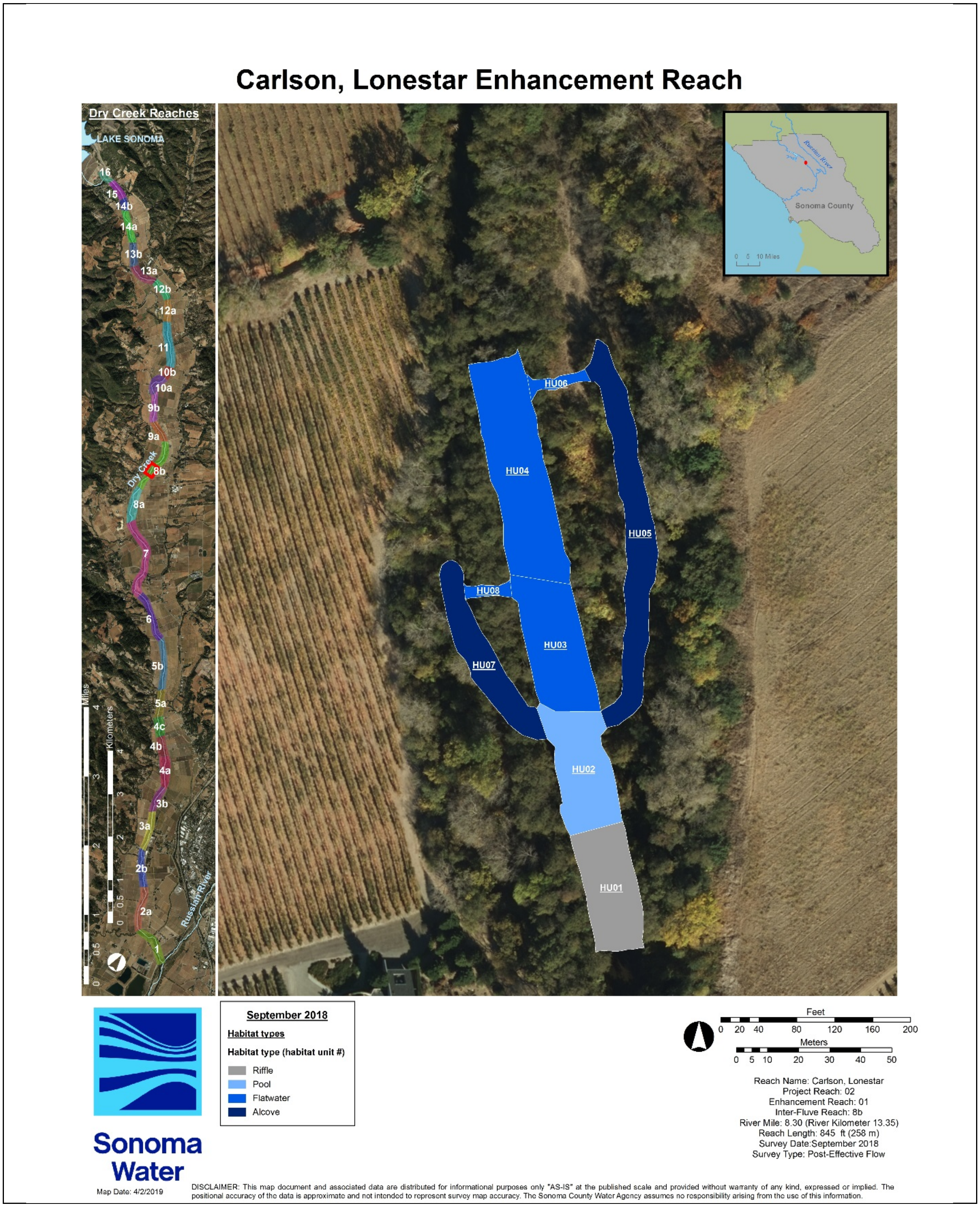


**Figure 5.2.63. Habitat unit number and type within the Carlson, Lonestar enhancement reach, September 2018.**

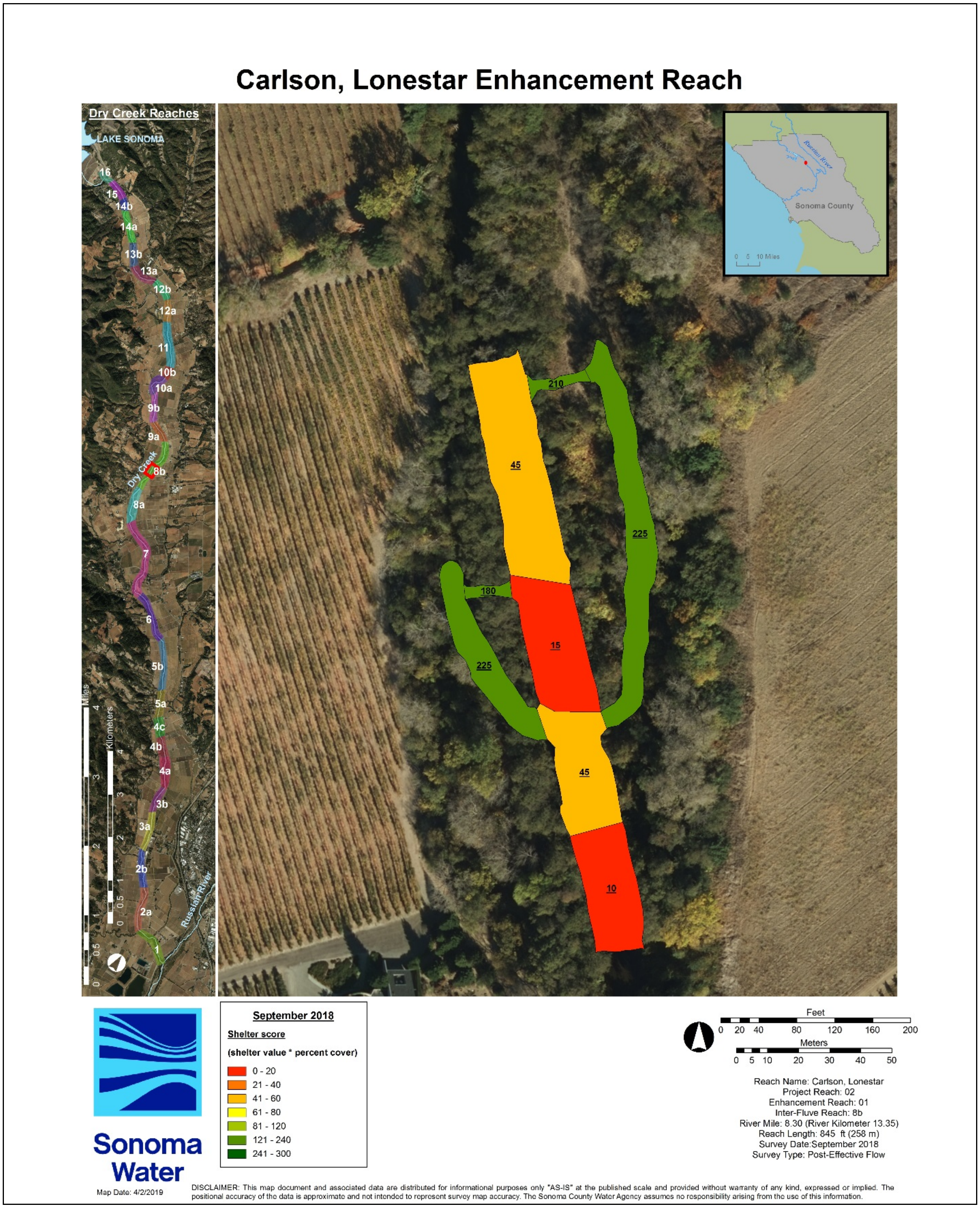


**Figure 5.2.64. Habitat unit shelter scores within the Carlson, Lonestar enhancement reach, September 2018.**

*Feature, habitat unit, site, and reach ratings*

**Table 5.2. 47. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Carlson, Lonestar enhancement reach, September 2018.**

| Site number | | 1 | 2 | 3 | |
|---|---|---|---|---|---|
| Site type | | Main channel | Side channel | Side channel | |
| Site average feature rating | Site average feature quantitative rating[a] | 14 | 13 | 14 | |
| | Site average feature qualitative rating[a] | Excellent | Excellent | Excellent | |
| Site average habitat unit rating | Site average habitat unit quantitative rating[b] | 12 | 29 | 28 | |
| | Site average qualitative rating[b] | Poor | Excellent | Excellent | |
| Site rating | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | 26 | 41 | 42 | |
| | Site qualitative rating[c] | Fair | Excellent | Excellent | |
| Enhancement reach rating | Enhancement reach quantitative rating (average of site rating)[c] | 34 | | | |
| | Enhancement reach qualitative rating[c]: | Good | | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

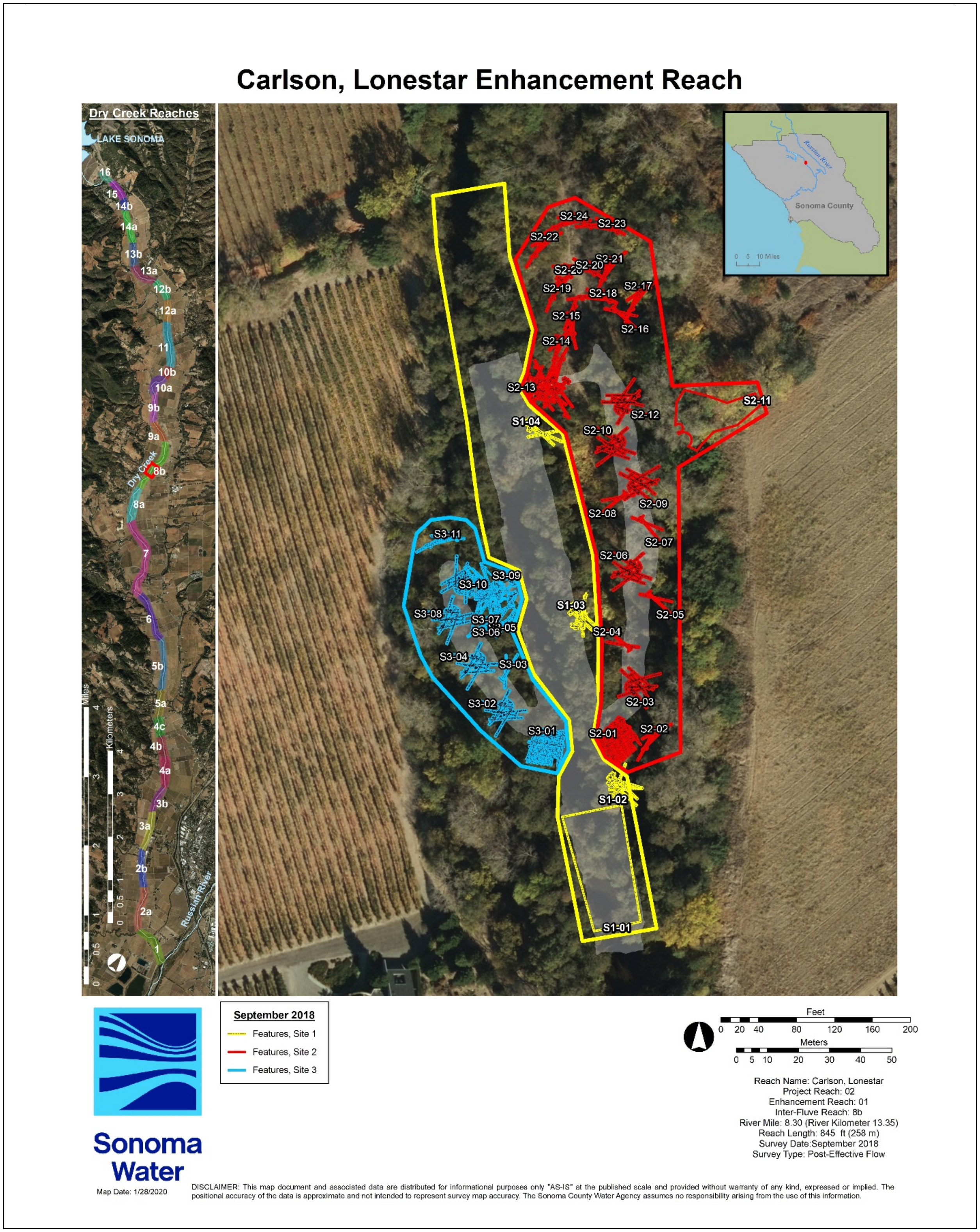


**Figure 5.2.65. Enhancement sites and features within the Carlson, Lonestar enhancement reach, September 2018.**

# Carlson, Lonestar Enhancement Reach

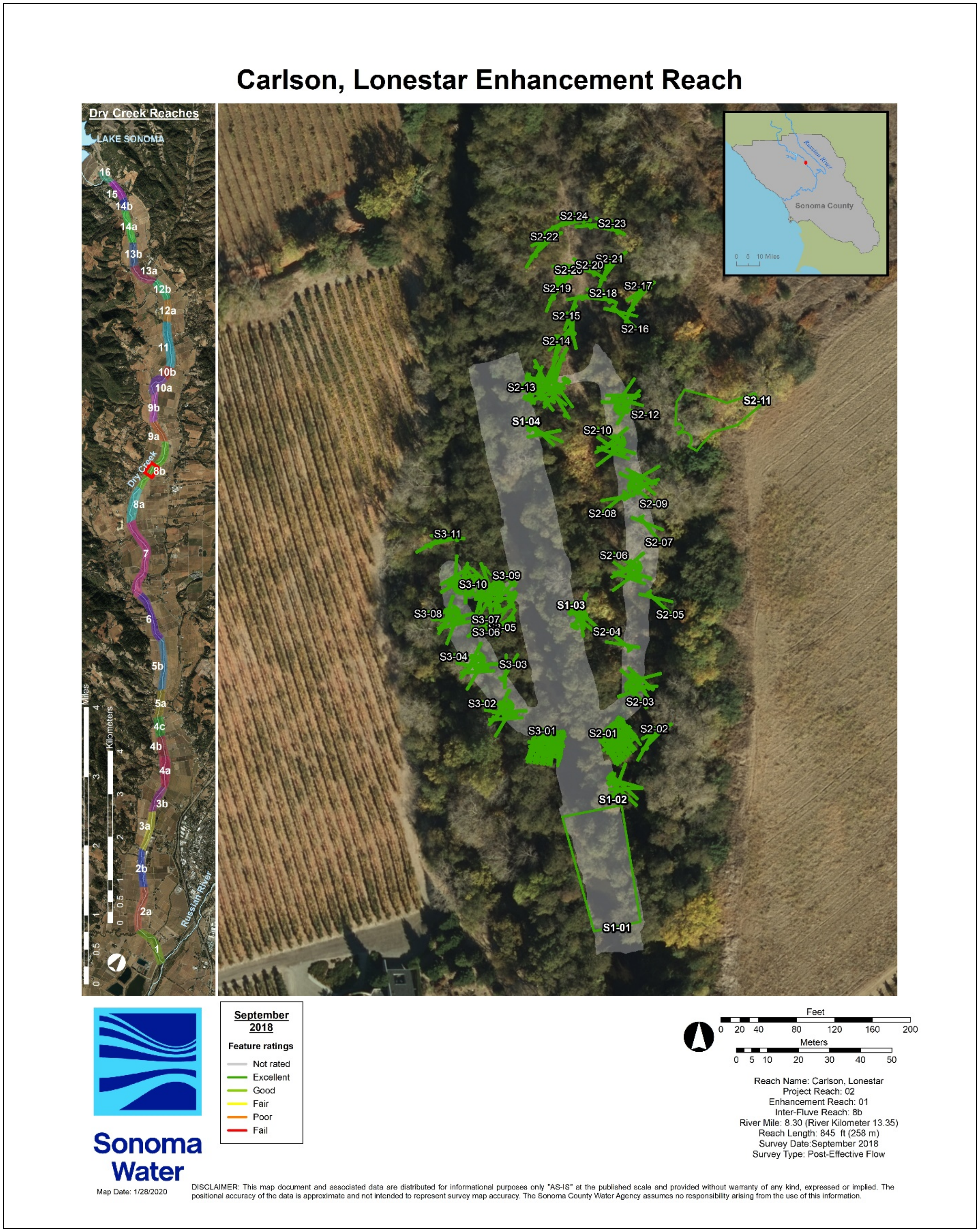


**Figure 5.2.66. Feature ratings for the Carlson, Lonestar enhancement reach, September 2018.**


**Figure 5.2.67. Habitat unit ratings for the Carlson, Lonestar enhancement reach, September 2018.**

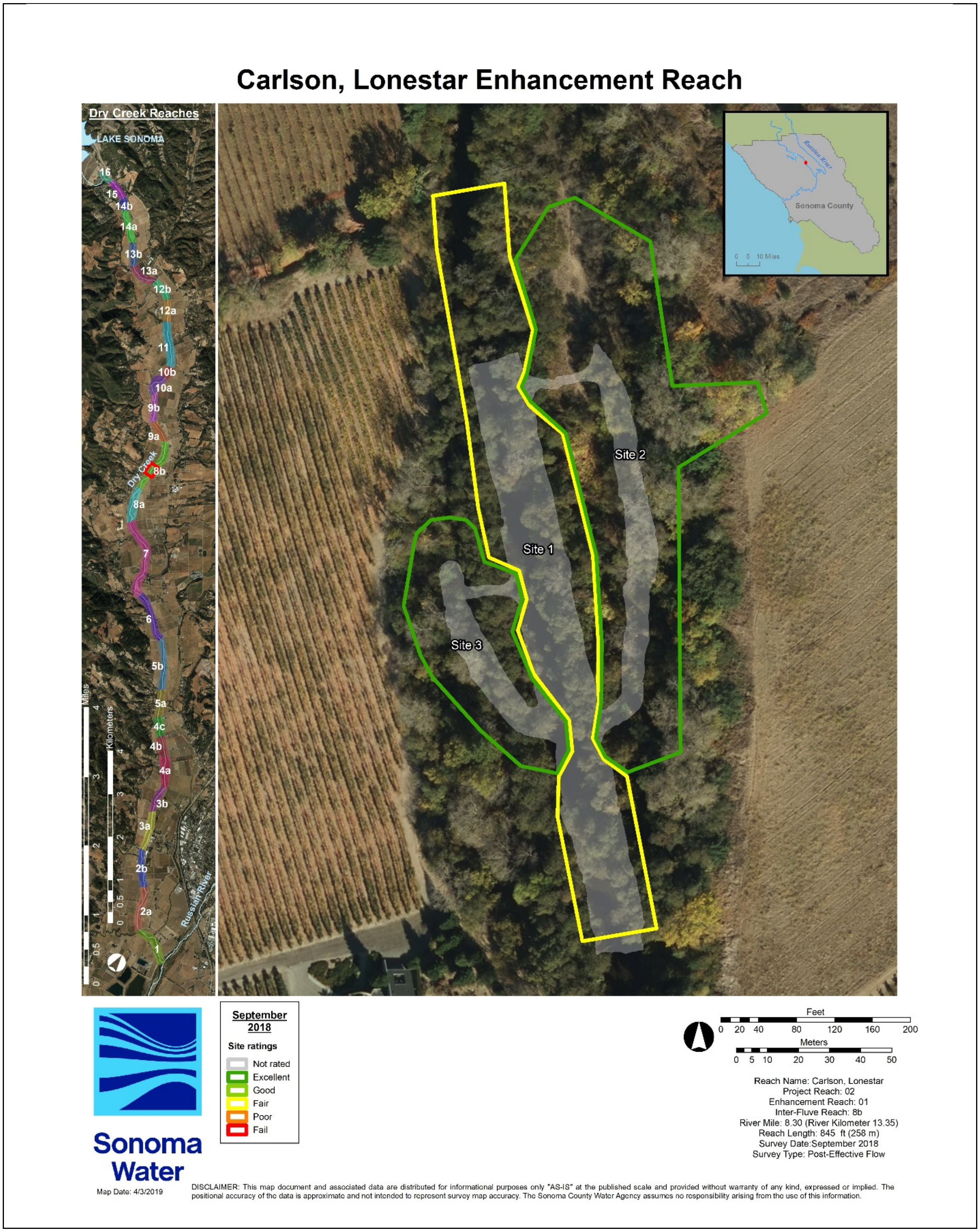


**Figure 5.2.68. Post-effective flow site ratings for the Carlson, Lonestar enhancement reach, September 2018**.

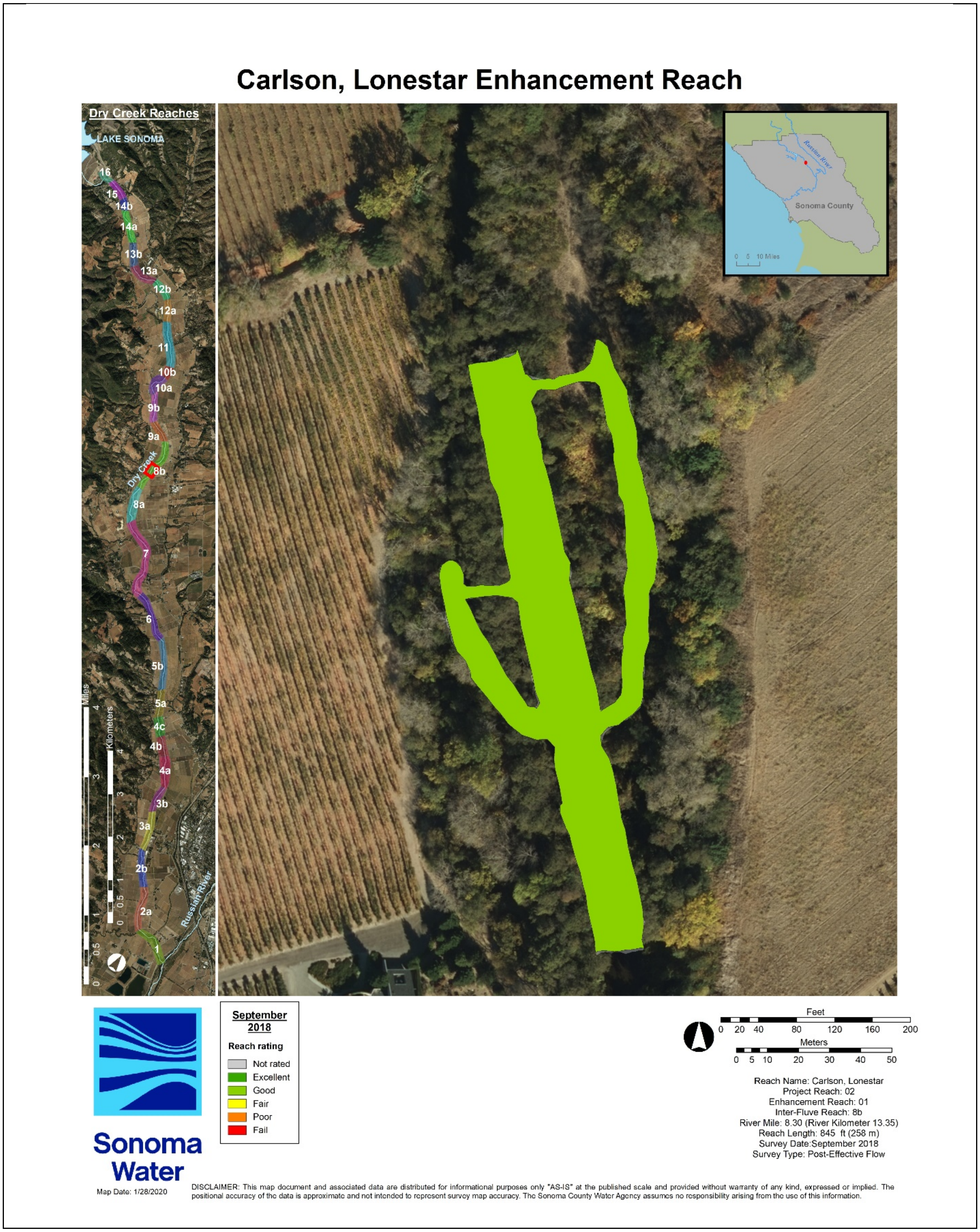


**Figure 5.2.69. Post-effective flow reach rating for the Carlson, Lonestar enhancement reach, September 2018.**

## City of Healdsburg Yard Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the City of Healdsburg enhancement reach in October 2018. Previous effectiveness monitoring surveys occurred in June 2017 (pre-enhancement) and September 2017 (post-enhancement) receiving fair and good ratings, respectively. The enhanced reach encompassed 70,027 $ft^2$ within main- and off-channel areas of Dry Creek with 23% of the total area meeting optimal depth and velocity criteria (Table 5.2.48, Figure 5.2.73). The monitoring characterized 3,936 ft2 of main channel alcove area, 2,378 ft2 of side channel alcove area, and 19,409 ft2 of side channel area, of which 84%, 82%, and 23% met optimal depth and velocity criteria, compared with 45,128 ft2 and 22% for the main channel area. Twenty one habitat units composed the enhancement reach, with a pool to riffle ratio of 6:2 (3.00) and average shelter score of 115 (Table 5.2.49, Figure 5.2.74, Figure 5.2.75). Nine habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised five enhancement sites (one main-channel, two alcoves, two side channels; Table 5.2.50, Figure 5.2.76), with excellent site average feature ratings, and fair to excellent site average habitat unit ratings, likely driven by shelter scores (Table 5.2.50, Figure 5.2.77, Figure 5.2.78). Enhancement sites received good to excellent ratings (Table 5.2.50, Figure 5.2.79). Overall, the City of Healdsburg Yard enhancement reach received a good effectiveness monitoring rating (Table 5.2.50, Figure 5.2.80; see Appendix 5.1 for all measured values, scores, and ratings).

*Depth and velocity*

**Table 5.2. 48. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the City of Healdsburg Yard enhancement reach, July 2018.**

| City of Healdsburg Yard Post-effective flow July 2018 | Wetted area ($ft^2$) | Optimal depth ($ft^2$) 0.5 – 2.0 ft | Optimal depth ($ft^2$) 2.0 – 4.0 ft | Optimal depth ($ft^2$) Total | Optimal velocity ($ft^2$) < 0.5 ft/s | Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 45,128 | 33,146 | 5,710 | 38,857 | 14,214 | 8,984 | 962 | 9,945 |
| Main channel alcove area | 3,936 | 971 | 2,393 | 3,364 | 3,880 | 967 | 2,340 | 3,308 |
| Side channel alcove area | 2,378 | 1,592 | 359 | 1,951 | 2,378 | 1,592 | 359 | 1,951 |
| Side channel area | 19,409 | 10,442 | 5,468 | 15,910 | 6,388 | 3,477 | 917 | 4,394 |
| **Total area** | **70,852** | **46,151** | **13,931** | **60,081** | **26,859** | **15,020** | **4,579** | **19,598** |
| Main channel % of wetted area | 64% | 73% | 13% | 86% | 31% | 20% | 2% | 22% |
| Main channel alcove % of wetted area | 6% | 25% | 61% | 85% | 99% | 25% | 59% | 84% |
| Side channel alcove % of wetted area | 3% | 67% | 15% | 82% | 100% | 67% | 15% | 82% |
| Side channel % of wetted area | 27% | 54% | 28% | 82% | 33% | 18% | 5% | 23% |
| **Total % of wetted area** | **100%** | **64%** | **23%** | **87%** | **43%** | **22%** | **10%** | **32%** |

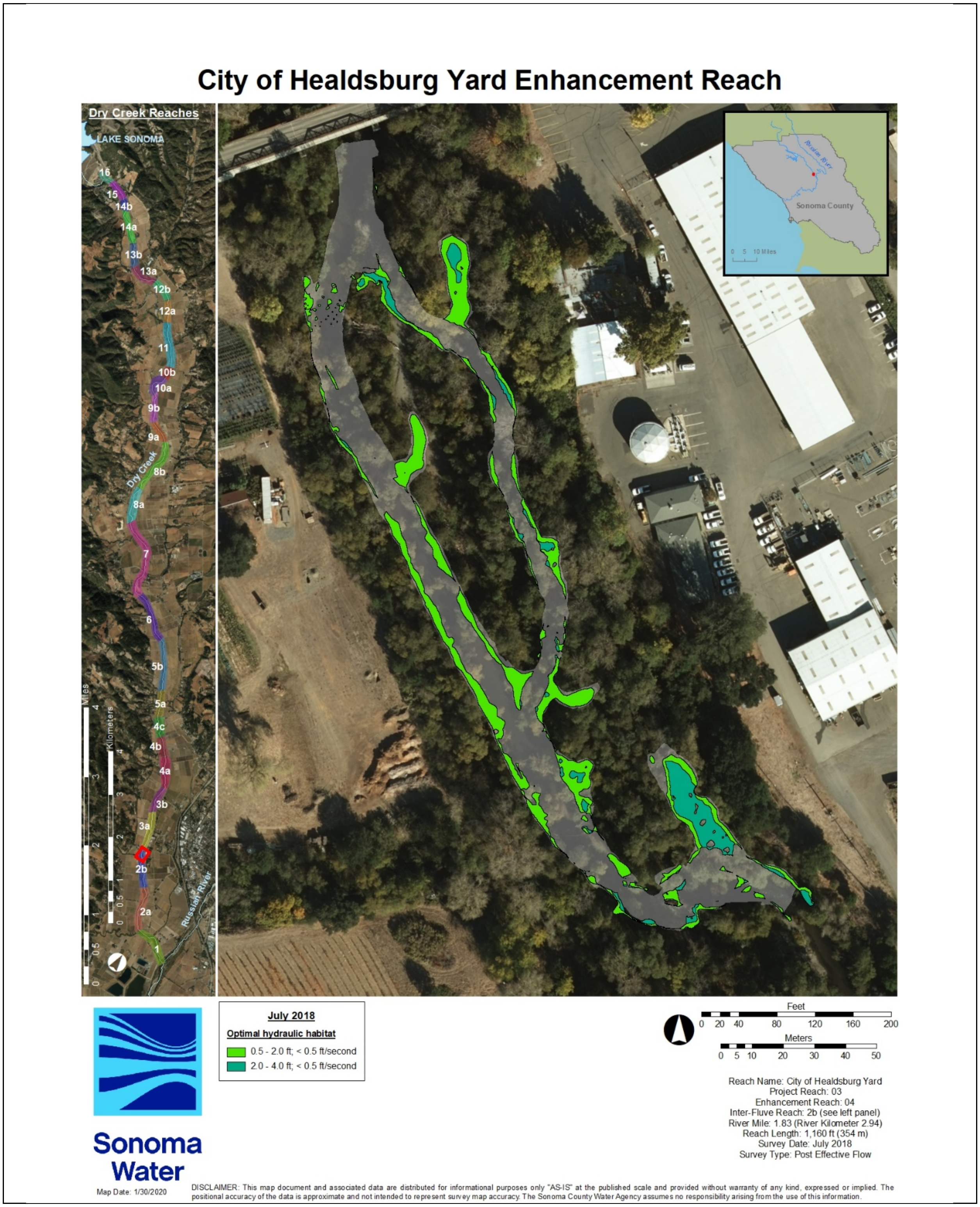


**Figure 5.2.70. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the City of Healdsburg Yard enhancement reach, July 2018.**

### *Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 49. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the City of Healdsburg Yard enhancement reach, July 2018, post-effective flow. HU12 was a disconnected tributary inlet and was not included in assessment.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Pool | 2 | 15 | 30 |
| HU02 | Pool | 3 | 25 | 75 |
| HU03 | Alcove | 3 | 95 | 285 |
| HU04 | Riffle | 3 | 15 | 45 |
| HU05 | Pool | 2 | 35 | 70 |
| HU06 | Pool | 2 | 25 | 50 |
| HU07 | Flatwater | 2 | 20 | 40 |
| HU08 | Flatwater | 3 | 25 | 75 |
| HU09 | Alcove | 3 | 90 | 270 |
| HU10 | Alcove | 3 | 95 | 285 |
| HU11 | Riffle | 3 | 30 | 90 |
| HU13 | Flatwater | 3 | 30 | 90 |
| HU14 | Alcove | 3 | 50 | 150 |
| HU15 | Pool | 3 | 30 | 90 |
| HU16 | Flatwater | 1 | 5 | 5 |
| HU17 | Pool | 3 | 30 | 90 |
| HU18 | Flatwater | 3 | 15 | 45 |
| HU19 | Alcove | 3 | 80 | 240 |
| HU20 | Flatwater | 1 | 5 | 5 |
| HU21 | Alcove | 3 | 90 | 270 |
| **Pool: riffle** | **6: 2 (3.00)** | | | **Avg = 115** |


**Figure 5.2.71. Habitat unit number and type within the City of Healdsburg Yard enhancement reach, July 2018.**

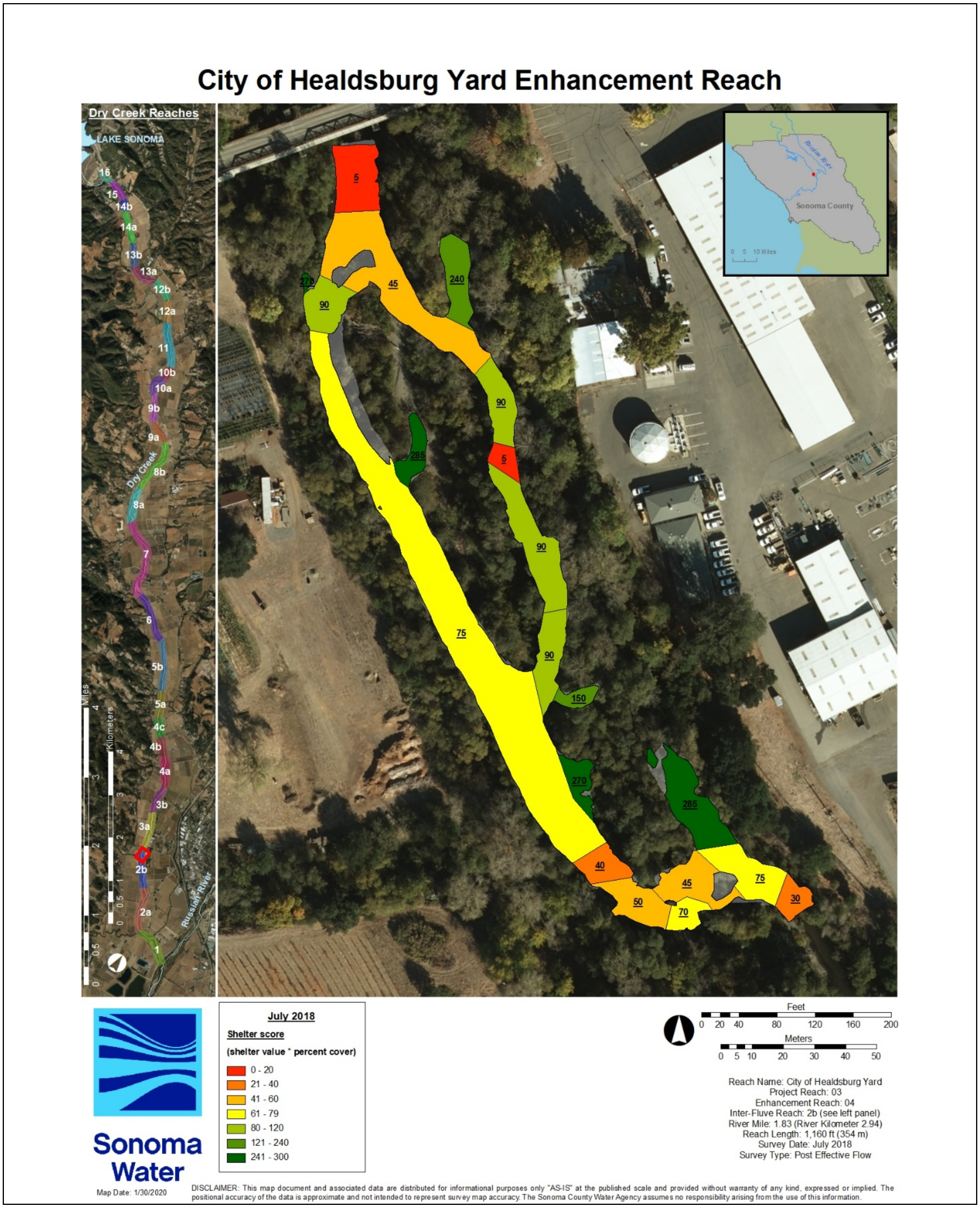


**Figure 5.2.72. Habitat unit shelter values within the City of Healdsburg Yard enhancement reach, July 2018.**

### *Feature, habitat unit, site, and reach ratings*

**Table 5.2. 50. Post-enhancement average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the City of Healdsburg Yard enhancement reach, July 2018.**

| Site number | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Site type | | Main channel | Alcove | Side channel | Alcove | Side channel |
| **Site average feature rating** | Site average feature quantitative rating[a] | 13 | 13 | 13 | 14 | 13 |
| | Site average feature qualitative rating[a] | Excellent | Excellent | Excellent | Excellent | Excellent |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 18 | 25 | 20 | 29 | 27 |
| | Site average qualitative rating[b] | Fair | Good | Fair | Excellent | Good |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating)[c] | 31 | 38 | 33 | 43 | 40 |
| | Site qualitative rating[c] | Good | Good | Good | Excellent | Excellent |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[c] | 37 | | | | |
| | Enhancement reach qualitative rating[c]: | Good | | | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=38), Good (>=28), Fair (>=19), Poor (>=9), Fail (<9)

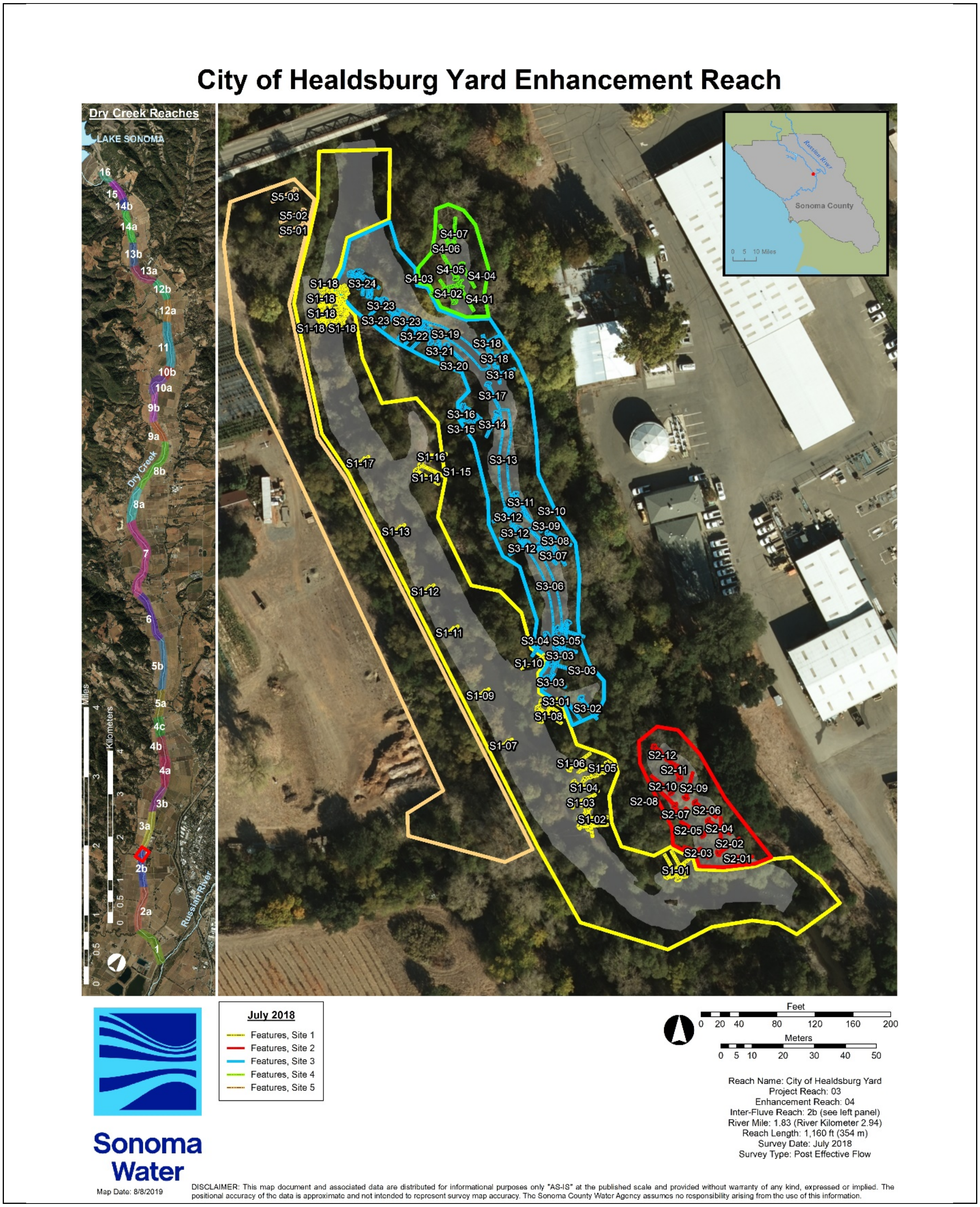


**Figure 5.2.73. Enhancement sites and features within the City of Healdsburg Yard enhancement reach, July 2018.**

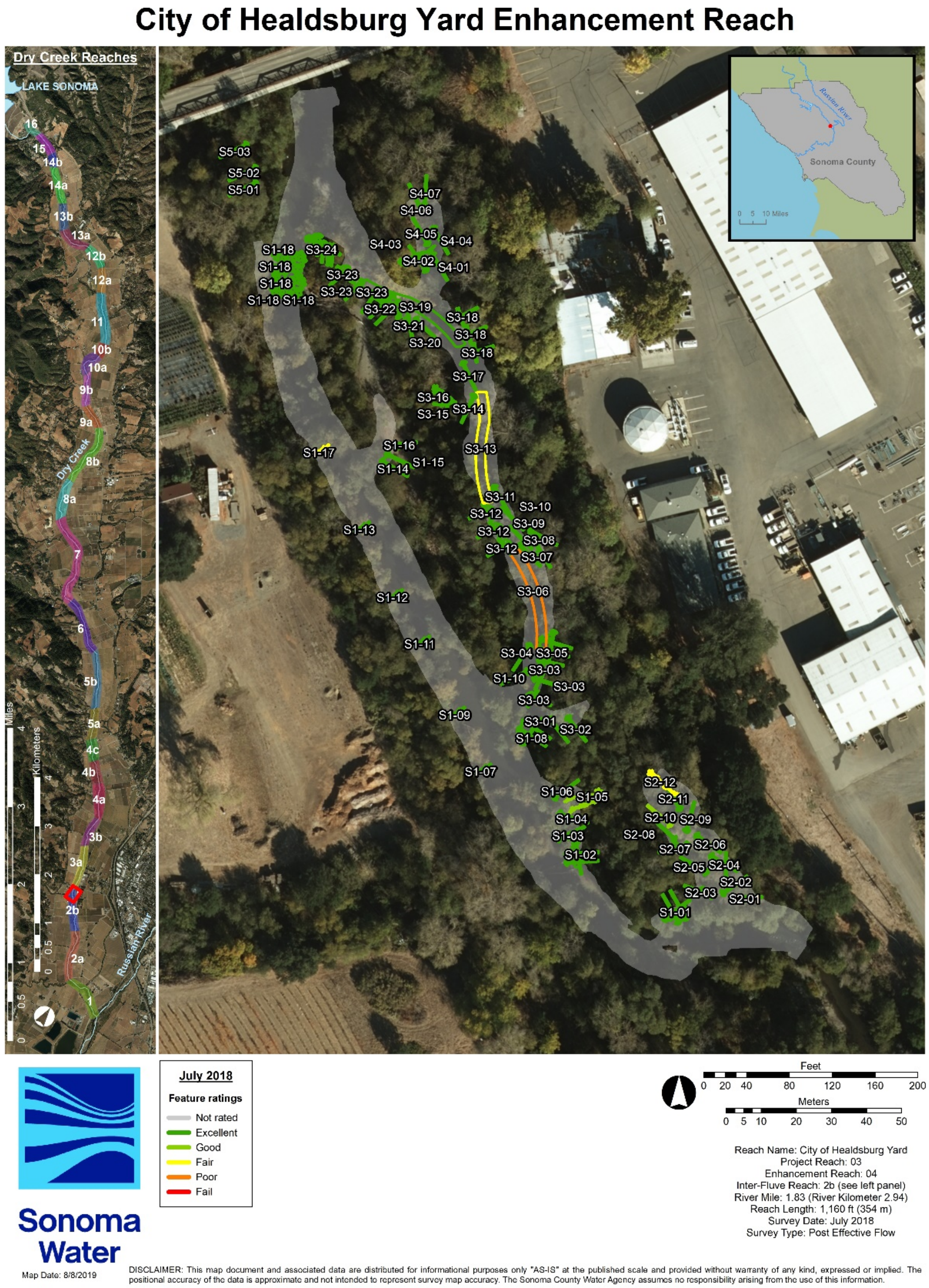


**Figure 5.2.74. Feature ratings for the City of Healdsburg Yard enhancement reach, July 2018.**

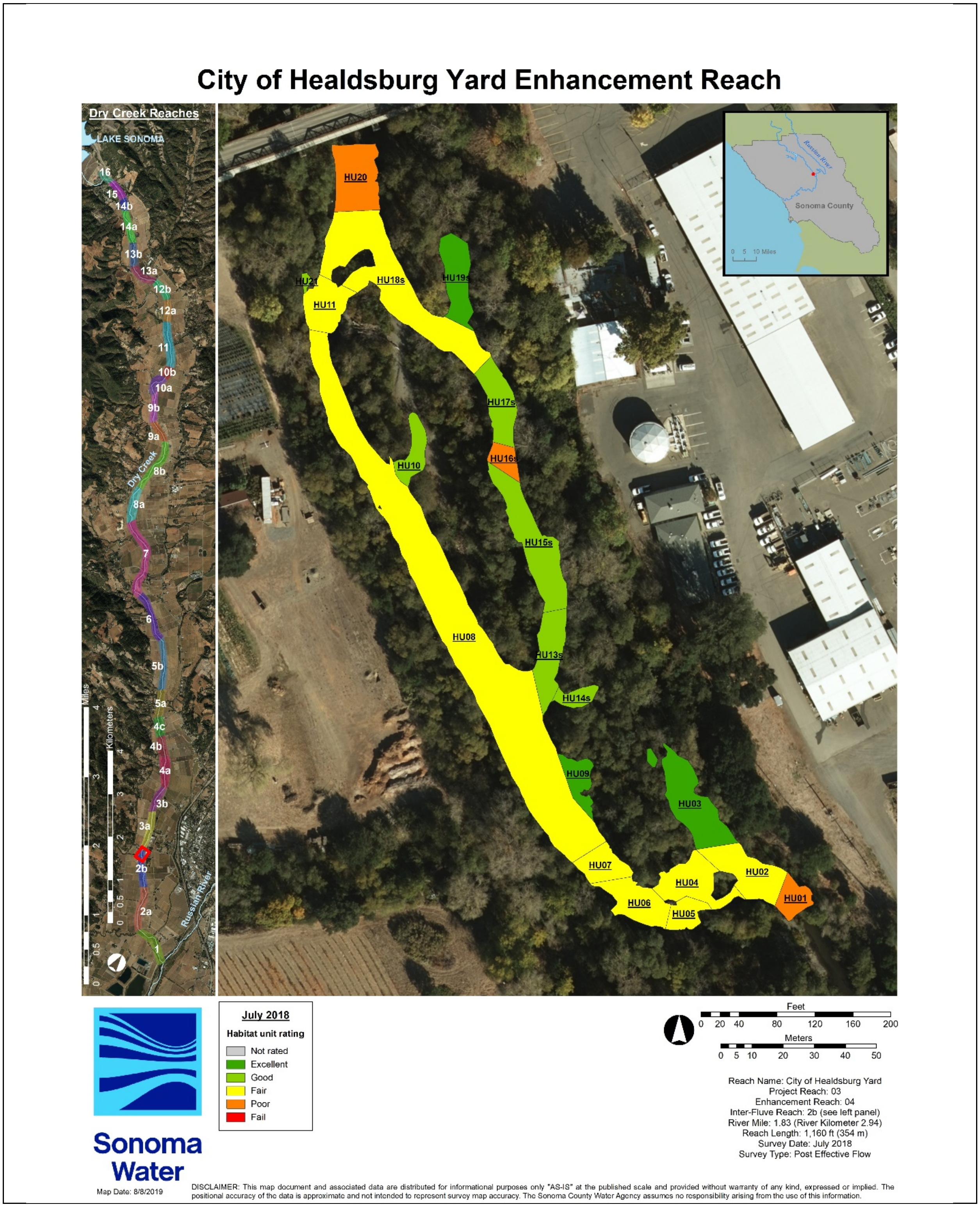


**Figure 5.2.75. Habitat unit ratings for the City of Healdsburg Yard enhancement reach, July, 2018.**

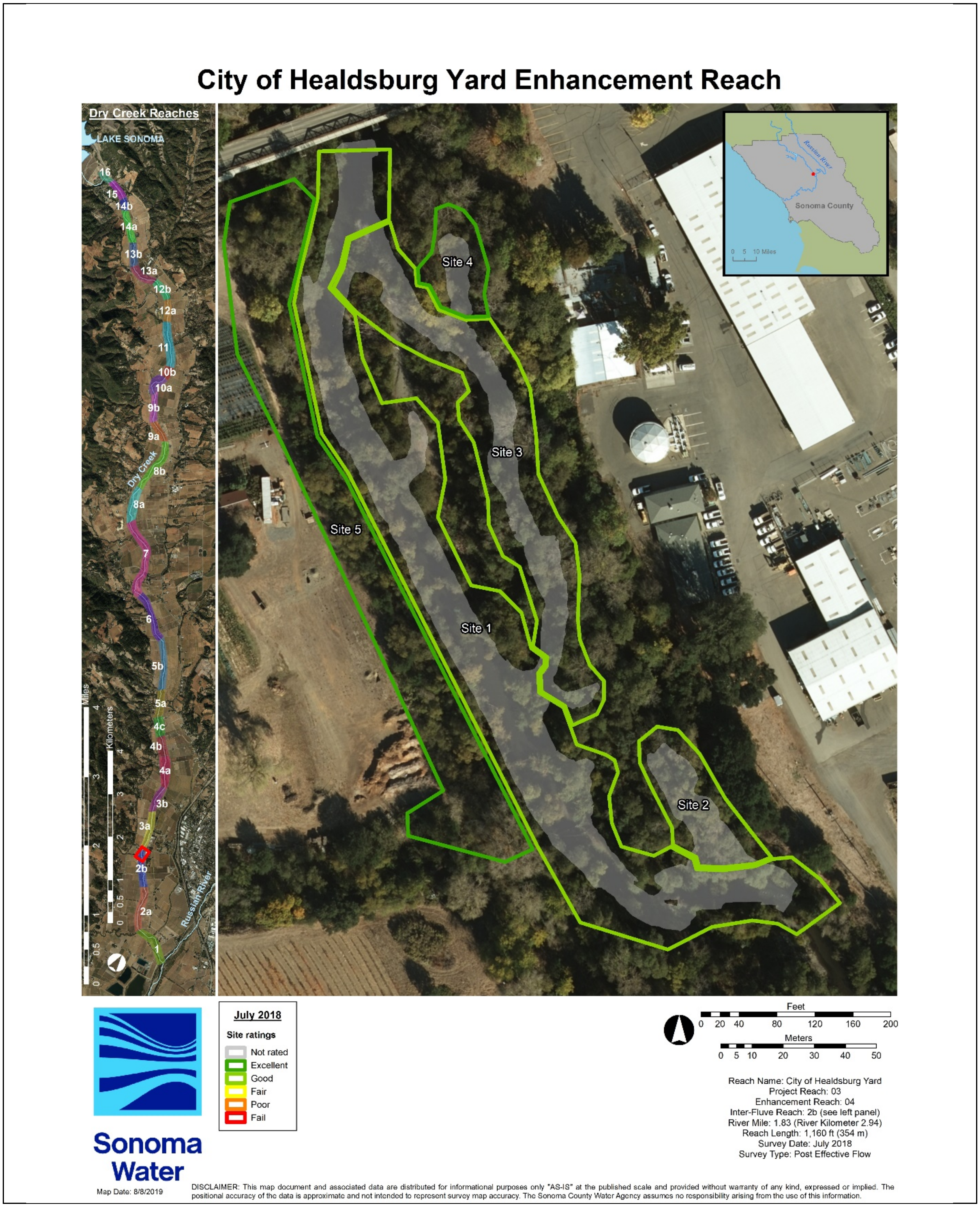


**Figure 5.2.76. Post enhancement site ratings for the City of Healdsburg Yard enhancement reach, July 2018.**


**Figure 5.2.77. Post-enhancement reach rating for the City of Healdsburg Yard enhancement reach, July 2018.**

## Geyser Peak Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Geyser Peak enhancement reach in July 2018. Sonoma Water originally constructed the Geyser Peak enhancement reach in October 2016, but aggradation caused by large storms in winter 2016/2017 led to a fail effectiveness monitoring rating in July 2017 and repairs in summer 2017. Crews monitored again in October 2017 and the enhancement reach received a fair post-repair rating (see 2017 report for results). The results below characterize the post effective flow, post-repair habitat condition of the Geyser Peak enhancement reach. The enhancement reach encompassed 35,785 $ft^2$ with main and off-channel areas, with 10% meeting optimal depth and velocity criteria, mainly along the channel margins (Table 5.2.51, Figure 5.2.81). Effectiveness monitoring characterized 9,558f $ft^2$ of off-channel area, of which 11% met optimum depth and velocity criteria, compared 26,170 $ft^2$ 9% within the main channel. Fourteen habitat units made up the enhancement reach, with a pool to riffle ratio of 5:2 (2.50) and an average shelter score of 64 (Table 5.2.52, Figure 5.2.82, Figure 5.2.83). Four habitat units met or exceeded the optimum shelter value of 80. The enhancement reach comprised four enhancement sites (one main channel and two side channel sites, and one bank site that received fail to good site average feature ratings, and poor to fair site average habitat unit ratings (Table 5.2.53, Figure 5.2.84, Figure 5.2.85, Figure 5.2.86). Summer 2017 repairs added site 2 (side channel) and site 3 (bank) that included features installed above water surface elevation, but no aquatic habitat. As such, sites 2 and 3 did not receive a site average habitat unit rating. After the summer 2017 repairs, site 1 (main channel), contained a single feature that failed due to burial by bedload in 2018, leading to a fail site average feature rating. (See Appendix 5.1 for measured values, scores, and ratings). Enhancement site ratings ranged from poor (sites 1 and 3) to fair (site 2) to good site 4 (Table 5.2.53, Figure 5.2.87). Overall, the Geyser Peak enhancement reach received a fair effectiveness monitoring score in July 2018 (Table 5.2.53, Figure 5.2.88; see Appendix 5.1 for all measured values, scores, and ratings).

*Depth and velocity*

**Table 5.2. 51. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Geyser Peak enhancement reach, July 2018.**

| Geyser Peak Post-effective flow July 2018 | Wetted area ($ft^2$) | Optimal depth ($ft^2$) 0.5 – 2.0 ft | Optimal depth ($ft^2$) 2.0 – 4.0 ft | Optimal depth ($ft^2$) Total | Optimal velocity ($ft^2$) < 0.5 ft/s | Optimal habitat ($ft^2$) 0.5 – 2.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) 2.0 – 4.0 ft < 0.5 ft/s | Optimal habitat ($ft^2$) Total |
|---|---|---|---|---|---|---|---|---|
| Main channel area | 26,170 | 16,801 | 1,781 | 18,583 | 5,162 | 1,898 | 480 | 2,378 |
| Side channel area | 9,588 | 6,053 | 2,414 | 8,468 | 2,029 | 1,017 | 67 | 1,084 |
| **Total area** | **35,758** | **22,855** | **4,196** | **27,050** | **7,191** | **2,916** | **547** | **3,462** |
| Main channel % of wetted area | 73% | 64% | 7% | 71% | 20% | 7% | 2% | 9% |
| Side channel % of wetted area | 27% | 63% | 25% | 88% | 21% | 11% | 1% | 11% |
| **Total % of wetted area** | **100%** | **64%** | **12%** | **76%** | **20%** | **8%** | **2%** | **10%** |

# Geyser Peak Enhancement Reach

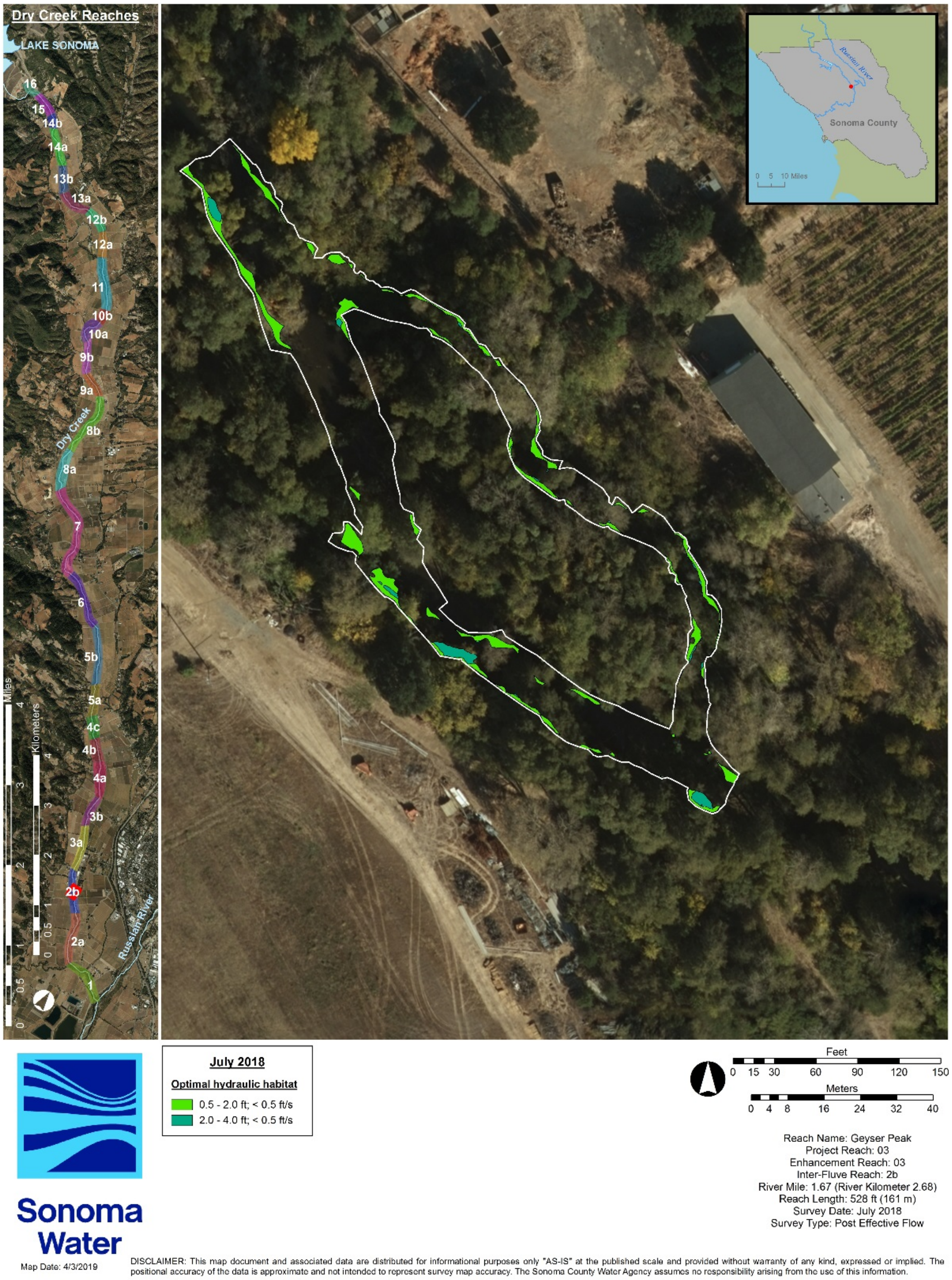


**Figure 5.2.78. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Geyser Peak enhancement reach, July 2018.**

*Habitat types, pool to riffle ratio, and shelter scores*

**Table 5.2. 52. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Geyser Peak enhancement reach, July 2018, post-effective flow.**

| Habitat Unit # | Habitat Type | Shelter Value | Percent Cover | Shelter Score |
|---|---|---|---|---|
| HU01 | Pool | 1 | 5 | 5 |
| HU02 | Riffle | 2 | 25 | 50 |
| HU03 | Pool | 3 | 40 | 120 |
| HU04 | Riffle | 2 | 25 | 50 |
| HU05 | Alcove | 3 | 50 | 150 |
| HU06 | Flatwater | 3 | 15 | 45 |
| HU09 | Flatwater | 3 | 10 | 30 |
| HU10 | Pool | 3 | 30 | 90 |
| HU11 | Flatwater | 3 | 15 | 45 |
| HU12 | Pool | 3 | 30 | 90 |
| HU13 | Pool | 3 | 15 | 45 |
| HU14 | Flatwater | 3 | 15 | 45 |
| **Pool: riffle** | **5: 2 (2.50)** | | | **Avg = 64** |

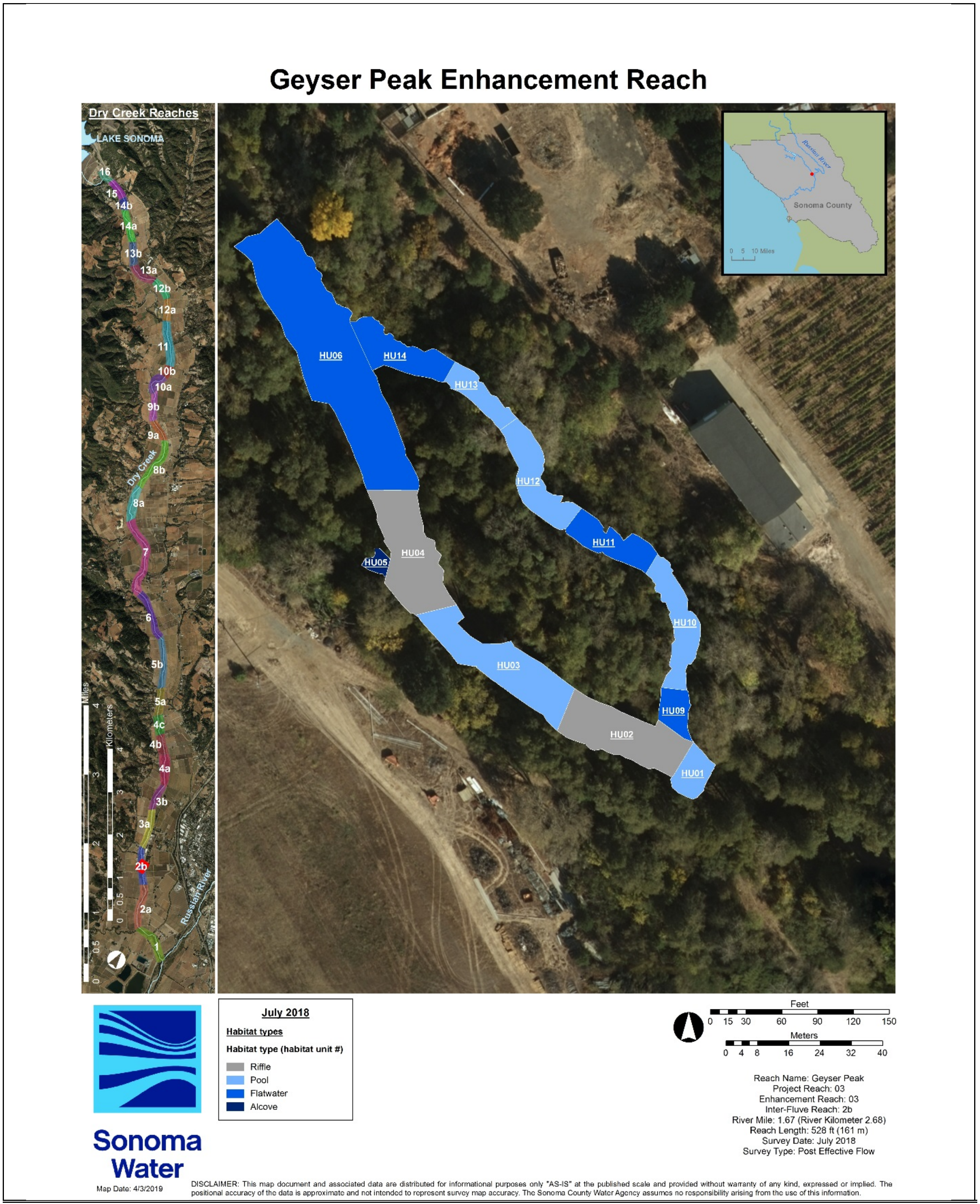


**Figure 5.2.79. Habitat unit number and type within the Geyser Peak enhancement reach, July 2018.**

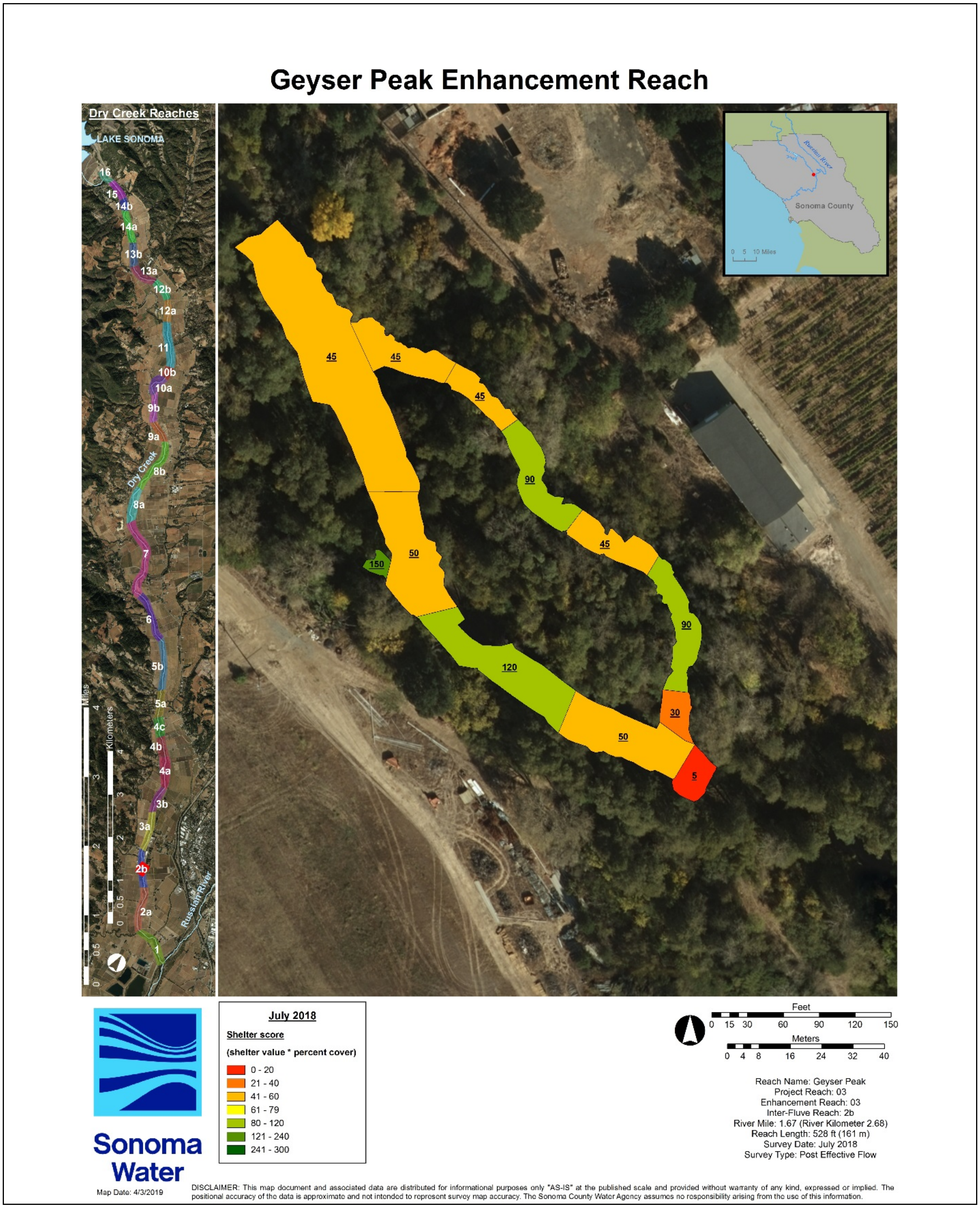


**Figure 5.2.80. Habitat unit shelter scores within the Geyser Peak enhancement reach, July 2018.**

*Feature, habitat unit, site, and reach ratings*

**Table 5.2. 53. Post-effective flow average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Geyser Peak enhancement reach, July 2018.**

| Site number | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Site type | | Main channel | Side channel | Side channel | Bank |
| **Site average feature rating** | Site average feature quantitative rating[a] | 0 | 11 | 5 | 10 |
| | Site average feature qualitative rating[a] | Fail | Good | Poor | Good |
| **Site average habitat unit rating** | Site average habitat unit quantitative rating[b] | 16 | 12 | 0 | 0 |
| | Site average qualitative rating[b] | Fair | Poor | Not Rated | Not Rated |
| **Site rating** | Site quantitative rating (sum of site average feature and habitat unit rating) | 16[c] | 23[c] | 5[a] | 10[a] |
| | Site qualitative rating | Poor[c] | Fair[c] | Poor[a] | Good[a] |
| **Enhancement reach rating** | Enhancement reach quantitative rating (average of site rating)[d] | 13 | | | |
| | Enhancement reach qualitative rating[d]: | Fair | | | |

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair (>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair(>=20), Poor (>=10), Fail (<10)
[d]out of 33; Excellent (>=26), Good (>=20), Fair (>=13), Poor (>=7), Fail (<7)

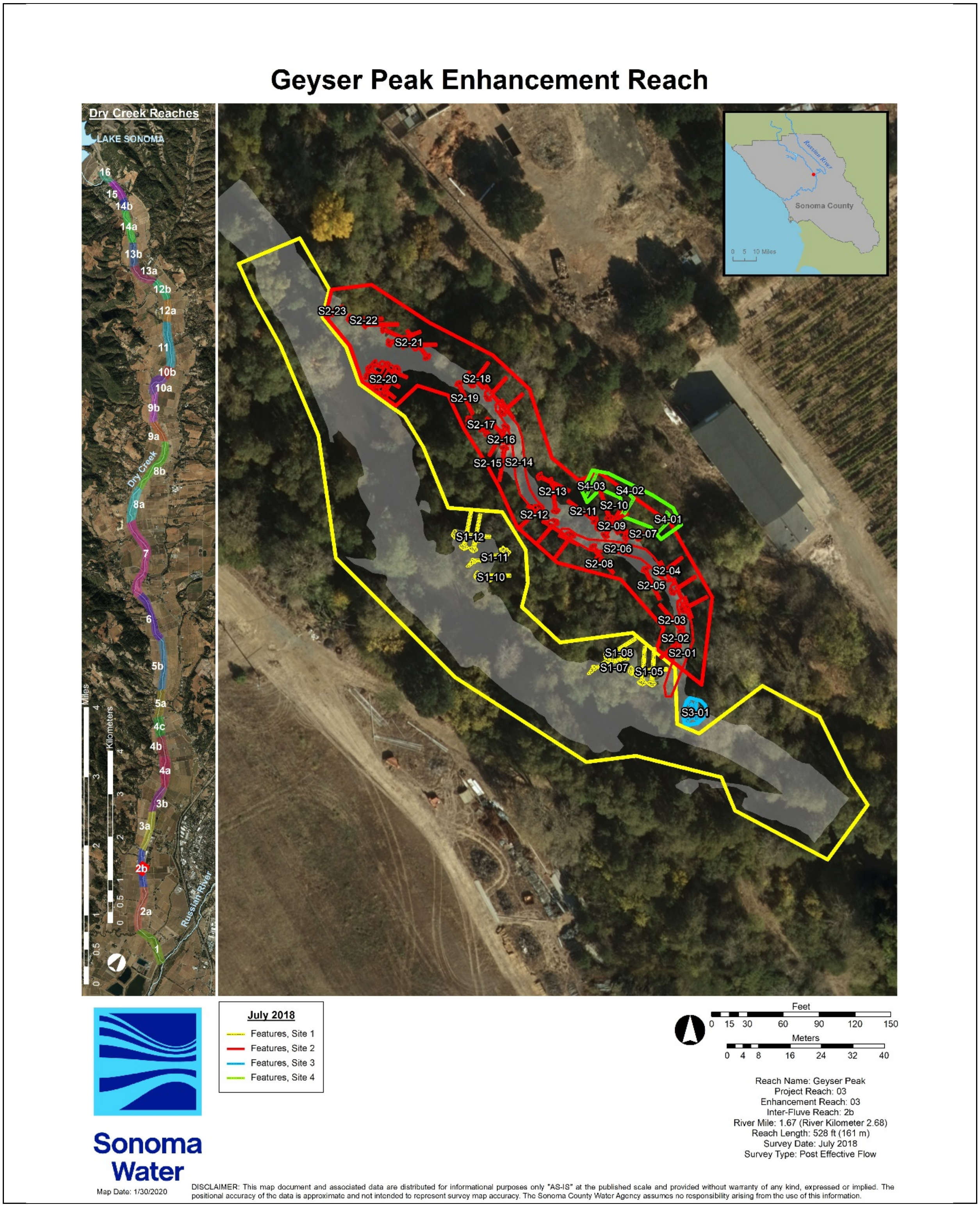


**Figure 5.2.81. Enhancement sites and features within the Geyser Peak enhancement reach, July 2018.**

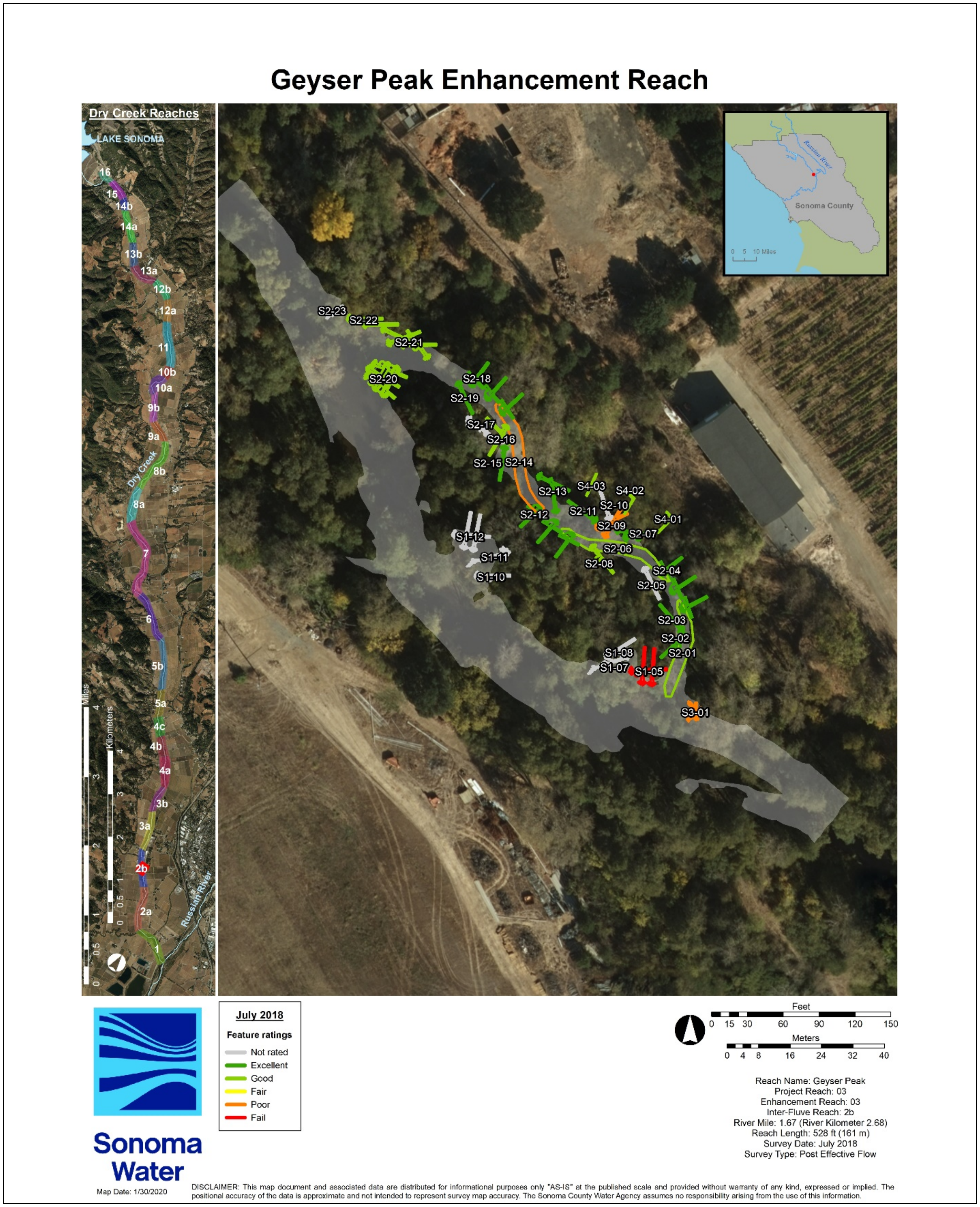


**Figure 5.2.82. Feature ratings for the Geyser Peak enhancement reach, July 2018.**

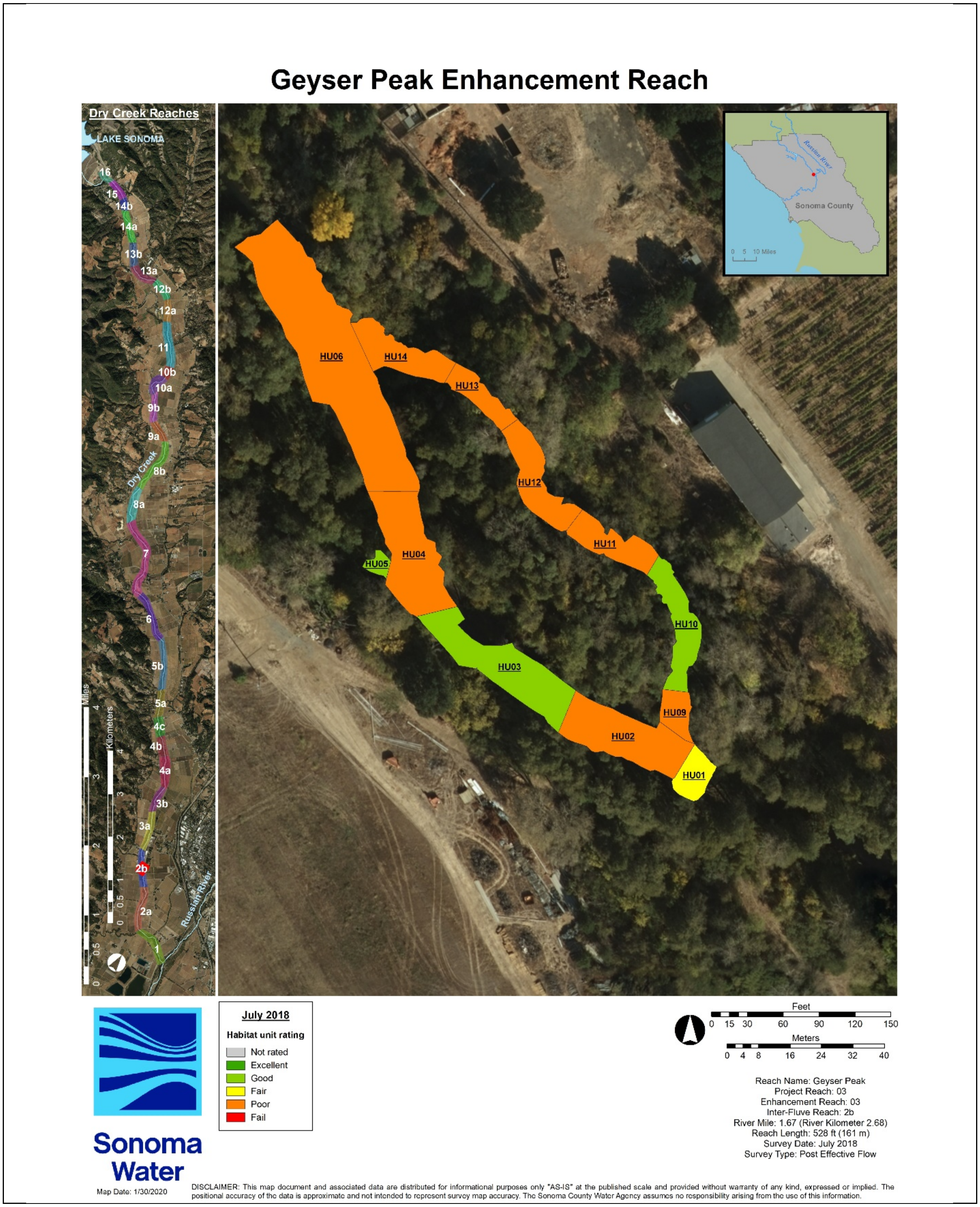


**Figure 5.2.83. Post-effective flow habitat unit rating for the Geyser Peak enhancement reach, July 2018.**


**Figure 5.2.84. Post-effective flow site ratings for the Geyser Peak enhancement reach, July 2018.**


**Figure 5.2.85. Post-effective flow reach rating for the Geyser Peak enhancement reach, July 2018.**

# Discussion

## Summary

Effectiveness monitoring in 2018 showed an increase in the percent of optimal depth and velocity area from pre-enhancement (20%) to post-enhancement (33%) to post-effective flow (24%), while average shelter scores slightly decreased from pre-enhancement (69) to post-enhancement (65), then increased post-effective flow (95, exceeding the optimal shelter value of 80 (Table 5.2.54). The high number of alcoves observed (9) and high average shelter score for alcoves (239) observed during post-effective flow surveys likely contributed to a higher average shelter score (Table 5.2.37). Observed pool to riffle ratio remained within 1:2 to 2:1 (0.50 to 2.00) for all monitoring time periods.

**Table 5.2. 54. Summary of percent optimal depth and velocity, average shelter score and pool to riffle ratio for all monitoring time periods.**

| Monitoring time-period | % optimal depth and velocity | Average shelter score | Pool to riffle ratio |
|---|---|---|---|
| Pre-enhancement | 20% | 69 | 14:9 (1.55) |
| Post-enhancement | 33% | 65 | 18: 16 (1.13) |
| Post-effective Flow | 24% | 95 | 22:13 (1.69) |

## Depth and Velocity

Effectiveness monitoring data from all monitoring time periods in 2018 showed substantial differences in the amount of optimal depth and velocity habitat between main and off-channel areas, and between habitat types. Overall, 26% of main and off-channel area supported optimal depth and velocity, compared with 20% in main channel areas, and 42% in off-channel areas (Figure 5.2.89). Alcoves supported the greatest area of optimal depth and velocity, regardless of channel location (main and off-channel [80%], main channel [78%], off-channel [80%]), followed by pools (main and off-channel [30%], main channel [26%], off-channel [38%]). The percentage of optimal depth and velocity in flatwaters and riffles remained consistently lower than alcoves or pools across all channel areas. Inter-Fluve (2010) recorded similar observations for flatwaters during pre-enhancement habitat surveys in 2010, prompting recommendations to construct low velocity habitats, such as alcoves and side channels, as a primary strategy to enhance Dry Creek. Riffles typically have higher water velocity and shallow depths at low flows, and by character do not support the optimal depth and velocity conditions recommended by the BO or the AMP, but still perform important ecological roles, such as nutrient retention and food production.

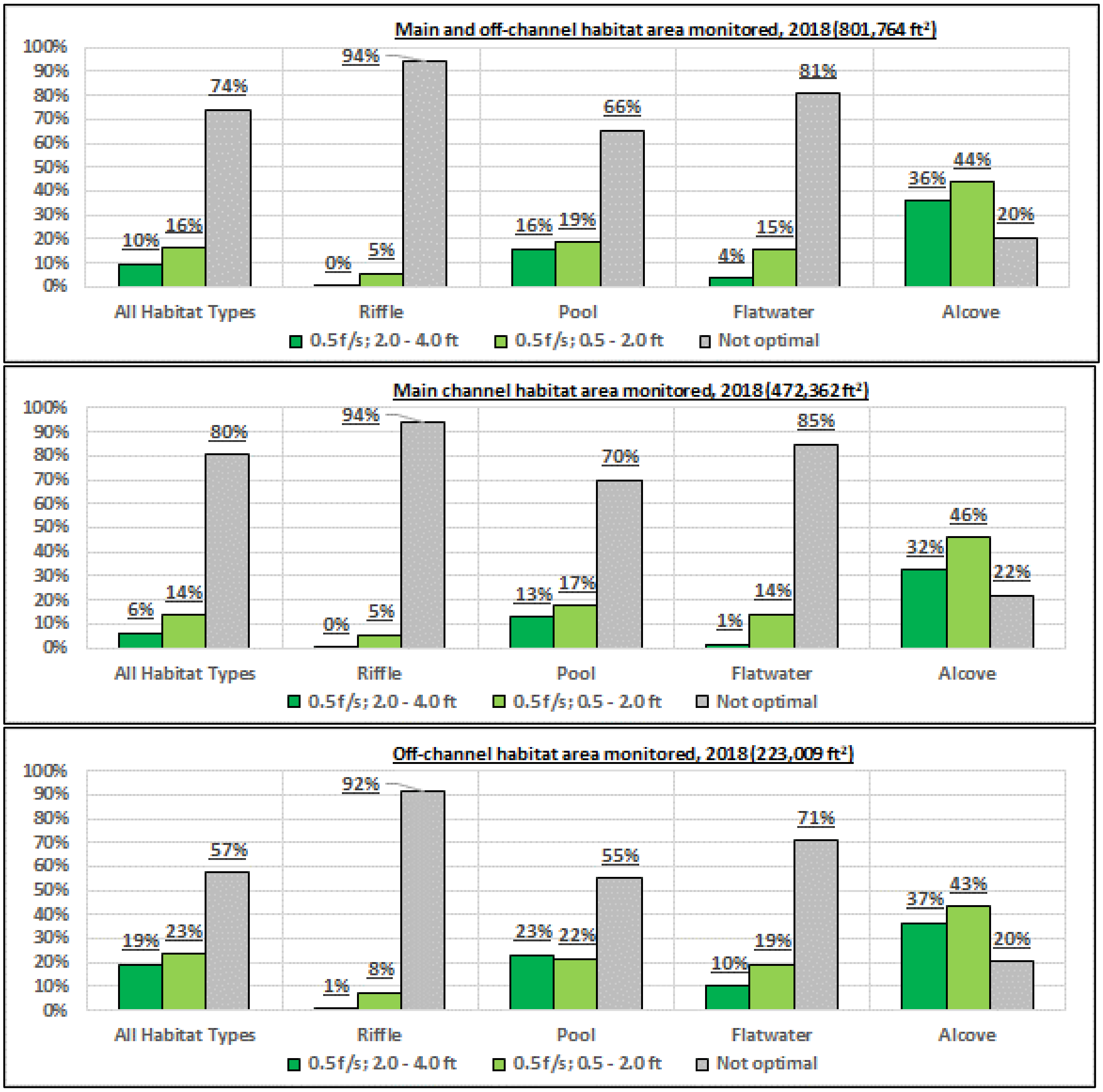


**Figure 5.2. 89. Percentages of optimal depth and velocity within main and off-channel areas (top panel), main, channel areas (middle panel), and off-channel areas (lower panel), and across riffle, pool, flatwater, and alcove habitat type.**

## Habitat Types, Pool to Riffle Ratio, and Shelter Scores

Effectiveness monitoring data from all monitoring time periods in 2018 did show differences in average shelter score between main and off-channel areas, and differences between habitat types (Figure 5.2.90). Overall, main and off-channel area supported an average shelter score of 79, compared with 70 in main channel areas, and 91 in off-channel areas. Alcoves supported the highest average shelter score, regardless of channel location (main and off-channel [169], main channel [204], off-channel [147], all above the optimum shelter score of 80), followed by pools (main and off-channel [86], main channel [76], off-channel [101]). As with the percentage of optimal depth and velocity habitat, average shelter score in flatwaters and riffles remained consistently lower than alcoves and pools across all channel locations The results reinforce depth and velocity observations (above) that side-channels and alcoves are effective at providing habitat conditions recommended in the RRBO and in the AMP.

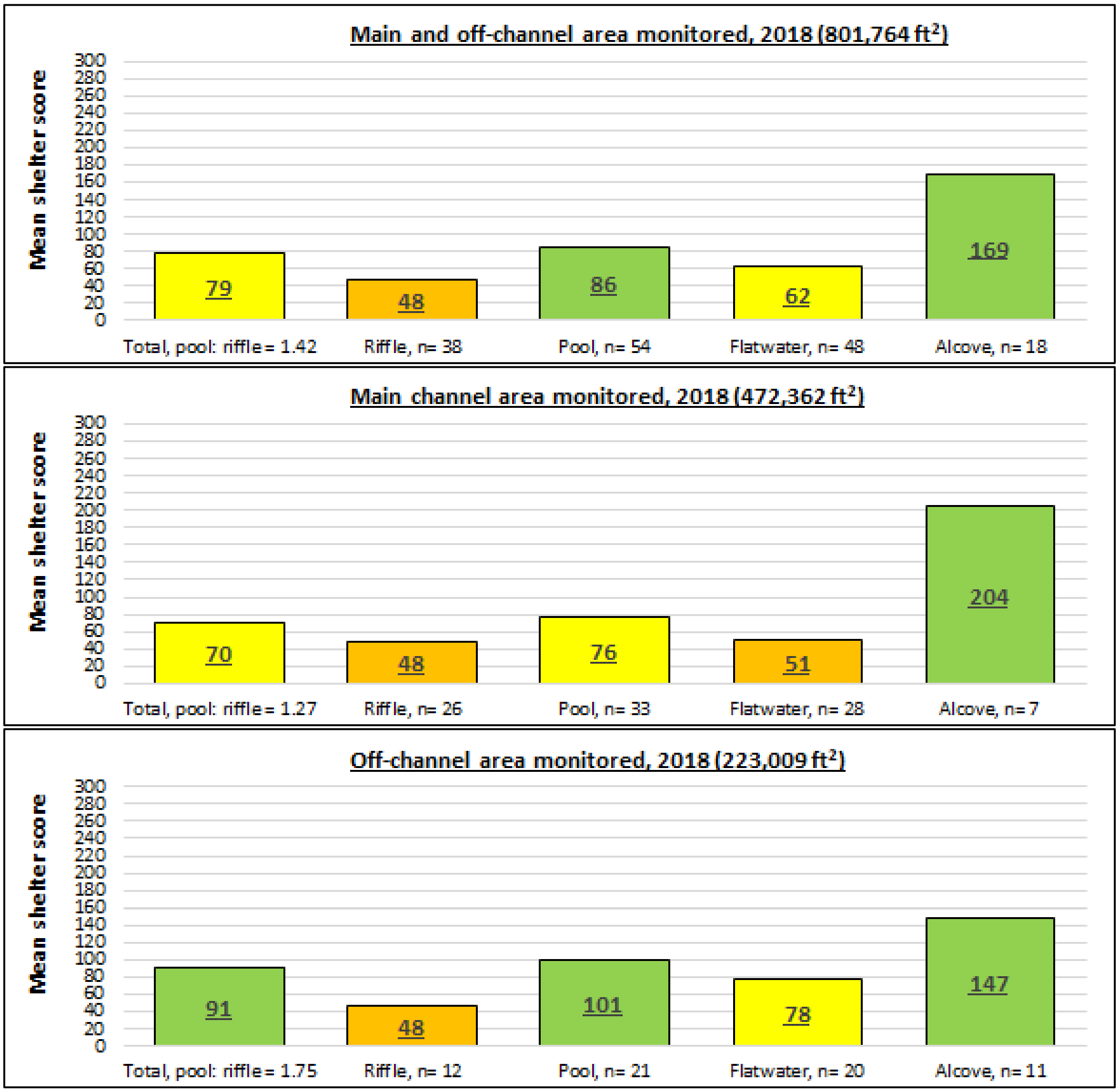


**Figure 5.2. 90. Average shelter scores within main and off-channel areas (top panel), main, channel areas (middle panel), and off-channel areas (lower panel), and across riffle, pool, flatwater, and alcove habitat type.**

## Reach Ratings

Enhancement reach ratings from 2018 effectiveness monitoring vary according to monitoring time period (Table 5.2.55). Pre-enhancement ratings of Army Corps reach 14, Weinstock and Ferrari-Carano, Olson enhancement reaches improved from fair to good post-enhancement, consistent with the addition of off-channel areas. The Gallo enhancement reach also received a fair pre-enhancement rating, but will not be constructed until 2019. As described above, Truett Hurst, Meyer, and Geyser Peak enhancement reaches received poor, fair, and fail post-effective flow ratings in 2017 that necessitated repairs. Post 2017 repair, post-effective flow enhancement reach ratings of Truett Hurst, Meyer, and Geyser Peak improved to good, fair, and fair in 2018. Post-effective flow, effectiveness monitoring of Carlson, Lonestar and City of Healdsburg Yard enhancement reaches, constructed in 2017, resulted in good and fair ratings in 2018.

**Table 5.2. 55. Dry Creek enhancement reaches monitored in 2018, type of monitoring conducted, and reach ratings for each monitoring time period. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River) (-- indicates monitoring not conducted).**

| Enhancement Reach | Pre-enhancement | Post-enhancement | Post-effective Flow | Post-repair |
|---|---|---|---|---|
| Army Corps Reach 14 | Fair | Good | -- | -- |
| Weinstock | Fair | Good | -- | -- |
| Gallo | Fair | -- | -- | -- |
| Truett Hurst | -- | -- | Good | -- |
| Meyer | -- | -- | Fair | -- |
| Carlson Lonestar | -- | -- | Good | -- |
| Ferrari-Carano Olson | Fair | Good | -- | -- |
| City of Healdsburg Yard | -- | -- | Good | -- |
| Geyser Peak | -- | -- | Fair | -- |

## Conclusion

Qualitative ratings describe the relative success of habitat enhancement measures within enhancement sites and enhancement reaches and determine potential future outcomes (management actions; see Effectiveness Ratings above). Post-effective flow enhancement reach ratings occur after exposure to at least one effective flow and likely reflect restored habitat conditions more accurately than post-enhancement ratings determined just after construction. As such, the ratings that determine management actions (Table 5.2.2) should likely be the most recent post-effective flow ratings (Table 5.2.56). The latest post-effective flow ratings, as of 2018, show two excellent ratings, five good ratings, and three fair ratings (70% of ratings either good or excellent), suggest management actions, such as developing and implementing plans to correct site or metric deficiencies, adding sites/features, and increase monitoring on sites and features exhibiting negative performance. Sonoma water will continue to monitor habitat units, features, sites, and enhancement reaches according to the AMP, and any future actions will be guided by monitoring data.

**Table 5.2. 56. Creek enhancement reaches monitored, year(s) of post-effective flow effectiveness monitoring and effectiveness rating, and latest post effective flow effectiveness monitoring score. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River).**

| Enhancement Reach | 2015 | 2016 | 2017 | 2018 | Latest post-effective flow rating |
|---|---|---|---|---|---|
| Army Corps | | Excellent | | | Excellent |
| Quivira | | Excellent | | | Excellent |
| Van Alyea | | | Good | | Good |
| Farrow Wallace | | | Fair | | Fair |
| Rued | Good | | | | Good |
| Truett Hurst | | | Poor | Good | Good |
| Meyer | | | Fair | Fair | Fair |
| Carlson, Lonestar | | | | Good | Good |
| City of Healdsburg Yard | | | | Good | Good |
| Geyser Peak | | | Poor | Fair | Fair |

# 5.3 Validation Monitoring

Part of the Adaptive Management Plan (AMP) for validating the effectiveness of habitat enhancement in mainstem Dry Creek calls for a multiscale monitoring approach in both space and time (Porter et al. 2014). The current section of this report focuses on the results of validation monitoring for juvenile and smolt salmonid populations in mainstem Dry Creek in 2018. These data are part of an ongoing pre-construction (baseline) monitoring effort begun in 2008 and outlined in the Reasonable and Prudent Alternative section of NMFS' Russian River Biological Opinion. Validation monitoring data collected in newly-constructed habitats are reported as well as continued efforts to monitor trends in juvenile and smolt abundance at the reach and watershed scale.

In the Russian River Biological Opinion status and data report year 2009-10 (Manning and Martini-Lamb 2011), Sonoma Water outlined six possible metrics that could be considered for validation monitoring of juvenile salmonids with respect to eventual habitat enhancements in the mainstem Dry Creek: habitat use, abundance (density), size, survival, growth and fidelity (Table 5.3.1). In 2009-2010, a major focus of validation monitoring in Dry Creek was on evaluating the feasibility of sampling methods to accurately estimate each of those metrics while simultaneously attempting to understand how limitations in sampling approaches may affect our ability to validate project success. These same validation metrics and associated limitations and uncertainties have been discussed in the context of the results of those evaluations and are incorporated into the Dry Creek AMP (Porter et al. 2014). The methods currently employed for validation monitoring in Dry Creek are largely based on the outcome of that work (Manning and Martini-Lamb 2011; Martini-Lamb and Manning 2011).

**Table 5.3.1. Proposed target life stages, validation metrics, spatiotemporal scale and monitoring tools for validation monitoring in mainstem Dry Creek.**

| Spatial scale | Target life stage | Target metric(s) | Temporal scale | Primary monitoring tools |
|---|---|---|---|---|
| Site/feature | Juvenile (non-smolt) | Habitat use, abundance (density), size, growth | Post-construction | Snorkeling, electrofishing, PIT tags and antennas |
| Reach | Juvenile (non-smolt) | Abundance (density), size, survival, growth, fidelity | Pre-construction (baseline) vs. post-construction | Electrofishing, PIT tags and antennas |
| Mainstem Dry Creek | Smolt | Abundance | Ongoing to capture long-term trend | Downstream migrant trap, PIT antennas |

# Methods

In order for juvenile Coho Salmon to take advantage of the habitat enhancements created in Dry Creek, fish will need to come from somewhere and although there is a substantial population of juvenile steelhead that rear in mainstem Dry Creek, Coho are extremely scarce. Therefore, our strategy for juvenile Coho validation monitoring must rely on hatchery releases coupled with visual observations of Coho in the backwaters during snorkel surveys and observations on PIT antennas within habitat enhancement sites. Because of this, much of our juvenile salmonid monitoring has been focused on steelhead.

To address use of newly created habitat by juvenile steelhead at the site and feature scale, sampling consisted of PIT-tagging in the summer, operation of stationary PIT antennas in the winter and snorkeling in summer. We also conducted mark-recapture electrofishing in enhancement areas to estimate juvenile population density where possible. To better isolate how data collected at the site-scale indicate the effect of habitat enhancement, we also conducted backpack electrofishing in stream sections (reach-scale) that were not enhanced. Finally, we continued to operate a downstream migrant trap seasonally in lower Dry Creek to assess trends in smolt production over time. Broad-scale efforts that are part of the Coastal Monitoring Program (CMP) now being implemented in the Russian River provide a framework for placing our results in the context of watershed-scale patterns in those population metrics identified in Fish Bulletin 180 (the guiding document for California Coastal Salmonid Monitoring Program implementation, Adams et al. 2011).

## Habitat utilization

### *Summer/Fall*

We conducted four snorkel surveys in Dry Creek habitat enhancement sites from May to September, 2018. Surveys were conducted with two snorkelers working in tandem. During site visits we measured water temperature and dissolved oxygen at 0.25 m depth increments throughout the water column allowing us to construct vertical temperature and dissolved oxygen profiles.

### *Winter*

Similar to previous years, we operated PIT antennas in newly constructed habitat enhancement sites during the winter in the Ferrari-Carano side channel (rkm: 5.13, rkm 5.39), Lonestar side channel (rkm 13.47, rkm 13.52) and Army Corps Reach 14 side channel (rkm 21.05, rkm 21.21) (Figure 5.3.1, Figure 5.3.2). Although antennas did not necessarily span the width of channels, they did cover most of the wetted width. The source of PIT-tagged fish included: (1) PIT-tagged juvenile Coho that were released from Warm Springs Hatchery into Dry Creek; (2) wild (natural-origin) juvenile steelhead that were PIT-tagged during mainstem Dry Creek electrofishing surveys; (3) adult anadromous salmonids that had been previously PIT-tagged as juveniles.

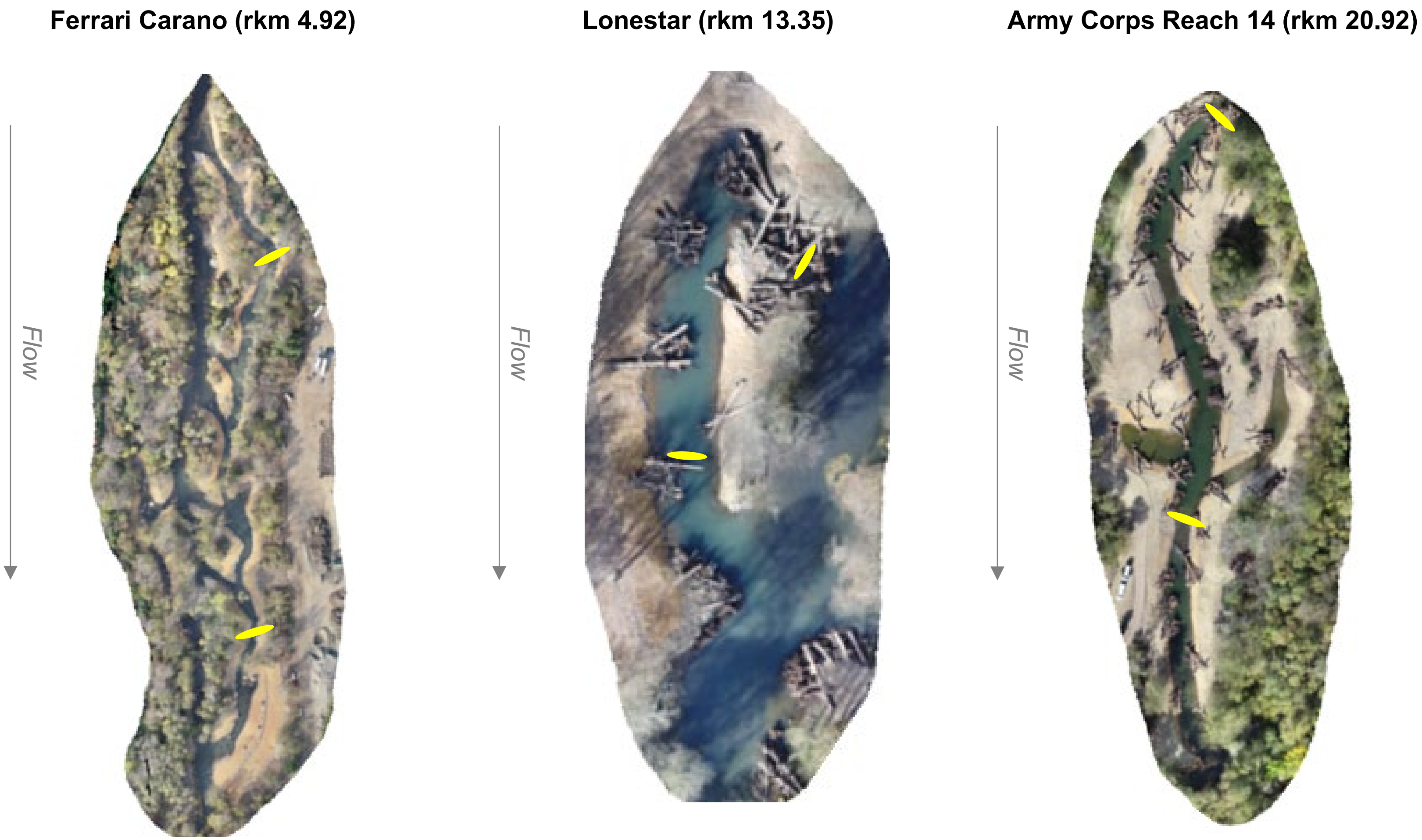


**Figure 5.3.1. Approximate location of PIT antennas (yellow ovals) in Dry Creek habitat enhancements completed in late fall/early winter, 2018-19. River kilometers (rkm) correspond to downstream extent of the stream section surveyed for effectiveness monitoring. Images are "as built".**

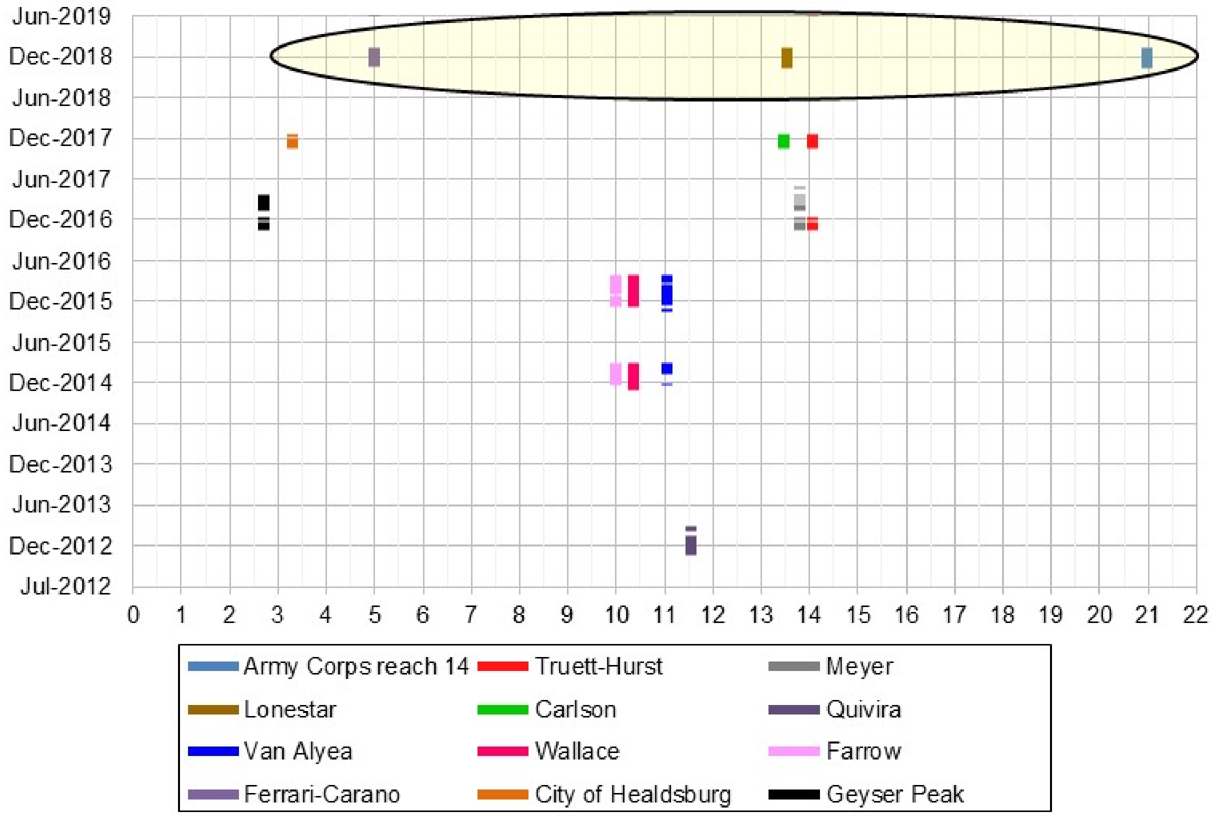


**Figure 5.3.2. Dates of PIT antenna operation in Dry Creek habitat enhancement sites, November 2012 to February 2019. Sites shaded with yellow area represent the focus for the current year's data report.**

## Late summer population density

*Site-scale sampling*

We were able to conduct sampling to estimate population density in enhanced (constructed) side channel habitat at Geyser Peak (rkm 2.49), City of Healdsburg (rkm 3.2), Truett Hurst (rkm 14.01) and Army Corps Reach 15 (rkm 21.4). During late July through August, we sampled with a backpack electrofisher by making a single pass through the entire side channel on day 1 (the marking event) followed by a second pass two days later (the recapture event). Individuals captured on day 1 were PIT-tagged, released near their capture location and subject to recapture on day 2. From these paired sampling events, we used the Petersen mark-recapture model in Program MARK (White and Burnham 1999) to estimate end-of-summer abundance ($\widehat{N}$). Provided recapture probability, mortality and the proportion of fish leaving the section between the marking and recapture events was the same for the marked group as it was for the unmarked group, the abundance estimates from the paired mark and recapture events in early autumn will be unbiased (White et al. 1982). Density estimates were calculated as the quotient of $\widehat{N}$ and wetted area of the site.

*Reach-scale sampling*

The Biological Opinion as well as the primary literature (e.g., Roni 2005) acknowledge the problem of biological monitoring that is too limited in time and space to accurately detect changes in population that may result from artificial habitat enhancements as opposed to larger scale factors. To overcome this we sought to place our results in a broader context. Beginning in 2015, we added to our targeted site-scale sampling by employing a reach-based approach that relied on the spatially-balanced random sampling framework afforded by the generalized random tessellation stratified (GRTS) framework outlined for the CMP (Adams et al. 2011). Sampling reaches in this manner over time will allow us to place our results in a broader spatial context thereby facilitating more accurate validation of the effectiveness of habitat enhancement measures in Dry Creek (Figure 5.3.3). Towards that end, we sampled one randomly selected stream section in each of nine “GRTS” reaches defined in mainstem Dry Creek for CMP monitoring (Sonoma Water and CSG 2015). We sampled using methods similar to those described for the paired sample, site-scale electrofishing so that we could estimate juvenile steelhead abundance using the Petersen mark-recapture model. Stream sections (sub-reaches) were typically longer (average 861 feet, and range 381 – 1760 feet) than sites sampled during site-scale sampling.

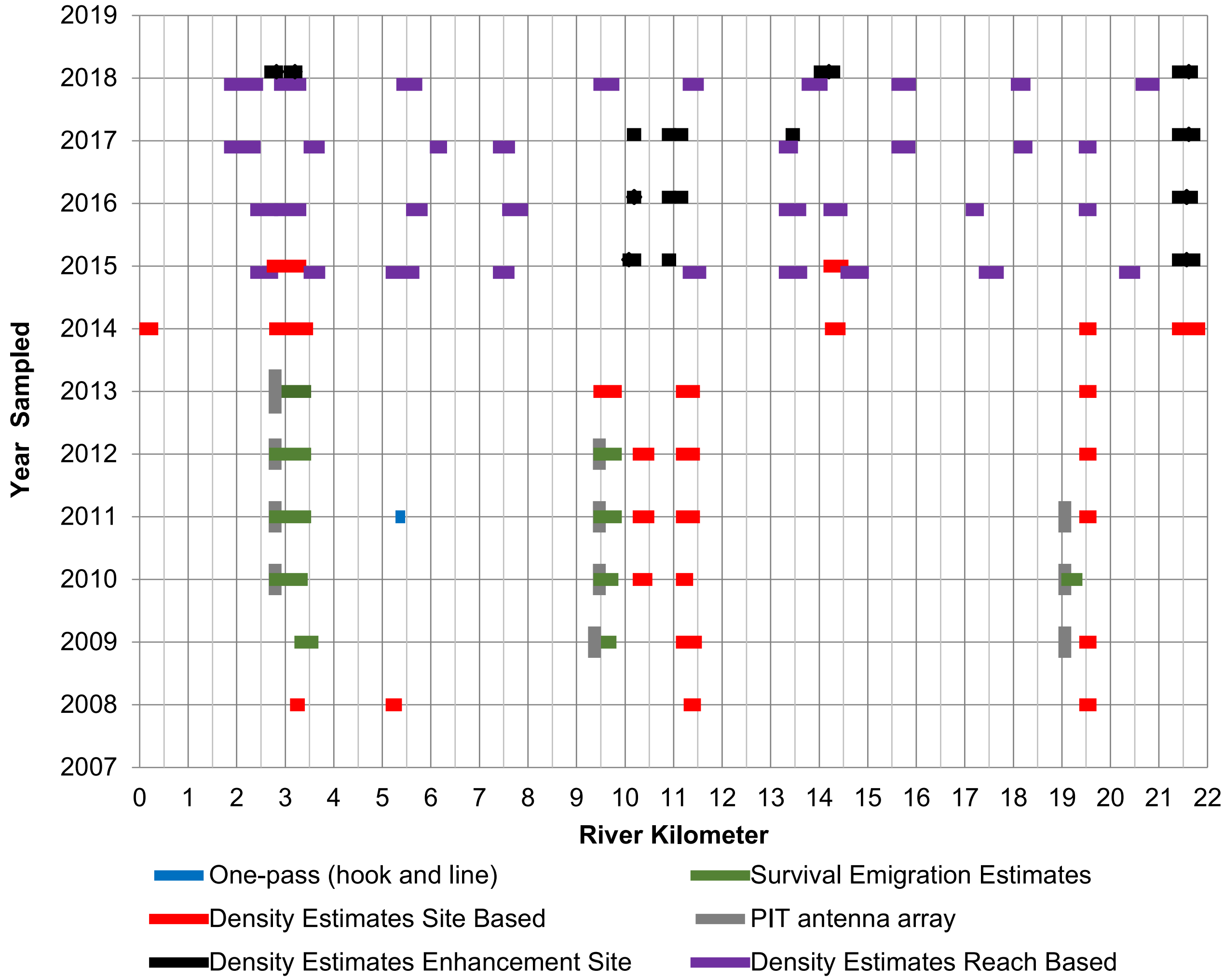


**Figure 5.3.3. Years sampled and river kilometer (from the mouth) where juvenile steelhead populations were sampled in mainstem Dry Creek, 2008-2018. Line length for each site is scaled to the length of stream sampled. Data collected at the site scale were analyzed using mark-recapture (either a multiple-pass depletion or Petersen model) and reach-scale data collected in 2009 were analyzed with the core-sampling approach (see Manning and Martini-Lamb 2011 for details) while reach scale data collected in 2011-13 were analyzed with the multistate model using program MARK (White and Burnham 1999) to estimate survival and emigration.**

## Smolt abundance

A rotary screw trap with a 1.5 m diameter cone was anchored to the Westside Road bridge, located 3.3 km upstream from the confluence of Dry Creek and the Russian River. Wood-frame mesh panels were installed adjacent to the rotary screw trap in order to divert downstream migrating salmonids into the trap that may have otherwise avoided the trap.

Fish handling methods and protocols were similar to those used in previous years (see Manning and Martini-Lamb 2011). Fish captured in the trap were identified to species and enumerated. A sample of each species was anesthetized and measured for fork length each day, and a sample of salmonid species was weighed each week. With the exception of up to 50 Chinook Salmon smolts each day, all fish were released downstream of the first riffle located downstream of the trap. Each day, up to 50 Chinook smolts (≥60 mm) were marked and released upstream of the trap for the purpose of estimating trap efficiency and constructing a population estimate. Both fin clips and PIT tags were used to mark fish. Fin-clipped and PIT-tagged fish that were recaptured in the trap were noted and released downstream (the lengths and weights of recaptured fish were not recorded a second time). The population estimate of Chinook Salmon smolts produced in the Dry Creek watershed upstream of the trap were based on recapture rates of PIT-tagged fish only. The abundance estimate of Chinook smolts reported in 2018 applies only to the period of trap operation (March 28-July 31). PIT-tagged fish provided the potential to evaluate migration mortality and migration time as fish were detected at downstream monitoring sites on mainstem Russian River.

# Results

## Habitat utilization

*Summer/Fall*

Juvenile salmonids were observed in all the Dry Creek habitat enhancement sites that were surveyed in 2018. Dive surveys were conducted at the City of Healdsburg, Geyser Peak, Truett Hurst, and Meyer constructed side channels on May 31, at the City of Healdsburg, Geyser Peak, Truett-Hurst, Meyer, Carlson, and Lonestar side channels on July 10 and August 2, and at the City of Healdsburg, Carlson, and Lonestar side channels and at the Wallace backwater on September 26. Visibility was generally favorable ranging from 6 to 10 feet for most surveys with the exception of the September 26 surveys where the Carlson and Lonestar side channels had visibility ranging from 3 to 5 feet. A total of 1,889 juvenile steelhead were observed with the majority being young-of-the-year in the Truett Hurst and Meyer side channels on May 31 (Table 5.3.2). In addition to steelhead, 3 Chinook smolts were observed in the Truett Hurst side channel and 13 Chinook smolts where observed in the Meyer side channel on May 31. At the City of Healdsburg side channel 21 Coho young-of-the-year were observed on July 10, and 12 Coho young-of-the-year were observed on August 2 (Figure 5.3.4). Dissolved oxygen levels were favorable for salmonids with the exception of the Farrow backwater which had low dissolved oxygen, averaging 3.0 mg/L on September 26, (Figure 5.3.5). The presence of aquatic vegetation in the Farrow backwater reduced visibility to the point that it was not surveyed for juvenile salmonids. It is likely that the Farrow backwater is more valuable to salmonids as winter habitat. The number of fish observed in 2018 may seem high when compared to recent years, but unlike in recent years viewing conditions (high visibility) were favorable in 2018.

**Table 5.3.2. Number of steelhead observed during snorkel surveys in Dry Creek habitat enhancement sites, 2018. Dashes indicate that the site was not surveyed.**

| Site | 5/31 | 7/10 | 8/2 | 9/26 |
|---|---|---|---|---|
| Wallace backwater | - | - | - | 14 |
| Truett Hurst side channel | 680 | 170 | 65 | - |
| Meyer side channel | 428 | 372 | 2 | - |
| Geyser Peak side channel | 0 | 5 | 2 | - |
| City of Healdsburg side channel | 1 | 49 | 5 | 8 |
| Carlson side channel | - | 31 | 13 | 3 |
| Lonestar side channel | - | 18 | 20 | 3 |

**Figure 5.3.4. Young-of-the-year Coho in the City of Healdsburg side channel.**

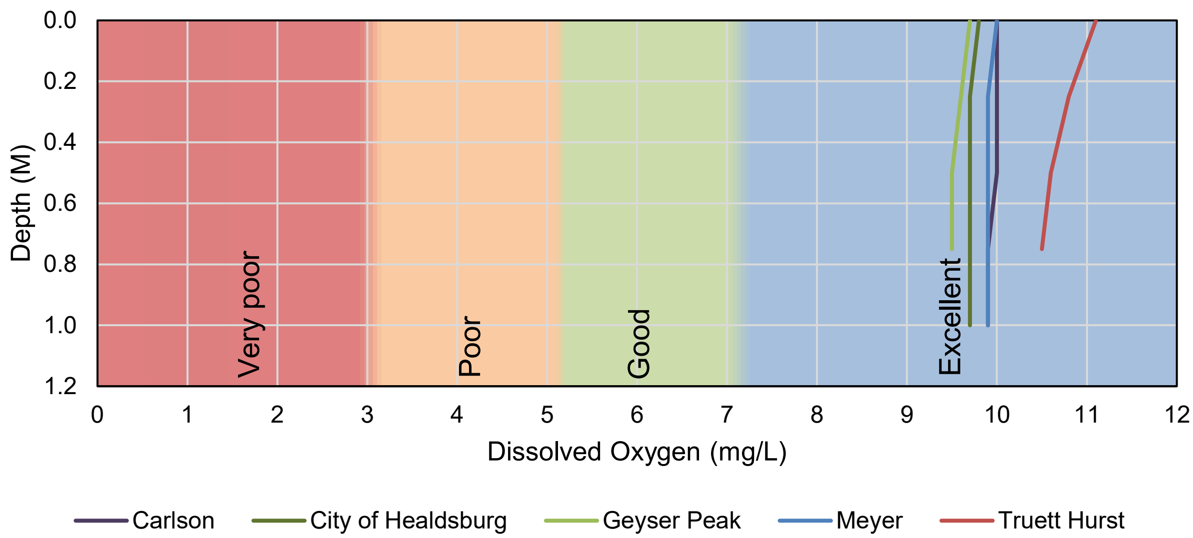


**Figure 5.3.5. Dissolved oxygen from vertical water quality profiles collected with a handheld probe at 0.25 m depth increments in the City of Healdsburg, Truett Hurst, Carlson, Geyser peak, and Meyer side channels, August, 2018.**

*Winter*

Of the 1,468 juvenile steelhead that were PIT-tagged in 2018 during electrofishing surveys (Table 5.3.3), 82 (5.6%) were detected in the three constructed side channels where PIT antennas were operated in late fall/early winter 2018-19. Most of the detections (46) were from fish that were tagged within 2 km of the enhancement site (Figure 5.3.6-Figure 5.3.8). From these data, it is reasonable to conclude that a significant portion of all juveniles made use of these enhanced off-channel habitats during the winter, but, not surprisingly, the highest use is by fish residing in close proximity to the habitat enhancements.

In addition to juvenile salmonid detections in the habitat enhancements, we also documented use by adult salmonids. Of the 44 PIT-tagged individual Coho detected entering Dry Creek (all Dry Creek antennas combined including the Coastal Monitoring Program life cycle monitoring antenna array at rkm 0.36), 20 entered at least one of the three side channels: 17 in Ferrari-Carano; 1 in Lonestar; 12 in Army Corps reach 14. Nine individuals entered at least two side channels with 1 of those detected in all three. In addition, 5 unique adult steelhead and 16 unique adult Chinook Salmon were detected in the three side channels.

**Table 5.3.3. Number of juvenile steelhead PIT-tagged during mainstem Dry Creek electrofishing surveys and subsequent number detected (and percent of total tagged in that reach) on PIT antennas in habitat enhancement side channels, late fall/early winter 2018. Reaches in bold italic text indicate reaches where constructed off-channel habitats with PIT antenna monitoring were located.**

| CMP reach[1] of PIT applied | Reach Upper (rkm) | Reach Lower (rkm) | EF tagged (Fall 2018) | Ferrari Carano (rkm=4.92) | Lonestar (rkm=13.35) | Army Corps reach 14 (rkm=20.92) |
|---|---|---|---|---|---|---|
| DRY 1 | 0.00 | 2.82 | 162 | 2 (1.2%) | 0 | 0 |
| DRY 2 | 2.82 | 5.20 | 221 | 2 (0.9%) | 2 (0.9%) | 0 |
| ***DRY 3*** | ***5.20*** | ***6.87*** | ***119*** | ***25 (21.0%)*** | 0 | 0 |
| DRY 4 | 6.87 | 9.99 | 96 | 3 (3.1%) | 1 (1.0%) | 0 |
| DRY 5 | 9.99 | 11.62 | 19 | 0 | 1 (5.3%) | 0 |
| ***DRY 6*** | ***11.62*** | ***13.93*** | ***225*** | 0 | ***19 (4.7%)*** | 1 (0.9%) |
| DRY 7 | 13.93 | 17.07 | 429 | 3 (0.7%) | 11 (2.6%) | 4 (0.9%) |
| DRY 8 | 17.07 | 18.90 | 133 | 0 | 1 (0.8%) | 4 (3.0%) |
| ***DRY 9*** | ***18.90*** | ***21.81*** | ***64*** | 1 (0.7%) | 0 | ***2 (3.1%)*** |
| | | **Totals** | **1,468** | **36 (2.5%)** | **35 (2.3%)** | **11 (1.8%)** |

[1] Refers to GRTS reaches used for Coastal Monitoring Program monitoring in the Russian River watershed (Sonoma Water and CSG 2015).

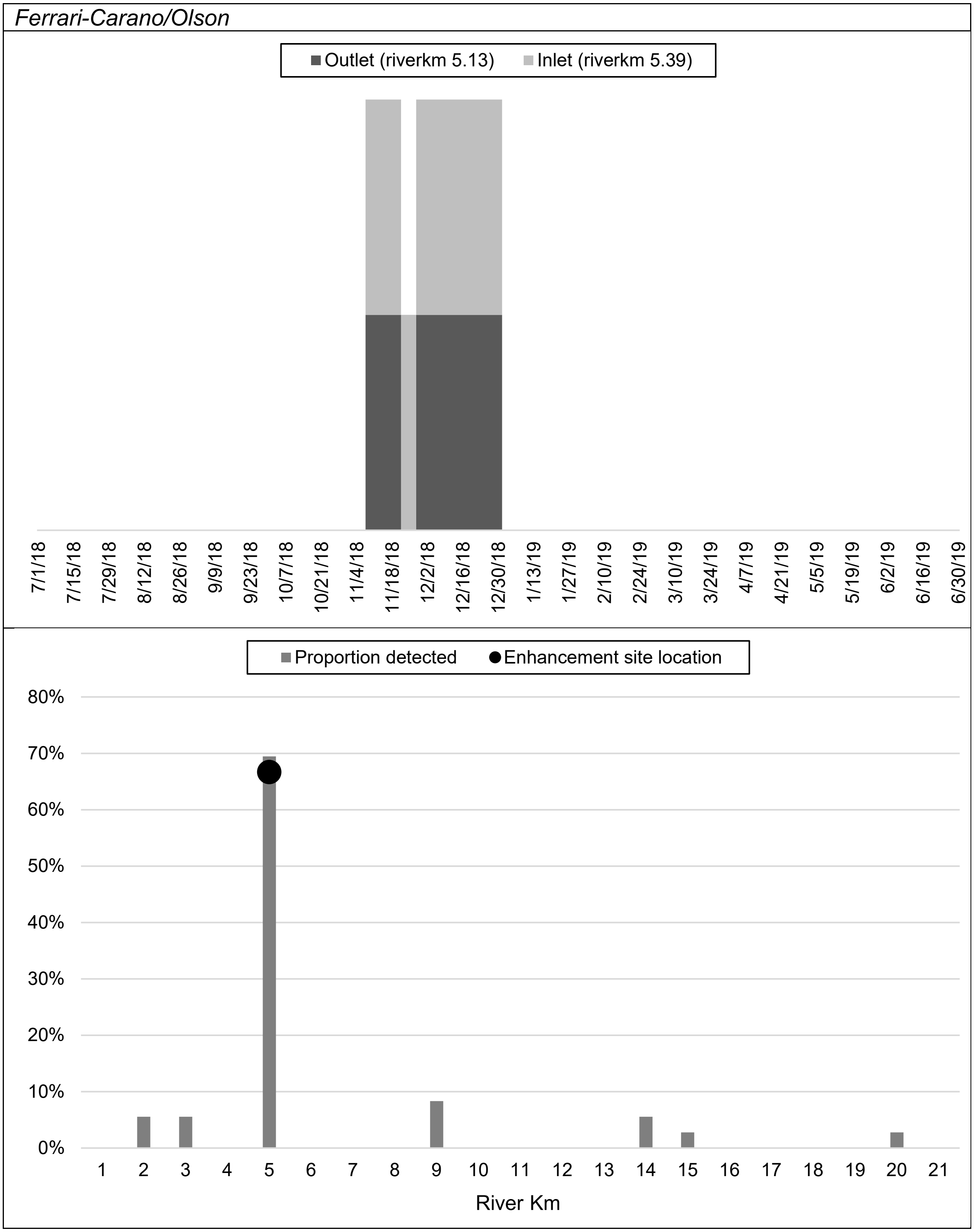


**Figure 5.3.6. Period of antenna operation (upper panel, gaps indicate antenna non-operation) and proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek that were later detected in Ferrari-Carano, Olson habitat enhancement.**

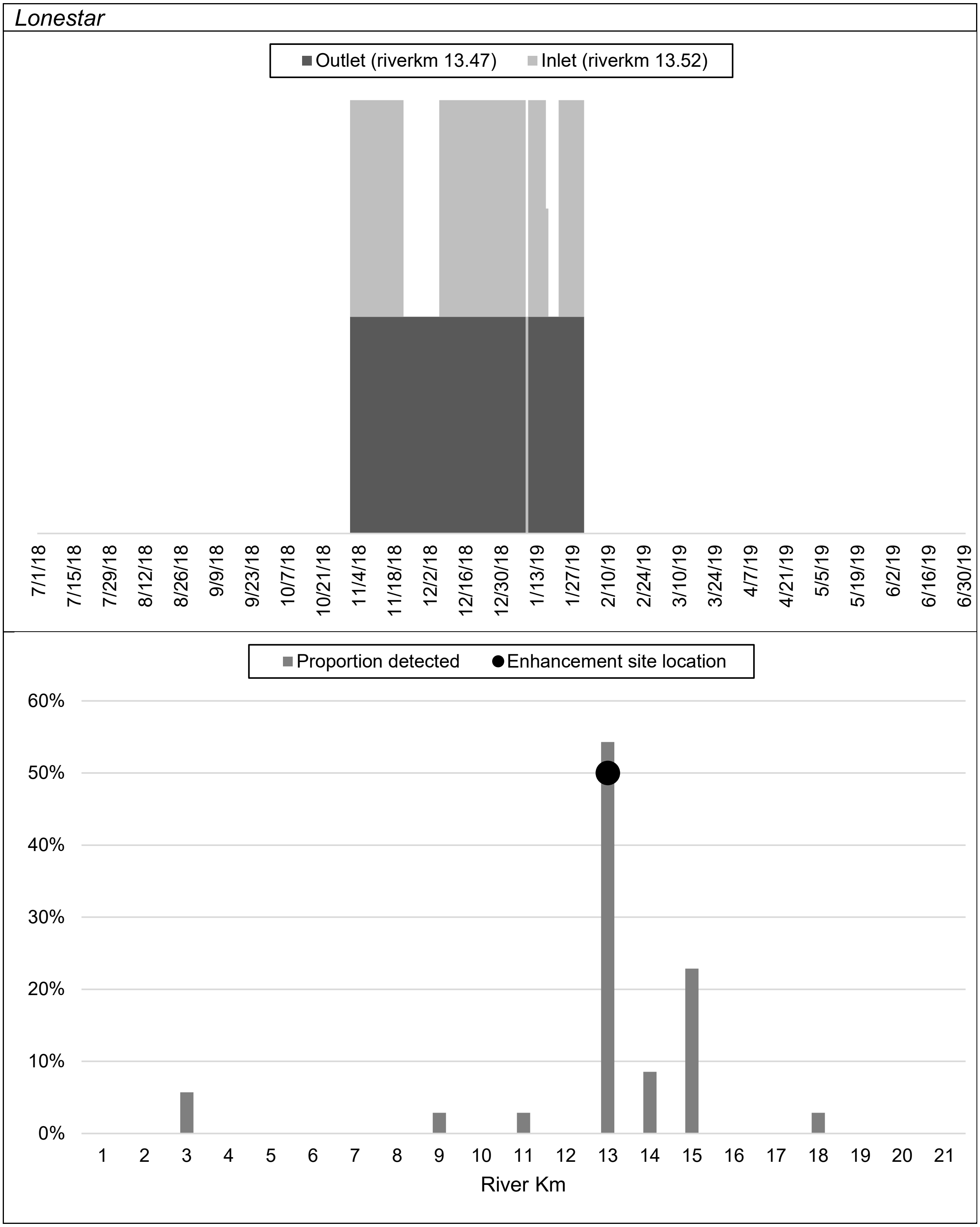


**Figure 5.3.7. Period of antenna operation (upper panel, gaps indicate antenna non-operation) and proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek that were later detected in Lonestar habitat enhancement.**

*Army Corps Reach 14*

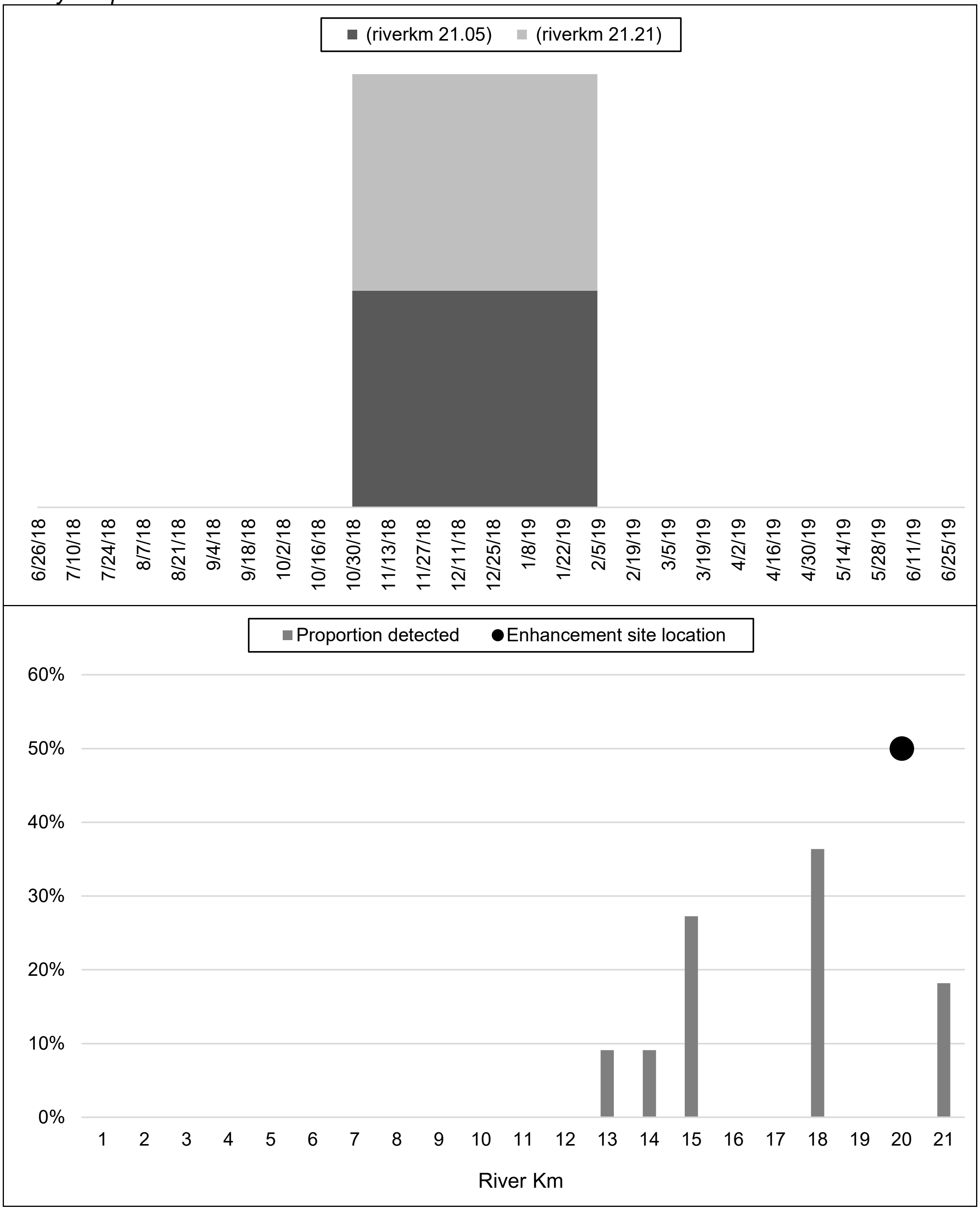


**Figure 5.3.8. Period of antenna operation (upper panel, gaps indicate antenna non-operation) and proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek that were later detected in Army Corps Reach 14 habitat enhancement.**

## Late summer population density

*Site-scale sampling*

Electrofishing surveys in constructed side channels were conducted between July 17 and 25, 2018. Geyser Peak and Truett Hurst side channels had greater density of steelhead juveniles compared to both the City of Healdsburg and Army Corps Reach 15 side channels (Table 5.3.4). While we did not encounter enough Coho Salmon in the side channels to generate a population estimate we did capture juvenile Coho in the City of Healdsburg, Truett Hurst and Army Corps Reach 15 side channels (Table 5.3.5).

**Table 5.3.4. Juvenile steelhead density estimates generated from mark recapture sampling in four constructed side channels in the summer of 2018.**

| Site | River km | Density estimate (fish*m$^{-2}$) | 95% CI |
|---|---|---|---|
| Geyser Peak | 2.49 | 0.37 | 0.68 |
| City of Healdsburg | 3.20 | 0.1 | 0.04 |
| Truett Hurst | 14.01 | 0.36 | 0.13 |
| Army Corps Reach 15 | 21.4 | 0.07 | 0.03 |

**Table 5.3.5. Total number of juvenile Coho Salmon captured during electrofishing surveys in four constructed side channels in the summer of 2018.**

| Site | Number of Coho Salmon |
|---|---|
| Geyser Peak | 0 |
| City of Healdsburg | 44 |
| Truett Hurst | 1 |
| Army Corps Reach 15 | 16 |

*Reach-scale sampling*

Electrofishing surveys in nine GRTS sub-reaches in the main channel of Dry Creek were conducted between August 13 and September 20, 2018. We were unable to generate a density estimate in one of the nine sub-reaches due to a very poor recapture rate between pass 1 and pass 2 sampling events. The sub-reach habitat was predominately slow and deep water, conditions that render electrofishing ineffective. The average density of juvenile steelhead in these sub-reaches was 0.1 fish*m$^{-2}$ (range 0.02 to 0.17 fish*m$^{-2}$, Figure 5.3.9). The average population density was greater in the enhanced sites compared to un-enhanced sites, and overall steelhead densities were slightly lower than those calculated for 2017 (Figure 5.3.10).

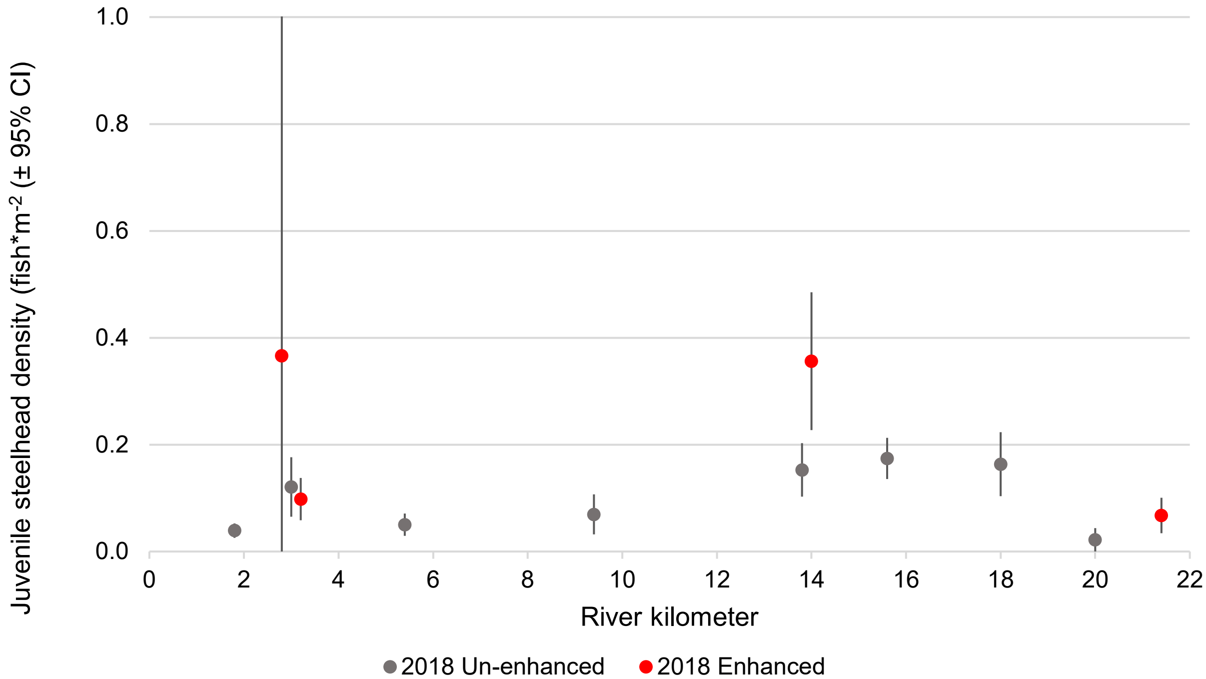


**Figure 5.3.9. Estimated density of juvenile steelhead in mainstem Dry Creek, in habitat-enhanced stream sections (site-scale monitoring) and un-enhanced stream sections (reach-scale monitoring). Estimates are based on the Petersen mark-recapture model.**

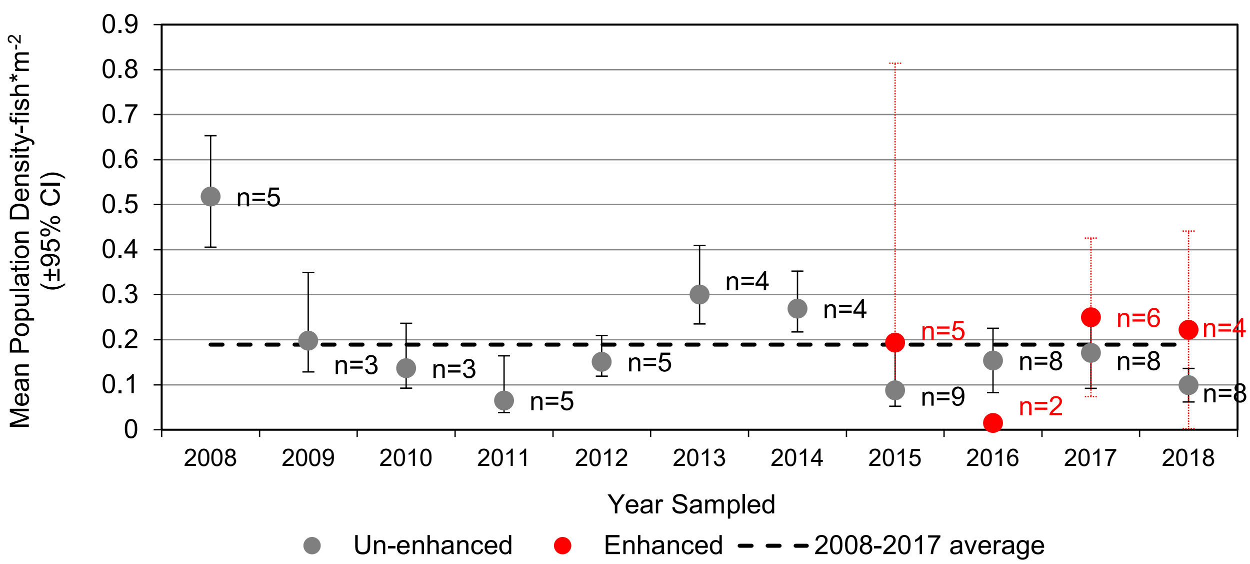


**Figure 5.3.10. Mean juvenile steelhead density among all sites sampled within a year in Dry Creek, 2008-2018. "n" refers to the number of sites sampled per year.**

## Smolt abundance

We installed the rotary screw trap on March 28 (Figure 5.3.11). Except for brief periods when trapping was suspended because of high debris loading in the trap from high winds, the trap was checked daily during operation until it was removed on July 31.

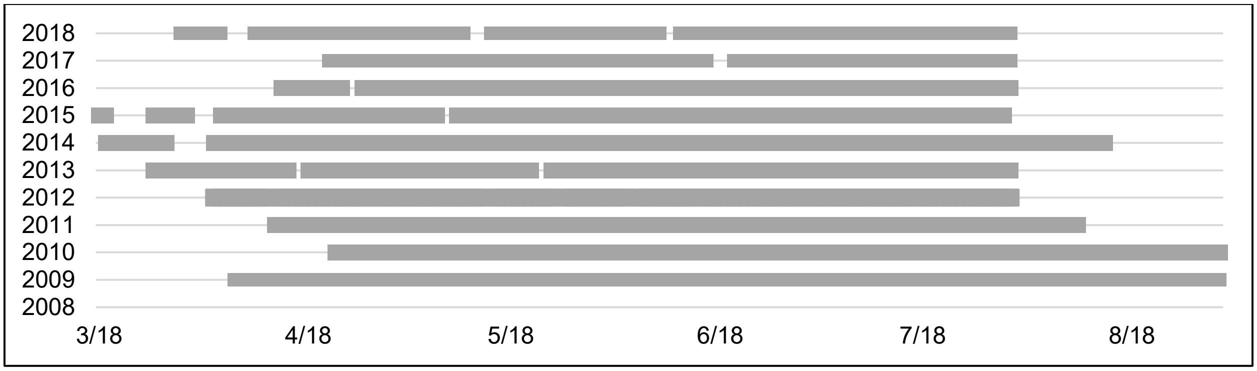

**Figure 5.3.11. Begin and end dates and data gaps (spaces in lines) for operation of the Dry Creek downstream migrant trap, 2009-2018.**

The peak capture of Chinook Salmon smolts (869) occurred during the week of 6/4 (Figure 5.3.12). Based on the estimated average weekly capture efficiency (range: 5% to 53%), the resulting population size of Chinook Salmon smolts passing the Dry Creek trap between March 26 and July 16 was 43,250 (±95% CI: 12,335, Figure 5.3.13). This is the third smallest population estimate since we began trapping Dry Creek in 2009.

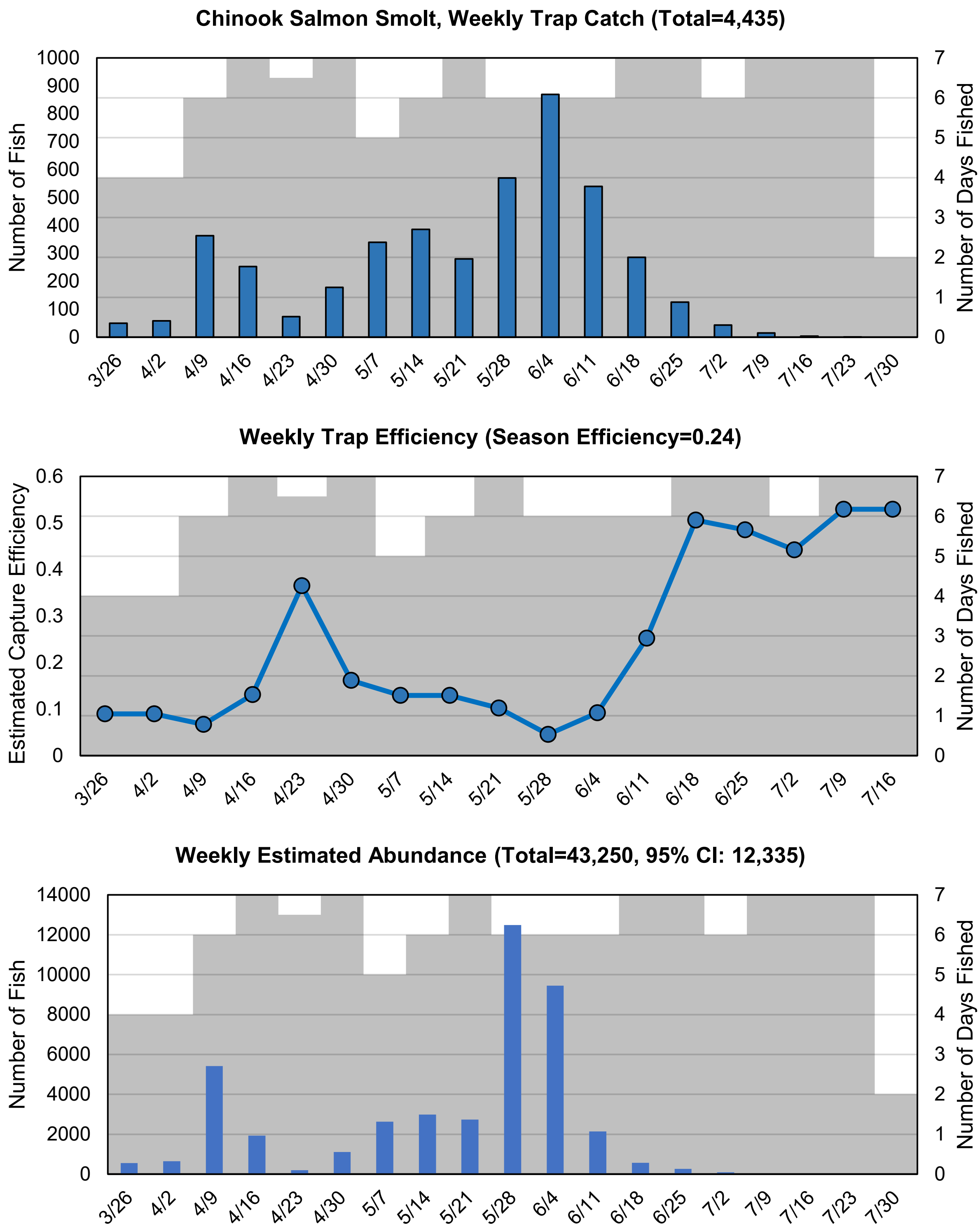


**Figure 5.3.12. Weekly trap catch (upper panel), estimated average weekly capture efficiency (middle panel) and population estimate of Chinook Salmon smolts in the Dry Creek rotary screw trap (lower panel), 2018. Estimates are from DARR (Bjorkstedt 2005). The number of days each week the trap was fished is represented by the shaded area.**

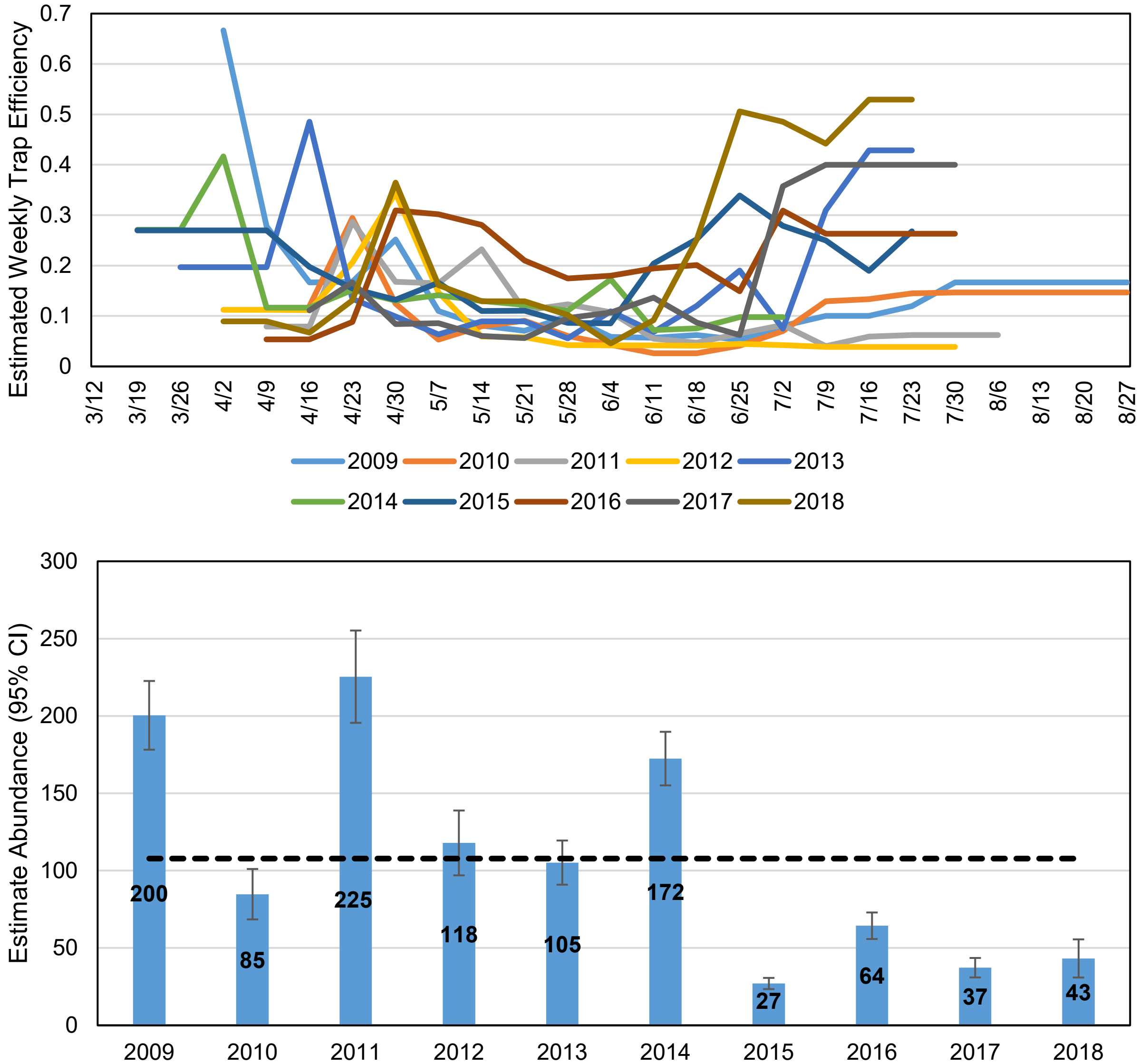


**Figure 5.3.13. Estimated average weekly capture efficiency (upper panel) and population estimate of Chinook Salmon smolts (x1000) produced from the Dry Creek watershed upstream of Westside Road smolt trap site (rkm=3.3) (lower panel), 2009-2018. Dashed line is the ten-year average abundance for all years combined.**

Coho Salmon were the least abundant of the three salmonid species captured. Hatchery smolts dominated the catch with a total of 83 individuals captured. Steelhead parr and smolt capture was highest in June and in May, respectively (Figure 5.3.14).

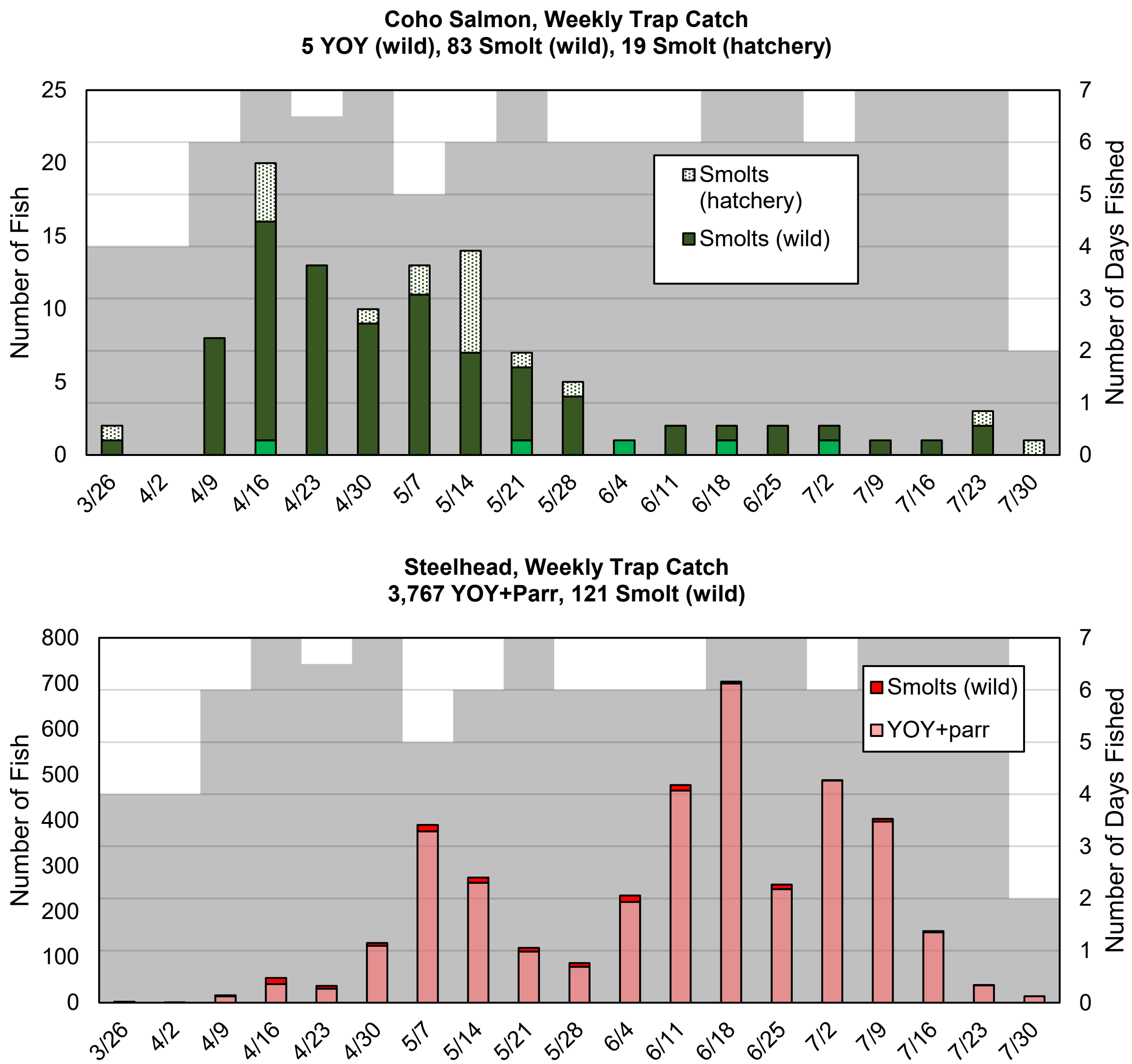


**Figure 5.3.14. Weekly trap catch of juvenile Coho Salmon and steelhead in the Dry Creek rotary screw trap, 2018.**

Coho Salmon smolt trap catch for the season was relatively low and similar to the catch in 2011, 2012 and 2015 (Figure 5.3.15). The capture of wild Coho smolts was still quite low at 83 individuals and is similar to previous year's totals. Steelhead smolt and parr captures (121 and 3,767) were also similar to totals from previous years.

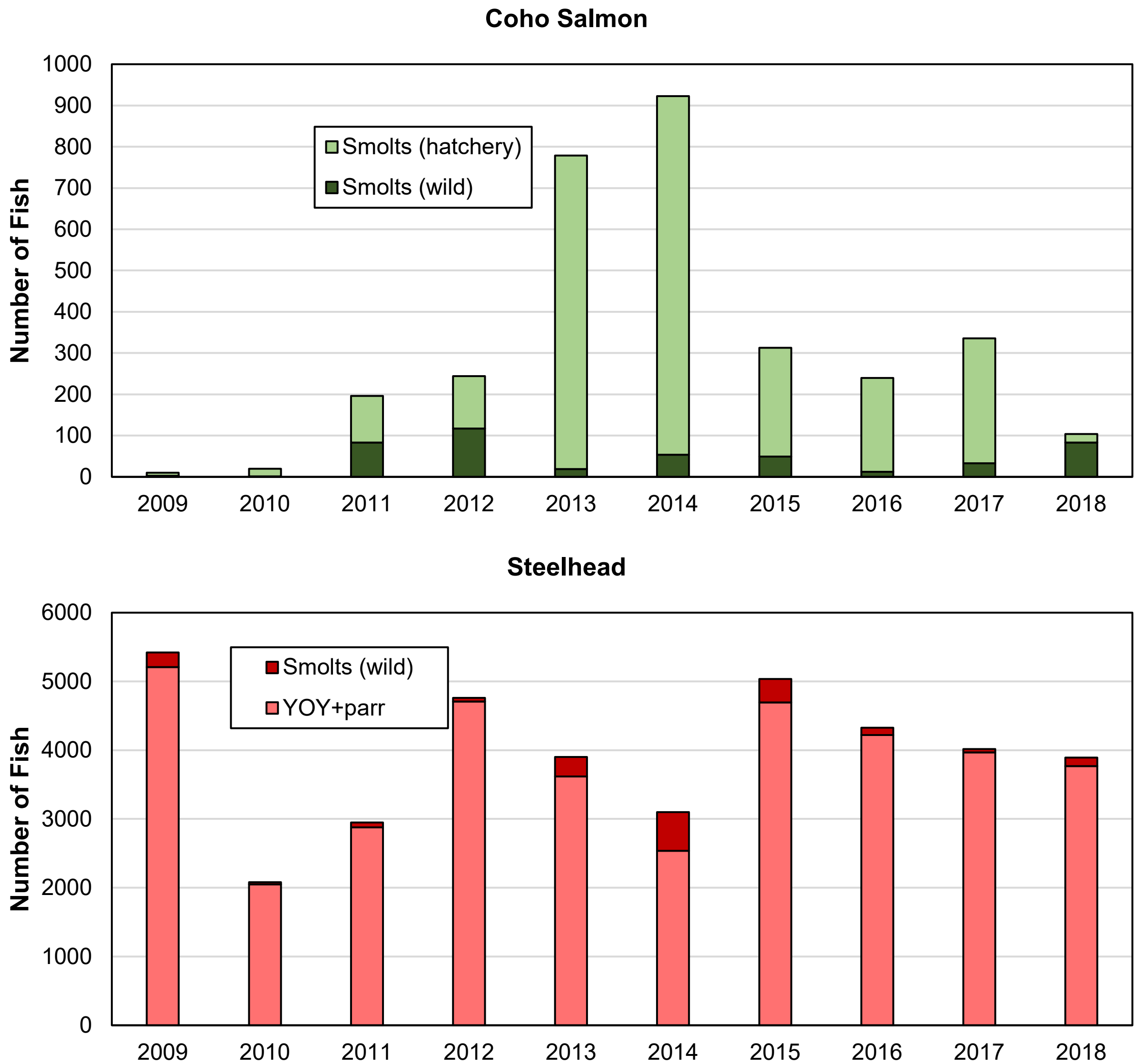


**Figure 5.3.15. Trends in trap catch for Coho Salmon smolts and steelhead smolts and parr, 2009-2018.**

Weekly sizes of all salmonids captured at the Dry Creek trap increased over the course of the trapping season in 2018 (Figure 5.3.16).

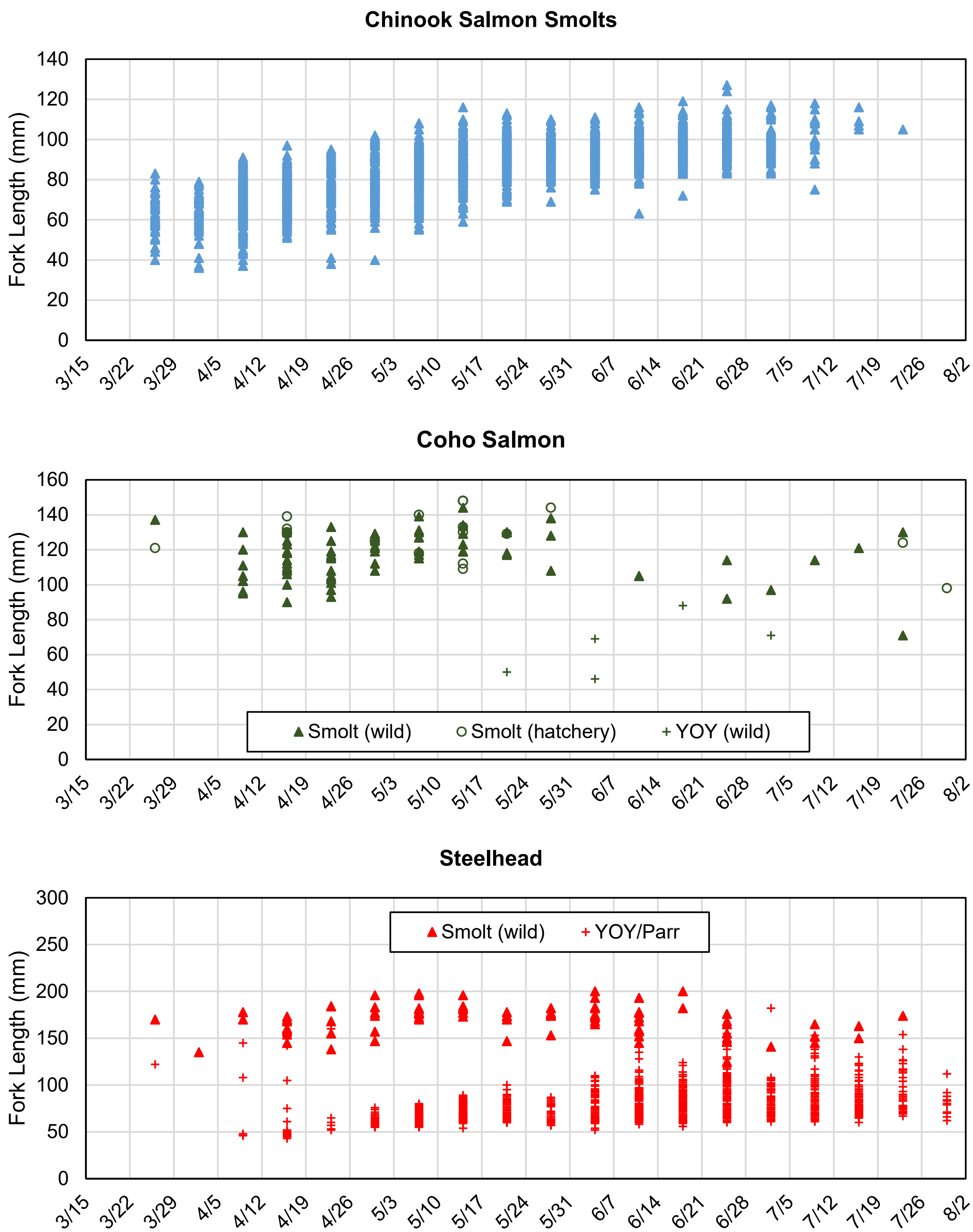


**Figure 5.3.16. Fork lengths of juvenile salmonids captured in the Dry Creek rotary screw trap by week, 2018.**

## Conclusions and Recommendations

Evaluating the biological impacts of habitat enhancement is inherently challenging given the external factors also influencing the survival and abundance of the species of interest. Using a combination of site, reach, and stream level metrics we attempt to place the results of validation monitoring within the context of the population throughout the basin.

Based on validation monitoring conducted in 2018, there is clear evidence that juvenile salmonids are utilizing habitat enhancements in Dry Creek during all seasons (Table 5.3.6). Through a combination of snorkel surveys, backpack electrofishing, and stationary PIT antennas we are able to show that all three species of salmonids (including juveniles, smolts and adults) will utilize enhanced areas just after construction and they will continue to use these habitats for multiple seasons. Additionally, all three species of salmonids were also found to utilize the enhanced off channel habitat during the winter.

While it is not possible to electrofish and therefore calculate a steelhead density estimate for all enhancement sites, in 2018 we were able to compare estimated densities at sites in four constructed side channels to estimated densities at eight main channel sites (i.e., un-enhanced habitat) spread throughout mainstem Dry Creek. Similar to our results in 2017, overall enhanced locations showed a greater density of steelhead compared to the main channel locations. While the City of Healdsburg and Army Corps Reach 15 sites had low steelhead densities, they were similar to or slightly higher as compared to adjacent main channel locations that were sampled. In the future we will consider alternate methods for evaluating summer habitat use by juvenile salmonids including seining, PIT tagging and stationary PIT antennas, and, perhaps, acoustic telemetry.

**Table 5.3.6. Outcomes from validation monitoring conducted in 2018 in Dry Creek habitat enhancements.**

| Metric | Life stage | Species | Habitat river km | Habitat name | Habitat type[1] | Method | Season | Outcome |
|---|---|---|---|---|---|---|---|---|
| habitat use | juvenile | Coho Salmon | 3.10 | City of Healdsburg | SC | snorkel | spr-fall | present |
| | | | | | | efish | sum/fall | present |
| | | | 4.92 | Ferrari-Carano, Olson | SC | PIT ant | fall-win | present |
| | | | 13.35 | Lonestar | SC | PIT ant | fall-win | present |
| | | | 14.02 | Truett Hurst | SC | efish | sum/fall | present |
| | | | 21.4 | Army Corps Reach 15 | SC | efish | sum/fall | present |
| | | steelhead | 2.70 | Geyser Peak | SC | snorkel | spr-fall | present |
| | | | 3.10 | City of Healdsburg | SC | snorkel | spr-fall | present |
| | | | 4.92 | Ferrari-Carano, Olson | SC | PIT ant | fall-win | present |
| | | | 9.97 | Wallace | BW | snorkel | spr-fall | present |
| | | | 13.35 | Carlson | SC | snorkel | spr-fall | present |
| | | | 13.35 | Lonestar | SC | snorkel | spr-fall | present |
| | | | | | | PIT ant | fall-win | present |
| | | | 13.82 | Meyer | SC | snorkel | spr-fall | present |
| | | | 14.02 | Truett Hurst | SC | snorkel | spr-fall | present |
| | | | 20.92 | Army Corps Reach 14 | SC | PIT ant | fall-win | present |
| | smolt | Coho Salmon | 4.92 | Ferrari-Carano, Olson | SC | PIT ant | fall-win | present |
| | | Chinook Salmon | 13.82 | Meyer | SC | snorkel | spr-fall | present |
| | | | 14.02 | Truett Hurst | SC | snorkel | spr-fall | present |
| | adult | Coho Salmon | 4.92 | Ferrari-Carano, Olson | SC | PIT ant | fall-win | present |
| | | | 13.35 | Lonestar | SC | PIT ant | fall-win | present |
| | | | 20.92 | Army Corps Reach 14 | SC | PIT ant | fall-win | present |
| | | steelhead | 2.70 | Geyser Peak | SC | snorkel | spr-fall | present |
| | | | 4.92 | Ferrari-Carano, Olson | SC | PIT ant | fall-win | present |
| | | | 13.35 | Lonestar | SC | PIT ant | fall-win | present |
| | | | 13.82 | Meyer | SC | snorkel | spr-fall | present |
| | | | 14.02 | Truett Hurst | SC | snorkel | spr-fall | present |
| | | | 20.92 | Army Corps Reach 14 | SC | PIT ant | fall-win | present |
| | | Chinook Salmon | 4.92 | Ferrari-Carano, Olson | SC | PIT ant | fall-win | present |
| | | | 20.92 | Army Corps Reach 14 | SC | PIT ant | fall-win | present |

| Metric | Life stage | Species | Habitat river km | Habitat name | Habitat type[1] | Method | Season | Outcome |
|---|---|---|---|---|---|---|---|---|
| density (fish * $m^{-2}$) | juvenile | steelhead | 2.70 | Geyser Peak | SC | efish | sum/fall | 0.37 +0.68 |
| | | | 3.10 | City of Healdsburg | SC | efish | sum/fall | 0.10 +0.04 |
| | | | 14.02 | Truett Hurst | SC | efish | sum/fall | 0.36 +0.13 |
| | | | 21.40 | Army Corps Reach 15 | SC | efish | sum/fall | 0.07 +0.03 |

[1]SC=side channel; BW=backwater; CR=constructed riffle

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# CHAPTER 6 Coho Salmon Broodstock Program Enhancement

NMFS' Russian River Biological Opinion compels the USACE to continue operation of a conservation hatchery to provide a source of genetically appropriate juvenile Coho Salmon to release into the Russian River watershed. The hatchery program is instrumental to Russian River Coho population recovery and Coho releases are widely recognized as the main reason the Russian River population was not extirpated. The Biological Opinion and Consistency Determination obligate Sonoma Water to provide hatchery support by increasing the production of Coho smolts. This support has primarily been in the form of funding for fish-rearing tanks, purchase of PIT tags, and technical staff to assist with hatchery operations including PIT-tagging of hatchery-reared juveniles. Sonoma Water has also contributed a significant amount of information through direct data collection, financial and staff support to partner entities, and consistent participation on the Russian River Coho Salmon Captive Broodstock Program (RRCSCBP) Technical Advisory Committee (TAC).

In addition to hatchery operations, USACE must also conduct annual monitoring of the distribution and survival of stocked juvenile salmon and the subsequent return of adult Coho to the Russian River. Much of the Coho monitoring in the Russian is implemented by CSG with base funding from USACE. However, Sonoma Water has and will continue to make significant contributions to the collection of monitoring data to allow evaluation of program success. These contributions include data collected at Sonoma Water operated fish monitoring sites (i.e., downstream migrant traps and stationary PIT antenna arrays) as well as assistance to CSG in conducting studies to identify population bottlenecks (e.g., low flow studies) and inform solutions to overcoming those bottlenecks (e.g., Russian River Coho Water Resources Partnership).

The technical aspects of Coho Salmon population recovery are complex, and it is often difficult to evaluate recovery strategies and program success in light of the host of factors operating at a variety of scales to shape Coho populations. The RRCSCBP TAC is a multi-partner effort involving USACE, CDFW, NMFS, CSG, and Sonoma Water. The TAC provides invaluable advice to ensure genetically sound broodstock management, and it develops annual plans for hatchery Coho releases with the primary objective of balancing survival of early life stages in the wild against the risk of artificial selection from releasing older life stages that are reared in the hatchery for a longer period of time. Many of the innovative monitoring methods spearheaded by CSG and Sonoma Water feedback to inform these plans while at the same time providing metrics of program success such as tributary-specific smolt production and numbers of adult returns (see CSG data reports 2004 through present) – both of which have been identified as key metrics in state and federal recovery plans.

A component that has been lacking until recently is a better understanding of the broader context in which salmonid demographic processes operate. In 2013, Sonoma Water and CSG began implementing CDFW's Coastal Monitoring Program (CMP, Adams et al. 1980). The broad-scale metrics from this coastwide effort have and will continue to inform Coho Salmon recovery in the Russian River watershed and elsewhere by helping to decouple those factors that are largely outside our control (e.g., marine survival) from in-watershed recovery efforts.

## References

Adams, P. B., L. B. Boydstun, S. P. Gallagher, M. K. Lacy, T. McDonald, and K. E. Shaffer. 2011. California coastal salmonid population monitoring strategy design and methods. CA Department of Fish and Game, Sacramento, CA.

California Sea Grant (CSG). 2004-present. UC Coho Salmon and Steelhead Monitoring Reports. https://caseagrant.ucsd.edu/project/coho-salmon-monitoring/reports.

# CHAPTER 7 Adult Salmonid Returns

## 7.1 Adult Salmonid Escapement

Since 2000, Sonoma Water has been operating video cameras in the east and west fish ladders to assess the adult Chinook salmon run passing the Mirabel inflatable dam located at river km 39 (rkm 39).

### Methods

A digital camera and lighting system was installed in the east and west Mirabel fish ladders. Individuals were counted as moving upstream once they exited the upstream end of the camera's view. For each adult salmonid observed, the reviewer recorded the species, date, and time of upstream passage. During periods of low visibility it was not always possible to identify fish to species although identification as an adult salmonid was usually possible. Adult salmonids that could not be identified to species were included in a general category called "unknown salmonid." Unknown salmonids were then partitioned into species by taking the proportion of each species positively identified in the ladder on a given day and multiplying the number of unknown salmonids on that same day by these proportions. On days when no salmonids could be identified to species, an average proportion from adjacent days was used to assign species for the unidentified salmonids on that day.

### Results

In 2018, the Mirabel fish ladder cameras were in operation from September 1 to December 14, 2018. With a few exceptions these cameras were operated 24 hours/day after installation until they were removed due to high winter flows.

#### Chinook Salmon

During the 2018 video monitoring season, 1,219 adult Chinook salmon were observed passing the Mirabel fish counting station (including "unknown salmonids" prorated as Chinook) (Table 7.1.1). A total of 64 fish were categorized as an "unknown salmonid" (i.e., they possessed the general body shape of an adult salmonid, but could not be identified to species). Of these 64 unknown salmonids 40 were partitioned to Chinook salmon.

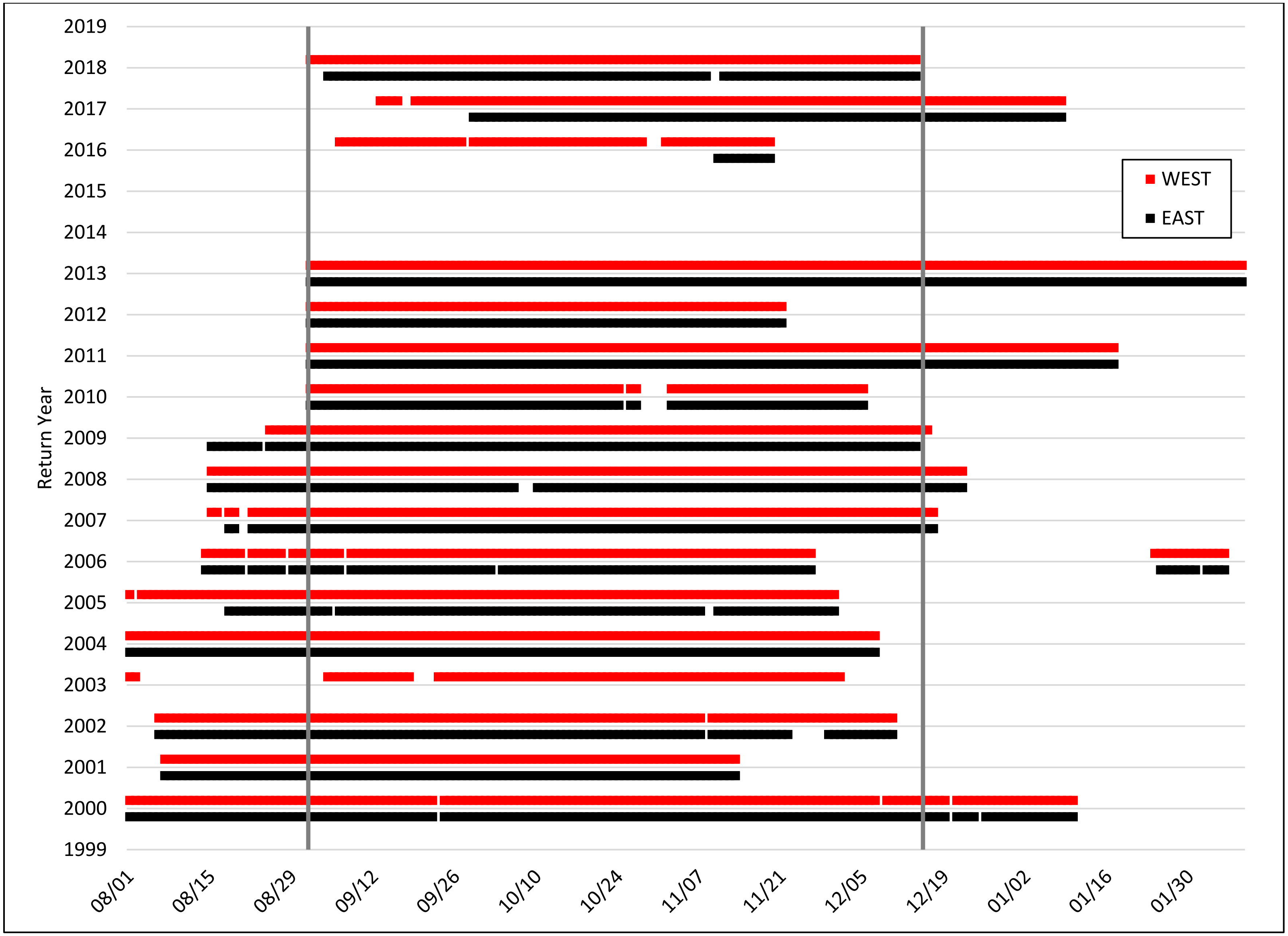


**Figure 7.1.1. Period of operation by adult salmonid return year of video counting station at the Mirabel dam from 2000 to 2018.**

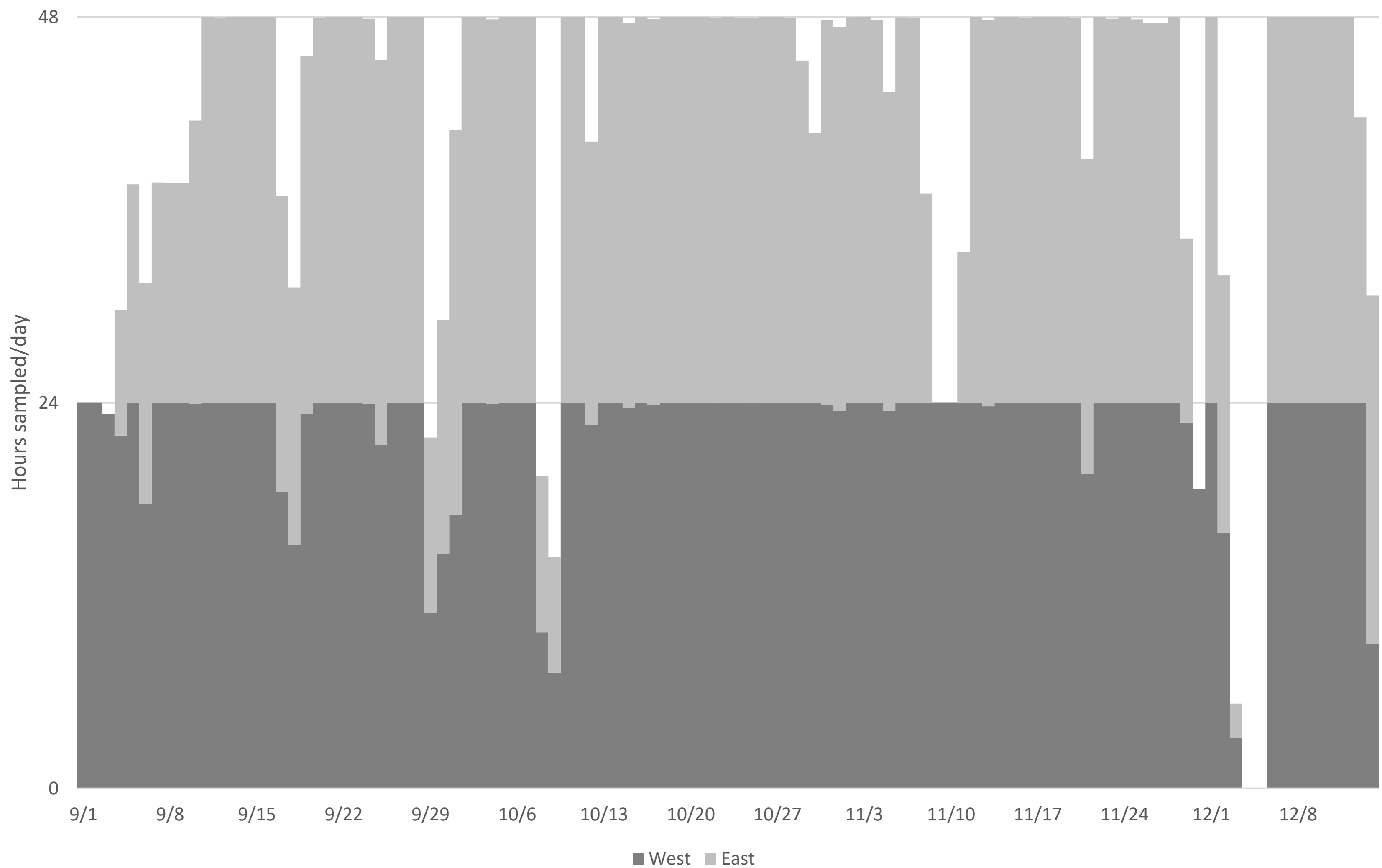


**Figure 7.1.2. Number of hours of video reviewed per day from the Mirabel dam in 2018. A maximum of 24 hours of video was collected in one day at west fish ladder and an additional maximum of 24 hours was collected at the east ladder for a total of 48 hours of video collected in a day.**

**Table 7.1.1. Weekly count of adult Chinook salmon at the Mirabel dam fish ladders, 2000-2018. Dashes indicate that no sampling occurred during that week.**

| Week | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006* | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014** | 2015** | 2016*** | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15-Aug | 0 | 0 | 1 | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | | | -- | -- | -- |
| 22-Aug | 1 | 0 | 8 | -- | 0 | 1 | 1 | 0 | 0 | 0 | -- | -- | -- | -- | | | -- | -- | -- |
| 29-Aug | 0 | 3 | 7 | 2 | 1 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | | | -- | -- | 2 |
| 5-Sep | 9 | 1 | 18 | 7 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | | | 0 | -- | 0 |
| 12-Sep | 36 | 7 | 19 | 20 | 3 | 14 | 3 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | | | 0 | 0 | 1 |
| 19-Sep | 25 | 12 | 65 | 23 | 8 | 14 | 4 | 1 | 17 | 0 | 3 | 1 | 0 | 1 | | | 0 | 3 | 4 |
| 26-Sep | 50 | 17 | 1223 | 181 | 16 | 31 | 8 | 4 | 84 | 0 | 1 | 158 | 70 | 17 | | | 8 | 2 | 37 |
| 3-Oct | 31 | 240 | 113 | 146 | 42 | 27 | 317 | 10 | 126 | 78 | 669 | 534 | 51 | 44 | | | 32 | 91 | 77 |
| 10-Oct | 115 | 51 | 628 | 515 | 52 | 112 | 87 | 39 | 82 | 562 | 896 | 390 | 551 | 4 | | | 291 | 50 | 47 |
| 17-Oct | 81 | 10 | 272 | 232 | 651 | 556 | 532 | 26 | 13 | 177 | 153 | 1070 | 1886 | 8 | | | 392 | 125 | 158 |
| 24-Oct | 465 | 300 | 153 | 532 | 2287 | 309 | 114 | 106 | 22 | 285 | 280 | 273 | 996 | 27 | | | 131 | 81 | 50 |
| 31-Oct | 64 | 661 | 505 | 2969 | 185 | 613 | 1531 | 250 | 511 | 135 | 94 | 223 | 1654 | 315 | Not Operated | Not Operated | 56 | 612 | 68 |
| 7-Nov | 23 | 81 | 2337 | 1289 | 1189 | 699 | 298 | 429 | 174 | 335 | 169 | 90 | 619 | 731 | | | 50 | 366 | 60 |
| 14-Nov | 182 | -- | 20 | 47 | 221 | 127 | 459 | 154 | 15 | 38 | 43 | 120 | 851 | 1063 | | | 103 | 508 | 145 |
| 21-Nov | 201 | -- | 37 | 95 | 57 | 63 | 53 | 96 | 24 | 129 | 113 | 266 | 50 | 179 | | | -- | 71 | 461 |
| 28-Nov | 110 | -- | 14 | 45 | 60 | 33 | -- | 425 | 19 | 24 | 76 | 6 | -- | 99 | | | -- | 82 | 66 |
| 5-Dec | 19 | -- | 53 | -- | 16 | -- | -- | 476 | 18 | 9 | 5 | 1 | -- | 172 | | | -- | 24 | 38 |
| 12-Dec | 15 | -- | -- | -- | -- | -- | -- | 4 | 8 | 28 | -- | 2 | -- | 125 | | | -- | 24 | 6 |
| 19-Dec | 17 | -- | -- | -- | -- | -- | -- | -- | 13 | -- | -- | 10 | -- | 73 | | | -- | 16 | -- |
| 26-Dec | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 16 | -- | 32 | | | -- | 27 | -- |
| 2-Jan | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 53 | | | -- | 11 | -- |
| 9-Jan | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10 | -- | 58 | | | -- | -- | -- |
| 16-Jan | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | 28 | | | -- | -- | -- |
| 23-Jan | -- | -- | -- | -- | -- | -- | 0 | -- | -- | -- | -- | -- | -- | 73 | | | -- | -- | -- |
| 30-Jan | -- | -- | -- | -- | -- | -- | 0 | -- | -- | -- | -- | -- | -- | 36 | | | -- | -- | -- |
| 6-Feb | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10 | | | -- | -- | -- |
| **Total** | **1,445** | **1,383** | **5,474** | **6,103** | **4,788** | **2,607** | **3,407** | **2,021** | **1,129** | **1,800** | **2,502** | **3,173** | **6,730** | **3,152** | **--** | **--** | **1,062** | **2,093** | **1,219** |

*Video cameras were reinstalled and operated from 4/1-6/27/2007, but Chinook salmon were not observed.

**Video cameras were not operated in 2014 and 2015 because the site was under construction in order to construct the new fish screens and ladder.

***Typically 1 camera is operated in both fish ladders but in 2016 a video camera was only operated in the east ladder for the final 10 days of the season.

### Coho Salmon

During the monitoring period for the 2018 return year, 71 adult coho salmon were observed. These images were reviewed by fisheries biologist from Sonoma Water and California Sea Grant (CSG). Because of the timing of camera operations, which are tied to dam operations, and the location of these monitoring sites upstream of significant amounts of coho habitat in the basin, these counts are not the best indicator of adult coho returns to the basin. Instead, we suggest the basinwide spawner survey estimate of 127 (95% CI: 81-173) as the most comprehensive and accurate indicator of all adult coho (hatchery- and natural-origin) returning to the Russian River basin in 2018-19. This estimate is based on spawner surveys in the coho stratum of the Russian River Coastal Monitoring Program sample frame (see Adams et al. 2011 for details).

### Steelhead

Based on hatchery returns, steelhead migrate and spawn in the Russian River primarily between December and March; however, the Mirabel cameras were removed in December and a significant portion of the steelhead run occurs after December. In total, 189 adult steelhead were observed migrating through the Mirabel Fish ladders between September 4 and December 14, 2018.

## Conclusions and Recommendations

In 2018, Sonoma Water was able to successfully operate video cameras in both fish ladders for the duration of the Chinook migration, but this was not without some difficulty. In 2016, Sonoma Water determined that it is unsafe to supply 120 volt power to the east side video camera and lights by routing the cable underwater along the river bottom. There are few alternative ways to supply power to the east side of the river. In 2018, Sonoma Water staff relied on deep cycle batteries to supply power to the lights on the east side of the river. This required frequent battery changes. In addition to the difficulties supplying power to the east side Chinook salmon continued to spend an unusually long time in front of the west video camera in 2018. Frequently there were many Chinook milling in front of the camera. These fish would move upstream out of view of the camera and then drop back downstream out of the view of the camera. When many fish were exhibiting this behavior at the same time double counting became a possibility. The reviewers had to watch the video at a slower speed, which made the review process more laborious. Even with these limitations, the Mirabel video system continues to provide useful data on the Russian River Chinook run and Sonoma Water recommends continuing to operate the camera system in future years.

# 7.2 Chinook Salmon Spawning Ground Surveys

Although not an explicit requirement of the Biological Opinion, the Sonoma Water performs spawning ground surveys for Chinook salmon in the mainstem Russian River and Dry Creek. This effort compliments the required video monitoring of adult fish migration and has been stipulated in temporary D1610 flow change orders issued by the State Water Resources Control Board to satisfy the Biological Opinion.  The Sonoma Water began conducting Chinook salmon spawning surveys in fall 2002 to address concerns that reduced water supply releases from Coyote Valley Dam (Lake Mendocino) may affect migrating and spawning Chinook salmon (Cook 2003). Spawner surveys in Dry Creek began in 2003. In recent years, spawning surveys have been curtailed or cancelled due to poor water turbidity and weather conditions.

Background information on the natural history of Chinook salmon in the Russian River is presented in the 2011 Russian River Biological Opinion annual report (SCWA 2011). The primary objectives of the spawning ground surveys are to (1) characterize the distribution and relative abundance of Chinook salmon spawning sites, and (2) compare annual results with findings from previous study years.

## Methods

Chinook salmon redd (spawning nest) surveys are conducted annually in the upper Russian River and Dry Creek during fall (Figure 7.2.1). The study area includes approximately 114 km of the Russian River mainstem from Riverfront Park (40 rkm), located south of Healdsburg, upstream to the confluences of the East and West Forks of the Russian River (154 rkm) near Ukiah. The study area along the Dry Creek consists of 22 rkm of stream between Warm Springs Dam at Lake Sonoma to the Russian River confluence. River kilometer (rkm) is the meandering stream distance from the Pacific Ocean upstream along the Russian River mainstem and for Dry Creek the distance from the confluence with the Russian River upstream.

The Chinook salmon spawning ground study consists of a single-pass survey during the estimated peak of Chinook salmon fall spawning. A crew of two biologists in kayaks visually search for redds along the streambed. Riffles with several redds are inspected on foot. The locations of redds are recorded using a global positioning system (GPS).

Surveys may be cancelled or postponed if increased turbidity from heavy rainfall and subsequent high flows obscures the detection of redds. During high flows surveys are often possible in Dry Creek due to regulated, clear water releases from Lake Sonoma. Also, increases in turbid water releases from Coyote Dam at Lake Mendocino since around 2011 have prevented an accurate count of redds in the Ukiah and Canyon study reaches.

The Russian River in Alexander Valley reach was surveyed on December 6 and 12, 2018 (Figure 7.2.1). Chinook salmon spawner surveys were curtailed during fall 2018 due to high turbidity in the Ukiah, Canyon, Upper Healdsburg and Lower Healdsburg reaches. To follow salmon spawning and determine peak activity in Dry Creek five semi-monthly surveys were conducted from October 25, 2018 to February 28, 2018.

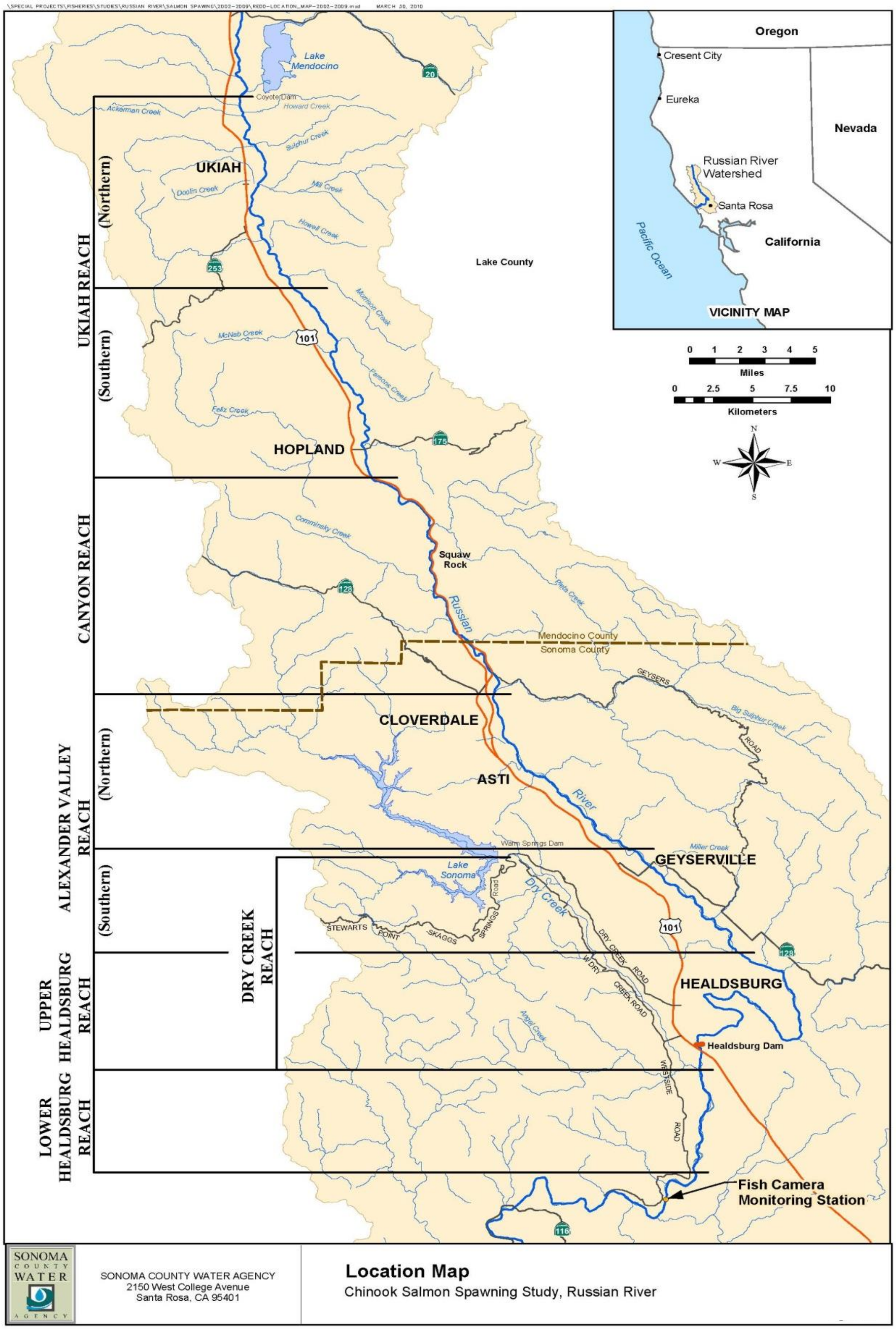


**Figure 7.2.1. Chinook salmon spawning survey reaches along the Russian River and Dry Creek.**

## Results

Most of the Chinook salmon spawning typically occurs in the upper Russian River mainstem and Dry Creek (Table 7.2.1). During 2018, there were 25 redds observed in the Alexander Valley reach. This is the lowest observation of redds in Alexander Valley since surveys began in 2002 and follows a continuous decline in redd abundance since 2015. No other Russian River mainstem reaches were sampled due to poor survey conditions (see Methods). During five surveys of Dry Creek 86 Chinook salmon redds were detected on two separate surveys on November 21 and December 5, 2018. This single pass number is the third lowest since 2003. The highest count of redds in Dry Creek was in 2012 at 362 redds.

## Conclusions and Recommendations

Although Chinook salmon surveys were restricted to two reaches in 2018 the distribution and abundance of redds appear to be similar to or within the range of other redd numbers observed during previous study years.  The abundance of fall-run Chinook salmon redds have shown a sharp decline for several years. Although there are many factors that could be driving this downward trend, it is likely that several years of severe drought, interspersed with intensive flooding that could scour redds, may be major contributors.

**Table 7.2.1. Chinook salmon redd abundances by reach, upper Russian River and Dry Creek, 2002-2018. Redd counts are from a single pass survey conducted during the peak of fall spawning activity. *Survey either not completed or incomplete. No surveys conducted in 2005 and 2014.**

| | **Reach** | **Redd Observations (years)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach** | **(rkm)** | **02** | **03** | **04** | **06** | **07** | **08** | **09** | **10** | **11** | **12** | **13** | **15** | **16** | **17** | **18** |
| Ukiah | 33.1 | 511 | 464 | 284 | 248 | 118 | 20 | 38 | * | * | 90[2] | 81 | * | * | * | * |
| Canyon | 20.8 | 277 | 190 | 169 | 68 | 88 | 36 | 38 | * | * | * | 43 | * | 16[2] | * | * |
| Alexander Valley | 26.2 | 163 | 213 | 90 | 62 | 131 | 65 | 129 | * | 97 | 185 | 163 | 61[2] | 41[2] | 39 | 25 |
| Upper Healdsburg | 25.6 | 79 | 40 | 8 | 23 | 67 | 48 | 38 | * | 66 | 53 | 57 | * | 1[2] | 14 | * |
| Lower Healdsburg | 8.2 | 6 | 0 | 7 | 1 | 2 | 9 | 30 | * | 7 | 4 | 18 | * | * | 6 | * |
| **Russian River Total** | **113.9** | **1036** | **907** | **558** | **402** | **406** | **178** | **273** | * | **170** | **332** | **362** | * | * | * | * |
| Dry Creek | 21.7 | * | 256 | 342 | 201 | 228 | 65[1] | 223 | 269 | 229 | 362 | 325 | 78 | 90 | 112 | 86 |
| **Total** | **135.6** | * | **1163** | **900** | **603** | **637** | **243** | **496** | * | * | * | * | * | * | | * |
| **Relative Contribution of Redds** | | | | | | | | | | | | | | | | |
| Russian River (%) | 84.0 | * | 78.0 | 62.0 | 66.7 | 63.7 | 73.3 | 55.0 | * | * | * | 52.7 | * | * | * | * |
| Dry Creek (%) | 16.0 | * | 22.0 | 38.0 | 33.3 | 36.3 | 26.7 | 45.0 | * | * | * | 47.3 | * | * | * | * |

[1]Redd numbers are an estimate.

[2]Redd numbers are presumably an underestimate due to poor survey conditions.

## References

Cook, D. (Sonoma County Water Agency). 2003. Chinook salmon spawning study, Russian River, fall 2002. Santa Rosa, (CA): Sonoma County Water Agency.

Sonoma County Water Agency (SCWA). 2011. Russian River biological opinion status and data report 2009-10. February 28. Santa Rosa (CA): Sonoma County Water Agency.

# Chapter 8 Synthesis

## Introduction

Sonoma Water has collected a variety of fish and water quality monitoring data relevant to fulfilling the overall monitoring objectives in the Reasonable and Prudent Alternative (RPA) of the Russian River Biological Opinion. Those efforts have been detailed in portions of this report leading to this chapter. The objectives specific to this synthesis chapter are to illustrate the spatial and temporal extent of monitoring activities in the basin.

As in previous years of RPA implementation, we collected fish and related environmental data from a broad spatial and temporal extent in the Russian River Basin (Figure 8.1 and Figure 8.2). We collected juvenile and smolt data from multiple locations in Dry Creek, Mark West Creek, Dutch Bill Creek, Austin Creek and the Russian River estuary. We counted adult salmonids with a DIDSON at the mouth of mainstem Dry Creek and opportunistically conducted Chinook spawner surveys on the 22 km of stream length in mainstem Dry Creek downstream of Warm Springs Dam and in portions of mainstem Russian River. Juvenile salmonids were sampled throughout the watershed using a variety of techniques. In the mainstem Russian, juvenile salmonids were sampled using beach seining at 10 fixed locations in the estuary and passive integrated transponder (PIT) antenna arrays operated near the upstream extent of the tidal portion of the estuary in Duncans Mills and at Sonoma Water's Mirabel inflatable dam. Downstream migrant trapping for smolts and juveniles and video monitoring of upstream migrating adults also occurred at the Mirabel dam. In tributaries of the lower river, juvenile salmonids were sampled using downstream migrant traps on Mark West Creek at Trenton-Healdsburg Road, Austin Creek at the gravel mine and Dutch Bill Creek in Monte Rio. PIT antennas were operated in conjunction with downstream migrant trap sites on Austin Creek and Dutch Bill Creek. In Dry Creek, juvenile salmonids were sampled using a downstream migrant trap and backpack electrofishing. PIT antennas were operated in at the mouth of mainstem Dry Creek and constructed off-channel habitat sites in Dry Creek. Complementary data on water quality were collected by means of continuously-recording data sondes at multiple sites in the mainstem Russian and throughout the estuary/lagoon. Water quality grab samples including algae samples were collected at additional sites in mainstem Russian River. Details regarding the specifics of water quality and fisheries monitoring activities are covered in individual chapters of this report.

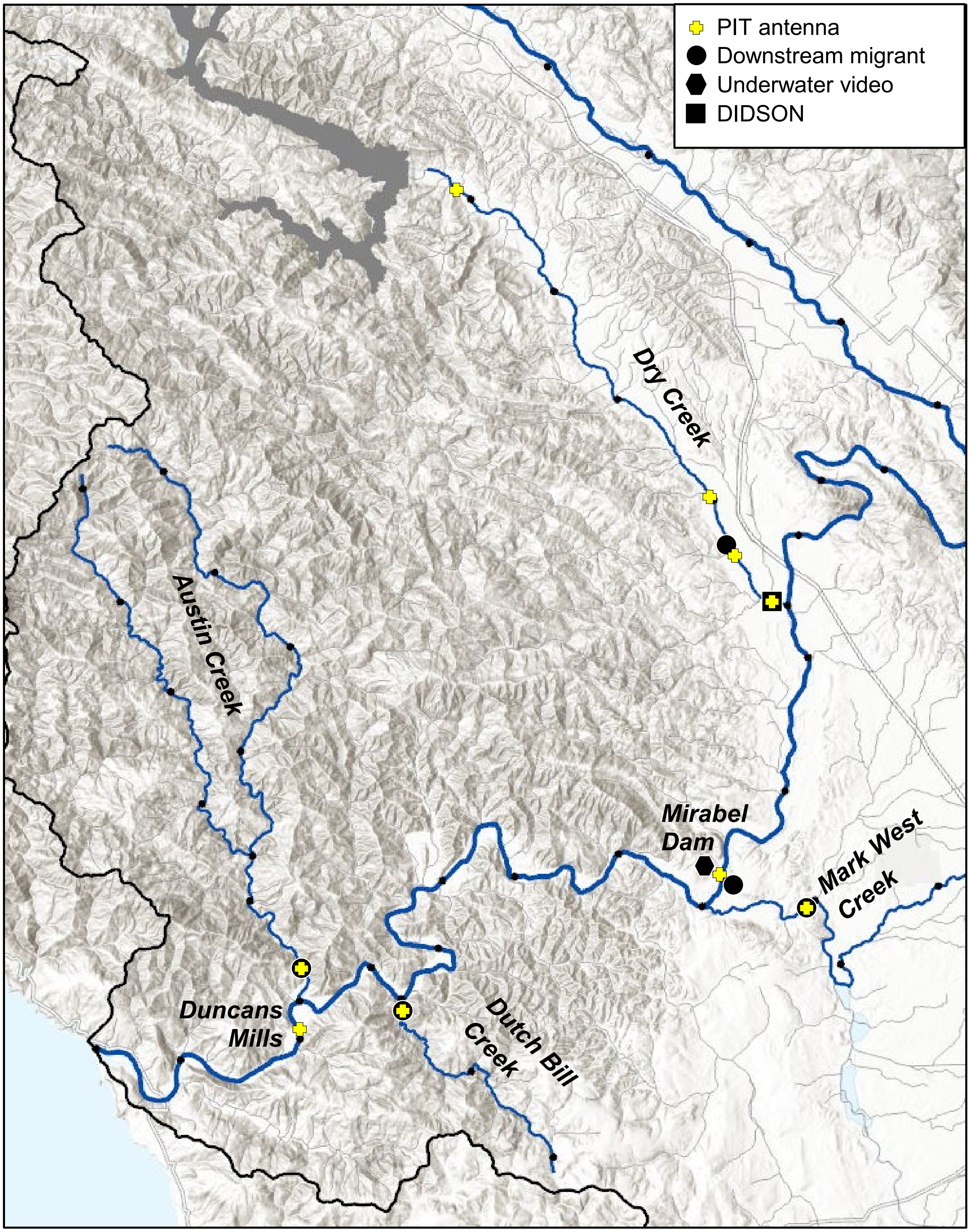


**Figure 8.1. Spatial extent of fisheries monitoring related to the Russian River Biological Opinion, 2018.**

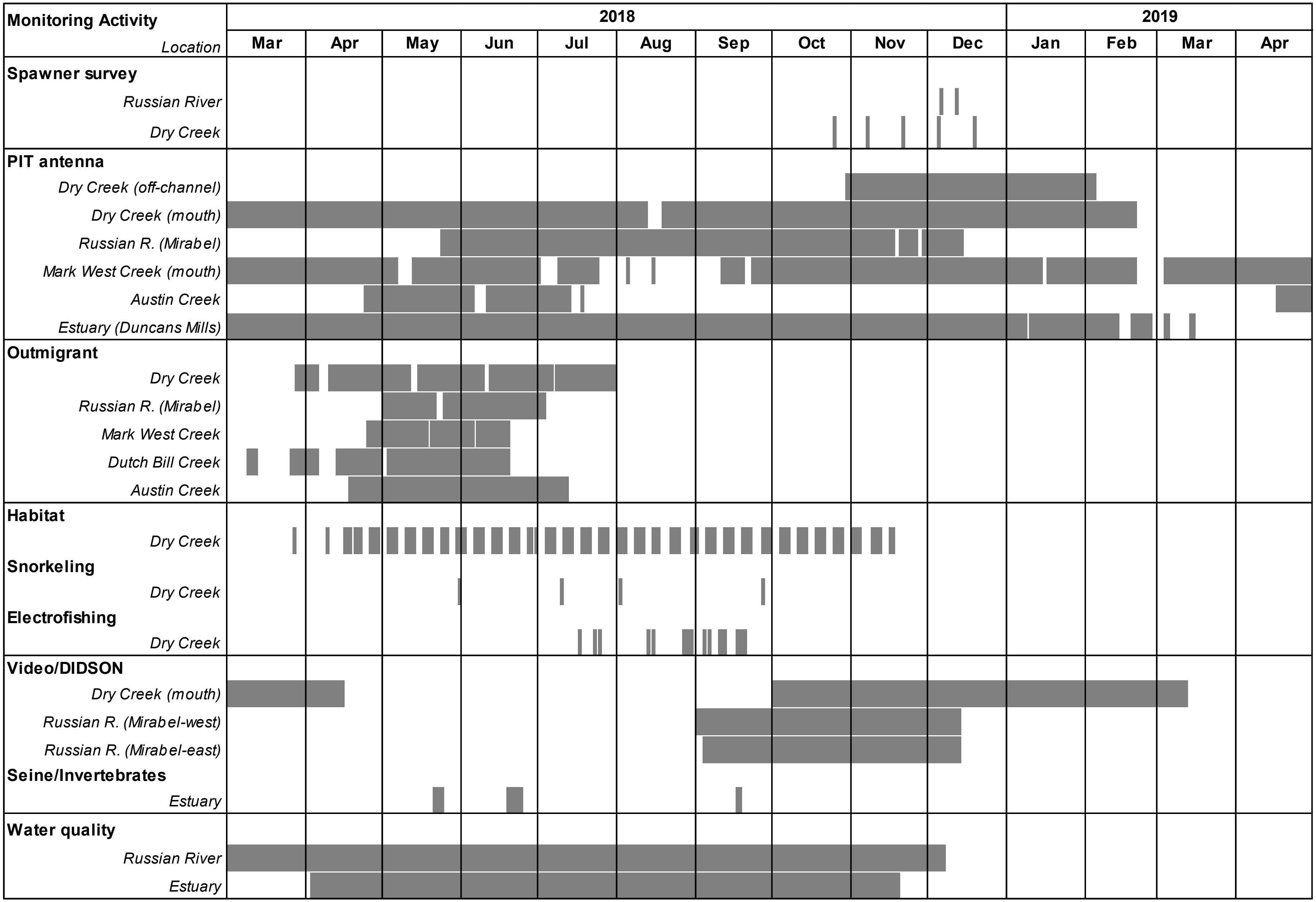


**Figure 8.2.** Temporal extent of fish and water quality monitoring related to the Russian River Biological Opinion, spring 2018-winter 2019.

In the sections that follow, we summarize indicators of juvenile and smolt salmonids based on data from tributary and mainstem sites sampled in 2018 into early 2019. Sonoma Water used PIT tags and fin-clipping as primary tools for characterizing fish population abundance. As described in other sections of this report and reports from prior years, PIT-tagged fish were detected during beach seining sampling in the estuary, at downstream migrant traps, and stationary PIT-tag antennas located throughout the system (Figure 8.1).

# Abundance

Combined juvenile steelhead downstream migrant trap (DSMT) catch at Dry Creek, Dutch Bill Creek and Austin Creek displayed a slight increase over 2017 mostly due to an increase at Austin Creek (Figure 8.3). Juvenile steelhead density from backpack electrofishing on mainstem Dry Creek showed a slight decrease relative to recent years (Figure 8.4) and the Dry Creek Chinook smolt estimate in Dry Creek was again low compared to 2010-2014 but similar to estimates from 2015 through 2017 (Figure 8.4). Chinook smolt estimates were once again possible at Mirabel due to better trap operation conditions than in recent years – the 2018 Chinook smolt estimate was nearly identical to Dry Creek. Captures of wild Coho smolts were low everywhere as has been the case since we began monitoring (Figure 8.4). Relative to previous years, adult steelhead returns to Russian River hatcheries were higher than in recent years (Figure 8.5) while the adult Chinook run was disappointingly low. The 2018-19 adult Coho estimate was not quite as high as 2017-18 but the overall trend is encouraging.

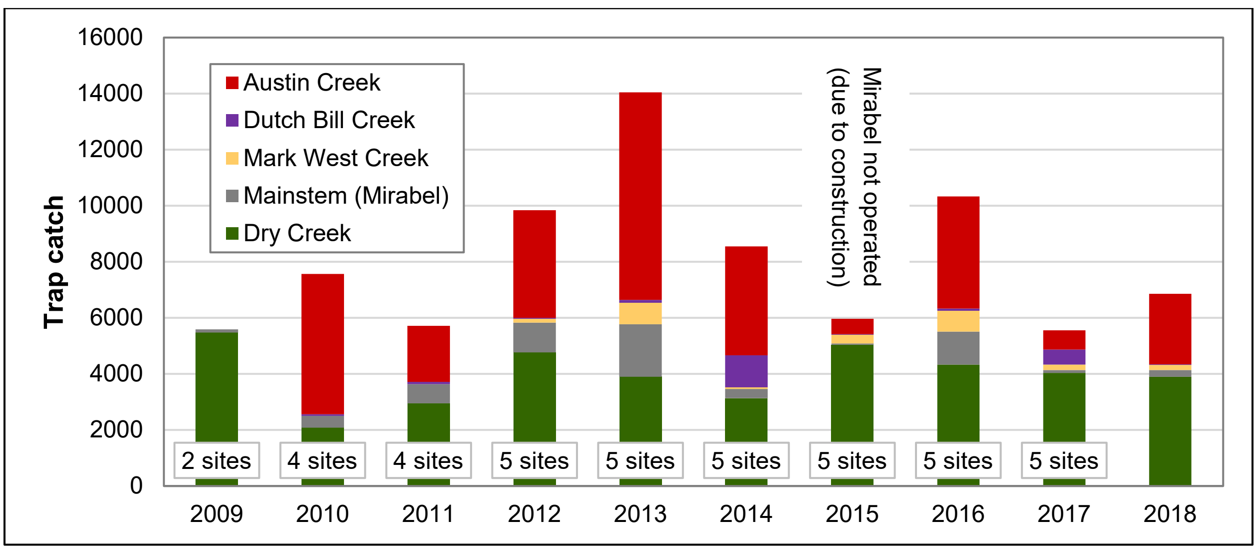


**Figure 8.3. Number of juvenile (YOY and smolt combined) steelhead captured at downstream migrant traps operated by Sonoma Water, 2009-2018.**

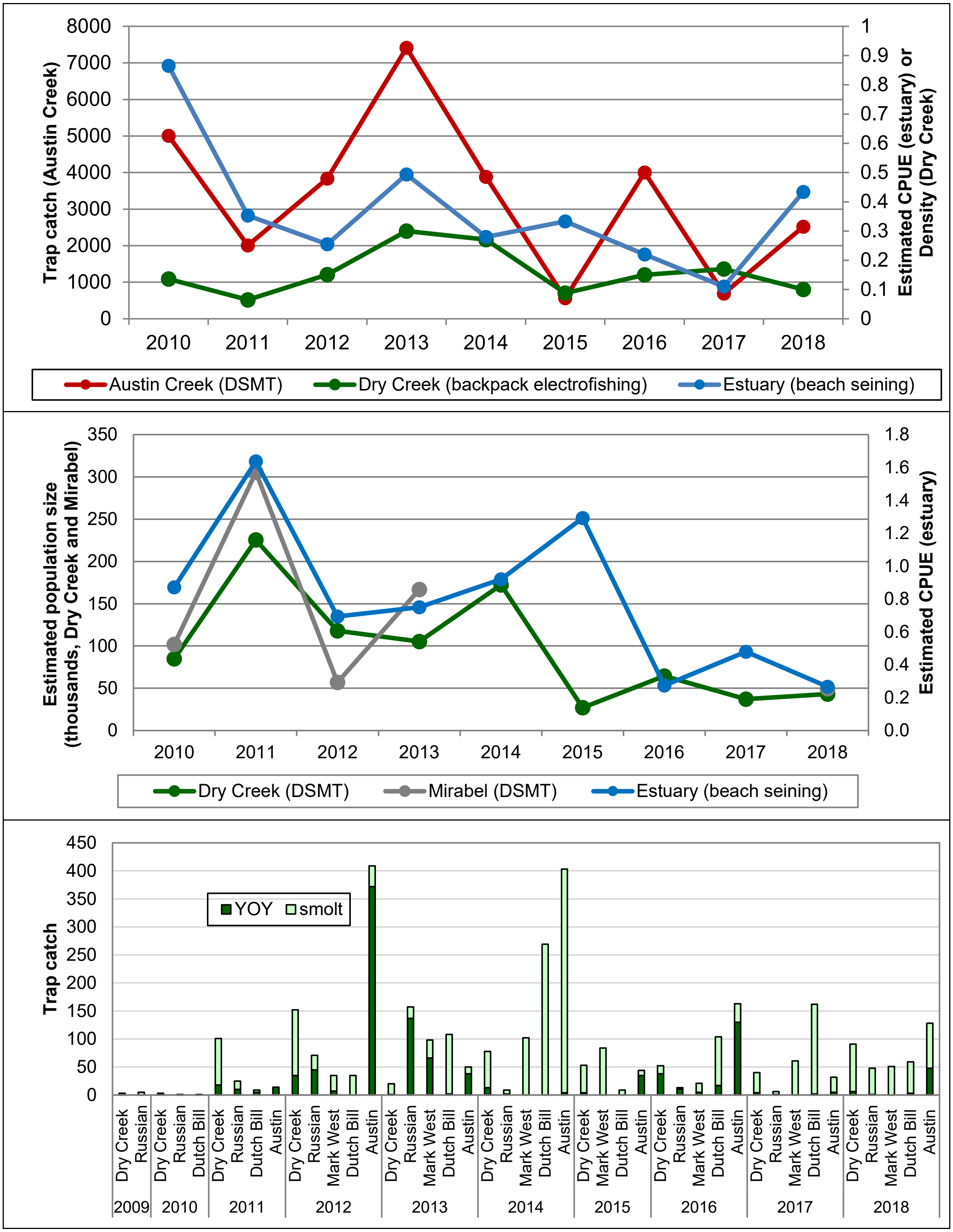


**Figure 8.4. Indicators of trends in juvenile steelhead (top panel), Chinook smolts (middle panel) and wild Coho smolt/YOY (lower panel) based on monitoring conducted by the Sonoma Water, 2009-2018.**

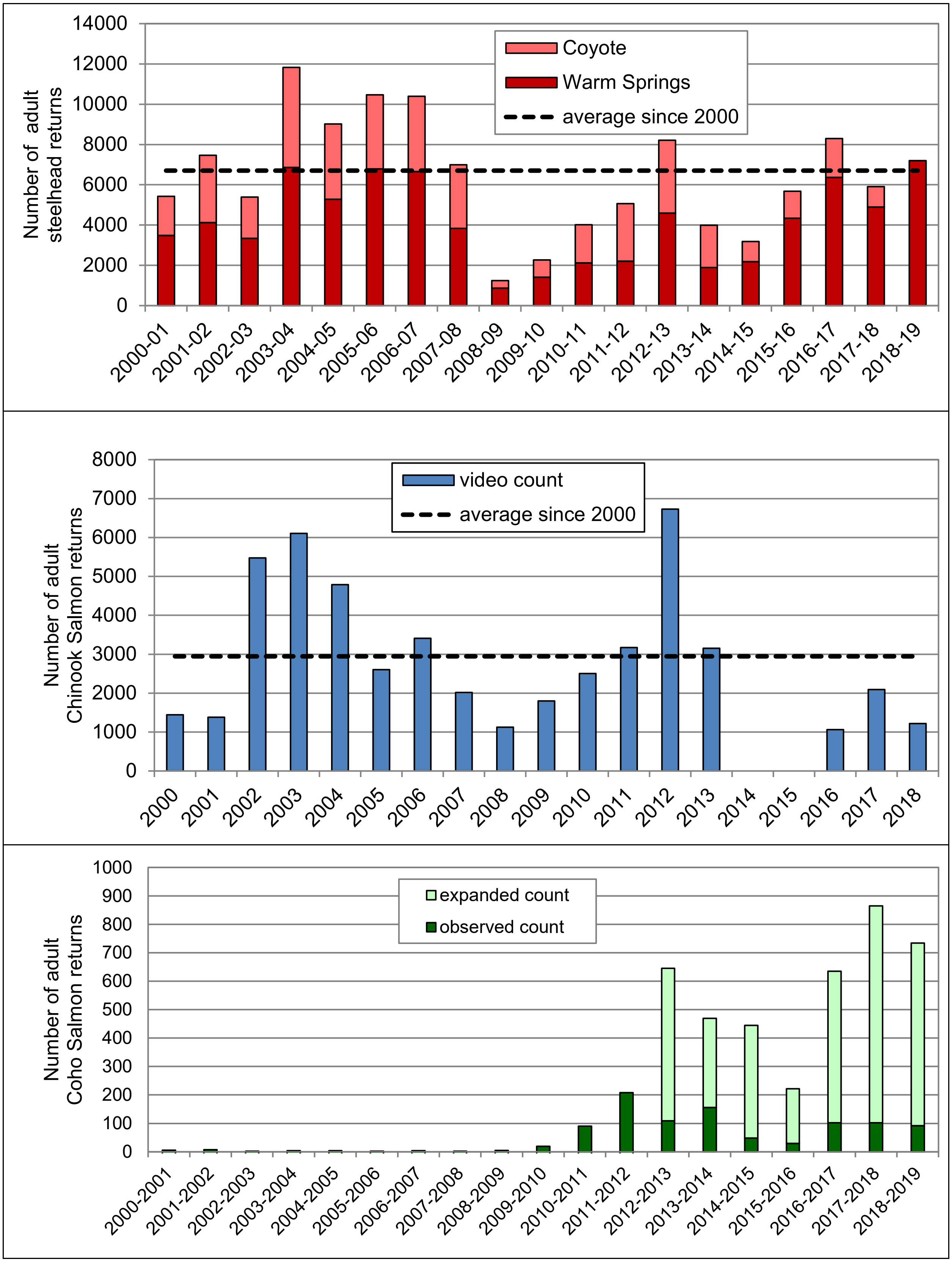


**Figure 8.5. Indicators of adult steelhead (counted at Russian River hatcheries), adult Chinook (based on video counts at Wohler-Mirabel) and Coho Salmon returns (UC/CA Sea Grant).**

## Conclusions and Recommendations

In 2018, Sonoma Water continued to implement monitoring approaches that are beginning to show that they are serving the important need to understand the context in which salmon and steelhead populations in the Russian are being affected by RPA implementation as opposed to environmental conditions or other factors outside our control. The degree to which various measures of population abundance track each other (e.g., Figure 8.5) suggests that despite the many challenges of monitoring in a watershed the size of the Russian, monitoring that goes beyond what is required in the RPA (e.g., PIT monitoring) is paying dividends in terms of informing a broader context. Continuation of California Coastal Monitoring Program (Adams et al. 2011) implementation throughout the watershed begun in 2013 by Sonoma Water and UC/CA Sea Grant is further assist in providing that context.

## References

Adams, P. B., and coauthors. 2011. California coastal salmonid population monitoring strategy design and methods. CA Department of Fish and Game, Sacramento, CA. 82 p.