Russian River Biological Opinion Status and Data Report

Year 2021 – 2022

February 2024

Sonoma Water

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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 (Water Agency), 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 the Water Agency. Each organization has its own reporting requirements to NMFS. Because coho salmon are also listed as endangered by the California Endangered Species Act (CESA), the Water Agency is party to a Consistency Determination issued by the California Department of Fish and Wildlife (CDFW) in November 2009. The Consistency Determination mandates that the Water Agency implement a subset of Biological Opinion projects that pertain to coho and the Water Agency is required to report progress on these efforts to CDFW.

Project implementation timelines in the Biological Opinion, and Consistency Determination, specify Water Agency reporting requirements to NMFS and CDFW and encourage frequent communication among the agencies. The Water Agency 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, the Water Agency has elected to coalesce reporting requirements into one annual volume for presentation to the agencies. The following document represents the thirteenth report for year 2021-2022. Previous annual reports can be accessed at http://www.sonomawater.gov.

Water Agency 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 Water Agency 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.

Water Agency Public Outreach Activities – 2021

Meetings

Public Policy Facilitating Committee (PPFC) meeting - The PPFC met virtually on March 9, 2021r. Notices for the meetings were sent out to approximately 800 individuals and agencies, a press release was issued and advertisements were placed in the Press Democrat and the Gazette. Approximately 78 people attended of the 90 that registered for the event.

The 2021 meeting included a brief summary of 2020 projects, a preview of 2021 projects and a summary of a study of the Dry Creek project's effects on flood patterns in the Dry Creek valley.

Presentations included: Russian River Estuary Management Project Monitoring, Jessica Martini-Lamb, Sonoma Water Environmental Resources Manager, and Josh Fuller, National Marine Fisheries Service Fishery Biologist; Dry Creek Habitat Enhancement Project Update & Monitoring Effort, David Manning, Sonoma Water Environmental Resources Manager and Joel Flannery, U.S. Army Corps of Engineers; Fish Habitat Flows & Water Rights Project, Jessica Martini-Lamb and Barry Dugan, Sonoma Water Principal Programs Specialist; 2020 Project

[1] DFG (Department of Fish and Game) is now known as the California Department of Fish and Wildlife.
[2] Sonoma County Water Agency is now know as Sonoma Water

Overview, Sonoma Water's environmental staff, including Principal Environmental Specialists Dave Cuneo, Neil Lassettre, Keenan Foster and Gregg Horton.

Other Outreach

Monthly BO Updates to WAC and TAC – On a monthly basis, Sonoma Water provides an update on all Biological Opinion activities to the Water Advisory and Technical Advisory committees, which consist of the agency's water contractors. The reports are also posted to Sonoma Water's website.

Fish Flow Videos – Sonoma Water staff worked with a consultant to create bilingual versions of videos created to improve communication and understanding of key topics contained in Fish Habitat Flows and Water Rights Project Draft EIR. The videos include Russian River Story: Watershed Stream Flows, Salmon in the River and Fish Habitat Flows and can be found on the Sonoma Water website and YouTube channel.

Free Media –In 2021, press releases were issued the Public Policy Facilitating Committee meeting and on reduced river flows.

Electronic Media – Sonoma Water updated its Biological Opinion webpage, including links on new documents and meetings. In addition, Sonoma Water posted Spanish language videos on the Fish Flow DEIR, which can be accessed via the agency's website. Email alerts were sent to interested stakeholders 32 times regarding activities in the estuary.

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. The Water Agency 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, the Water Agency manages the water supply storage space in these reservoirs to provide a water supply and maintain summertime Russian River and Dry Creek streamflows.

The Water Agency holds water-right permits[1] issued by the State Water Resources Control Board (SWRCB) that authorize the Water Agency to divert[2] Russian River and Dry Creek flows and to re-divert[3] water stored and released from Lake Mendocino and Lake Sonoma. The Water Agency 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 the Water Agency's facilities at Wohler and Mirabel Park (near Forestville). The Water Agency 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

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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.

to 8 years) process of petitioning the SWRCB for changes to minimum instream flow 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 the Water Agency "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 the Water Agency 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. The Water Agency 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.

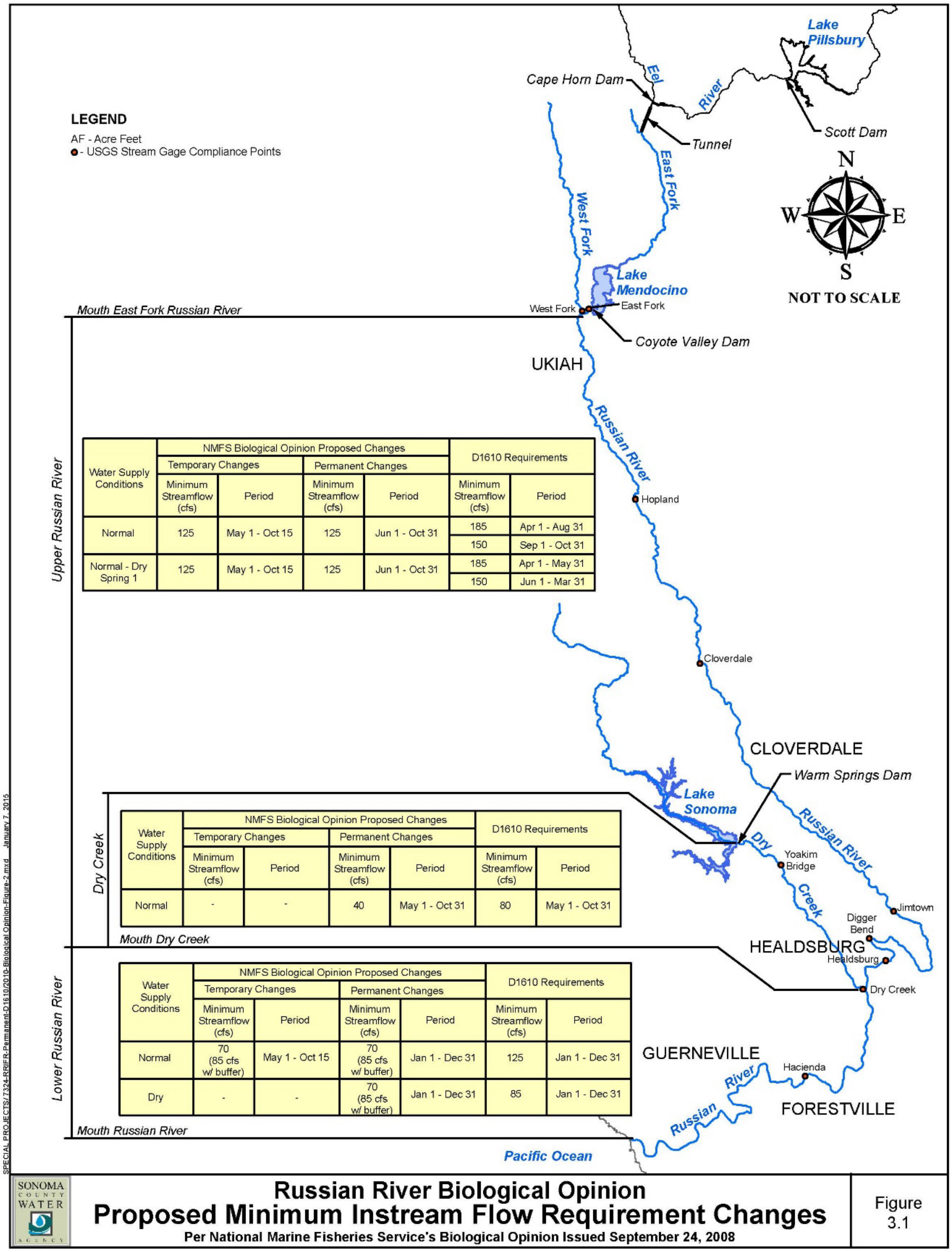
Summary Status

The SWRCB issued a second amended public notice of the Water Agency's petition to modify Decision 1610 for public comment on March 29, 2010. Following filing of the petition to change Decision 1610, the Water Agency 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 2021.

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 the Water Agency 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 the Water Agency'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

The Water Agency submitted multiple Temporary Urgency Change (TUCP) packages to the SWRCB in 2021 due to ongoing drought conditions and issues related to Pacific Gas and Electric's (PG&E) Potter Valley Project. The Water Agency submitted a TUCP to the SWRCB on January 7, 2021, due to drought conditions, severely low storage levels in Lake Mendocino, and a hydrologic index for establishing minimum instream flows not aligning with the watershed conditions (Appendix A-1). The requested temporary change was implementation of an alternative hydrologic index based on Lake Mendocino storage values in lieu of the Decision 1610 hydrologic index based on cumulative Lake Pillsbury inflow. The alternative hydrologic index based on Lake Mendocino would then be used to determine which minimum instream flow requirements would apply to the upper Russian River. No changes in this TUCP were requested for how minimum instream flow requirements were determined for Dry Creek or the lower Russian River (from its confluence with Dry Creek to the Pacific Ocean (Appendix A-2). The SWRCB issued an Order approving the Water Agency's TUCP on February 4, 2021 (Appendix A-2).

The SWRCB's Order made the following changes to the Water Agency's permits until July 26, 2021: minimum instream flow in the upper Russian River (from its confluence with the East Fork of the Russian River to its confluence with Dry Creek) was to be established using a hydrologic index based on water storage in Lake Mendocino and defined in the February 4, 2021, Order (Appendix A-2, Terms and Condition 1).

The February 4, 2021, Order included several terms and conditions, including: requirements for fisheries habitat monitoring and regular consultation with National Marine Fisheries Service and California Department of Fish and Wildlife regarding fisheries conditions; continuation of ongoing water quality monitoring at existing USGS sonde sites on the Russian River; additional consultation with the North Coast Water Quality Control Board by April 16, 2021, to discuss whether additional water quality monitoring should be required; reporting on hydrologic conditions of the Russian River system; weekly consultation meetings with NMFS, CDFW, and the North Coast Regional Water Quality Control Board for fishery and water quality conditions updates; submission of a schedule of milestones and completion dates for activities necessary for SWRCB consideration of and potential action on pending petitions to permanently change the Water Agency's water right permits; and, if certain conditions occurred, reporting of water conservation measures and water savings being implemented in areas served by Lake Mendocino, reporting of recommendations on what additional diversion information from other water users in the watershed might support improved real-time demand forecasts and operational buffers for Lake Mendocino in coordination with Mendocino County Russian River

Flood Control and Water Conservation Improvement District (District) . The Order also included a condition that the Water Agency submit a proposed accounting methodology to characterize the source and basis of right of water flowing into and released from Lake Mendocino. The February 4, 2021, Order also included a term and condition for flow reductions when releases from Lake Mendocino were to be reduced under the Order to protect against stranding of fish.

Reports to fulfill the terms of the February 4, 2021, Order were prepared and submitted to the SWRCB and are provided in Appendices A-3 to A-5.

The Water Agency filed a TUCP (Appendix A-6) on May 13, 2021, requesting temporary reductions to the Russian River instream flow requirements to address the ongoing severe drought conditions in the Russian River watershed and the extreme low storage conditions in Lake Mendocino, and to avoid potential violations of the Incidental Take Statement contained in the 2008 National Marine Fisheries Service (NMFS) Biological Opinion. The SWRCB issued an Order approving the TUCP on June 14, 2021 (Appendix A-7) establishing that minimum instream flow requirements would be set to *Critical* water supply classification of 25 cfs in the upper Russian River and 35 cfs in the lower Russian River, and that the minimum instream flow requirement will be implemented as a 5-day running average of average daily stream flow measurements with instantaneous minimum instream flows being no less than 15 cfs on the upper Russian River and no less than 25 cfs on the lower Russian River (Appendix A-7, Terms and Conditions 1). The June 14, 2021, Order included terms and conditions that required: fisheries and water quality monitoring to monitor habitat and water quality conditions and hydrologic connectivity in the Russian River; preparation and implementation of a water quality monitoring plan; weekly consultation meetings with NMFS, CDFW, and the North Coast Regional Water Quality Control Board for fishery and water quality conditions updates; reporting on hydrologic conditions of the Russian River system; a 20 percent reduction, as compared to the same period of the previous year, in total diversions across all downstream points of diversion or rediversion authorized under the Water Agency's water rights from July 1, 2022, to the end of the Order, and monthly reporting documenting the reductions and projections of Lake Mendocino and Lake Sonoma storages; and submission of a proposed account methodology that characterizes inflows and releases from Lake Sonoma, flows in the lower Russian River, and rediversion of water by Sonoma Water and its contractors. The June 14, 2021, Order also included a condition that Sonoma Water submit weekly reports of daily average release rates and characterization of releases from Lake Mendocino and Lake Sonoma to the SWRCB.

Water quality and fishery monitoring reports to fulfill the terms of the June 14, 2021, Order were prepared and submitted to the SWRCB and are provided in Appendix A-8 and Appendix A-9. Water quality monitoring in the Russian River Estuary is further discussed in Chapter 4.

Sonoma Water filed a TUCP on November 16, 2021, due to the ongoing drought conditions and the exacerbated disconnection of the current index, Lake Pillsbury inflow in the Eel River, and Russian River watershed conditions. In October 2021, the PG&E Potter Valley Project hydroelectric plant was shuttered due to equipment failure of the transformer bank, which resulted in a severe reduction in the anticipated inter-basin transfers. The shutdown coincided with historically low storage levels in Lake Mendocino and Lake Sonoma due to the statewide drought (Appendix A-10). The TUCP requested implementation of a hydrologic index based on Lake Mendocino storage values in lieu of the Decision 1610 hydrologic index based on cumulative Lake Pillsbury inflow.

The SWRCB issued an Order approving the Water Agency's TUCP on December 10, 2021 (Appendix A-11). The Order established that minimum instream flow requirements for the upper Russian River, lower Russian River, and Dry Creek would be based on a hydrologic index based on water storage in Lake Mendocino (Appendix A-11, Terms and Conditions 1). The Order included several terms and conditions, including: requirements for fisheries habitat monitoring and regular consultation with NMFS and CDFW regarding fisheries conditions; continuation of ongoing water quality monitoring at existing USGS sonde sites on the Russian River; additional consultation with the North Coast Water Quality Control Board by April 22, 2022, to discuss whether additional water quality monitoring should be required; weekly consultation meetings with NMFS, CDFW, and the North Coast Regional Water Quality Control Board for fishery and water quality conditions updates; reporting on hydrologic conditions of the Russian River system; and reporting of status of implementation of Sonoma Water and its contractors and other wholesale customer's Water Shortage Contingency Plans (WSCP); and reporting of monthly summaries of reduction in total diversions by Sonoma Water and reduction in monthly deliveries to its water contractors and other customers as compared to the 2013 water use benchmark. The December 10, 2021, Order also included a condition that Sonoma Water submit weekly reports of daily average release rates and characterization of releases from Lake Mendocino and Lake Sonoma to the SWRCB. The December 10, 2021, Order also included a term and condition for consultation with NMFS and CDFW when releases were to be reduced under the Order to protect against stranding of fish.

Fisheries and water quality monitoring reports to fulfill the terms of the December 10, 2021, Order were prepared and submitted to the SWRCB and are provided in Appendix A-12 and Appendix A-13.

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

4.0 Introduction

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 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. 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 Reasonable and Prudent Alternative (RPA) 2, Alterations to Estuary Management (NMFS 2008) requires 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.

Barrier Beach Management

Adaptive Management Plan

RPA 2 requires 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. Sonoma Water, in collaboration with the resource management agencies, conducted an extensive review of the plan in 2018. This update resulted in a substantial update to the 2019 plan. The measures developed in the 2019 management plan, when implemented, may not fully meet the objective established by the RPA. The concept of this approach has been developed and continues to evolve in coordination with NMFS, CDFW, and state and federal agencies. Estuary management for 2021 was discussed at a meeting on March 25, 2021, that included representatives from NMFS and CDFW, as well as Sonoma Water, Bodega Marine Laboratory, the U.S. Army Corps of Engineers, the North Coast Regional Water Quality Control Board, and ESA. A draft of the 2020 plan was provided to the Estuary Management Team on March 23, 2021, for review. Comments on the draft plan from these representatives informed the revision of the draft plan to create the final plan, which was finalized on June 21, 2021.

Beach Topographic Surveys

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 2021 and provided to NMFS and CDFW. The May 2021 topographic survey was cancelled due to the presence of neonate (less than 1 week old) harbor seals at the mouth of the Russian River. 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. A summary of beach topography changes in 2021 is provided in Attachment Q, Physical Process during the 2021 Management Period in the Russian River Estuary Adaptive Management Plan 2022 (ESA, 2022).

2021 Beach and River Mouth Conditions

A barrier beach formed ten times in 2021 (Table 4.0.1). Seven river mouth closures ended in self-breaches and Sonoma Water conducted water level management activities during three closures. The Russian River mouth was closed to the ocean for a total of 74 days (or 201%) in 2021.

Table 4.0.1. Summary of Russian River mouth closures in 2021. Three beach management activities were conducted in 2021.

Closure Date	Beach Management Date	No. Days Closed	Activity Time[1]	Water Elevation (ft)[2]	Beach Management Activity[3]	Excavated Volume (CY)[4]
2-Jan	7-Jan	5	None	10.4	none	0
9-Jan	12-Jan	3	11:36am-12:26pm	9.17	Pilot Channel	160
15-Jan	19-Jan	4	9:26am-12:00pm	8.8	Pilot Channel	417
26-Jan	28-Jan	2	None	10.37	none	0
5-Mar	10-Mar	5	11:55am-1:08pm	8.8	Pilot Channel	366
21-Apr	6-May	15	None	6.2	none	0
10-May	18-May	8	None	4.9	none	0
28-Sep	24-Oct	26	None	11.2	none	0
26-Nov	28-Nov	2	None	5.27	none	0
30-Nov	4-Dec	4	None	7.42	none	0

[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 in feet (NGVD29).

[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.

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 4.0.1 for the entire 2021 lagoon management season (ESA, 2022). The lagoon water level time series (Figure 4.0.1a) 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 similar to 2020 conditions with flow rates below 100 cfs during summary (ESA, 2022).

As in prior years, wave heights declined from April to September and were lowest through July and August (Figure 4.0.1b). Although swell events during the summer tended to have wave heights of less than 5 feet throughout the summer, there were nearly a dozen times that waves had periods above 15 seconds, and the first several days of July experienced swells with

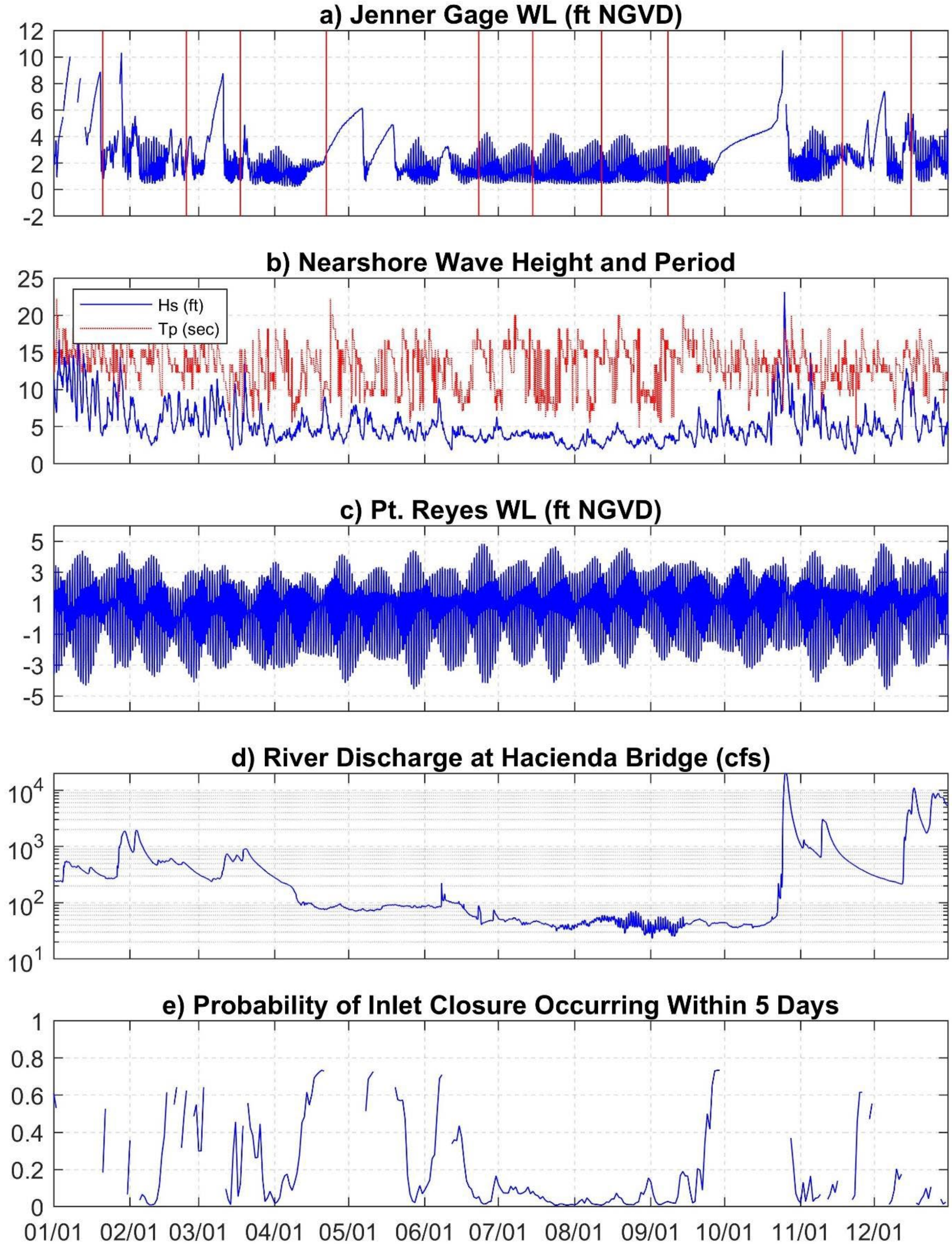


Figure 4.0.1. Estuary, Ocean, and River Conditions Compared with Closure Probability, 2021.

periods above 18 seconds. Long-period waves are relevant because they are known to be more effective at moving sand onto the beach. For instance, the long-period swells in early July were coincident with a significant shallowing of the inlet thalweg during a partial closure event (indicated by a smaller tide range in the estuary caused by an upward shift of low tides). The location of the inlet played a role in the shape of the beach and the hydrology of the Estuary. The mouth was located next to the jetty groin for the duration of the management season (similar to other years wit low inflows the prior wet season), which may have influenced the likelihood of closure (ESA, 2022).

During the 2021 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. The winter of 2020/2021 was dry, with discharge at the USGS Hacienda Bridge station reaching a maximum of 1,940 cubic feet per second (cfs) in February 2021, and only a few other short periods that winter above 500 cfs. Despite the dry conditions, inlet closure events occurring in January and early February 2021 caused water surface elevations to reach 10.2 ft at the Jenner gage. Taking a broader view of 2021, the inlet never migrated to the north end of the beach due to low discharge conditions. It remained adjacent to the jetty's groin for the entire season. The mouth has two major closures during the 2021 management season, including an event in mid-May lasting about two weeks, and another one-month closure from late September to late October that ended due to high inflows from the October 2021 atmospheric river event. Eight inlet closure events occurred outside of the management season, and three were artificially breached.

Appendix Q of the 2022 Russian River Estuary Adaptive Beach Management Plan (ESA, 2022) offers lessons learned based on 2021 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 ESA, 2022 for fuller context:

- As observed in similarly dry years from 2012 to 2015, 2018 and 2020, peak 2021 winter flows of less than 40,000 cfs limited the inlet's northward excursion, and the inlet remained near the groin for the entire management period.
- In prior annual monitoring reviews, it was noted that dry years usually were associated with stable or growing conditions for the beach berm north of the jetty groin. However, conditions in September 2021 may indicate that coastal influences may also erode the beach. This has been documented elsewhere in the state, and can occur when waves with high steepness (wave height vs length) erode part of the beach face, or when wave overtopping pushes material from the beach crest into the backbeach area. Sonoma Water surveys in August, September, and October indicate that the latter may have been a factor. However, this only lowered the beach crest by about one foot and the crest elevation recovered within one to two months after the erosion.
- As with observations in 2020, the gap in the jetty groin was again observed to allow swash from southern swell waves to penetrate through the jetty and deposit sand in the inlet. This wave energy may have deposited sand in the mouth of the inlet and contributed to the early June partial closure event.

Artificial Breaching

There were ten mouth closures in 2021; two occurred during the lagoon management season. Three beach management activities were conducted by Sonoma Water in 2021, all outside the lagoon management season. More information about the wave and water level conditions during these closures are available in Appendix Q of the 2022 Russian River Estuary Adaptive Beach Management Plan (ESA, 2022).

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 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."

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, 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 plans 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.

Conclusions and Recommendations

A barrier beach formed ten times in 2021. Seven river mouth closures ended in self-breaches and Sonoma Water conducted three water level management activities outside the lagoon management season (Table 4.0.1). The Russian River mouth was closed to the ocean for a total of 74 days (or 20%) in 2021.

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.

Section 4.0, Introduction, 2021 Beach and River Mouth Conditions, provides a summary of the river mouth closures in 2021.

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 (DO; 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.

Five (5) stations were established for continuous water quality monitoring, including three stations in the mainstem Estuary and two tributary stations (Figure 4.1.1). The first 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 (Willow Creek Station), which flows into the middle reach of the Estuary upstream of Patty’s Rock. The second mainstem station was located in the upper reach of the Estuary downstream of

Freezeout Creek (Freezeout Creek Station). The third mainstem station was located in the upper reach of the Estuary 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.

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 (Figure 4.1.1). 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.

Mainstem Estuary monitoring stations up to Brown's Pool 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, and Brown's Pool stations had a vertical array of two datasondes to collect water quality profiles (Figure 4.1.2). 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 (~5-6m) portion of the water column. The Freezeout Creek station 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 mid-depth (~3-4m) and bottom (~6-7m) portions of the water column. Similarly, the Brown's Pool station in the upper reach of the Estuary had sondes placed at the mid-depth (~5-6m) and bottom (~9-12m) portions of the water column.

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 and Freezeout Creek stations were deployed from April to October. The Brown's Pool station was deployed from July to October. The Austin Creek sonde was deployed from June to August when a lack of water required equipment removal for the remainder of the season. The Willow Creek sonde was deployed year-round.

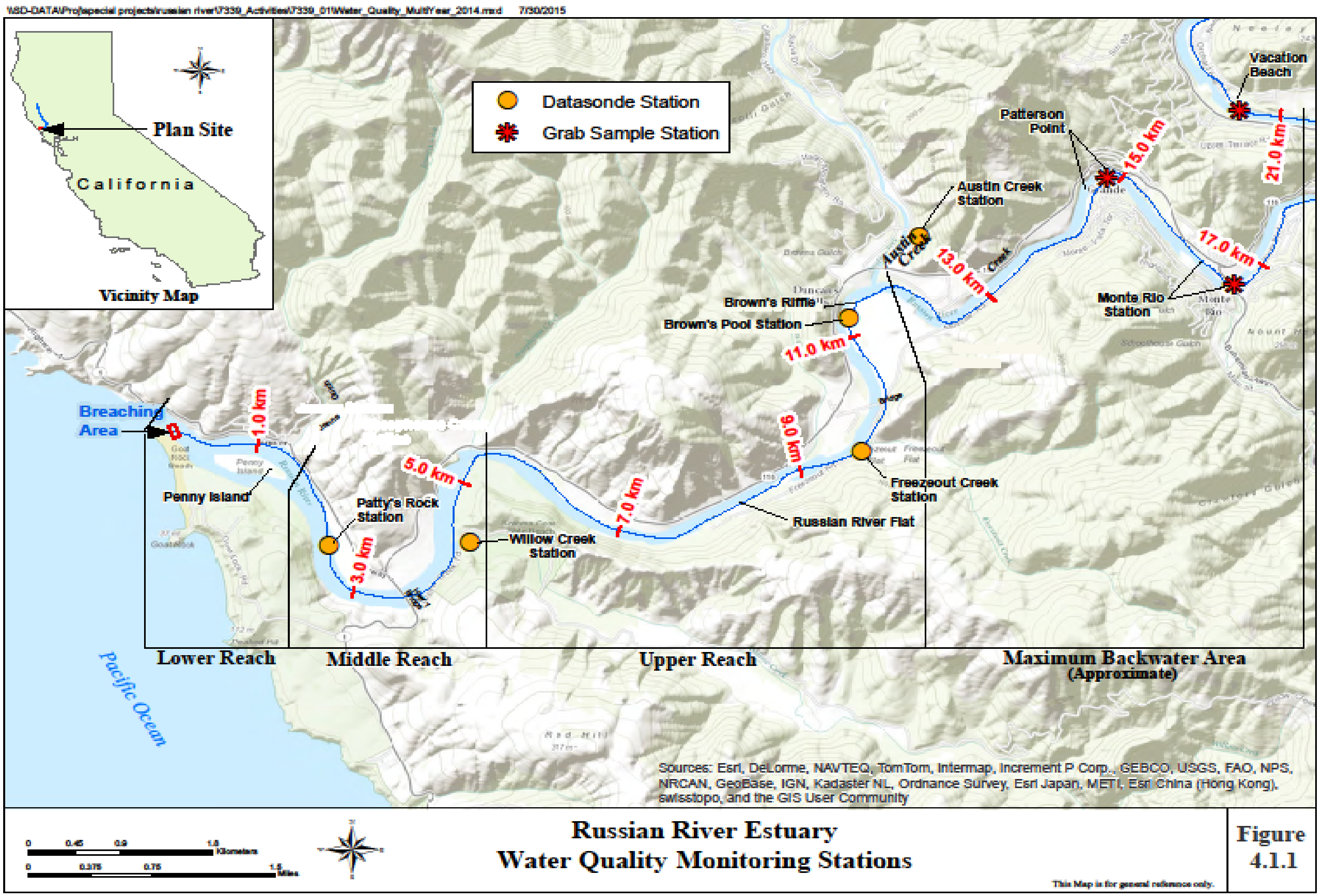


Figure 4.1.1. 2021 Russian River Estuary Water Quality Monitoring Stations

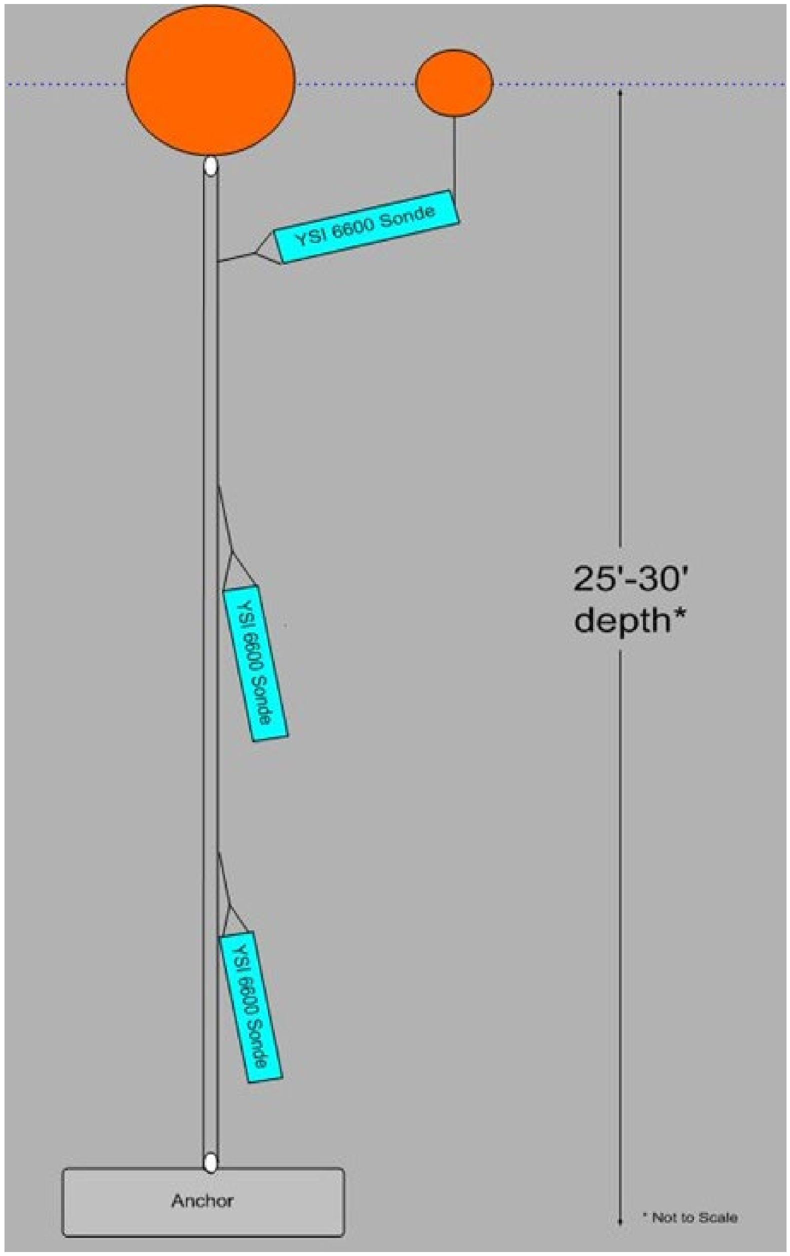


Figure 4.1.2. Typical Russian River Estuary monitoring station datasonde array.

Grab Sample Collection

In 2021, 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 Maximum Backwater Area (MBA), including one station established in 2010 just downstream of the Monte Rio Bridge (Monte Rio Station). The 2021 grab sampling effort represented the eighth year of collecting samples at Patterson Point in Villa Grande (Patterson Point Station) and downstream of the Vacation Beach summer dam (Vacation Beach station). Refer to Figure 4.1.1 for grab sampling locations.

Sonoma Water staff collected grab samples weekly from 4 May to 19 October. 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; however, an analysis and discussion of these constituents is not included in this report.

Results

Water quality conditions in 2021 were similar to trends observed in sampling from 2004 to 2020. 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, dissolved oxygen, 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 4.1.30. These data gaps may affect minimum, mean, and maximum values of the various constituents monitored in 2021, including: temperature, dissolved oxygen, and salinity at the Patty's Rock bottom sonde from mid-July to early August; pH at the Patty's Rock bottom sonde from mid-May to early August; all consituents at Willow Creek from mid-July to late-September; temperature, salinity, and pH at the Freezeout Creek bottom and mid-depth sondes from late-

Table 4.1.1. Russian River Estuary 2021 Water Quality Monitoring Results. Minimum, mean, and maximum values for temperature (degrees Celsius), depth (meters), dissolved oxygen concentration (milligrams per Liter), dissolved oxygen (percent) saturation, hydrogen ion (pH units), and salinity (parts per thousand).

Monitoring Station *Sonde*	**Temperature** (°C)	**Depth** (m)	**Dissolved Oxygen** (mg/L)	**Dissolved Oxygen** (%) saturation	**Hydrogen Ion** (pH)	**Salinity** (ppt)
Patty's Rock						
Surface April 27, 2021 - October 22, 2021						
Min	10.9	0.9	6.5	74.4	7.7	0.9
Mean	16.8	1.2	10.3	119.8	8.2	19.8
Max	**22.5**	**1.5**	**19.7**	**241.8**	**9.2**	**33.5**
Mid-Depth April 30, 2021 - October 22, 2021						
Min	9.5	4.9	0.0	0.0	5.1	19.8
Mean	13.5	5.6	6.5	75.1	7.8	30.9
Max	**16.8**	**5.9**	**15.9**	**182.0**	**8.6**	**35.4**
Willow Creek						
Mid-Depth February 8, 2021 - December 31, 2021						
Min	6.0	0.0	0.1	1.4	6.7	0.1
Mean	15.1	0.8	8.1	84.0	7.5	8.4
Max	**26.5**	**3.2**	**18.2**	**208.0**	**8.9**	**30.8**
Freezeout Creek						
Mid-Depth April 27, 2021 - October 22, 2021						
Min	13.8	3.9	0.0	0.2	6.9	0.1
Mean	19.4	4.1	6.8	74.6	8.0	1.7
Max	**23.0**	**4.2**	**15.3**	**175.7**	**9.1**	**6.9**
Bottom April 27, 2021 - September 29, 2021						
Min	16.0	5.8	0.2	1.9	6.0	0.1
Mean	19.5	6.6	0.7	8.2	6.6	8.0
Max	**22.6**	**7.3**	**9.0**	**100.1**	**8.7**	**10.5**
Brown's Pool						
Mid-Depth July 21, 2021 - October 22, 2021						
Min	14.1	5.7	1.7	19.0	7.1	0.1
Mean	19.7	5.8	6.6	72.6	7.6	0.1
Max	**23.1**	**5.9**	**10.3**	**119.4**	**8.6**	**0.4**
Bottom July 21, 2021 - October 22, 2021						
Min	14.0	9.3	0.0	0.0	5.7	0.1
Mean	17.7	10.7	0.2	1.8	6.4	0.4
Max	**21.2**	**11.8**	**8.5**	**83.3**	**7.7**	**1.0**
Austin Creek						
Surface June 23, 2021 - August 3, 2021						
Min	14.2	0.3	0.0	0.0	7.0	0.2
Mean	16.4	0.4	1.5	15.8	7.1	0.2
Max	**19.2**	**0.6**	**6.5**	**69.4**	**7.3**	**0.2**

June to late-July; dissolved oxygen at the Freezeout Creek bottom sonde from late-June to late-July; and dissolved oxygen at the Freezeout Creek mid-depth sonde from mid-May to late-July.

Although gaps exist in the 2021 data that affect sample statistics, Sonoma Water staff have 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.

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.

In the upper reach, the Estuary typically begins to transition from predominantly saline conditions to brackish and freshwater conditions in the Heron Rookery area, located downstream from the town of Duncans Mills. Further upstream, the Freezeout Creek area is located in a predominantly freshwater environment; however, brackish conditions can occur during open estuary conditions with lower in-stream flows, as well as during barrier beach closure or perched conditions. The upper extent of the upper reach of the estuary is located in the Brown's Pool area where conditions are predominantly freshwater habitat with periodic salinity migration creating brackish conditions at depth. This area is located next to Casini Ranch just downstream of the confluence with Austin Creek and what is considered the beginning of the MBA. The Austin Creek station is located in the MBA in freshwater habitat that can become inundated during high tides, barrier beach closures, perched conditions, and lagoon formation.

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 to 2 meters, 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 0.9 to 33.5 ppt at the Patty's Rock surface sonde with a mean salinity value of 19.8 ppt (Table 4.1.1).

The mid-depth sonde at the Patty's Rock station was suspended at a depth of approximately 5 to 6 meters, and also experienced fluctuations in salinity concentrations, though to a lesser

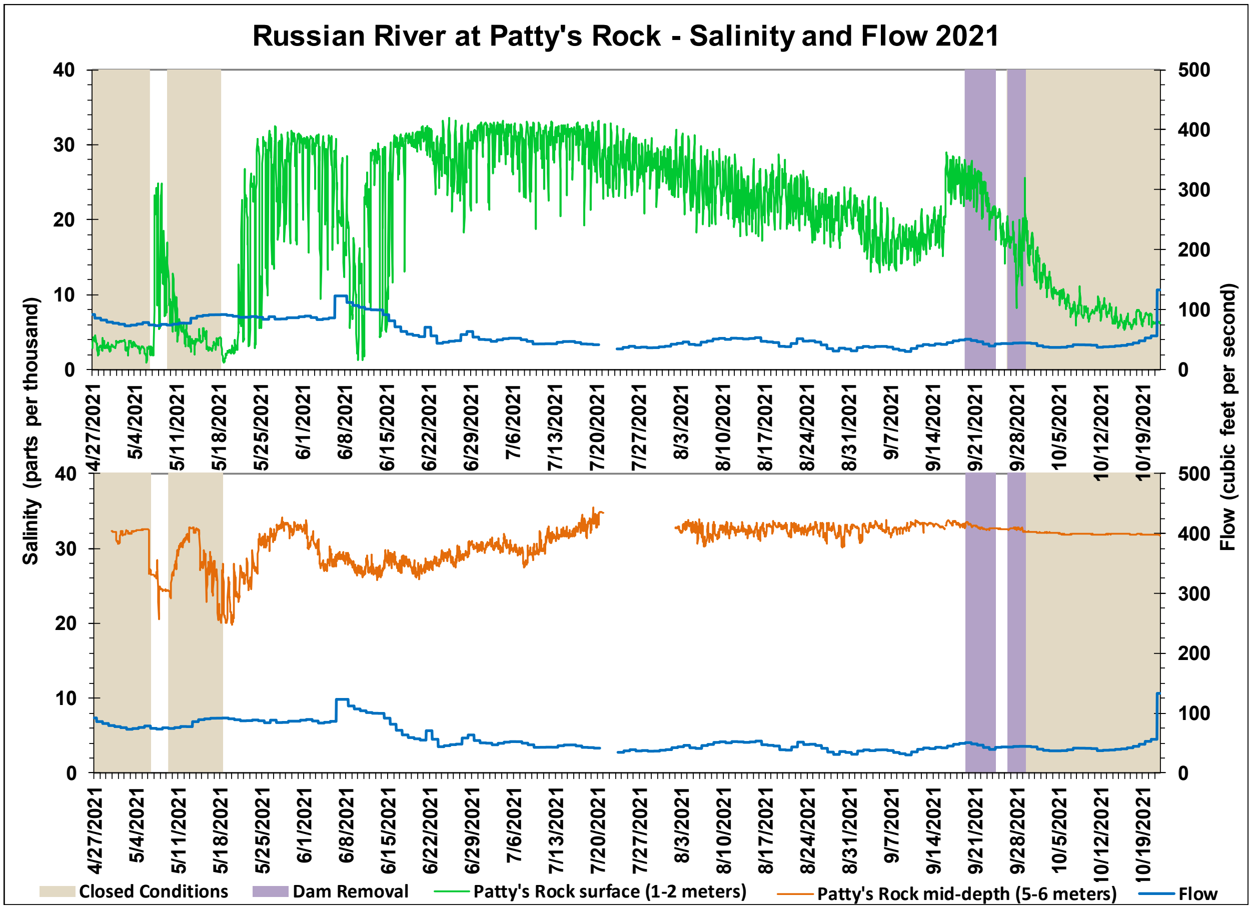


Figure 4.1.3. 2021 Russian River at Patty's Rock Salinity and Flow Graph

degree and frequency than the surface sonde. Concentrations ranged from 19.8 to 35.4 ppt at the Patty's Rock mid-depth sonde with a mean salinity value of 30.9 ppt (Table 4.1.1).

The Estuary experienced two closures during the 2021 management period, including one closure that occurred over eight (8) days from 10 May to 18 May and a second closure that lasted twenty-six (26) days from 28 September to 24 October (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 tidal inflow, the compression and leveling out of the salt layer, and seepage of saline water through the barrier beach. Salinity typically 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 during elevated flows in February and

March, but became increasingly brackish as spring flows declined and remained relatively saline until the sonde was removed in early-July due to an equipment malfunction (Figure 4.1.4).

Salinity concentrations at Willow Creek were observed to fluctuate significantly at times during open barrier beach conditions in late spring and early summer, with concentrations generally declining during closed conditions. The mean salinity concentration observed at the Willow Creek station was 8.4 ppt, with a minimum concentration of 0.1 ppt, and a maximum concentration of 30.8 ppt (Table 4.1.1).

After being redeployed in September, conditions at Willow Creek were observed to be saline but decreasing during estuary closure and returned to freshwater conditions as the barrier beach opened and storm flows flushed out the remaining brackish water at the end of October (Figure 4.1.4). Conditions were observed to become briefly saline during lower flows in early December before returning to predominantly freshwater conditions in mid-December with increasing flows.

Upper Reach Salinity

Two stations were monitored in the upper reach in 2021; Freezeout Creek and Brown's Pool. Both stations included a bottom sonde and a mid-depth sonde. 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 fresh to brackish habitat in spring that became predominantly brackish as the salt wedge migrated up the Estuary during open conditions from late June through September (Figure 4.1.5). The mid-depth sonde at Freezeout Creek had a mean salinity concentration of 1.7 ppt, and salinity levels that ranged from 0.1 to 6.9 ppt (Table 4.1.1). The bottom sonde at Freezeout Creek had a mean salinity concentration of 8.0 ppt, and salinity levels that ranged from 0.1 to 10.5 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 generally considered the demarcation between the Estuary and the MBA, where salinity levels have not been observed to occur past this point.

This station experienced slightly elevated salinity levels at the bottom sonde that generally remained below 1 ppt, and otherwise remained predominantly freshwater habitat during the 2021 monitoring season (Figure 4.1.6). The mid-depth sonde at Brown's Pool had a mean salinity concentration of 0.1 ppt, and salinity levels that ranged from 0.1 to 0.4 ppt (Table 4.1.1). The bottom sonde at Brown's Pool had a mean salinity concentration of 0.4 ppt, and salinity levels that ranged from 0.1 to 1.0 ppt.

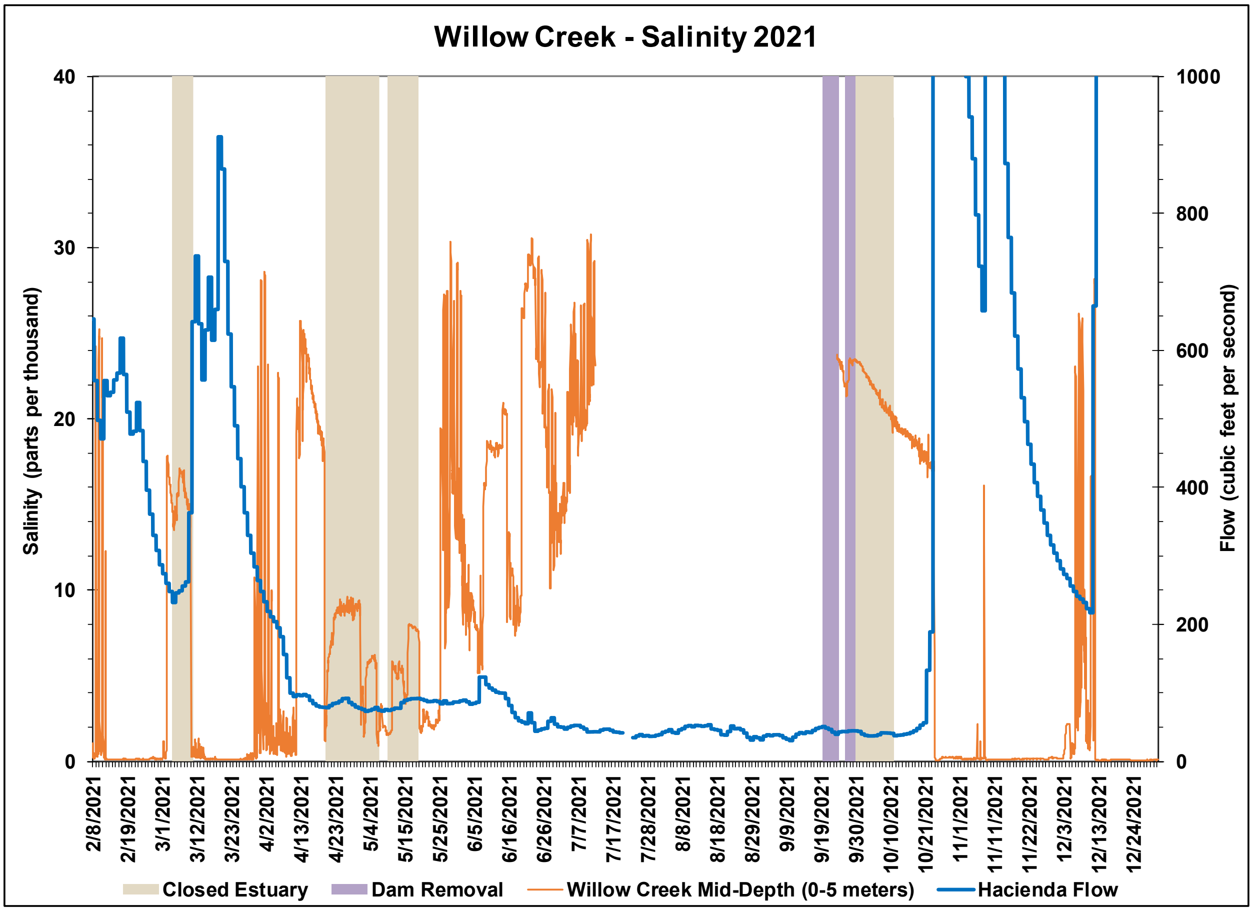


Figure 4.1.4. 2021 Willow Creek Salinity and Russian River Flow Graph

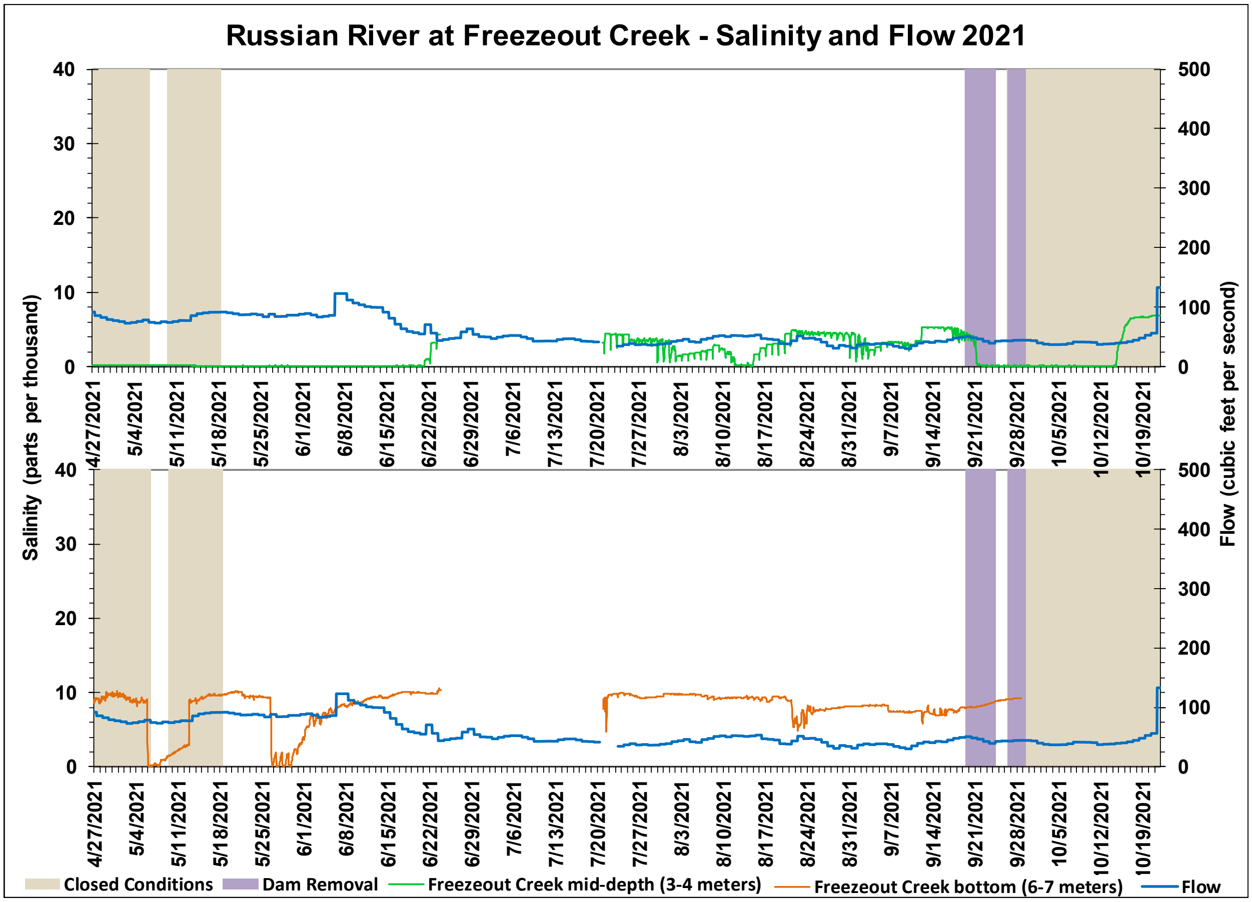


Figure 4.1.5. 2021 Russian River at Freezeout Creek Salinity and Flow Graph

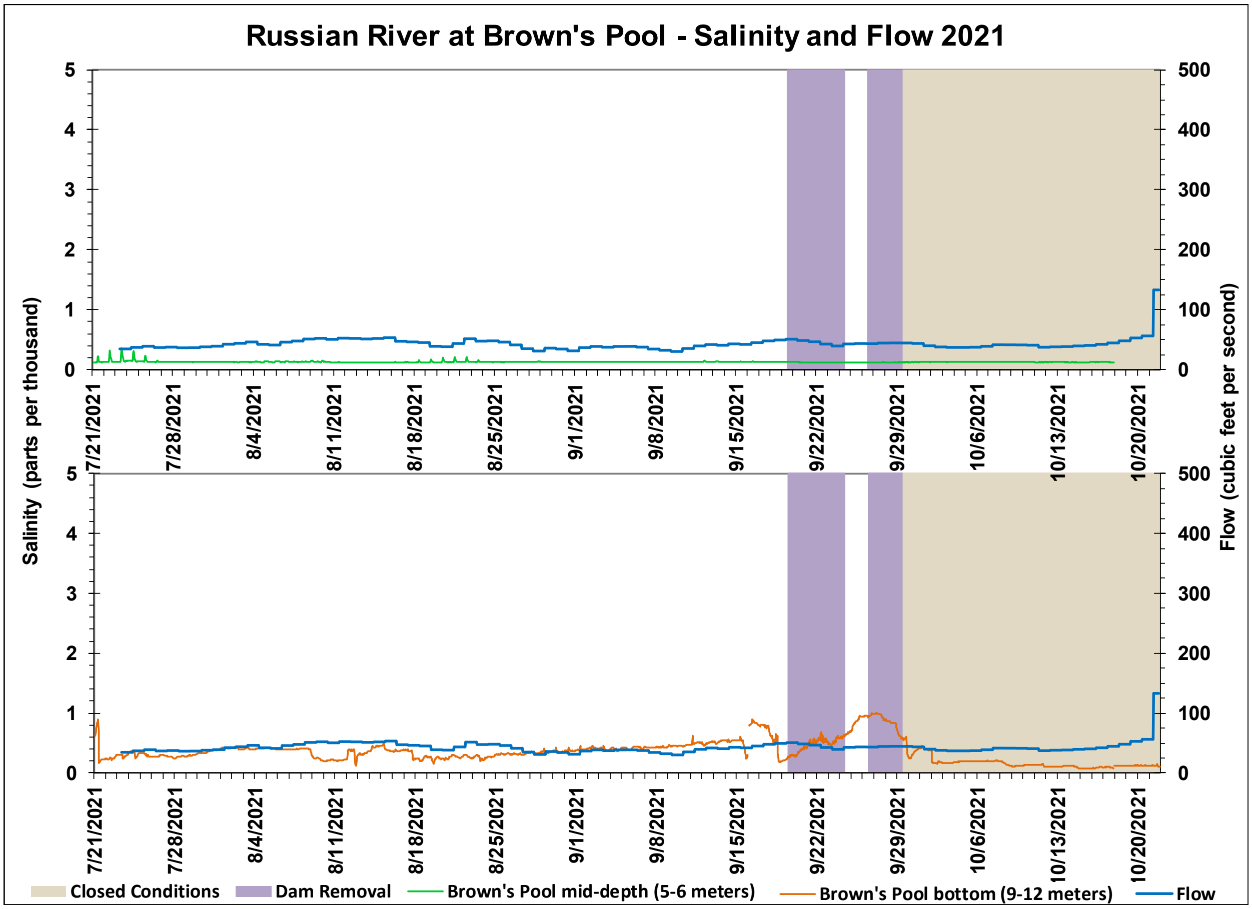


Figure 4.1.6. 2021 Russian River at Brown's Pool Salinity and Flow Graph

Maximum Backwater Area Salinity

One station was located in the MBA in lower Austin Creek (Figure 4.1.1). Austin Creek was not observed to have salinity levels above normal background conditions expected in freshwater habitats during the period of observation, which was cut short by a lack of water in early August during drought conditions (Figure 4.1.7). The Austin Creek station had a mean salinity concentration of 0.2 ppt, a minimum concentration of 0.2 ppt, and a maximum concentration of 0.2 ppt (Table 4.1.1).

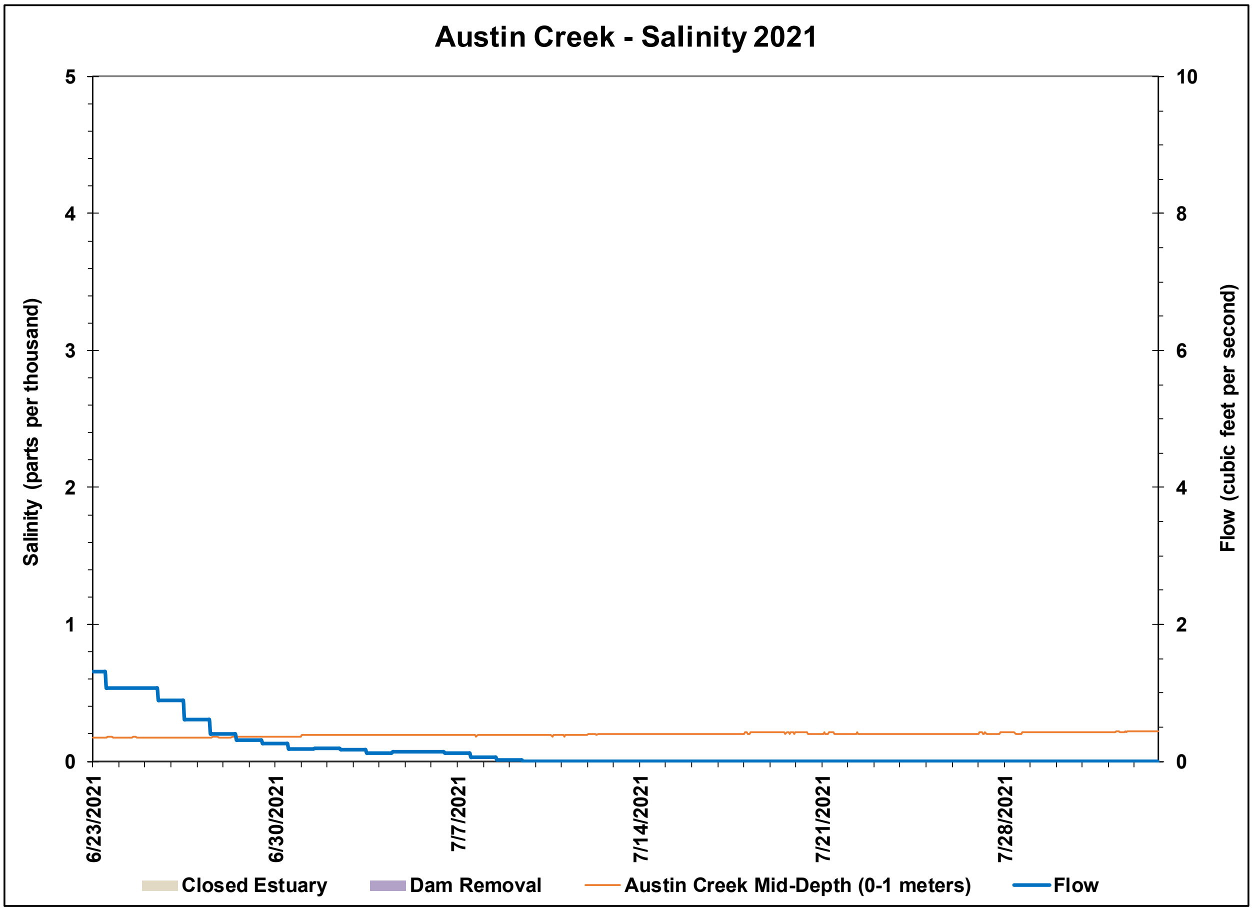


Figure 4.1.7. 2021 Austin Creek Salinity and Flow Graph

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 4.1.8 through 4.1.11). 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.

During closed Estuary conditions, increasing temperatures associated with fresh/saltwater stratification were observed to occur at the Patty's Rock station (Figure 4.1.8). 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 warmer dry months of summer and fall, when the estuary is closed or the river mouth is perched and the supply of cool tidal inflow is reduced, solar radiation heats the overlying freshwater surface layer and underlying saline layer. The overlying freshwater surface layer restricts the release of this heat from the underlying saline layer, which can result in higher water temperatures in the underlying

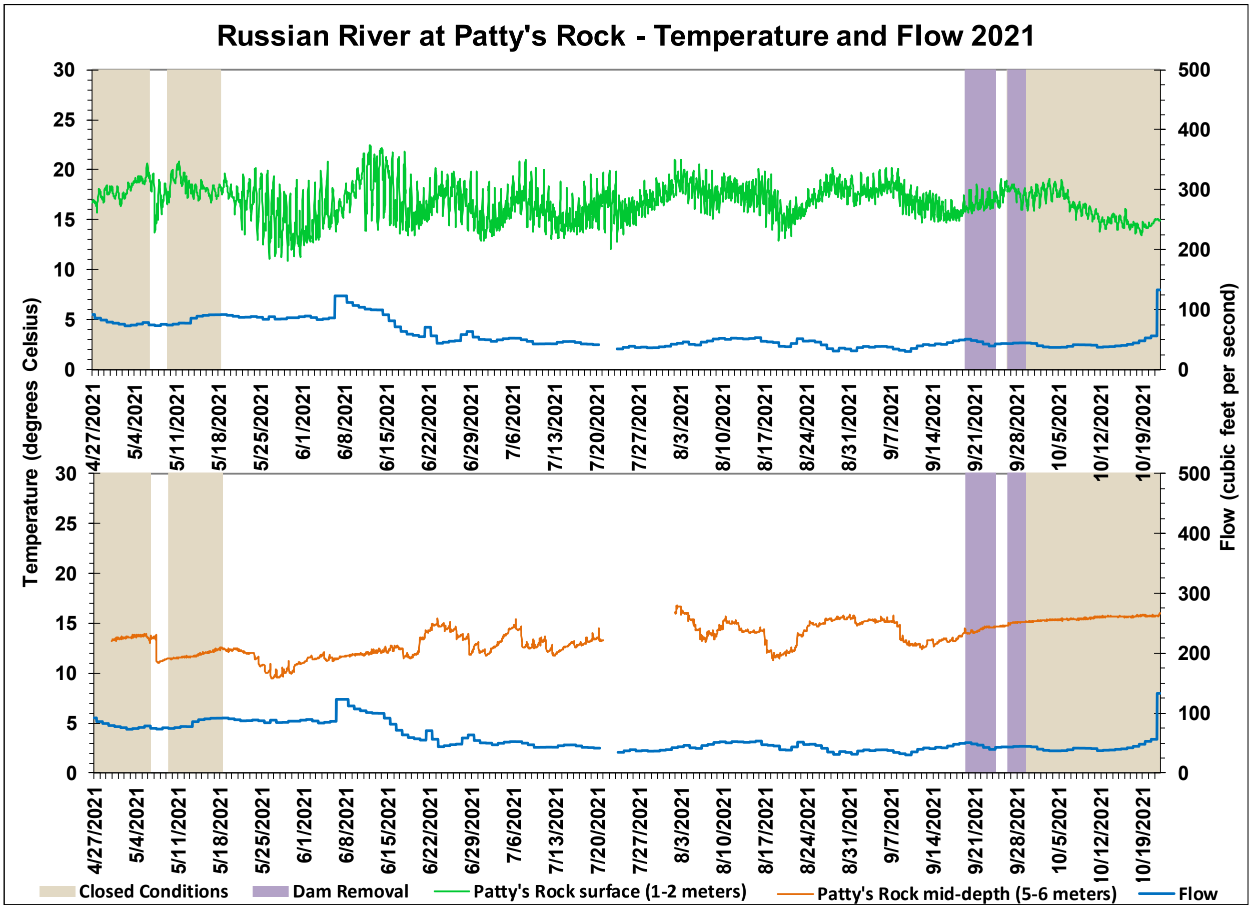


Figure 4.1.8. 2021 Russian River at Patty's Rock Temperature and Flow Graph

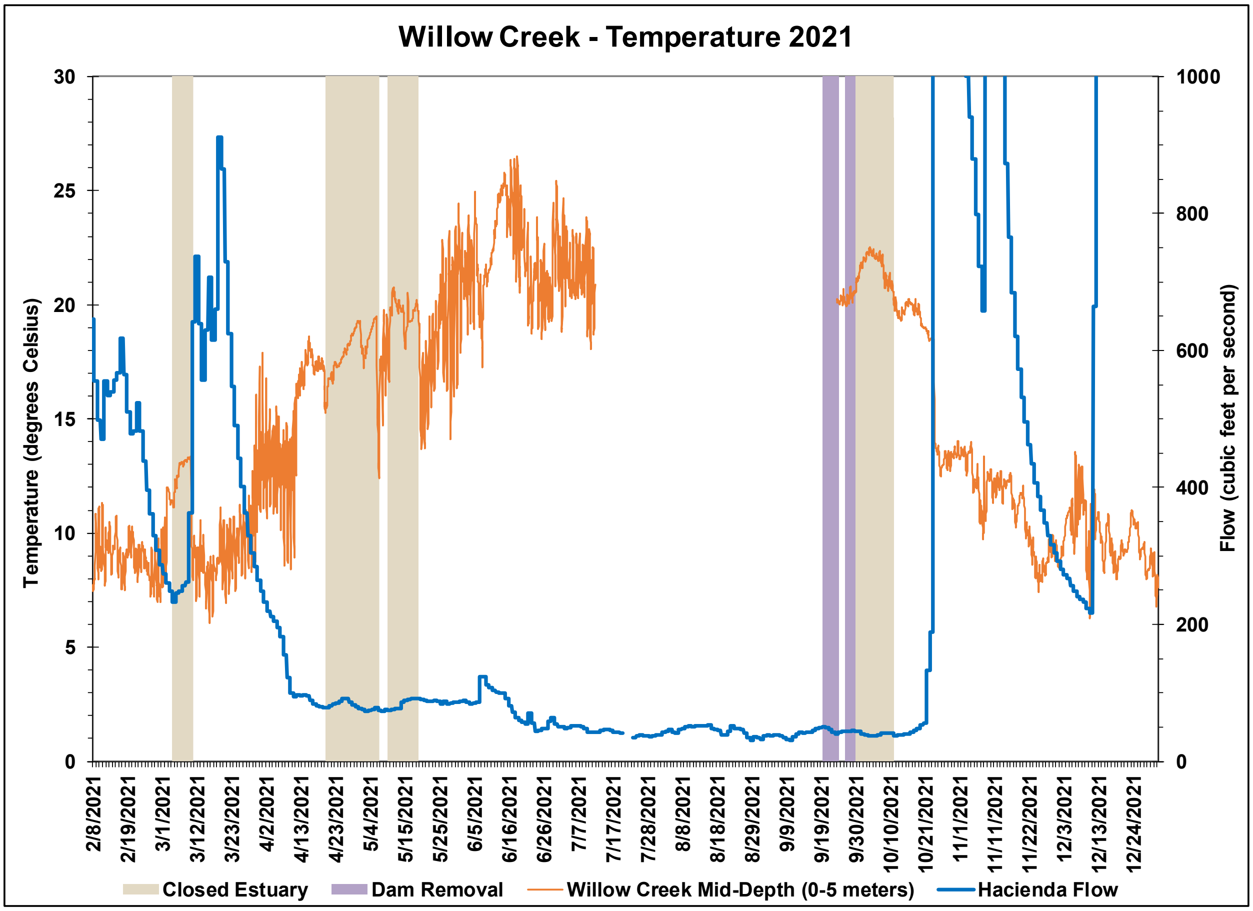


Figure 4.1.9. 2021 Willow Creek Temperature with Russian River Flow Graph

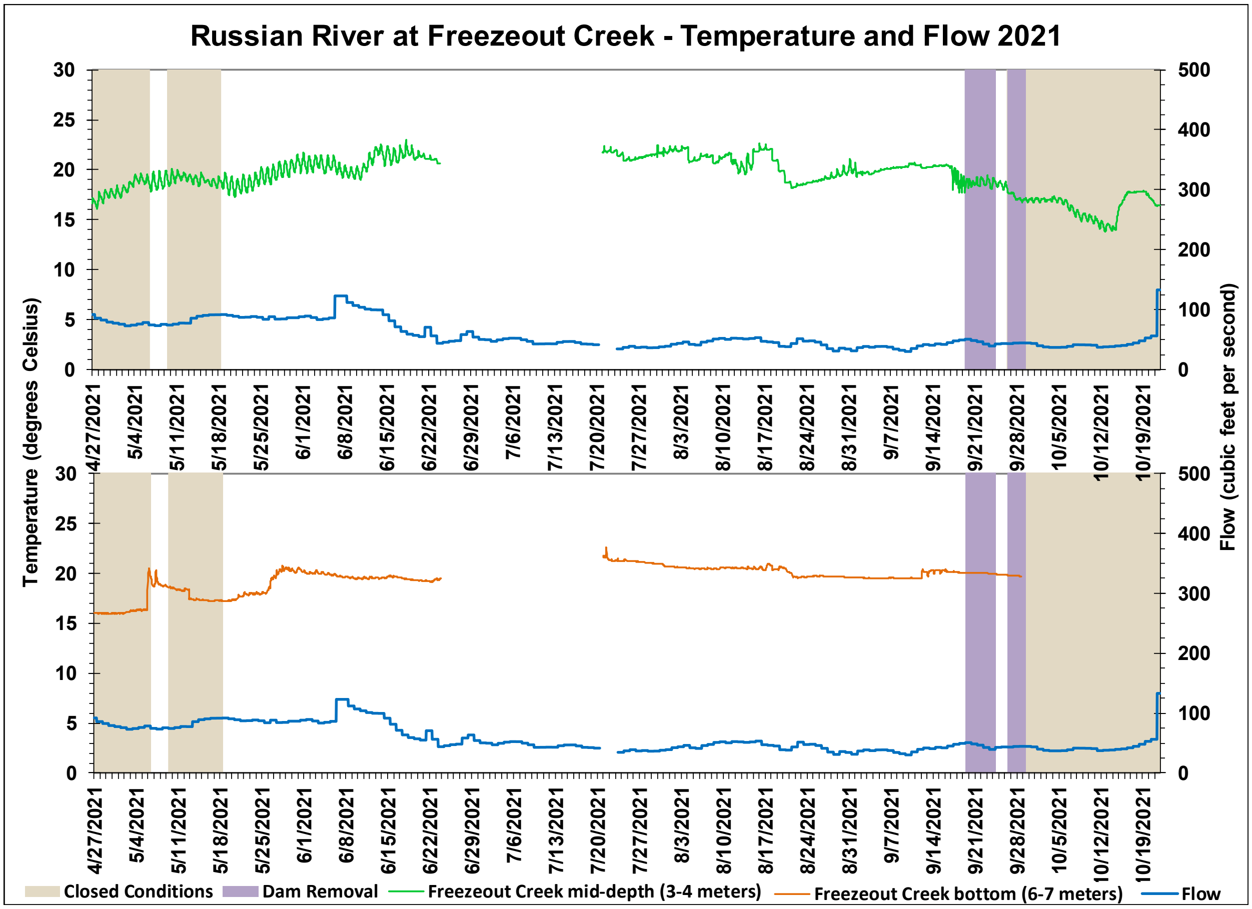


Figure 4.1.10. 2021 Russian River at Freezeout Creek Temperature and Flow Graph

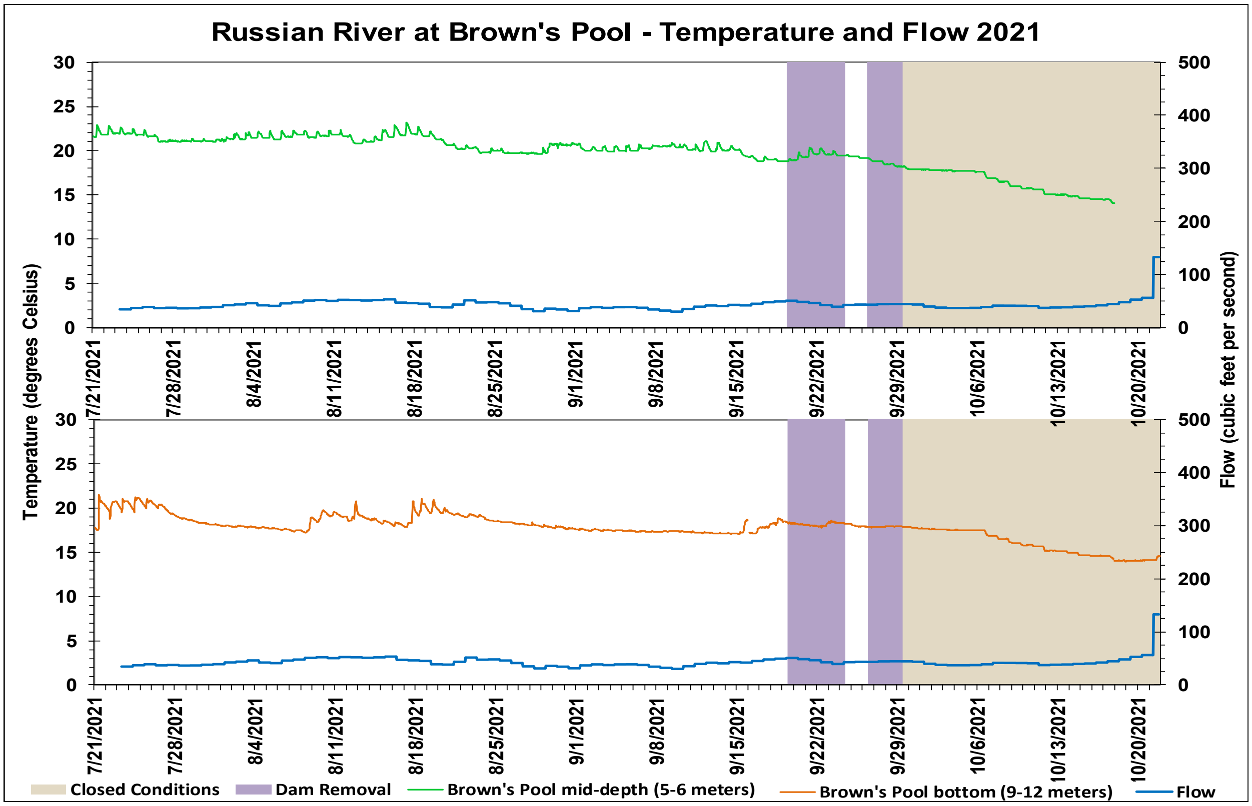


Figure 4.1.11. 2021 Russian River at Brown's Pool Temperature and Flow Graph

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 water column. 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 22.5 °C (Table 4.1.1). Whereas, the mid-depth sonde was located primarily in saltwater and had a maximum temperature of 16.8 °C. Maximum temperatures at the surface sonde were observed in brackish to saline water during open barrier beach conditions in June. Maximum temperatures at the mid-depth sonde were observed in saline water during open barrier beach conditions in August (Figures 4.1.8 and 4.1.3). The Patty's Rock surface sonde had a mean temperature of 16.8 °C and a minimum temperature of 10.9 °C. The mid-depth sonde had a mean temperature of 13.5 °C and a minimum temperature of 9.5 °C.

The Willow Creek station had a maximum temperature of 26.5 °C, which occurred on 18 June in brackish water and open conditions (Figures 4.1.9 and 4.1.4). The mean temperature was 15.1 °C, and the minimum temperature was 6.0 °C, which occurred in mid-March (Table 4.1.1). 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 to a lesser degree, closed Estuary conditions (Figure 4.1.9).

Upper Reach Temperature

Overall estuarine temperatures in both the saline layer and freshwater layer were typically warmest 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 mid-depth sonde had a maximum temperature of 23.0 °C, a mean temperature of 19.4 °C, and a minimum temperature of 13.8 °C (Table 4.1.1). The Freezeout Creek bottom sonde had a maximum temperature of 22.6 °C, a mean temperature of 19.5 °C, and a minimum temperature of 16.0 °C (Table 4.1.1). Maximum temperatures were observed to occur in freshwater during open estuary conditions (Figures 4.1.10 and 4.1.5). Minimum temperatures occured in brackish and freshwater during closed conditions in April and October (Figures 4.1.10 and 4.1.5).

The Brown’s Pool mid-depth sonde had a maximum temperature of 23.1 °C, a mean temperature of 19.7 °C, and a minimum temperature of 14.1 °C (Table 4.1.1). The Brown’s Pool bottom sonde had a maximum temperature of 21.2 °C, a mean temperature of 17.7 °C, and a minimum temperature of 14.0 °C. Under open and closed conditions, daily temperatures were often lower at Brown’s Pool bottom sonde compared to the mid-depth sonde, which suggests that thermal stratification may be occurring at depth (Figure 4.1.11). It is also possible that a groundwater or tidally influenced source could be contributing colder water at depth, or it could a combination of effects occurring in tandem. Minimum temperatures at the Brown’s Pool station were observed in freshwater habitat during closed conditions in October (Figures 4.1.11 and 4.1.6).

Maximum Backwater Area Temperature

Austin Creek had a maximum temperature of 19.2 °C, a mean temperature of 16.4 °C, and a minimum temperature of 14.2 °C (Table 4.1.1). Temperatures remained fairly consistent during the period of observation, which was cut short by a lack of water in early August during drought conditions (Figure 4.1.12).

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.

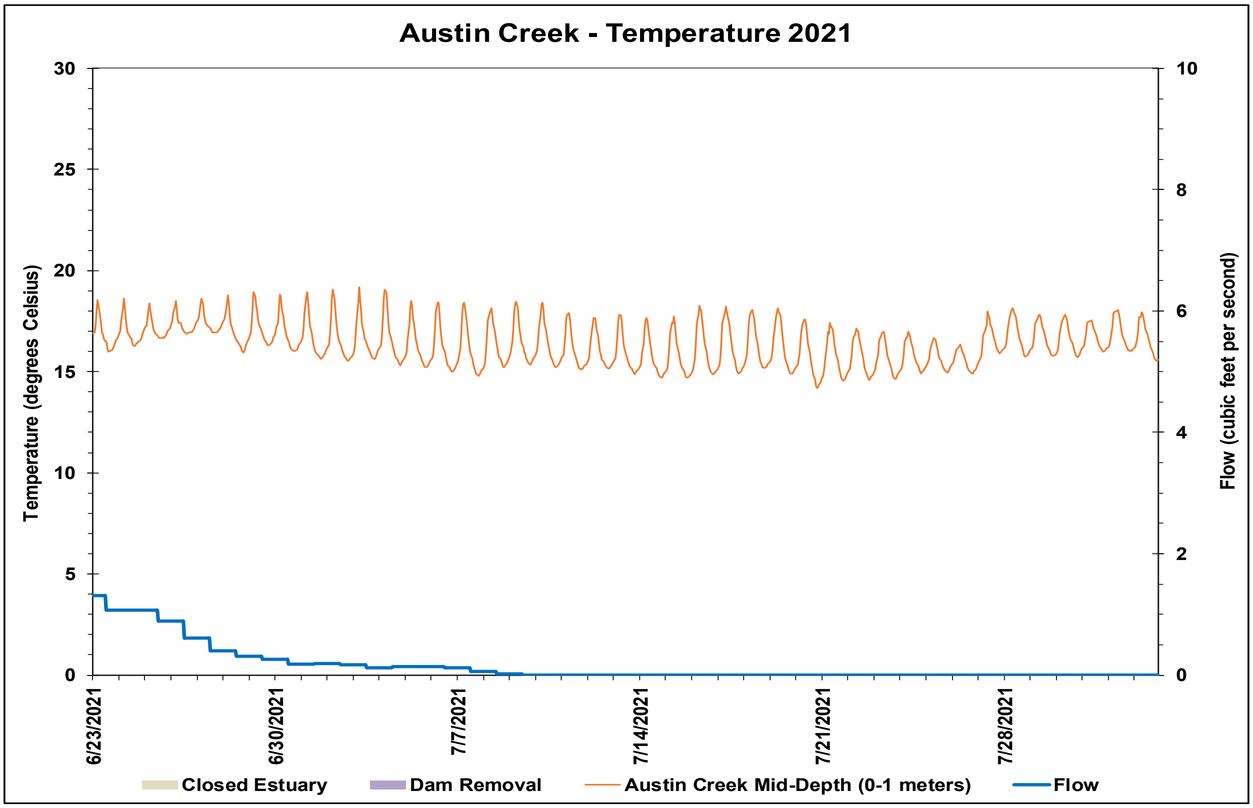


Figure 4.1.12. 2021 Austin Creek Temperature and Flow Graph. Sonde pulled early due to lack of creek flow during drought conditions.

DO levels are also a function of nutrients, which can accumulate in water and promote plant and algal growth that both produce and consume 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 system.

Lower and Middle Reach DO

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 10.3 mg/L, the mid-depth sonde had a mean DO concentration of 6.5 mg/L (Table 4.1.1). The surface sonde was observed to experience supersaturation concentrations, primarily during open conditions, that contributed to the higher mean value. The mid-depth sonde was also observed to experience supersaturation conditions, as well as occasional hypoxic to anoxic conditions that contributed to the lower mean value. These supersaturation

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

events were generally observed during open conditions, whereas anoxic to hypoxic events were observed during open and closed conditions (Figure 4.1.13).

The effect of closed conditions at the surface sonde was variable as DO concentrations were observed to decrease in the degree of daily fluctuation during May and October closures, but otherwise remain consistent with overall seasonal concentrations (Figure 4.1.13). The Patty's Rock surface sonde had a minimum DO concentration of 6.5 mg/L (Table 4.1.1). Minimum concentrations were observed to occur in brackish to saline water during open conditions (Figures 4.1.13 and 4.1.3).

DO concentrations were observed to become hypoxic to anoxic at the Patty's Rock mid-depth sonde during open and closed conditions (Figure 4.1.7). The minimum DO concentration at the mid-depth sonde was 0.0 mg/L, which occurred in between early May closure events as well as during the October closure event (Table 4.1.1 and Figure 4.1.13).

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 sonde primarily during open estuary conditions (Figure 4.1.13). Supersaturation events typically occurred during open conditions at the mid-depth sonde. 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 19.7 mg/L, which corresponded to approximately 242% saturation (Table 4.1.1). The maximum DO concentration at the mid-depth sonde was 15.9 mg/L, which corresponded to approximately 182% 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 brackish to saline water and freshwater to a lesser degree during open barrier beach conditions (Figure 4.1.14). Whereas, dissolved oxygen concentrations were observed to steadily decline over a period of days during barrier beach closures in brackish to saline conditions. However, dissolved oxygen concentrations were observed to recover between and after closures as oxygenated saline water or freshwater migrated back into the station (Figure 4.1.14).

The Willow Creek sonde had a minimum DO concentration of 0.1 mg/L, a mean DO concentration of 8.1 mg/L, and a maximum DO concentration of 18.2 mg/L (208%) (Table 4.1.1).

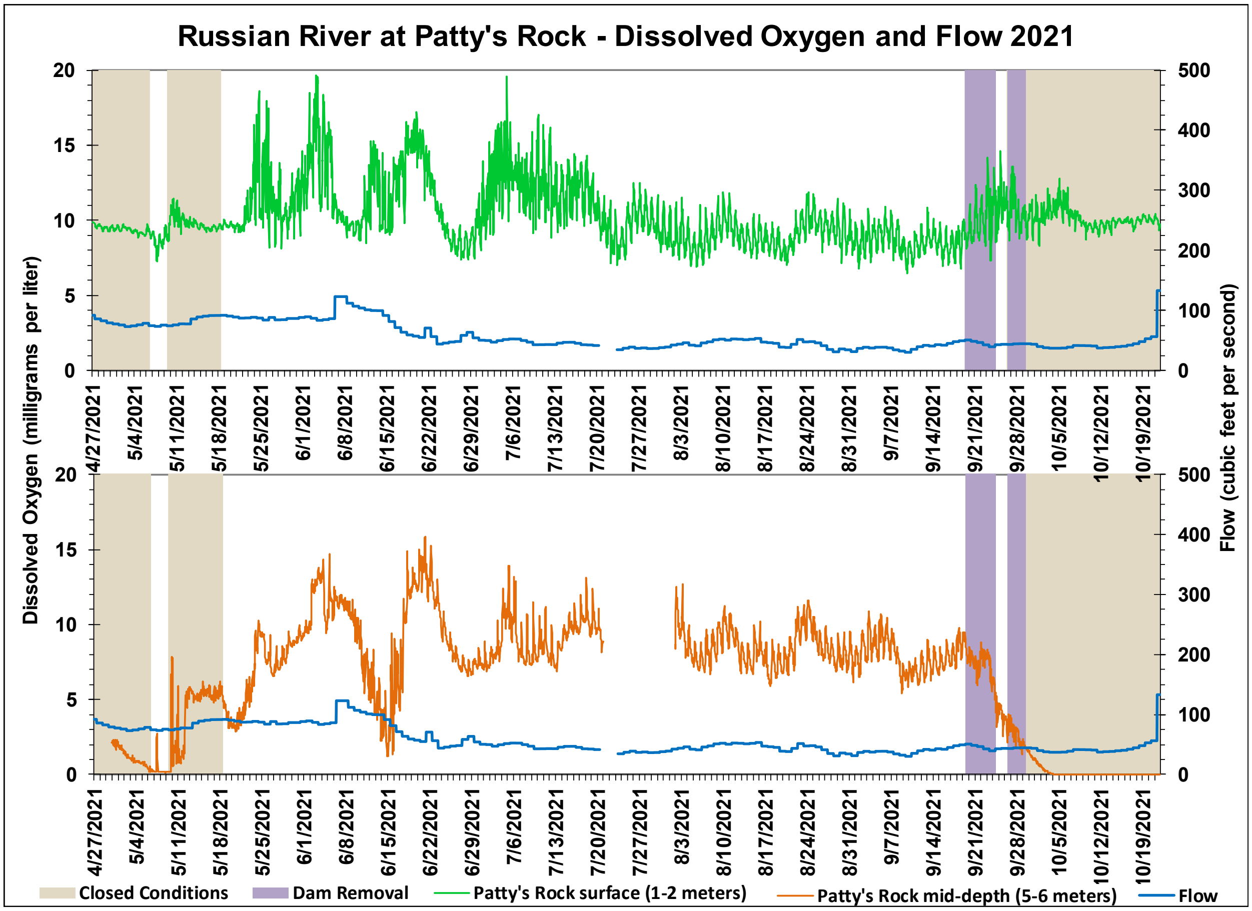


Figure 4.1.13. 2021 Russian River at Patty's Rock Dissolved Oxygen and Flow Graph

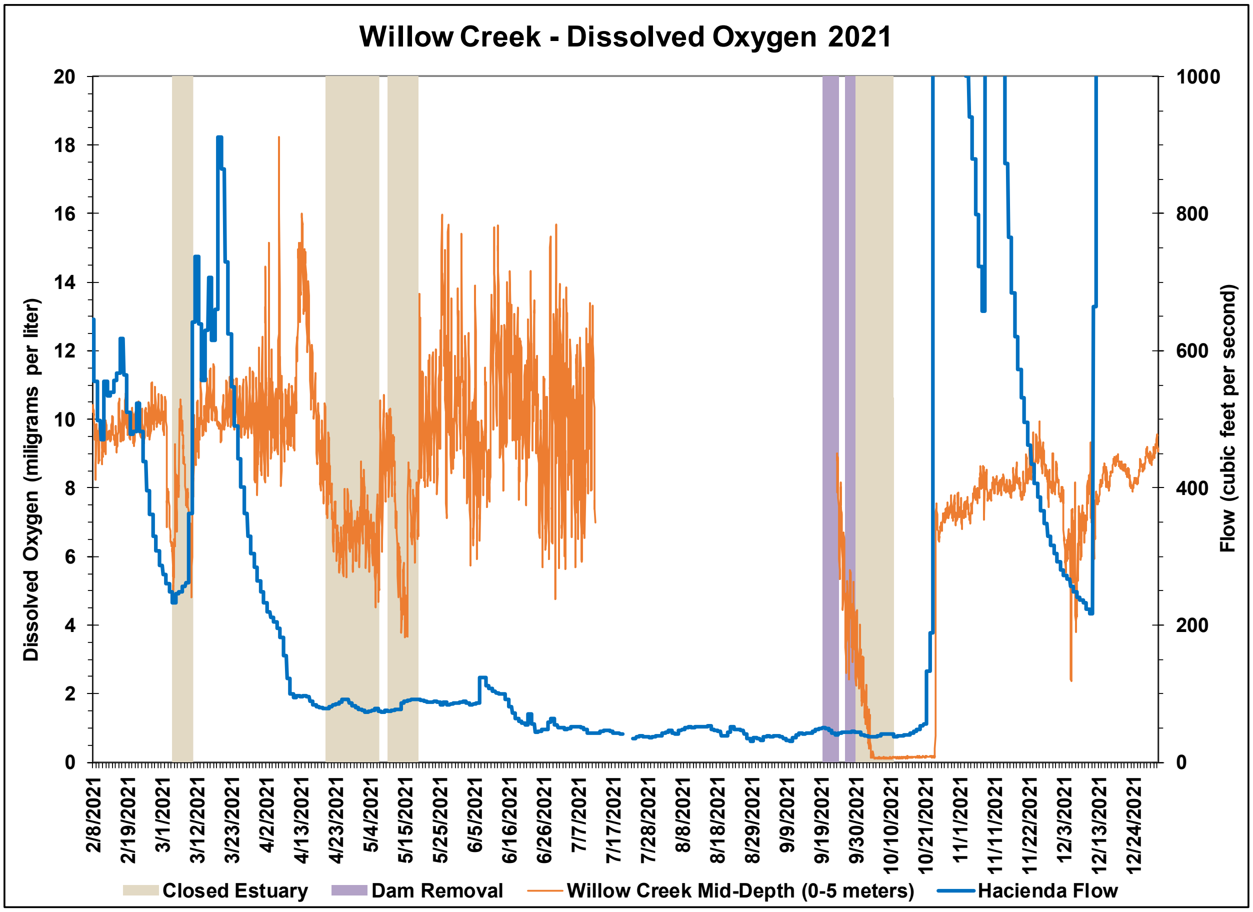


Figure 4.1.14. 2021 Willow Creek Dissolved Oxygen and Russian River Flow Graph

Upper Reach DO

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.

Conditions at the bottom sonde at Freezeout Creek remained predominantly brackish throughout the monitoring season. Whereas the mid-depth sonde remained predominantly freshwater habitat through late-June before becoming brackish through late September during open conditions (Figure 4.1.5). Conditions briefly returned to freshwater during summer dam removal and estuary closure at the end of September before becoming brackish again during closure in mid-October. The Brown's Pool station remained predominantly freshwater habitat at the mid-depth sonde during the 2021 monitoring season, with slightly brackish conditions that remained below 1 ppt occurring predominantly at the bottom sonde (Figure 4.1.6).

Depressed oxygen concentrations declining to hypoxic and anoxic levels were observed to occur at both sondes at the Freezeout Creek station in brackish and freshwater habitat during open and closed Estuary conditions (Figure 4.1.15). Anoxic conditions were predominant during

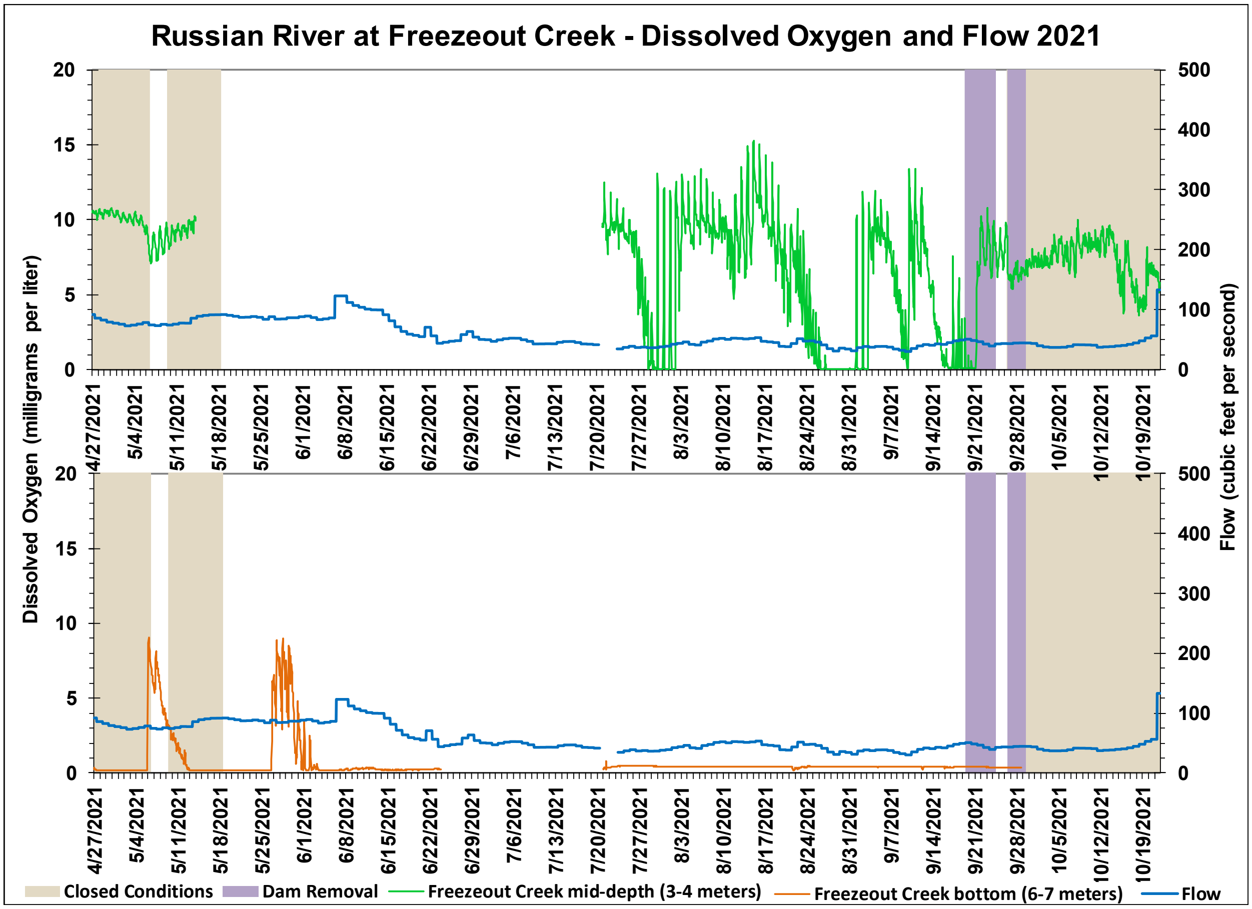


Figure 4.1.15. 2021 Russian River at Freezeout Creek Dissolved Oxygen and Flow Graph

open and closed conditions at the bottom of the Brown's Pool station, whereas they were only briefly hypoxic at the mid-depth sonde during open conditions (Figure 4.1.16).

The Freezeout Creek mid-depth sonde malfunctioned from mid-May through late-July, but had a minimum concentration of 0.0 mg/L, a mean DO concentration of 6.8 mg/L, and a maximum concentration of 15.3 mg/L (176%) during the time it was functioning (Table 4.1.1).

The Freezeout Creek bottom sonde had a minimum concentration of 0.2 mg/L, a mean DO concentration of 0.7 mg/L, and a maximum concentration of 9.0 mg/L (100%) (Table 4.1.1).

The Brown's Pool mid-depth sonde had a minimum concentration of 1.7 mg/L, a mean DO concentration of 6.6 mg/L, and a maximum concentration of 10.3 mg/L (119%) (Table 4.1.1). The Brown's Pool bottom sonde was observed to have a minimum DO concentration of 0.0 mg/L, a mean concentration of 0.2 mg/L, and a maximum concentration of 8.5 mg/L (83%) (Table 4.1.1).

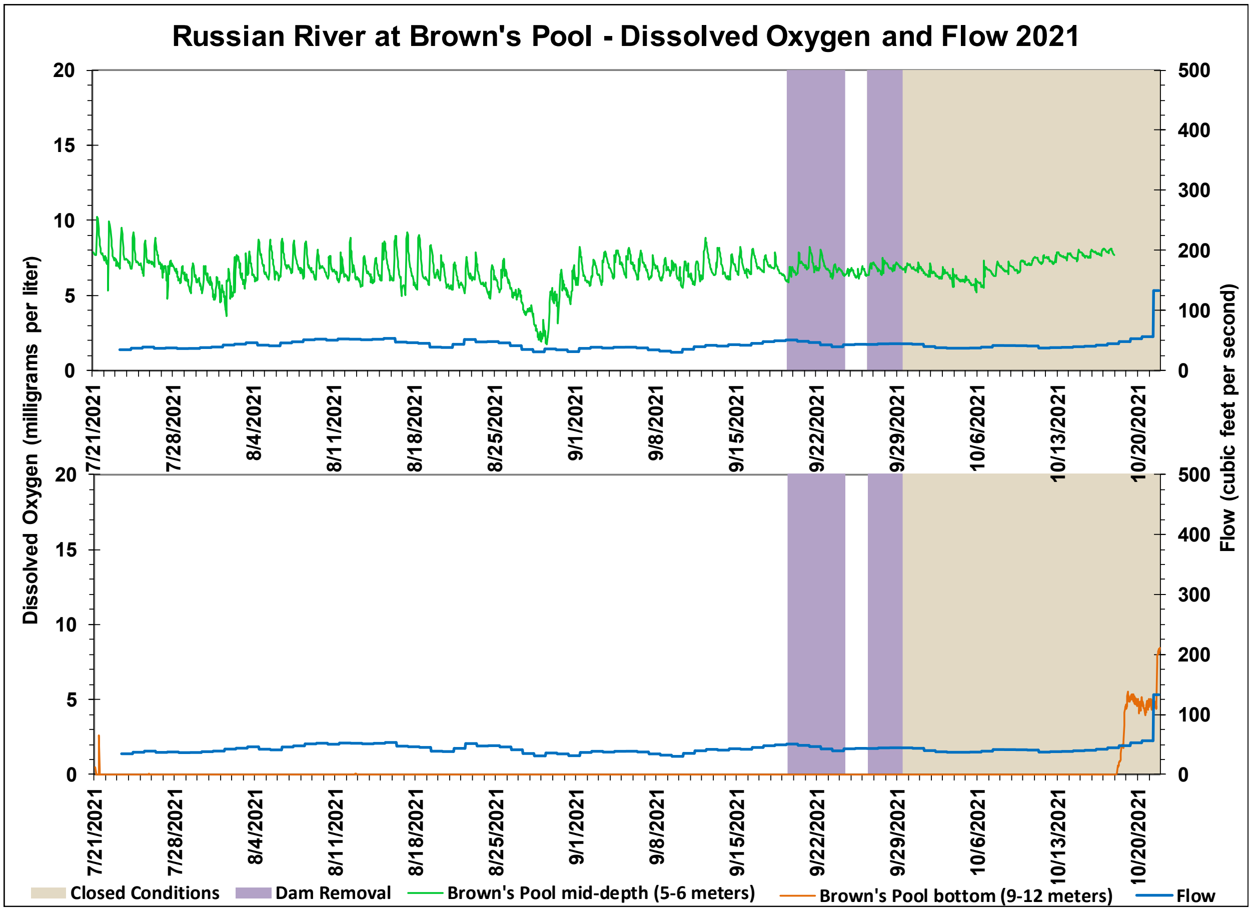


Figure 4.1.16. 2021 Russian River at Brown's Pool Dissolved Oxygen and Flow Graph

Maximum Backwater Area DO

The Austin Creek sonde was deployed from June to early 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 0.0 mg/L, a mean concentration of 1.5 mg/L, and a maximum concentration of 6.5 mg/L (69%) (Table 4.1.1).

Minimum concentrations at Austin Creek were observed when flows dropped to zero (0) cfs in July and the remaining pools, including the Austin Creek station, became isolated from each other (Figure 4.1.17).

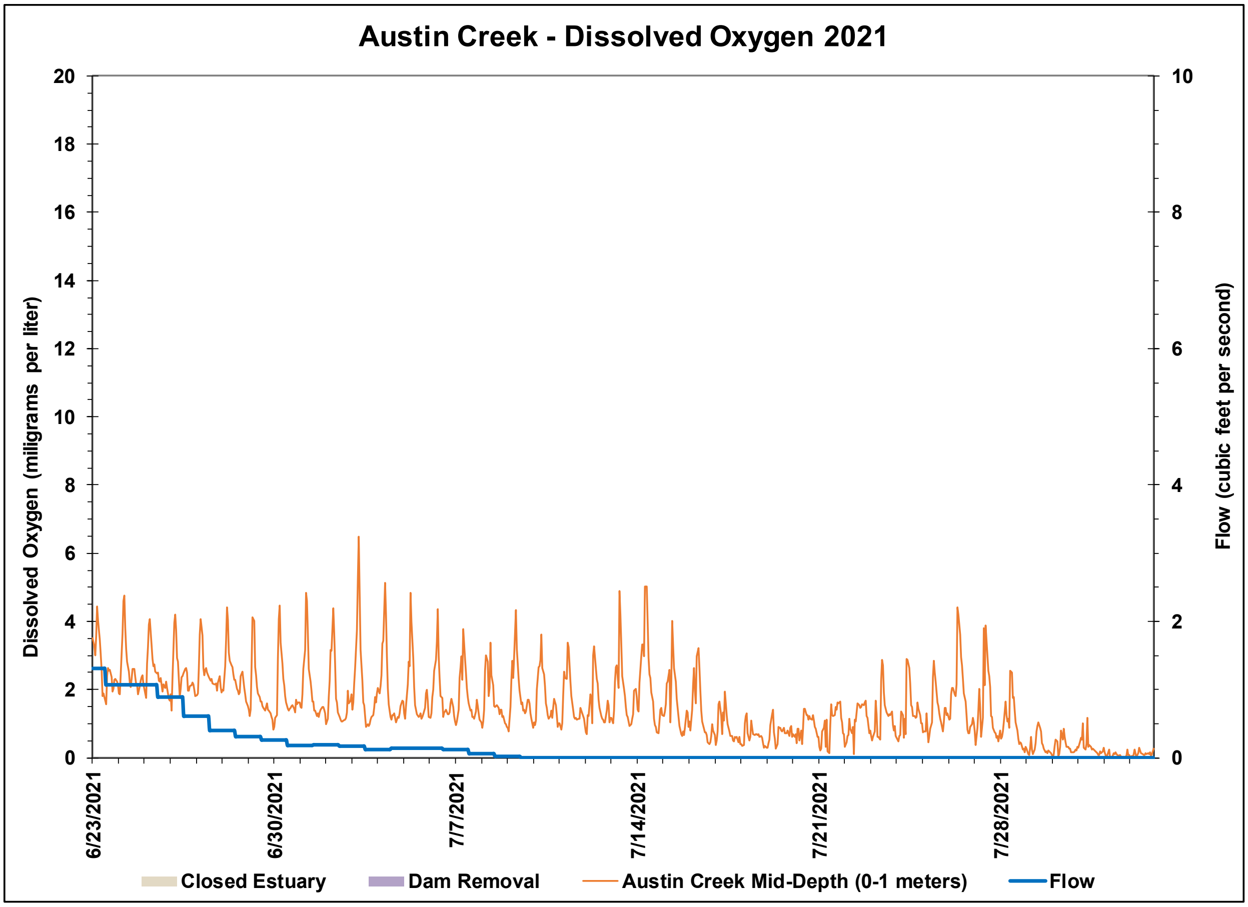


Figure 4.1.17. 2021 Austin Creek Dissolved Oxygen and Flow Graph. Sonde pulled early due to lack of creek flow during drought conditions.

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 may be 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).

Lower and Middle Reach pH

The Patty's Rock surface sonde had a minimum pH value of 7.7, a mean pH value of 8.2, and a maximum pH value of 9.2 pH (Table 4.1.1). The Patty's Rock mid-depth sonde had a minimum pH value of 5.1, a mean pH value of 7.8, and a maximum pH value of 8.6 pH. (Figure 4.1.18).

Patty's Rock pH values were observed to vary with increases and decreases of DO concentrations, with higher values generally observed during supersaturation conditions and lower values during hypoxic and anoxic conditions (Figures 4.1.18 and 4.1.13). Overall, pH

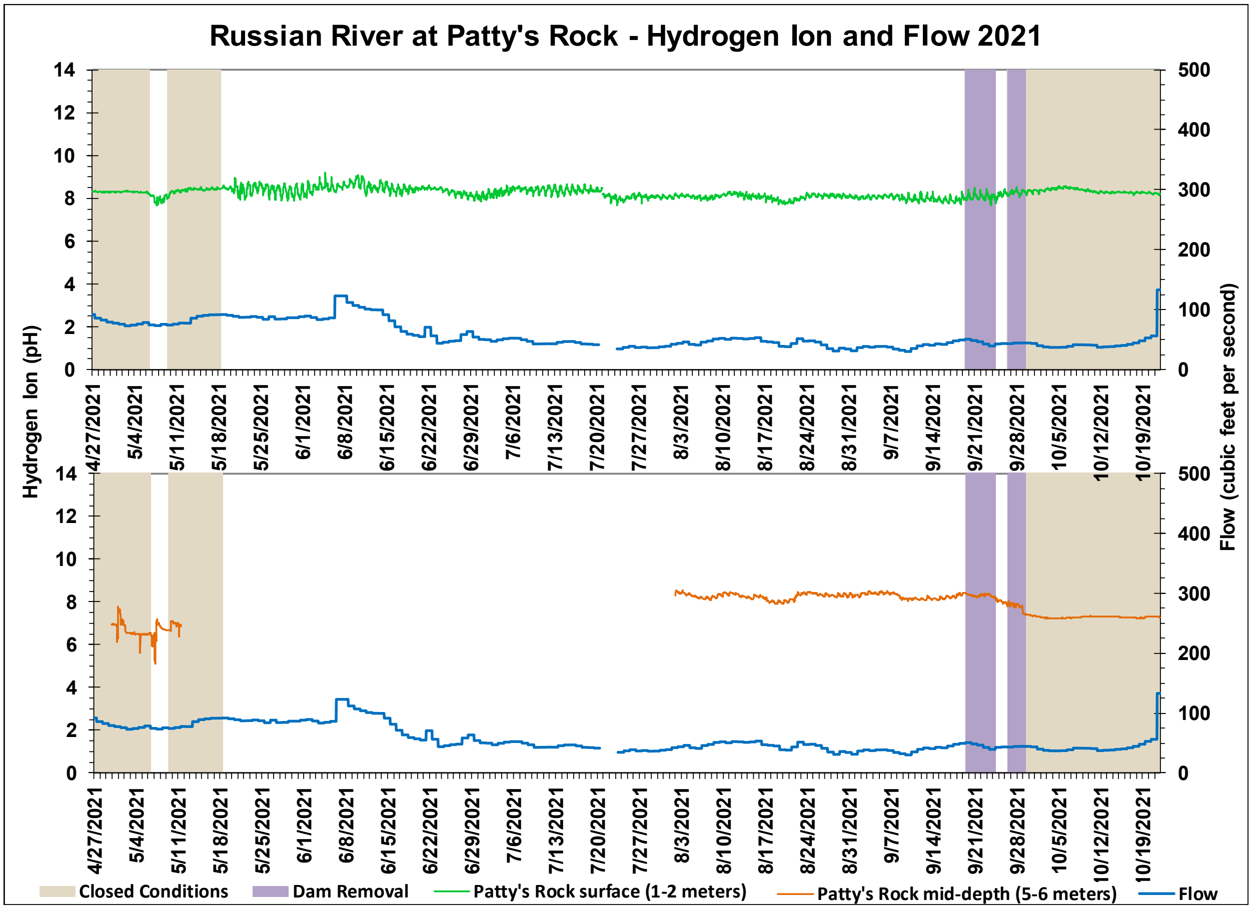


Figure 4.1.18. 2021 Russian River at Patty's Rock Hydrogen Ion and Flow Graph

values did not appear to be significantly affected by summer flows or closed conditions and remained fairly stable through the monitoring period.

The Willow Creek station had a minimum pH value of 6.7, a mean pH value of 7.5, and a maximum pH value of 8.9 (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 4.1.19 and 4.1.14).

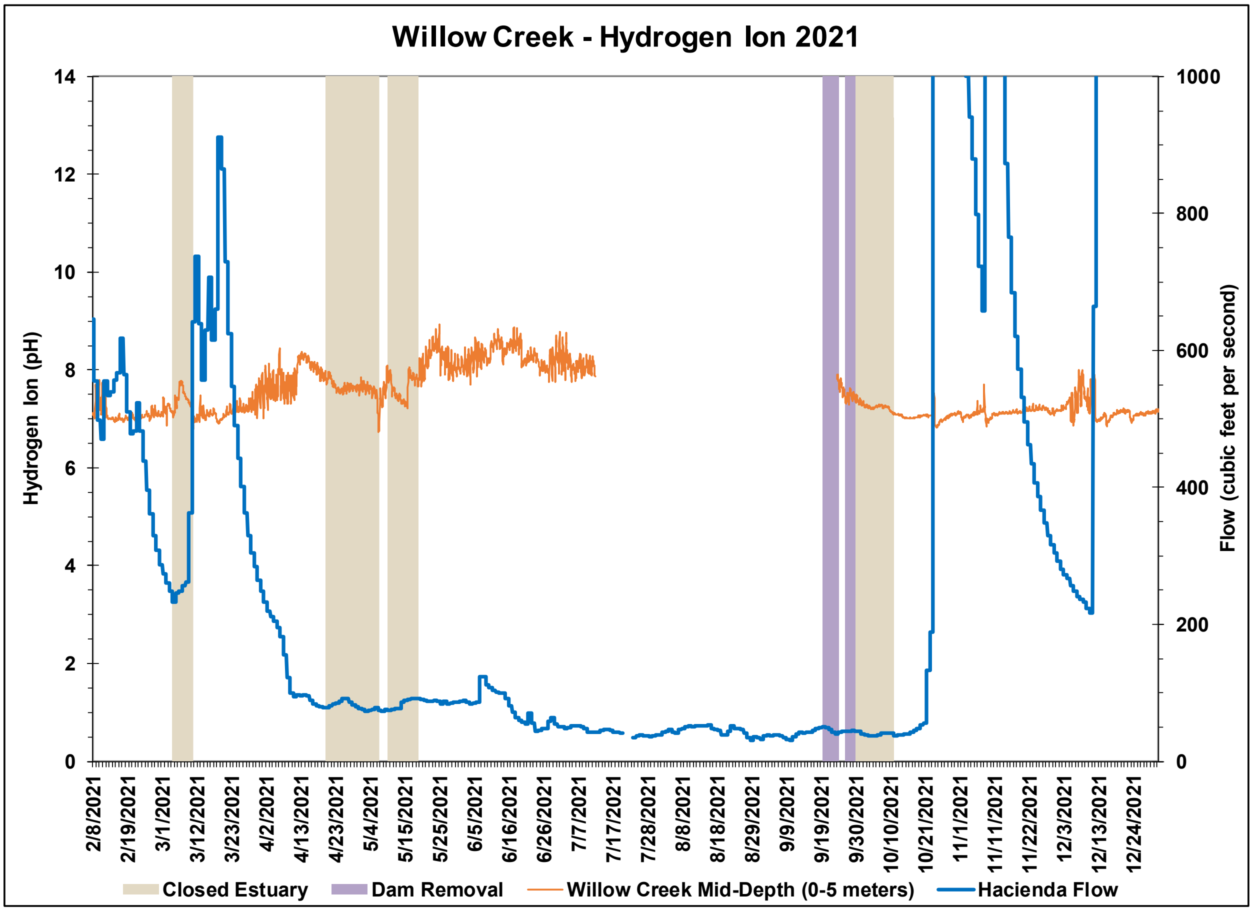


Figure 4.1.19. 2021 Willow Creek Hydrogen Ion and Russian River Flow Graph

Upper Reach pH

The Freezeout Creek mid-depth sonde recorded a minimum pH value of 6.9, a mean pH value of 8.0, and a maximum pH value of 9.1 (Table 4.1.1). The Freezeout Creek bottom sonde had a minimum pH value of 6.0, a mean pH value of 6.6, and a maximum pH value of 8.7 (Table 4.1.1).

The Freezeout Creek station had pH values that were observed to vary with DO concentrations in the presence of both freshwater and brackish water (Figures 4.1.20 and 4.1.15).

The Brown's Pool mid-depth sonde had a minimum pH value of 7.1, a mean pH value of 7.6, and a maximum pH value of 8.6 (Table 4.1.1). The Brown's Pool bottom sonde had a minimum pH value of 5.7, a mean pH value of 6.4, and a maximum pH value of 7.7 (Table 4.1.1). Minimum pH values occurred at the bottom sonde in brackish water during anoxic conditions when the Estuary was open (Figures 4.1.21 and 4.1.16).

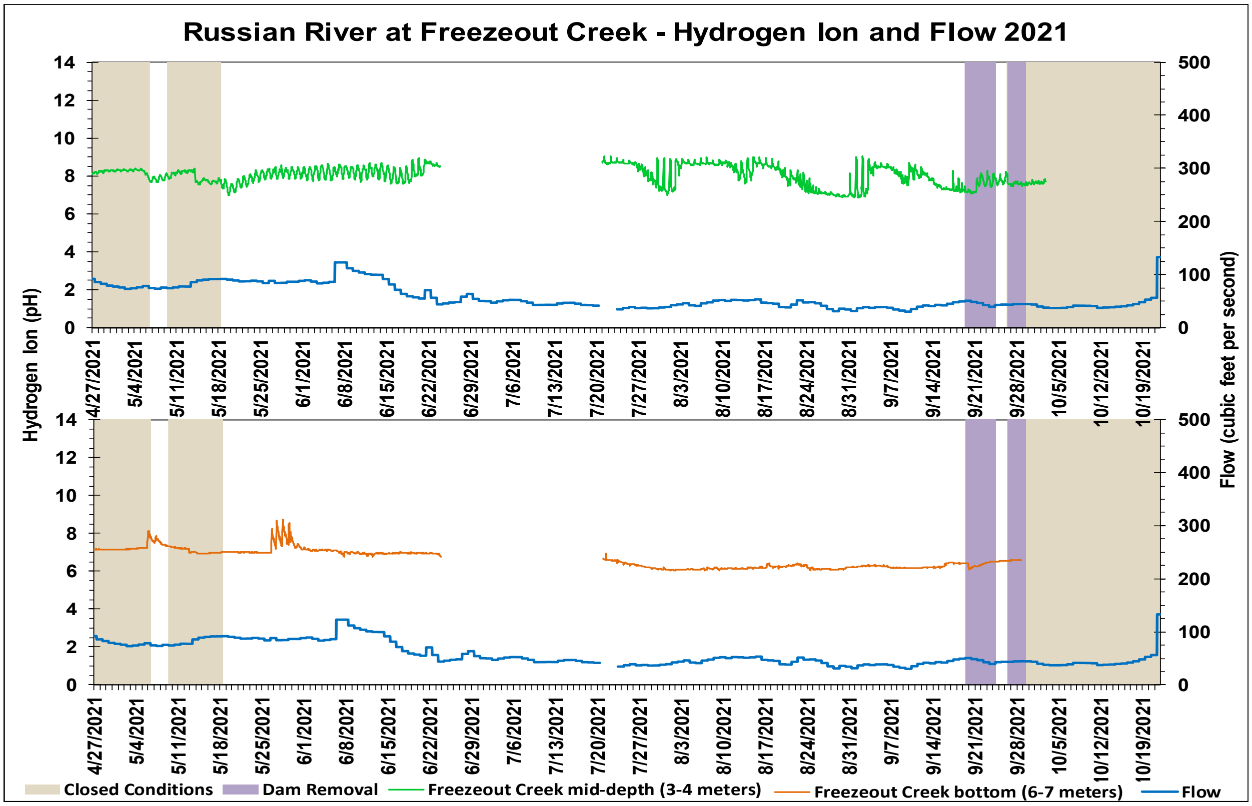


Figure 4.1.20. 2021 Russian River at Freezeout Creek Hydrogen Ion and Flow Graph

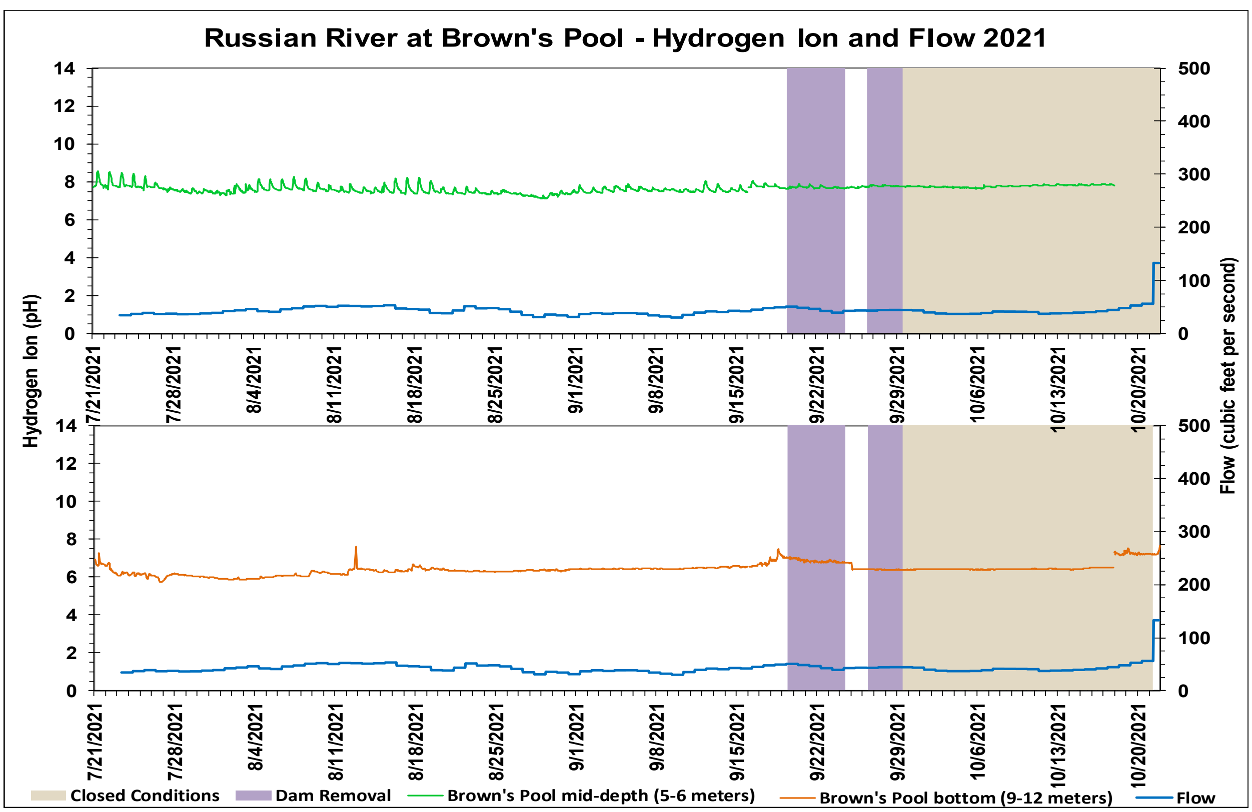


Figure 4.1.21. 2021 Russian River at Brown's Pool Hydrogen Ion and Flow Graph

Maximum Backwater Area pH

The Austin Creek sonde had a minimum pH value of 7.0, a mean pH value of 7.1, and a maximum pH value of 7.3 (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 4.1.22 and 4.1.17).

Grab Sampling

Sonoma Water staff conducted weekly grab sampling from 4 May to 19 October at three freshwater stations in the MBA, 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 over a ten day period (Tables 4.1.2 through 4.1.7). Samples collected and analyzed for nutrients, turbidity, *Chlorophyll a*, and indicator bacteria are discussed below. Other sample results including total and dissolved organic carbon and total dissolved solids are not discussed, but are included (Table 4.1.2 through 4.1.4).

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).

Highlighted values indicate those values exceeding EPA Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion III (EPA, 2000). Lab analysis constraints in 2021 resulted in a method detection limit (MDL) for *Chlorophyll a*, which is the level of accuracy for a given lab analysis to provide a valid concentration of a given constituent, that was higher than the EPA criteria for exceedances for *Chlorophyll a* in rivers and streams. Put simply, the EPA exceedance criteria for *Chlorophyll a* in rivers and streams is approximately 0.0018 mg/L, whereas the lab analysis MDL for *Chlorophyll a* was 0.0030 mg/L. Therefore, some lab results for *Chlorophyll a* that are listed as non-detect (ND) could potentially have concentrations above the criteria and below the MDL, which in turn could result in an under representation of the actual number of exceedances observed. However, for reporting purposes, only those exceedances that are quantified will be included in the summation.

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.

Finally, it must be emphasized that the EPA criteria are not adopted standards and are therefore both subject to change (if it is determined that the guidelines or criteria are not accurate indicators) and are not currently enforceable.

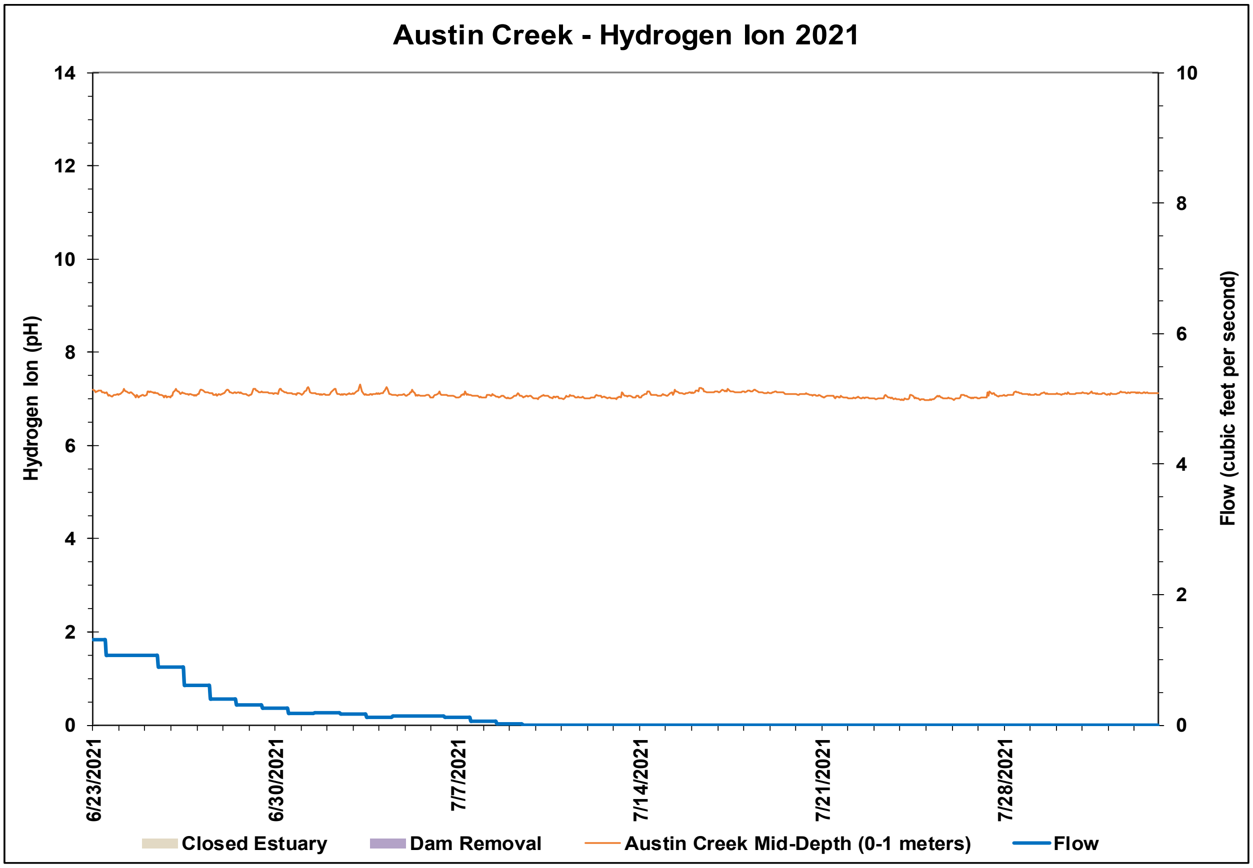


Figure 4.1.22. 2021 Austin Creek Hydrogen Ion and Flow Graph. Sonde pulled early due to lack of creek flow during drought conditions.

Total Nitrogen

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.

The EPA criteria for Total Nitrogen was exceeded five times (5 of 87 or 5.8%), including two exceedances at Vacation Beach and three exceedances at Patterson Point during the 2021 monitoring period with Hacienda flows ranging from approximately 33.8 cfs to 44.4 cfs (Tables 4.1.2 through 4.1.4 and Figure 4.1.23). Most of the exceedances were observed to occur during summer dam removal and closed estuary conditions in September and October (Figure 4.1.23). There were several non-detects (ND) of total nitrogen that occurred periodically throughout the season during open and closed conditions, as well as during summer dam removal, with flows ranging from 36.5 cfs to 120 cfs (Tables 4.1.2 through 4.1.4 and Figure 4.1.23).

The maximum total nitrogen concentration observed at Patterson Point was 0.56 mg/L on 30 September during closed conditions with a flow of approximately 44.4 cfs (Table 4.1.2 and Figure 4.1.23). The minimum concentration at Patterson Point was non-detect (ND), which

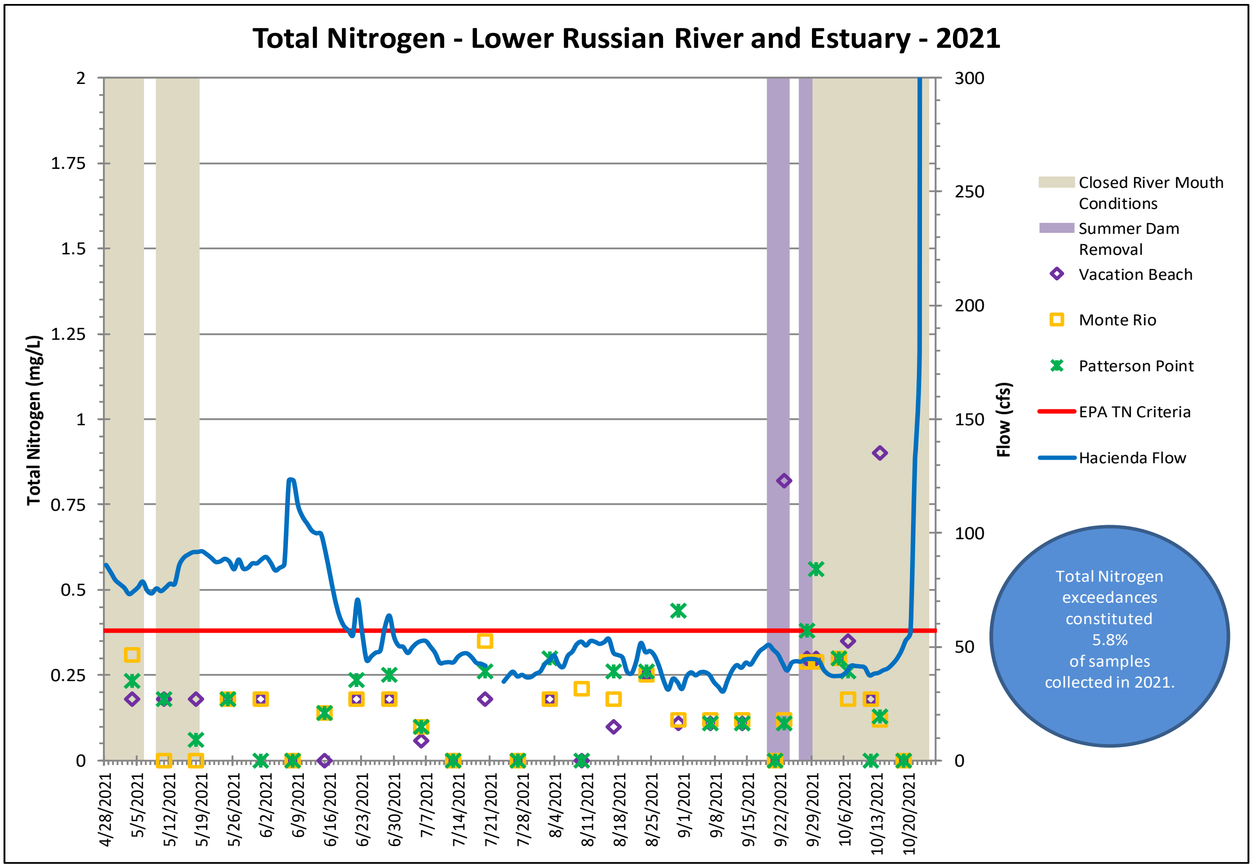


Figure 4.1.23. 2021 Russian River Grab Sampling Results for Total Nitrogen

occurred eight (8) times during open and closed conditions with flows ranging from approximately 36.5 cfs to 120 cfs (Table 4.1.2).

The maximum total nitrogen concentration observed at Monte Rio was 0.35 mg/L on 20 July during open conditions with a flow of approximately 41.4 cfs (Table 4.1.3 and Figure 4.1.23). The minimum concentration at Monte Rio was ND, which occurred seven (7) times during open and closed conditions and flows that ranged from approximately 36.5 to 120 cfs (Table 4.1.3).

The maximum total nitrogen concentration observed at Vacation Beach was 0.90 mg/L which occurred on 14 October during closed conditions and a flow of approximately 38.1 cfs (Table 4.1.4 and Figure 4.1.23). The minimum concentration at Vacation Beach was ND, which occurred seven (7) times during open and closed conditions and flows that ranged from approximately 36.5 to 120 cfs (Table 4.1.4).

Total Phosphorus

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). All three lower river stations predominantly exceeded the EPA criteria for total phosphorous (61 of 87 or 70.1%) in 2021 with flows that ranged from 33.8 cfs to 120 cfs, continuing a trend of consistent exceedances observed in previous years (Tables 4.1.2 through 4.1.4 and Figure 4.1.24).

Table 4.1.2. 2021 Russian River at Patterson Point Station Grab Sample Results

Patterson Point	Temperature	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen**	Phosphorus, Total	Total Orthophosphate	Dissolved Organic Carbon	Total Organic Carbon	Total Dissolved Solids	Turbidity	Chlorophyll-a	USGS 11467000 RR near Guerneville (Hacienda)***	Estuary Condition	Jenner Gauge
MDL*		0.20	0.10	0.00010	0.040	0.050	0.20	0.50	0.010	0.030	0.600	0.300	10	0.10	0.0010	Flow Rate****		
Date	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	(cfs)		(ft)
5/4/2021	22.4	0.18	ND	ND	ND	ND	ND	0.18	**0.050**	0.11	1.44	1.83	140	2.2	ND	72.8	Closed	5.90
5/11/2021	22.4	0.18	ND	ND	ND	ND	ND	0.18	**0.054**	0.12	1.66	1.74	160	1.2	**0.0037**	74.3	Closed	2.74
5/18/2021	19.8	0.18	ND	ND	ND	ND	ND	0.18	**0.043**	0.075	1.53	1.61	80	2.1	ND	91.6	Closed	4.89
5/25/2021	21.1	0.18	ND	ND	ND	ND	ND	0.18	**0.037**	0.069	1.20	1.69	140	1.0	ND	86.6	Open	1.30
6/1/2021	22.6	0.18	ND	ND	ND	ND	ND	0.18	**0.037**	0.071	1.59	1.84	140	**2.7**	ND	87.8	Open	0.67
6/8/2021	20.6	ND	ND	ND	ND	ND	ND	ND	**0.037**	0.052	1.3	1.68	120	1.0	ND	120	Open	2.95
6/15/2021	22.7	ND	ND	ND	ND	ND	ND	ND	**0.035**	0.053	1.39	1.74	140	1.8	**0.0037**	90.8	Open	0.93
6/22/2021	23.4	0.18	ND	ND	ND	ND	ND	0.18	**0.041**	0.073	1.72	2.16	150	1.1	**0.0043**	70.3	Open	0.97
6/29/2021	23.3	0.18	ND	ND	ND	ND	ND	0.18	**0.057**	0.10	1.57	2.14	130	**2.6**	**0.0053**	63.6	Open	0.67
7/6/2021	23.1	ND	ND	ND	0.057	ND	ND	0.057	**0.040**	0.074	1.59	1.96	140	0.66	ND	52.5	Open	0.80
7/13/2021	23.2	ND	ND	ND	ND	ND	ND	ND	**0.039**	0.066	1.54	1.94	130	0.44	ND	42.9	Open	0.67
7/20/2021	23.6	0.18	ND	ND	ND	ND	ND	0.18	**0.040**	0.063	1.49	1.77	140	0.40	**0.0032**	41.4	Open	1.30
7/27/2021	22.4	ND	ND	ND	ND	ND	ND	ND	**0.036**	0.054	1.73	1.83	130	1.6	ND	36.5	Open	0.46
8/3/2021	23.0	0.18	ND	ND	ND	ND	ND	0.18	**0.042**	0.056	1.33	1.84	140	1.6	ND	43.8	Open	0.97
8/10/2021	23.3	ND	ND	ND	ND	ND	ND	ND	**0.030**	0.039	1.60	1.66	140	1.5	ND	52.2	Open	0.50
8/17/2021	23.5	0.10	ND	ND	ND	ND	ND	0.10	**0.026**	0.031	1.56	1.60	140	0.54	ND	47.2	Open	1.00
8/24/2021	21.0	0.14	ND	ND	0.11	ND	ND	0.25	**0.022**	0.031	1.21	1.51	150	0.83	ND	47.4	Open	0.70
8/31/2021	22.0	ND	ND	ND	0.11	ND	ND	0.11	0.017	0.038	1.12	1.66	160	0.87	ND	33.8	Open	1.64
9/7/2021	21.4	ND	ND	ND	0.11	ND	ND	0.11	0.013	ND	1.49	1.65	160	0.88	**0.0040**	37.2	Open	0.55
9/14/2021	21.2	ND	ND	ND	0.11	ND	ND	0.11	0.017	ND	1.52	1.90	140	0.86	**0.0035**	40.5	Open	1.52
9/21/2021	19.9	ND	ND	ND	ND	ND	ND	ND	0.018	ND	1.43	1.78	130	0.81	ND	48.6	Open	0.80
9/23/2021	20.3	0.70	ND	ND	0.12	ND	0.70	**0.82**	**0.060**	0.038	1.30	1.76	130	**3.1**	**0.0083**	42.5	Open	1.09
9/28/2021	19.9	0.18	ND	ND	0.12	ND	ND	0.30	0.020	0.039	1.24	1.62	140	0.84	**0.0032**	44.2	Closed	2.44
9/30/2021	19.9	0.18	ND	ND	0.12	ND	ND	0.30	0.021	0.031	1.37	1.55	150	0.57	ND	44.4	Closed	2.95
10/5/2021	18.0	0.18	ND	ND	0.12	ND	ND	0.30	0.018	ND	1.57	1.54	140	2.1	ND	36.6	Closed	3.54
10/7/2021	17.2	0.35	ND	ND	ND	ND	0.35	0.35	**0.025**	ND	1.25	1.60	150	0.58	**0.0032**	38.6	Closed	3.71
10/12/2021	15.5	0.18	ND	ND	ND	ND	ND	0.18	0.018	ND	1.13	1.45	140	1.3	ND	37.0	Closed	4.13
10/14/2021	15.5	0.79	ND	ND	0.11	ND	0.79	**0.90**	0.015	0.031	1.09	1.34	140	2.2	ND	38.1	Closed	4.26
10/19/2021	14.3	ND	ND	ND	ND	ND	ND	ND	0.015	0.12	1.14	1.46	140	**2.4**	ND	48.1	Closed	4.68

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** 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 Phosphorus: 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

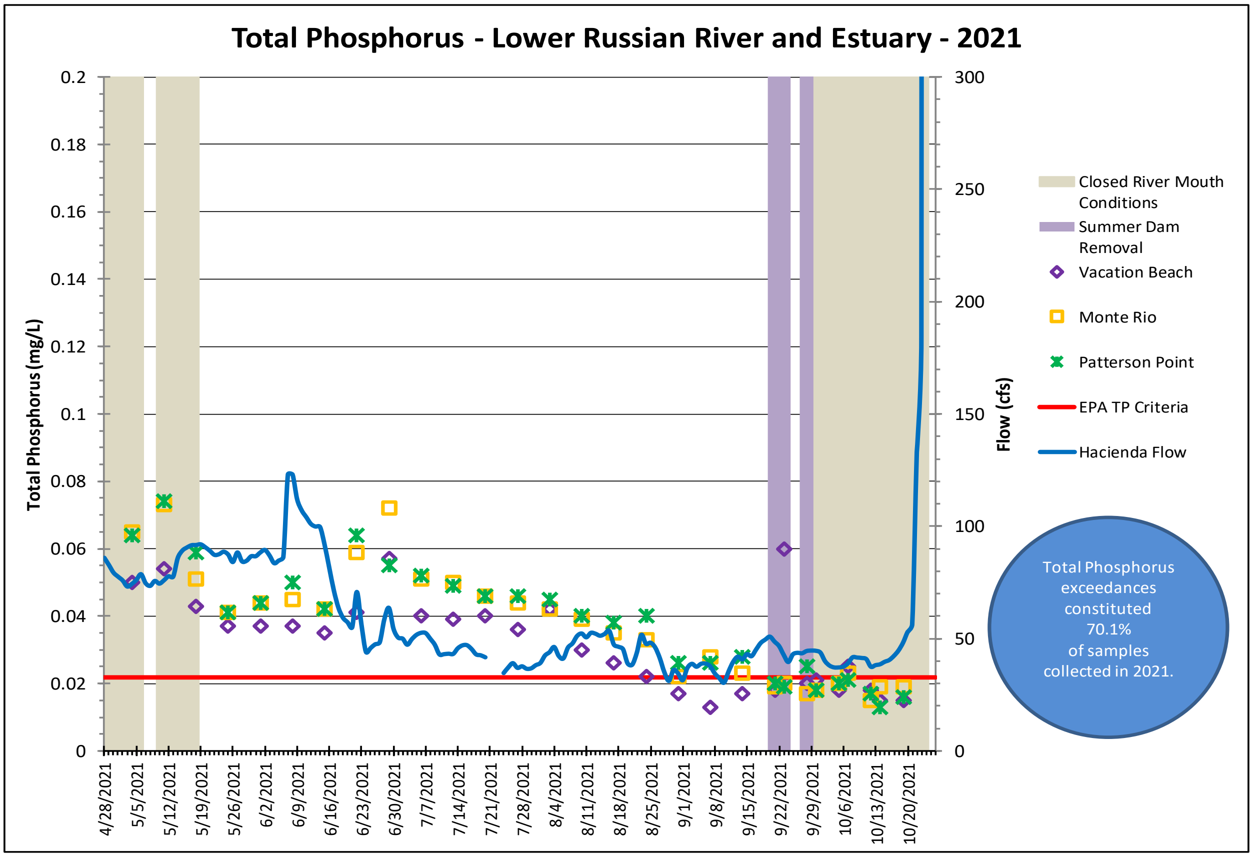


Figure 4.1.24. 2021 Russian River Grab Sampling Results for Total Phosphorus

Exceedances occurred during open and closed conditions, with concentrations generally declining through the monitoring season, including several concentrations below the EPA criteria from late August through October (Figure 4.1.24).The maximum total phosphorus concentration observed at Patterson Point was 0.074 mg/L on 11 May during closed conditions with a flow of approximately 74.3 cfs (Table 4.1.2 and Figure 4.1.24).

The minimum concentration at Patterson Point was 0.013 mg/L, which occurred on 14 October during closed conditions with a flow of approximately 38.1 cfs (Table 4.1.2). The lowest flow recorded during the sampling events was approximately 33.8 cfs, which occurred on 31 August during open conditions, with a concentration of 0.026 mg/L (Table 4.1.2).

The maximum total phosphorus concentration observed at Monte Rio was 0.073 mg/L on 11 May during closed conditions with a flow of approximately 74.3 cfs (Table 4.1.3 and Figure 4.1.24). The minimum concentration at Monte Rio was 0.015 mg/L, which occurred on 12 October during closed conditions, with a flow of approximately 37.0 cfs (Table 4.1.3). The lowest flow recorded during the sampling events was approximately 33.8 cfs, which occurred on 31 August during open conditions, with a concentration of 0.022 mg/L (Table 4.1.3).

The maximum total phosphorus concentration observed at Vacation Beach was 0.060 mg/L on 23 September during open conditions and summer dam removal, with a flow of approximately 42.5 cfs (Table 4.1.4 and Figure 4.1.24). The minimum concentration at Vacation Beach was

Table 4.1.3. 2021 Russian River at Monte Rio Station Grab Sample Results

Monte Rio	Temperature	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen**	Phosphorus, Total	Total Orthophosphate	Dissolved Organic Carbon	Total Organic Carbon	Total Dissolved Solids	Turbidity	Chlorophyll-a	USGS 11467000 RR near Guerneville (Hacienda)***	Estuary Condition	Jenner Gauge
MDL*		0.20	0.10	0.00010	0.040	0.050	0.20	0.50	0.010	0.030	0.600	0.300	10	0.10	0.0010	Flow Rate****		
Date	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	(cfs)		(ft)
5/4/2021	21.6	0.26	ND	ND	0.053	ND	0.26	0.31	**0.065**	0.15	1.54	1.87	170	1.5	ND	72.8	Closed	5.90
5/11/2021	22.0	ND	ND	ND	ND	ND	ND	ND	**0.073**	0.18	1.40	1.85	150	1.0	ND	74.3	Closed	2.74
5/18/2021	19.9	ND	ND	ND	ND	ND	ND	ND	**0.051**	0.13	1.19	1.60	1100	1.5	ND	91.6	Closed	4.89
5/25/2021	20.6	0.18	ND	ND	ND	ND	ND	0.18	**0.041**	0.081	1.25	1.78	140	0.94	ND	86.6	Open	1.14
6/1/2021	22.5	0.18	ND	ND	ND	ND	ND	0.18	**0.044**	0.088	1.31	1.86	140	1.6	ND	87.8	Open	0.71
6/8/2021	21.6	ND	ND	ND	ND	ND	ND	ND	**0.045**	0.089	1.65	1.75	130	1.1	ND	120	Open	2.95
6/15/2021	22.7	0.14	ND	ND	ND	ND	ND	0.14	**0.042**	0.078	1.42	1.85	140	1.9	ND	90.8	Open	0.93
6/22/2021	23.2	0.18	ND	ND	ND	ND	ND	0.18	**0.059**	0.12	1.59	2.11	130	1.1	ND	70.3	Open	0.97
6/29/2021	23.0	0.18	ND	ND	ND	ND	ND	0.18	**0.072**	0.077	1.58	2.40	130	1.6	ND	63.6	Open	0.84
7/6/2021	23.2	0.10	ND	ND	ND	ND	ND	0.10	**0.051**	0.090	1.58	2.03	160	0.99	ND	52.5	Open	0.71
7/13/2021	23.9	ND	ND	ND	ND	ND	ND	ND	**0.050**	0.083	1.59	1.90	140	0.71	ND	42.9	Open	0.63
7/20/2021	23.1	0.35	ND	ND	ND	ND	0.35	0.35	**0.046**	0.083	1.45	1.85	150	0.85	ND	41.4	Open	1.26
7/27/2021	21.9	ND	ND	ND	ND	ND	ND	ND	**0.044**	0.070	1.58	1.90	140	**2.8**	ND	36.5	Open	0.50
8/3/2021	22.5	0.18	ND	ND	ND	ND	ND	0.18	**0.042**	0.064	1.36	2.03	150	2.1	ND	43.8	Open	0.84
8/10/2021	22.7	0.21	ND	ND	ND	ND	0.21	0.21	**0.039**	0.051	1.36	1.73	140	**3.0**	ND	52.2	Open	0.50
8/17/2021	22.9	0.18	ND	ND	ND	ND	ND	0.18	**0.035**	0.039	1.35	1.65	150	1.0	ND	47.2	Open	1.00
8/24/2021	20.8	0.14	ND	ND	0.11	ND	ND	0.25	**0.033**	0.039	1.20	1.59	140	1.2	ND	47.4	Open	0.70
8/31/2021	21.7	ND	ND	ND	0.12	ND	ND	0.12	**0.022**	0.038	1.23	1.72	160	0.82	ND	33.8	Open	1.56
9/7/2021	21.1	ND	ND	ND	0.12	ND	ND	0.12	**0.028**	ND	1.47	1.67	170	1.0	**0.0032**	37.2	Open	0.46
9/14/2021	21.0	ND	ND	ND	0.12	ND	ND	0.12	**0.023**	ND	1.51	1.89	130	0.91	ND	40.5	Open	1.56
9/21/2021	19.7	ND	ND	ND	ND	ND	ND	ND	0.019	ND	1.40	1.76	150	0.98	ND	48.6	Open	0.71
9/23/2021	20.0	ND	ND	ND	0.12	ND	ND	0.12	0.020	ND	1.44	1.74	170	1.4	**0.063**	42.5	Open	0.97
9/28/2021	19.0	0.18	ND	ND	0.11	ND	ND	0.29	0.017	ND	1.34	1.65	150	0.79	**0.0048**	44.2	Closed	2.40
9/30/2021	18.8	0.18	ND	ND	0.11	ND	ND	0.29	0.018	ND	1.40	1.62	140	0.71	ND	44.4	Closed	2.95
10/5/2021	18.2	0.18	ND	ND	0.12	ND	ND	0.30	0.020	ND	1.43	1.66	150	2.2	ND	36.6	Closed	3.58
10/7/2021	17.2	0.18	ND	ND	ND	ND	ND	0.18	**0.023**	ND	1.23	1.63	140	1.0	**0.0037**	38.6	Closed	3.71
10/12/2021	14.8	0.18	ND	ND	ND	ND	ND	0.18	0.015	ND	1.16	1.46	140	1.2	**0.011**	37.0	Closed	4.13
10/14/2021	14.8	ND	ND	ND	0.12	ND	ND	0.12	0.019	0.039	1.12	1.41	150	1.5	ND	38.1	Closed	4.21
10/19/2021	14.1	ND	ND	ND	ND	ND	ND	ND	0.019	0.030	1.10	1.53	130	1.4	ND	48.1	Closed	4.59

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.

** 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 Phosphorus: 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

Table 4.1.4. 2021 Russian River at Vacation Beach Station Grab Sample Results

Vacation Beach	Temperature	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen**	Phosphorus, Total	Total Orthophosphate	Dissolved Organic Carbon	Total Organic Carbon	Total Dissolved Solids	Turbidity	Chlorophyll-a	USGS 11467000 RR near Guerneville (Hacienda)***	Estuary Condition	Jenner Gauge
MDL*		0.20	0.10	0.00010	0.040	0.050	0.20	0.50	0.010	0.030	0.600	0.300	10	0.10	0.0010	Flow Rate****		
Date	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	(cfs)		(ft)
5/4/2021	22.4	0.18	ND	ND	ND	ND	ND	0.18	**0.050**	0.11	1.44	1.83	140	2.2	ND	72.8	Closed	5.90
5/11/2021	22.4	0.18	ND	ND	ND	ND	ND	0.18	**0.054**	0.12	1.66	1.74	160	1.2	**0.0037**	74.3	Closed	2.74
5/18/2021	19.8	0.18	ND	ND	ND	ND	ND	0.18	**0.043**	0.075	1.53	1.61	80	2.1	ND	91.6	Closed	4.89
5/25/2021	21.1	0.18	ND	ND	ND	ND	ND	0.18	**0.037**	0.069	1.20	1.69	140	1.0	ND	86.6	Open	1.30
6/1/2021	22.6	0.18	ND	ND	ND	ND	ND	0.18	**0.037**	0.071	1.59	1.84	140	**2.7**	ND	87.8	Open	0.67
6/8/2021	20.6	ND	ND	ND	ND	ND	ND	ND	**0.037**	0.052	1.3	1.68	120	1.0	ND	120	Open	2.95
6/15/2021	22.7	ND	ND	ND	ND	ND	ND	ND	**0.035**	0.053	1.39	1.74	140	1.8	**0.0037**	90.8	Open	0.93
6/22/2021	23.4	0.18	ND	ND	ND	ND	ND	0.18	**0.041**	0.073	1.72	2.16	150	1.1	**0.0043**	70.3	Open	0.97
6/29/2021	23.3	0.18	ND	ND	ND	ND	ND	0.18	**0.057**	0.10	1.57	2.14	130	**2.6**	**0.0053**	63.6	Open	0.67
7/6/2021	23.1	ND	ND	ND	0.057	ND	ND	0.057	**0.040**	0.074	1.59	1.96	140	0.66	ND	52.5	Open	0.80
7/13/2021	23.2	ND	ND	ND	ND	ND	ND	ND	**0.039**	0.066	1.54	1.94	130	0.44	ND	42.9	Open	0.67
7/20/2021	23.6	0.18	ND	ND	ND	ND	ND	0.18	**0.040**	0.063	1.49	1.77	140	0.40	**0.0032**	41.4	Open	1.30
7/27/2021	22.4	ND	ND	ND	ND	ND	ND	ND	**0.036**	0.054	1.73	1.83	130	1.6	ND	36.5	Open	0.46
8/3/2021	23.0	0.18	ND	ND	ND	ND	ND	0.18	**0.042**	0.056	1.33	1.84	140	1.6	ND	43.8	Open	0.97
8/10/2021	23.3	ND	ND	ND	ND	ND	ND	ND	**0.030**	0.039	1.60	1.66	140	1.5	ND	52.2	Open	0.50
8/17/2021	23.5	0.10	ND	ND	ND	ND	ND	0.10	**0.026**	0.031	1.56	1.60	140	0.54	ND	47.2	Open	1.00
8/24/2021	21.0	0.14	ND	ND	0.11	ND	ND	0.25	**0.022**	0.031	1.21	1.51	150	0.83	ND	47.4	Open	0.70
8/31/2021	22.0	ND	ND	ND	0.11	ND	ND	0.11	0.017	0.038	1.12	1.66	160	0.87	ND	33.8	Open	1.64
9/7/2021	21.4	ND	ND	ND	0.11	ND	ND	0.11	0.013	ND	1.49	1.65	160	0.88	**0.0040**	37.2	Open	0.55
9/14/2021	21.2	ND	ND	ND	0.11	ND	ND	0.11	0.017	ND	1.52	1.90	140	0.86	**0.0035**	40.5	Open	1.52
9/21/2021	19.9	ND	ND	ND	ND	ND	ND	ND	0.018	ND	1.43	1.78	130	0.81	ND	48.6	Open	0.80
9/23/2021	20.3	0.70	ND	ND	0.12	ND	0.70	**0.82**	**0.060**	0.038	1.30	1.76	130	**3.1**	**0.0083**	42.5	Open	1.09
9/28/2021	19.9	0.18	ND	ND	0.12	ND	ND	0.30	0.020	0.039	1.24	1.62	140	0.84	**0.0032**	44.2	Closed	2.44
9/30/2021	19.9	0.18	ND	ND	0.12	ND	ND	0.30	0.021	0.031	1.37	1.55	150	0.57	ND	44.4	Closed	2.95
10/5/2021	18.0	0.18	ND	ND	0.12	ND	ND	0.30	0.018	ND	1.57	1.54	140	2.1	ND	36.6	Closed	3.54
10/7/2021	17.2	0.35	ND	ND	ND	ND	0.35	0.35	**0.025**	ND	1.25	1.60	150	0.58	**0.0032**	38.6	Closed	3.71
10/12/2021	15.5	0.18	ND	ND	ND	ND	ND	0.18	0.018	ND	1.13	1.45	140	1.3	ND	37.0	Closed	4.13
10/14/2021	15.5	0.79	ND	ND	0.11	ND	0.79	**0.90**	0.015	0.031	1.09	1.34	140	2.2	ND	38.1	Closed	4.26
10/19/2021	14.3	ND	ND	ND	ND	ND	ND	ND	0.015	0.12	1.14	1.46	140	**2.4**	ND	48.1	Closed	4.68

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** 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.
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Recommended EPA Criteria based on Aggregate Ecoregion III
Total Phosphorus: 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

0.013 mg/L, which occurred on 7 September during open conditions and a flow of approximately 37.2 cfs (Table 4.1.4). The lowest flow recorded during the sampling events was approximately 33.8 cfs, which occurred on 31 August during open conditions, with a concentration of 0.017 mg/L (Table 4.1.4).

Turbidity

The EPA recommended criteria of 2.34 nephelometric turbidity units (NTU) for turbidity was exceeded one (1) time at Patterson Point, two (2) times at Monte Rio, and four (4) times at Vacation Beach (7 of 87 or 8.1%) during the 2021 monitoring season (Tables 4.1.2 through 4.1.4). Exceedances were observed to occur periodically through the season with open and closed conditions and flows ranging from 36.5 cfs to 87.8 cfs (Figure 4.1.25). One of the exceedances at Vacation Beach occurred during summer dam removal. Turbidity values were occasionally higher at Vacation Beach than at the other stations, and may be a result of increased turbulence from the Vacation Beach summer dam located just upstream of the monitoring location.

The maximum turbidity value observed at Patterson Point was 7.5 NTU on 10 August during open conditions and a flow of approximately 52.2 cfs at the Hacienda USGS gage (Table 4.1.2 and Figure 4.1.25). The minimum value at Patterson Point was 0.46 NTU, which occurred on 13 July during open conditions, with a flow of approximately 42.9 cfs (Table 4.1.2). The lowest flow recorded during sampling was approximately 33.8 cfs, which occurred on 31 August during open conditions, with a value of 1.2 NTU (Table 4.1.2).

The maximum turbidity value observed at Monte Rio was 3.0 NTU on 10 August during open conditions and a flow of approximately 52.2 cfs (Table 4.1.3 and Figure 4.1.25). The minimum value at Monte Rio was 0.71 NTU, which occurred twice, on 13 July during open conditions and a flow of approximately 42.9 cfs and on 30 September during closed conditions and a flow of 44.4 cfs (Table 4.1.3). The lowest flow recorded during sampling was approximately 33.8 cfs, which occurred on 31 August during open conditions, with a value of 0.82 NTU (Table 4.1.3).

The maximum turbidity value observed at Vacation Beach was 3.1 NTU on 23 September during open conditions and summer dam removal, with a flow of approximately 42.5 cfs (Table 4.1.4 and Figure 4.1.25). The minimum value at Vacation Beach was 0.40 NTU, which occurred on 20 July during open conditions and a flow of approximately 41.4 cfs (Table 4.1.4). The lowest flow recorded during sampling was approximately 33.8 cfs, which occurred on 31 August during open conditions, with a value of 0.87 NTU (Table 4.1.4).

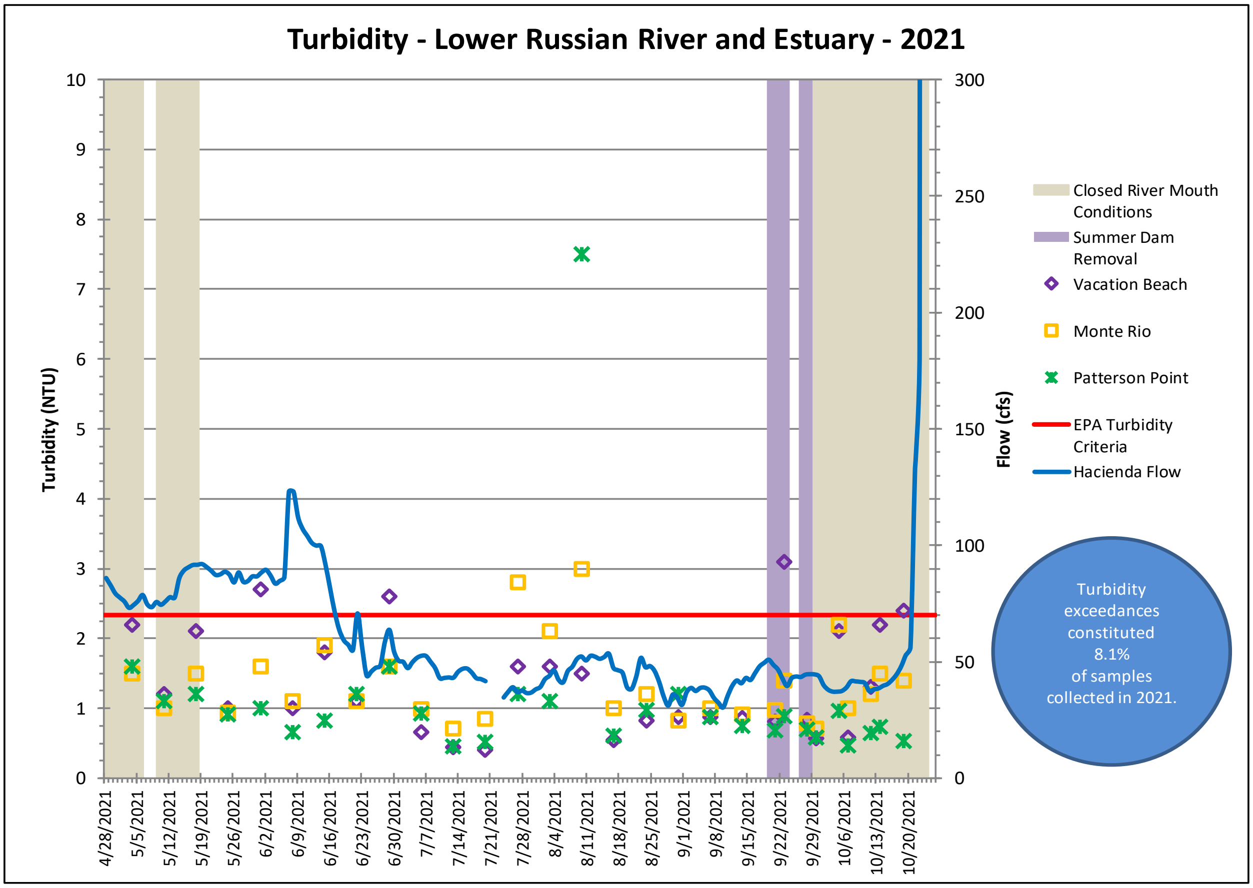


Figure 4.1.25. 2021 Russian River Grab Sampling Results for Turbidity

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).

As mentioned above, lab analysis constraints in 2021 resulted in the MDL for *Chlorophyll a* being higher than the EPA criteria for exceedances for *chlorophyll a* in rivers and streams. Therefore, some lab results for *Chlorophyll a* that are listed as non-detect (ND) could potentially have concentrations above the criteria and below the MDL. However, for reporting purposes, only those exceedances that are quantified will be included in the summation.

In addition, 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 results exceeded the EPA criteria ten (10) times at Vacation Beach and five (5) times each at Monte Rio and Patterson Point (20 of 87 or 23.0%) under open and closed conditions and summer dam removal, with flows that ranged from 36.6 cfs to 91.6 cfs (Tables 4.1.2 through 4.1.4 and Figure 4.1.26).

Chlorophyll a values varied through the season with several ND values occurring at all three stations, including during summer dam removal in September and barrier beach closures in May and October (Figure 4.1.26).

The maximum *Chlorophyll a* concentration observed at Patterson Point was 0.0040 mg/L on 3 August during open conditions with a flow of approximately 43.8 cfs (Table 4.1.2 and Figure 4.1.26). The minimum value at Patterson Point was ND, which occurred twenty-four (24) times through the season, during open and closed conditions and summer dam removal and flows that ranged from 33.8 to 120 cfs (Table 4.1.2).

The maximum *Chlorophyll a* concentration observed at Monte Rio was 0.063 mg/L on 23 September during open conditions and summer dam removal and a flow of approximately 42.5 cfs (Table 4.1.3 and Figure 4.1.26). The minimum value at Monte Rio was ND, which occurred twenty-four (24) times through the season during open and closed conditions with flows that ranged from 33.8 to 120 cfs (Table 4.1.3).

The maximum *Chlorophyll a* concentration observed at Vacation Beach was 0.0083 mg/L on 23 September during open conditions and summer dam removal and a flow of approximately 42.5 cfs (Table 4.1.4 and Figure 4.1.26). The minimum value at Vacation Beach was ND, which occurred nineteen (19) times through the season during open and closed conditions and summer dam removal and flows that ranged from 33.8 to 120 cfs (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 75th 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

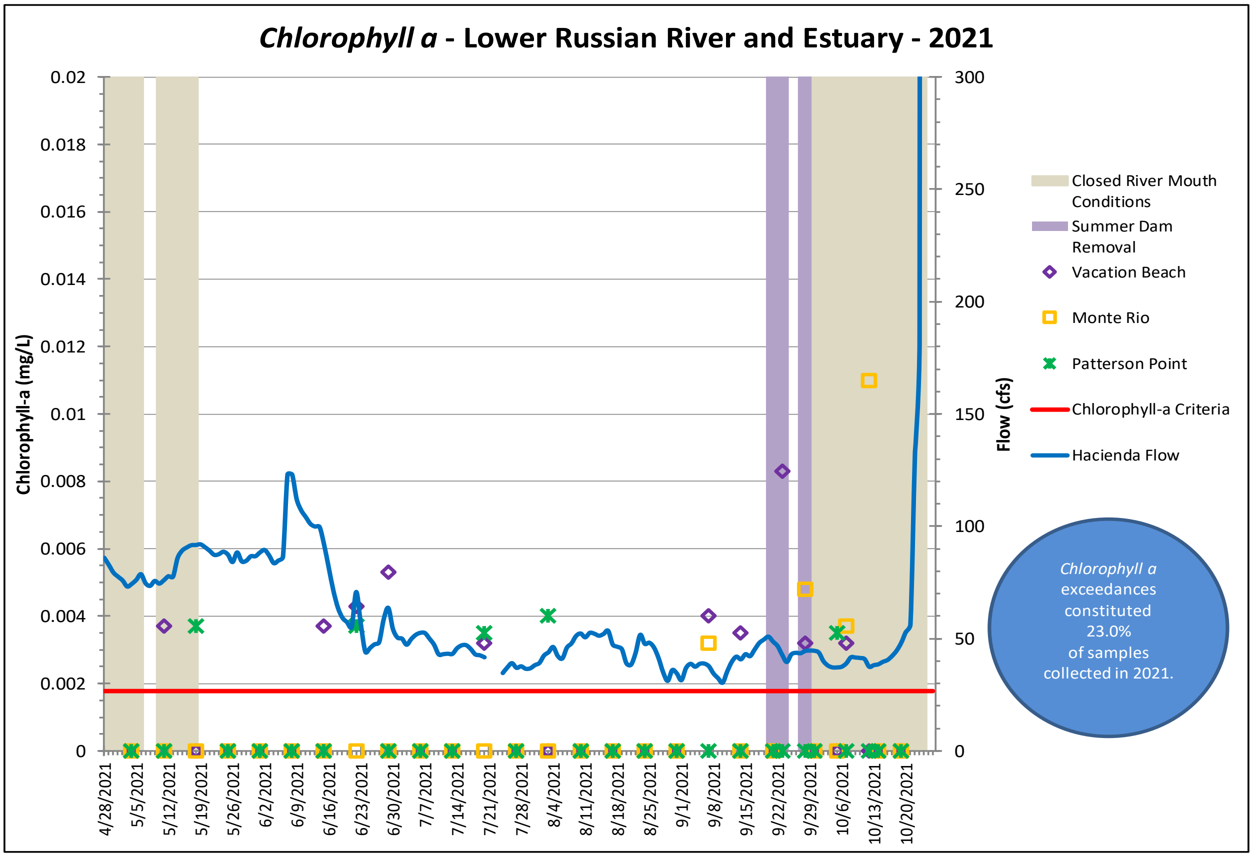


Figure 4.1.26. 2021 Russian River Grab Sampling Results for *Chlorophyll a*

standards, and are therefore both subject to change (if it is determined that the guidelines and/or criteria are not accurate indicators).

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 4.1.5 through 4.1.7 and Figures 4.1.27 and 4.1.28. Samples collected for Enterococcus were undiluted only and results are included in Tables 4.1.5 through 4.1.7 and Figure 4.1.29. 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. Total Coliform and E. coli data presented in Figures 4.1.27 and 4.1.28 utilize undiluted sample results unless the reporting limit has been exceeded, at which point the diluted results are utilized.

Beginning in 2014, staff at the NCRWQCB indicated that Enterococcus was not being utilized as a fecal indicator bacteria in freshwater environments due to evidence that Enterococcus colonies can be persistent in the water column and therefore its presence at a given freshwater 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

Table 4.1.5. 2021 Russian River at Patterson Point Station Indicator Bacteria Grab Sample Results

Patterson Point	Temperature	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)**	Estuary Condition	Jenner Gauge
MDL*		<1	<10	<1	<10	<1	Flow Rate***		
Date	°C	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)		(ft)
5/4/2021	21.1	435.2	650	10.9	10	8.4	72.8	Closed	5.90
5/11/2021	21.2	1119.9	1014	10	10	4.1	74.3	Closed	2.74
5/18/2021	19.9	1299.7	1274	13.5	41	4.1	91.6	Closed	4.89
5/25/2021	20.1	456.9	586	8.6	20	3.0	86.6	Open	0.97
6/1/2021	21.7	1046.2	906	12.2	30	5.2	87.8	Open	0.97
6/8/2021	21.5	1553.1	1354	24.6	10	28.8	120	Open	2.91
6/15/2021	22.1	1299.7	934	10.0	<10	14.8	90.8	Open	1.09
6/22/2021	22.9	1553.1	1119	6.2	20	8.5	70.3	Open	0.84
6/29/2021	22.8	816.4	1250	12.0	<10	29.6	63.6	Open	0.84
7/6/2021	23.1	1119.9	1553	13.4	10	3.0	52.5	Open	0.67
7/13/2021	23.1	1413.6	248	2.0	<10	2.0	42.9	Open	0.71
7/20/2021	22.8	1986.3	1935	1.0	<10	5.2	41.4	Open	1.09
7/27/2021	22.1	1732.9	2143	7.3	20	2.0	36.5	Open	0.55
8/3/2021	22.5	1299.7	1515	6.3	<10	8.5	43.8	Open	0.71
8/10/2021	22.6	1413.6	1439	4.1	10	10.7	52.2	Open	0.55
8/17/2021	22.8	>2419.6	1333	18.9	10	31.8	47.2	Open	1.00
8/24/2021	20.7	1119.9	1314	2.0	20	5.1	47.4	Open	0.70
8/31/2021	21.7	1732.9	1720	5.2	<10	**131.4**	33.8	Open	1.56
9/7/2021	21.0	1553.1	1314	5.2	74	8.6	37.2	Open	0.50
9/14/2021	20.9	980.4	882	19.3	10	14.5	40.5	Open	1.56
9/21/2021	19.8	>2419.6	1627	72.3	52	**112.4**	48.6	Open	0.63
9/23/2021	19.8	1986.3	2481	41.0	75	**73.3**	42.5	Open	0.97
9/28/2021	19.1	1203.3	1529	4.1	<10	16.8	44.2	Closed	2.40
9/30/2021	18.7	1203.3	1112	17.3	10	17.3	44.4	Closed	2.95
10/5/2021	18.4	727.0	1483	18.5	148	22.6	36.6	Closed	3.54
10/7/2021	17.8	1299.7	1210	35.5	31	23.5	38.6	Closed	3.75
10/12/2021	15.5	920.8	1067	33.6	41	38.8	37.0	Closed	4.13
10/14/2021	15.1	613.1	414	38.8	41	33.6	38.1	Closed	4.21
10/19/2021	14.6	547.5	323	22.6	10	47.1	48.1	Closed	4.63

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** United States Geological Survey (USGS) Continuous-Record Gaging Station
*** Flow rates are preliminary and subject to final revision by USGS.
Recommended California Department of Public Health (CDPH) Draft Guidance - Single Sample Maximum (SSM):
Total Coliform (SSM): 10,000 per 100ml
Environmental Protection Agency (EPA) Recreational Water Quality Criteria - Beach Action Value (BAV):
E. coli (BAV): 235 per 100 ml
Enterococcus(BAV): 61 per 100 ml
(Beach notification is recommended when indicator organisms exceed the SSM for Total Coliform or the BAV for *E. coli*) - Indicated by red text

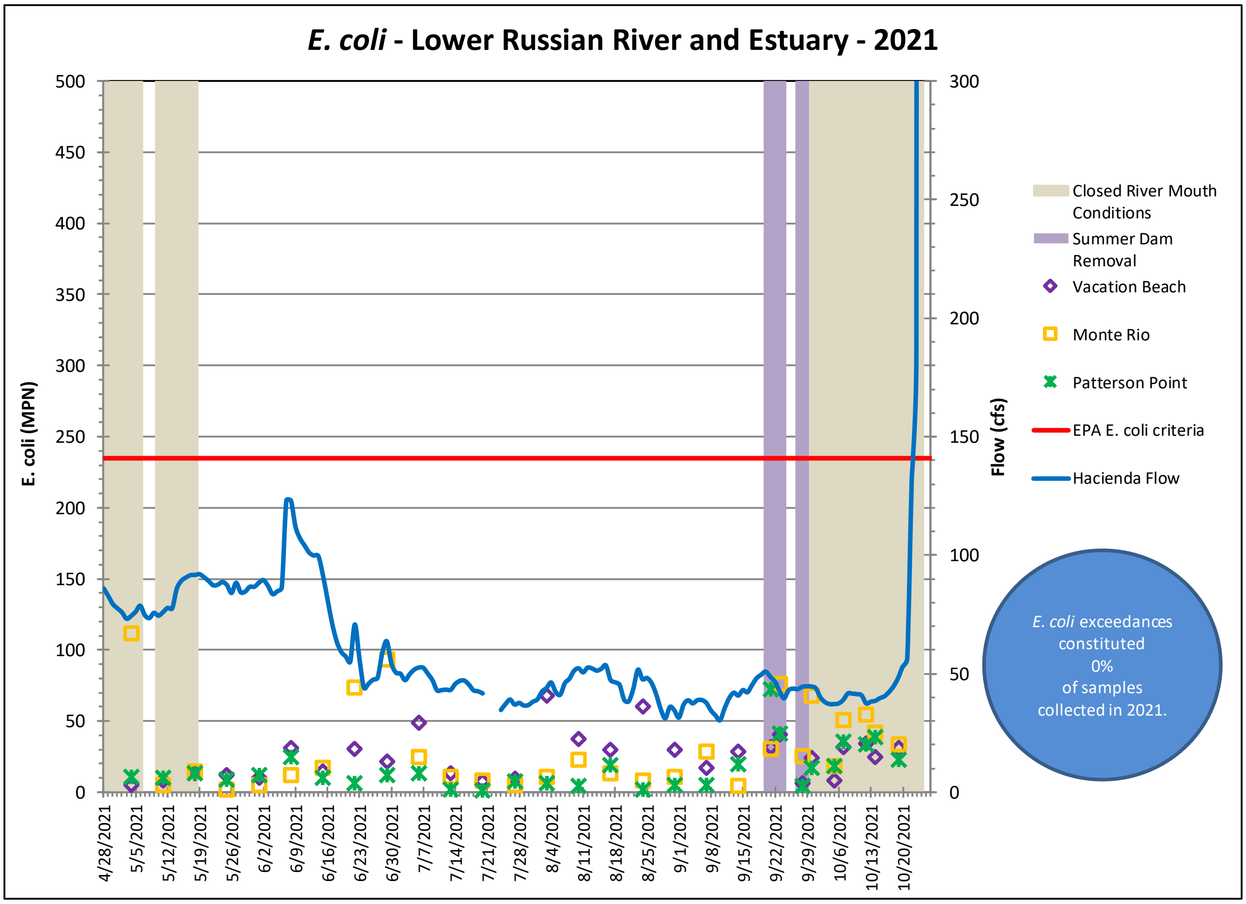


Figure 4.1.27. 2021 Russian River Grab Sampling Results for E. coli

management actions including mechanical breaching of the barrier beach to address potential threats to public health.

E. coli

There were no exceedances (0 of 87 or 0%) of the EPA criteria for E. coli during the 2021 monitoring season at the lower river stations (Tables 4.1.5 through 4.1.7 and Figure 4.1.27).

The maximum E. coli concentration observed at Patterson Point was 72.3 MPN/100mL, which occurred on 21 September during open conditions and summer dam removal and a flow of approximately 48.6 cfs (Table 4.1.5 and Figure 4.1.27).

The maximum E. coli concentration observed at Monte Rio was 111.9 MPN/100mL, which occurred on 4 May during closed conditions and a flow of approximately 72.8 cfs (Table 4.1.6 and Figure 4.1.27).

The maximum E. coli concentration observed at Vacation Beach was 67.6 MPN/100mL, which occurred on 3 August during open conditions and a flow of approximately 43.8 cfs (Table 4.1.7 and Figure 4.1.27).

Table 4.1.6. 2021 Russian River at Monte Rio Station Indicator Bacteria Grab Sample Results

Monte Rio	Temperature	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)**	Estuary Condition	Jenner Gauge
MDL*		<1	<10	<1	<10	<1	Flow Rate***		
Date	°C	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)		(ft)
5/4/2021	21.6	648.8	933	111.9	108	**128.1**	72.8	Closed	5.90
5/11/2021	22.0	816.4	1376	5.2	10	2.0	74.3	Closed	2.74
5/18/2021	19.9	1203.3	1137	14.6	41	4.1	91.6	Closed	4.89
5/25/2021	20.6	579.4	908	2.0	10	4.1	86.6	Open	1.14
6/1/2021	22.5	980.4	1211	5.2	<10	4.1	87.8	Open	0.71
6/8/2021	21.6	1732.9	1500	12.1	10	21.3	120	Open	2.95
6/15/2021	22.7	113.6	1274	17.3	10	18.7	90.8	Open	0.93
6/22/2021	23.2	>2419.6	4611	73.8	75	**128.1**	70.3	Open	0.97
6/29/2021	23.0	2419.6	2143	93.2	110	29.5	63.6	Open	0.84
7/6/2021	23.2	>2419.6	1860	24.9	52	7.5	52.5	Open	0.71
7/13/2021	23.9	>2419.6	2143	10.7	10	13.4	42.9	Open	0.63
7/20/2021	23.1	>2419.6	2613	8.4	<10	11.0	41.4	Open	1.26
7/27/2021	21.9	1986.3	2098	5.2	<10	13.4	36.5	Open	0.50
8/3/2021	22.5	1413.6	1616	10.9	10	14.5	43.8	Open	0.84
8/10/2021	22.7	1732.9	1872	22.8	31	26.2	52.2	Open	0.50
8/17/2021	22.9	1986.3	1935	13.2	10	27.2	47.2	Open	1.00
8/24/2021	20.8	1732.9	1935	8.4	10	3.1	47.4	Open	0.70
8/31/2021	21.7	1732.9	1565	10.9	20	20.3	33.8	Open	1.56
9/7/2021	21.1	920.8	1396	28.8	10	17.5	37.2	Open	0.46
9/14/2021	21.0	1413.6	1421	4.1	<10	12.1	40.5	Open	1.56
9/21/2021	19.7	1732.9	1153	30.1	20	53.7	48.6	Open	0.71
9/23/2021	20.0	2419.6	1664	75.9	75	59.1	42.5	Open	0.97
9/28/2021	19.0	1986.3	1723	25.3	10	36.4	44.2	Closed	2.40
9/30/2021	18.8	1986.3	1860	67.6	31	53.8	44.4	Closed	2.95
10/5/2021	18.2	1119.9	1354	18.5	20	23.3	36.6	Closed	3.58
10/7/2021	17.2	1299.7	1483	50.4	63	20.3	38.6	Closed	3.71
10/12/2021	14.8	980.4	985	54.6	134	**76.2**	37.0	Closed	4.13
10/14/2021	14.8	686.7	738	42.0	52	21.8	38.1	Closed	4.21
10/19/2021	14.1	547.5	414	33.6	52	39.9	48.1	Closed	4.59

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** United States Geological Survey (USGS) Continuous-Record Gaging Station
*** Flow rates are preliminary and subject to final revision by USGS.
Recommended California Department of Public Health (CDPH) Draft Guidance - Single Sample Maximum (SSM):
Total Coliform (SSM): 10,000 per 100ml
Environmental Protection Agency (EPA) Recreational Water Quality Criteria - Beach Action Value (BAV):
E. coli (BAV): 235 per 100 ml
Enterococcus(BAV): 61 per 100 ml
(Beach notification is recommended when indicator organisms exceed the SSM for Total Coliform or the BAV for *E. coli*) - Indicated by red text

Table 4.1.7. 2021 Russian River at Vacation Beach Station Indicator Bacteria Grab Sample Results

Vacation Beach	Temperature	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)**	Estuary Condition	Jenner Gauge
MDL*		<1	<10	<1	<10	<1	Flow Rate***		
Date	°C	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)		(ft)
5/4/2021	22.4	816.4	1259	5.2	10	4.1	72.8	Closed	5.90
5/11/2021	22.4	1986.3	2481	8.5	<10	6.3	74.3	Closed	2.74
5/18/2021	19.8	1203.3	1421	13.2	10	24.3	91.6	Closed	4.89
5/25/2021	21.1	980.4	906	12.2	<10	6.3	86.6	Open	1.30
6/1/2021	22.6	1553.1	1533	9.8	20	7.5	87.8	Open	0.67
6/8/2021	20.6	1732.9	2064	30.9	52	49.5	120	Open	2.95
6/15/2021	22.7	2419.6	2187	14.6	10	8.4	90.8	Open	0.93
6/22/2021	23.4	>2419.6	**>24196**	30.5	31	**190.4**	70.3	Open	0.97
6/29/2021	23.3	>2419.6	**14136**	21.8	10	31.3	63.6	Open	0.67
7/6/2021	23.1	>2419.6	5172	48.7	<10	39.9	52.5	Open	0.80
7/13/2021	23.2	>2419.6	4352	13.2	10	31.8	42.9	Open	0.67
7/20/2021	23.6	>2419.6	1935	7.5	10	11.0	41.4	Open	1.30
7/27/2021	22.4	2419.6	2909	9.7	20	13.2	36.5	Open	0.46
8/3/2021	23.0	>2419.6	2014	67.6	75	22.6	43.8	Open	0.97
8/10/2021	23.3	2419.6	1616	37.4	31	35.9	52.2	Open	0.50
8/17/2021	23.5	>2419.6	1860	29.5	52	27.5	47.2	Open	1.00
8/24/2021	21.0	>2419.6	2098	60.2	31	22.1	47.4	Open	0.70
8/31/2021	22.0	2419.6	2359	29.5	31	**65.0**	33.8	Open	1.64
9/7/2021	21.4	1413.6	2046	17.3	31	3.1	37.2	Open	0.55
9/14/2021	21.2	>2419.6	1281	28.2	20	28.5	40.5	Open	1.52
9/21/2021	19.9	1986.3	1658	31.8	20	26.9	48.6	Open	0.80
9/23/2021	20.3	>2419.6	1119	40.8	20	28.5	42.5	Open	1.09
9/28/2021	19.9	1732.9	1178	6.3	10	9.8	44.2	Closed	2.44
9/30/2021	19.9	1986.3	1500	24.1	10	7.2	44.4	Closed	2.95
10/5/2021	18.0	1413.6	1989	8.5	20	7.5	36.6	Closed	3.54
10/7/2021	17.2	1413.6	1497	31.5	52	8.6	38.6	Closed	3.71
10/12/2021	15.5	629.4	695	34.1	20	19.5	37.0	Closed	4.13
10/14/2021	15.5	727.0	762	24.9	52	22.6	38.1	Closed	4.26
10/19/2021	14.3	461.1	762	30.9	41	22.6	48.1	Closed	4.68

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** United States Geological Survey (USGS) Continuous-Record Gaging Station
*** Flow rates are preliminary and subject to final revision by USGS.
Recommended California Department of Public Health (CDPH) Draft Guidance - Single Sample Maximum (SSM):
Total Coliform (SSM): 10,000 per 100ml
Environmental Protection Agency (EPA) Recreational Water Quality Criteria - Beach Action Value (BAV):
E. coli (BAV): 235 per 100 ml
Enterococcus(BAV): 61 per 100 ml
(Beach notification is recommended when indicator organisms exceed the SSM for Total Coliform or the BAV for *E. coli*) - Indicated by red text

Summer dam removal and barrier beach closure may have had an effect on E. coli concentrations, as values were observed to slightly increase at Monte Rio,Patterson Point, and Vacation Beach to a lesser degree in late September and October (Figure 4.1.27).

Total Coliform

There were two exceedances (2 of 87 or 2.3%) of the CDPH guideline for Total Coliform during the 2021 monitoring season (Tables 4.1.5 through 4.1.7 and Figure 4.1.28). Aside from the two exceedances at Vacation Beach, Total Coliform concentrations remained low at all three stations during the monitoring season (Figure 4.1.28).

The maximum Total Coliform concentration observed at Patterson Point was >2419.6 MPN/100mL, which occurred twice, first on 17 August during open estuary conditions and a flow of approximately 47.2 cfs, and then on 21 September during open estuary conditions and summer dam removal and a flow of approximately 48.6 cfs (Table 4.1.5 and Figure 4.1.28).

The maximum Total Coliform concentration observed at Monte Rio was 4611 MPN/100mL, which occurred on 22 June during open conditions and a flow of approximately 70.3 cfs (Table 4.1.6 and Figure 4.1.28).

There were two exceedances of the Total Coliform guideline at the Vacation Beach station including a maximum concentration of >24,196 MPN/100mL, which occurred on 22 June during open conditions and a flow of approximately 70.3 cfs (Table 4.1.7 and Figure 4.1.28).

Enterococcus

Enterococcus results exceeded the EPA criteria twice at Vacation Beach and three times each at Patterson Point and Monte Rio (8 of 87 or 9.2%) during open and closed conditions and summer dam removal with flows that ranged from 33.8 to 72.8 cfs (Tables 4.1.5 through 4.1.7 and Figure 4.1.29).

The Patterson Point station had a maximum Enterococcus concentration of 131.4 MPN/100mL on 31 August during open conditions with a flow of approximately 33.8 cfs (Table 4.1.5 and Figure 4.1.29).

The Monte Rio station had a maximum Enterococcus concentration of 128.1 MPN/100mL that occurred twice, first on 4 May during closed conditions with a flow of approximately 72.8 cfs and again on 22 June during open conditions with a flow of approximately 70.3 cfs (Table 4.1.6 and Figure 4.1.29).

The Vacation Beach station had a maximum concentration of 190.4 MPN/100mL that occurred on 22 June during open conditions and a flow of approximately 70.3 cfs (Table 4.1.7 and Figure 4.1.29).

External factors including contact recreation, barrier beach closure, and the late-September removal of summer dams in the lower river likely had an effect on elevated Enterococcus concentrations observed during the 2021 monitoring season (Figure 4.1.29).

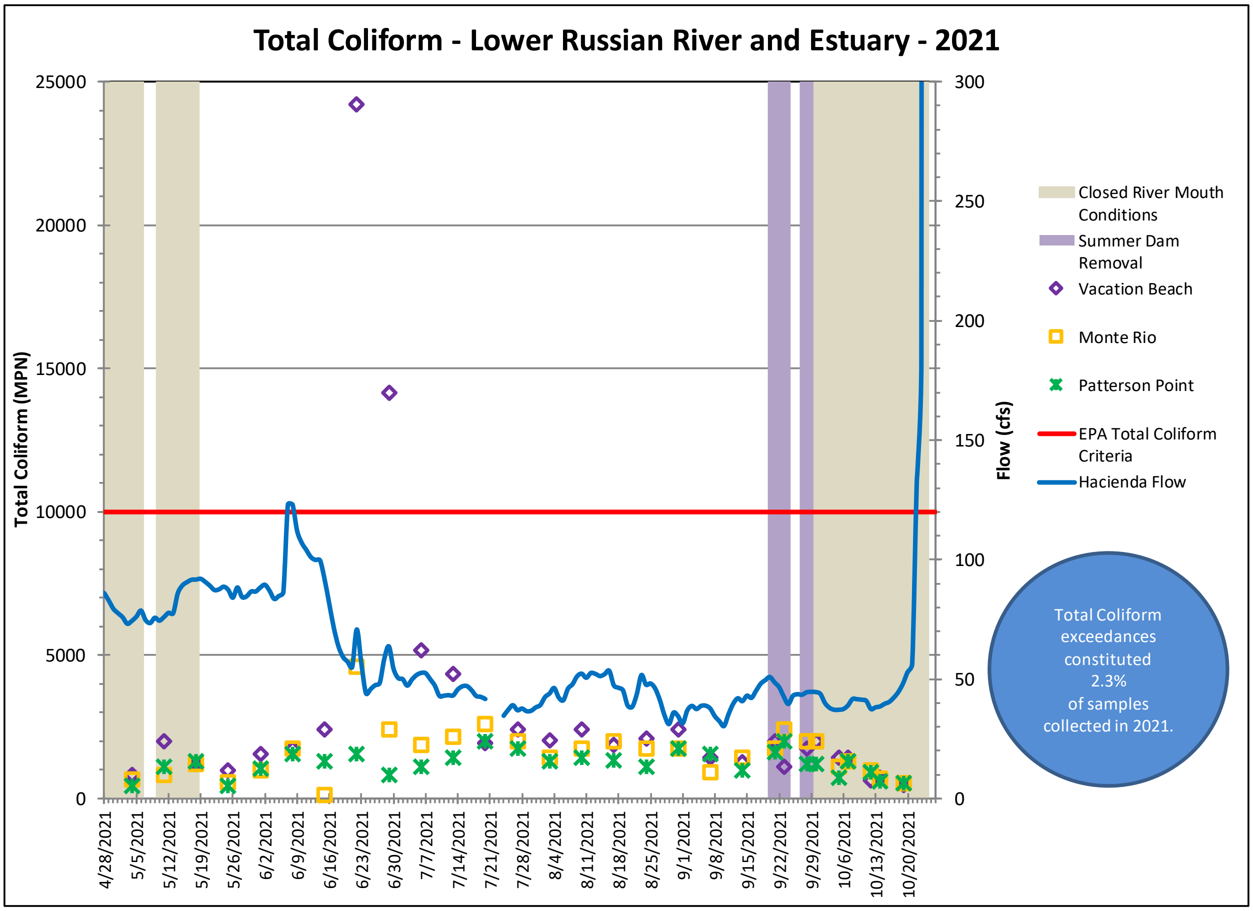


Figure 4.1.28. 2021 Russian River Grab Sampling Results for Total Coliform

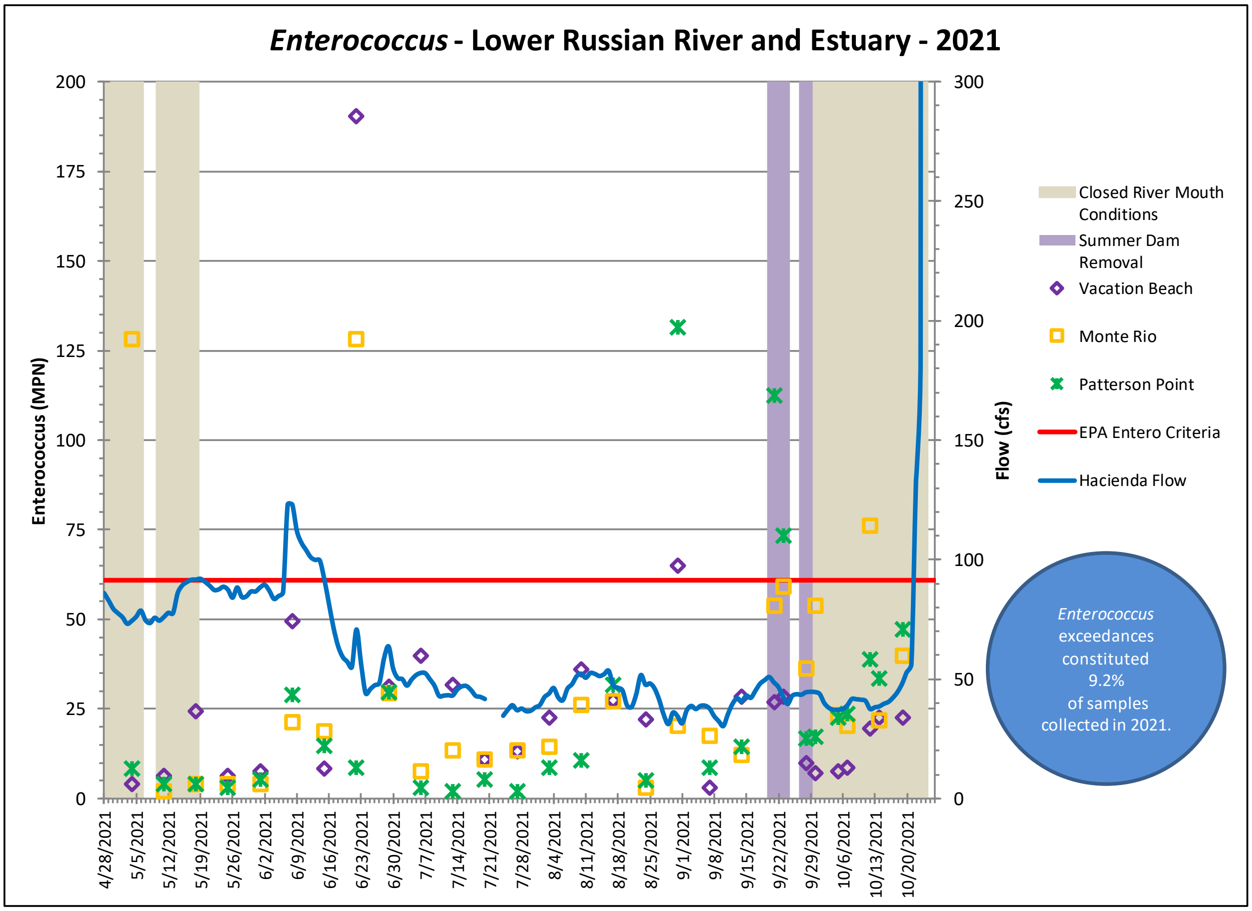


Figure 4.1.29. 2021 Russian River Grab Sampling Results for Enterococcus

Conclusions and Recommendations

Continuous Water Quality Monitoring Conclusions

Water quality conditions observed during the 2021 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 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 2021 as the mouth of the Estuary self-breached naturally after each closure. The barrier beach closed on 10 May for eight (8) days before breaching naturally on 18 May. The barrier beach also closed at the end of the management period for twenty-six (26) days from 28 September to 24 October before breaching naturally.

Consequently, there was limited opportunity for Sonoma Water staff to assess the availability of suitable aquatic habitat for rearing salmonids in comparison to closed and open Estuary conditions during the late September closure. Although Sonoma Water staff were not able to assess the merits of a lagoon outlet channel, 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. However, the degree of salinity migration can be highly variable depending on the orientation and aspect of the river mouth in relation to the barrier beach and jetty. The jetty can serve to mute the strength of the tidal cycle if the river mouth is oriented against the jetty.

Salinity migration patterns in the upper reach of the Estuary were fairly similar to prior monitoring years of 2017 through 2019, with the Brown’s Pool (RK 11.3) station observed to remain primarily freshwater during the 2021 management period with a maximum concentration of 1.0 ppt at the bottom and 0.4 ppt at the mid-depth. Whereas in 2016, the bottom of Brown’s Pool became predominantly brackish during open and closed conditions throughout the 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.

Salinity migration patterns in the MBA of the Estuary were not monitored in 2021 at Patterson Point due to a lack of boat access to the site. However, monitoring conducted in 2020 in the MBA at the Patterson Point station continued to show freshwater conditions with a maximum salinity value of approximately 0.3 ppt (Table 4.1.2). 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 (RK 11.4) and the confluence of Austin Creek (RK 11.65) provide a significant hydrologic barrier to salinity migration in the mainstem Russian River.

Temperature, pH, and dissolved oxygen patterns during the 2021 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 (BO) 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 2021 is being presented (Figure 4.1.30). 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 generally 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 eleven meter depths at the Brown's Pool station, six to eight meter depths at Villa Grande, nine to eleven 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.

The graph also illustrates the variable nature of salinity levels in the Upper Reach of the Estury. 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, 2018, and 2019 the maximum salinity concentration was 0.2 ppt.

Note that there are no elevated salinity levels recorded in the Maximum Backwater Area during any monitoring. 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.

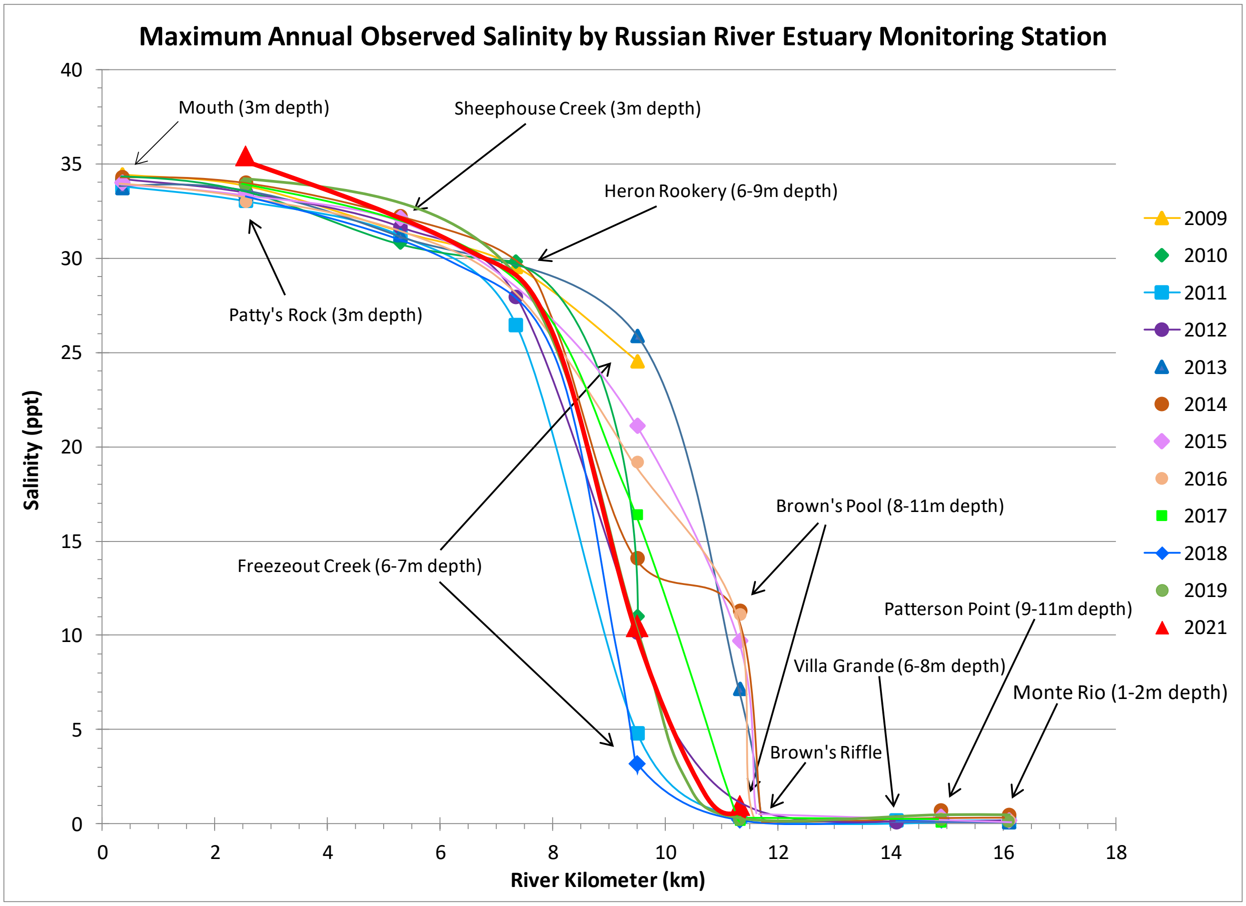


Figure 4.1.30. The maximum salinities at monitoring stations throughout the Russian River Estuary and Maximum Backwater Area between the years of 2009 and 2021.

Water Quality Grab Sampling Conclusions

The 2021 grab sampling effort in the Russian River Estuary continued to collect a robust set of data similar in effort to the 2012 through 2020 monitoring seasons. Additional focused sampling was conducted during summer dam removal in late September and barrier beach closure in October. Table 4.1.8 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 BO in 2009.

The mainstem Russian River, as measured at the USGS Hacienda gage, experienced lower flows in 2021 due to ongoing drought conditions compared to past years including 2019 (Figure 4.1.31). For example, a late season storm in 2019 significantly elevated flows from approximately 600 cfs to over 3000 cfs at Hacienda in mid-May. Flows remained above 500 cfs into early June, resulting in mainstem flows decreasing to base summertime flows later in the dry season compared to previous years, including 2021 (Figure 4.1.31).

Table 4.1.8. 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
2019	25	75
2020	24	72
2021	29	87

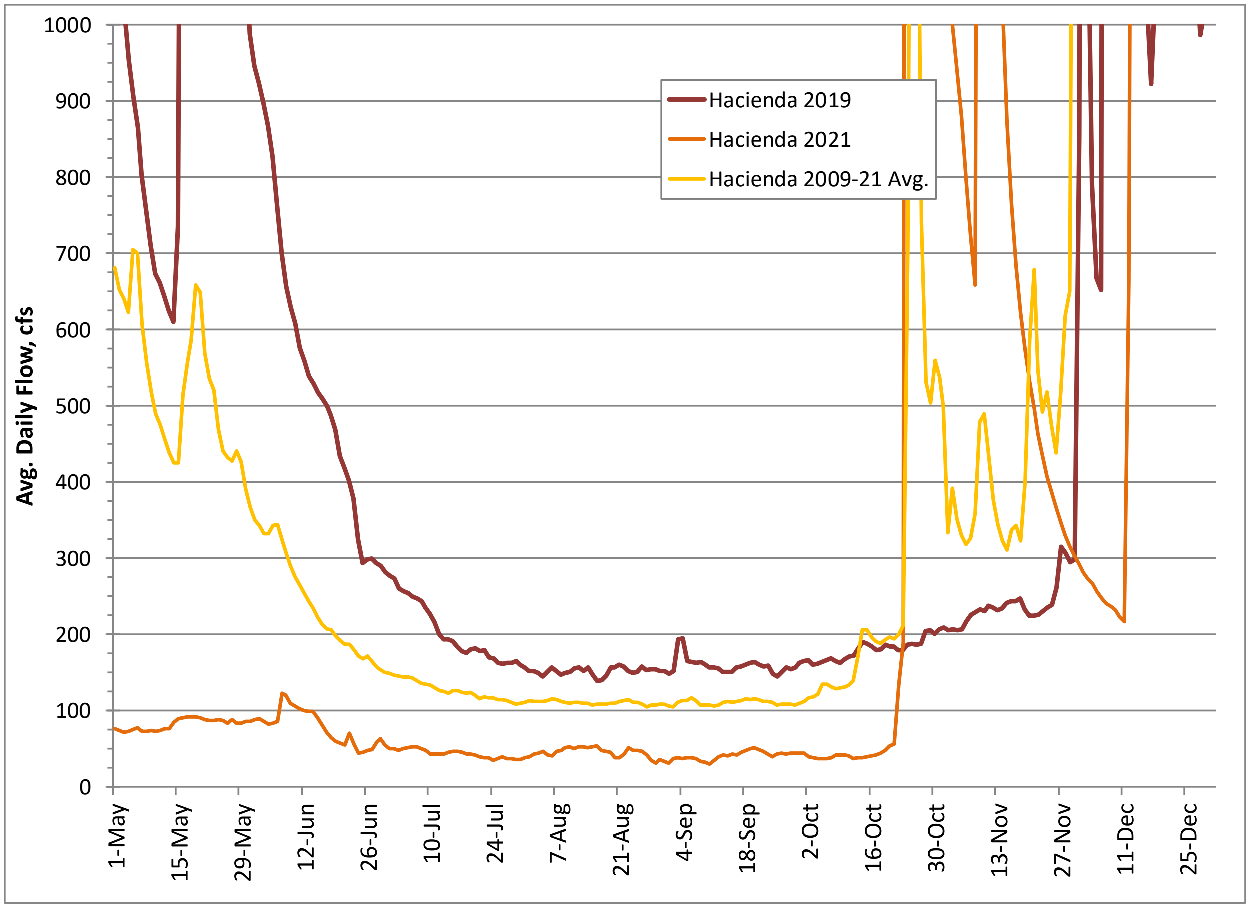


Figure 4.1.31. Comparison of 2019, 2021 and 2009-2021 average daily flows in the Lower Russian River as measured at USGS Hacienda gage in cubic feet per second. Flow rates are preliminary and subject to final revision by USGS.

By comparison a dry spring in 2021 resulted in Hacienda flows dropping below 100 cfs before May, resulting in flows decreasing far earlier in the season compared to previous years (Figure 4.1.31). Finally, while summertime base flows at Hacienda remained above 150 cfs in 2019, summertime base flows in 2021 were generally below 75cfs and frequently below 50 cfs (Figure 4.1.31).

The 2021 grab sampling effort observed Total Phosphorus exceedances in 70.1% of all samples collected (Table 4.1.9). This is not uncommon in the lower Russian River, and was on the lower end of percent exceedances of samples analyzed for Total Phosphorus during previous monitoring seasons. Table 4.1.9 shows the percentage of samples that were in exceedance each season since 2009.

The Total Nitrogen, *Chlorophyll a*, and Turbidity exceedances in 2021 were also on the lower end of percentages observed in previous monitoring years (Table 4.1.9).

Year to year variability in the percentage of exceedances, and concentrations and values, for the constituents discussed above can be attributed in large part to: the frequency, timing, and severity of storm events; fluctuating stream flow rates; atmospheric conditions; contact

Table 4.1.9. 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. Finally, samples were not analyzed for Turbidity in 2009.

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	Percentage of Turbidity Samples in Exceedance
2009	100	N/A	N/A	N/A
2010	84.6	15.4	18.0	23.1
2011	92.3	30.8	23.7	25.0
2012	61.5	6.9	11.5	2.8
2013	99.0	15.3	44.9	13.3
2014	100	14.4	23.1	22.0
2015	86.5	1.9	26.0	3.9
2016	83.9	8.1	39.1	19.5
2017	97.3	9.3	54.7	38.7
2018	93.3	5.3	36.6	9.3
2019	85.3	9.5	48.0	53.3
2020	98.6	0	19.4	8.3
2021	70.1	5.8	23.0	8.1

recreation; 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 from 2009 until 2021 can be seen in Table 4.1.10. The percentage of exceedances for Total coliform and E. coli have been observed to remain relatively low over the years of sampling.

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 2021 were analyzed using the Colilert Quanti-Tray method. Percentages for total coliform samples are not included prior to 2015, since values

Table 4.1.10. The percentages of freshwater samples taken that were in exceedance of CDPH Guidelines for E. coli and Total Coliform for the sampling years 2009 through 2021. Note that for 2009, the analyzing method was multiple tube fermentation, and for 2011-2021 the method was Colilert Quanti-Tray.

Estuary Monitoring Season	Percentage of Total E. coli Samples in Exceedance	Percentage of Total Coliform Samples in Exceedance
2009	0	N/A
2010	N/A	N/A
2011	0	N/A
2012	0	N/A
2013	1.0	N/A
2014	6.3	N/A
2015	1.9	3.8
2016	2.2	0
2017	1.3	4.0
2018	1.3	0
2019	4.0	2.7
2020	0	1.4
2021	0	2.3

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 for those monitoring seasons.

Overall, data collected through the grab sampling effort in 2021 appear consistent with data collected between 2009 and 2020.

Additionally, based on the assemblage of data collected by Sonoma Water, it does not appear that lower flows observed in 2021 negatively affected water quality or the availability of aquatic habitat, or provided a significant contribution to biostimulatory conditions when compared to data collected during years with normal water year flow rates, such as 2019.

Time series trend analyses of the data collected could prove useful in the future. 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.

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.

4.2 Algae Sampling

Monitoring of periphytic and planktonic algae was conducted to document the algal response following Estuary closure; and establish baseline ecological data for algal populations representative of habitats available in the Russian River at Patterson Point. Monitoring for both was conducted as soon as river flows allowed a systematic investigation of abundance, cover, and successional processes. Data collected in 2021 is currently being analyzed and will be provided in a supplemental report.

4.3 Invertebrate Prey Monitoring, Salmonid Diet Analysis and Juvenile Steelhead Behavior

The 2008 Biological Opinion stated that “densities of steelhead appear to be low in the Russian River Estuary, a condition that is likely due to reduced water quality (e.g., elevated salinity and other water quality dynamics) as well as diminished production of invertebrates that are typically the forage base of juvenile salmonids. 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 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; and to provide a qualitative description of salmonid diet in the Estuary.

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 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.

Sonoma Water entered into an agreement with Dr. Charles "Si" Simenstad and his colleagues at 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. Dr. Simenstad is a researcher with expertise in estuarine/early marine ecology of juvenile Pacific salmon, feeding ecology of fishes, estuarine food webs, tidal wetland landscape ecology, restoring estuarine wetlands, and the ecological effects of anthropogenic alterations to coastal ecosystems. 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 2009. 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 Estuary through 2019. The following information was provided in the annual report for monitoring year 2020 and is repeated here for informational purposes.

Sonoma Water implemented ten years of extensive aquatic invertebrate research for the Estuary Management Project. Monitoring reports were completed annually, including a summary and synthesis report of the decadal dataset and findings (Accola et al., 2021). This report provides a long-term analysis and summary of several independent studies related to salmonid diet, prey availability, juvenile steelhead distribution and behavior, and comparison of invertebrate composition and steelhead performance in other Pacific coast estuaries. In addition, these Estuary studies evaluated the response of invertebrates and steelhead to changing river mouth conditions. The scope of many of these studies are beyond the requirements stated in the Biological Opinion. Scientific journal articles and graduate theses/dissertation produced from Estuary invertebrate research are listed below.

- Fuller, J. A. 2011. Extended residency and movement behavior of juvenile steelhead (*Oncorhynchus mykiss*) in the Russian River Estuary, California. Master's thesis. Humboldt State University.
- Seghesio, E. E. 2011. The influence of an intermittently closed, Northern California estuary on the feeding ecology of juvenile steelhead (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*). Master's thesis. University of Washington, School of Aquatic and Fishery Sciences.
- Matsubu, W. C., C. A. Simenstad, and G. E. Horton. 2017. Juvenile steelhead locate coldwater refugia in an intermittently closed estuary. Transactions of the American Fisheries Society 146:680–695.
- Matsubu, W. C. 2019. Tradeoffs of juvenile steelhead (*Oncorhynchus mykiss*) rearing in an intermittently closed estuary, northern California USA. PhD dissertation. University of Washington, School of Aquatic and Fishery Sciences.

Summary of Methods

Field sampling and laboratory process methods implemented by Sonoma Water and UW-WET are described in previous reports. Following is a summary of the field and laboratory efforts conducted over the entire monitoring effort.

Invertebrate surveys were conducted from 2010 to 2019 in the Estuary. Surveys were completed monthly and at 7 and 14 days after a river mouth closure to monitor conditions during the transition from tidal Estuary to lagoon. Sampling for fish diet and prey availability was 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). Each survey event consisted of sampling at four sites distributed through the three estuarine reaches (Figure 4.3.1): Lower Reach—River Mouth and Penny Point; Middle Reach—Willow Creek; and Upper Reach—Freezeout Bar. Each of the sites included three, lateral transects across the Estuary over which four sampling methods were deployed to sample availability of juvenile steelhead prey (Figures 4.3.2 – 4.3.7 for more specific locations by different sampling methods). Collections at each station consisted of 12 benthic, 14 epibenthic, and 3 zooplankton for a total of 29 samples/station and combined total of

116 samples/survey event. During mouth closures an additional three benthic and three epibenthic samples were collected along the inundated shoreline. These samples were placed in jars, preserved, and sent to UW-WET for taxonomic identification, enumeration, and analysis. Over the course of study, 48 survey events were completed (32 open mouth, 16 closed mouth) for a total collection of 5,585 invertebrate samples.

In addition, gastric-lavaged stomach samples were collected from 338 juvenile steelhead and 662 Chinook salmon smolts, and processed by UW-WET. Overall, there were 6,585 diet and prey availability samples collected, processed, and analyzed since 2010. UW-WET processed a subset of samples in the latter years of the study and targeted samples collected in association with river mouth closure events.

Salmonid diet samples have been coincident with beach seining at 11 sites (Figure 4.3.1; 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. These locations also overlap with sites established by water quality measurements for dissolved oxygen, temperature and salinity.

Summary of Results

Accola et al. (2021) compiled and reviewed all of the Estuary invertebrate studies into a summary and synthesis report of the decadal dataset and findings. Below is a summary of the important research findings that comply with the Biological Opinion invertebrate monitoring requirements.

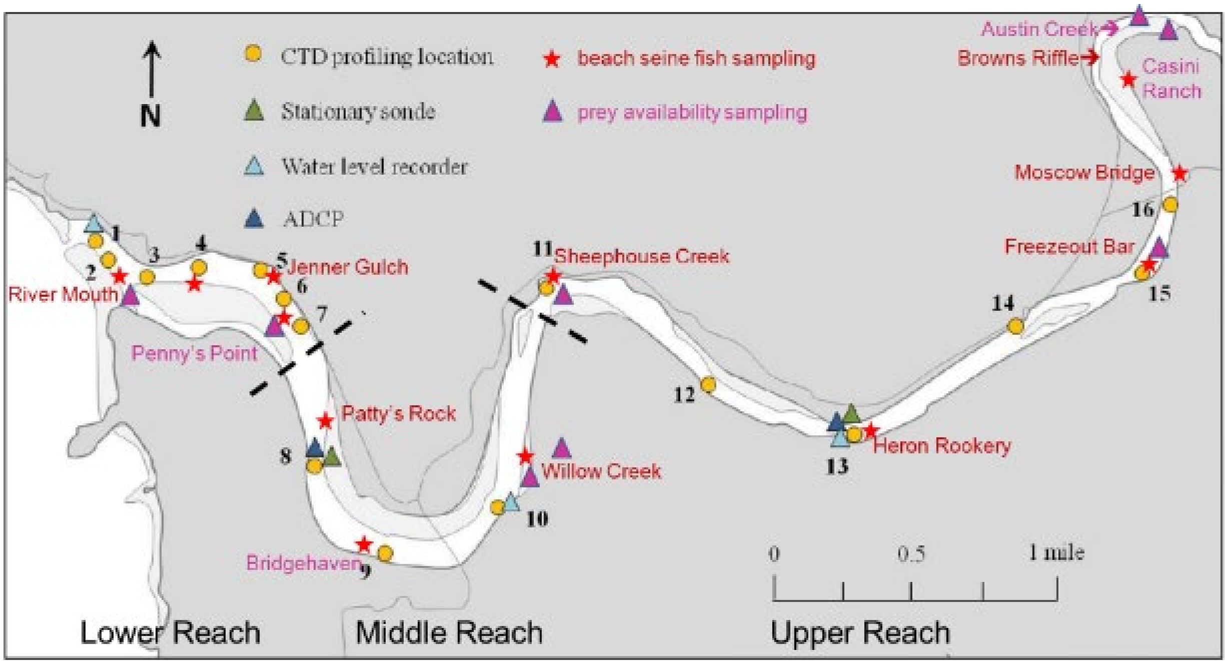


Figure 4.3.1. Locations of sampling stations for juvenile salmon diet (seining location) and prey resource availability (benthic infauna, epibenthos, zooplankton) in three reaches of the Russian River Estuary.

Figure 4.3.2 . Distribution of juvenile salmonid prey resource availability in three reaches of the Russian River Estuary.

Figure 4.3.3. Distribution of juvenile salmonid prey availability sampling transects and techniques at the River Mouth site in the Russian River Estuary.

Figure 4.3.4. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Penny Point site in the Russian River Estuary.

Figure 4.3.5. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Willow Creek site in the Russian River Estuary.

Figure 4.3.6. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Freezeout Bar site in the Russian River Estuary.

Figure 4.3.7. 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.

Spatial Distribution, Composition, and Relative Abundance of Invertebrates

Invertebrate composition showed differences between and among the three reaches of the Estuary that appeared to follow longitudinal water conditions transitioning from seawater in the lower reach to freshwater in the upper reach. However, the invertebrates that are important prey for juvenile steelhead were relatively consistent during a decade of study, see below for more details. Epibenthic sampling indicated a somewhat distinct invertebrate prey community composition between the River Mouth and the Penny Point sampling sites in the lower reach, but often distinct prey assemblages between the upper reach at Freezeout Bar site versus the lower reach and assemblages at the Willow Creek site in the middle reach. Presumably, salinity distribution is a likely determinant of these distinctions but cannot preclude the other influences of tidal exchange, substrate or other factors.

Salmonid Diet and Invertebrate Response to River Mouth Condition

Prey composition and densities in the Estuary were relatively comparable over the ten years of study, implying a relatively consistent estuarine prey community available for juvenile steelhead despite some variability in the occurrence and duration of freshwater outflow and Estuary closure events. The supplemental epibenthic sled sampling along the inundated shoreline during continued Estuary closures suggested no recognizable gradient or differentiation in the composition and relative density distribution of preferred prey. This would suggest that within the three Estuary reaches (lower, middle, upper) there was uniform or a relatively minor gradient of prey density distribution from their deeper channel to their shallower, marginal habitats due to Estuary closure.

In comparing juvenile steelhead diets between open and closed Estuary mouth conditions, there was no detection of any significant changes in diet composition. Juvenile steelhead consistently fed on common prey taxa over an inter-annual timespan. Spatial variation among Estuary reaches accounted for prey differences more than temporal variation or even variation due to open or closed mouth condition. Prey distributions are consistently organized along a salinity gradient (primarily distinguishing the upper reach of the Estuary dominated by freshwater river flows); however, prey composition was consistent within the three Estuary reaches (lower, middle, and upper) regardless of mouth condition.

A bioenergetics model investigating the relationship of diet composition and water temperature determined that growth rates of juvenile steelhead in the Estuary rival the highest in literature both in natural environments and under laboratory conditions. Therefore, growth of juvenile steelhead in the Estuary is likely not a limiting factor in the recovery of threatened steelhead in the Russian River watershed.

Diet composition of both juvenile steelhead and Chinook salmon in the Estuary indicated that these fish feed on relatively few taxa of aquatic invertebrates, consisting of epibenthic crustaceans and aquatic insects, that are common in the Estuary. In addition, there was a persistent uniformity in juvenile steelhead foraging on epibenthic prey. Accola et al. (2021) concluded that “our results and related accounts from other intermittent estuaries in the region indicates that juvenile salmonid feeding ecology in the Estuary is of relatively modest diversity and remarkably consistent. Thus, their feeding should be predictable as long as the spectrum of available prey is not dramatically altered…and…these prey taxa are reported to be common components in juvenile steelhead (and Chinook salmon, in a few cases) diets in other intermittent systems estuaries along the California coast.”

Conclusions

The invertebrate studies in the Estuary were able to quantify and determine several characteristics of the invertebrate community and their importance as prey for rearing juvenile steelhead, which are listed below.

- The annual composition and abundance of invertebrates in the Estuary were similar across the ten years of study, implying a relatively consistent prey base for juvenile steelhead.
- Invertebrate distributions were consistently organized along a salinity gradient from seawater at the river mouth to freshwater at the upstream end of the Estuary.
- Invertebrate composition was consistent within the three reaches of the Estuary regardless of mouth condition.
- During river mouth closures that inundated the shoreline, the density and distribution of invertebrates in the newly created marginal habitat was similar to the adjacent deeper channel.

- Juvenile steelhead consistently fed on relatively few taxa of common aquatic invertebrates consisting of epibenthic crustaceans and aquatic insects.
- The diet of juvenile steelhead did not appear to change under open or closed mouth conditions.
- The development of juvenile steelhead was exceptionally high in the Estuary, indicating that growth rate is likely not a limiting factor in the recovery of steelhead in the Russian River watershed.
- The high growth rates of juvenile steelhead suggest that prey abundance is not a limiting factor for rearing steelhead survival.

4.4 Fish Sampling – Beach Seining

Sonoma Water has been fish sampling 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 2021, Sonoma Water presents and discusses 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, the catch of several common species are described to help characterize 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 4.4.1).

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

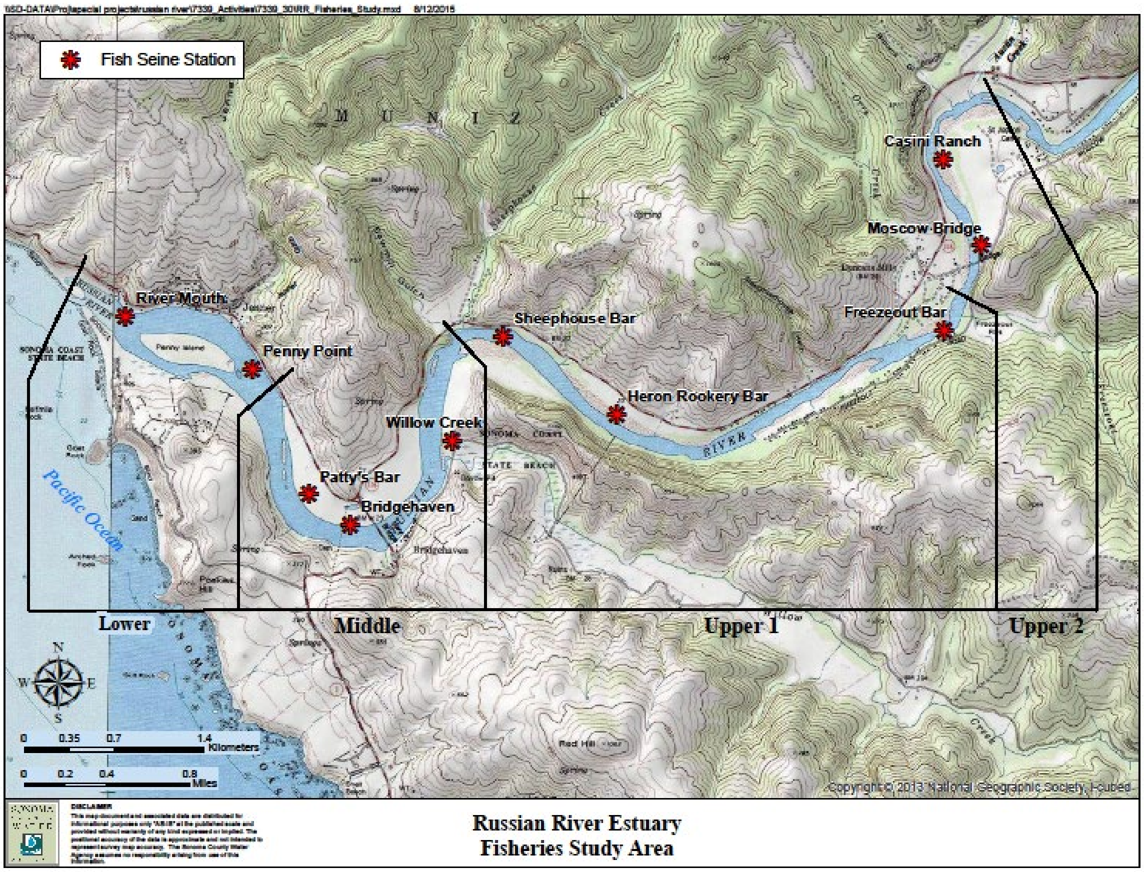


Figure 4.4.1. Russian River Estuary fisheries seining study reaches and sample sites, 2021.

than 60 mm fork length were 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 2021, four seining events were completed in May, June, September and October with the October event following a prolonged river mouth closure.

For data summary purposes 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 (Figure 4.4.1). 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.

Due to difficulties accessing the upper reach during the ongoing drought conditions in 2021, seining effort was shifted from the upper estuary sites to the lower and middle estuary sites for the September, 2021 sampling event. Jenner Gulch in the lower Estuary was added as a sample site for the September sampling event to help redistribute some of the effort from the upper estuary sample sites. An additional seining event was conducted in October in order to document lagoon conditions following a river mouth closure. However, high flows following a rain event made seining unfeasible during part of the October seining event and not all sites were sampled (Table 4.4.1).

Table 4.4.1 The number of seine sets for the May, June, September, and October seine events shown by reach. Due to difficulties accessing the upper reach seining effort was shifted from the upper estuary sites to the lower and middle estuary sites for the September. High flows following a rain event made seining unfeasible during part of the October seining event.

Seine event	Lower	Middle	Upper1	Upper2	**Total**
May	10	15	15	10	**50**
June	10	15	15	10	**50**
September	15	20	12	0	**47**
October	10	15	11	0	**36**
Total	**45**	**65**	**53**	**20**	**183**

Results

Fish Distribution and Abundance

Fish captures from seine surveys in the Russian River Estuary for 2021 are summarized in Table 4.4.2. During the 15 years of study over 50 fish species were caught in the Estuary. In 2021, seine captures consisted of 32,156 fish comprised of 35 species. In addition to fin fish 734 European green crabs and 217 Dungeness crabs were captured. European green crabs are a non-native species and only 1 individual had been captured seining prior to 2021. European green crabs were observed in the lower, middle and upper1 reaches of the estuary in 2021 and captured during the May, June, September, and October sampling events.

The distribution of fish in the Estuary is, in part, based on a species preference for or tolerance to salinity. 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 4.4.2). 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 2021, a total of 35 steelhead were captured (Table 4.4.2) in 183 seine sets. These steelhead were all wild origin fish. The resulting CPUE was 0.19 fish/set (Figure 4.4.3). In comparison, during 2019, a total of 43 steelhead were captured in 148 seine sets for a CPUE of 0.29 fish/set. There has been an overall decline in steelhead abundance since 2008 when the CPUE was 1.32 fish/set. The seasonal abundance of steelhead captures varied annually in the Estuary (Figure 4.4.4). In 2021 juvenile steelhead were captured during the May, June, and September survey, but not in October. During 2021, steelhead captures were higher during May than during June or September with CPUE of 0.43 and 0.20 and 0.15 fish/set, respectively. 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 4.4.5). 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.

Overall, there were few steelhead found in the Estuary in 2021, which limited the temporal and spatial evaluation of steelhead in the Estuary (Figure 4.4.6). 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, and then most steelhead found in the Lower Estuary in September. The pattern observed in 2021 consisted of parr steelhead in the upper and middle all reaches of the estuary in May and June and in the lower estuary in September.

Table 4.4.2. Total fish caught seining in the Russian River Estuary, 2021. Due to access issues resulting from drought conditions Freezeout, Moscow, and Casini were not sampled in September and the seining effort typically allotted to these upper sites was shifted to downstream sites in September.

Species	River Mouth	Jenner Gulch	Penny Point	Patty's Bar	Bridge-haven	Willow Creek	Sheep-house Bar	Heron Rookery Bar	Freeze-out Bar	Moscow Bridge	Casini Ranch	Total
American shad	809		5	80	331	1	1	18				1245
Chinook salmon	105		4	5	31	17	1					163
coho salmon	23	1			2					1		27
steelhead		7				4		1	15	3	5	35
Dungeness crab	209		2	6								217
black crappie											11	11
bluegill							1	5	1		1	8
buffalo sculpin	3											3
cabezon	4											4
cyprinid sp											2	2
English sole	1											1
European green crab	160	47	62	146	298	7	14					734
hardhead								1				1
hitch									53			53
largemouth bass										8	59	67
lingcod	16		1									17
Pacific sand sole	21											21
penpoint gunnel	1											1
prickly sculpin	21	1	48	131	281	114	238	62	53	26	28	1003

Species	River Mouth	Jenner Gulch	Penny Point	Patty's Bar	Bridge-haven	Willow Creek	Sheep-house Bar	Heron Rookery Bar	Freeze-out Bar	Moscow Bridge	Casini Ranch	Total
Russian River tule perch					5	2	72	46	217	450	56	848
Sacramento pikeminnow							11	29	38	24	38	140
Sacramento sucker							3	21	19	43	16	102
sculpin sp	6	1		6	3						4	20
sebastes sp	90					1	2					93
sharpnose sculpin	2											2
bay pipefish	14	2	6	9	36	36	48	21				172
shiner surfperch				12	288	284	116	816				1516
smallmouth bass										1	5	6
starry flounder	28		10	25	15	34	12	5	1	3		133
staghorn sculpin	268		88	582	97	127	34	8				1204
tidepool sculpin	1											1
California halibut			1									1
topsmelt	746	96	160	388	205	471	81	141				2288
surf smelt	571	8	12	3	2							596
northern anchovy				6	1							7
threespine stickleback	33	5	128	3723	2472	3843	2553	3553	4192	1505	243	22250
Dover sole	15		26									41

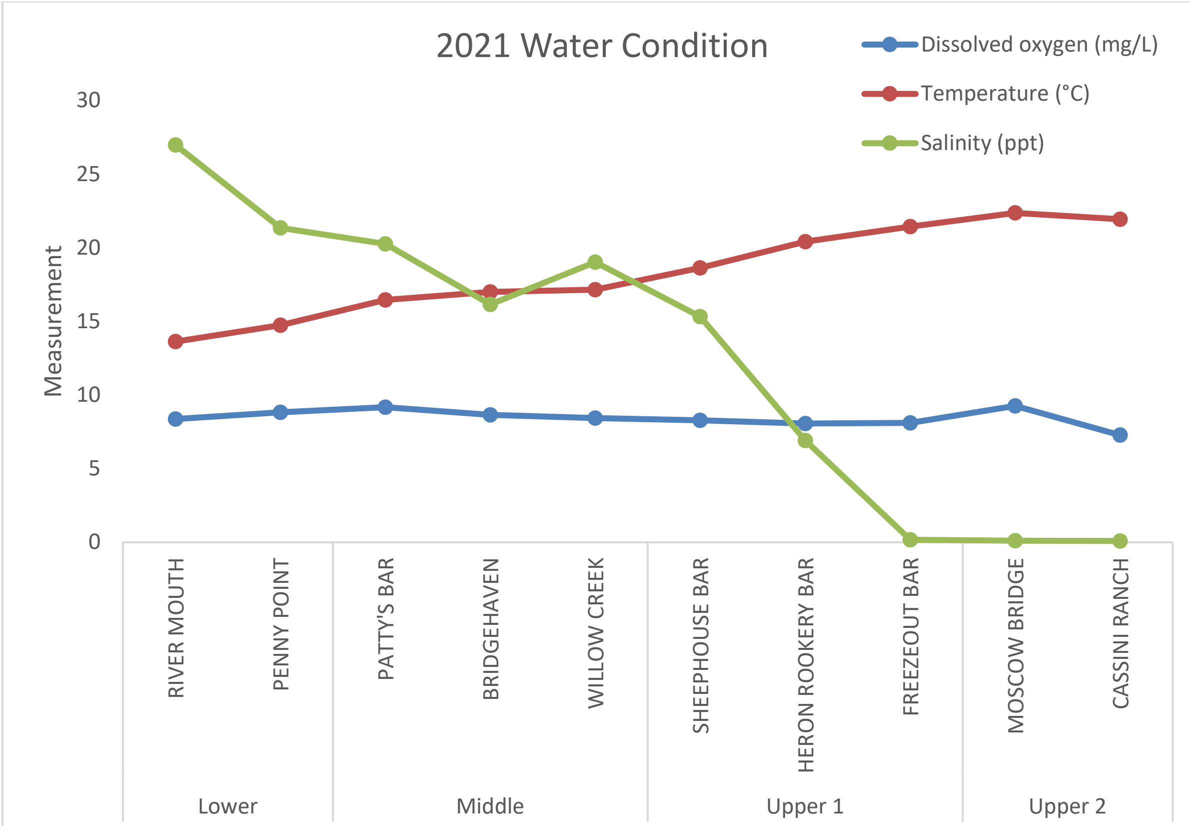


Figure 4.4.2. Generalized water conditions at fish seining stations in the Russian River Estuary, 2021. Values are averages collected at 0.5 m intervals in the water column during beach seining events from May, June, September, and October during primarily open mouth conditions. Water measurements are salinity in parts per thousand (ppt), dissolved oxygen in milligrams per liter (mg/L), and temperature in Celsius (°C).

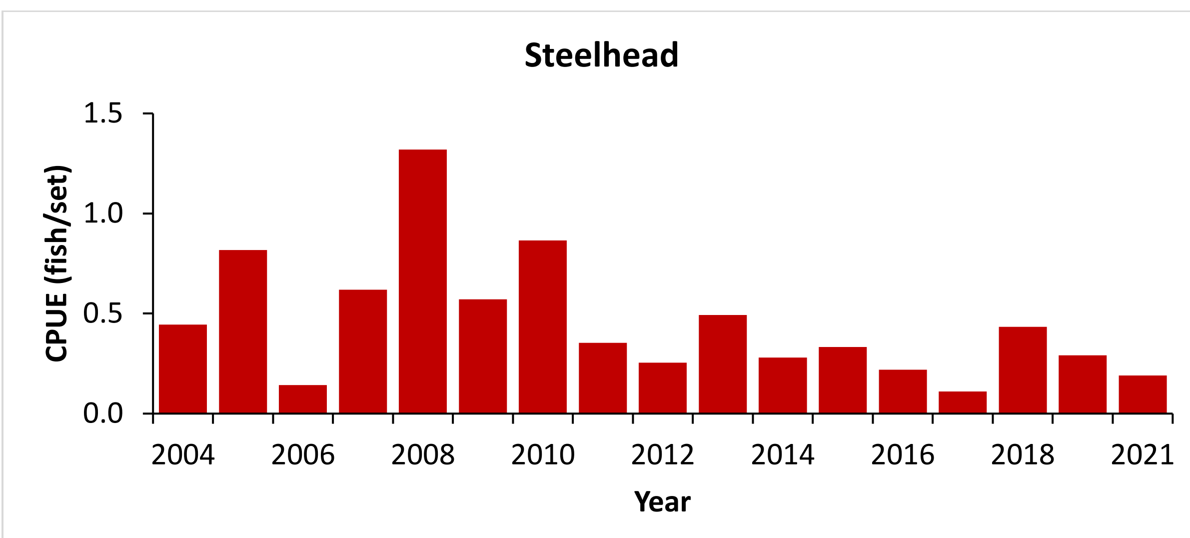


Figure 4.4.3. Annual abundance of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2021. Samples are from 96 to 300 seine sets conducted yearly from May to October.

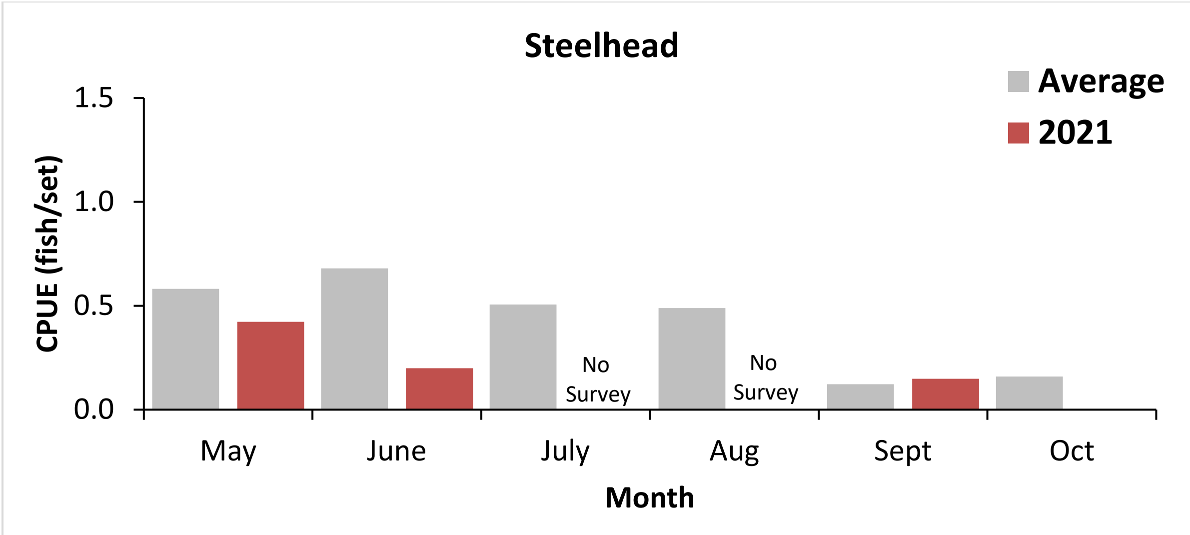


Figure 4.4.4. Seasonal abundance of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2021. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010.

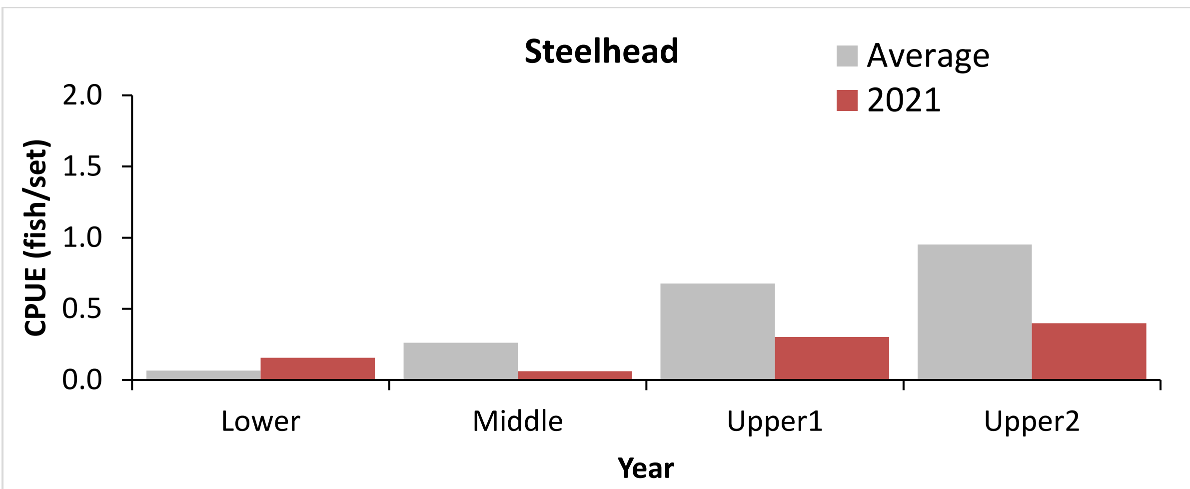


Figure 4.4.5. Distribution of juvenile steelhead in the Russian River Estuary, 2004-2021. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2021 were averaged.

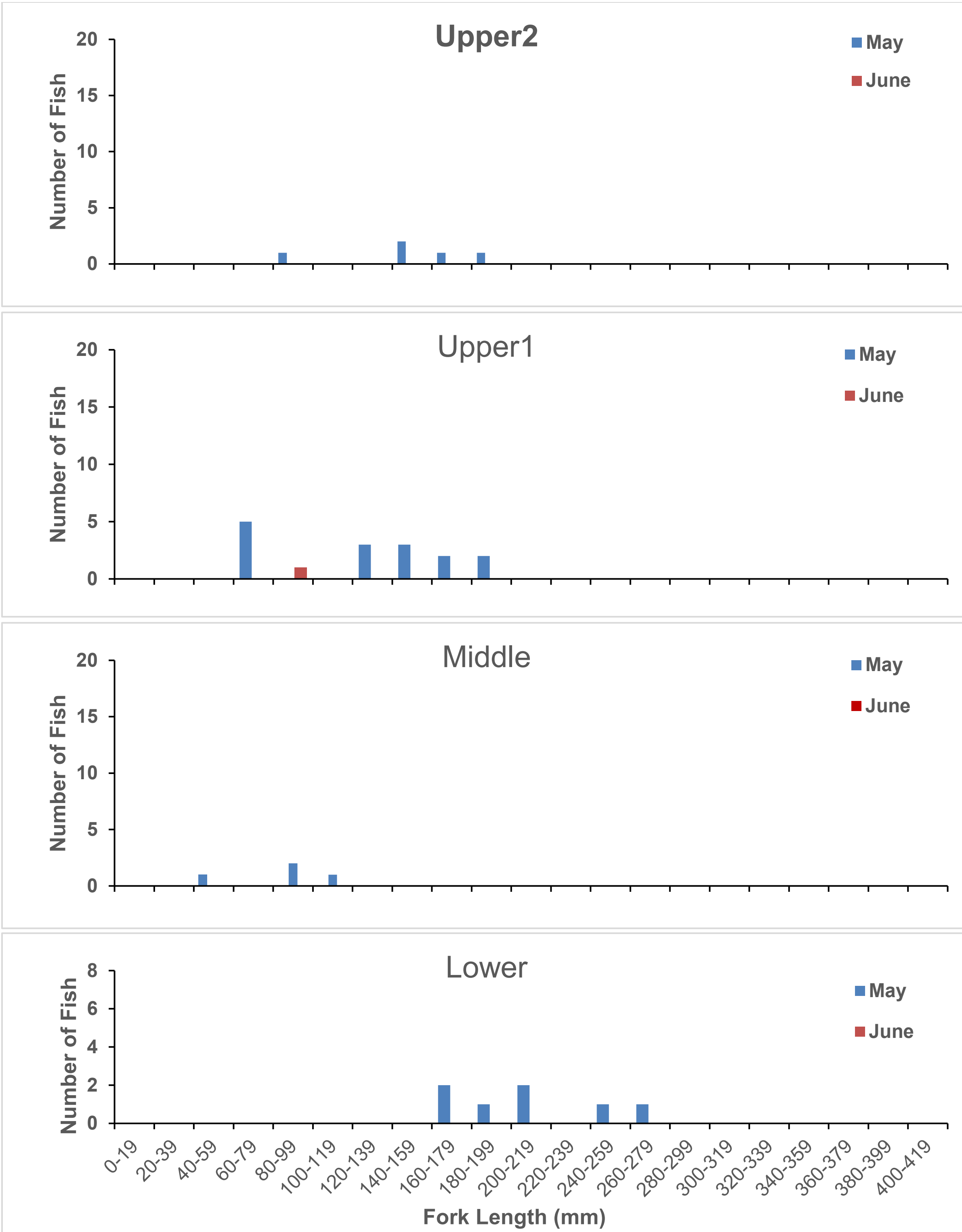


Figure 4.4.6. Length frequency of juvenile steelhead captured by beach seine in the Russian River Estuary, 2021. Fish captures are grouped by Estuary reach and month.

Most juvenile steelhead captured in 2021 were age 0+ parr or age 1+ smolts and ranged in size from 40 mm to 180 mm fork length (Figure 4.4.7).

In 2021, 31 juvenile steelhead captured during Estuary seining surveys were implanted with PIT tags. In addition, 285 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 2021 seining.

Chinook Salmon

A total of 163 Chinook salmon smolts were captured by beach seine in the Estuary during 2021 (Table 4.4.2). The abundance of smolts in the Estuary has varied since studies began in 2004 (Figure 4.4.8). 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. In 2021 the CPUE for Chinook was 0.89. Chinook salmon smolts are usually most abundant during May and June (Figure 4.4.9) and rarely encountered after July. Monthly smolt captures in 2021 were highest during May at 3.4 fish/set. Chinook salmon smolts were distributed throughout the Estuary with captures at most sample stations and reaches annually (Figure 4.4.10).

Coho Salmon

There have been relatively few Coho Salmon smolts captured in the Estuary during our beach seining surveys (Figure 4.4.11). 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 2021 the total capture of Coho was 27 smolts at a CPUE of 0.15 fish/set. Six smolts were not marked and presumed wild. The remaining smolts were hatchery raised. Nearly all Coho Salmon smolts are captured by June and in 2021 all but one smolt was captured in May (Figure 4.4.12). The spatial distribution of Coho smolts has varied annually (Figure 4.4.13). In 2021 Coho were captured in all reaches, with the highest abundance in the Lower Reach.

All Coho raised at the Don Clausen Hatchery are implanted with a coded wire tag and a portion are also implanted with a PIT tag. Three PIT tagged Coho were recaptured at in the Estuary. These fish were captured at the River Mouth on May 24, and July 1, and at Moscow Road Bridge on May 27, 2021. The history of these Coho are shown in Table 4.4.3. These fish were initially released in three different tributaries of the Russian River (East Austin Creek, Dry Creek, Green Valley Creek). Two Coho parr were stocked in tributaries during the fall of 2020 one of which was also captured in a downstream migrant trap in the spring of 2021. The remaining fish was released by the hatchery in the winter of 2021.

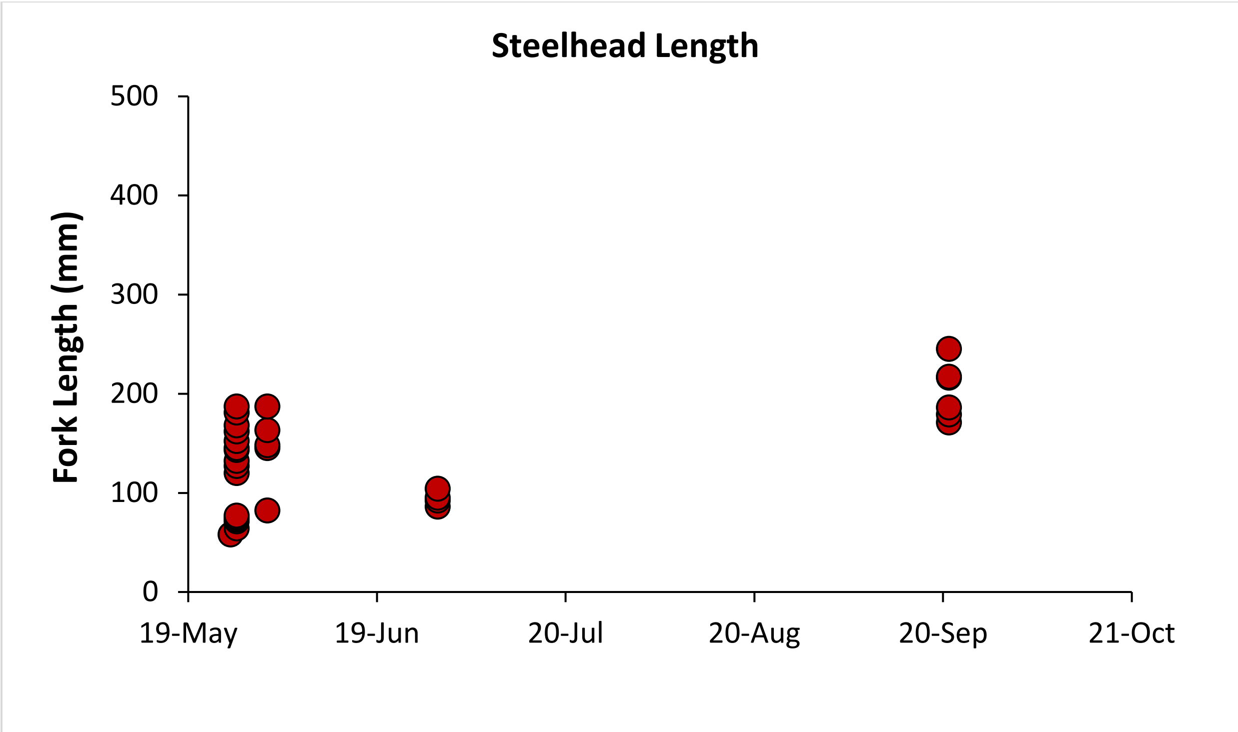


Figure 4.4.7. Juvenile steelhead sizes captured by beach seine in the Russian River Estuary, 2021.

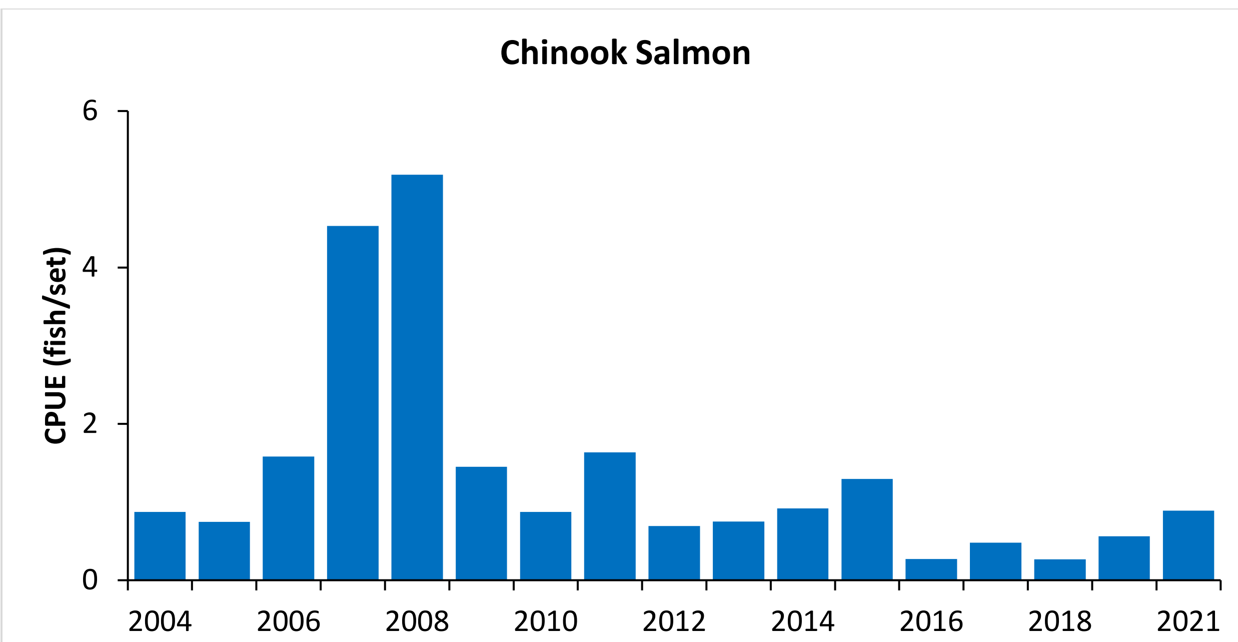


Figure 4.4.8. Annual abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2021. Samples are from 96 to 300 seine sets yearly from May to October.

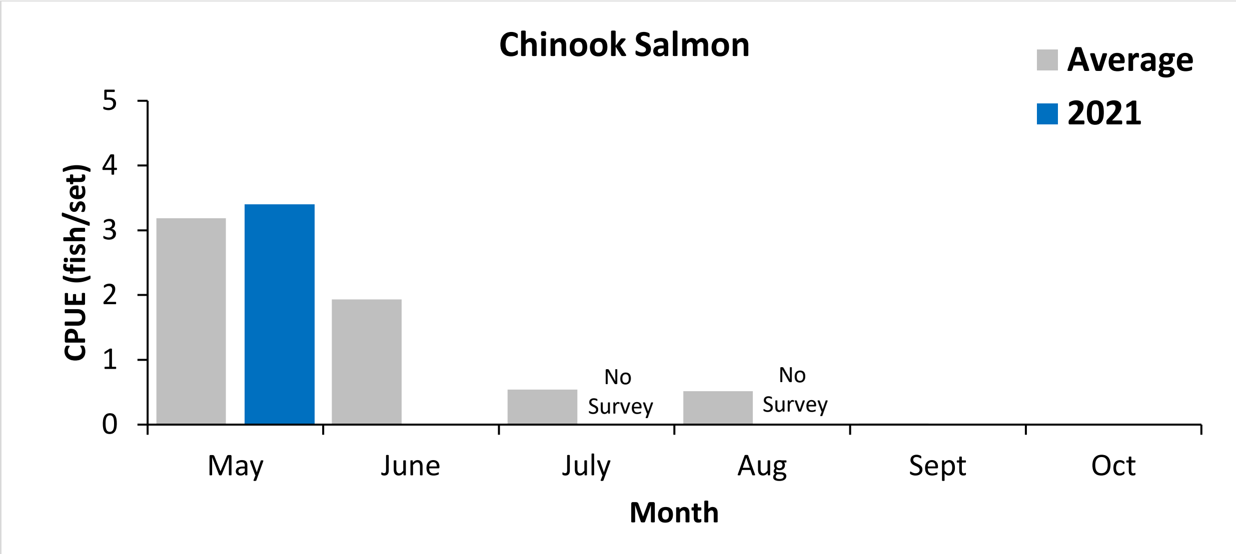


Figure 4.4.9. Seasonal abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2021. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2021 were averaged.

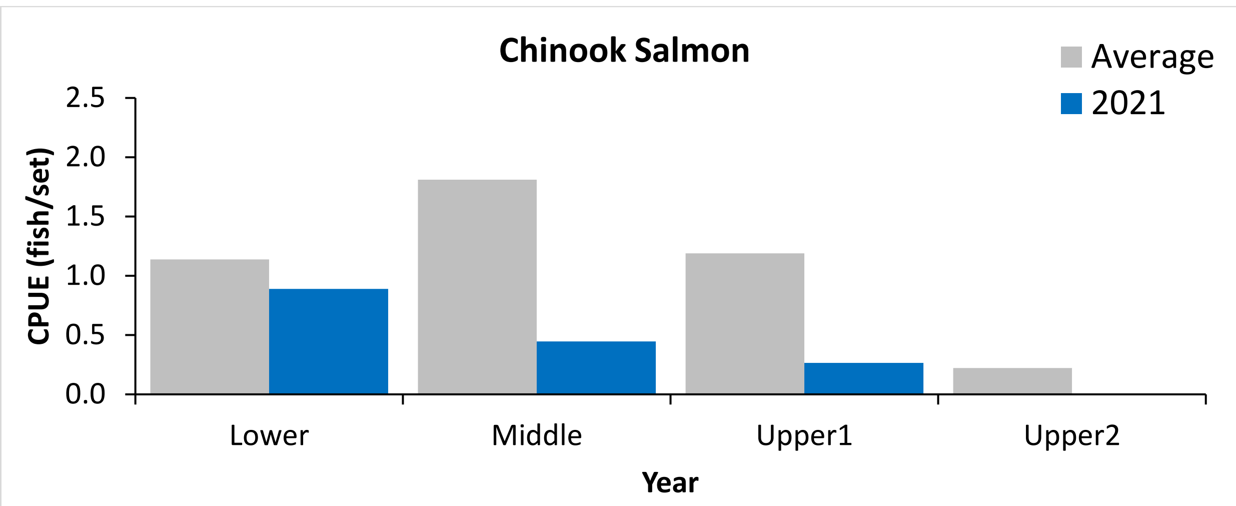


Figure 4.4.10. Spatial distribution of Chinook salmon smolts in the Russian River Estuary, 2004-2021. Fish were sampled by beach seine consisting of 96 to 300 sets annually. Data from 2004 to 2021 were averaged. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009.

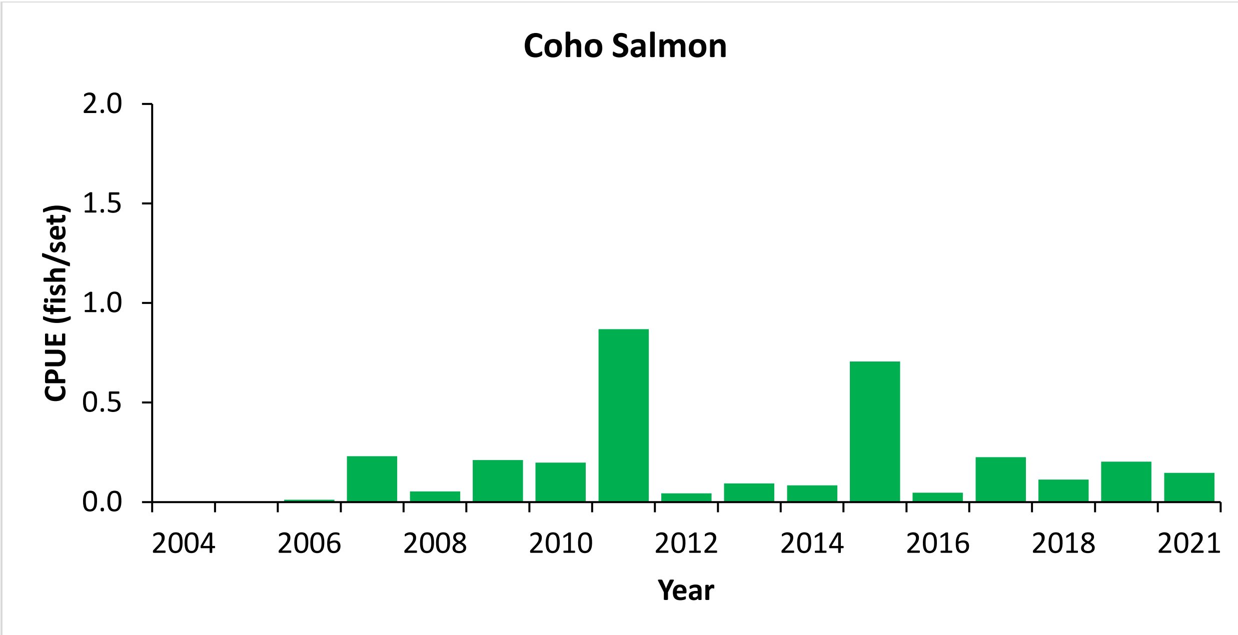


Figure 4.4.11. Annual abundance of Coho Salmon smolts captured by beach seine in the Russian River Estuary, 2004-2021. Samples are from 96 to 300 seine sets yearly from May to October.

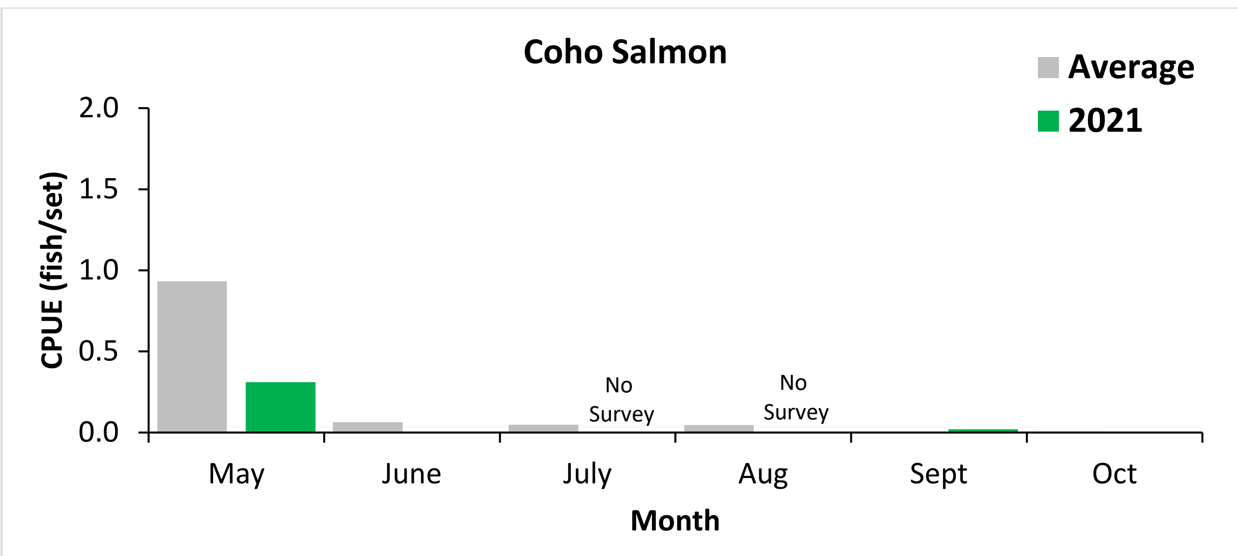


Figure 4.4.12. Seasonal abundance of Coho Salmon smolts captured by beach seine in the Russian River Estuary, 2004-2021. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2021 were averaged.

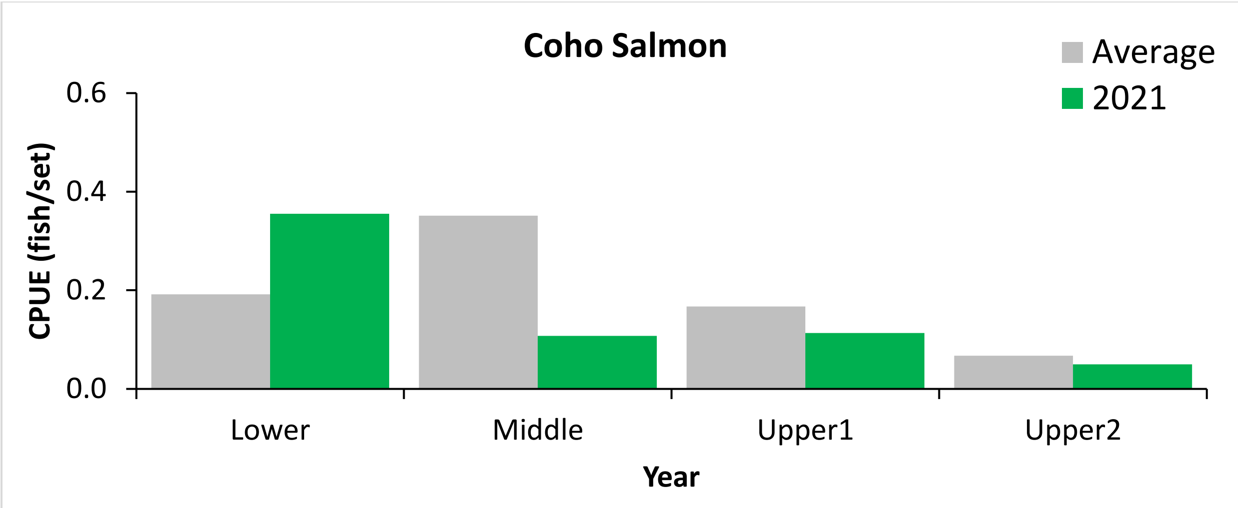


Figure 4.4.13. Spatial distribution of Coho Salmon smolts in the Russian River Estuary, 2004-2021. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2021 were averaged.

Table 4.4.3. Hatchery Coho Salmon detection sites and seasons captured in the Russian River Estuary in 2021. 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	Recapture Date	Recapture Fork Length (mm)
3DD.003D98E7E7	East Austin Creek	11/16/2020	85	RIVER MOUTH	5/24/2021	133
3DD.003D98DA0D	Dry Creek Gallo side channel / Dry Creek DSMT	10/29/20 5/14/2021	88 / 104	MOSCOW BRIDGE	5/27/2021	-
3DD.003D98C3C3	Green Valley Creek	2/23/21	109	RIVER MOUTH	7/1/2021	155

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 2021 was the second highest since 2004 at 6.80 fish/set (Figure 4.4.14). Shad are typically distributed throughout the Estuary, although in 2021 they were found mostly in the lower two reaches (Figure 4.4.15).

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 4.4.16). 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 2021 was above average at 12.50 fish/set. Topsmelt are mainly distributed in the Lower and Middle Reaches in the Estuary (Figure 4.4.17).

Conclusions and Recommendations

Fish Sampling - Beach Seining

The results of Estuary fish surveys from 2004 to 2021 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 2021 fish studies contribute to the 17-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.

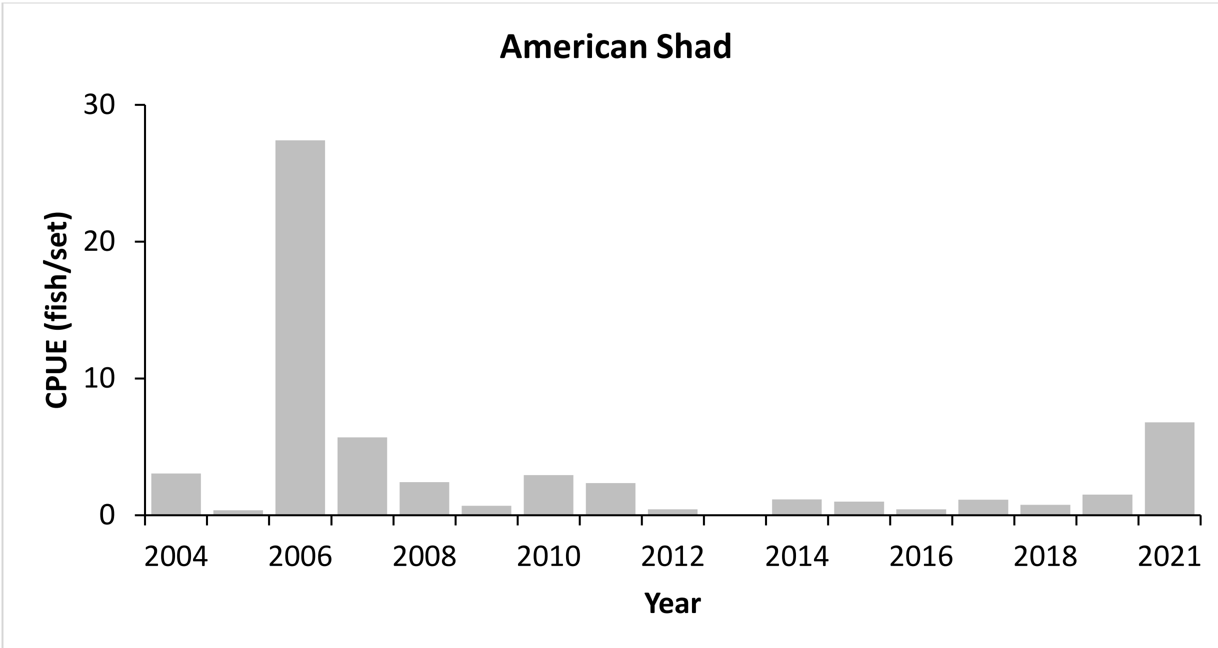


Figure 4.4.14. Annual abundance of juvenile American shad captured by beach seine in the Russian River Estuary, 2004-2021. Samples are from 96 to 300 seine sets yearly from May to October.

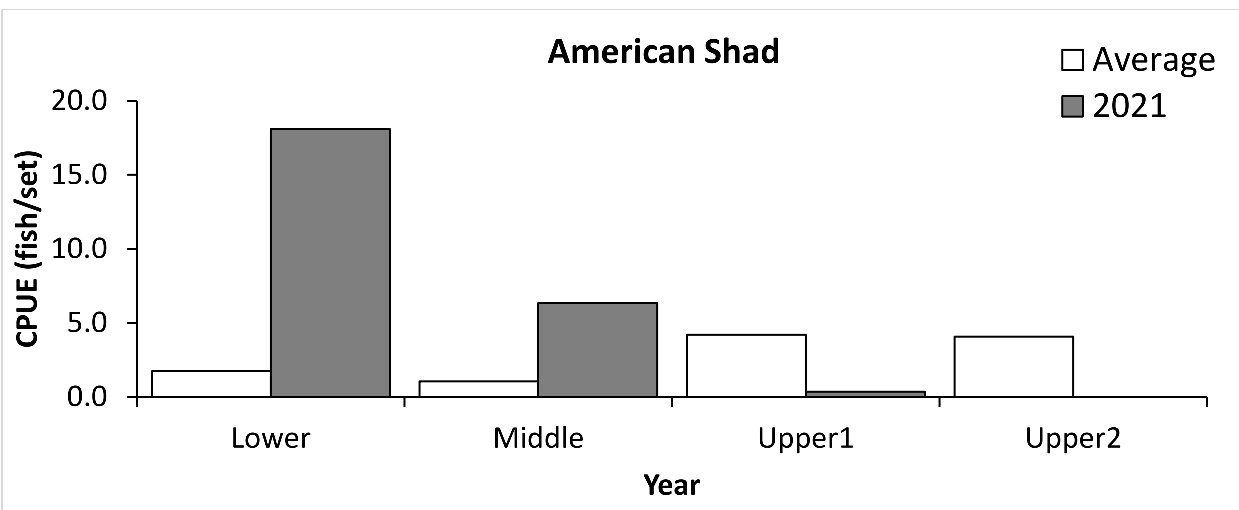


Figure 4.4.15. Spatial distribution of juvenile American shad in the Russian River Estuary, 2004-2021. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach during 2004 and 2009. Data from 2004 to 2021 were averaged.

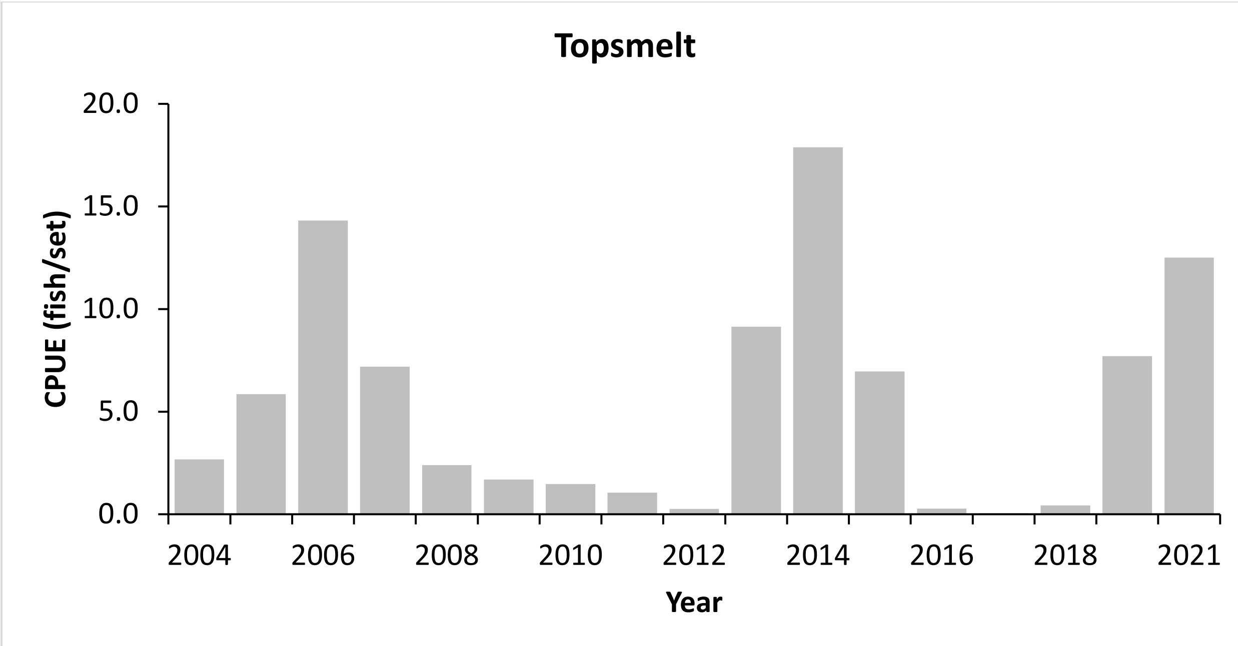


Figure 4.4.16. Annual abundance of topsmelt captured by beach seine in the Russian River Estuary, 2004- 2021. Samples are from 96 to 300 seine sets yearly from May to October.

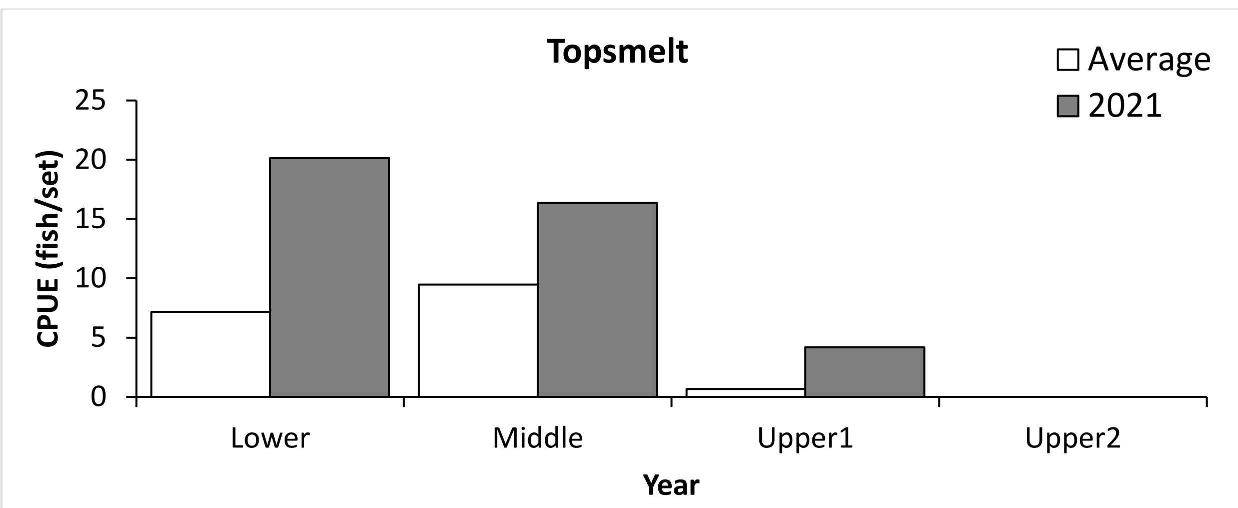


Figure 4.4.27. Spatial distribution of topsmelt in the Russian River Estuary, 2004-2021. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach during 2004 and 2009. Data from 2004 to 2021 were averaged.

All three salmonid species in the Russian River watershed were detected in the Russian River Estuary at the parr and/or smolt life stages. The fluctuation in abundance of steelhead annually is likely attributed to the variability of 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. In addition, a prolonged and severe drought that began in 2013 likely contributed to the low abundance of steelhead in the Russian River Estuary in 2021. It is worth noting that steelhead abundance was low in 2021 at the Mainstem Russian River (Mirabel), Mark West Creek, Dutch Bill Creek, and Austin Creek downstream migrant traps. It is likely that the majority of steelhead captured in the Estuary pass these downstream migrant traps on the way to the estuary. Low abundance at these trap sites suggest that fewer steelhead young-of-the-year entered the Estuary when compared to some years in the past. For more information on Sonoma Water's downstream migrant trapping efforts see Chapter 4.5.

The capture of 734 European green crabs is alarming. Prior to 2021 only one individual had been captured seining and that capture occurred in 2014. European green crabs have been present in the estuary for some time and were captured in small numbers by Sonoma Water during invertebrate sampling. However, based on seining results from 2021 their abundance and distribution appears to have increased. Lower than normal winter rainfall may have resulted in increased salinity in the lower estuary that may be partly responsible for the increased number of European green crabs as there may have been more suitable habitat during the winter of 2021.

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.

4.5 Downstream Migrant Trapping

The Reasonable and Prudent Alternative (RPA) in the Russian River Biological Opinion requires Sonoma Water to provide information about the timing of downstream movements of juvenile steelhead into the Russian River Estuary, 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 4.5.1):

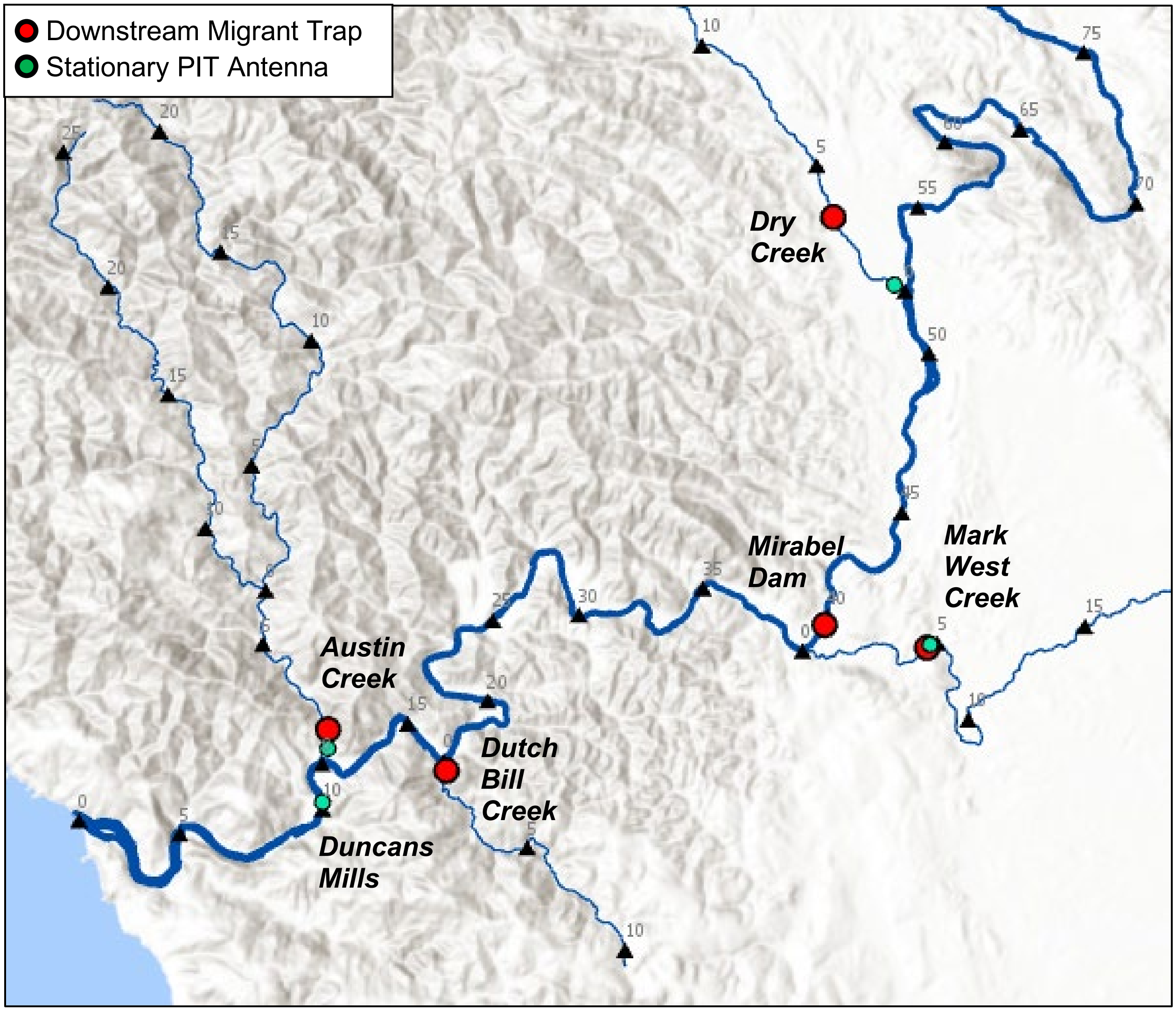


Figure 4.5.1. Map of downstream migrant detection sites in the lower Russian River, 2021. Numbered symbols along stream courses represent distance (km) from the mouth of each stream.

- Mainstem Russian River at Mirabel
- Mark West Creek
- Dutch Bill Creek
- Austin Creek
- Dry Creek (capture only, included for broader sampling context)

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 monitoring activities conducted in the estuary (e.g., water quality monitoring, beach seining) as well as fish trapping operations in Dry Creek are presented in other sections of the Russian River Biological Opinion Status and Data Report Year 2021-2022.

Methods

In 2021 Sonoma Water again relied on downstream migrant traps and stationary PIT antenna arrays at lower-basin trap sites to address the objectives in the RPA. Similar to 2010 through 2020, 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. The following sections describe the sampling methods and analyses conducted for data collected at each site.

Estuary/Lagoon PIT antenna systems

Typically, two antenna arrays with multiple flat plate antennas (antennas designed to lay flat on the stream bottom) are installed in the upper Russian River estuary near the town of Duncans Mills (riverkm 10.46) to detect PIT-tagged fish entering the estuary (Figure 4.5.2). Generally, 10 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 5 antennas placed side by starting at the west river bank and extending out into the channel.

Figure 4.5.2. Flat plate antenna arrays at Duncans Mills (river km 10.46). Rectangles represent individual flat plate antennas.

Lower Russian 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 4.5.1) 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 4.5.1). Downstream migrant traps are also operated at the Mirabel inflatable dam. Sonoma Water operated three types of downstream migrant traps in 2021: rotary screw trap, funnel trap and pipe trap depending on the stream, water depth, and velocity (Figure 4.5.3). Fish traps were checked

Mark West Creek: Pipe trap (fished 3/31-5/27).

Dutch Bill Creek: Pipe trap (fished 3/10-5/3).

Austin Creek: Funnel trap (fished 3/25-4/19), pipe trap (fished 4/20-5/22).

Figure 4.5.3. Photographs of downstream migrant traps operated by the Sonoma Water (Mark West, Dutch Bill and Austin creeks). See the Russian River Biological Opinion Status and Data Report Year 2021-2022 for details regarding operation of the Dry Creek trap.

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.

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 the Sonoma Water's inflatable dam site at Mirabel (approximately 38.7 km upstream of the river mouth in Jenner), although only one trap may be operated in years with relatively low stream flow (Table 4.5.1). Sonoma Water also operates a rotary screw trap at Dry Creek. The purpose of these trapping efforts was to fulfill a broader set of objectives in the Russian River Biological Opinion than what is described in the current section of this report.

Mark West Creek

A pipe trap was installed on Mark West Creek approximately 4.8 km upstream of the mouth on March 31. The pipe trap was removed and all trapping operations were suspended on May 27 when fish captures declined rapidly (Table 4.5.1).

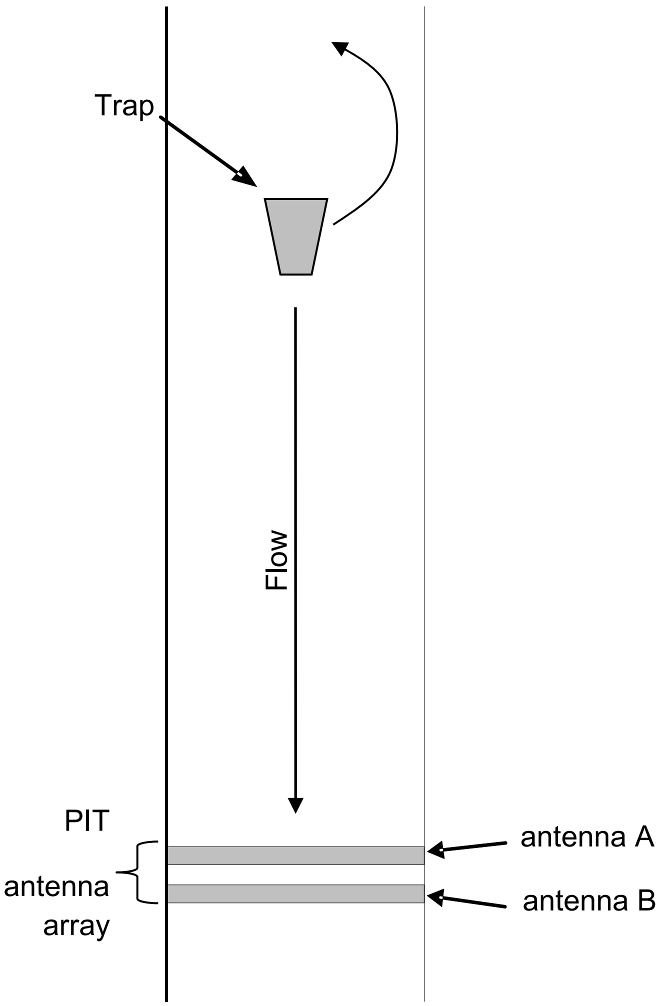
Dutch Bill Creek

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 10, and fished until the completion of trapping operations on May 3, when stream flow in lower Dutch Bill Creek became disconnected (Table 4.5.1).

Austin Creek

A funnel net was installed in Austin Creek on March 25. Due to low water velocity this trap was changed to a pipe trap on April 20. Trapping continued until May 22 when surface flow in lower Austin Creek was no longer contiguous and daily catches of steelhead dropped to zero (Table 4.5.1).

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 (Figure 4.5.4). Sonoma Water 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. 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, it is likely 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) is typically used to calculate antenna efficiency for the PIT antenna array located in Austin Creek, however due to a low number of detections at Duncans Mills the paired antenna array in Austin Creek was used to calculate efficiency in 2021.



1. Methods:

Capture and PIT-tag juvenile steelhead, then release newly tagged fish upstream while releasing previously-tagged fish (recaptures) downstream.

2. Estimating trap efficiency:

Of the PIT-tagged fish released upstream of the trap, how many were recaptured in the trap before being detected on either antenna in the downstream antenna array?

3. Estimating antenna efficiency:

Of the PIT-tagged fish detected on the downstream antenna in the array (antenna B), how many were also detected on the upstream antenna (antenna A).

Figure 4.5.4. 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.

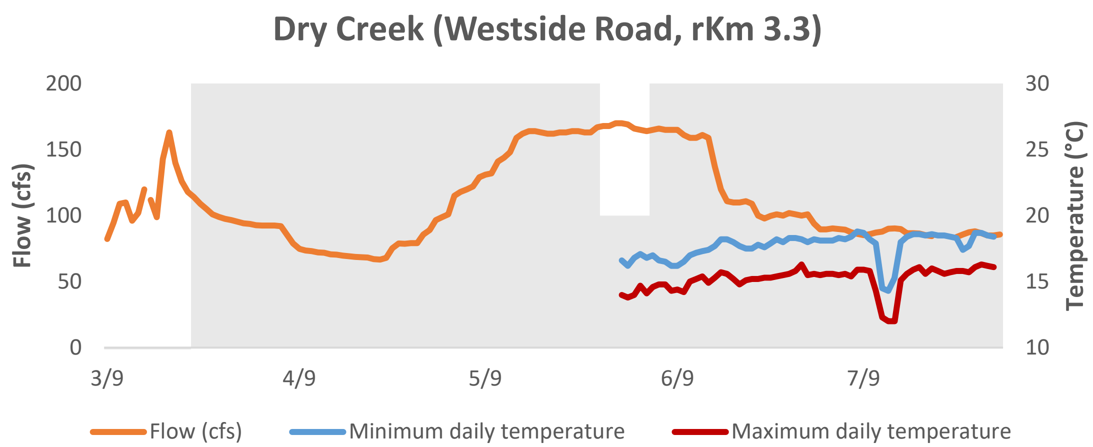
Table 4.5.1. Installation and removal dates, and total number of days fished for lower Russian River monitoring sites operated by Sonoma Water in 2021.

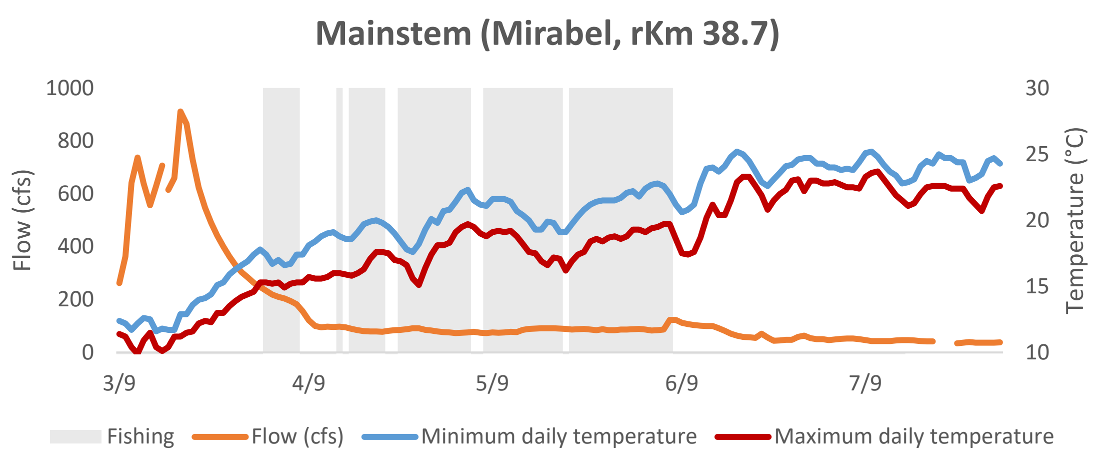
Monitoring site (gear type)	Installation date	Removal date	Number of days fished
Dry Creek (DSMT)	3/23	7/31	127
Mirabel (DSMT)	4/2	6/7	54
Mark West Creek (DSMT)	3/31	5/27	57
Dutch Bill Creek (DSMT)	3/10	5/3	52
Austin Creek (DSMT)	3/25	5/22	57
Duncans Mills (PIT antenna array)[1]	Continuous	Continuous	Continuous

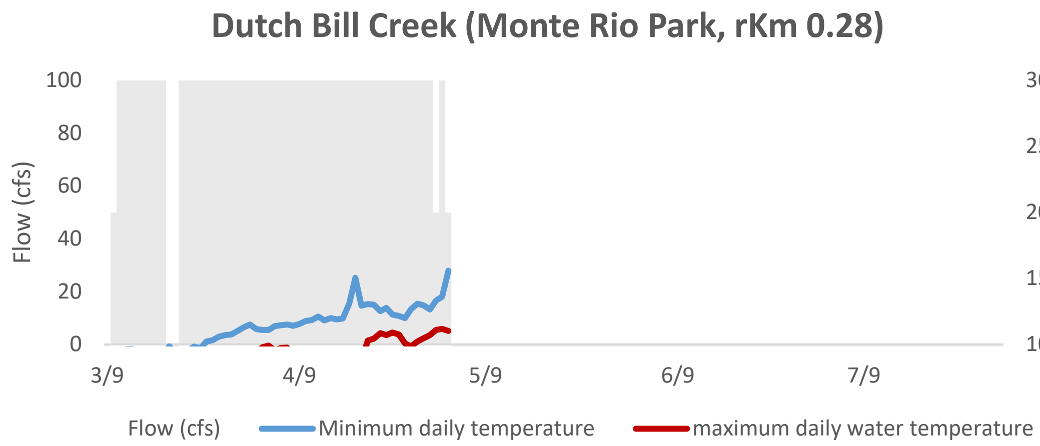
[1]See text for details on changes to PIT antenna array throughout the season.

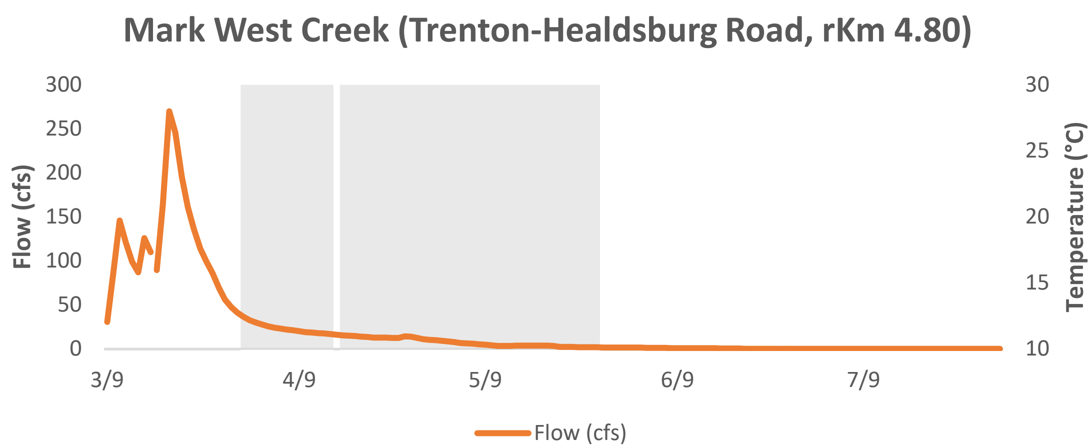
Results

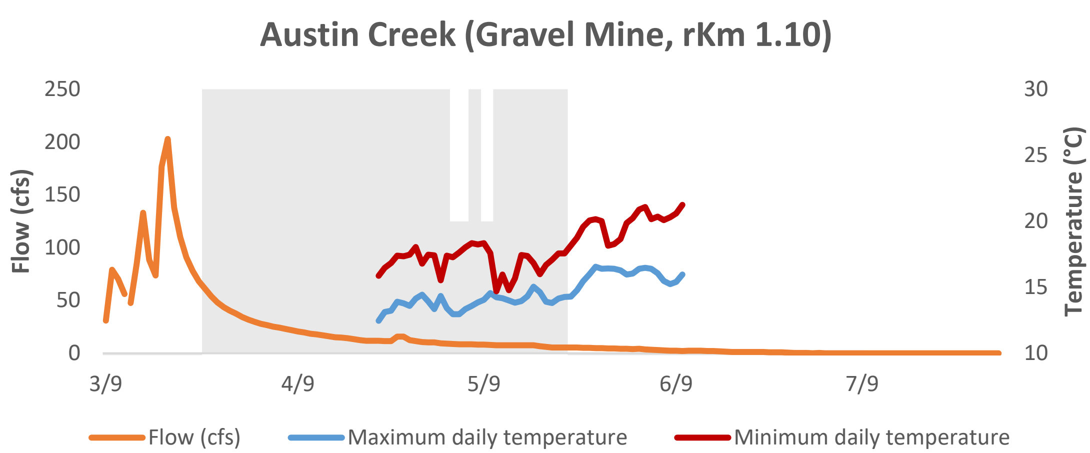
Stream flow largely dictates when downstream migrant traps can be installed (Figure 4.5.5). The sampling period most likely encompassed a high portion of the juvenile steelhead movement period but a substantial portion of the steelhead smolt migration period was likely missed due to the early run timing 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
3/9
4/9
5/9
6/9
7/9
Flow (cfs)
Minimum daily temperature
maximum daily water temperature


Mark West Creek (Trenton-Healdsburg Road, rKm 4.80)
Flow (cfs)
Temperature (°C)
300
250
200
150
100
50
0
30
25
20
15
10
3/9
4/9
5/9
6/9
7/9
Flow (cfs)


Austin Creek (Gravel Mine, rKm 1.10)
Flow (cfs)
Temperature (°C)
250
200
150
100
50
0
30
25
20
15
10
3/9
4/9
5/9
6/9
7/9
Flow (cfs)
Maximum daily temperature
Minimum daily temperature

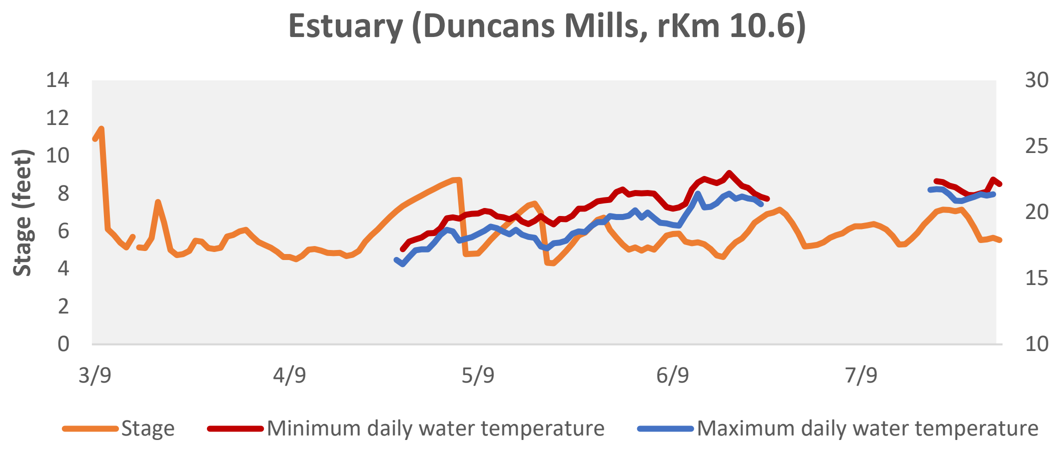
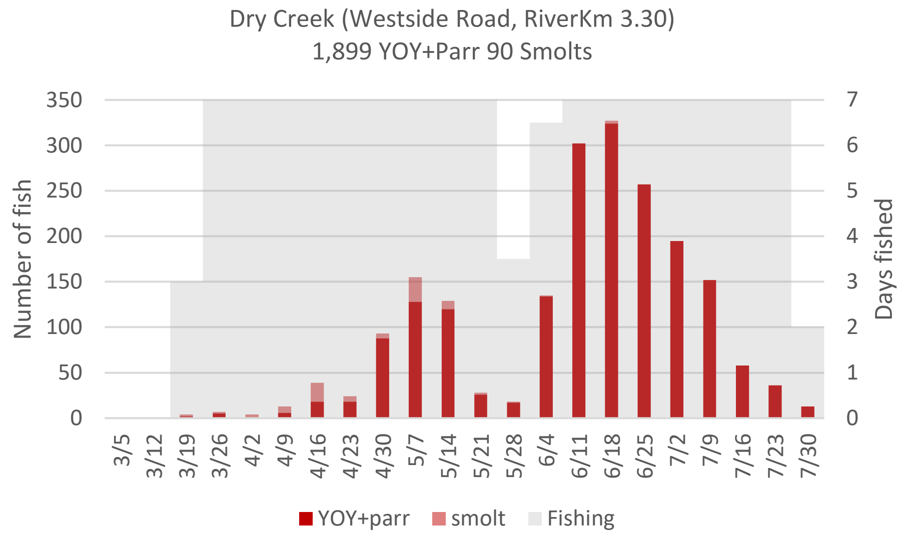


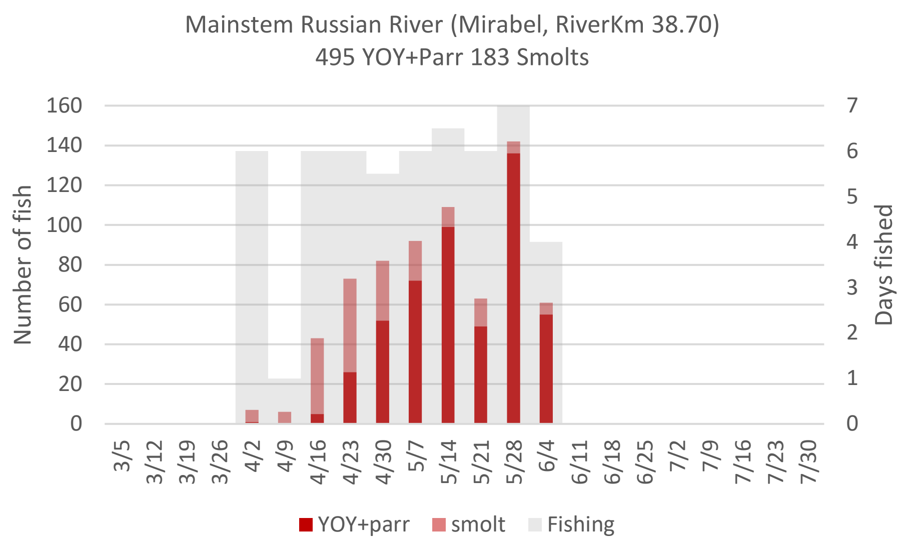
Figure 4.5.5. Environmental conditions at downstream migrant detection sites from March through July. Gray shading indicates the proportion of each day that each facility was operated. Discharge data are from the USGS gage at Healdsburg (mainstem Russian, 11464000), the USGS gage at Trenton-Healdsburg Road (Mark West Creek, 11466800), a gage operated by CMAR on Dutch Bill Creek (data unavailable in 2021) and the USGS gauge at Cazadero (Austin Creek, 11467200). Stage (max daily) data for the estuary are from the USGS gage near Highway 1 (11467270). Estuary water temperature was collected by Sonoma Water in the Russian River at Freezeout creek. Mainstem water temperature data are from the USGS Hacienda gage (11467000). Water temperature for Dry Creek was collected at the USGS Dry Creek gage at Lambert Bridge (11465240). At all other sites temperature data are from the data loggers operated by Sonoma Water at each monitoring site.

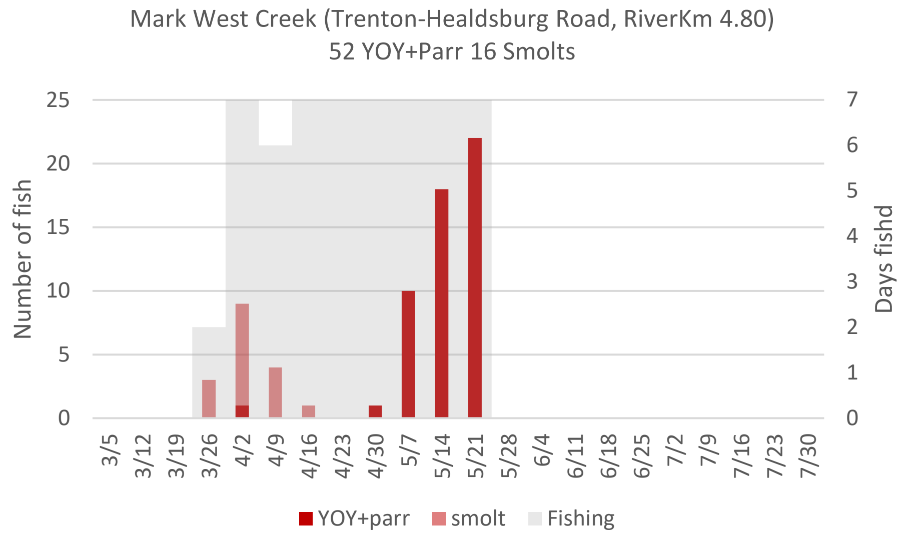
Steelhead

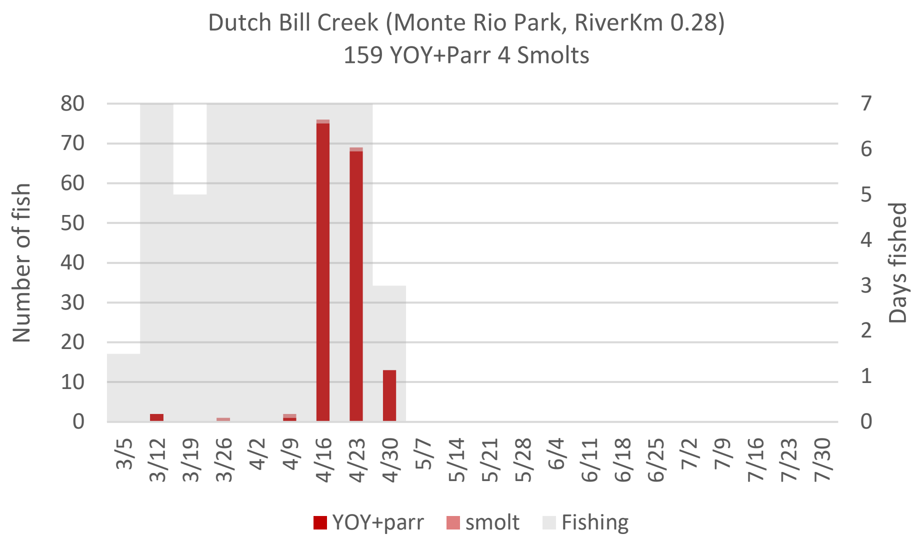
Steelhead were most frequently encountered at the Dry Creek trap. In total 1,899 YOY and parr, and 90 smolts were captured at the Dry Creek trap. In Austin Creek 830 YOY and parr and 4 smolt were captured. At Dutch Bill Creek 159 YOY and parr and 4 smolts were captured. At Mark West Creek 52 YOY and parr, and 16 smolts were captured. At the Mainstem Russian River trap 495 YOY and parr and 183 smolts were captured (Figure 4.5.6).

In 2021 Sonoma Water relied on the Duncans Mills PIT tag antennas for estimating the number of steelhead YOY and parr that entered the estuary. Of the 284 juvenile steelhead that were PIT-tagged in the downstream migrant traps, 3 (1%) were detected on the PIT antenna array at Duncans Mills (Table 4.5.2 and Table 4.5.3). 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.


Dry Creek (Westside Road, RiverKm 3.30)
1,899 YOY+Parr 90 Smolts
Number of fish
Days fished
0
50
100
150
200
250
300
350
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
YOY+parr
smolt
Fishing


Mainstem Russian River (Mirabel, RiverKm 38.70)
495 YOY+Parr 183 Smolts
Number of fish
Days fished
0
20
40
60
80
100
120
140
160
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
YOY+parr
smolt
Fishing


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
52 YOY+Parr 16 Smolts
Number of fish
Days fishd
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
YOY+parr
smolt
Fishing


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
159 YOY+Parr 4 Smolts
Number of fish
Days fished
80
70
60
50
40
30
20
10
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
YOY+parr
smolt
Fishing

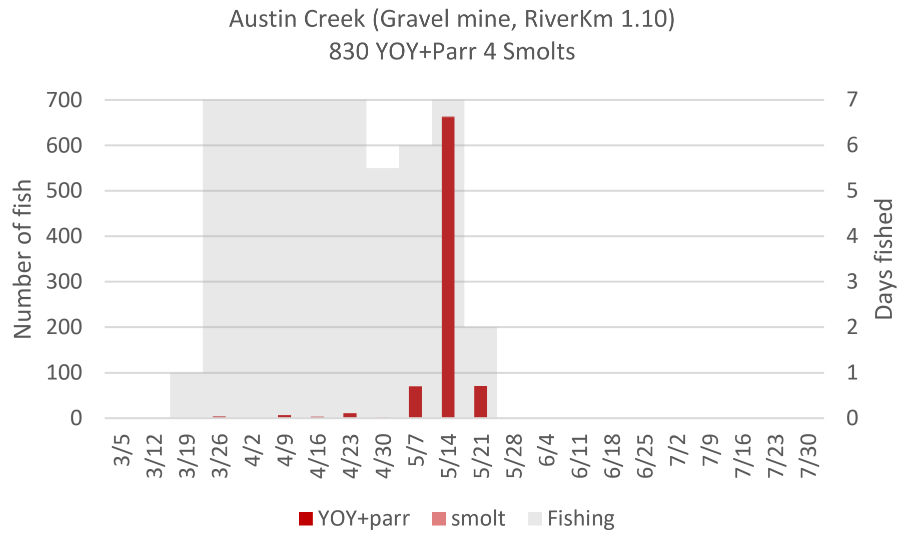


Figure 4.5.6. Weekly capture of steelhead by life stage at lower Russian River downstream migrant trapping sites, 2021. Gray shading indicates the number of days per week that the trap was fishing. Note the different vertical scale among plots for each site.

Table 4.5.2. Number of steelhead juveniles PIT-tagged at downstream migrant traps, 2009-2021 (N.T. indicates that tagging steelhead was not part of the protocol for that year, a dash indicates the trap was not operated).

Site	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dry Creek	N.T.	N.T.	N.T.	N.T.	2,703	1,348	N.T.	N.T.	N.T.	N.T.	N.T.	N.T	N.T.
Mainstem	5	96	99	315	100	101	-	-	1	63	40	46	100
Mark West Creek	-	-	-	43	135	18	19	546	49	62	125	14	22
Dutch Bill Creek	-	46	22	6	12	21	7	46	377	12	74	176	3
Austin Creek	-	996	500	1,636	1,749	590	107	1,205	359	780	172	383	159
Total	**5**	**1,138**	**621**	**2,000**	**4,699**	**2,078**	**133**	**1,797**	**791**	**917**	**411**	**618**	**284**

Table 4.5.3. The number of steelhead captured at downstream migrant traps, the number PIT tagged and the number detected on the Duncans Mills PIT tag detection systems before October 15, 2021.

Site	Number Captured	Number PIT- Tagged	Number (proportion) Detected at Duncans Mills
Mainstem	695	100	0 (0)
Mark West Creek	77	22	0 (0)
Dutch Bill Creek	165	3	1 (0.33)
Austin Creek	834	159	2 (0.01)
Total	1,771	284	3 (0.01)

Over the course of the season, 834 steelhead were captured at Austin Creek of which 808 were YOY (444 of the 808 YOY were ≥60 mm, Figure 4.5.11). Although Sonoma Water applied PIT tags to 159 total individuals (YOY+parr), based on their size, 148 of these PIT-tagged fish were estimated to be YOY. In total, 132 PIT-tagged steelhead YOY were released upstream of the trap and 14 were released downstream of the trap (Table 4.5.4). Because 54 of the 148 PIT-tagged YOY were detected on the Austin Creek PIT antenna array downstream of the trap, at least 36.5% (54/148) moved downstream into the estuary/lagoon. Because of imperfect antenna detection efficiency, 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 49 PIT tagged individuals (YOY+parr) detected on the downstream antenna in the array (Duncans Mills), 47 were also detected on the upstream antenna array (Austin Creek) resulting in an estimated antenna efficiency of 96% (47/49). In order to estimate the number of YOY out of the original 54 that actually moved downstream of the Austin Creek antenna array, this proportion was used to expand the detections to 56 (54/96%).

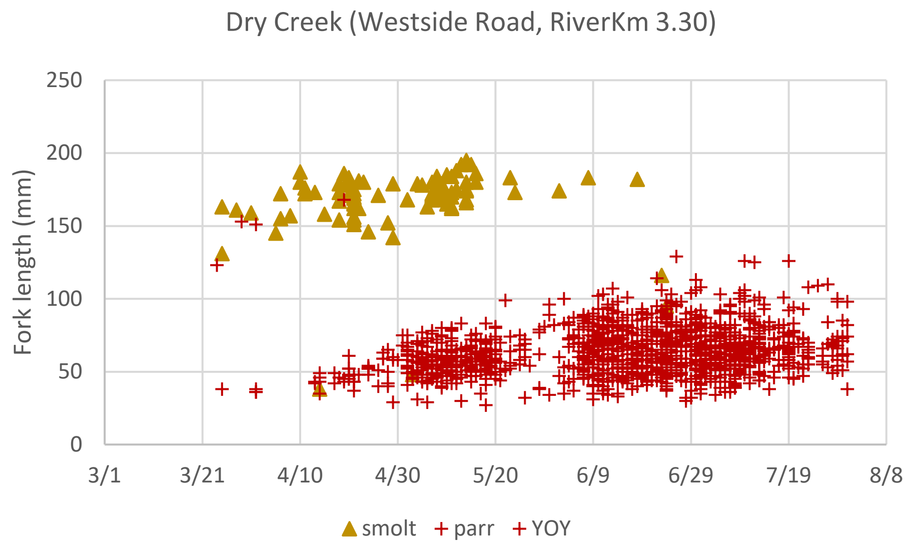
In total 40 YOY that were detected on either of the downstream PIT antenna arrays were also released upstream of the trap, however only 1 were recaptured in the trap. Because so few steelhead were recaptured in the trap a population estimate was not calculated.

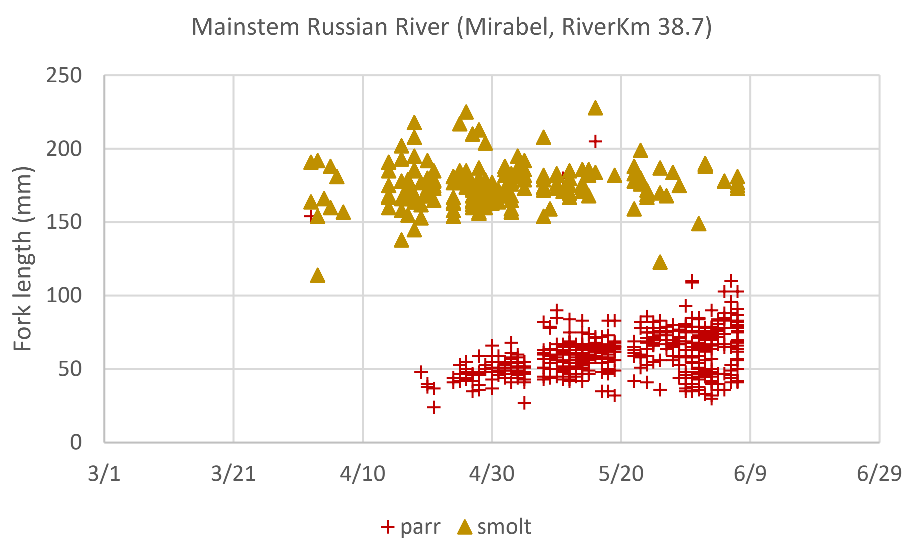
When compared to Austin, Dry, and Dutch Bill creeks fewer numbers of juvenile steelhead were captured at the mainstem Russian River and Mark West (Figure 4.5.6) meaning that fewer numbers of juvenile steelhead were PIT-tagged at these locations (Table 4.5.3). Fork lengths of fish caught at these traps show at least three year classes with steelhead YOY present at each of the trapping locations (Figure 4.5.7). As in other years, the low number of steelhead smolts captured at 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 (Figures 4.5.8 through 4.5.12).

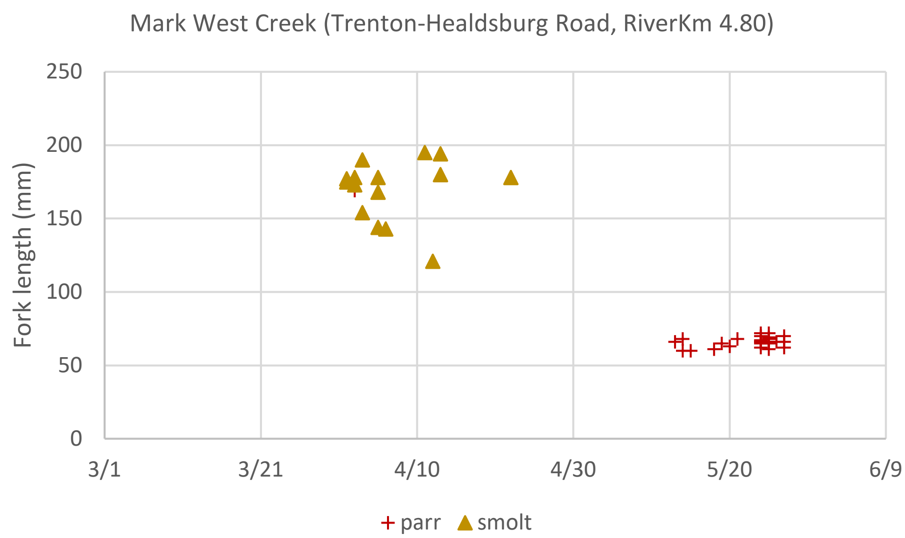
Table 4.5.4. PIT tag and trap capture metrics and values for young-of-year (YOY) steelhead in Austin Creek. Note that 2010 numbers differ from Martini-Lamb and Manning (2011) because they have been adjusted to only include YOY.

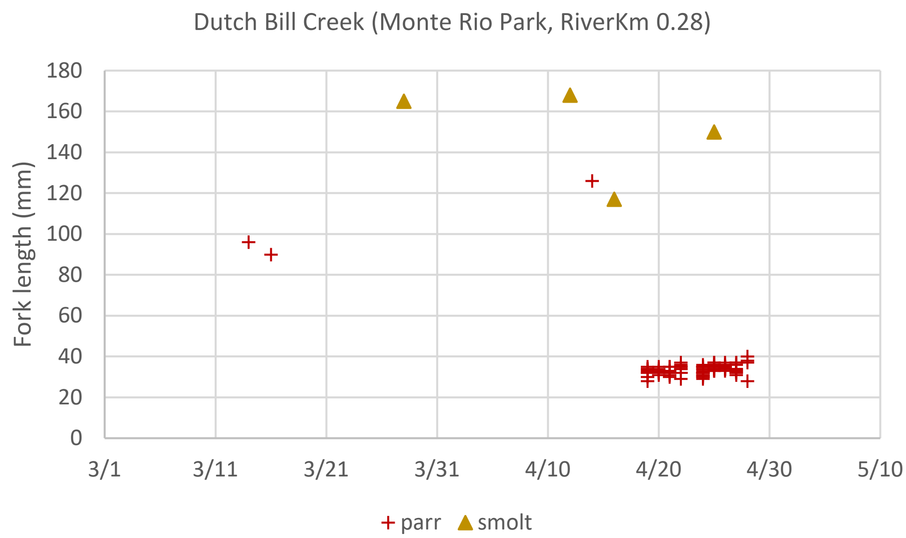
Metric	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number pit-tagged YOY released upstream of trap	765	324	1,356	0	214	101	1,132	244	713	128	273	132
Number pit-tagged YOY released downstream of trap	195	2	162	1,746	269	6	73	2	6	7	98	16
Number pit-tagged YOY detected on antenna array that were tagged in Austin creek	547	131	574	1,335	275	13	193	80	291	53	189	54
Number pit-tagged YOY released upstream & detected on antenna array	389	131	486	0	57	13	151	80	291	49	127	40
Number released upstream & recaptured in trap & detected on antenna	47	8	196	0	2	0	60	0	61	3	5	1
Estimated trap efficiency	**12.1%**	**6.1%**	**40.3%**	**N/A**	**N/A**	**N/A**	**39.7%**	**N/A**	**21.0%**	**5.7%**	**N/A**	**N/A**
Number YOY+parr detected on both antennas in array	241	93	85	399	129	34	76	52	60	64	31	47
Number YOY+parr detected on downstream antenna only	288	178	129	463	162	35	205	55	75	71	37	49
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]	**90.1%**	**83.7%**	**95.9%**
Number YOY captured and pit-tagged	960	324	1,518	1,746	483	42	993	319	719	168	371	148
Total number of YOY captured (≥60 mm only)	2,617	453	2,341	4,216	541	42	2,427	319	2,056	368	344	444
Estimated number of pit-tagged YOY emigrants (≥60 mm only)	**632**	**251**	**759**	**1,549**	**325**	**32**	**520**	**55**	**93**	**138**	**225**	**61**
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%**	**38%**	**50%**	**41.3%**
Estimated population size of YOY at trap	**21,628**	**7,426**	**5,804**	**N/A**	**N/A**	**N/A**	**6,113**	**N/A**	**9,791**	**6,456**	**N/A**	**N/A**
Estimated number of YOY in population that emigrated	**14,231**	**5,755**	**2,901**	**N/A**	**N/A**	**N/A**	**2,812**	**N/A**	**3,965**	**2,453**	**N/A**	**N/A**

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


Dry Creek (Westside Road, RiverKm 3.30)
250
200
150
100
50
0
Fork length (mm)
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
8/8
smolt
parr
YOY


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


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
Fork length (mm)
250
200
150
100
50
0
3/1
3/21
4/10
4/30
5/20
6/9
parr
smolt


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
Fork length (mm)
180
160
140
120
100
80
60
40
20
0
3/1
3/11
3/21
3/31
4/10
4/20
4/30
5/10
parr
smolt

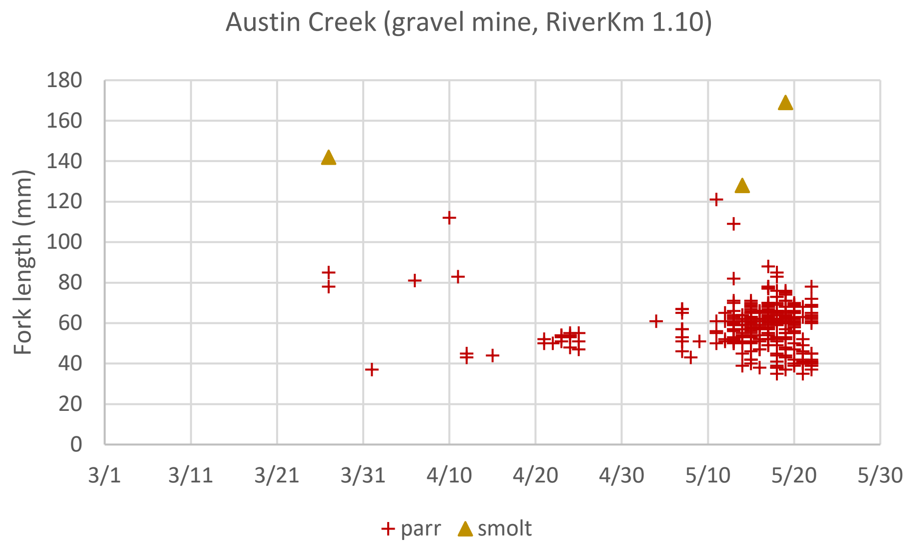
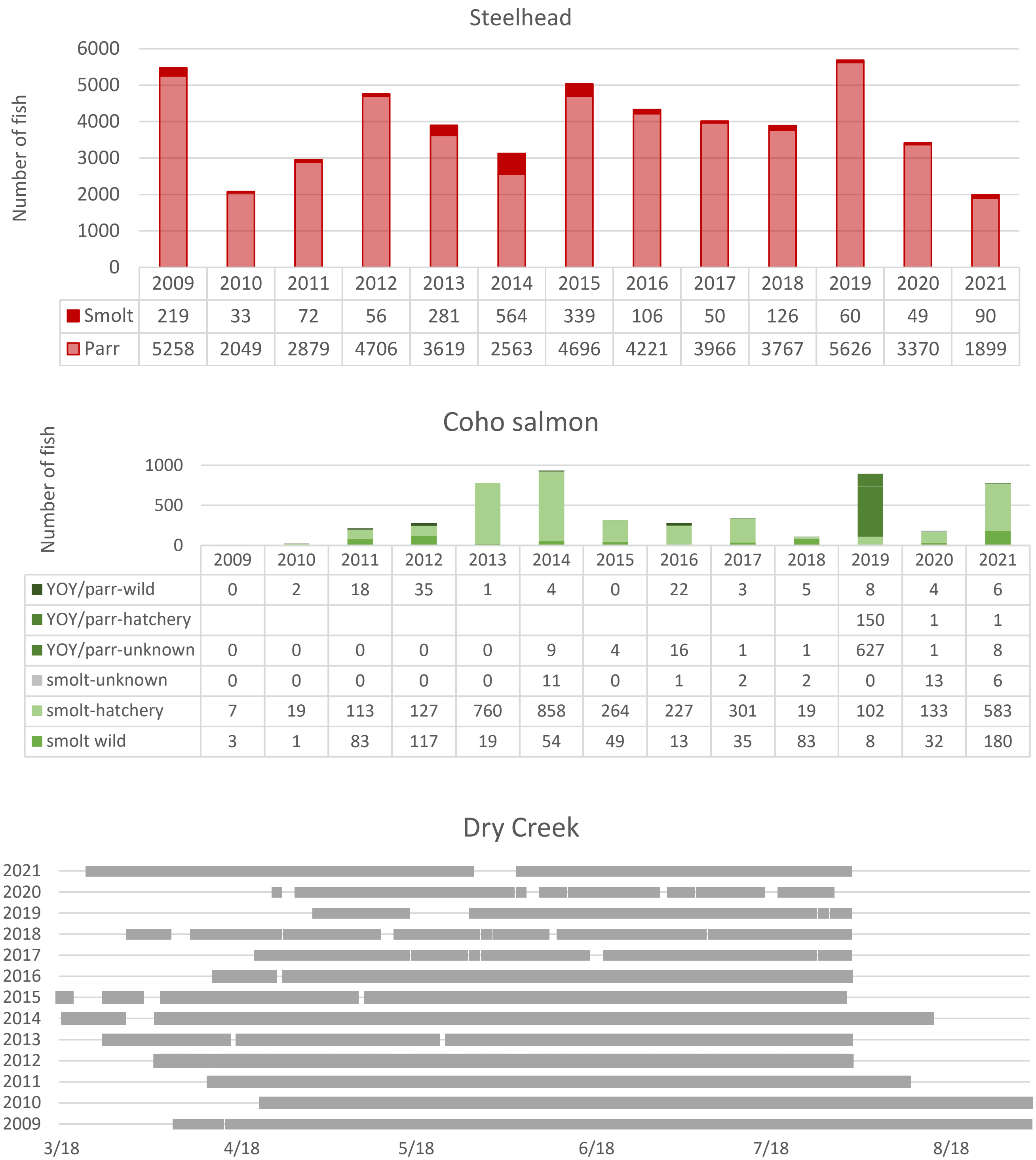


Figure 4.5.7. Weekly fork lengths of steelhead captured at lower Russian River downstream migrant trap sites, 2021.



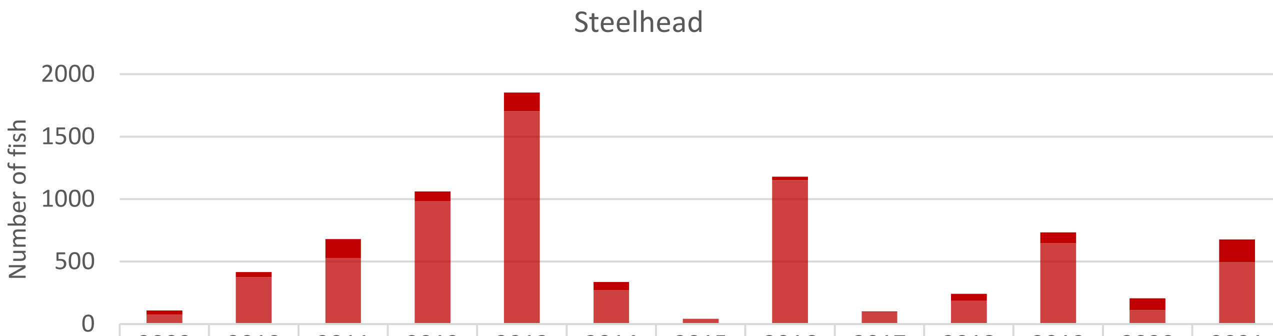
Steelhead

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Smolt	219	33	72	56	281	564	339	106	50	126	60	49	90
Parr	5258	2049	2879	4706	3619	2563	4696	4221	3966	3767	5626	3370	1899

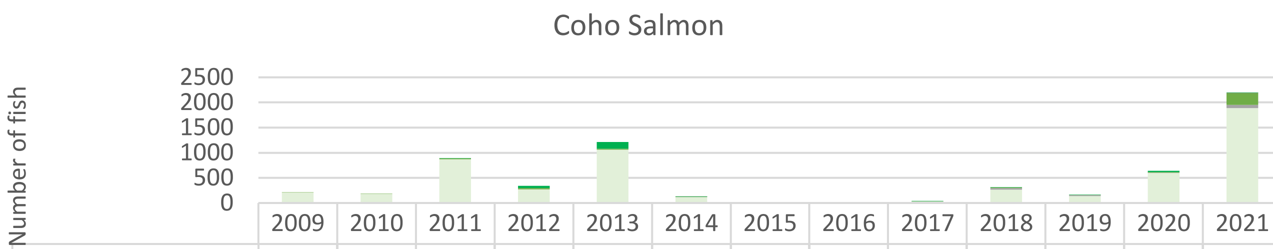
Coho salmon

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
YOY/parr-wild	0	2	18	35	1	4	0	22	3	5	8	4	6
YOY/parr-hatchery											150	1	1
YOY/parr-unknown	0	0	0	0	0	9	4	16	1	1	627	1	8
smolt-unknown	0	0	0	0	0	11	0	1	2	2	0	13	6
smolt-hatchery	7	19	113	127	760	858	264	227	301	19	102	133	583
smolt wild	3	1	83	117	19	54	49	13	35	83	8	32	180

Figure 4.5.8. 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), 2009-2021.

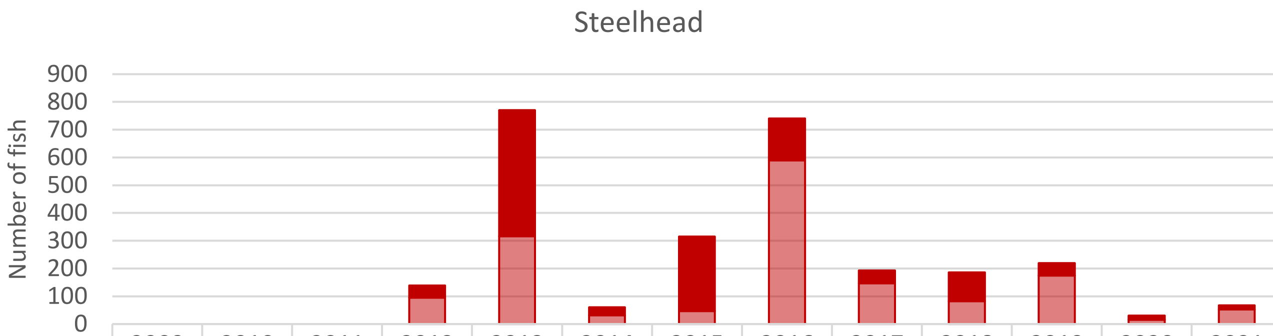


	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
smolt	33	42	151	78	148	67		28	7	57	86	94	183
parr	75	375	528	984	1705	270	42	1151	95	185	648	111	495

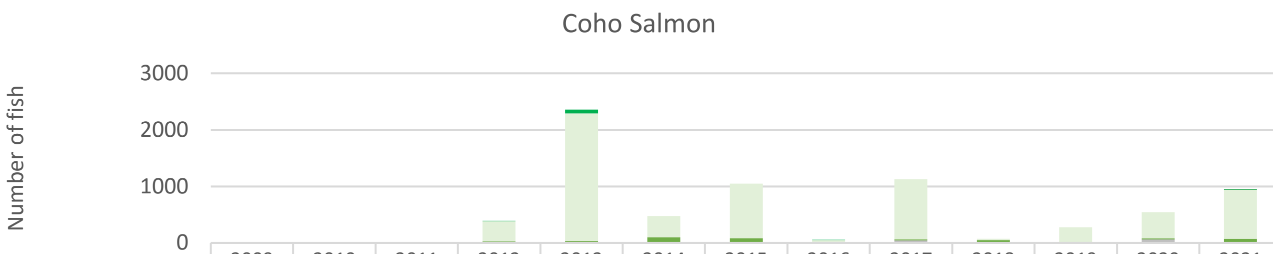


	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
YOY/parr-wild			10	45	137	1		11	1	1	2	24	8
YOY/parr-unknown						1							12
smolt-wild	5	1	15	26	20	6		2	4	14	8	16	228
smolt-unknown			0	0	0	1		0	1	33	21	3	61
smolt-hatchery	208	180	872	270	1059	117			28	265	136	599	1891

Figure 4.5.9. 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), 2009-2021.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Smolt				44	454	29	268	150	46	104	45	15	16
Parr				95	316	32	47	590	147	82	175	16	52



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
YOY/parr-unknown													1
YOY/parr-wild	0	0	0	7	66	0	0	5	0	0	0	0	15
smolt-hatchery				357	2258	375	967	37	1065	23	273	465	865
smolt-wild				28	32	84	80	16	17	50	3	14	67
smolt-unknown	0	0	0	0	0	18	4	0	44	1	0	65	8

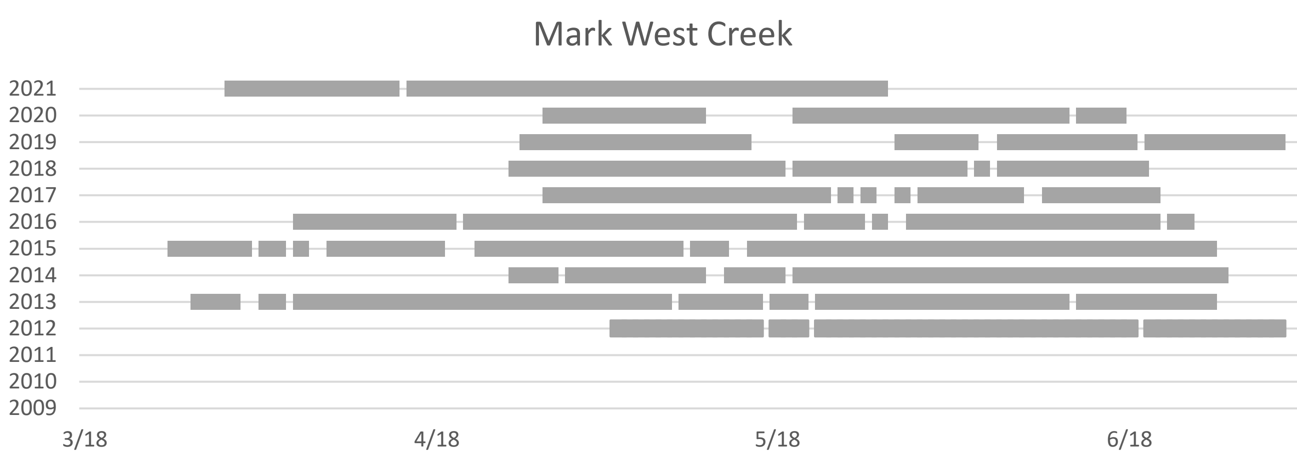
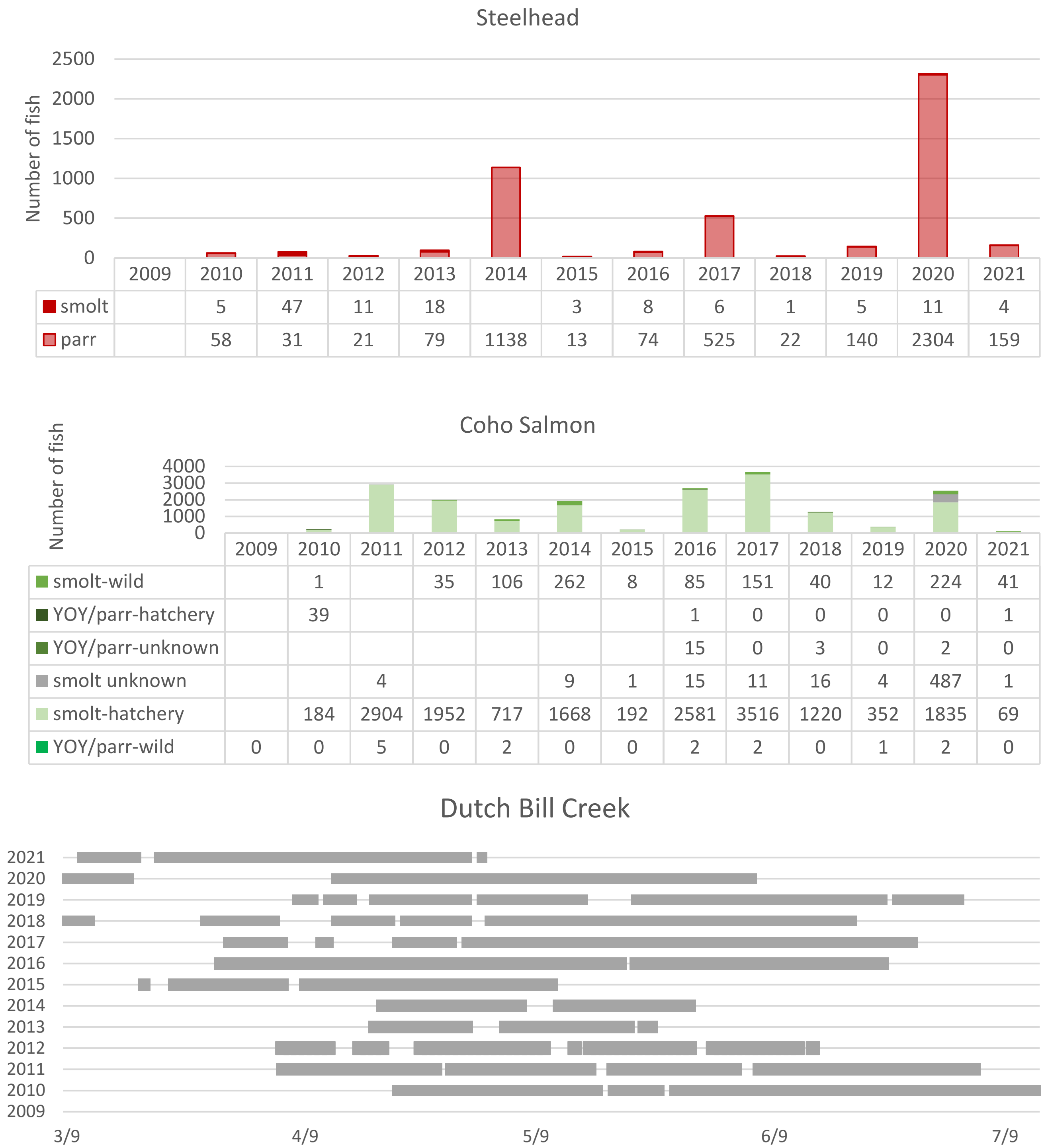


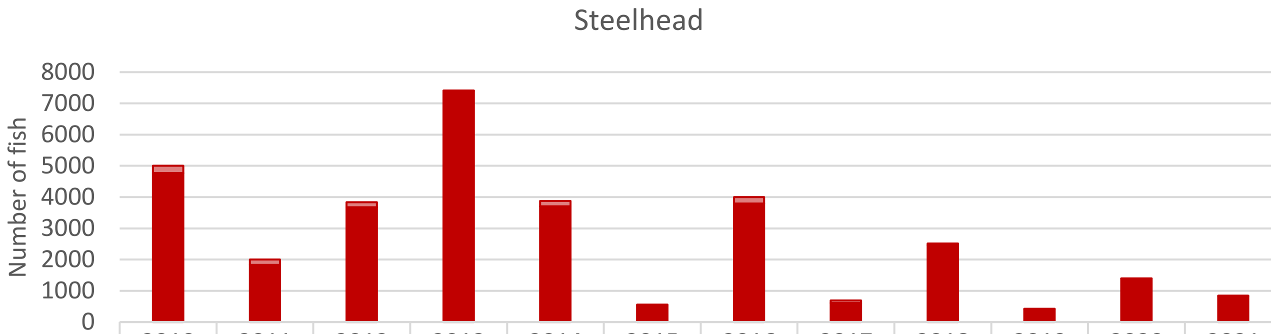
Figure 4.5.10. Number of steelhead and Coho Salmon captured by life stage and origin at the Mark West Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2021.



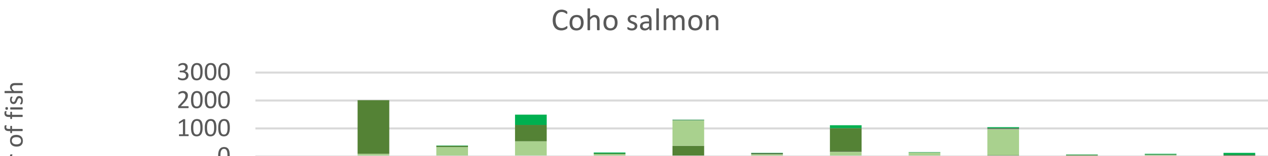
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
smolt		5	47	11	18		3	8	6	1	5	11	4
parr		58	31	21	79	1138	13	74	525	22	140	2304	159

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
smolt-wild		1		35	106	262	8	85	151	40	12	224	41
YOY/parr-hatchery		39						1	0	0	0	0	1
YOY/parr-unknown								15	0	3	0	2	0
smolt unknown			4			9	1	15	11	16	4	487	1
smolt-hatchery		184	2904	1952	717	1668	192	2581	3516	1220	352	1835	69
YOY/parr-wild	0	0	5	0	2	0	0	2	2	0	1	2	0

Figure 4.5.11. 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), 2009-2021.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Smolt	232	175	164	14	173	30	201	79	50	6	1	4
parr	4774	1829	3672	7397	3702	527	3798	611	2466	411	1387	830



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
YOY/parr wild			14	372	38	1	9	105	5	24	3	31	75
YOY/parr-Hatchery		1906	45	584	24			809			30		1
YOY/parr-unknown						3	26	25		24	2	1	27
smolt-unknown						13		3	1	25			3
smolt-hatchery		103	335	507	74	899	80	144	116	916	26	59	19
smolt-wild				37	12	386	9	32	26	55	2	10	11

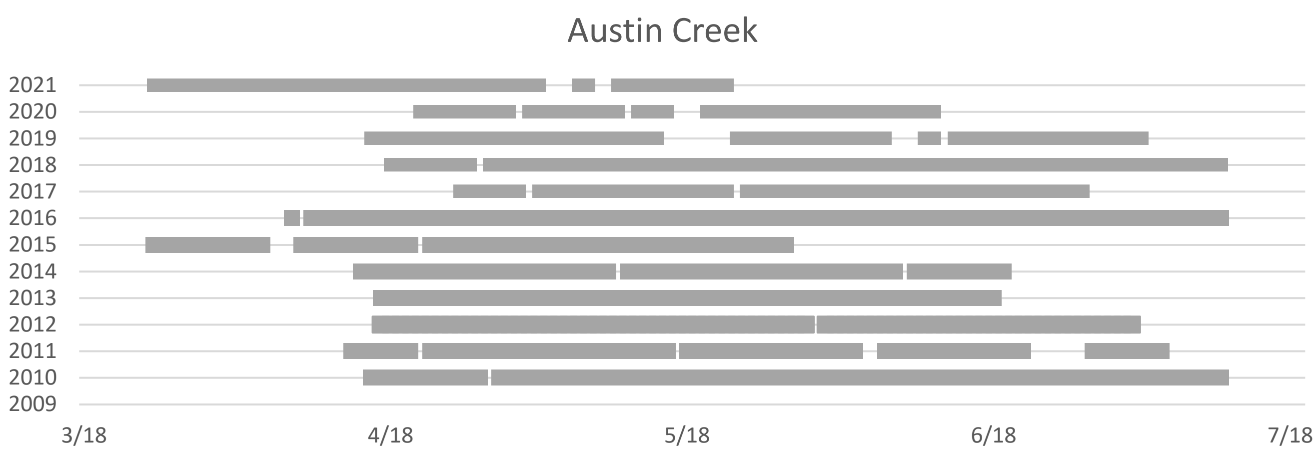


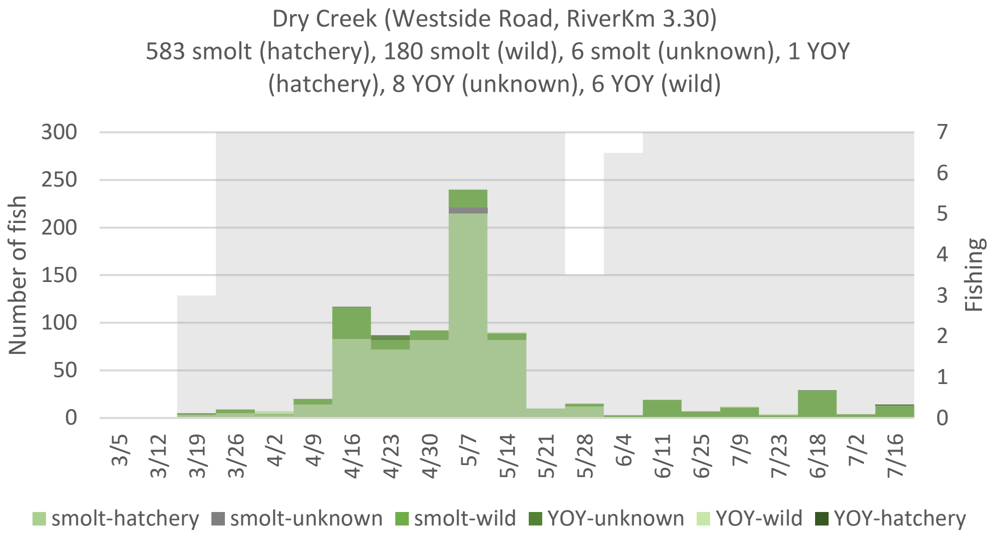
Figure 4.5.12. Number of steelhead and Coho Salmon captured by life stage and origin at the Austin Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2021.

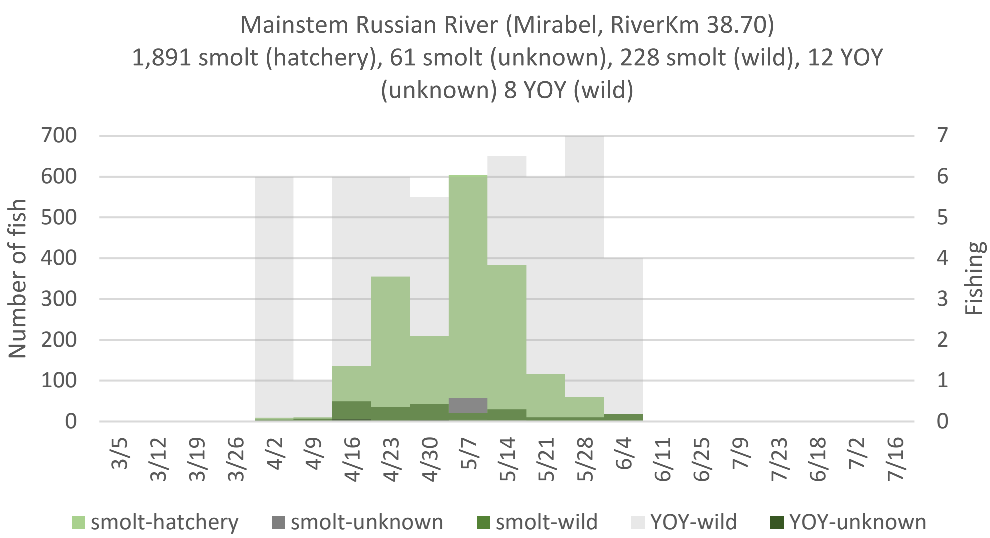
Coho Salmon

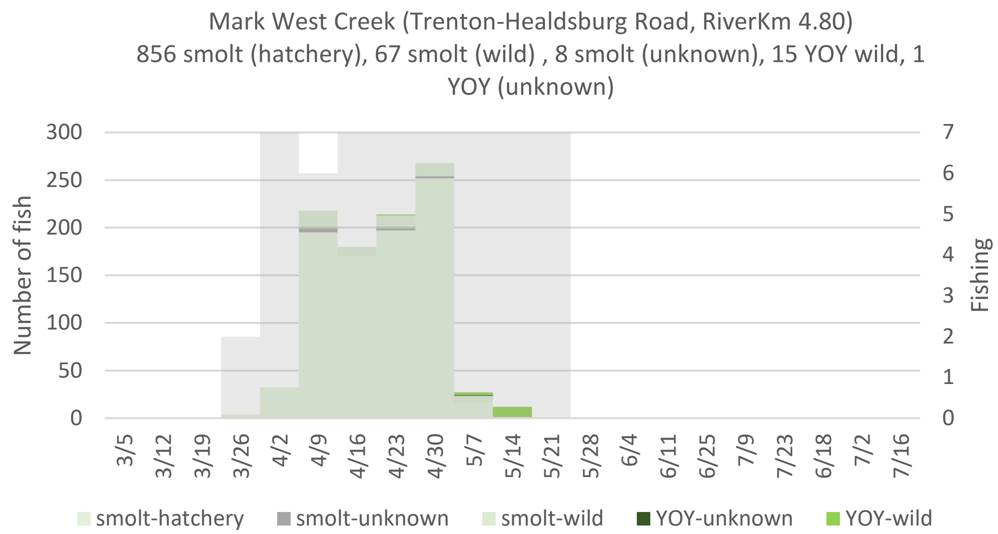
At Dry Creek 583 hatchery smolts, 180 wild smolts, 6 smolts of unknown origin, 1 hatchery YOY, 8 YOY of unknown origin, and 6 wild YOY were detected at the trap (Figures 4.5.8 and 4.5.14). On the mainstem Russian River 1,891 hatchery smolts, 228 wild smolts, 61 smolts of unknown origin, 8 wild YOY, and 12 YOY of unknown origin were detected at the trap (Figures 5.9 and 5.14). At Mark West Creek, 856 hatchery smolts, 67 wild smolts, and 8 smolts of unknown origin, 15 wild YOY, and 1 YOY of unknown origin were captured (Figures 4.5.10 and 4.5.14). A total of 69 hatchery smolts, 1 smolt of unknown origin, 41 wild smolts, and 1 hatchery YOY were captured at the Dutch Bill Creek trap (Figure 4.5.11 and Figure 4.5.14). At Austin Creek, 19 hatchery smolts, 11 wild smolts, 3 smolts of unknown origin, 1 hatchery YOY, 27 YOY of unknown origin, and 75 wild YOY were captured (Figures 4.5.12 and 4.5.14). Based on length data collected at the lower Russian River traps, there were at least two age groups (YOY: age-0 and parr/smolt: ≥age-1) of Coho captured (Figure 4.5.13). For a more detailed analysis of downstream migrant trapping catches of Coho from other Russian River streams see UCCE Coho Salmon Monitoring Program results for 2021.

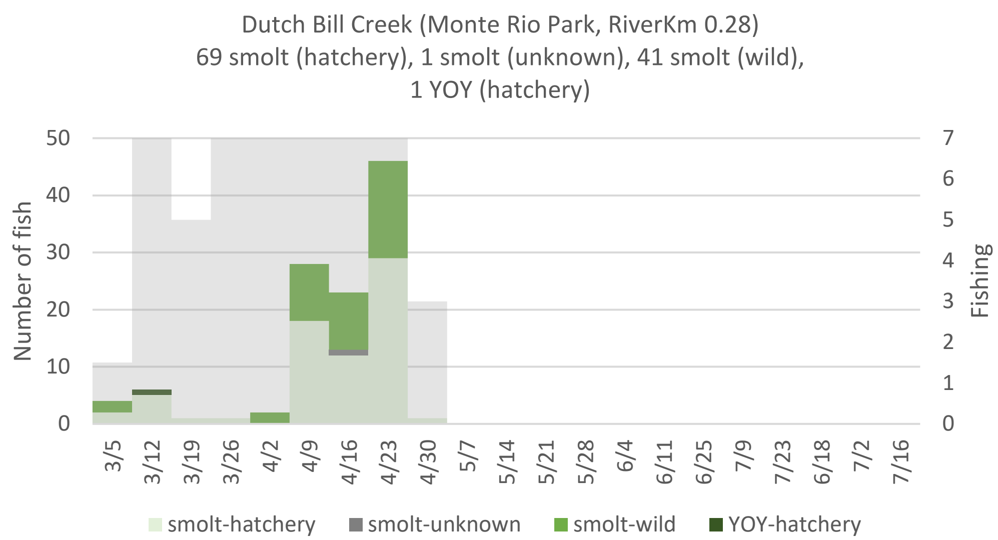
Chinook Salmon

In 2021 relatively few Chinook smolts were captured in Austin Creek, Dutch Bill Creek, and Mark West Creek (0, 0, and 3 respectively). In the mainstem Russian River 10,434 Chinook smolts were captured (Figures 4.5.15 and 4.5.16). Fork lengths of Chinook increased over the course of the trapping season (Figure 4.5.17). A total of 1,928 Chinook salmon smolts were marked with fin clips and released upstream of the mainstem Russian River trap. Of these, 302 (15.6 percent) were recaptured. Based on weekly recapture rates of fin clipped Chinook salmon it is estimated that 62,088 (95% CI: ± 7,276) Chinook smolts passed the Mirabel trap during the period that fin clips were applied (4/14-6/4). For more details on characteristics of Chinook smolts captured at Dry Creek see the Russian River Biological Opinion Status and Data Report Year 2021-2022.


Dry Creek (Westside Road, RiverKm 3.30)
583 smolt (hatchery), 180 smolt (wild), 6 smolt (unknown), 1 YOY (hatchery), 8 YOY (unknown), 6 YOY (wild)
Number of fish
Fishing
0
50
100
150
200
250
300
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
6/25
7/9
7/23
6/18
7/2
7/16
smolt-hatchery
smolt-unknown
smolt-wild
YOY-unknown
YOY-wild
YOY-hatchery


Mainstem Russian River (Mirabel, RiverKm 38.70)
1,891 smolt (hatchery), 61 smolt (unknown), 228 smolt (wild), 12 YOY (unknown) 8 YOY (wild)
Number of fish
Fishing
0
100
200
300
400
500
600
700
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
6/25
7/9
7/23
6/18
7/2
7/16
smolt-hatchery
smolt-unknown
smolt-wild
YOY-wild
YOY-unknown


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
856 smolt (hatchery), 67 smolt (wild) , 8 smolt (unknown), 15 YOY wild, 1 YOY (unknown)
Number of fish
Fishing
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
6/25
7/9
7/23
6/18
7/2
7/16
smolt-hatchery
smolt-unknown
smolt-wild
YOY-unknown
YOY-wild


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
69 smolt (hatchery), 1 smolt (unknown), 41 smolt (wild), 1 YOY (hatchery)
Number of fish
Fishing
50
40
30
20
10
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
6/25
7/9
7/23
6/18
7/2
7/16
smolt-hatchery
smolt-unknown
smolt-wild
YOY-hatchery

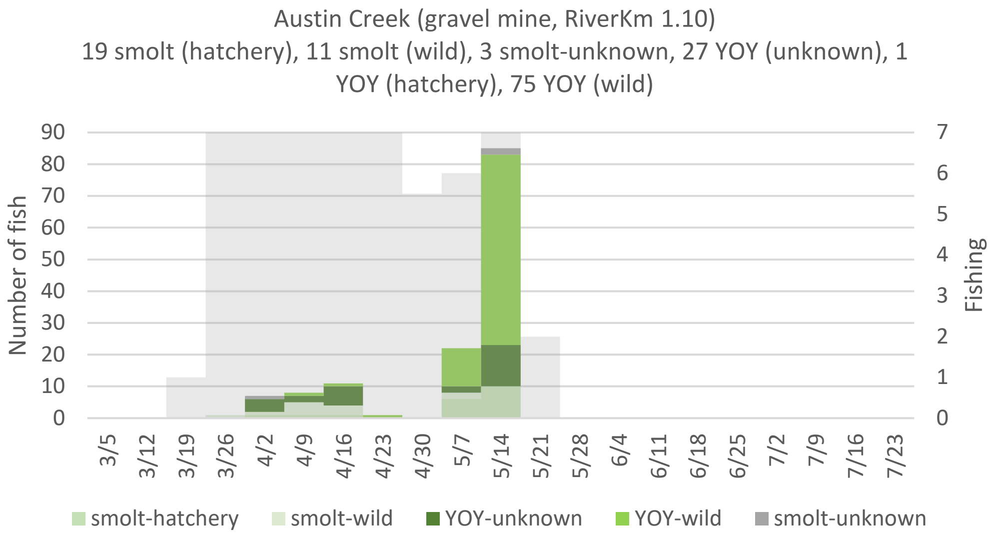
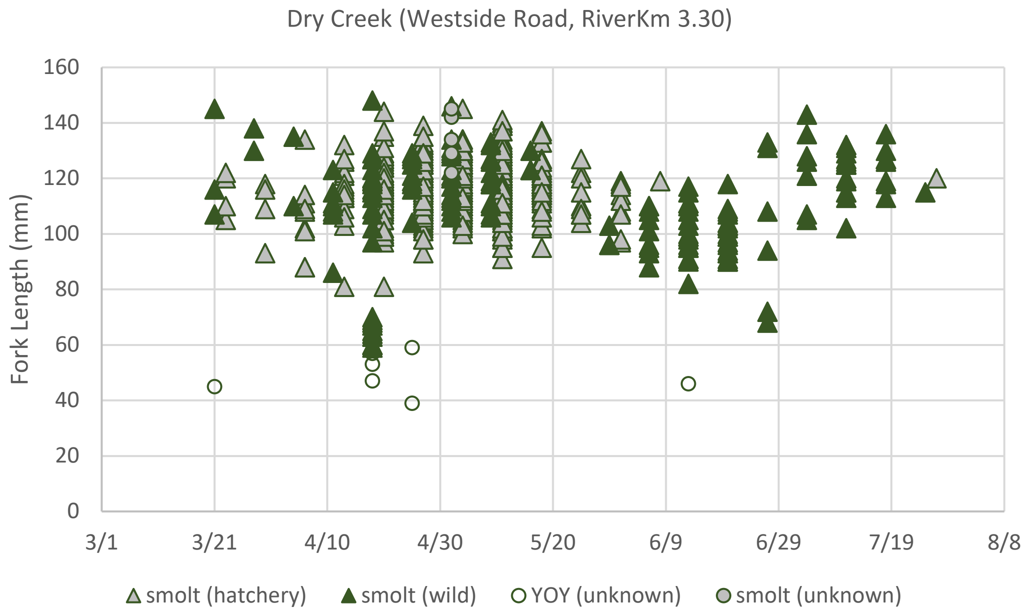
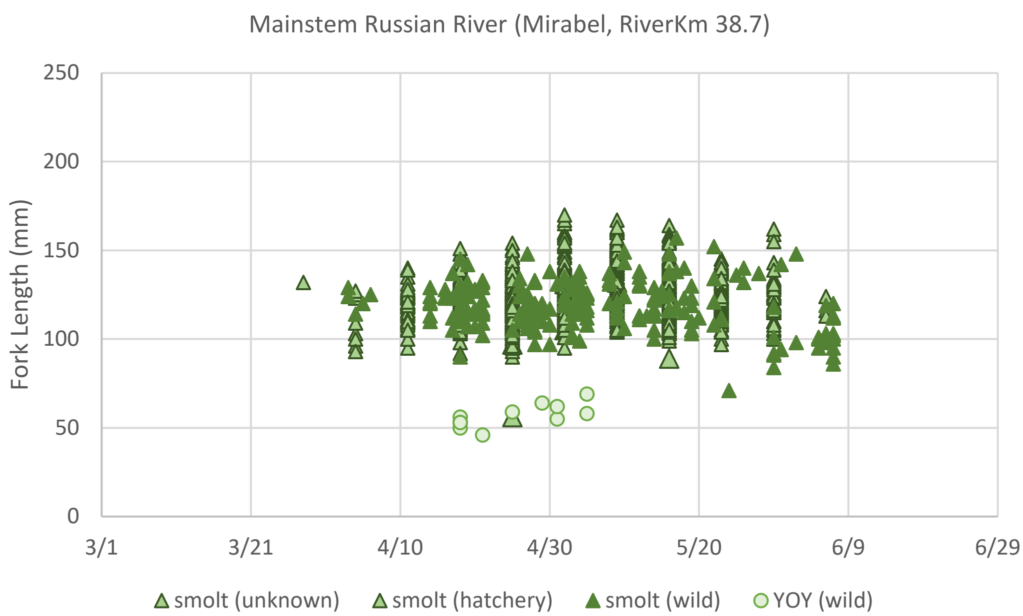
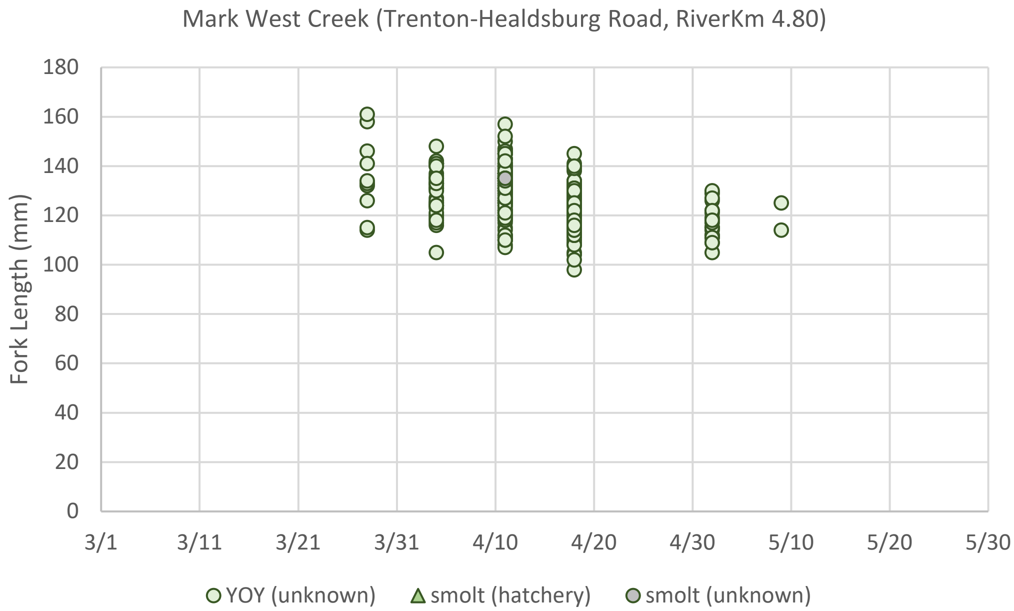
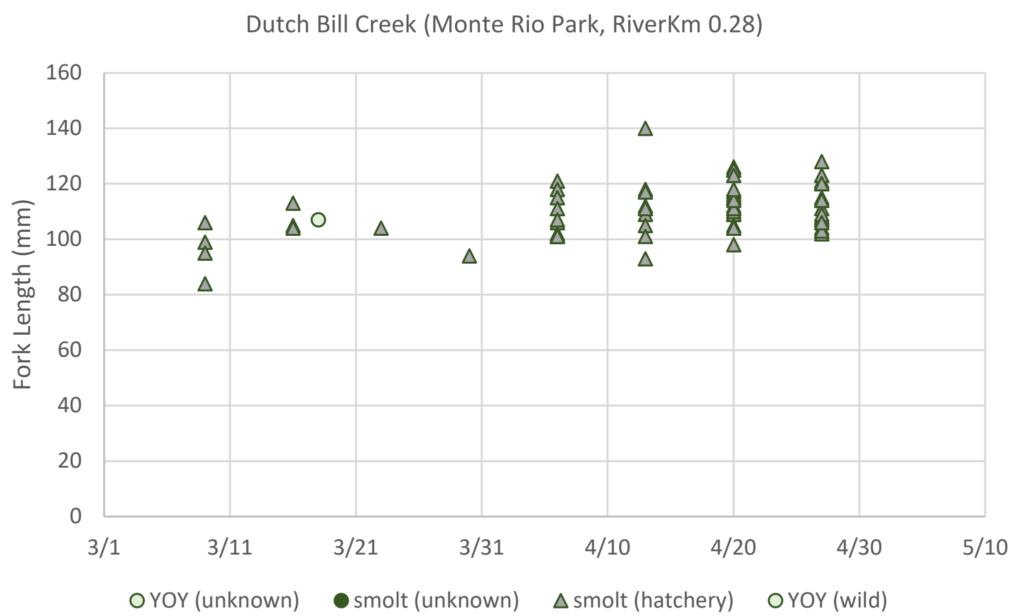


Figure 4.5.13. Weekly capture of Coho Salmon by life stage at lower Russian River downstream migrant trapping sites, 2021. Gray shading indicates the number of days per week that the trap was fishing. Note the different vertical scale among plots for each site.


Dry Creek (Westside 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
8/8
smolt (hatchery)
smolt (wild)
YOY (unknown)
smolt (unknown)


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
smolt (unknown)
smolt (hatchery)
smolt (wild)
YOY (wild)


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
Fork Length (mm)
180
160
140
120
100
80
60
40
20
0
3/1
3/11
3/21
3/31
4/10
4/20
4/30
5/10
5/20
5/30
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
3/11
3/21
3/31
4/10
4/20
4/30
5/10
YOY (unknown)
smolt (unknown)
smolt (hatchery)
YOY (wild)

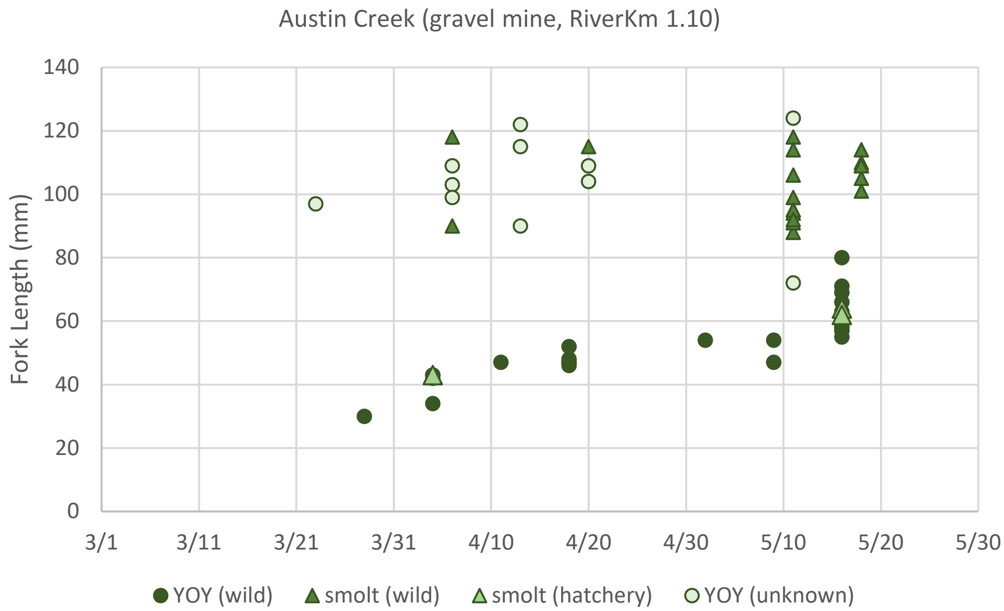


Figure 4.5.14. Weekly fork lengths of Coho Salmon captured at lower Russian River downstream migrant trap sites, 2021.

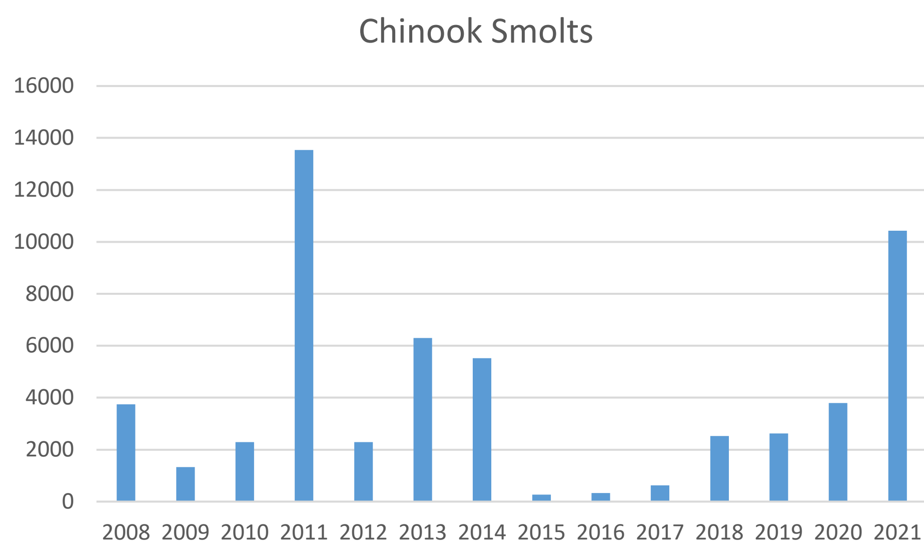


Figure 4.5.15. Number Chinook salmon smolts captured in the mainstem Russian River downstream migrant trap. In 2015 and 2016 the Mirabel dam was under construction and the mainstem Russian River trap was operated further upstream at Chalk Hill (river Km 69.82).

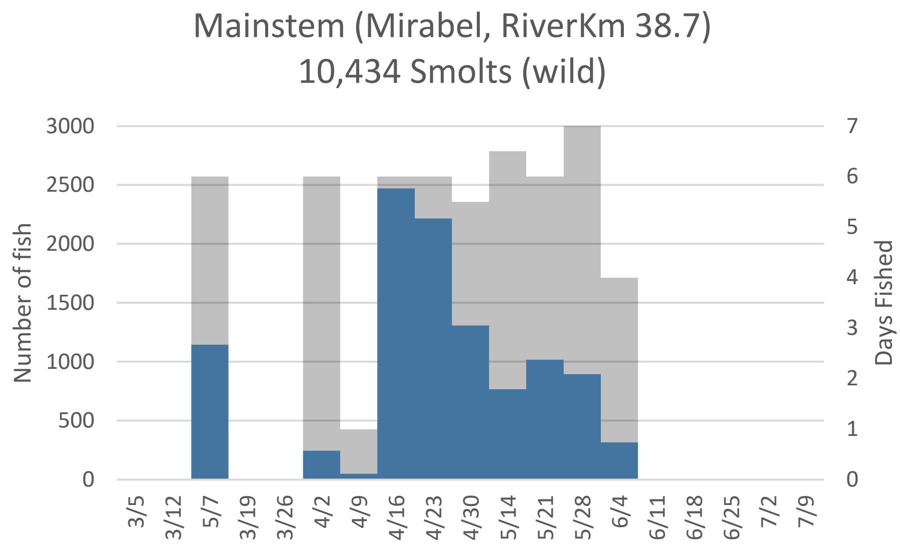


Figure 4.5.16. Weekly capture of Chinook salmon smolts at the Mirabel fish ladder on the mainstem Russian River, 2021. Gray shading indicates portion of each week trap was fishing.

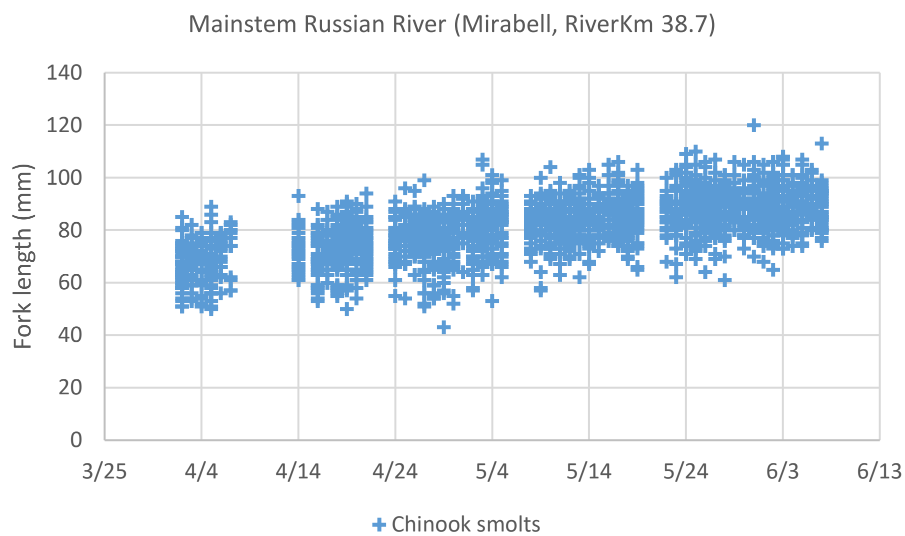


Figure 4.5.17 Weekly fork lengths of Chinook salmon captured at the Wohler Mirabel trap site on the mainstream Russian River downstream migrant trap sites, 2021.

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 2021, 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. Austin Creek has a large amount of spawning habitat in the lower portions of the creek, but this section of creek often becomes dry in the summer. More steelhead YOY may emigrate from Austin Creek when compared to our other sample sites because more steelhead YOY may be produced in Austin Creek and opportunities to over summer in lower Austin Creek are limited.

In 2021, PIT tag detection at Austin Creek were relied upon to estimate the number of young-of-the-year that entered the estuary. Detections of PIT tagged fish were not guaranteed because fish orientation (PIT tags must be perpendicular to the antenna for reliable detection), and multiple PIT-tagged fish in the detection field of the same antenna at the same time can effect detection probability. While these limitations result in decreased antenna efficiency they are not of concern as long as detection efficiency can be estimated for use in expanding the number of fish detected. 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) remains the best option for addressing the fish monitoring objectives in the Russian River Biological Opinion at this time. Attempts continue to measure antenna efficiency at Duncans Mills 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, the Water Agency 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 area). In 2016, Sonoma Water began construction on the Dry Creek Habitat Enhancement Phase 2, Part 1 Project (centered approximately a mile upstream of the Demonstration Project) and the Dry Creek Habitat Enhancement Phase 3, Part 1 Project (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. In 2018, Sonoma Water began construction of two sites (Corps of Engineers/Weinstock property site and Vala property site) of the Phase 2, Part 2 (Reach 14) habitat work. Also in 2018, the U.S. Army Corps of Engineers completed the Phase 3, Part 2 habitat work in Reach 4A. In 2019, Sonoma Water completed the remaining site (Gallo property) of the Phase 2, Part 2 habitat work in Reach 14. In 2020, Sonoma Water started construction of the Phase 3, Part 3 (Reach 5A) habitat work. Also in 2020, Sonoma Water conducted maintenance work at several of the existing habitat sites in Reaches 4A, 7, and 8 to maintain or restore habitat function. In 2021, Sonoma Water completed the remaining portion of the Phase 3, Part 3 (Reach 5A) habitat work. Additional sites in reaches 1, 2, 4, 5B, 10, and 13 are in design for tentative construction at a future date. Figure 5.2

provides an overview of the habitat sites that are completed as of 2021 and tentative future sites still in design.

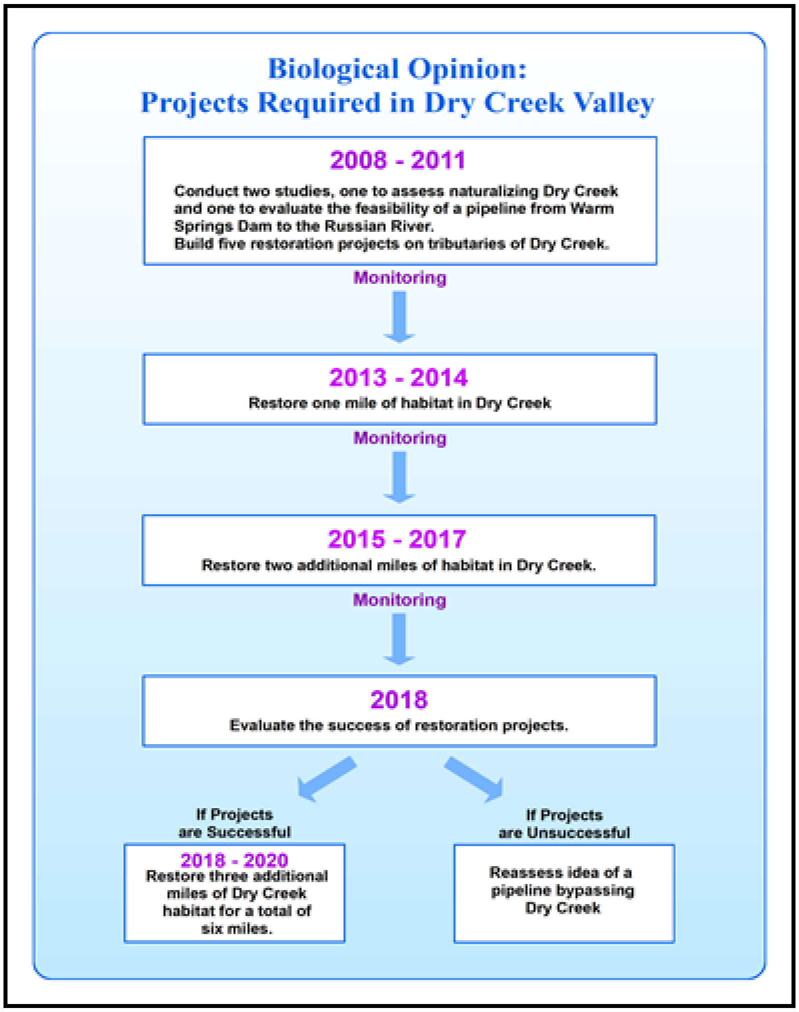

Figure 5.1. Timeline for implementation of Biological Opinion projects on Dry Creek.

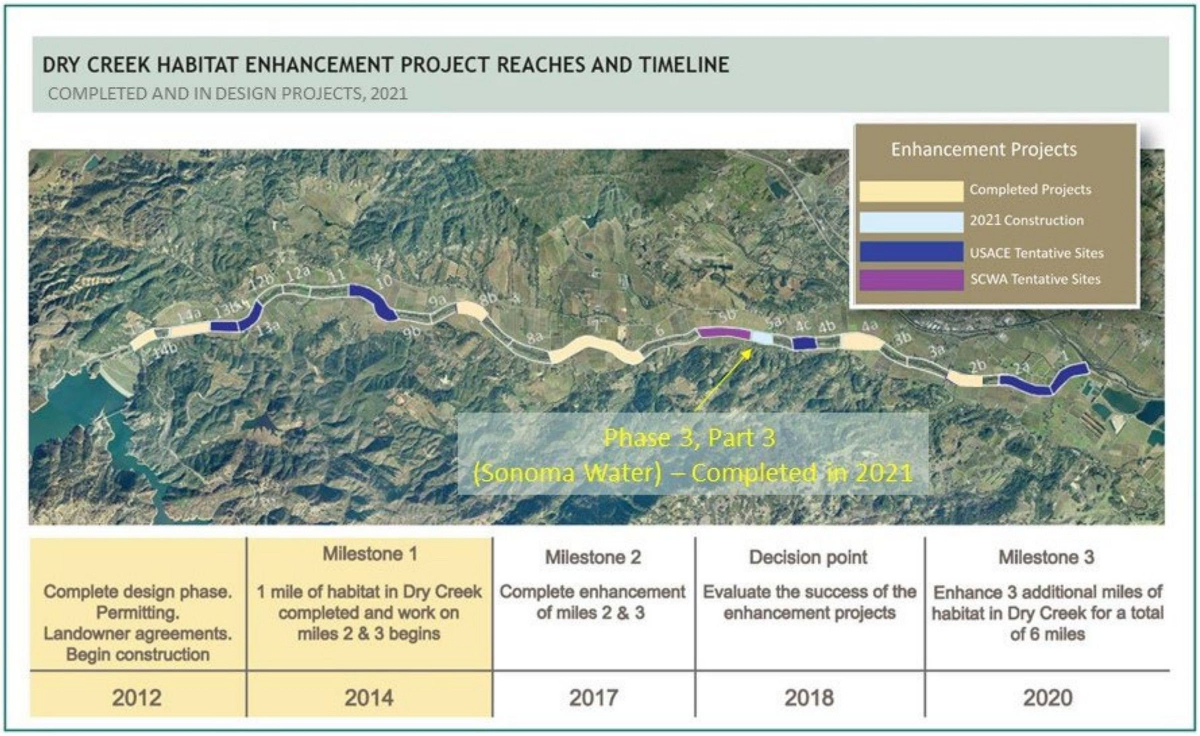

Figure 5.2. Dry Creek habitat projects constructed in 2021 and tentatively planned for future construction.

2021 Habitat Enhancement Overview

In 2020 construction was started on a portion of the Dry Creek Phase 3, Part 3 habitat project in Reach 5A (Boaz property). In 2021, construction continued on the remaining portions of the Phase 3, Part 3 project and included the construction of habitat features on the Stromberg and Gros-Balthazard properties. In the 2021 season, Sonoma Water staff monitored and rated the post-enhancement condition of one reach constructed in 2021 (Boaz Gros-Balthazard (Phase 3, Part 3 project), six enhancement reaches post-effective flow (Gallo, Truett Hurst, Van Alyea, Meyer, Carlson Lonestar Farrow Wallace, and Geyser Peak, and three reaches during 165 cubic feet per second (cfs) releases from Warm Springs Dam in June 2021 (Truett Hurst, Meyer, Carlson Lonestar). (Figure 5.3).

Of the six post-effective flow sites surveyed in 2021, monitoring data resulted in 5 of those reaches rated good and 1 rated fair (Table 5.1)

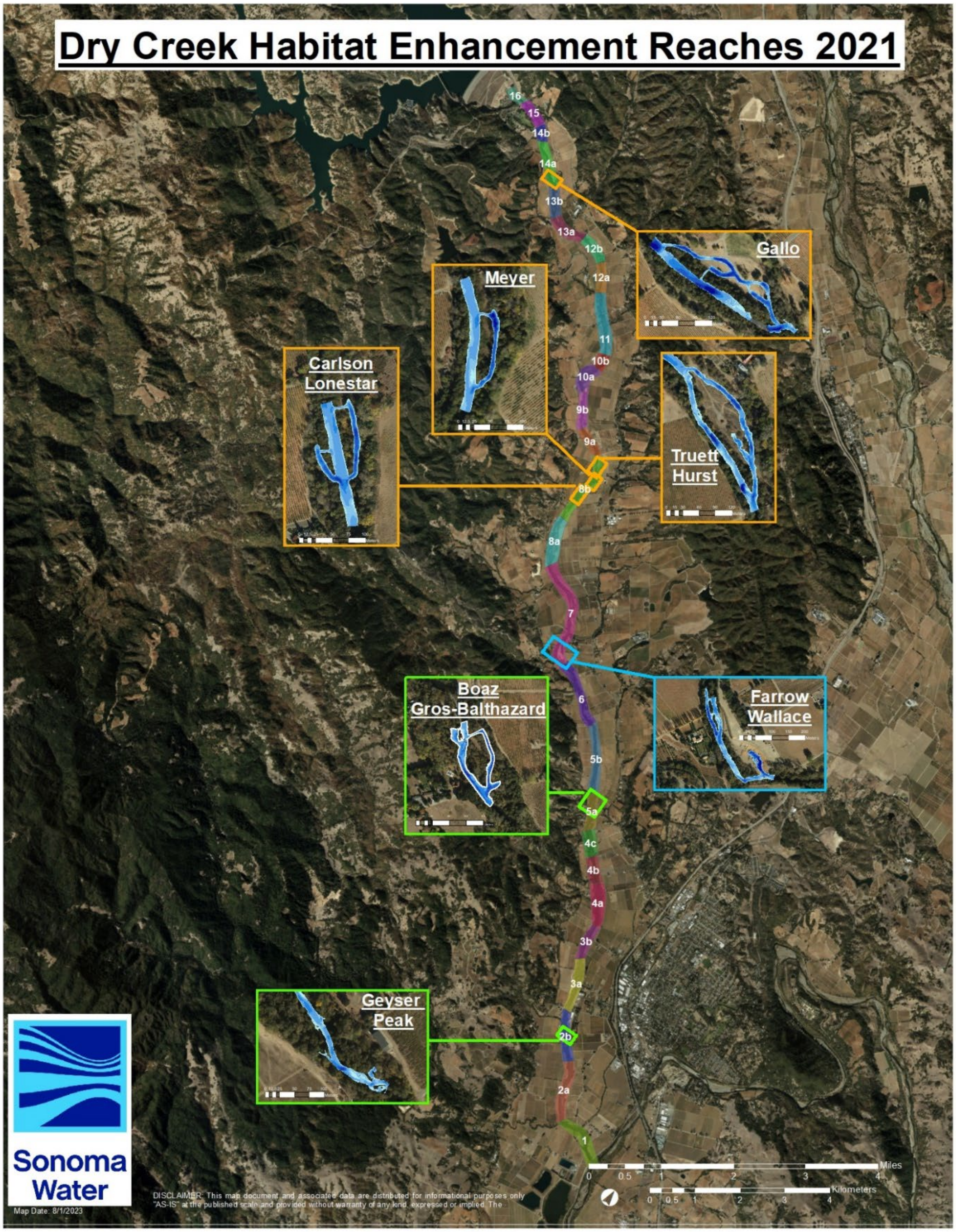

Figure 5.3. Location of Dry Creek habitat enhancement reaches monitored for effectiveness in 2019.

Table 5.1. Enhancement ratings for Dry Creek enhancement reaches surveyed in 2021.

Enhancement Reach	Post-effective Flow Rating
Gallo	Good
Truett-Hurst	Good
Meyer	Good
Carlson Lonestar	Good
Farrow, Wallace	Good
Geyser Peak	Fair
Boaz Gros-Balthazard	Good (post-enhancement, pre-effective flow rating for this site in 2021)

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 Timer#31combining 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 5.4).

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 5.4).

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.

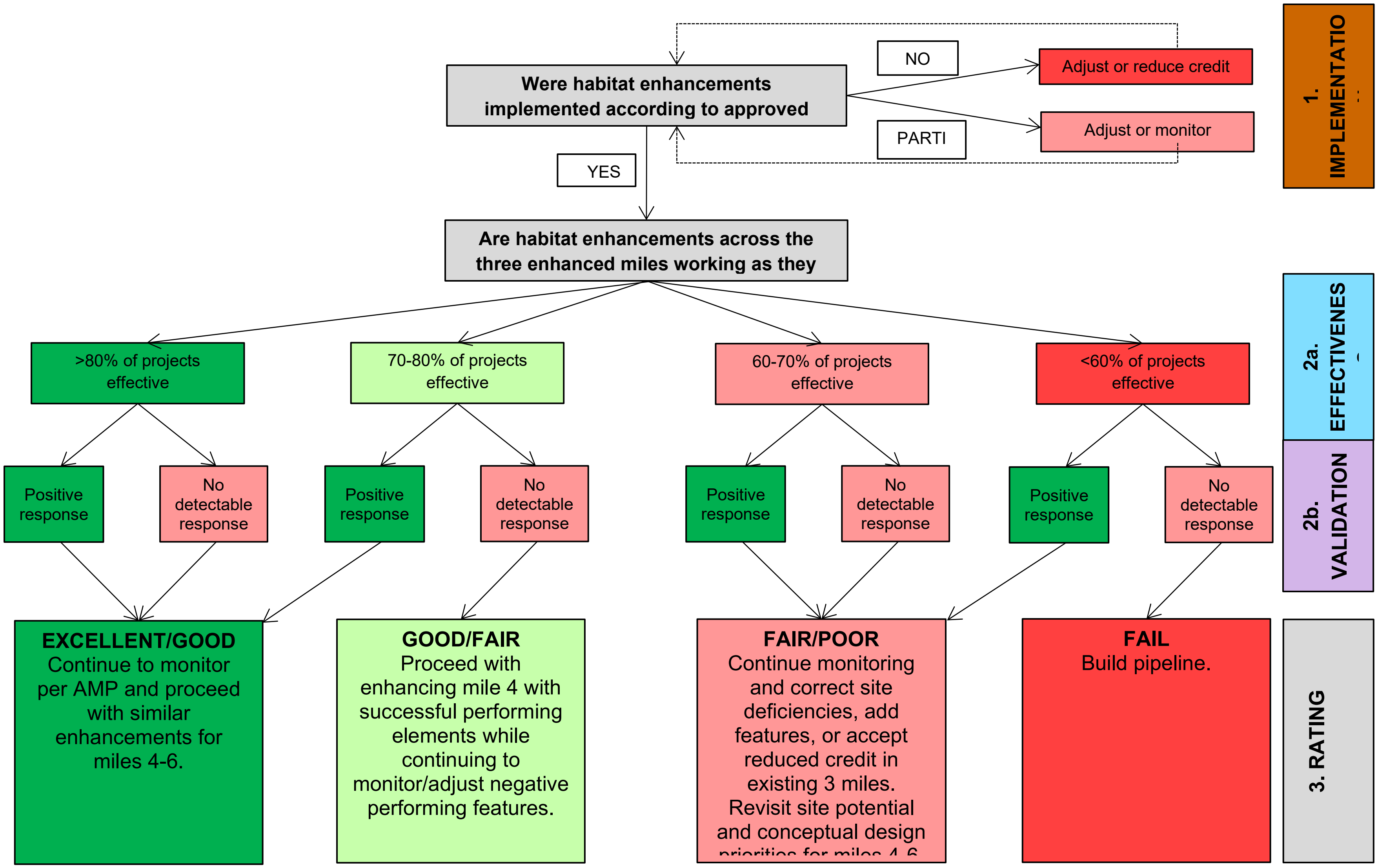

Figure 5.4. Process for determining course of action after the first three miles of Dry Creek have been enhanced. Ratings will be based on an objective evaluation in a step-wise phased monitoring approach which includes physical and biological quantitative measurements which lead to qualitative ratings (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 5.5).

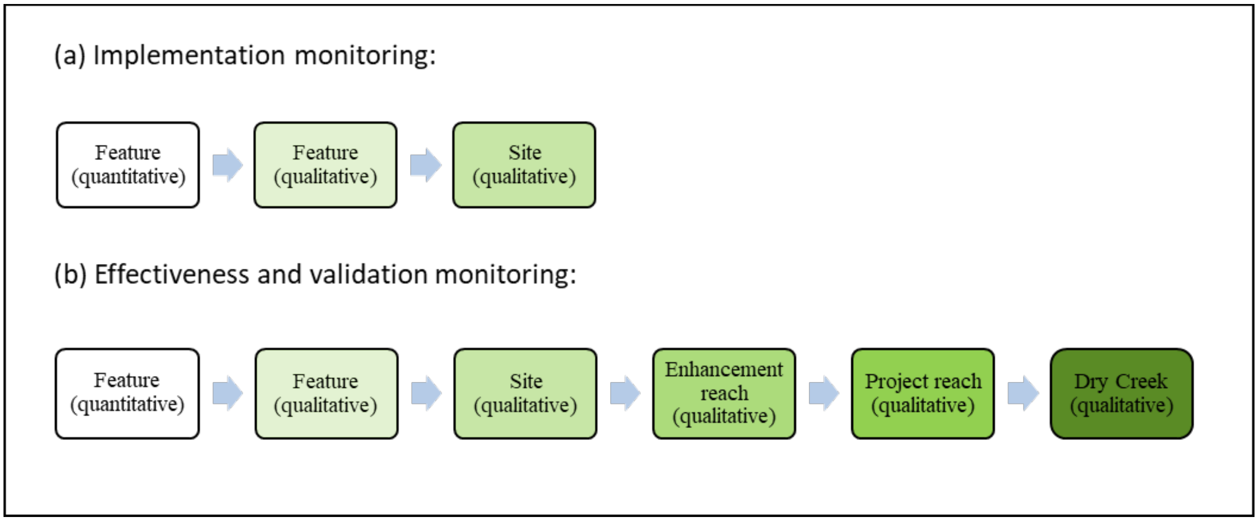

Figure 5.5. Illustration of the rollup concept for (a) implementation and (b) effectiveness and validation monitoring (from Porter et al. 2014).

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 5.4Figure 5.4).

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

5.1 Dry Creek Habitat Enhancement Implementation

Phase 3, Part 3

The 2020 construction season saw the start of construction for the Phase 3, Part 3 (Reach 5A) habitat work. The construction management for Phase 3, Part 3 was overseen by Sonoma Water. See Figure 5.3 above for the general project location and Figure 5.1.1 below for the project work area layout at the site.

The Phase 3, Part 3 project area is along approximately 800 feet of Dry Creek in the Reach 5A area of Dry Creek, approximately 2 miles downstream of Lambert Bridge. This site consists of large bank stabilization component and two constructed side-channel components. The bank stabilization component was the bulk of the work accomplished in 2020. The bank stabilization consisted of rock slope protection on the lower portion of the bank and vegetated soil lifts on the upper portion of the slope. Because of the instability of the existing slope here, and because of the proximity of an existing home close to this unstable bank, the slope stabilization effort was the initial focus of the construction work. Once the bank was stable, then the modifications to add the additional habitat features could begin. Please refer to Photo 5.1.1 through Photo 5.1.1.

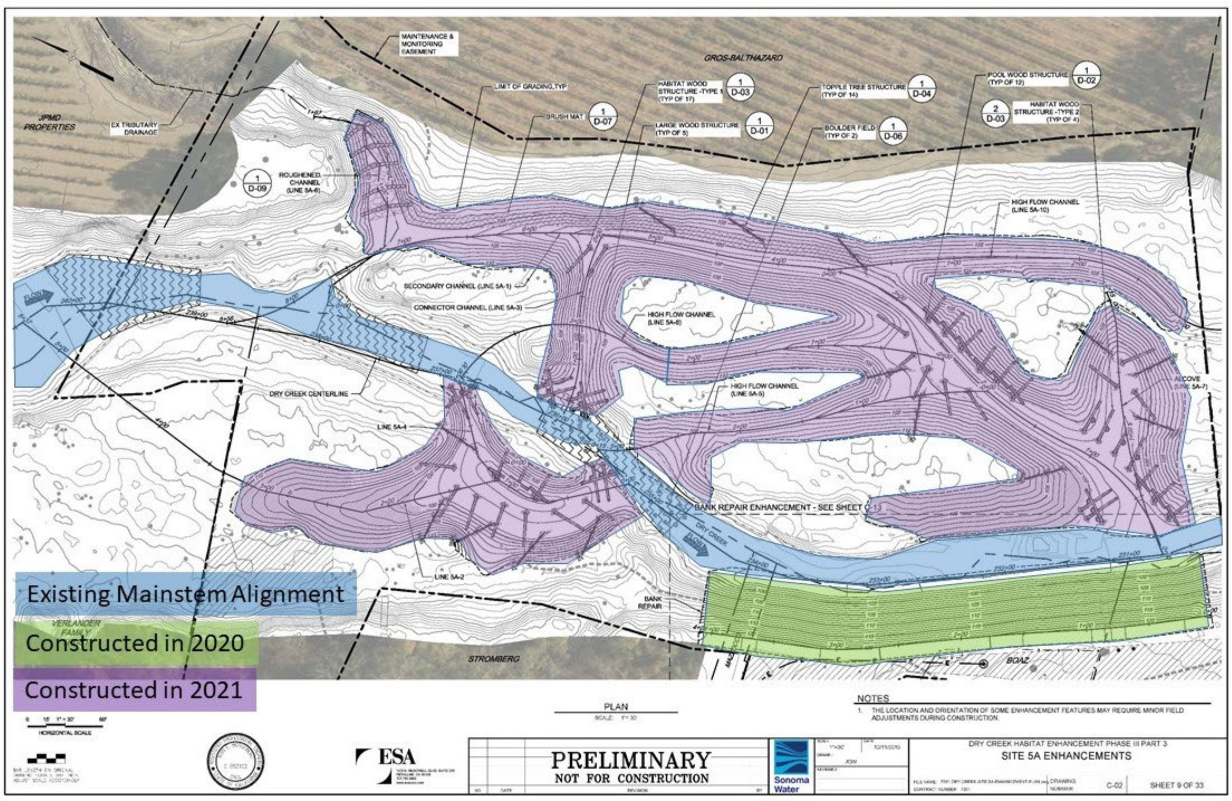

Figure 5.1.1. This figure shows the work area for the Dry Creek Habitat Enhancement Project, Phase 3, Part 3. The bank stabilization component of this work was constructed first during the 2020 construction season. The majority of the work for the habitat enhancement areas is scheduled to be constructed in 2021.

Photo 5.1.2. Phase 3, Part 3. Upper end of bank stabilization work area, looking downstream pre-project condition. July 30, 2020.

Photo 5.1 3. Phase 3, Part 3. Upper end of bank stabilization work area, looking downstream pre-project condition. July 30, 2020.

Photo 5.1.4. Phase 3, Part 3. Lower end of bank stabilization work area, looking upstream. Initial clearing and access road underway. July 30, 2020.

Photo 5.1.5. Phase 3, Part 3. Rock slope protection construction in progress. Note sheet-pile isolating work area from active flow of Dry Creek. September 10, 2020.

Photo 5.1.6. Phase 3, Part 3. Initial clearing of habitat site work area and being used as a dewatering basin for the bank stabilization work. September 10, 2020.

Photo 5.1.7. Phase 3, Part 3. Sonoma Water's biologists conducting fish rescue within the isolated work area. September 15, 2020.

Photo 5.1.8. Phase 3, Part 3. Bank stabilization section work is complete. November 3, 2020.

Photo 5.1.9. Phase 3, Part 3. Bank stabilization section work completed in 2020 and showing willow cuttings established and leafing out. May 19, 2021.

Photo 5.1.10. Phase 3, Part 3. New habitat side-channel feature under construction (Stromberg site). Photo is showing the side-channel inlet area with a turbidity curtain isolating the inlet area from the active flow of Dry Creek. June 24, 2021.

Photo 5.1.11. Phase 3, Part 3. New habitat side-channel feature (Stromberg site) recently completed, showing the side-channel outlet back into the mainstem of Dry Creek. Also visible in this photo is a newly installed boulder field in the mainstem of Dry Creek, and a portion of sheet piling being used to isolate the active flow of Dry Creek from the Gros-Balthazard site work area). August 25, 2021.

Photo 5.1.12. Phase 3, Part 3. New habitat side-channel feature (Stromberg site) recently completed. August 4, 2021.

Photo 5.1.13. Phase 3, Part 3. New habitat side-channel feature (Gros-Balthazard site). New side-channel excavation in process. August 25, 2021.

Photo 5.1.14. Phase 3, Part 3. Newly installed wood structures at the inlet to the habitat side-channel feature (Gros-Balthazard site). The side-channel is under construction and a turbidity curtain is visible isolating the work area from the active flow of Dry Creek. September 8, 2021.

Photo 5.1.15. Phase 3, Part 3. Newly completed habitat side-channel feature (Gros-Balthazard site). Photo is looking back upstream at the outlet of the side-channel on the right and the mainstem of Dry Creek is on the left. A portion of the bank stabilization work (Boaz property) that was completed in 2020 is visible on the far left of this photo. September 15, 2021.

Photo 5.1.16. Phase 3, Part 3. High flow event that occurred soon after completion of construction. View is from the river-right side of Dry Creek from the bank reapir area (Boaz site) looking downstream with the mainstem of Dry Creek in the foreground and the outlet of the Gros-Balthazard site side-channel towards the middle of the photo. Photo courtesy of Jason Boaz. October 24, 2021.

Photo 5.1.17. Phase 3, Part 3. Minor damage to erosion control fabric in the inlet area to the Gros-Balthazard site side channel as a result of the October 24, 2021 high flow event. November 3, 2021.

Photo 5.1.18. Phase 3, Part 3. Inlet area to the Gros-Balthazard, erosion control fabric repaired and area re-staked with willow cuttings after the October 24, 2021 high flow event. November 23, 2021.

Photo 5.1.19. Phase 3, Part 3. Buckeye balls collected from Dry Creek for planting at the Gros-Balthazard site. November 17, 2021.

Photo 5.1.20. Phase 3, Part 3. Buckeye balls being planted at the Gros-Balthazard site. November 17, 2021.

Photo 5.1.21. Phase 3, Part 3. Sonoma Water staff installing willow cuttings along the perimeter of the Phase 3, Part 3 project sites (Gros-Balthazard site shown). November 17, 2021.

2021 Dry Creek Habitat Maintenance Work

No notable maintenance work at any of the previously constructed habitat sites occurred during the 2021 construction season.

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 the Water Agency, 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
Primary	Depth (ft)	fry	0.5-2.0 ft	n/a	n/a
Primary	Velocity (ft/sec)	Summer/winter parr	0-0.5 ft/s	0-0.5 ft/s	0-0.5ft/s
Primary	Depth (ft)	Summer/winter parr	2-4 ft	2-4 ft	2-4 ft
Primary	Shelter value	Juvenile	$\geq$80	$\geq$80	$\geq$80
Primary	Pool: Riffle ratio	Juvenile	n/a	1:2 to 2:1	n/a
Secondary	Temperature (^{o}C)	Juvenile	n/a	8-16^{o} C	n/a
Secondary	Dissolved oxygen (mg/l)	Juvenile	n/a	6-10 mg/l	n/a
Secondary	Canopy (%)	Juvenile	80 %	80 %	80 %
Secondary	Quiet water (< 0.5 ft/s) (%)	Juvenile	n/a	n/a	$\geq$ 25%
Secondary	Off-channel access (off-ramps) (ft/sec)	Juvenile	.05 – 0.06 ft/s (Ucrit); 3.3 ft/s (burst speed)	.05 – 0.06 ft/s (Ucrit); 3.3 ft/s (burst speed)	.05 – 0.06 ft/s (Ucrit); 3.3 ft/s (burst speed)
Secondary	Connectivity	Juvenile	Undefined	Undefined	Undefined
Secondary	Substrate particle size (in.)	Adult	n/a	n/a	0.25-2.5 in.
Secondary	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 cubic feet per second (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 November during summer baseflow conditions. Daily average discharge ranged from 95 to 135 cubic feet per second (cfs) over the monitoring period (as measured at the Dry Creek below Lambert Bridge near Geyserville USGS gage [gage #11465240]), and most 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. In June 2021, Sonoma Water released 165 cfs from Warm Springs Dam to meet water supply needs, with discharges of 180 cfs occurring within enhancement reaches. We monitored side channel sites of three enhancement reaches during 165 cfs releases to evaluate conditions during higher than normal summer discharges (see Spring Flow below).

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.

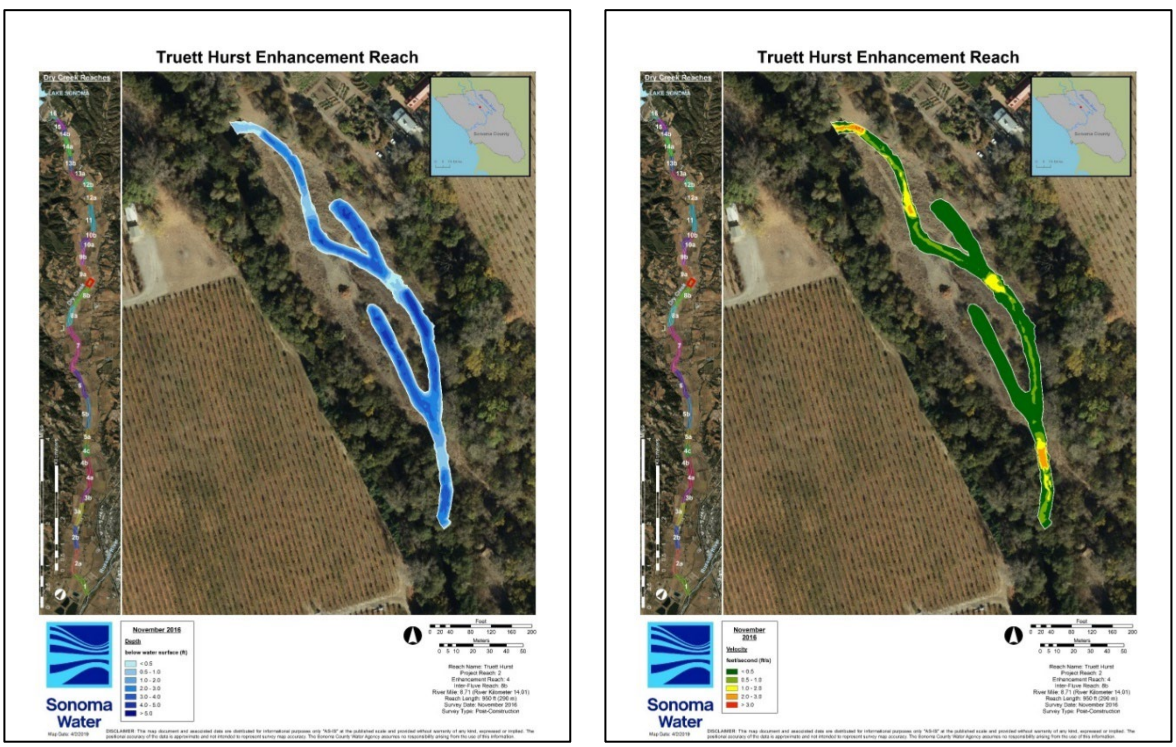

Figure 5.2.2. Digital elevation models (DEMs) created from spatially referenced depth and velocity points.

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).

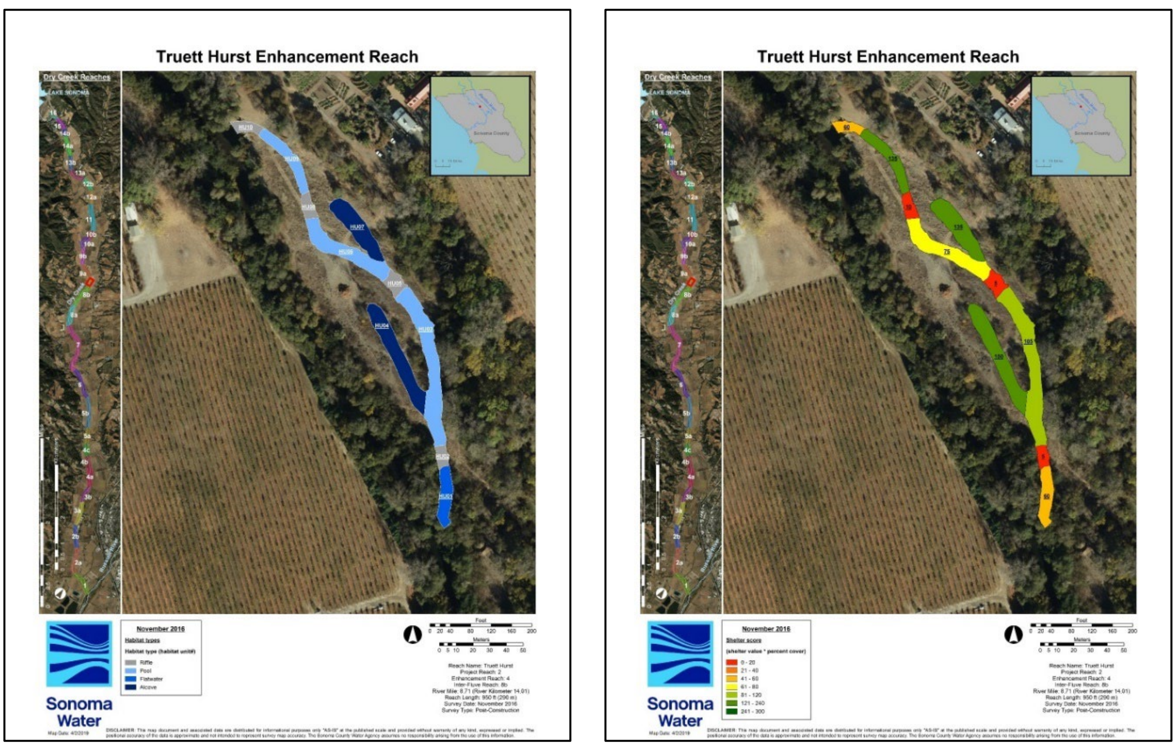

Figure 5.2.3. Example of inventoried habitat types and estimated shelter values within a Dry Creek habitat enhancement reach.

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 side channel, main channel, and areas along the bank for a total of six individual checklists (See Porter et al [2014], pp. 40-45). We modified side channel and main 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 side and main 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. Side 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 side and main 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 (>600 as of November 2021) 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 side and main 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 5.2). 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 (>800 as of November 2021) 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[a]		**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	Calculate the shelter rating for the **habitat unit**: 0-300[d]	5
28.	Percent of **habitat unit** within targeted velocity: (%)[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 quantitative rating	**(sum of above)**	**35**
Habitat qualitative rating[a]		**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). We calculated an average feature rating and an average habitat unit rating for each site. The sum of the site average feature rating and site average habitat unit ratings equaled the overall site quantitative rating (up to 50 points), which we 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 from habitat unit to site, the average of all sites within an enhancement reach determined 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** quantitative rating[a]	15	15	15
Site average **feature** qualitative rating[a]	Excellent	Excellent	Excellent
Site average **habitat unit** quantitative rating[b]	35	35	35
Site average **habitat unit** qualitative rating[b]	Excellent	Excellent	Excellent
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 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 of enhancement sites. 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.

In 2017, we 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 time periods to differentiate from post-enhancement monitoring that occurs after a site is newly constructed. We will include a post-repair monitoring time period as necessary in future monitoring reports.

In 2021, we added spring flow monitoring in response to higher than normal release flows from Warm Springs Dam. We typically collect data from April to November during summer baseflow conditions. Daily average discharge ranges from 95 to 135 cubic feet per second (cfs) over the monitoring period (as measured at the Dry Creek below Lambert Bridge near Geyserville USGS gage [gage #11465240; Lambert Bridge gage]), and most monitoring does not occur at discharges above 135 cfs to ensure accuracy and consistency when measuring depth and velocity, determining habitat types, and evaluating cover. In June 2021, Sonoma Water released 165 cfs from Warm Springs Dam to meet water supply needs, with discharges of 162-184 cfs recorded at the Lambert Bridge gage. We monitored side channel sites of three enhancement reaches during 165 cfs releases to evaluate conditions during higher than normal summer discharges (see Spring Flow below).

Results

During the summer and fall 2021, Sonoma Water effectiveness monitored seven enhancement reaches totaling nearly 420,000 ft^2 on mainstem Dry Creek, side channels, and alcoves (Table 5.2.8, Figure 5.2.4). Fields crews collected over 28,000 depth and velocity points, evaluated 422 features for their condition, and evaluated 138 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 14 (RM 12.75) (Figure 5.2.4). We monitored and rated the post-enhancement condition of one reach constructed in 2021 (Boaz Gros-Balthazard; see Post-enhancement results below), six enhancement reaches post-effective flow (Gallo, Truett Hurst, Van Alyea, Meyer, Carlson Lonestar Farrow Wallace, and Geyser Peak; see Post-effective flow results below), and), and three reaches during 165 cubic feet per second (cfs) releases from Warm Springs Dam in June 2021 (Truett Hurst, Meyer, Carlson Lonestar; see Spring flow results below). Sonoma Water constructed the Boaz Gros-Balthazard enhancement reach in 2020 and this is the post-enhancement monitoring survey for the reach. The results below summarize effectiveness monitoring results for post-enhancement, post-effective flow, and spring flow by enhancement reach. We did not conduct any pre- construction monitoring as no construction occurred in 2021. 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. Dry Creek enhancement reaches monitored in 2021, 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-release-flow (ft^2)
Gallo	--	--	79,465	--
Truett Hurst	--	--	23,528	27,458
Meyer	--	--	47,719	11,507
Carlson Lonestar	--	--	47,368	10,779
Farrow Wallace	--	--	80,286	--
Boaz, Gros Balthazard	--	61,559	--	--
Geyser Peak	--	--	31,883	--
TOTAL (ft^2)	**--**	**61,559**	**310,247**	**49,744**
GRAND TOTAL (ft^2)	**421,551**			

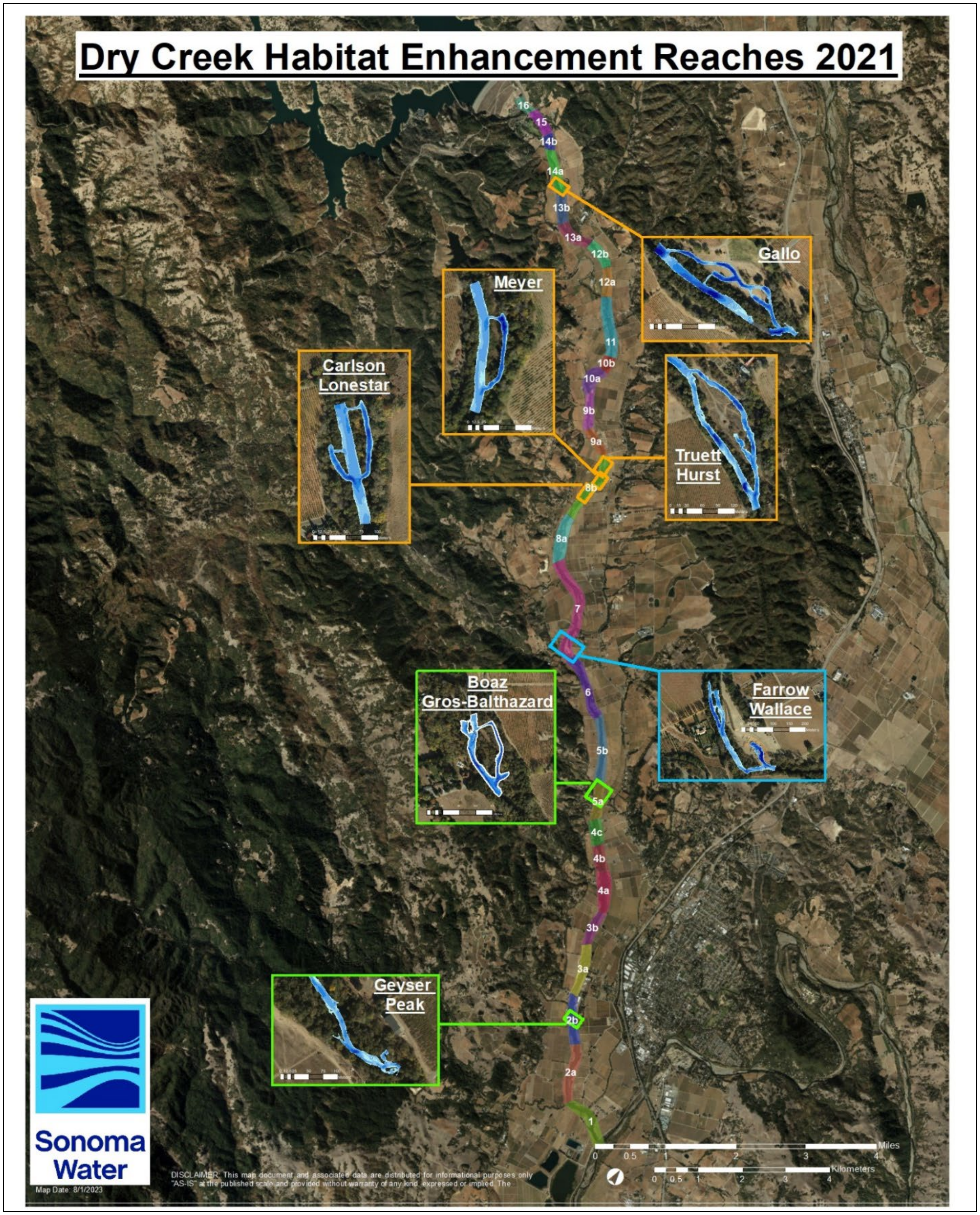

Figure 5.2.4. Location of Dry Creek habitat enhancement reaches monitored in 2021.

Post-enhancement

Boaz Gros-Balthazard Enhancement Reach

Sonoma Water monitored the post-enhancement condition of the Boaz Gros-Balthazard enhancement reach in October 2021. Previous effectiveness monitoring surveys occurred in May 2020 (pre-enhancement) (Table 5.2.9).

Table 5.2.9. Boaz Gros-Balthazard enhancement reach effectiveness monitoring surveys and ratings.

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2020	Fair	--		--	--
2021	--	Good	--	--	--

The enhanced reach covered 61,559 ft^2 within the main channel and side channel areas of Dry Creek, with 55% meeting optimal depth and velocity criteria (Table 5.2.10**,** Figure 5.2.5). The monitoring characterized 34,539 ft^2 of main channel area, 23,837 ft^2 of side channel area, and 3,183 ft^2 of side channel alcove area, of which 55%, 51%, and 89% met optimal depth and velocity criteria, respectively. Nine habitat units made up the enhancement reach, with a pool to riffle ratio of 4:0 and an average shelter score of 78 (Table 5.2.11, Figure 5.2.6, Figure 5.2.7). Five habitat units met or exceeded the optimal shelter value of 80. The enhancement reach comprised six enhancement sites (main channel, main channel floodplain, two side channels, side channel alcove; Table 5.2.12, Figure 5.2.8) that received excellent site average feature ratings, and fair to excellent site average habitat unit ratings (Figure 5.2.9; Figure 5.2.10). Enhancement sites received good to excellent ratings (Figure 5.2.11). Overall, Boaz-Gros Balthazard enhancement reach received a good effectiveness monitoring rating (Table 5.2.12, Figure 5.2.12; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.10. Post-enhancement flow areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Boaz Gros-Balthazard enhancement reach, October 2021.

Boaz Gros-Balthazard Post-enhancement, October 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	34,539	16,250	13,487	29,737	22,545	10,185	8,691	18,876
Side channel area	23,837	8,917	10,903	19,820	14,850	7,145	5,080	12,225
Side channel alcove area	3,183	938	1,882	2,820	3,183	938	1,882	2,820
Total area	**61,559**	**26,105**	**26,272**	**52,377**	**40,578**	**18,269**	**15,653**	**33,922**
Main channel % of wetted area	56%	47%	39%	86%	65%	29%	25%	55%
Side channel % of wetted area	39%	37%	46%	83%	62%	30%	21%	51%
Side channel alcove % of wetted area	5%	29%	59%	89%	100%	29%	59%	89%
Total % of wetted area	**100%**	**42%**	**43%**	**85%**	**66%**	**30%**	**25%**	**55%**

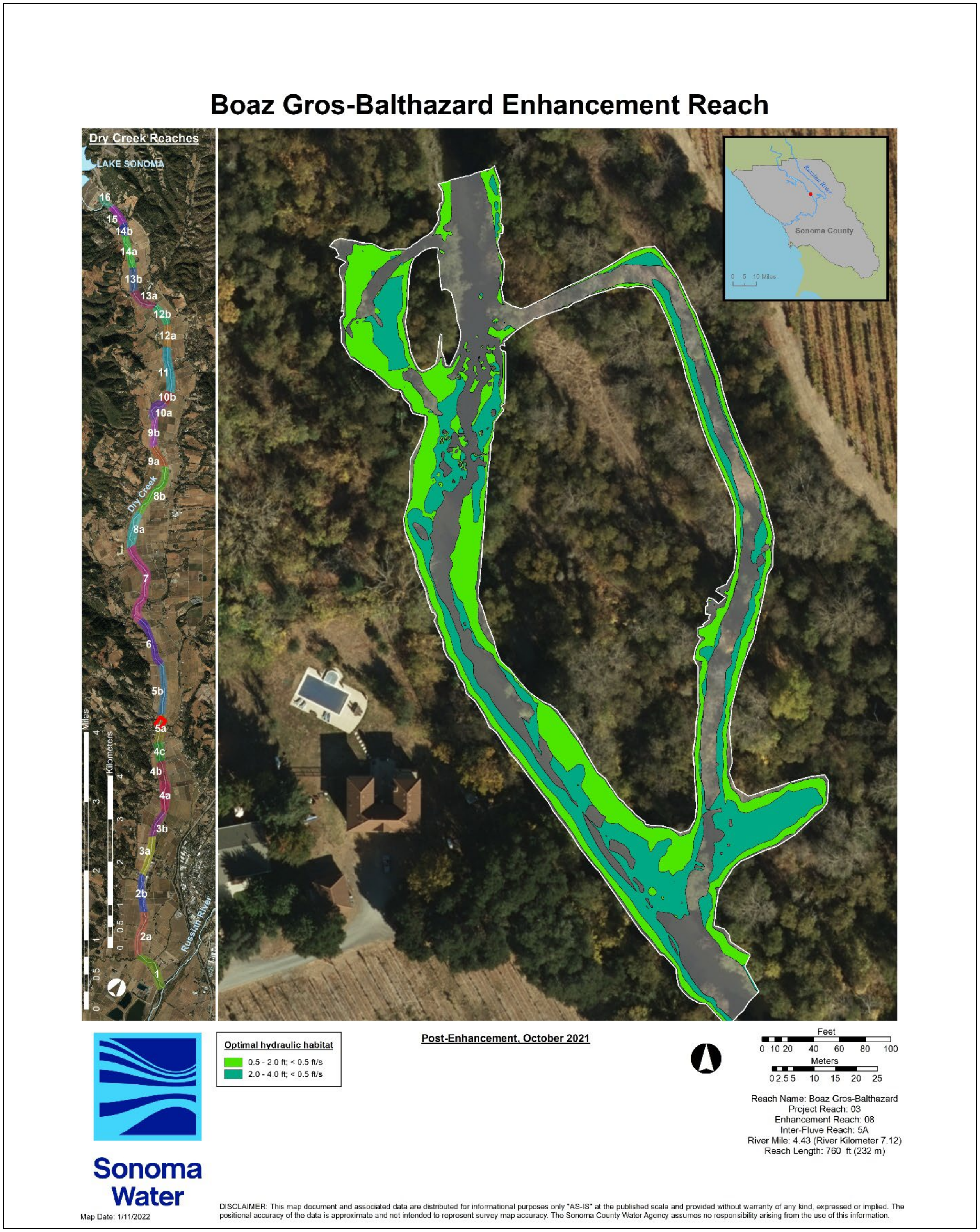

Figure 5.2.5. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Boaz Gros-Balthazard enhancement reach, October 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.11. Habitat, types, shelter score, percent cover, and shelter value for main channel habitat units within the Boaz Gros-Balthazard enhancement reach, October 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	35	105
HU02	Pool	3	45	135
HU03	Flatwater	3	40	120
HU04	Pool	3	15	45
HU05	Alcove	3	25	75
HU06	Flatwater	1	5	5
HU07	Pool	3	30	90
HU08	Alcove	3	40	120
HU09	Flatwater	1	5	5
Pool: riffle	**4: 0 (NA)**			**Avg = 78**

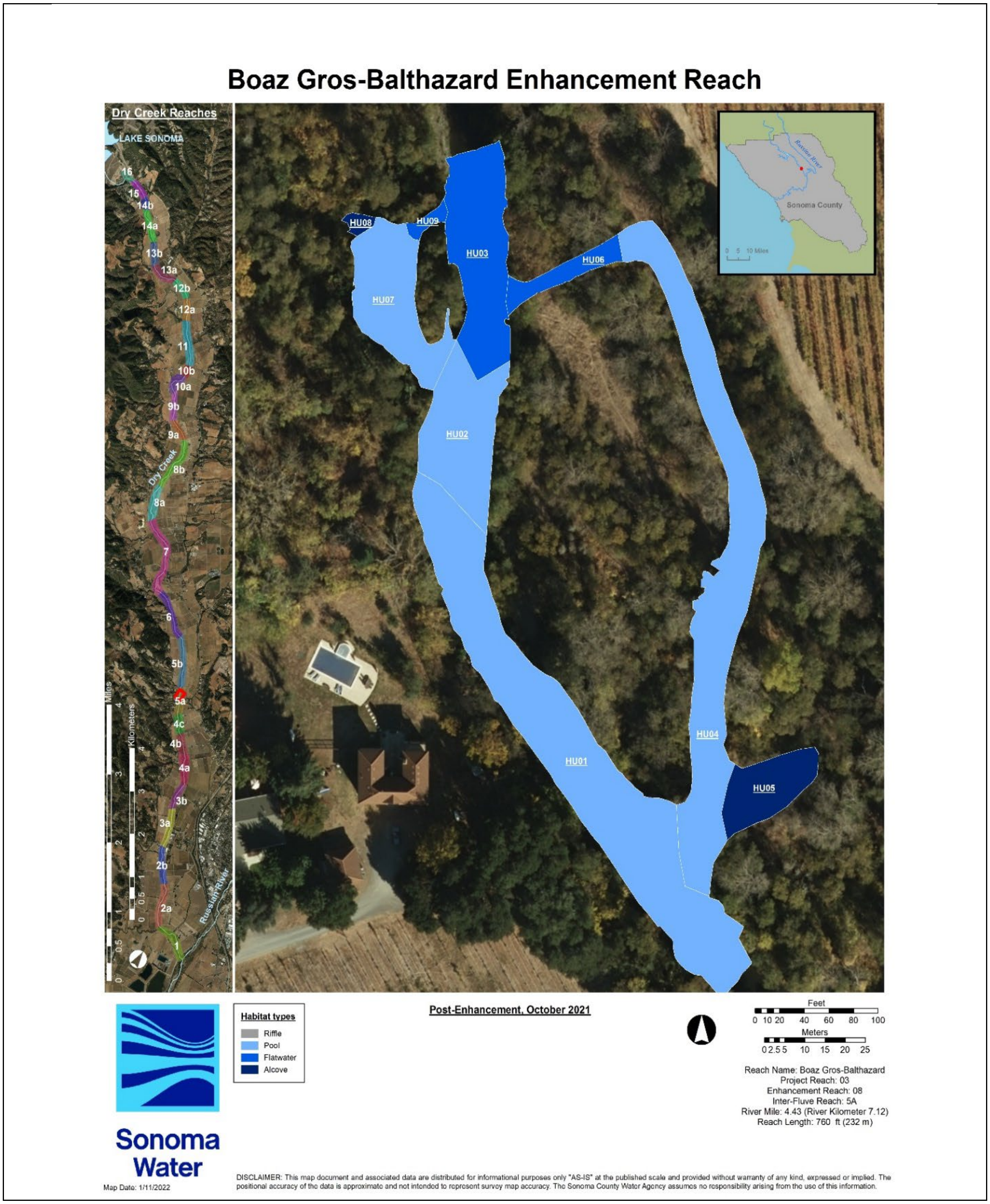

Figure 5.2.6. Habitat unit number and type within the Boaz Gros-Balthazard enhancement reach, October 2021.

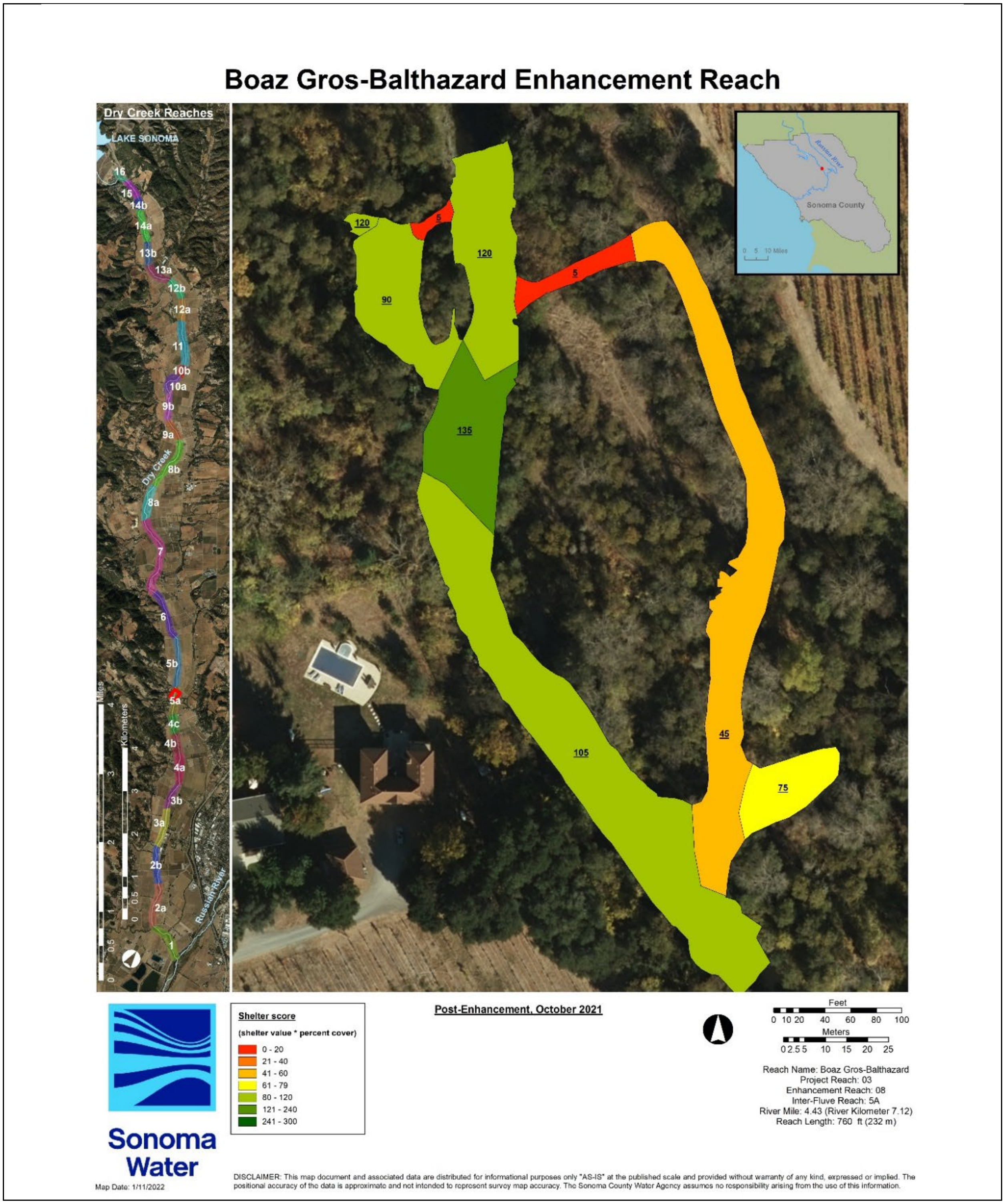

Figure 5.2.7. Habitat unit shelter values within the Boaz Gros-Balthazard enhancement reach, October 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.12. Post-enhancement average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the for the Boaz Gros-Balthazard enhancement reach, October 2021.

Site number	1	2	3	4	5	6
Site type	**Main channel**	**Main channel floodplain**	**Side Channel**	**Side channel alcove**	**Side channel bank floodplain**	**Side channel**
Site average feature quantitative rating[a]	14	14	14	14	14	14
Site average feature qualitative rating[a]	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Site average habitat unit quantitative rating[b]	26	28	21	25	21	19
Site average qualitative rating[b]	Good	Excellent	Fair	Good	Good	Fair
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	40	42	35	39	35	33
Site qualitative rating[c]	Excellent	Excellent	Good	Excellent	Excellent	Excellent
Enhancement reach quantitative rating (average of site rating)[c]	37					
Enhancement reach qualitative rating[c]:	Good					

[a]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)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

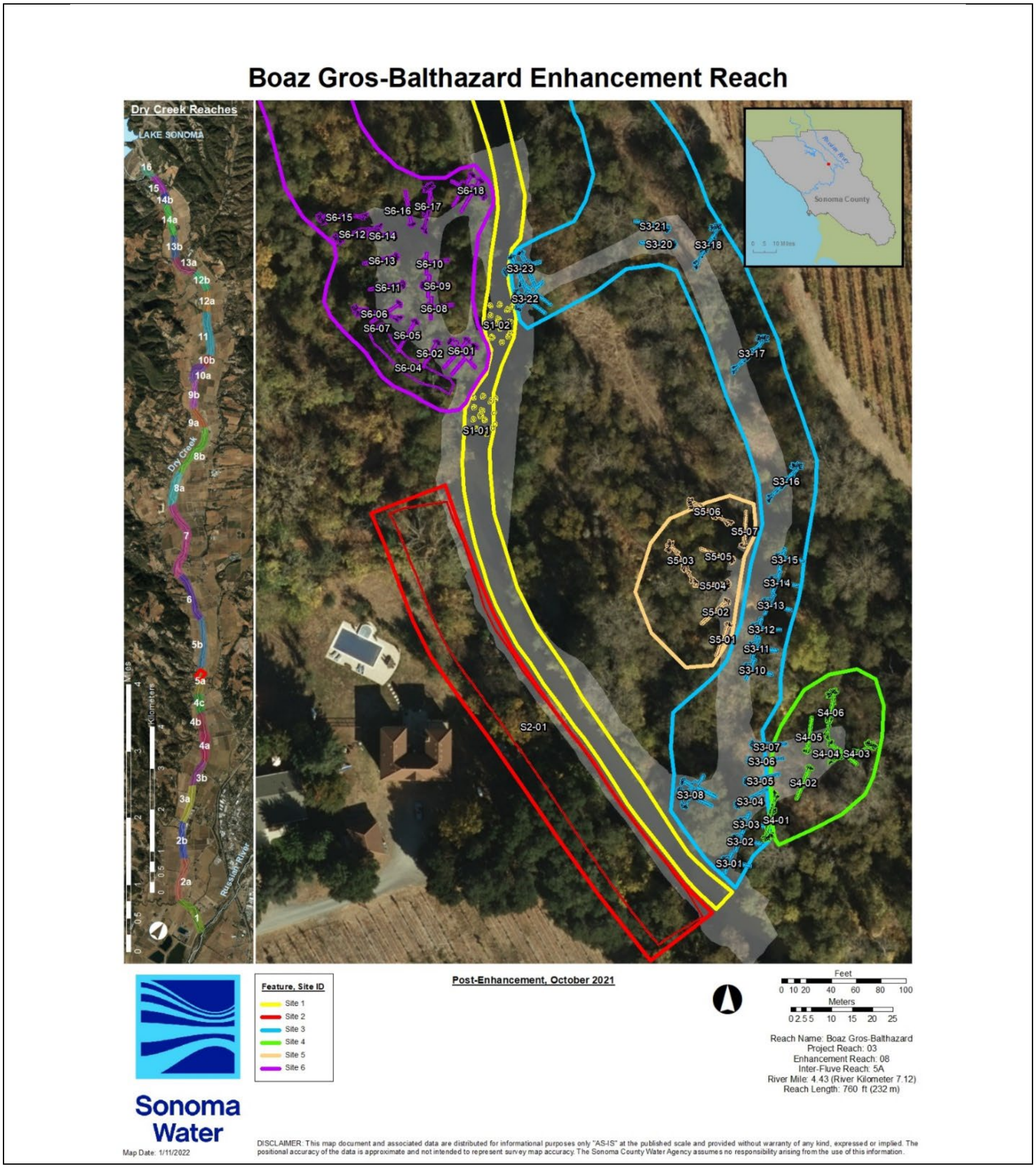

Figure 5.2.8. Enhancement sites and features within the Boaz Gros-Balthazard enhancement reach, October 2021.

Boaz Gros-Balthazard Enhancement Reach

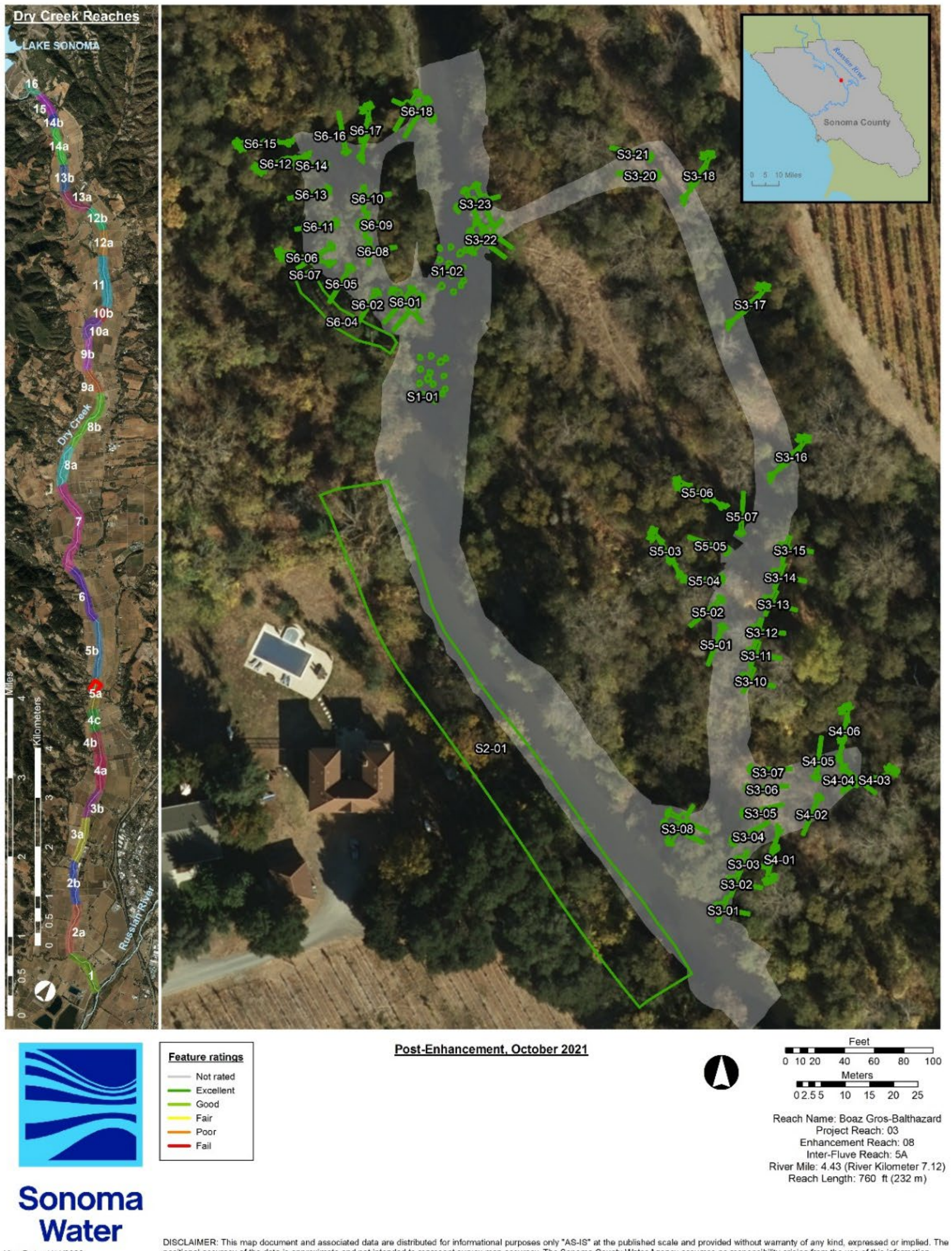

Figure 5.2.9. Feature ratings for the Boaz Gros-Balthazard enhancement reach, October 2021.

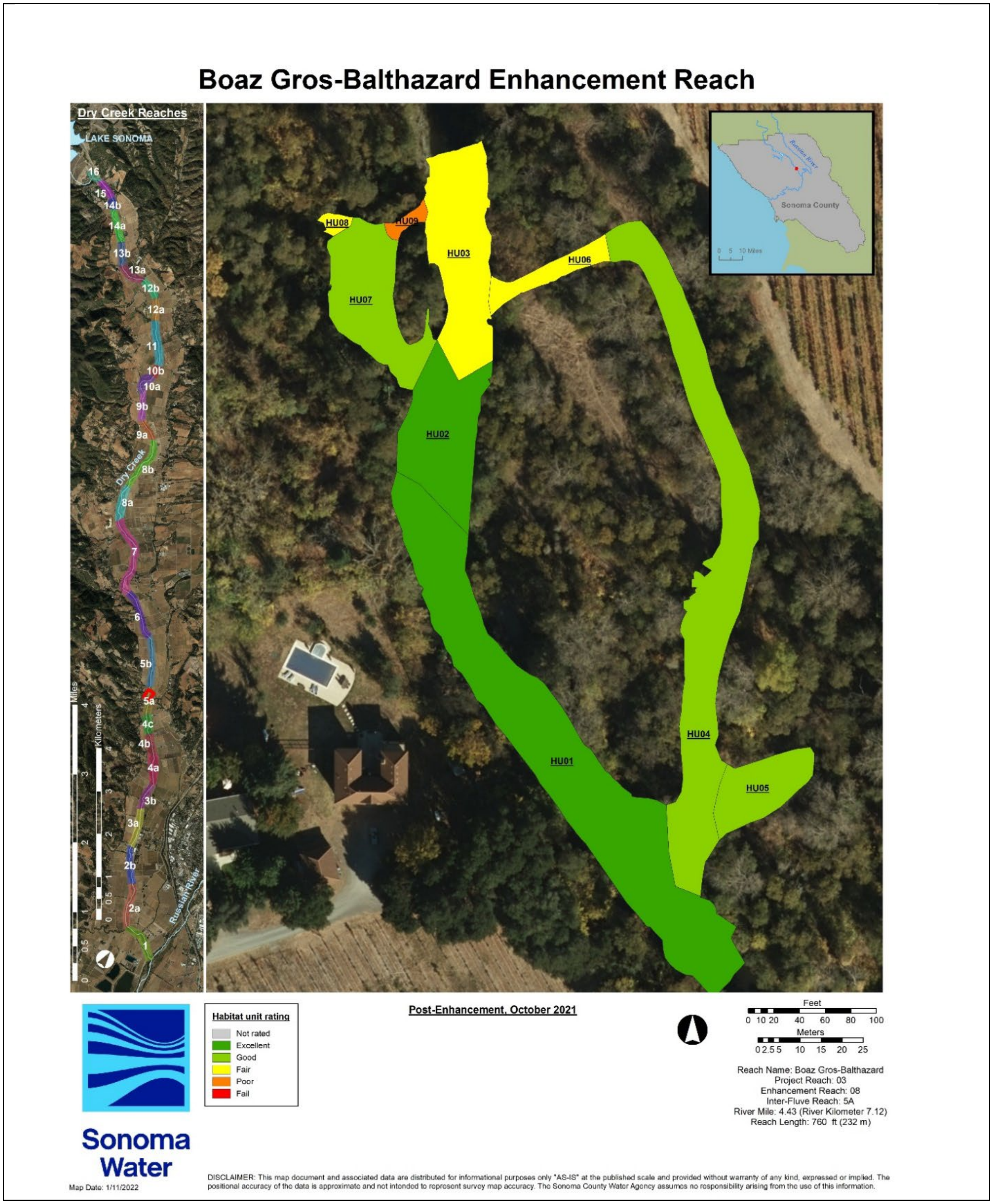

Figure 5.2.10. Habitat unit ratings for the Boaz Gros-Balthazard enhancement reach, October 2021.

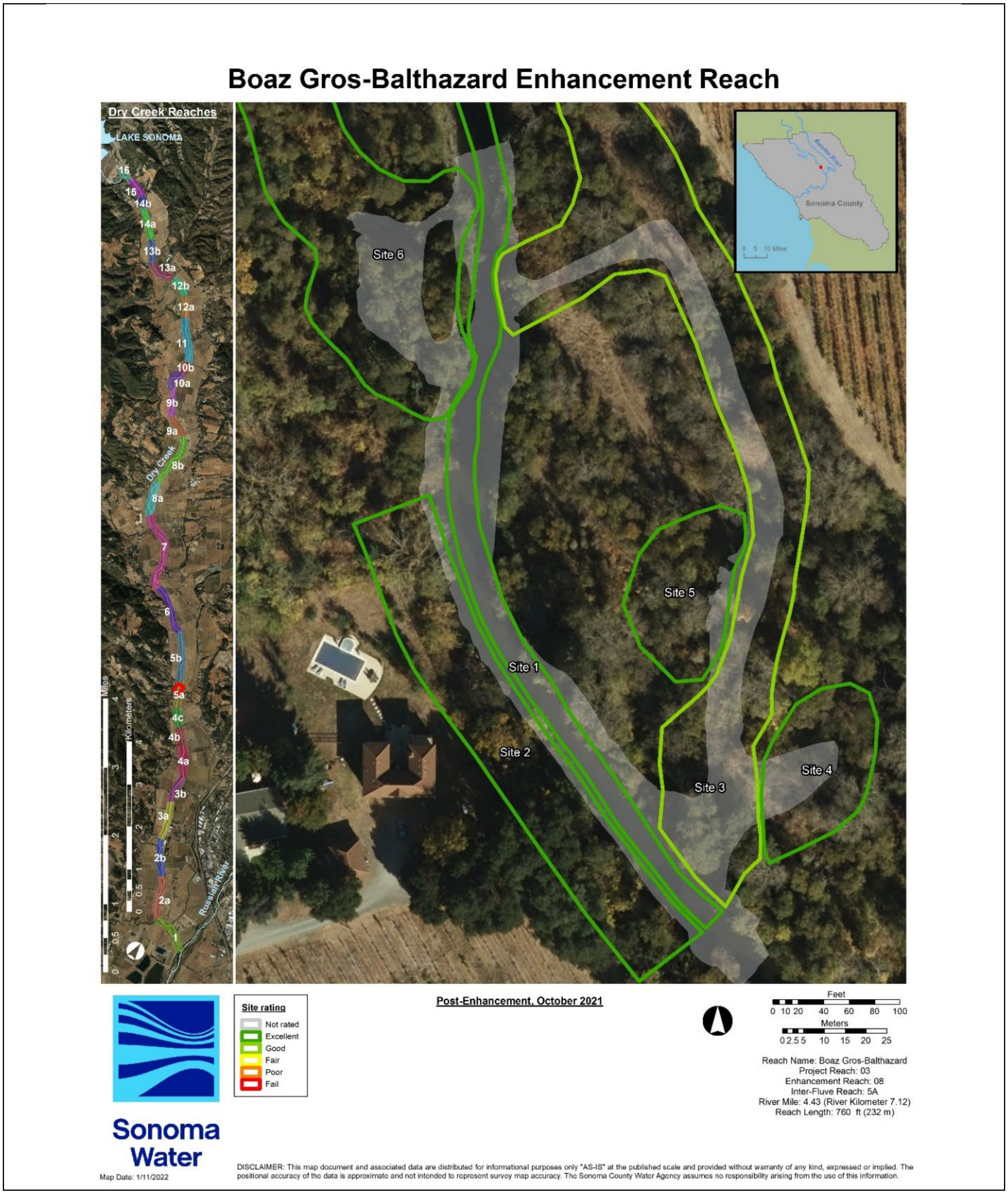

Figure 5.2.11. Post-enhancement site ratings for the Boaz Gros-Balthazard enhancement reach, October 2021.

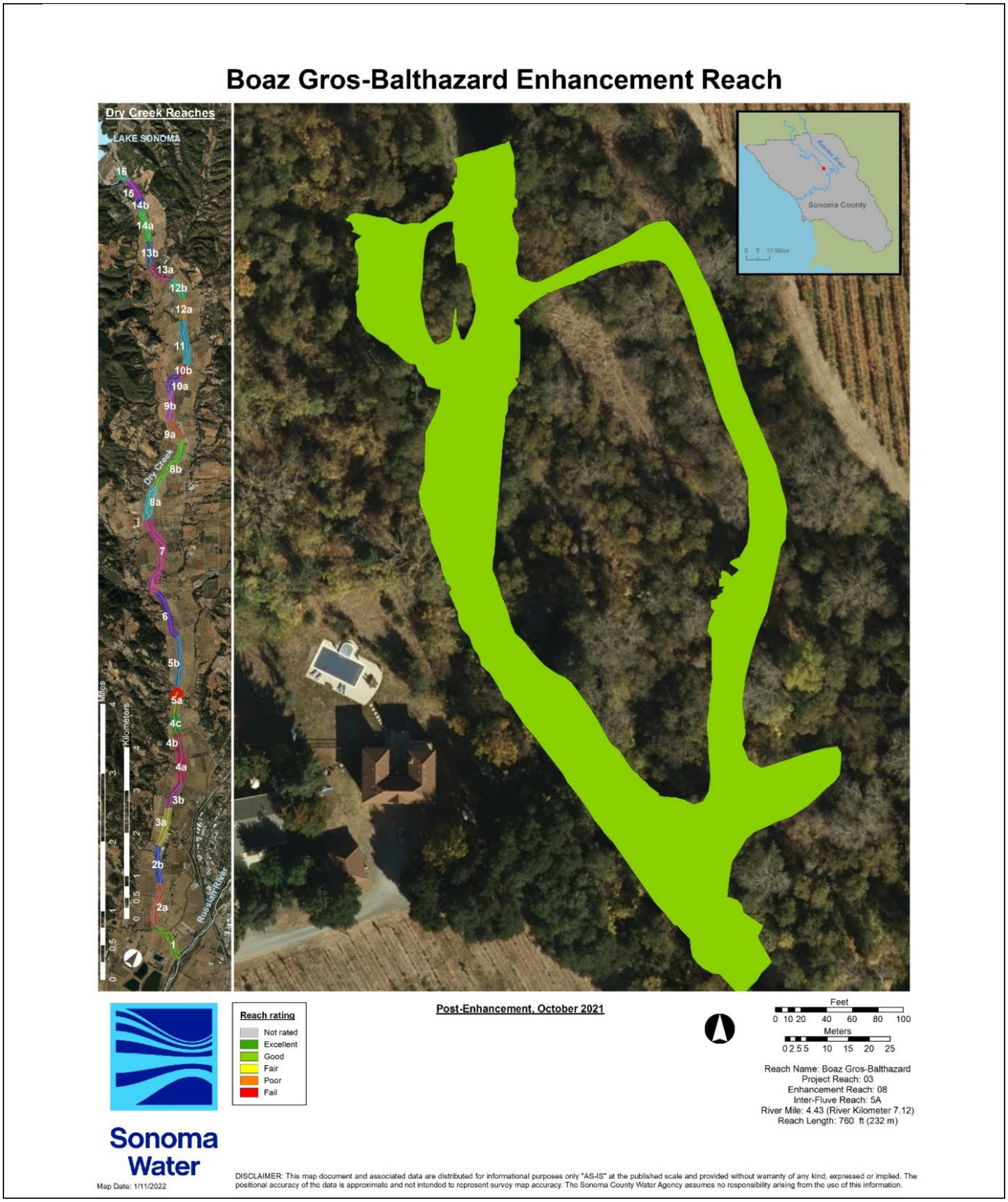

Figure 5.2.12. Post-enhancement reach rating for the Boaz Gros-Balthazard enhancement reach, October 2021.

Post-effective Flow

Summary

Sonoma Water monitored the post-effective flow conditions of the Gallo, Truett Hurst, Meyer, Carlson Lonestar, Farrow Wallace, and Geyser Peak enhancement reaches in 2021 (Table 5.2.8, Figure 5.2.4). Overall, the enhancement reaches encompassed 310,247 ft^2 within main and side channel areas, with 33% of the total area meeting optimal depth and velocity criteria (Table 5.2.13). Monitoring examined 91,205 ft^2 of side channel area, of which 45% met optimal depth and criteria, compared with 219,043 ft^2 and 22% in the main channel. Crews observed 97 habitat units across all enhancement reaches with a total pool to riffle ratio of 44:28 (1.57) and a total average shelter score of 149 (Table 5.2.14). Average shelter score for all habitat types exceeded the optimum shelter score of 80. Post-effective flow, Gallo, Truett Hurst, and Meyer, and Carlson Lonestar enhancement reaches rated good, and Farrow Wallace and Geyser Peak rated fair. (Table 5.2.15; see below for individual enhancement reach summaries and Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.13. Post-effective flow areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches surveyed in 2021.

Dry Creek, Post-effective Flow 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	219,043	125,101	50,953	176,054	74,037	28,172	20,719	48,891
Side channel area	91,205	40,902	25,397	66,298	76,255	32,524	22,319	54,843
Total area	**310,247**	**166,003**	**76,350**	**242,353**	**150,292**	**60,696**	**43,038**	**103,734**
Main channel % of wetted area	71%	57%	23%	80%	34%	13%	9%	22%
Side channel % of wetted area	29%	44%	29%	74%	84%	35%	26%	61%
Total % of wetted area	**100%**	**54%**	**25%**	**78%**	**48%**	**20%**	**14%**	**33%**

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.14. Post-effective flow habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches surveyed in 2021.

Habitat Type	# of Habitat Units	Shelter Score
Riffle	28	83
Pool	44	175
Flatwater	15	118
Alcove	11	252
Pool: riffle	**44:28 (1.57)**	**Avg: 149**

Reach ratings

Table 5.2.15. Post-effective flow ratings for Dry Creek enhancement reaches surveyed in 2021.

Enhancement Reach	Post-effective Flow Rating
Gallo	Good
Truett Hurst	Good
Meyer	Good
Carlson Lonestar	Good
Farrow Wallace	Good
Geyser Peak	Fair

Gallo Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Gallo enhancement reach in September 2021. Previous effectiveness monitoring surveys occurred in June 2018 (pre-enhancement), October 2019 (post-enhancement), and September 2020 (post-effective flow) (Table 5.2.16).

Table 5.2.16. Gallo enhancement reach effectiveness monitoring surveys and ratings.

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2018	Fair	--		--	--
2019	--	Good		--	--
2020	--	--	Good	--	--
2021	--	--	Good	--	--

In 2021, the enhanced reach encompassed 79,465 ft^2 within main and side channel areas of Dry Creek with 42% of the total area meeting optimal depth and velocity criteria (Table 5.2.17, Figure 5.2.13). The monitoring characterized 33,27 ft^2 of side channel area, of which 50% met optimal depth and velocity criteria, compared with 46,238 ft^2 and 35% for the main channel area. Eighteen habitat units composed the enhancement reach, with a pool to riffle ratio of 7:9 (0.78) and average shelter score of 143 (Table 5.2.18, Figure 5.2.14, Figure 5.2.15). Eleven 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 5.2.16), with excellent site average feature ratings, and good average habitat unit ratings (Table 5.2.19, Figure 5.2.17, Figure 5.2.18). Enhancement sites received good ratings (Figure 5.2.19). Overall, the Gallo enhancement reach received a good effectiveness monitoring rating (Table 5.2.19, Figure 5.2.20; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.17. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Gallo enhancement reach, September 2021.

Gallo, Post-effective flow, September 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	46,238	18,836	15,894	34,730	24,493	7,680	8,733	16,413
Side channel area	33,227	12,007	11,725	23,732	24,957	7,242	9,408	16,650
Total area	**79,465**	**30,843**	**27,619**	**58,462**	**49,450**	**14,923**	**18,141**	**33,064**
Main channel % of wetted area	58%	41%	34%	75%	53%	17%	19%	35%
Side channel % of wetted area	42%	36%	35%	71%	75%	22%	28%	50%
Total % of wetted area	**100%**	**39%**	**35%**	**74%**	**62%**	**19%**	**23%**	**42%**

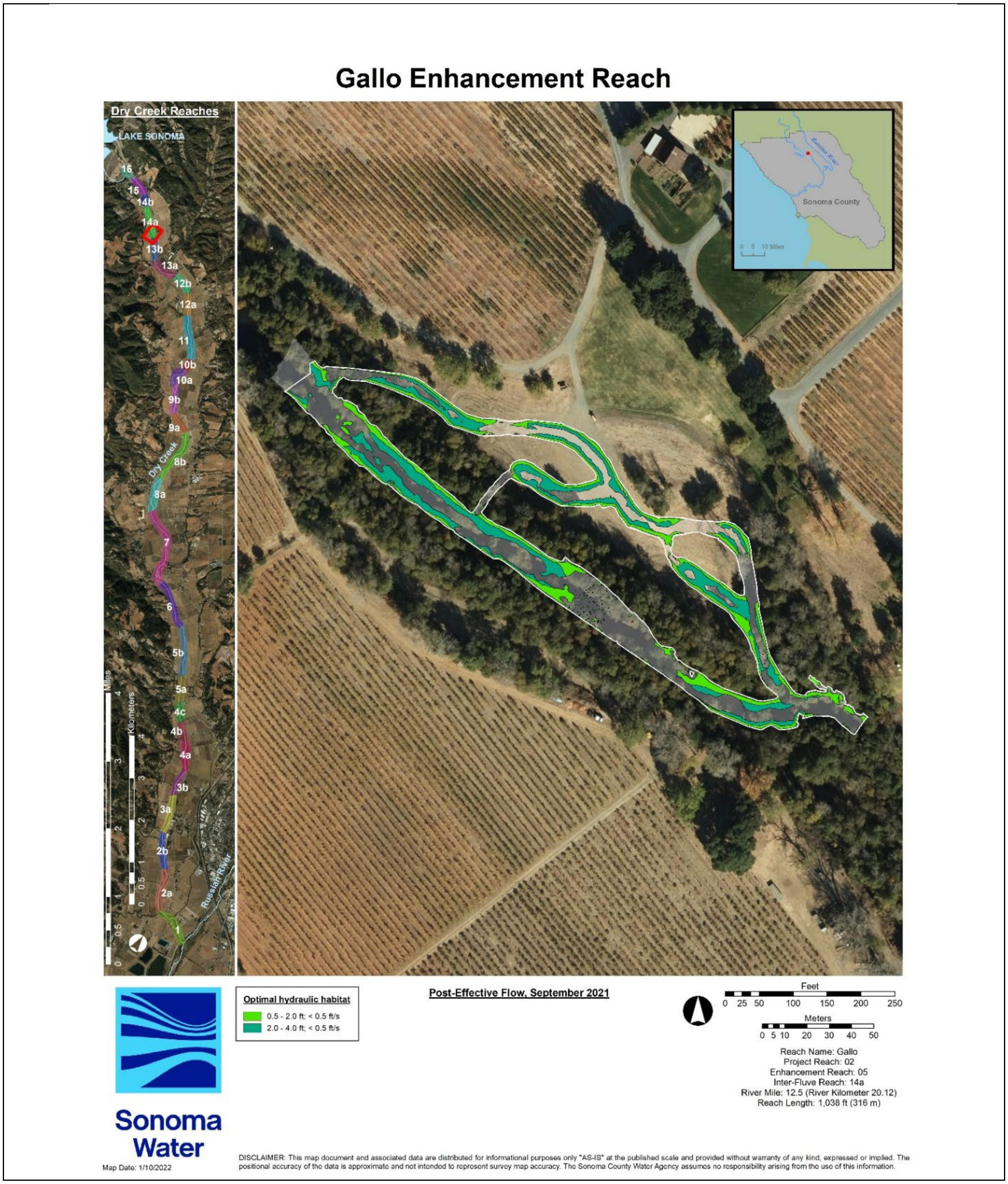

Figure 5.2.13. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Gallo enhancement reach, September 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.18. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Gallo enhancement reach, September 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Riffle	2	25	50
HU02	Alcove	3	40	120
HU03	Pool	3	80	240
HU04	Riffle	3	85	255
HU05	Pool	3	75	225
HU06	Riffle	1	5	5
HU07	Pool	3	40	120
HU08	Pool	3	80	240
HU09	Riffle	2	25	50
HU10	Pool	3	65	195
HU11	Riffle	1	10	10
HU12	Pool	3	80	240
HU13	Riffle	3	70	210
HU14	Riffle	3	50	150
HU15	Riffle	2	20	40
HU16	Pool	3	80	240
HU17	Riffle	2	20	40
Pool: riffle	**7:9 (0.78)**			**Avg = 143**

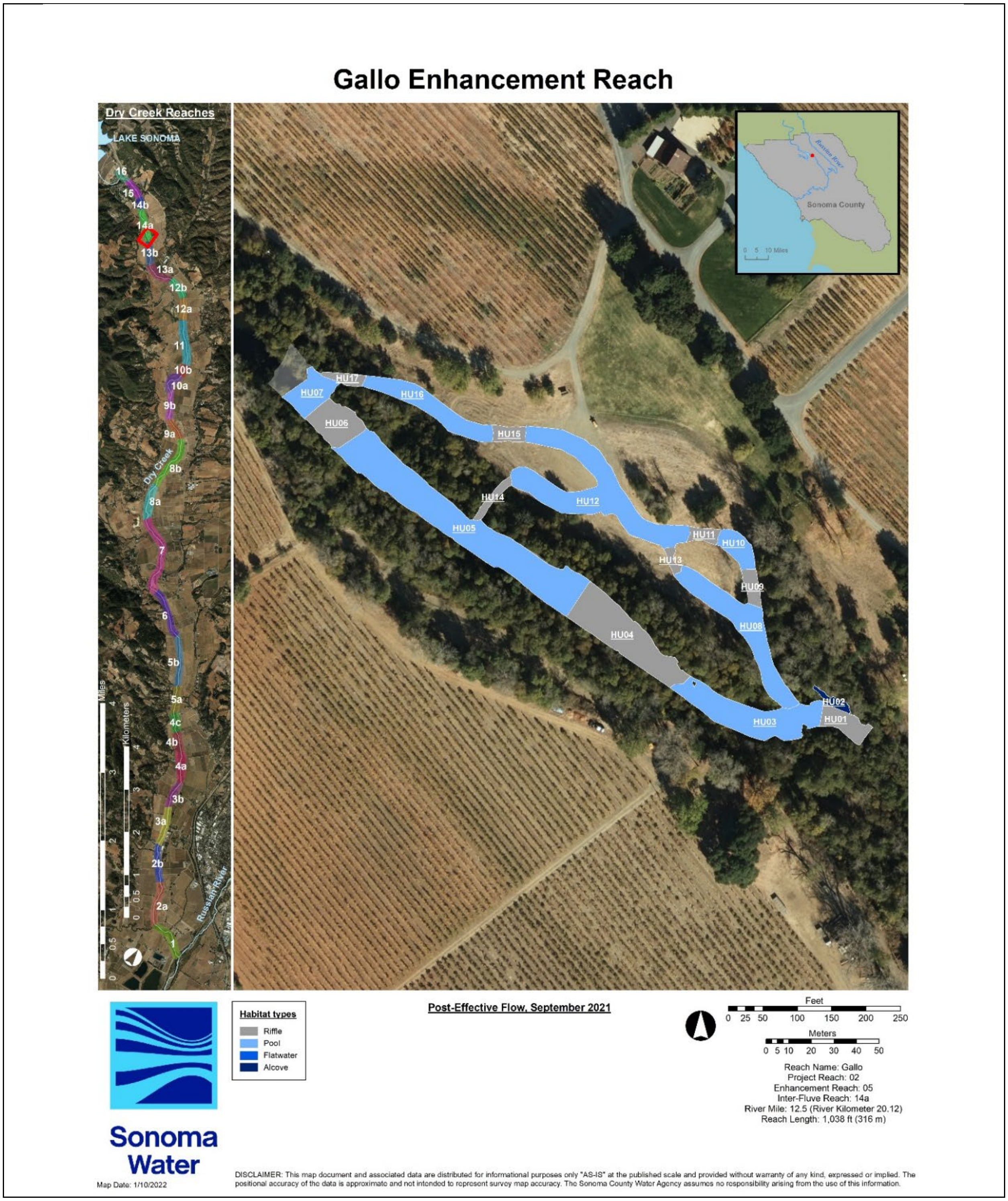

Figure 5.2.14. Habitat unit number and type within the Gallo enhancement reach, September 2021.

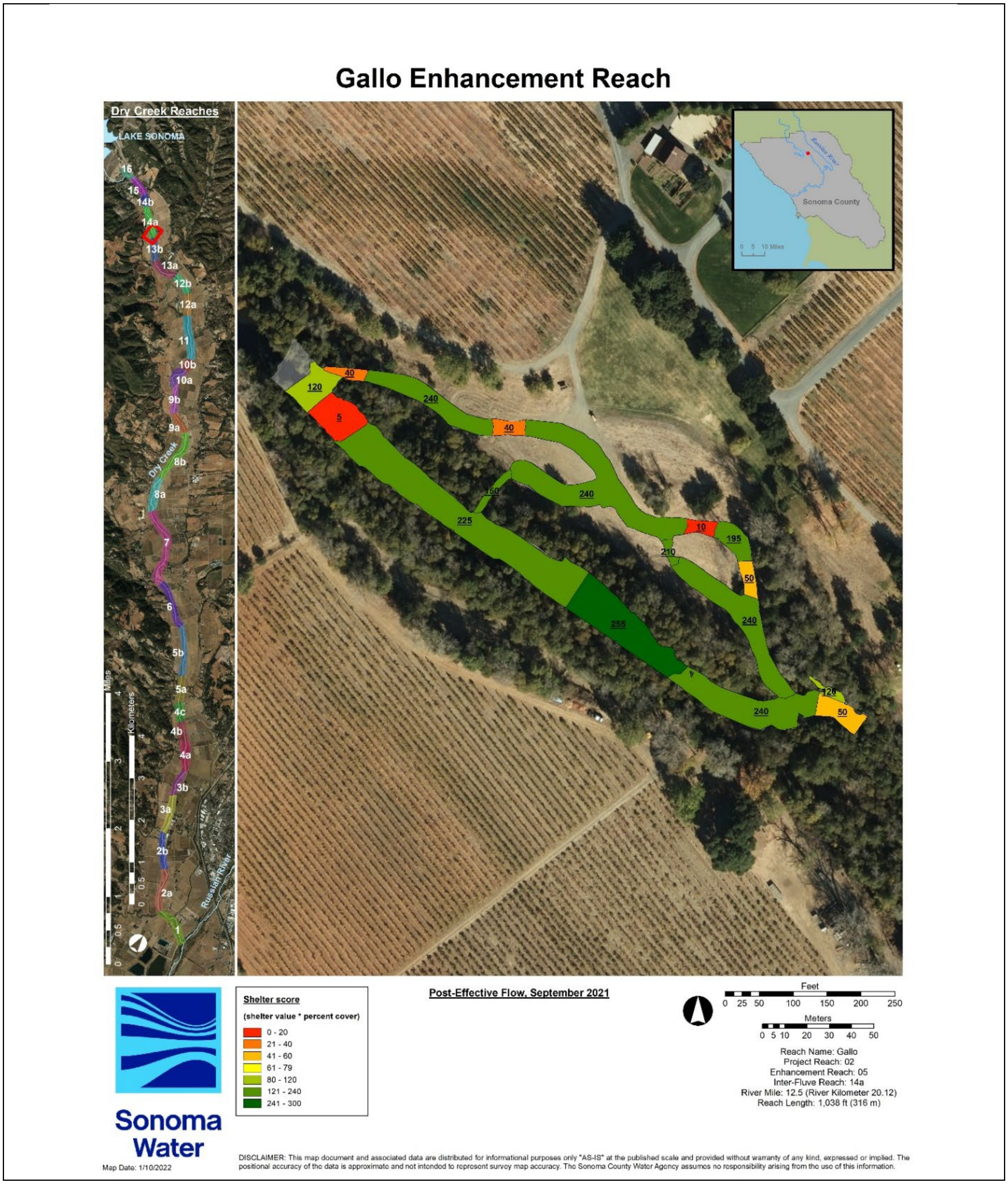

Figure 5.2.15. Habitat unit shelter scores within the Gallo enhancement reach, September 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.19. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Gallo enhancement reach, September 2021.

Site number	**1**	**2**		
Site type	Main channel	Side channel		
Site average feature quantitative rating[a]	14	14		
Site average feature qualitative rating[a]	Excellent	Excellent		
Site average habitat unit quantitative rating[b]	21	21		
Site average qualitative rating[b]	Good	Good		
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	35	35		
Site qualitative rating[c]	Good	Good		
Enhancement reach quantitative rating (average of site rating)[c]	35			
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)

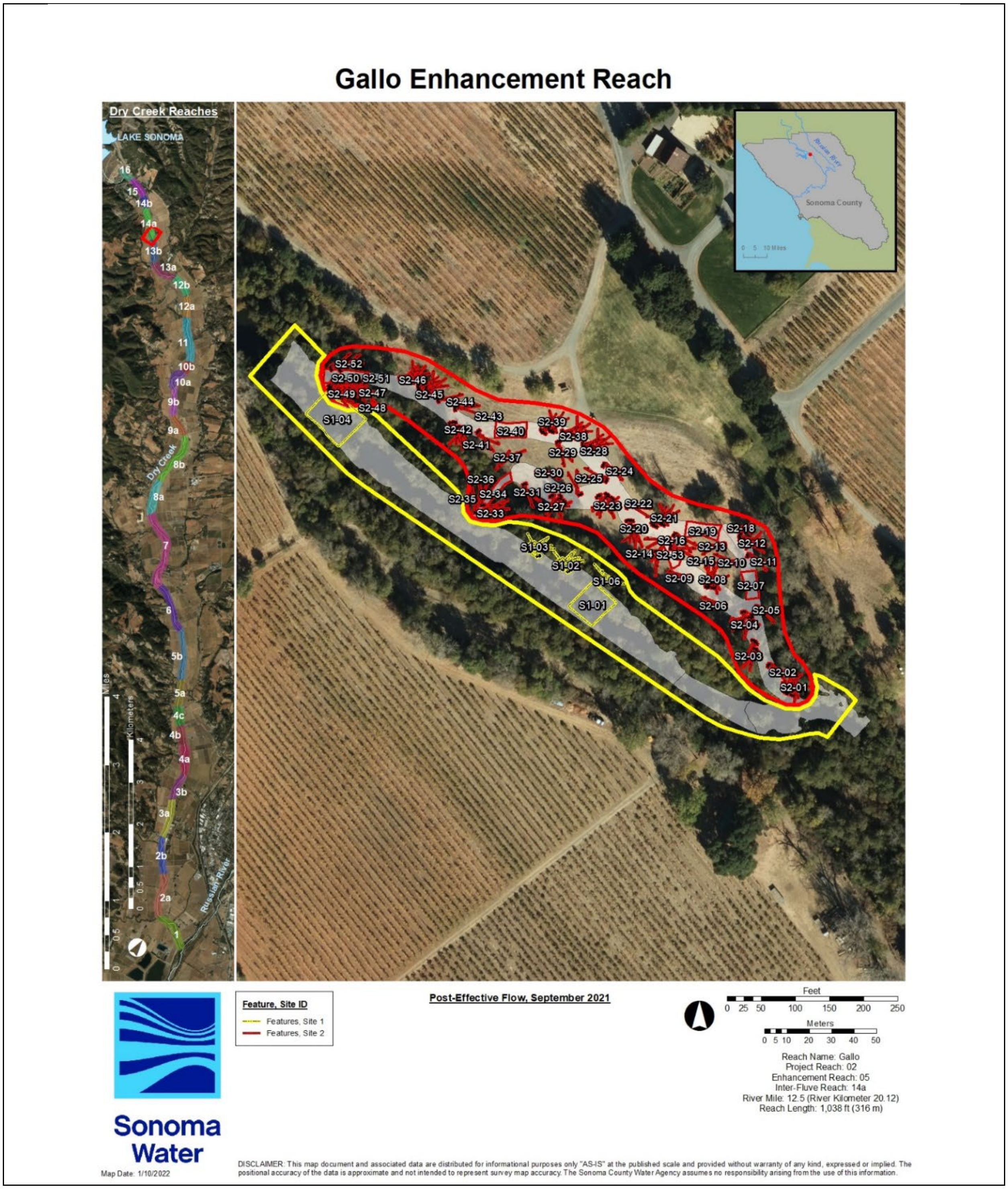

Figure 5.2.16. Enhancement sites and features within the Gallo enhancement reach, September 2021.

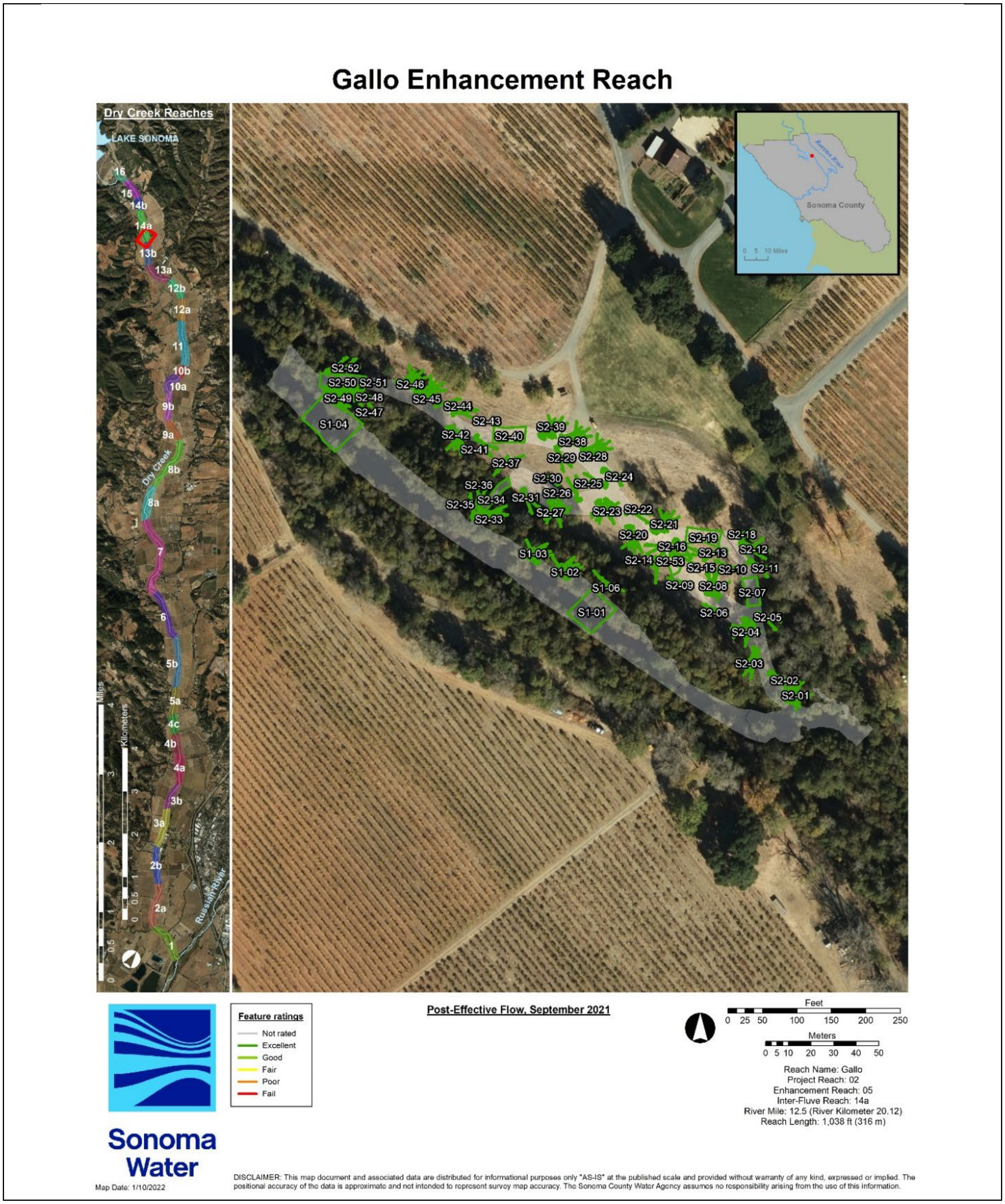

Figure 5.2.17. Feature ratings for the Gallo enhancement reach, September 2021.

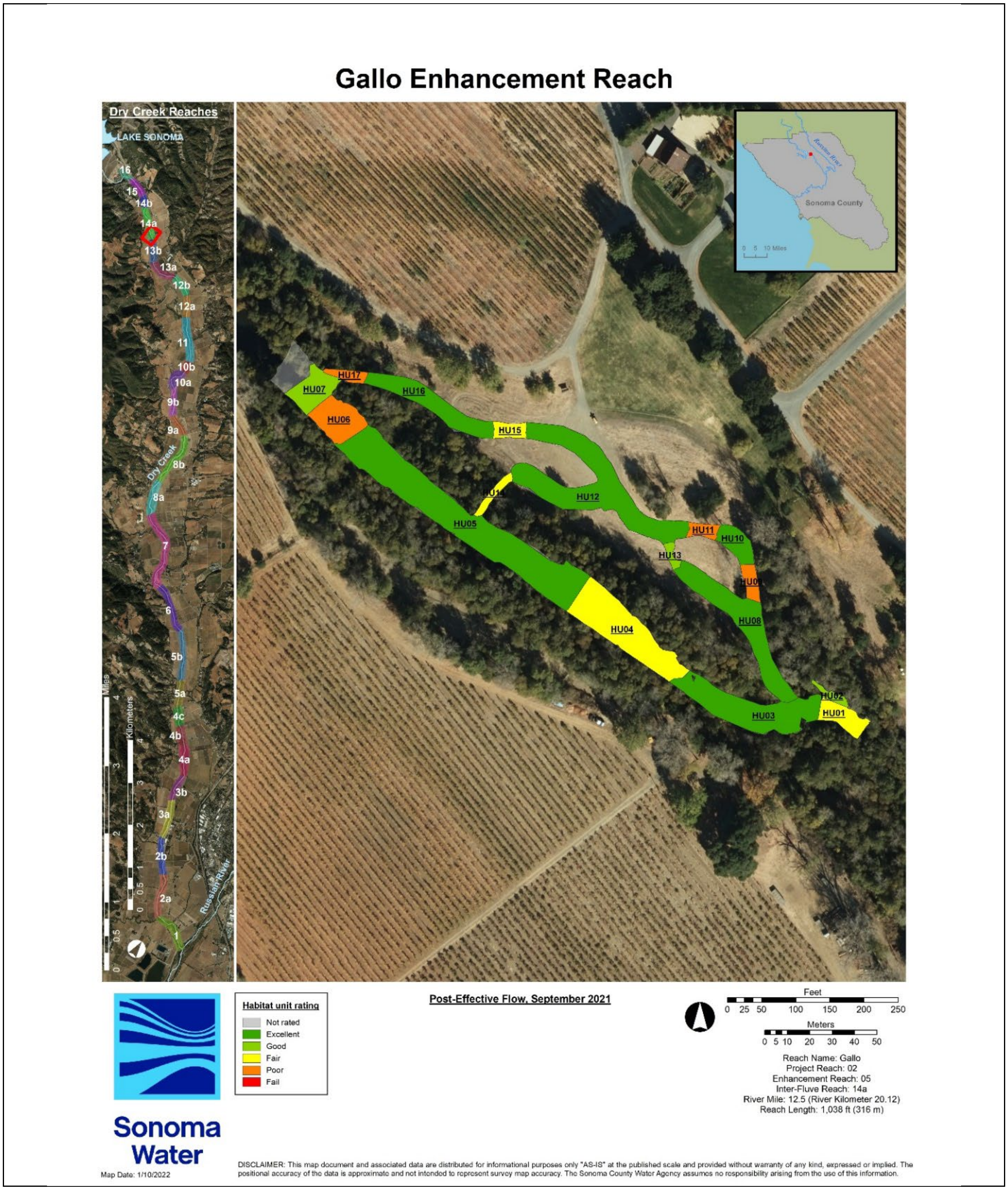

Figure 5.2.18. Habitat unit ratings for the Gallo enhancement reach, September 2021.

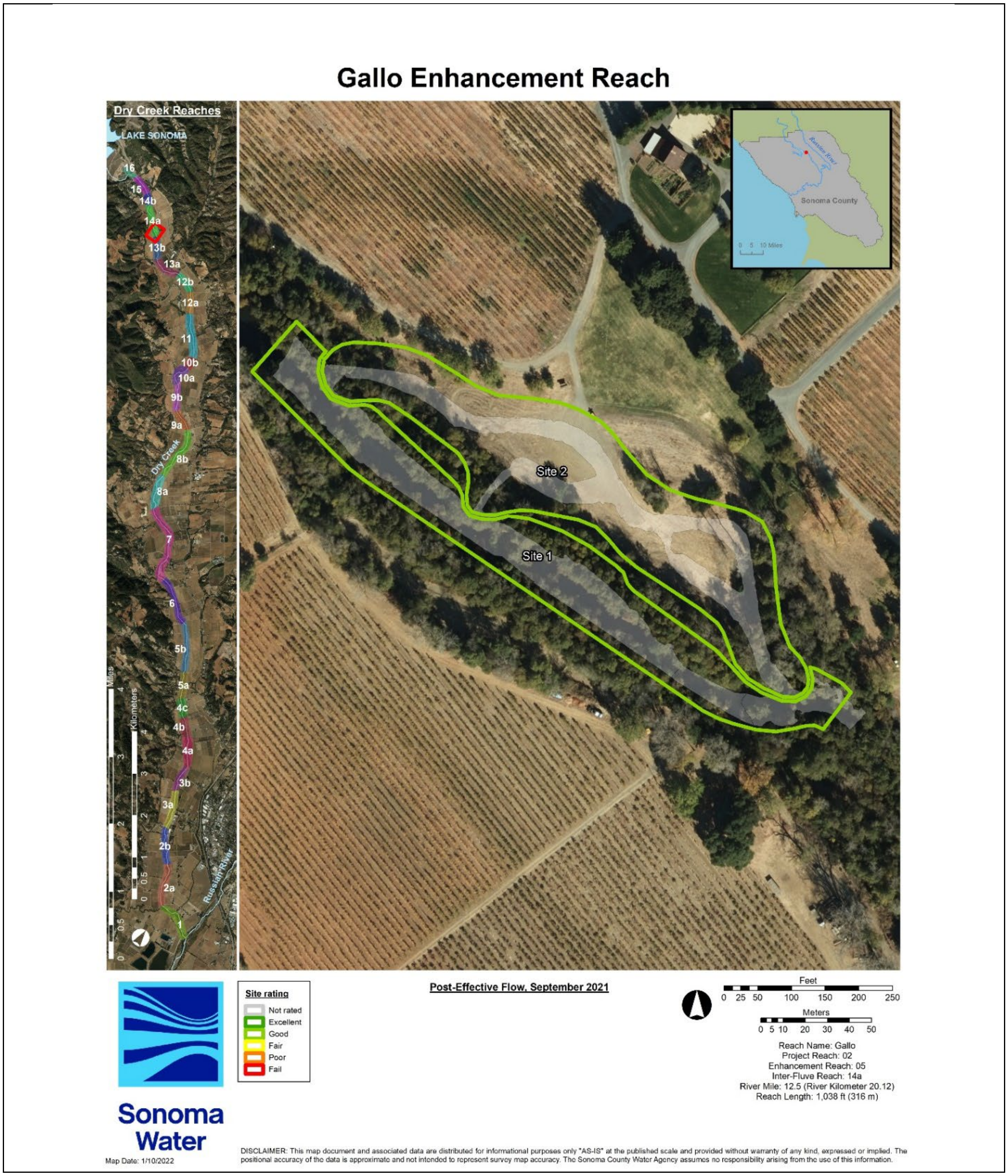

Figure 5.2.19. Post-enhancement site ratings for the Gallo enhancement reach, September 2021.

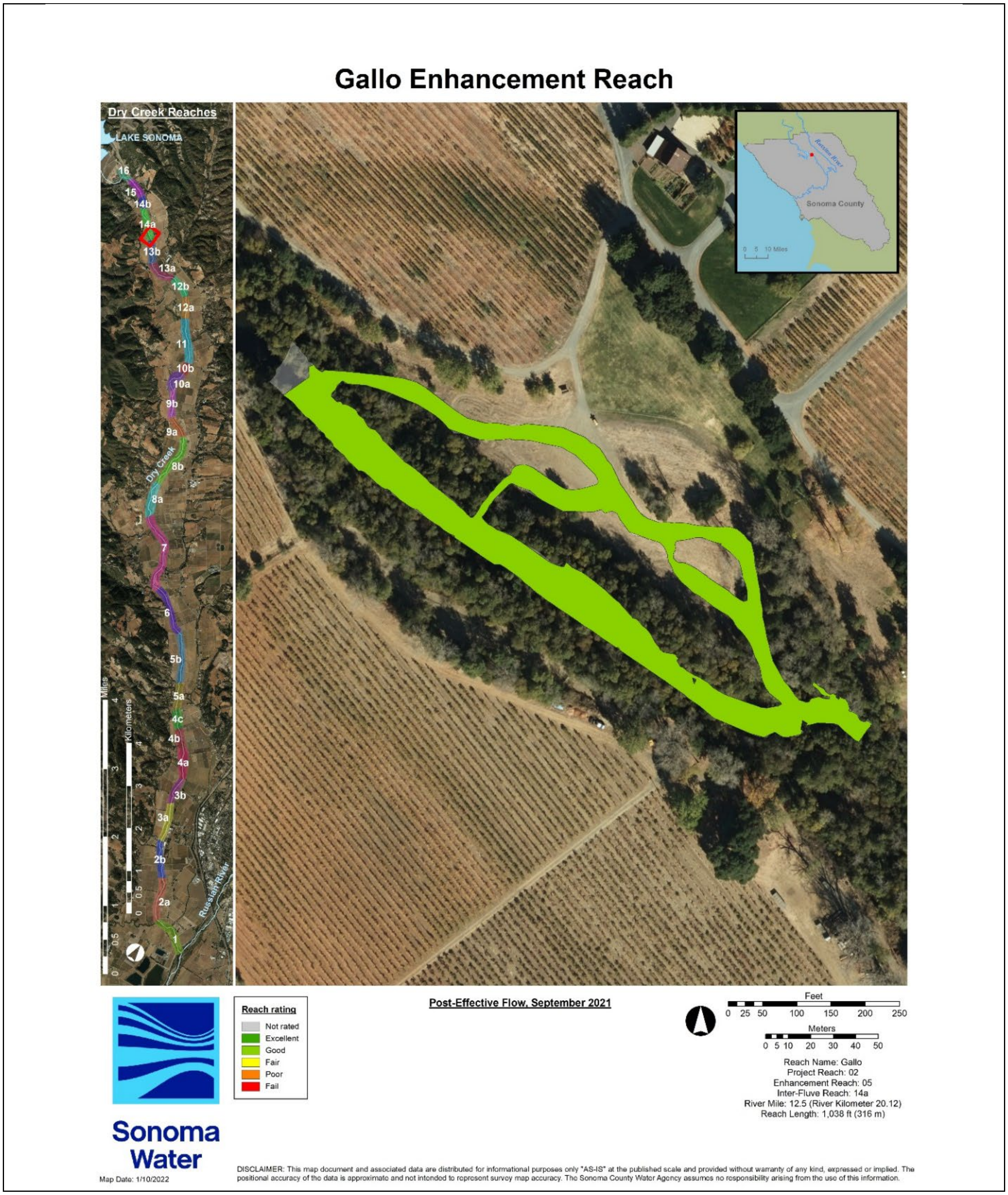

Figure 5.2.20. Post-enhancement reach rating for the Gallo enhancement reach, September 2021.

Truett Hurst Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Truett Hurst enhancement reach in April 2021. 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 subsequent repairs in summer 2017. Crews monitored again in October 2017. Sonoma Water monitored the post-effective flow habitat condition in August 2018, August 2019, and August 2020, and spring flow in May 2021 (Table 5.2.20; see Spring Flow section below for results).

Table 5.2.20. Truett Hurst enhancement reach effectiveness monitoring surveys and ratings.

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2016	Fair	Good			--
2017			Poor	Good	--
2018	--	--	Good	--	--
2019	--	--	Fair	--	--
2020	--	--	Good	--	--
2021	--	--	Good	--	Good

The 2021 monitored area encompassed 23,528 ft^2 within side channel areas with 57% of the total area meeting optimal depth and velocity criteria (Table 5.2.21, Figure 5.2.21). The monitored area included 19,524 ft^2 of side channel and 4,005 ft^2 of side channel alcove area, of which 58% and 55%, respectively met optimal depth and velocity criteria, but did not include main channel area as crews were unable to survey the main channel. Thirty habitat units composed the enhancement reach post-effective flow 2021, with a pool to riffle ratio of 16:8 (2.0) and an average shelter score of 145 (Table 5.2.22, Figure 5.2.22,Figure 5.2.23). Twenty-three 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 5.2.23, Figure 5.2.24) that received fair to excellent site average feature ratings (we did not rate enhancement site 1 [main channel] as crews were unable to survey), and fair to good site average habitat unit ratings (Table 5.2.23, Figure 5.2.25, Figure 5.2.26). Enhancement site ratings ranged from fair to good, with the main channel site (site 1) receiving no rating, the two alcove sites receiving excellent and fair ratings, and the side channel and bank sites receiving good and excellent ratings (Table 5.2.23, Figure 5.2.27). Overall, the Truett Hurst enhancement reach received a good effectiveness monitoring rating (Table 5.2.23, Figure 5.2.28; see Appendix 5.2 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 Truett Hurst enhancement reach, April 2021.

Truett Hurst, Post-effective flow, April 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	0	0	0	0	0	0	0	0
Side channel area	19,524	9,574	2,387	11,961	16,796	8,968	2,347	11,315
Side channel alcove area	4,005	2,613	42	2,655	3,440	2,152	42	2,194
Total area	**23,528**	**12,187**	**2,429**	**14,615**	**20,236**	**11,120**	**2,389**	**13,509**
Main channel % of wetted area	0%	0%	0%	0%	0%	0%	0%	0%
Side channel % of wetted area	83%	49%	12%	61%	86%	46%	12%	58%
Side channel alcove area % of wetted area	17%	65%	1%	66%	86%	54%	1%	55%
Total % of wetted area	**100%**	**52%**	**10%**	**62%**	**86%**	**47%**	**10%**	**57%**

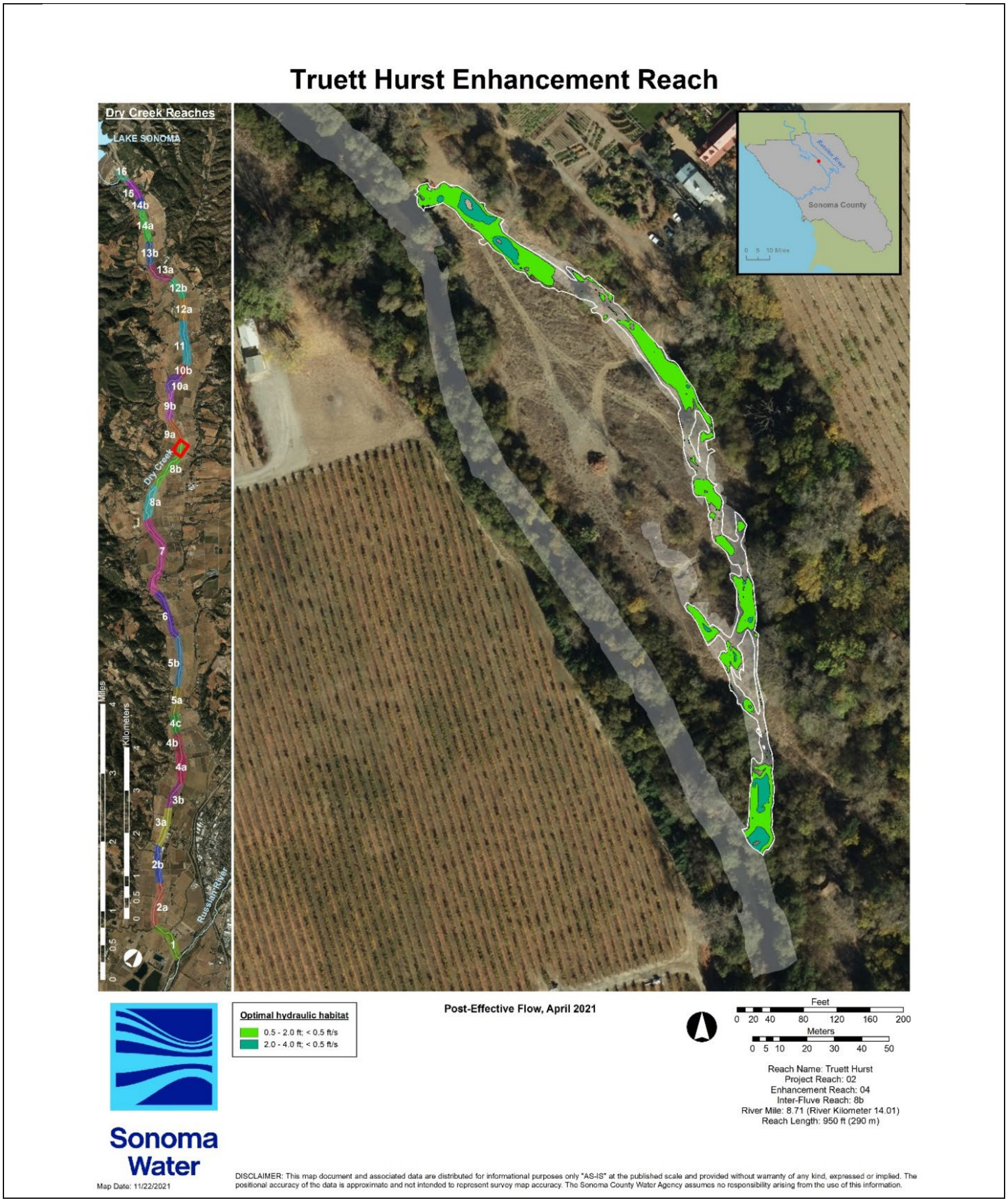

Figure 5.2.21. Optimal hydraulic habitat for fry (<0.5 f/s, 0.5-2.0 ft) and parr (<0.5 f/s, 2.0-4.0 ft) within the Truett Hurst enhancement reach, April 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.22. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Truett Hurst enhancement reach, April 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	100	300
HU02	Riffle	1	10	10
HU03	Pool	3	30	90
HU04	Riffle	3	35	105
HU05	Pool	3	60	180
HU06	Riffle	1	15	15
HU07	Alcove	3	100	300
HU08	Pool	3	40	120
HU09	Flatwater	2	100	200
HU10	Pool	3	50	150
HU11	Riffle	2	50	100
HU12	Pool	3	30	90
HU13	Alcove	3	100	300
HU14	Pool	3	40	120
HU15	Pool	3	35	105
HU16	Pool	1	30	30
HU17	Riffle	1	35	35
HU18	Pool	1	35	35
HU19	Riffle	1	40	40
HU20	Pool	3	85	255
HU21	Riffle	2	100	200
HU22	Pool	3	80	240
HU23	Pool	2	95	190
HU24	Pool	3	70	210
HU25	Flatwater	3	30	90
HU26	Alcove	3	60	180
HU27	Riffle	1	30	30
HU28	Pool	3	90	270
HU29	Pool	3	75	225
HU30	Flatwater	3	40	120
Pool: riffle	**16:8 (2.00)**			**Avg = 145**

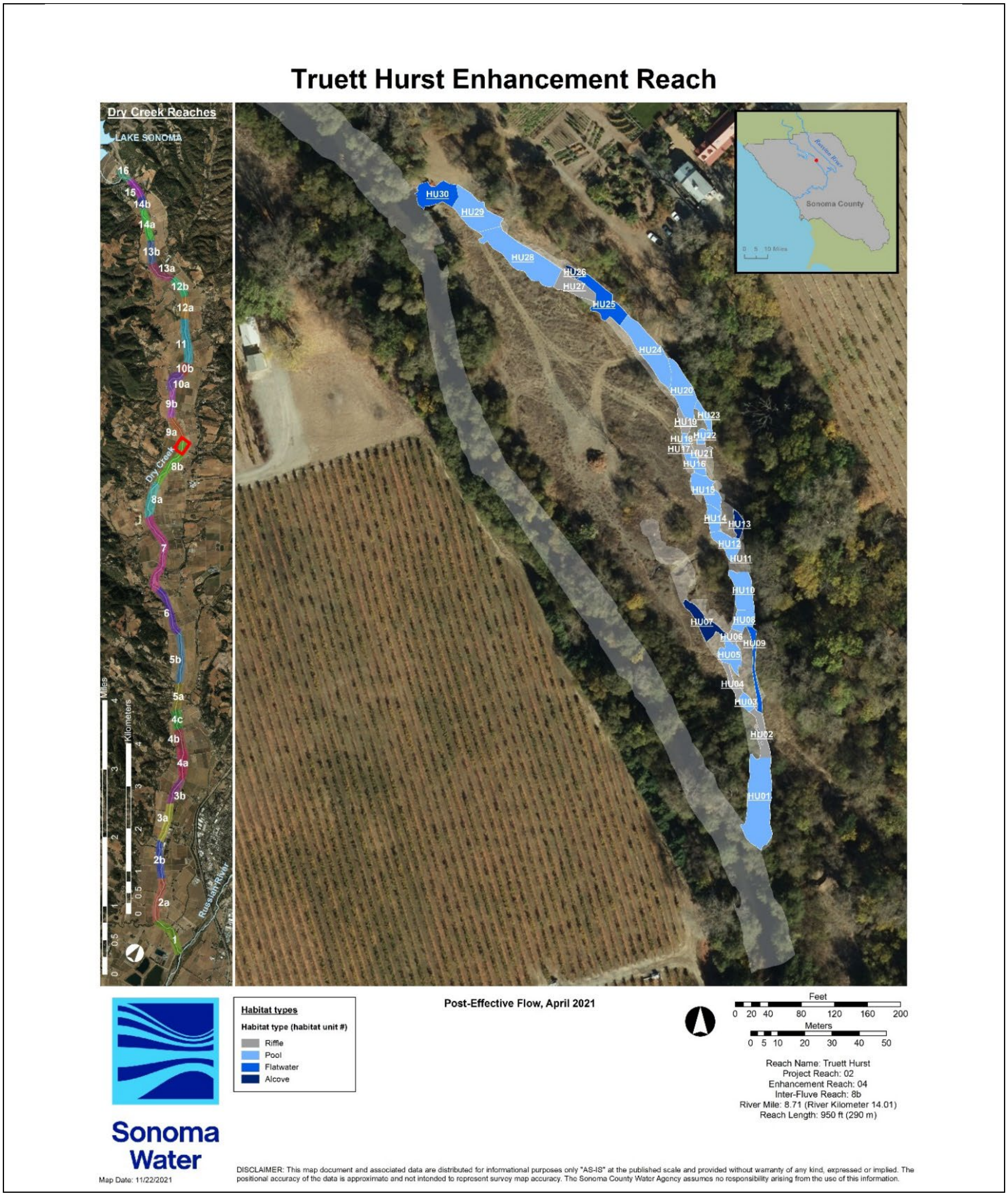

Figure 5.2.22. Habitat unit number and type within the Truett Hurst enhancement reach, April 2021.

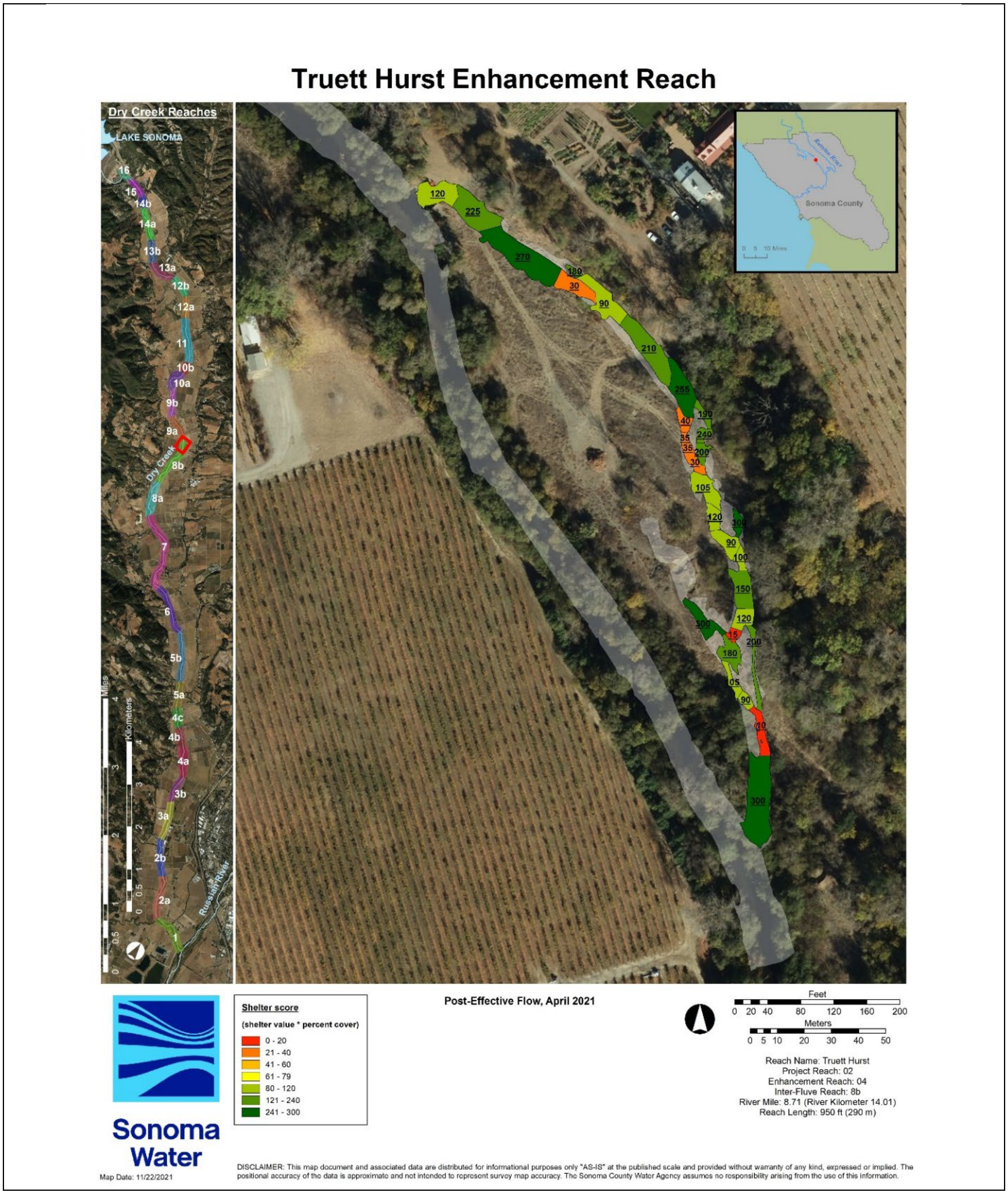

Figure 5.2.23. Habitat unit shelter scores within the Truett Hurst enhancement reach, April 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.23. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Truett Hurst enhancement reach, April 2021.

Site number	1	2	3	4	5
Site type	Main channel	Side channel	Alcove	Alcove	Bank
Site average feature quantitative rating[a]	0	12	9	10	12
Site average feature qualitative rating[a]	Not rated	Good	Fair	Good	Excellent
Site average habitat unit quantitative rating[b]	0	20	18	24	20
Site average qualitative rating[b]	Not Rated	Fair	Fair	Good	Fair
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	0	32	26	34	32
Site qualitative rating[c]	Not Rated	Good	Fair	Excellent	Excellent
Enhancement reach quantitative rating (average of site rating)[c]	30				
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)

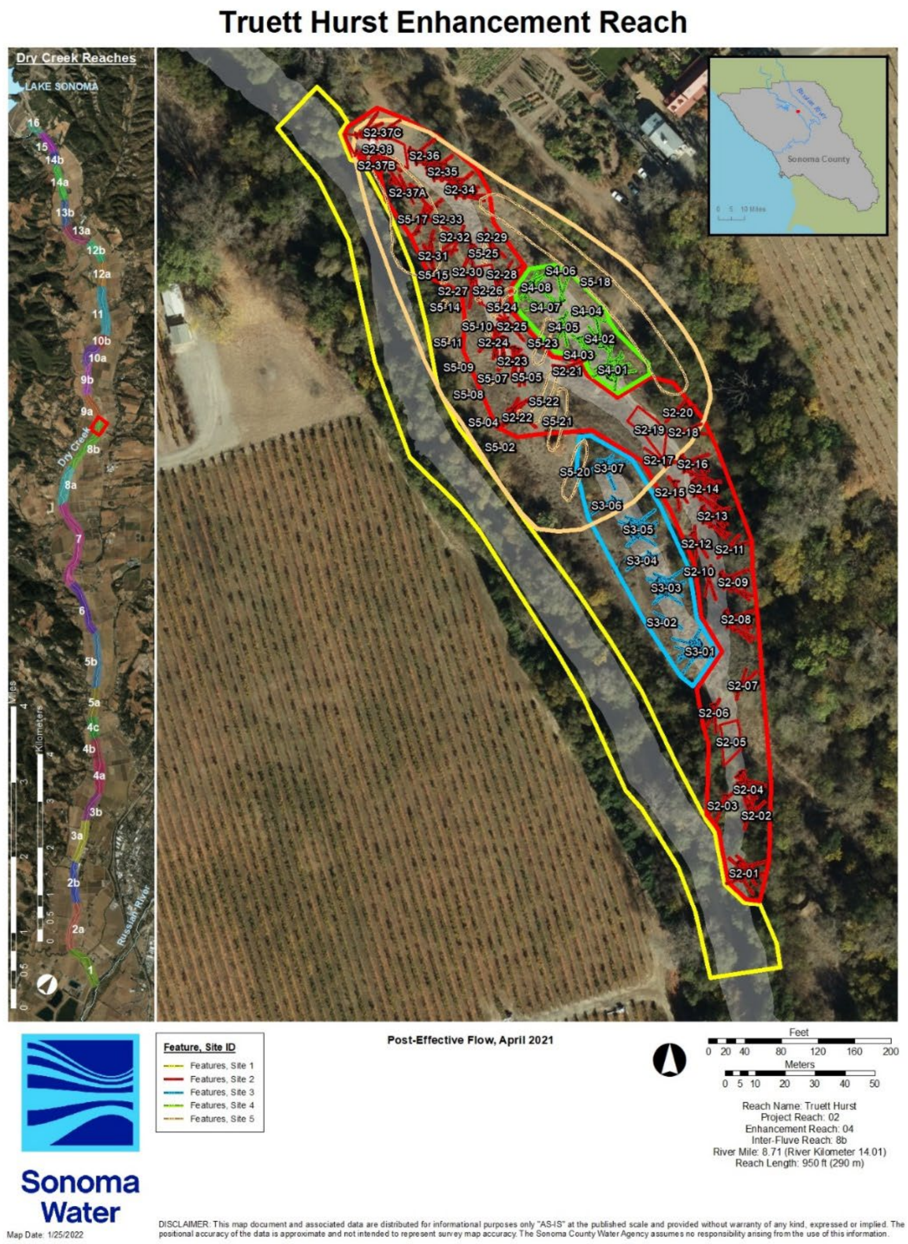

Figure 5.2.24. Enhancement sites and features within the Truett Hurst enhancement reach, April 2021.

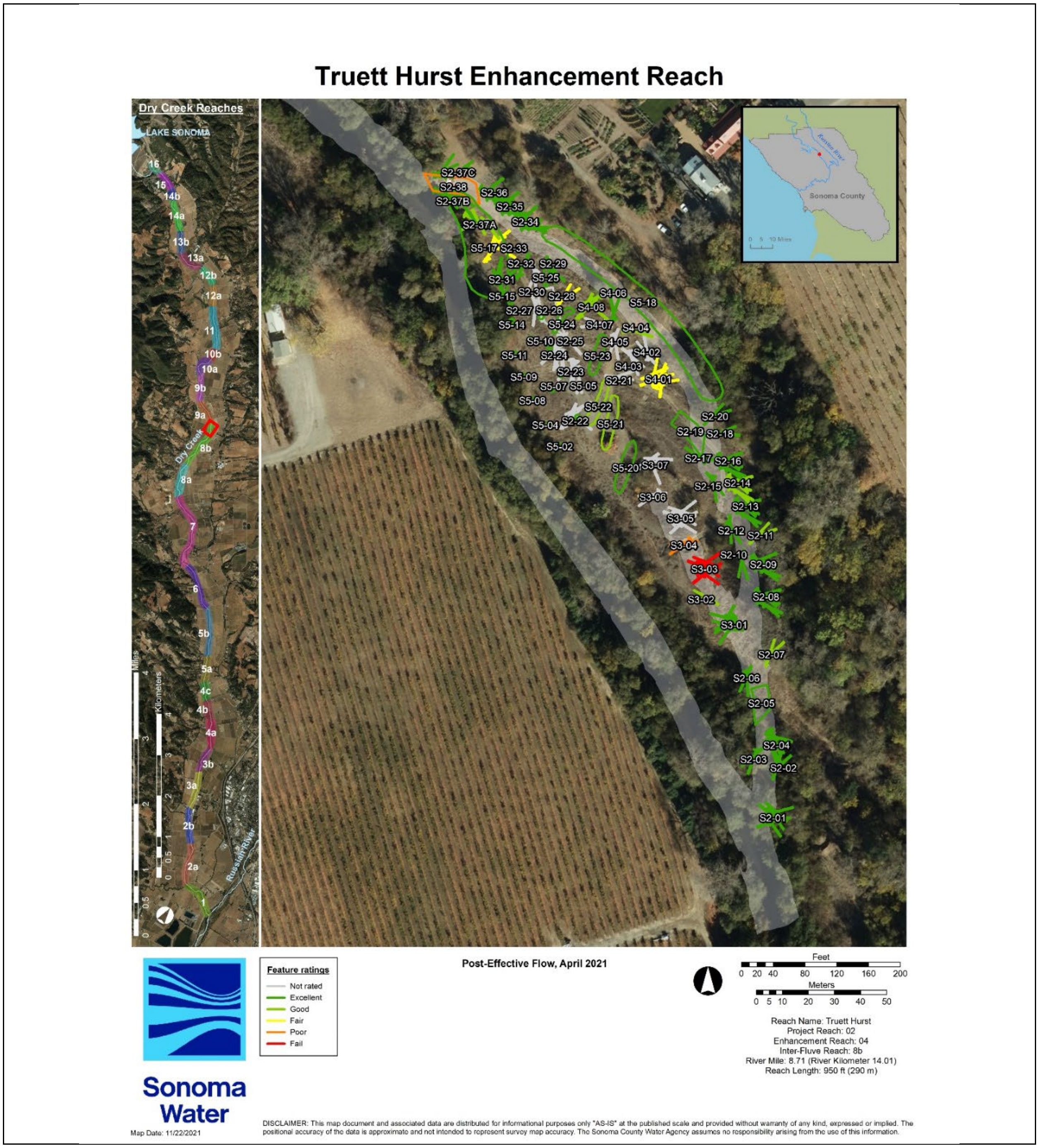

Figure 5.2.25. Feature ratings for the Truett Hurst enhancement reach, April 2021.

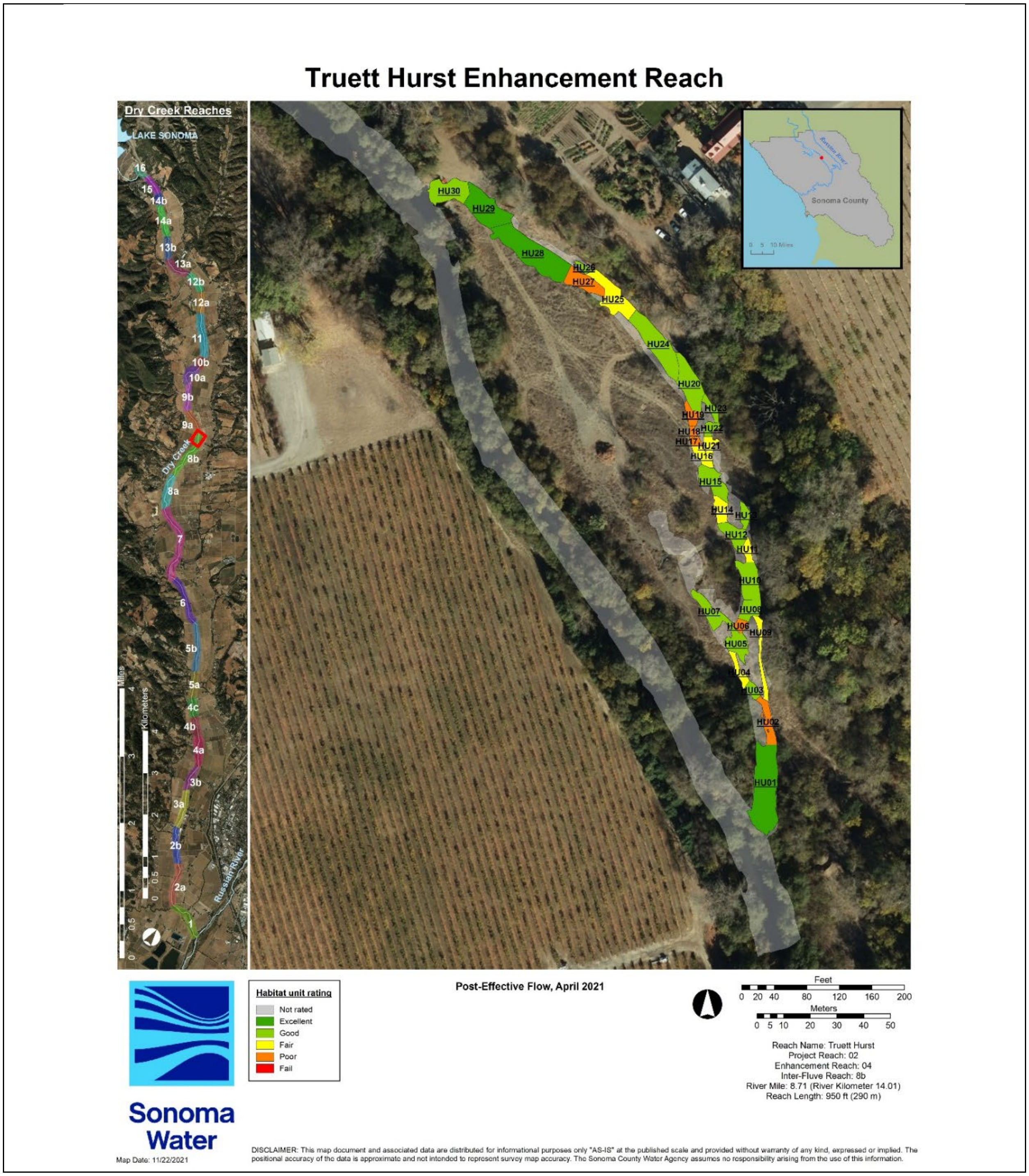

Figure 5.2.26. Habitat unit ratings for the Truett Hurst enhancement reach, April 2021.

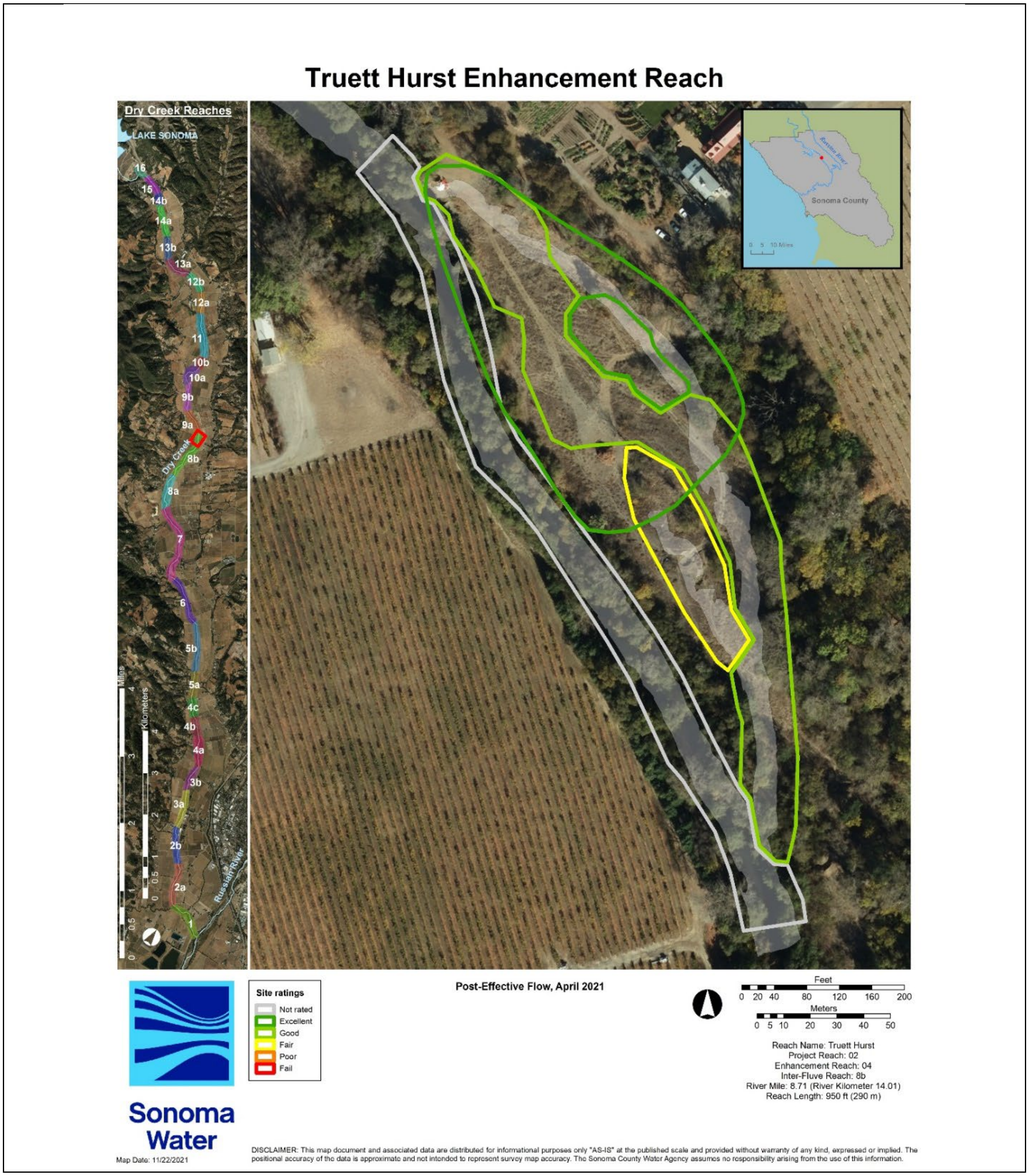

Figure 5.2.27. Post-effective flow site ratings for the Truett Hurst enhancement reach, April 2021.

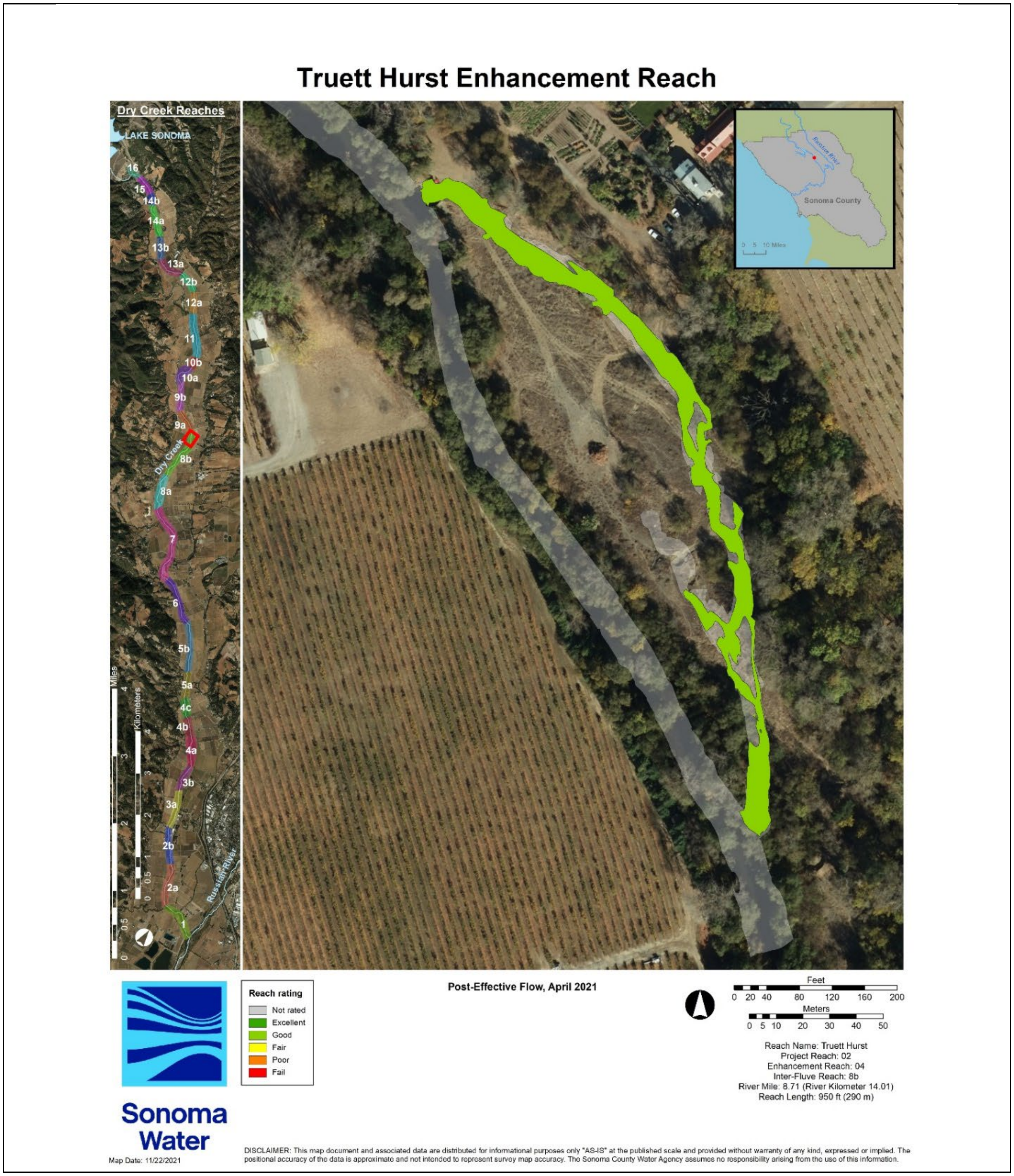

Figure 5.2.28. Post-effective flow reach rating for the Truett Hurst enhancement reach, April 2021.

Meyer Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Meyer enhancement reach in August 2021. Sonoma Water originally constructed the Meyer enhancement reach in November 2016, but aggradation caused by large storms in winter 2016/2017 led to repairs in summer 2017. Crews monitored again in October 2017 (post-repair), in August 2018 (post-effective flow), and in August 2021 (spring flow; see Spring Flow section below for results) (Table 5.2.24).

Table 5.2.24. Meyer enhancement reach effectiveness monitoring surveys and ratings.

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2016	Poor	Fair	--	--	--
2017	--	--	Poor	Good	--
2018	--	--	Good	--	--
2019	--	--	--	--	--
2020	--	--	--	--	--
2021	--	--	Good	--	Good

The monitored portion of the reach covered 47,719 ft^2 within main channel and side channel areas, with 71% of the total meeting optimal depth and velocity criteria (Table 5.2.25, Figure 5.2.29). The monitoring characterized 38,085 ft^2 of main channel area and 9,634 ft^2 of side channel area, of which 10% and 71% met optimal depth and velocity criteria. Ten habitat units composed the enhancement reach post-effective flow 2021, with a pool to riffle ratio of 5:2 (2.50) and an average shelter score of 109 (Table 5.2.26, Figure 5.2.30, Figure 5.2.31). Six habitat units met or exceeded the optimum shelter value of 80. The enhancement reach comprised three enhancement sites (one main channel and two side channels; Table 5.2.27, Figure 5.2.32) that received excellent site average feature rating (we did not rate enhancement site 1 as it contained no features) and fair to good site average habitat unit ratings (Table 5.2.27, Figure 5.2.33, Figure 5.2.34). Enhancement site ratings ranged from fair to good, with the main channel site (site 1) receiving a fair rating, the two side channel sites receiving good and fair ratings (Table 5.2.27, Figure 5.2.35). Overall, the Meyer enhancement reach received a good effectiveness monitoring score (Table 5.2.27, Figure 5.2.36; see Appendix 5.2 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.25. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Meyer enhancement reach, August 2021.

Meyer, Post-effective flow, August 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	38,085	29,032	2,405	31,436	7,267	3,301	538	3,840
Side channel area	9,634	4,282	4,140	8,421	8,008	3,250	3,607	6,857
Total area	**47,719**	**33,313**	**6,545**	**39,858**	**15,276**	**6,551**	**4,145**	**10,697**
Main channel % of wetted area	80%	76%	6%	83%	19%	9%	1%	10%
Side channel % of wetted area	20%	44%	43%	87%	83%	34%	37%	71%
Total % of wetted area	**100%**	**70%**	**14%**	**84%**	**32%**	**14%**	**9%**	**22%**

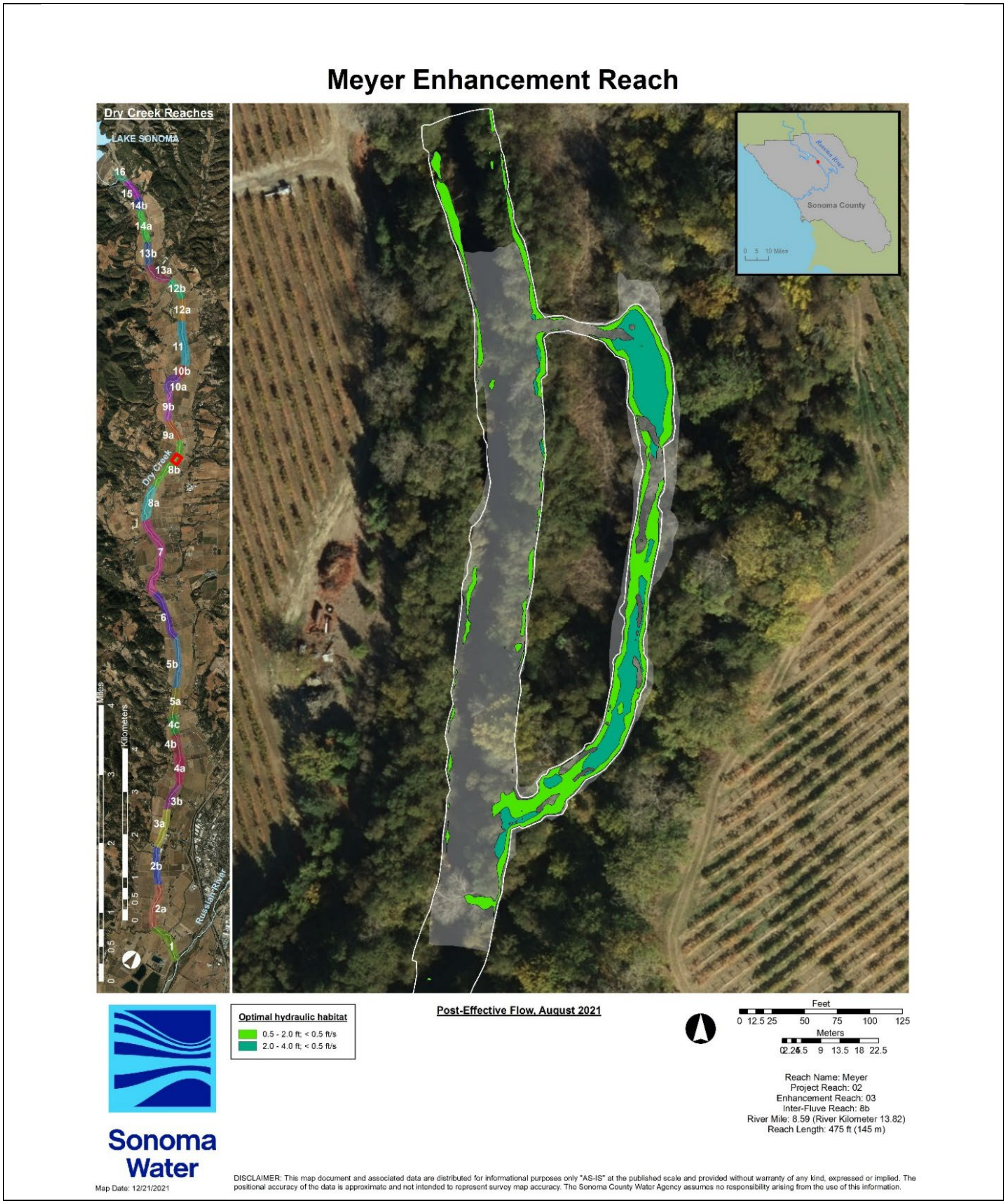

Figure 5.2.29. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Meyer enhancement reach, August 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.26. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Meyer enhancement reach, August 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	40	120
HU02	Flatwater	1	10	10
HU03	Pool	3	40	120
HU04	Riffle	2	15	30
HU05	Flatwater	2	15	30
HU06	Pool	3	40	120
HU07	Pool	3	95	285
HU08	Pool	3	95	285
HU09	Riffle	3	30	90
HU10	Flatwater	1	5	5
Pool: riffle	**5:2 (2.50)**			**Avg = 110**

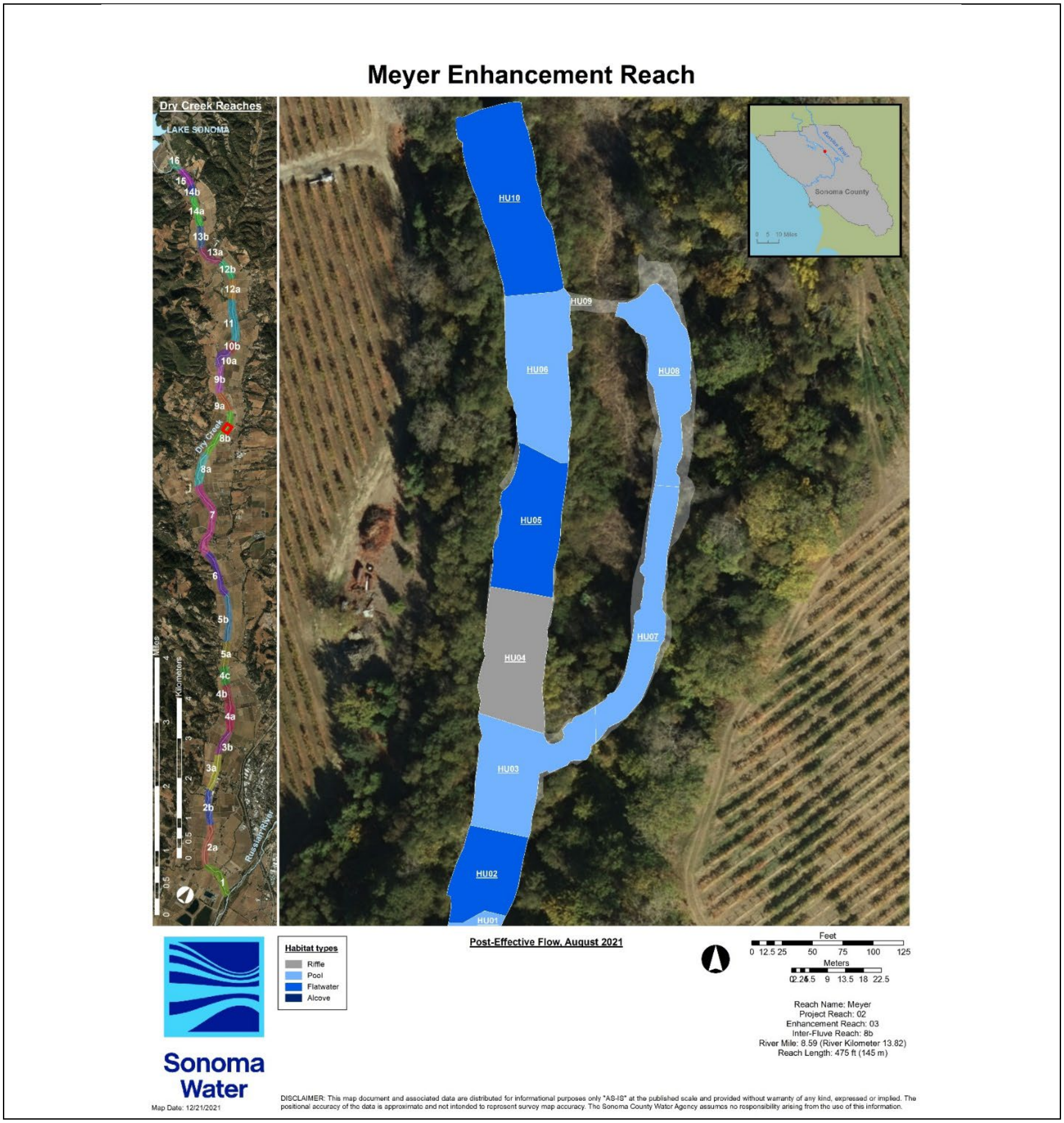

Figure 5.2.30. Habitat unit number and type within the Meyer enhancement reach, August 2021.

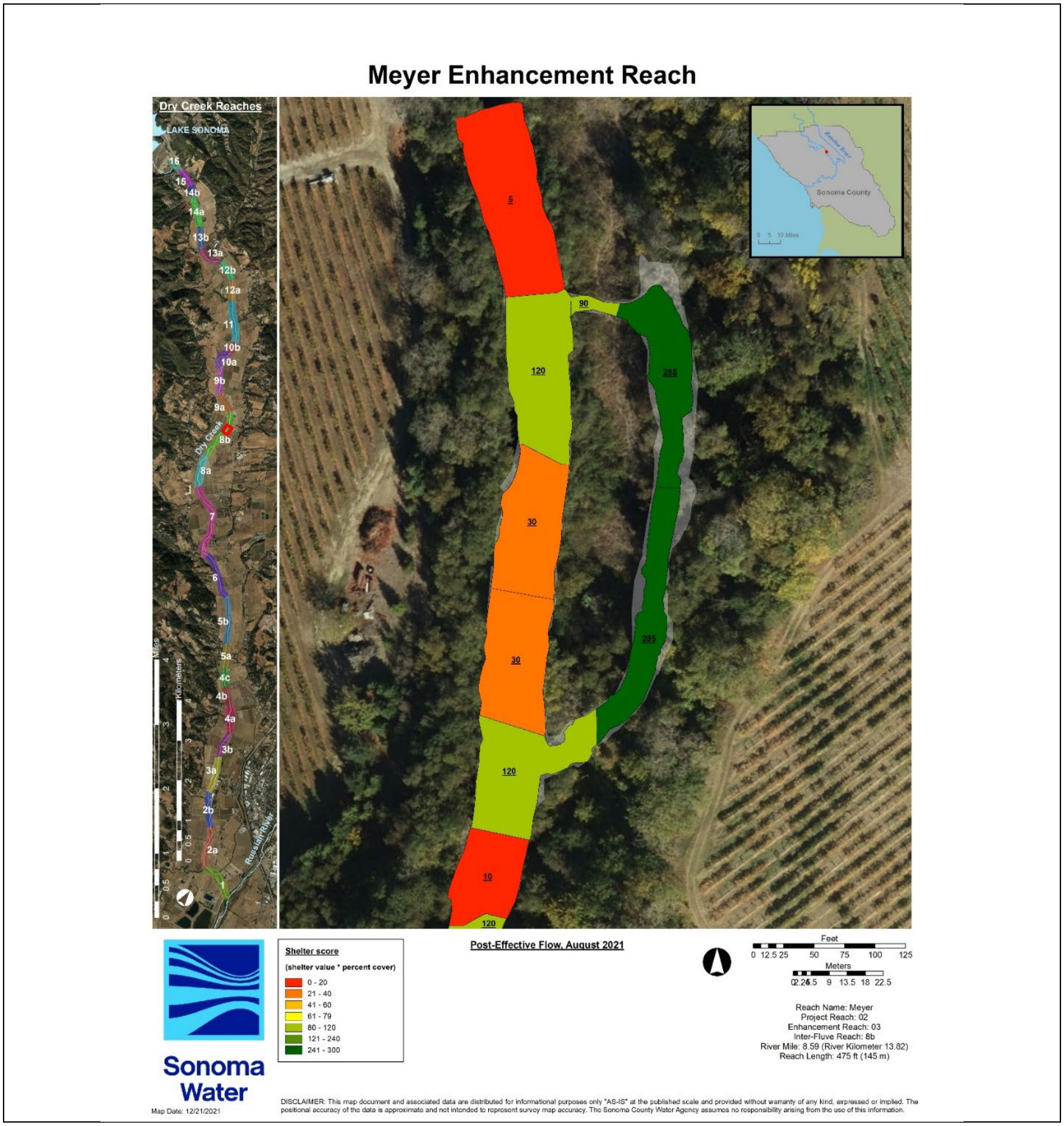

Figure 5.2.31. Habitat unit shelter scores within the Meyer enhancement reach, August 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.27. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Meyer enhancement reach, August 2021.

Site number	1	2	3	
Site type	**Main channel**	**Side channel**	**Side channel**	
Site average feature quantitative rating	0	13	13	
Site average feature qualitative rating[a]	Not rated	Excellent	Excellent	
Site average habitat unit quantitative rating	15	26	16	
Site average qualitative rating[b]	Fair	Good	Fair	
Site quantitative rating (sum of site average feature and habitat unit rating)	15	39	29	
Site qualitative rating	Fair[a]	Good[c]	Fair[c]	
Enhancement reach quantitative rating (average of site rating)[c]	28			
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 45; Excellent (>=36), Good (>=27), Fair (>=18), Poor (>=9), Fail (<9)

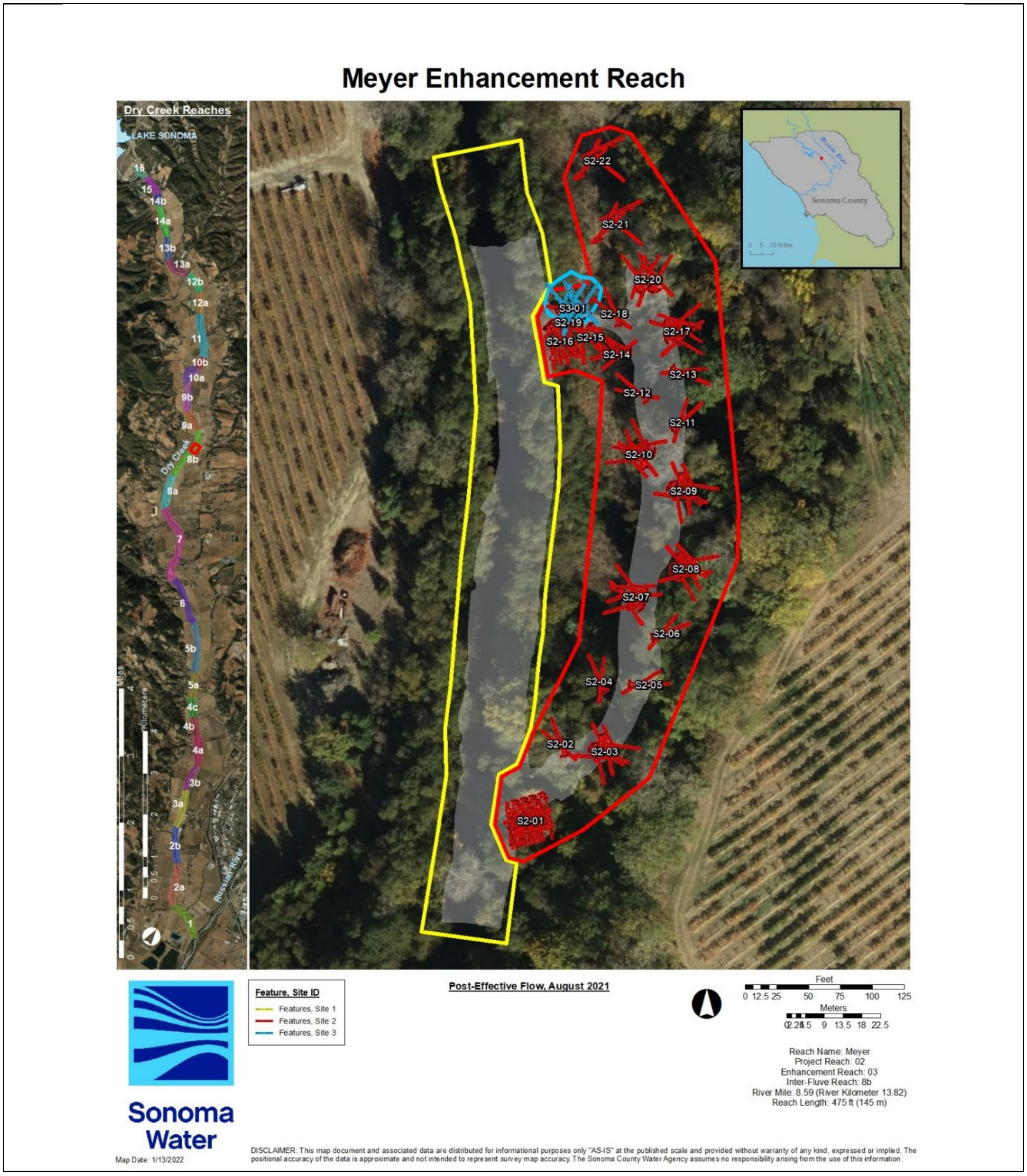

Figure 5.2.32. Enhancement sites and features within the Meyer enhancement reach, August 2021.

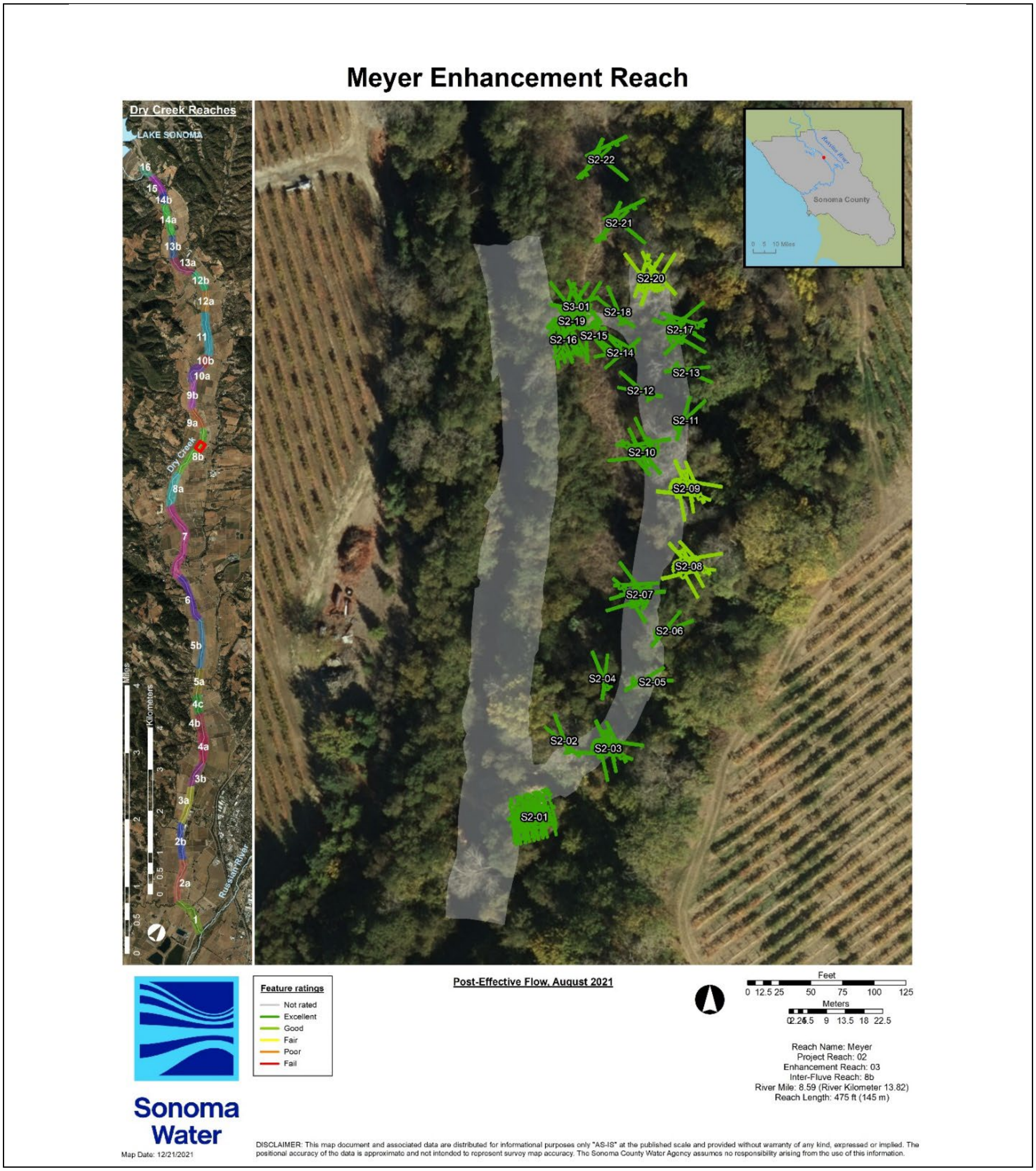

Figure 5.2.33. Feature ratings for the Meyer enhancement reach, August 2021.

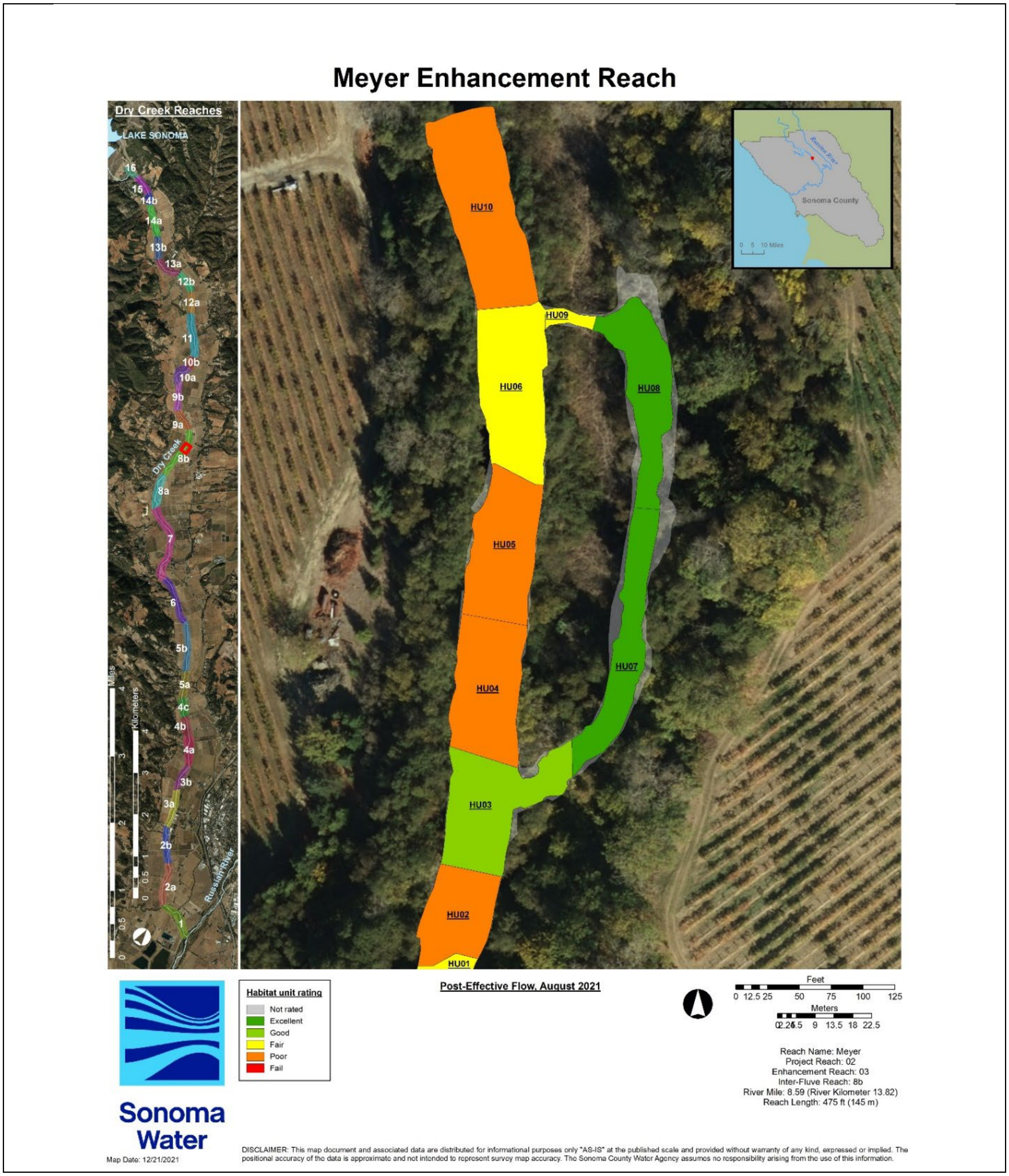

Figure 5.2.34. Habitat unit ratings for the Meyer enhancement reach, August 2021.

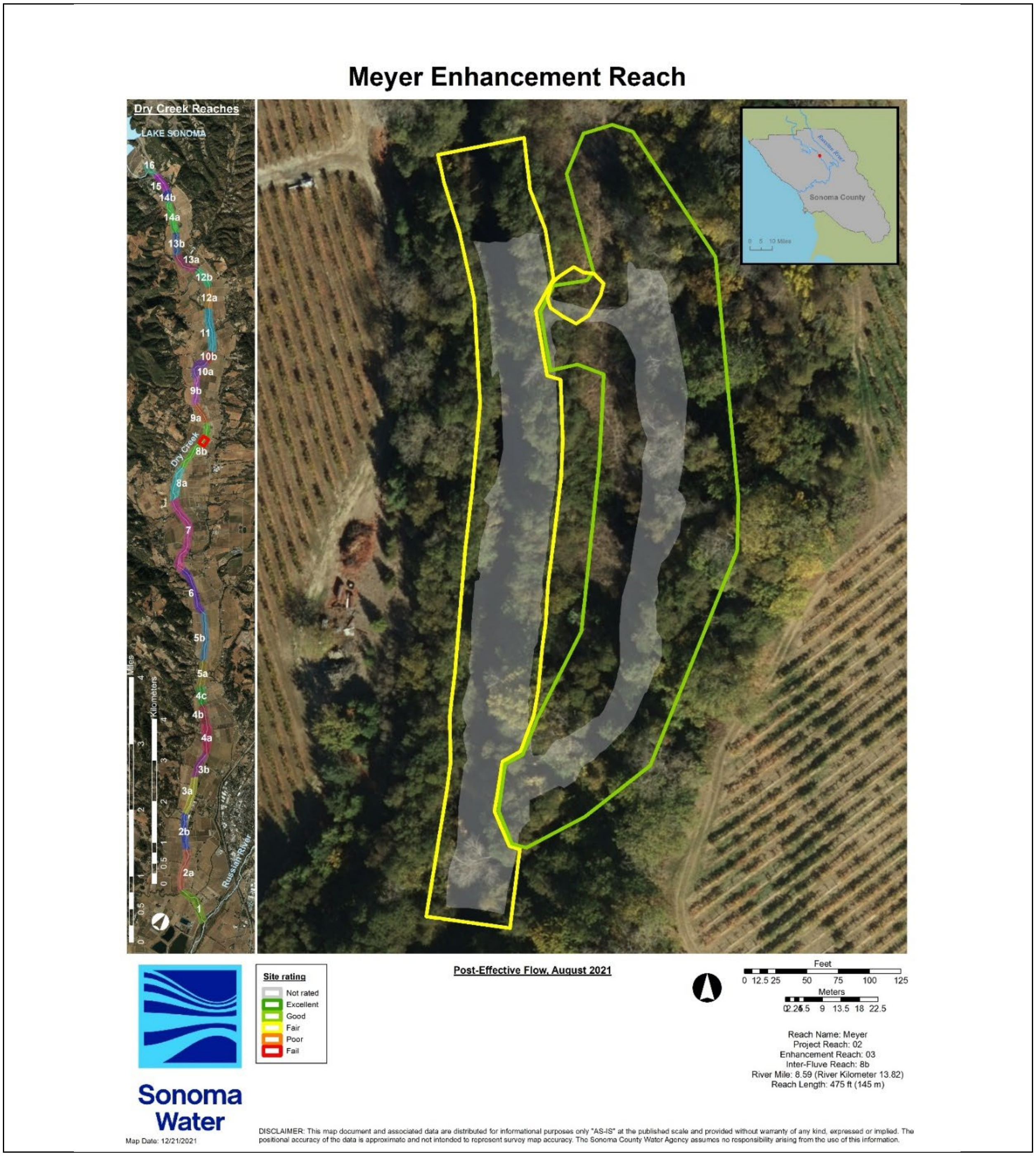

Figure 5.2.35. Post-effective flow site ratings for the Meyer enhancement reach, August 2021.

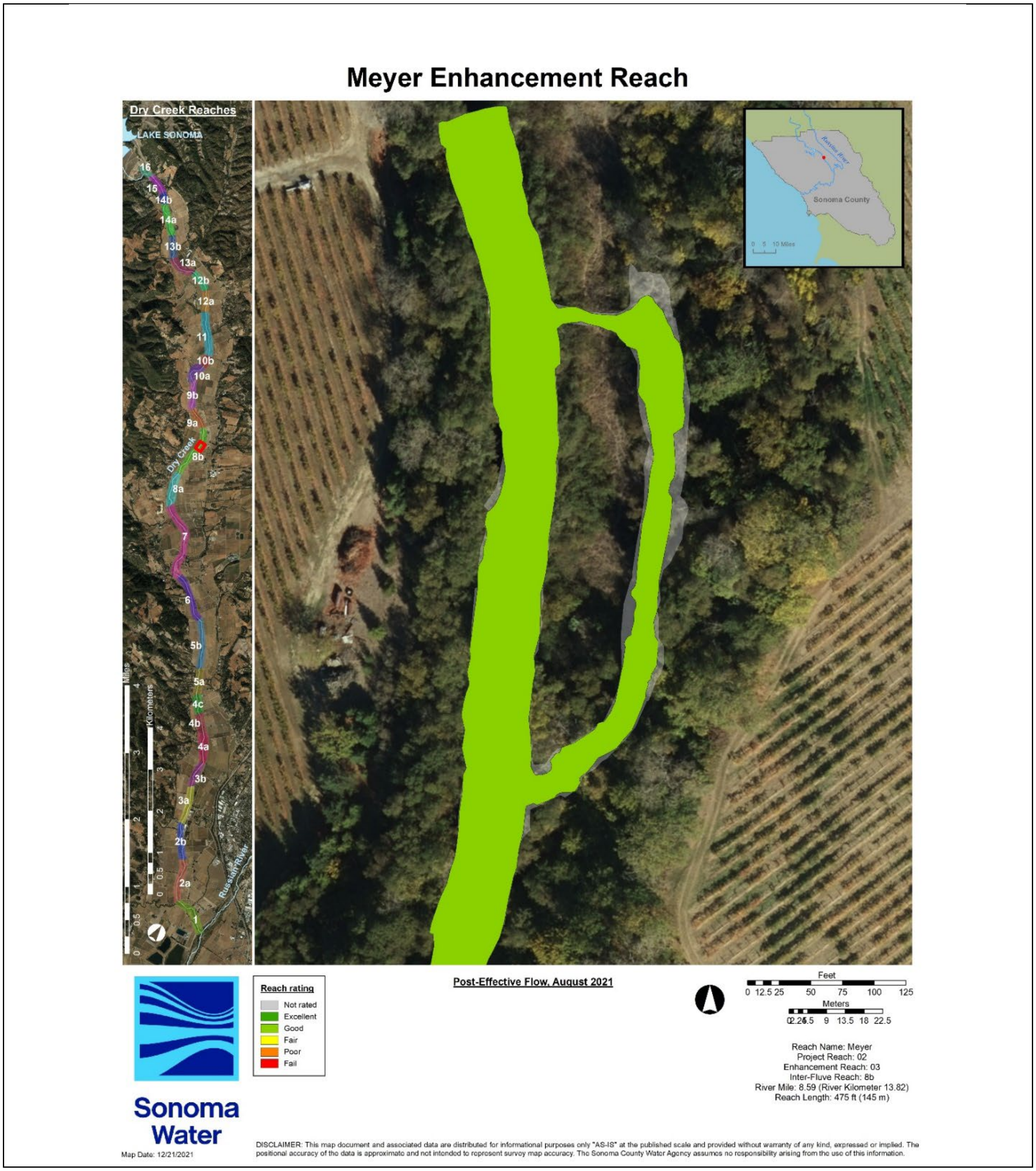

Figure 5.2.36. Post-effective flow reach rating for the Meyer enhancement reach, August 2021.

Carlson Lonestar Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Carlson Lonestar enhancement reach in August 2021. Previous effectiveness monitoring surveys occurred in May 2017 (pre-enhancement) and September 2017 (post-enhancement), September 2018 (post-effective flow), and May 2021 (spring flow0; see Spring Flow section below for results) (Table 5.2.28).

Table 5.2.28. Carlson Lonestar enhancement reach effectiveness monitoring surveys and ratings.

Year	Pre-enhancement	Post-enhancement	Post-effective Flow	Post-repair	Spring flow
2017	Poor	Good	--	--	--
2018	--	--	Good	--	--
2019	--	--	--	--	--
2020	--	--	--	--	--
2021	--	--	Good	--	Excellent

The 2021 monitored area encompassed 47,368 ft^2 within main and side channel areas with 29% of the total meeting optimal depth and velocity criteria. Crews monitored 10,125 ft^2 of side channel area, of which 68% met optimal depth and velocity criteria, compared with 18% for the main channel (Table 5.2.29, Figure 5.2.37). Fourteen habitat units made up the enhancement reach post-effective flow, with a pool to riffle ratio of 6:1 (6.00) and an average shelter score of 204 (Table 5.2.30, Figure 5.2.38, Figure 5.2.39. Twelve habitat units met or exceeded the optimal shelter value of 80. The enhancement reach comprised three enhancement sites (one main channel, two side channels) that all received excellent site average feature ratings and fair to excellent site average habitat unit ratings (Table 5.2.31, Figure 5.2.40, Figure 5.2.41, Figure 5.2.42). Enhancement sites received good to excellent qualitative ratings (Table 5.2.31, Figure 5.2.43). Overall, the Carlson Lonestar enhancement reach received a good enhancement reach rating (Table 5.2.31, Figure 5.2.44) (See Appendix 5.2 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.29. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Carlson Lonestar enhancement reach, August 2021.

Carlson Lonestar, Post-effective flow, August 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	37,354	25,850	5,077	30,927	10,547	4,393	2,507	6,900
Side channel area	10,014	5,392	2,492	7,884	9,027	4,472	2,467	6,938
Total area	**47,368**	**31,241**	**7,569**	**38,811**	**19,574**	**8,865**	**4,974**	**13,838**
Main channel % of wetted area	79%	69%	14%	83%	28%	12%	7%	18%
Side channel % of wetted area	21%	54%	25%	79%	90%	45%	25%	69%
Total % of wetted area	**100%**	**66%**	**16%**	**82%**	**41%**	**19%**	**11%**	**29%**

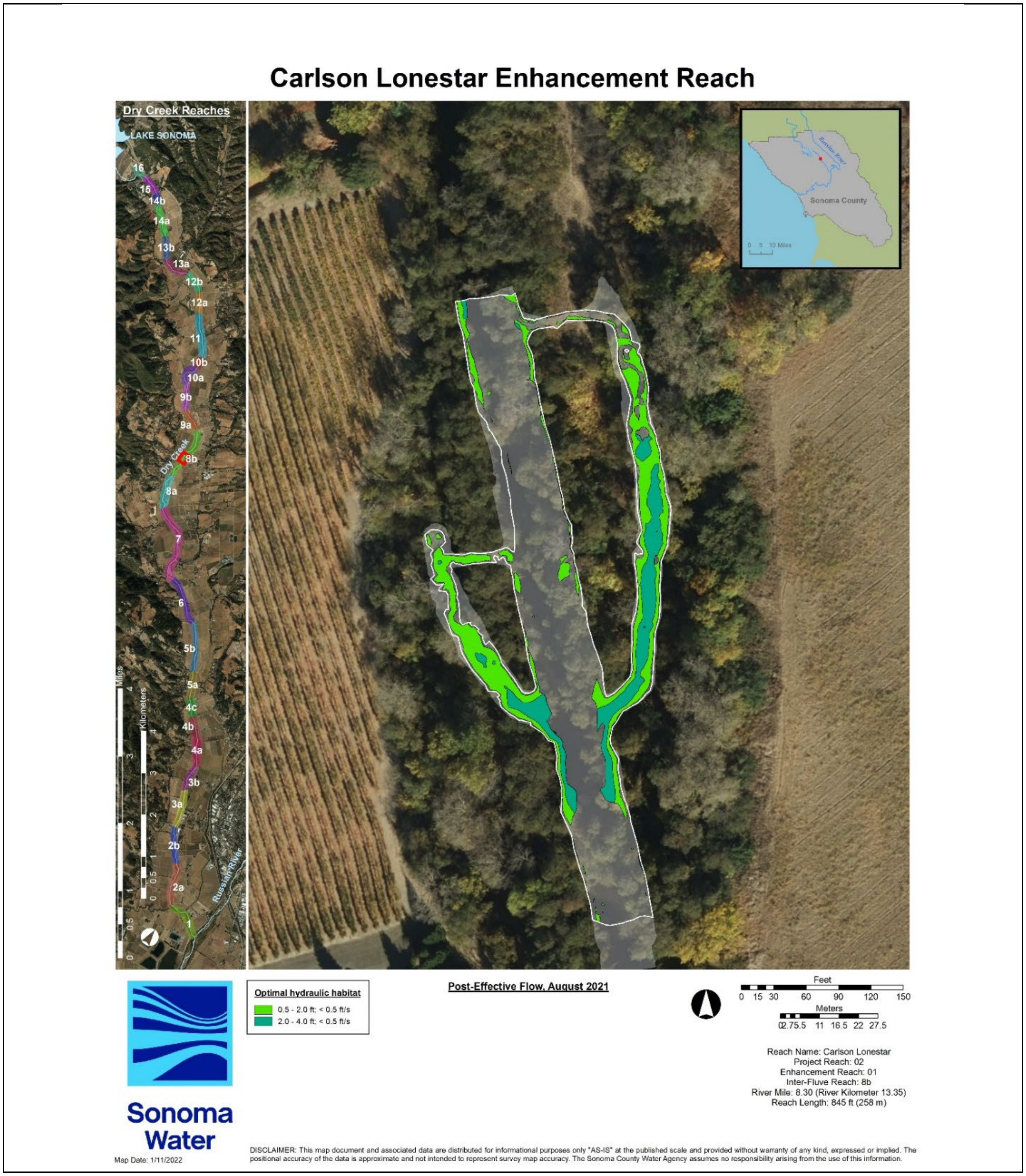

Figure 5.2.37. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Carlson Lonestar enhancement reach, August 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.30. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Carlson Lonestar enhancement reach, August 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Riffle	2	25	50
HU02	Pool	3	55	165
HU03	Flatwater	3	20	60
HU04	Pool	3	50	150
HU05	Flatwater	3	80	240
HU06	Pool	3	80	240
HU07	Alcove	3	100	300
HU08	Flatwater	3	70	210
HU09	Pool	3	85	255
HU10	Flatwater	3	90	270
HU11	Pool	3	80	240
HU12	Flatwater	3	75	225
HU13	Pool	3	80	240
HU14	Flatwater	3	70	210
Pool: riffle	**6:1 (6.00)**			**Avg = 204**

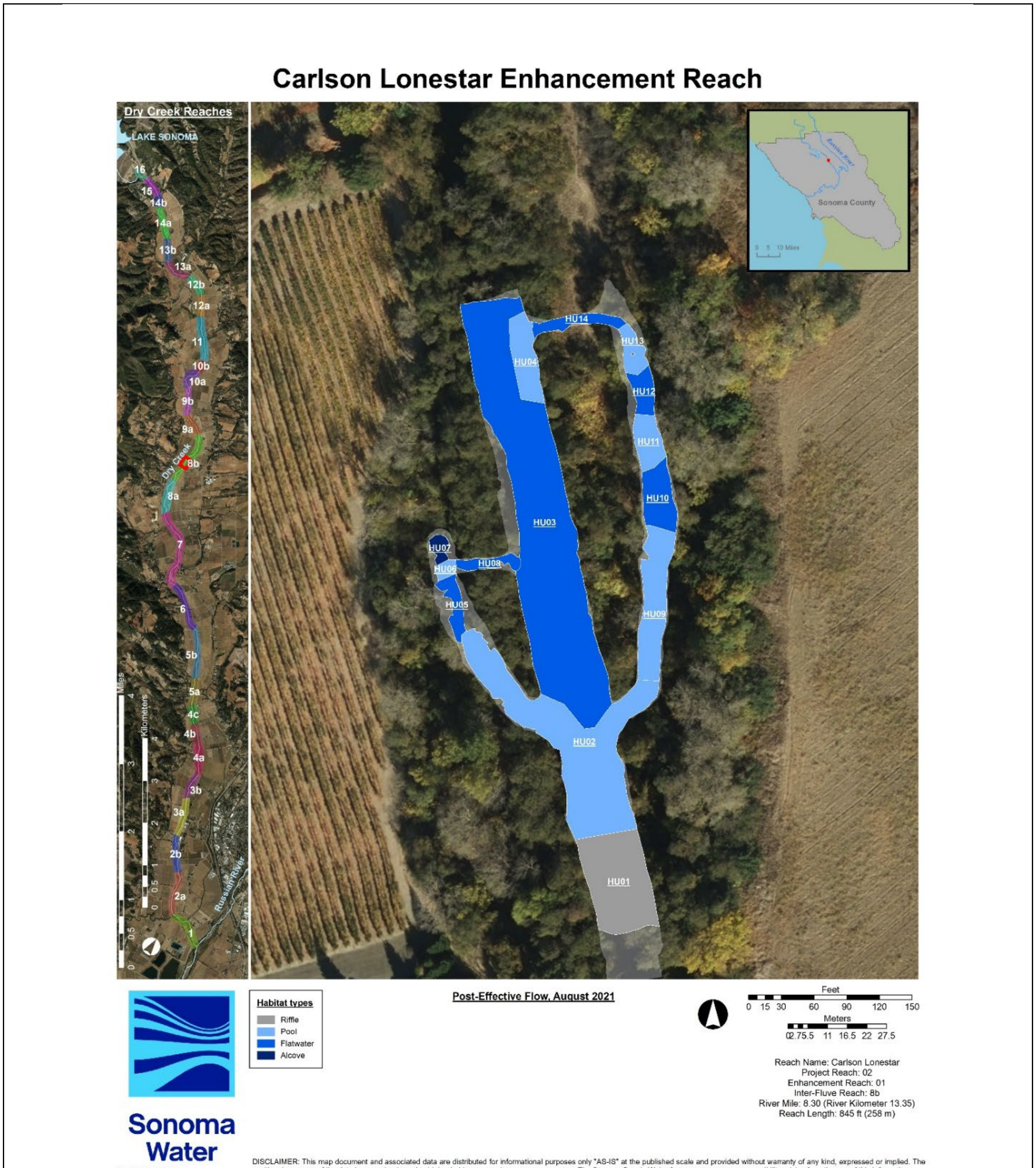

Figure 5.2.38. Habitat unit number and type within the Carlson Lonestar enhancement reach, August 2021.

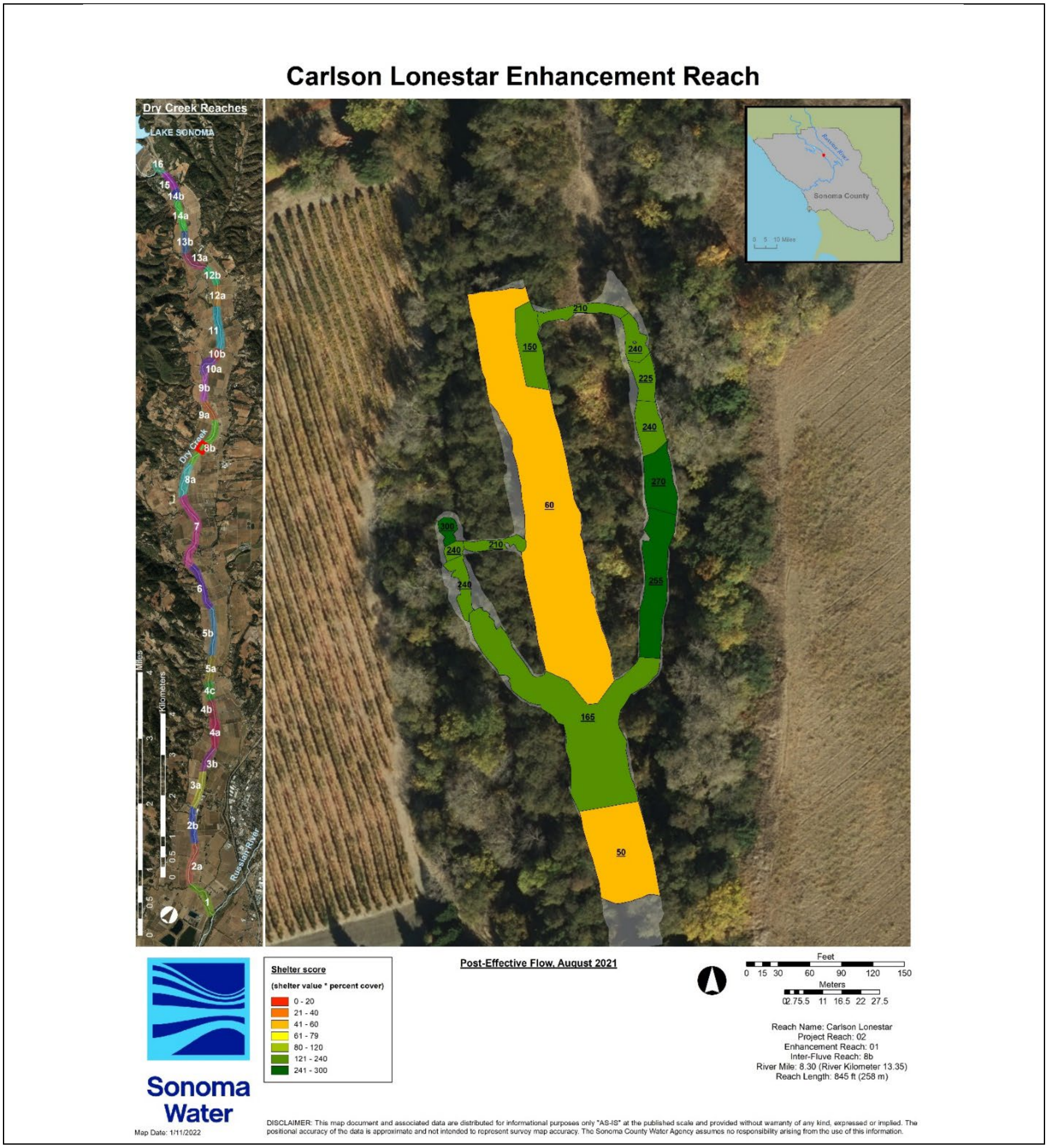

Figure 5.2.39. Habitat unit shelter scores within the Carlson Lonestar enhancement reach, August 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.31. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Carlson Lonestar enhancement reach, August 2021.

Site number	1	2	3	
Site type	Main channel	Side channel	Side channel	
Site average feature quantitative rating[a]	13	13	13	
Site average feature qualitative rating[a]	Excellent	Excellent	Excellent	
Site average habitat unit quantitative rating[b]	19	29	26	
Site average qualitative rating[b]	Fair	Excellent	Good	
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	32	42	39	
Site qualitative rating[c]	Good	Excellent	Good	
Enhancement reach quantitative rating (average of site rating)[c]	38			
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)

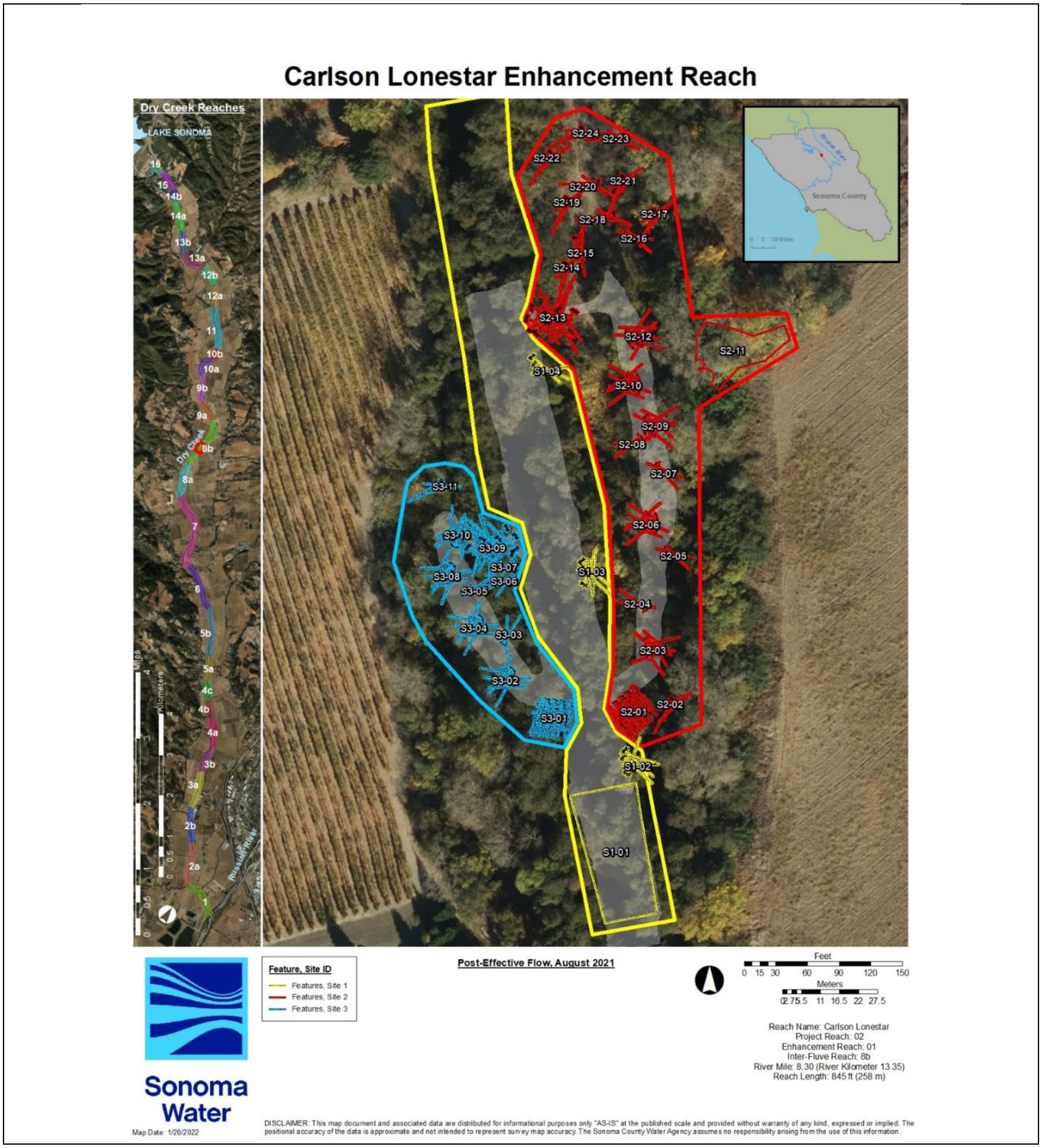

Figure 5.2.40. Enhancement sites and features within the Carlson Lonestar enhancement reach, August 2021.

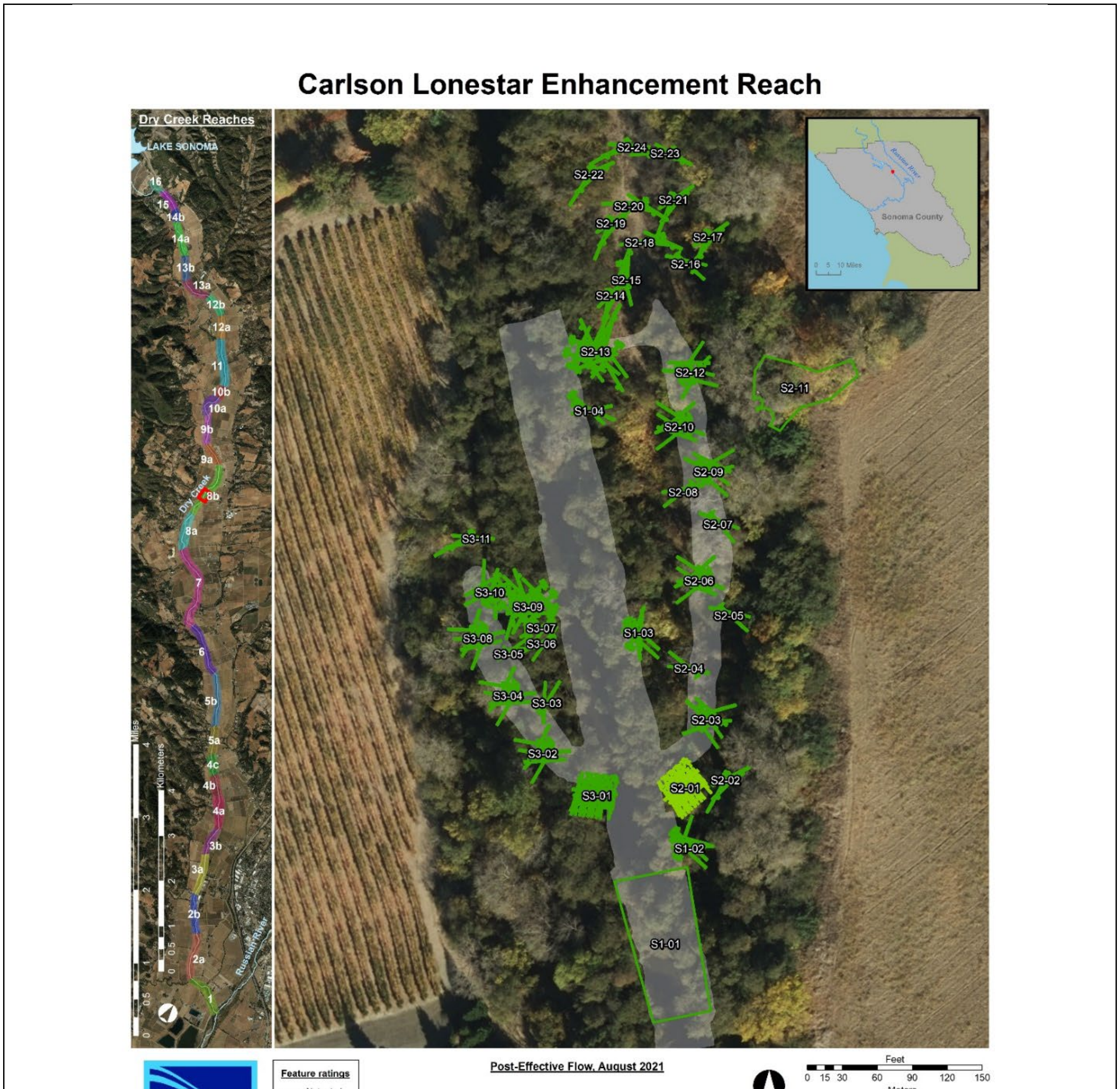

Figure 5.2.41. Feature ratings for the Carlson Lonestar enhancement reach, August 2021.

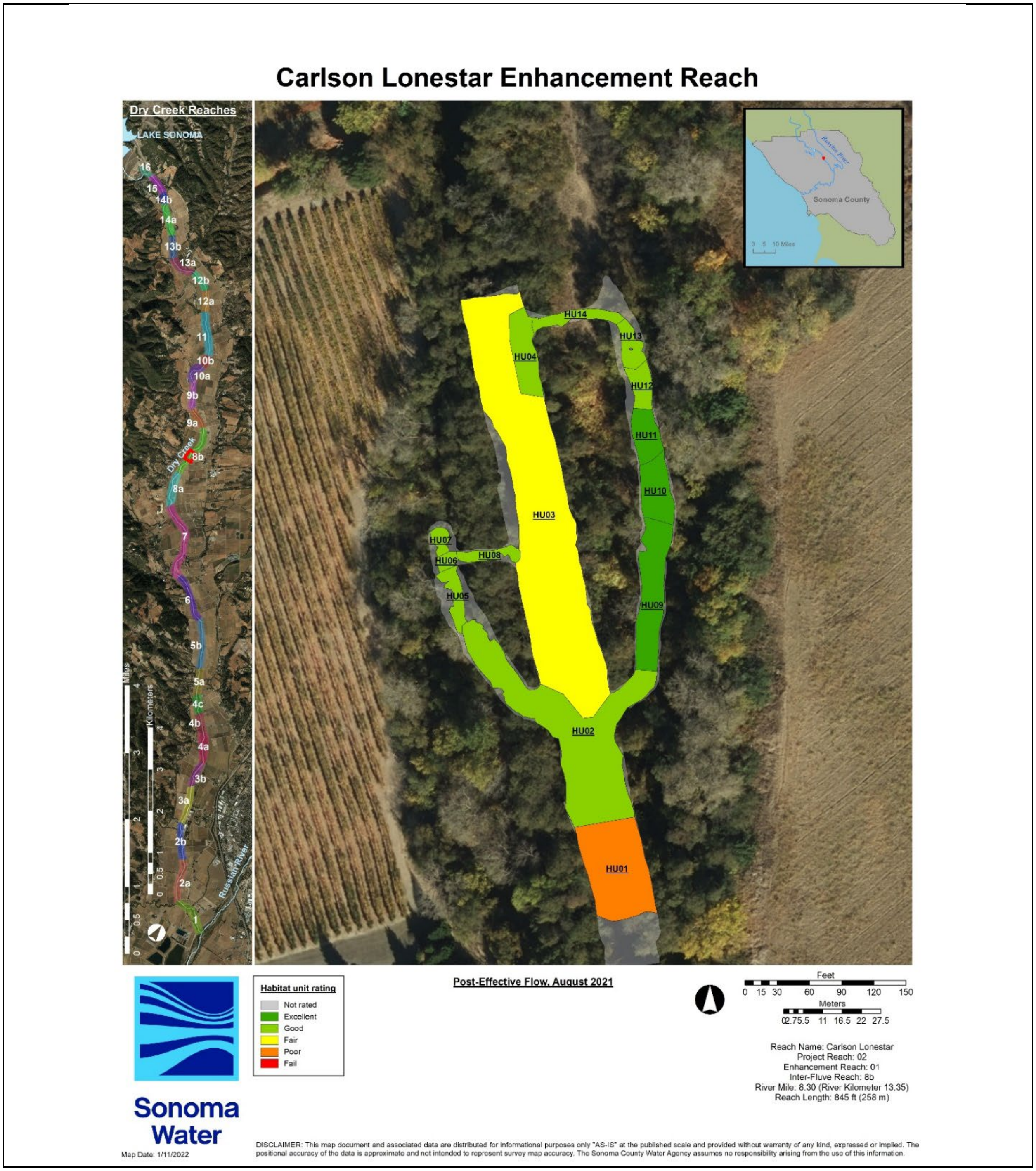

Figure 5.2.42. Habitat unit ratings for the Carlson Lonestar enhancement reach, August 2021.

Figure 5.2.43. Post-effective flow site ratings for the Carlson Lonestar enhancement reach, August 2021.

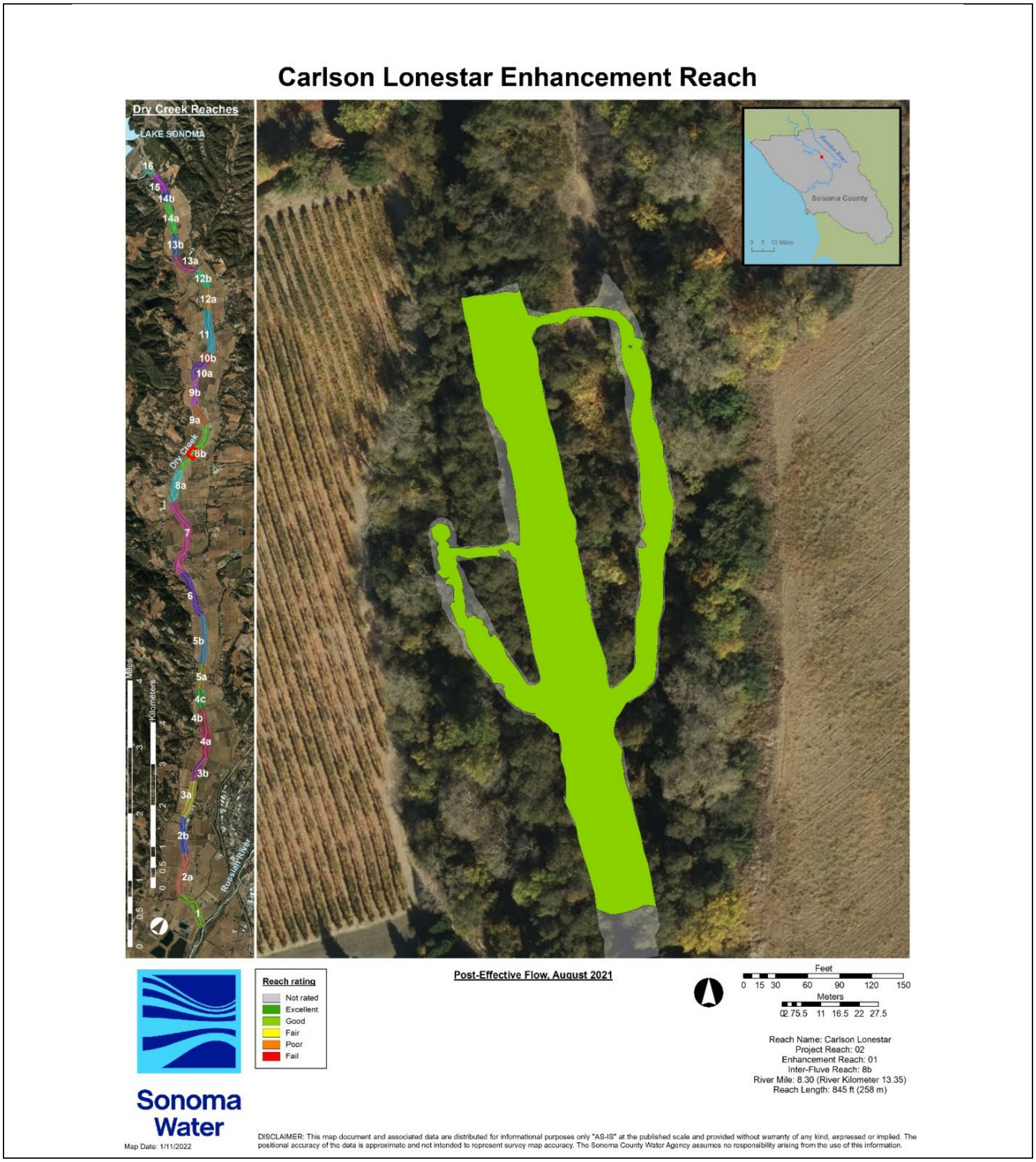

Figure 5.2.44. Post-effective flow reach rating for the Carlson Lonestar enhancement reach, August 2021.

Farrow Wallace Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Farrow Wallace enhancement reach in June 2021. Previous effectiveness monitoring surveys occurred (all post-effective flow) in August 2015, August 2017, November 2019, and July 2020 (Table 5.2.32).

Table 5.2.32. Farrow Wallace enhancement reach effectiveness monitoring surveys and ratings.

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2015	--	--	Good	--	--
2016	--	--	--	--	--
2017	--	--	Fair	--	--
2018	--	--	--	--	--
2019	--	--	Good	--	--
2020	--	--	Good	--	--
2021	--	--	Good	--	--

The 2021 monitored area encompassed 80,286 ft^2 within main and side channel areas of Dry Creek with 33% of the total area meeting optimal depth and velocity criteria (Table 5.2.33, Figure 5.2.45). The monitoring characterized 12,992 ft^2 of main channel alcove area and 15,505 ft^2 of side channel area, of which 73% and 52% met optimal depth and velocity criteria, compared with 51,789 ft^2 and 18% for the main channel area. Fifteen habitat units composed the enhancement reach, with a pool to riffle ratio of 6:5 (1.20) and average shelter score of 144 (Table 5.2.34, Figure 5.2.46, Figure 5.2.47). 11 habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised seven enhancement sites (four main channel sites, one alcove, one side channel, one bank site; Table 5.2.35, Figure 5.2.48), with good to excellent site average feature ratings (we did not rate enhancement site 2 as it contained no features), and fair to excellent average habitat unit ratings (we did not rate site 4 as it contained no aquatic habitat; Table 5.2.35, Figure 5.2.49, Figure 5.2.50). Enhancement sites received fair to excellent ratings (Table 5.2.35, Figure 5.2.51). Overall, the Farrow Wallace enhancement reach received a good effectiveness monitoring rating (Table 5.2.35, Figure 5.2.52; see Appendix 5.2 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 Farrow Wallace enhancement reach, June 2021.

Farrow Wallace, Post-effective flow, June 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	51,789	25,291	17,127	42,418	13,151	4,715	4,360	9,074
Main channel alcove area	12,992	6,010	4,139	10,149	12,302	5,497	3,977	9,474
Side channel area	15,505	6,033	5,996	12,028	10,563	4,240	3,815	8,055
Total area	**80,286**	**37,334**	**27,261**	**64,595**	**36,016**	**14,452**	**12,151**	**26,604**
Main channel % of wetted area	65%	49%	33%	82%	25%	9%	8%	18%
Main channel alcove % of wetted area	16%	46%	32%	78%	95%	42%	31%	73%
Side channel % of wetted area	19%	39%	39%	78%	68%	27%	25%	52%
Total % of wetted area	**100%**	**47%**	**34%**	**80%**	**45%**	**18%**	**15%**	**33%**

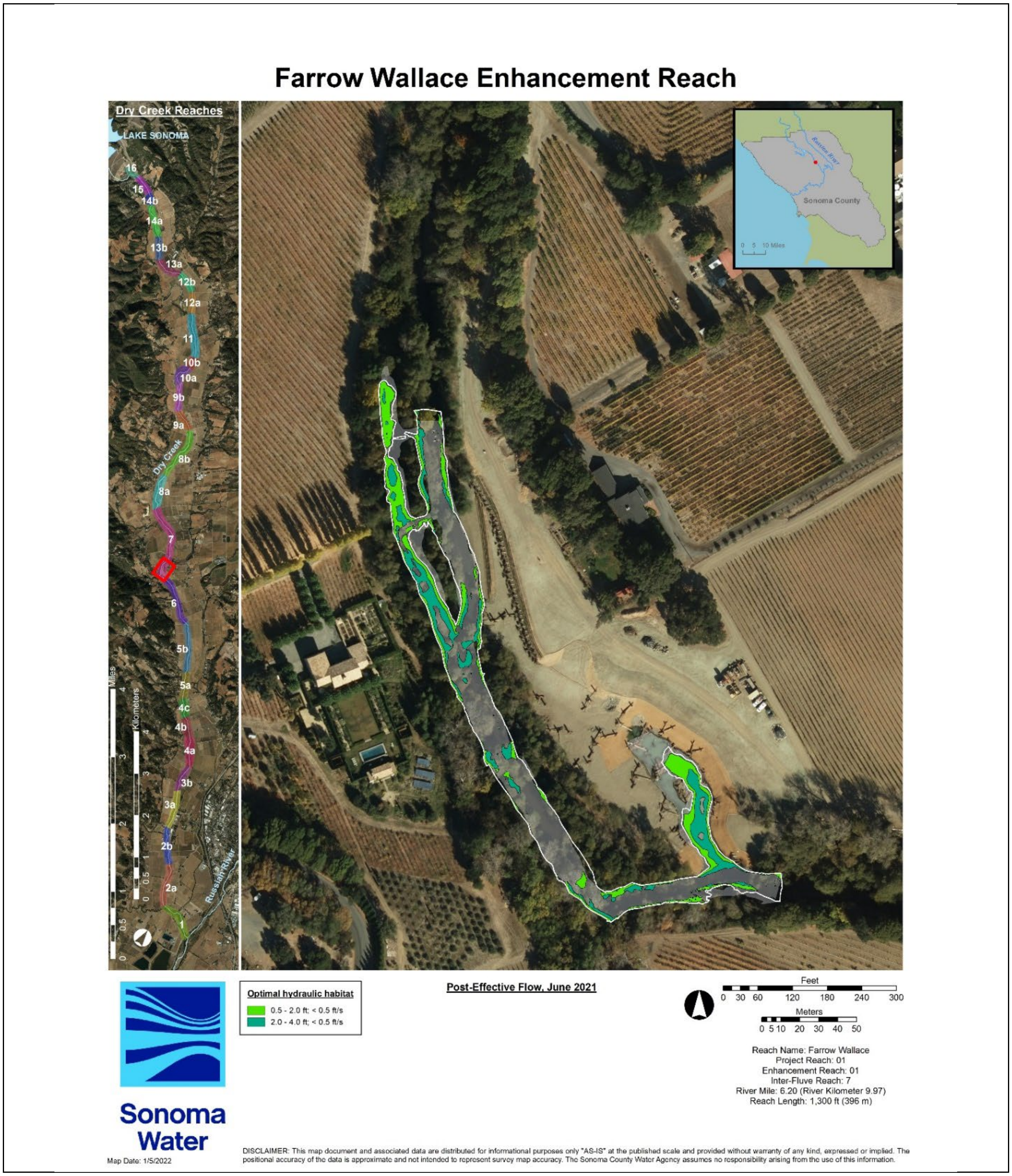

Figure 5.2.45. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Farrow Wallace enhancement reach, June 2021.

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 Farrow Wallace enhancement reach, June 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	40	120
HU02	Riffle	3	50	150
HU03	Pool	3	45	135
HU04	Riffle	2	10	20
HU05	Flatwater	2	15	30
HU06	Pool	2	20	40
HU07	Riffle	3	50	150
HU08	Pool	3	55	165
HU09	Riffle	2	40	80
HU10	Pool	2	30	60
HU11	Alcove	3	100	300
HU12	Pool	3	60	180
HU13	Riffle	3	65	195
HU14	Alcove	3	80	240
HU15	Alcove	3	100	300
Pool: riffle	**6:5 (1.20)**			**Avg = 144**

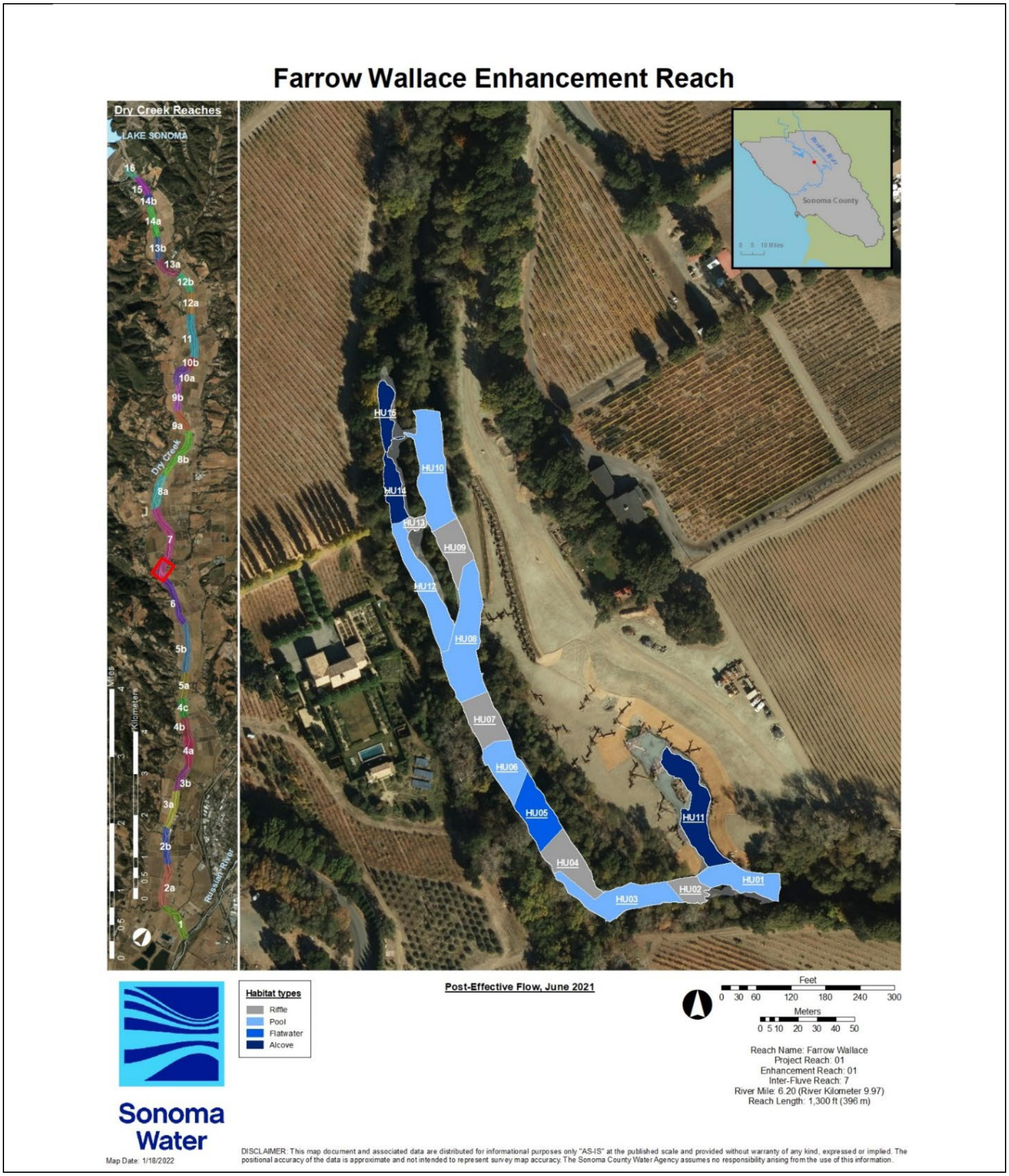

Figure 5.2.46. Habitat unit number and type within the Farrow Wallace enhancement reach, June 2021.

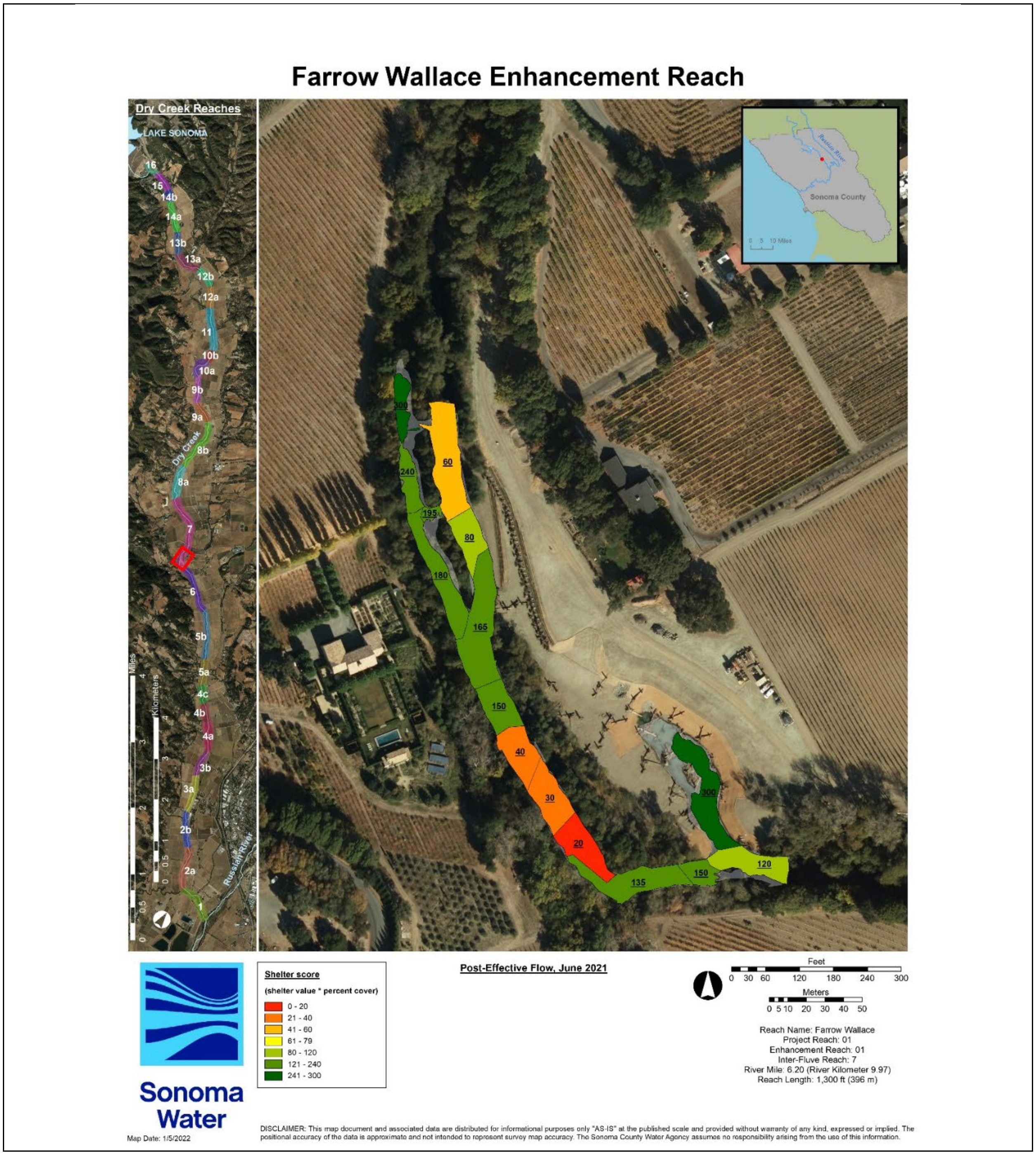

Figure 5.2.47. Habitat unit shelter scores within the Farrow Wallace enhancement reach, June 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.35. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Farrow Wallace enhancement reach, June 2021.

Site number	1	2	3	4	5	6	7
Site type	Alcove	Main chan	Main chan	Bank	Main chan	Side chan	Main chan
Site average feature quantitative rating[a]	12	0	13	13	13	12	13
Site average feature qualitative rating[a]	Excellent	Not rated	Excellent	Excellent	Excellent	Good	Excellent
Site average habitat unit quantitative rating[b]	26	15	20	0	20	28	17
Site average qualitative rating[b]	Good	Fair	Fair	Not rated	Fair	Excellent	Fair
Site quantitative rating (sum of site average feature and habitat unit rating)	38[c]	15[b]	33[c]	13[a]	33[b]	40[b]	30[b]
Site qualitative rating	Good[c]	Fair[b]	Good[c]	Excellent[a]	Good[c]	Excellent[c]	Good[c]
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 43; Excellent (>=34), Good (>=26), Fair (>=17), Poor (>=9), Fail (<9)

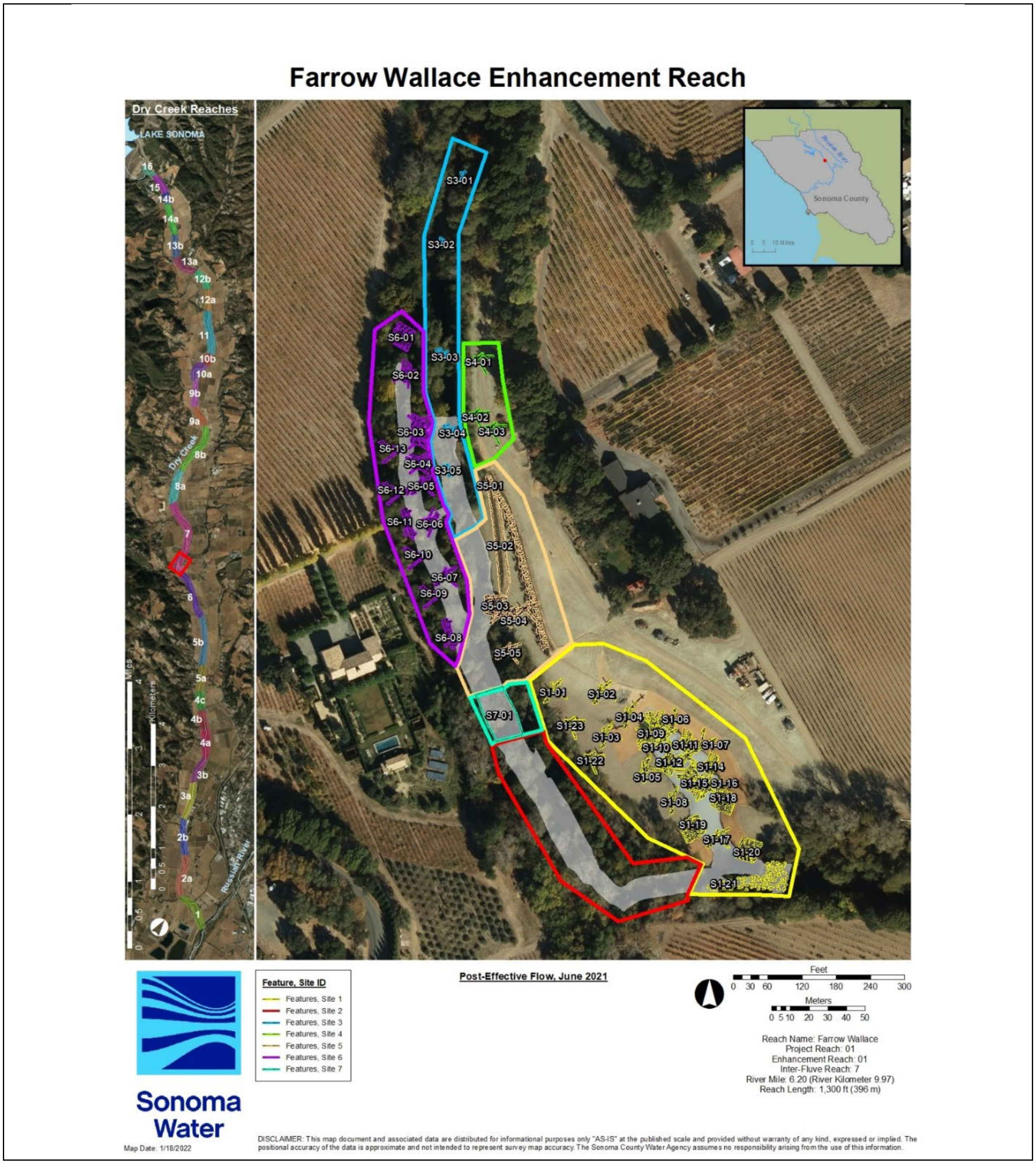

Figure 5.2.48. Enhancement sites and features within the Farrow Wallace enhancement reach, June 2021.

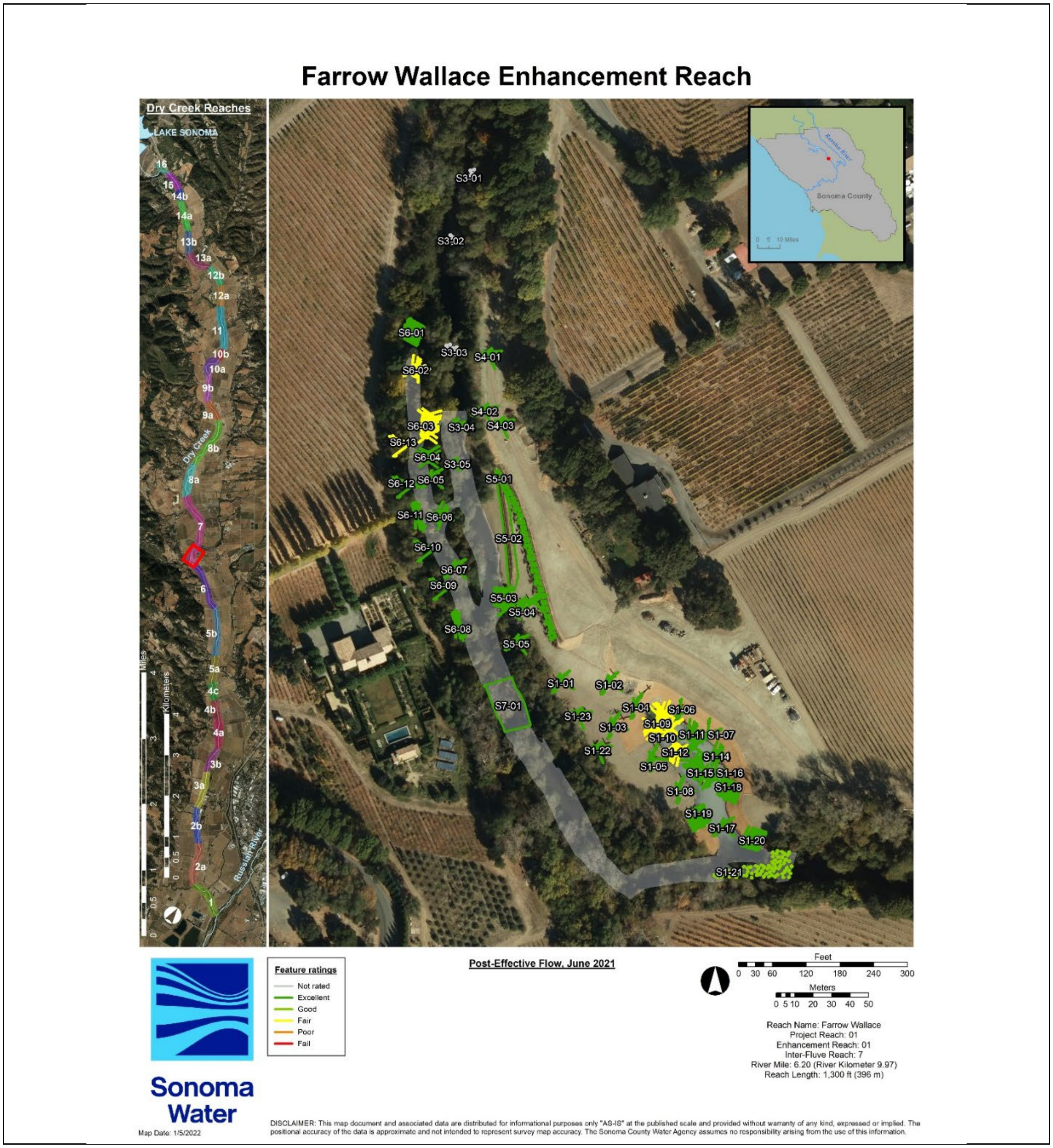

Figure 5.2.49. Feature ratings for the Farrow Wallace enhancement reach, June 2021.

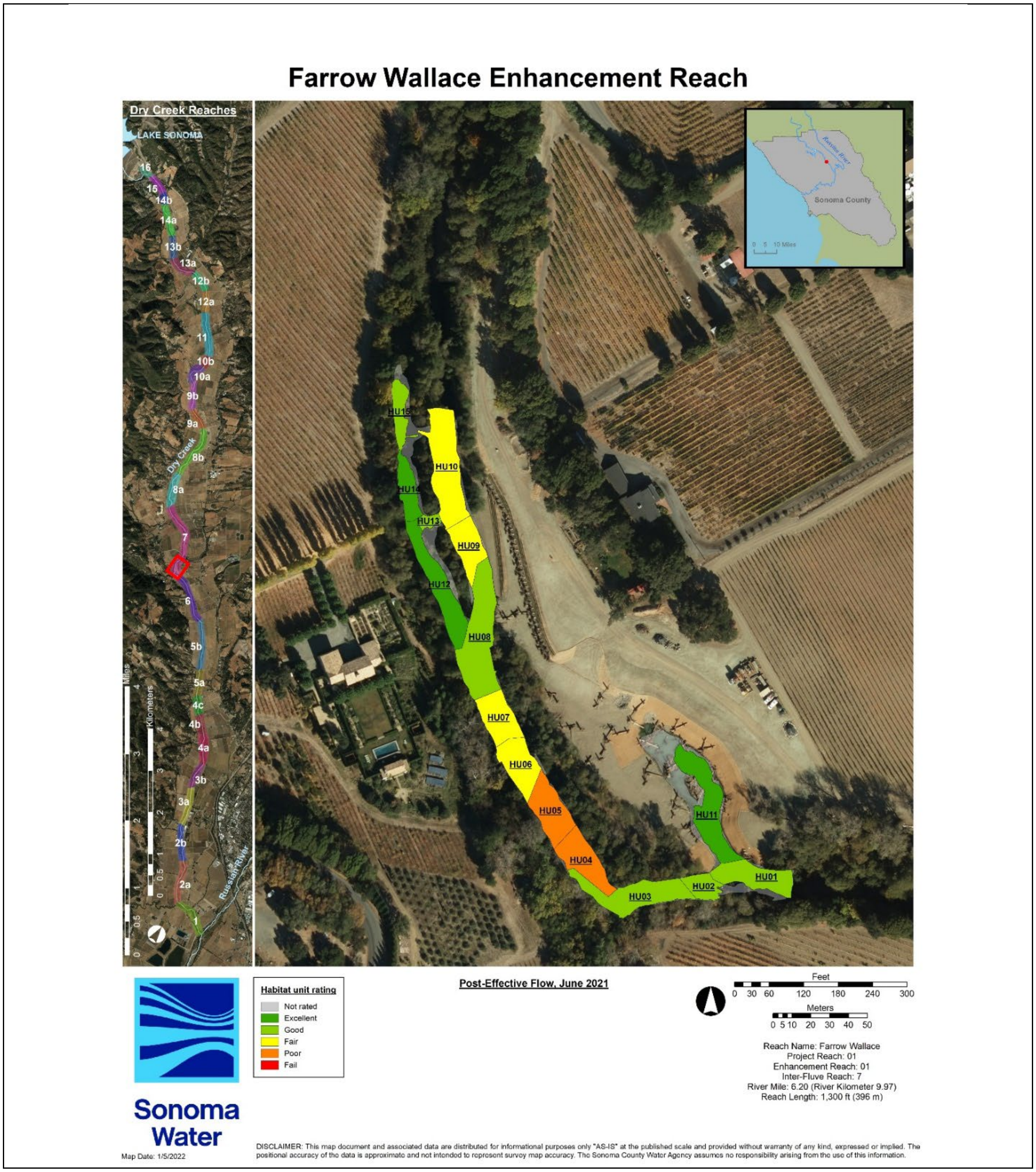

Figure 5.2.50. Habitat unit ratings for the Farrow Wallace enhancement reach, June 2021.

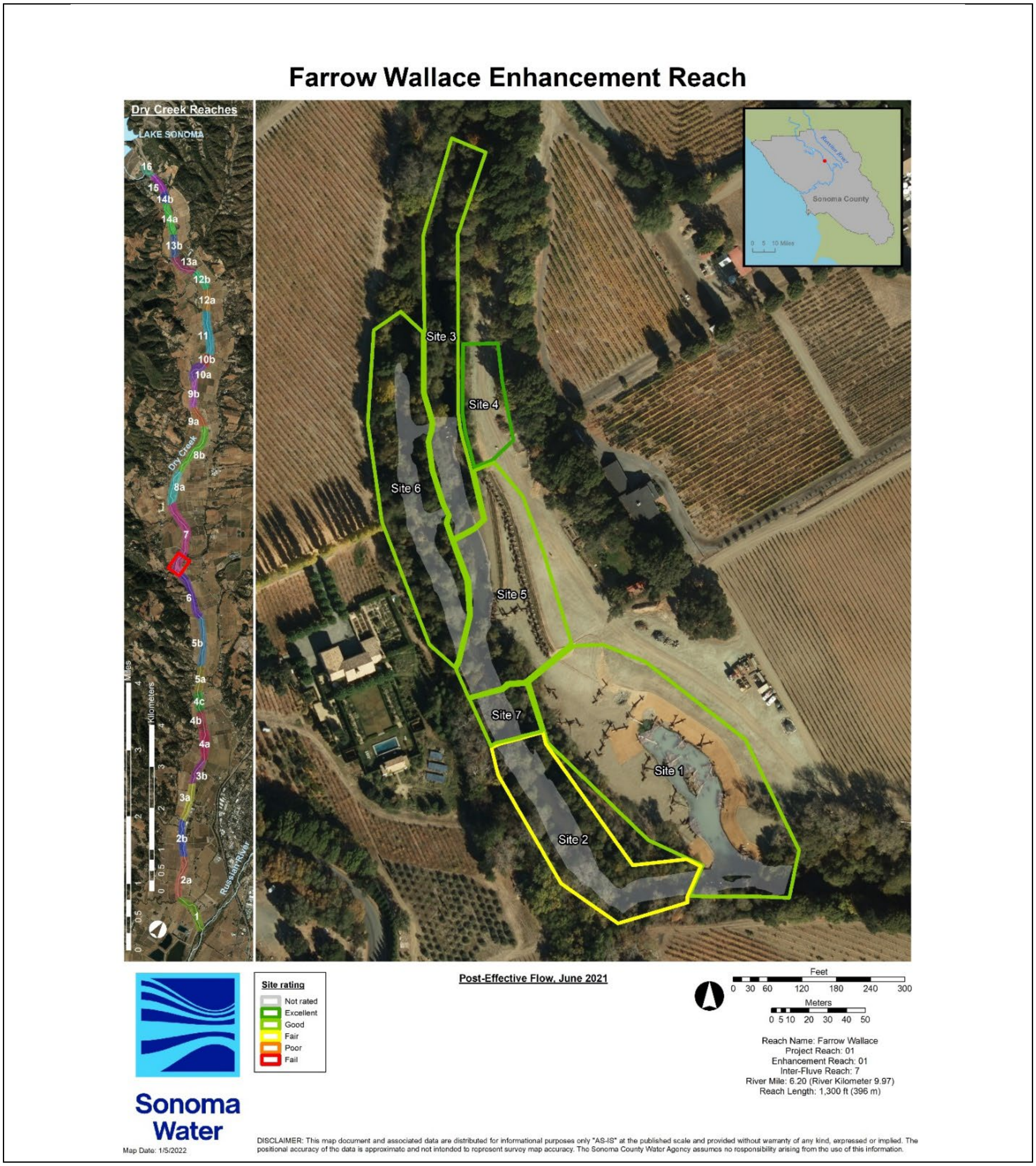

Figure 5.2.51. Post-effective flow site ratings for the Farrow Wallace enhancement reach, June 2021.

Figure 5.2.52. Post-effective flow reach rating for the Farrow Wallace enhancement reach, June 2021.

Geyser Peak Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Geyser Peak enhancement reach in July 2021. Sonoma Water originally constructed the Geyser Peak enhancement reach in October 2016. Aggradation caused by large storms in winter 2016/2017 reduced side channel area to 0 ft^2, leading to a fail effectiveness monitoring rating in July 2017 and repairs in summer 2017. Crews monitored again in October 2017 (post-repair) and July 2018 (post-effective flow). Similar to 2016/2017, aggradation caused by large storms in winter 2018/2019 reduced side channel area to 0 ft^2 in July 2019. Still, effectiveness monitoring from July 2019 and April 2020 (post-effective flow) resulted in fair ratings (Table 5.2.36).

Table 5.2.36. Geyser Peak enhancement reach effectiveness monitoring surveys and ratings.

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2016	Fair	Good	--	--	--
2017	--	--	Fail	Fair	--
2018	--	--	Fair	--	--
2019	--	--	Fair	--	--
2020	--	--	Fair	--	--
2021	--	--	Fair	--	--

In July 2021, the enhanced reach encompassed 31,833 ft^2, most occurring as main channel area (30,073 ft^2) with a small amount of side channel area (1,810 ft^2) as the side channel areas remain aggraded following 2018/2019 storms (Table 5.2.37, Figure 5.2.53). In 2021, 19% of total habitat area met optimal depth and velocity criteria, mainly along the channel margins in the mainstem (15% of total area) and within the outlet at the downstream end of the side channel (78%). 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 140 (Table 5.2.38, Figure 5.2.54, Figure 5.2.55). Eight 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 excellent site average feature ratings, and fail to excellent site average habitat unit ratings (Table 5.2.39, Figure 5.2.56, Figure 5.2.57,Figure 5.2.58). Site 4 (bank) included features installed above water surface elevation, but no aquatic habitat. As such, site 4 did not receive a site average habitat unit rating. Site 2 (side channel) completely aggraded from July 2018 to July 2019, burying nearly all features and aquatic habitat, leading to fail site average feature and site average habitat unit ratings. Enhancement site ratings ranged from fail (site 2) to poor (site 1) to good (site 4) to excellent (site 3) (Table 5.2.39, Figure 5.2.59). Overall, the Geyser Peak enhancement reach received a fair effectiveness monitoring score in July 2021 (Table 5.2.39, Figure 5.2.60; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.37. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Geyser Peak enhancement reach, July 2021.

Geyser Peak, Post-effective flow, July 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	30,073	20,060	4,455	24,515	8,016	3,843	766	4,609
Side channel area	1,810	1,024	472	1,496	1,723	942	472	1,414
Total area	**31,883**	**21,084**	**4,927**	**26,011**	**9,739**	**4,785**	**1,238**	**6,023**
Main channel % of wetted area	94%	67%	15%	82%	27%	13%	3%	15%
Side channel % of wetted area	6%	57%	26%	83%	95%	52%	26%	78%
Total % of wetted area	**100%**	**66%**	**15%**	**82%**	**31%**	**15%**	**4%**	**19%**

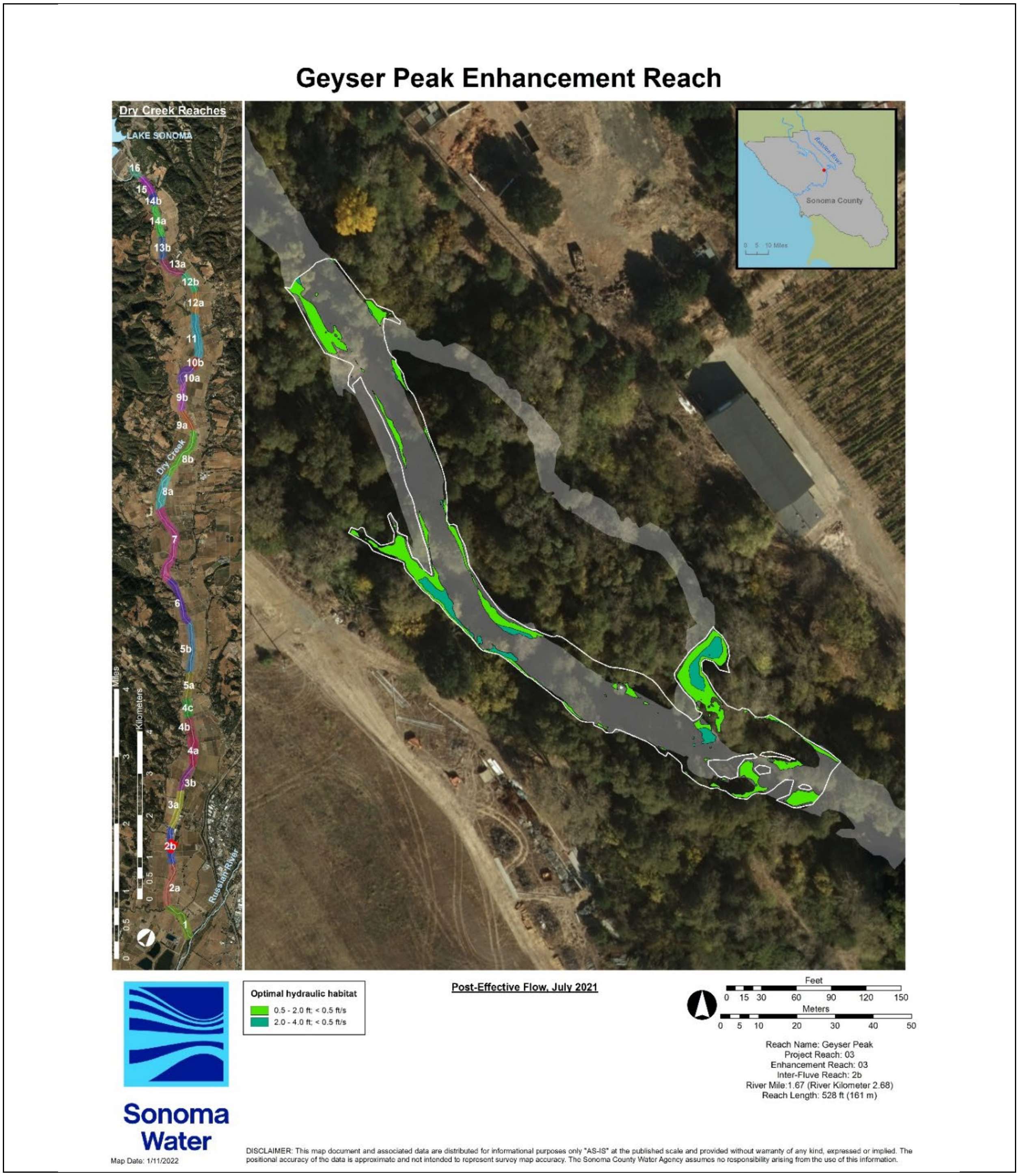

Figure 5.2.53. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Geyser Peak enhancement reach, July 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.38. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Geyser Peak enhancement reach, July 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	3	15	45
HU02	Pool	3	40	120
HU03	Riffle	3	50	150
HU04	Pool	3	60	180
HU05	Riffle	2	10	20
HU06	Pool	3	80	240
HU07	Alcove	3	90	270
HU08	Riffle	2	20	40
HU09	Pool	3	40	120
HU10	Alcove	3	60	180
HU11	Flatwater	2	15	30
HU12	Alcove	3	95	285
Pool: riffle	**4:3 (1.33)**			**Avg = 140**

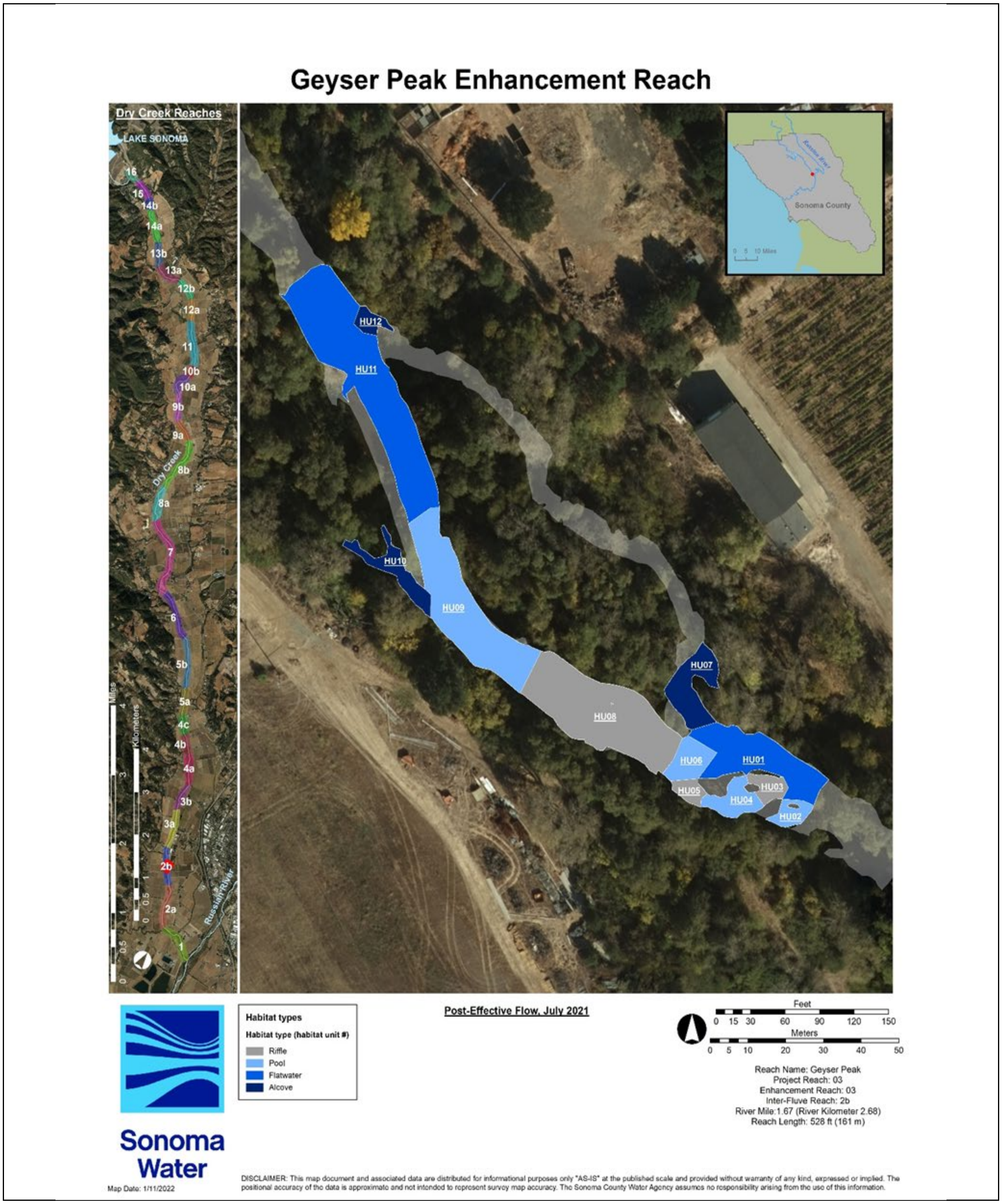

Figure 5.2.54. Habitat unit number and type within the Geyser Peak enhancement reach, July 2021.

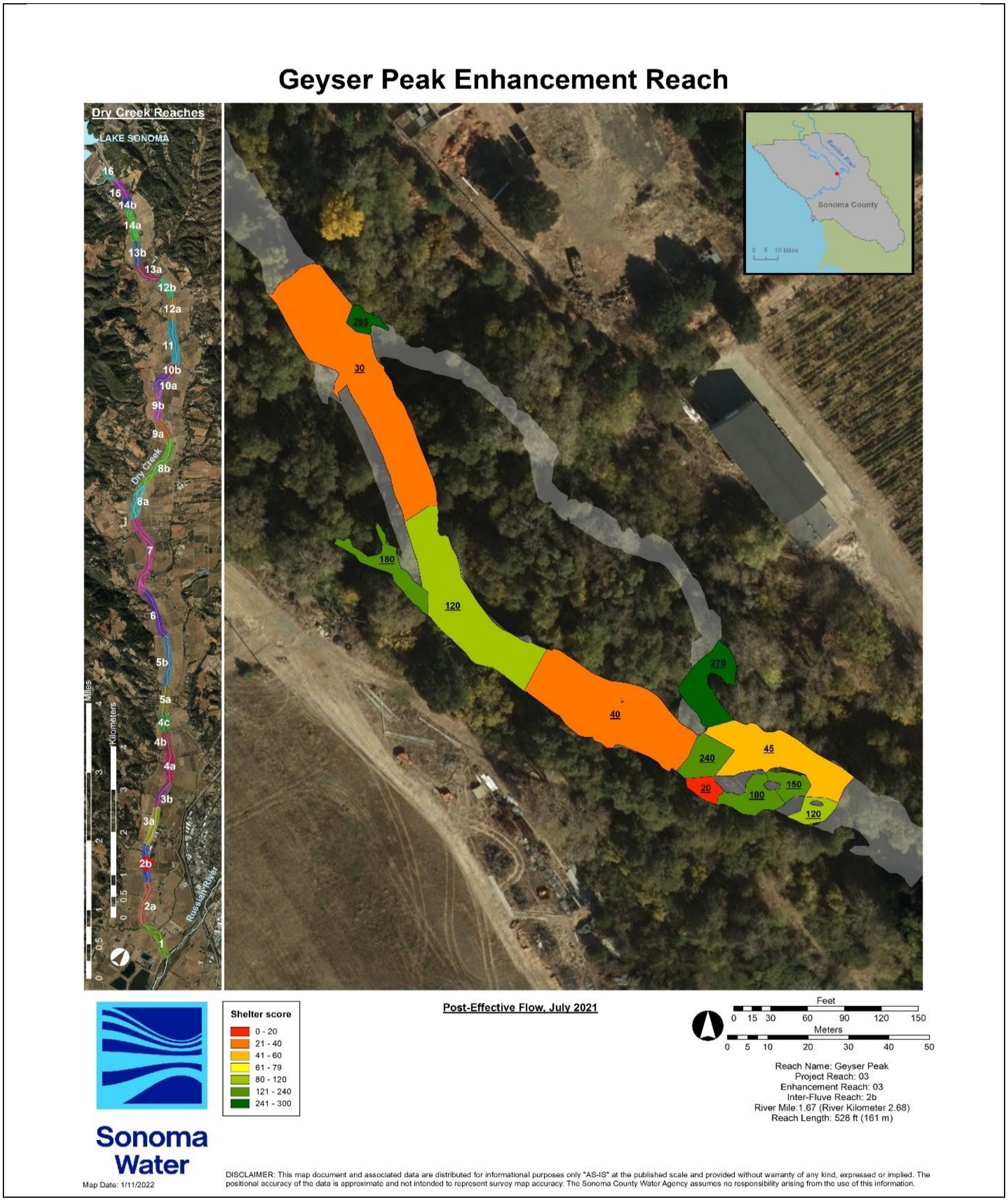

Figure 5.2.55. Habitat unit shelter scores within the Geyser Peak enhancement reach, July 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.39. Post-effective flow average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Geyser Peak enhancement reach, July 2021.

Site number	**1**	**2**	**3**	**4**
Site type	**Main channel**	**Side channel**	**Side channel**	**Bank**
Site average feature quantitative rating[a]	2	2	13	10
Site average feature qualitative rating[a]	Fail	Fail	Excellent	Good
Site average habitat unit quantitative rating[b]	20	0	31	0
Site average qualitative rating[b]	Fair	Fail	Excellent	Not Rated
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	22[c]	2[c]	44[c]	10[a]
Site qualitative rating[c]	Poor[c]	Fail[c]	Excellent[c]	Good[a]
Enhancement reach quantitative rating (average of site rating)[c]	20			
Enhancement reach qualitative rating[c]:	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)
[c]out of 41; Excellent (>=33), Good (>=25), Fair (>=17), Poor (>=8), Fail (<8)

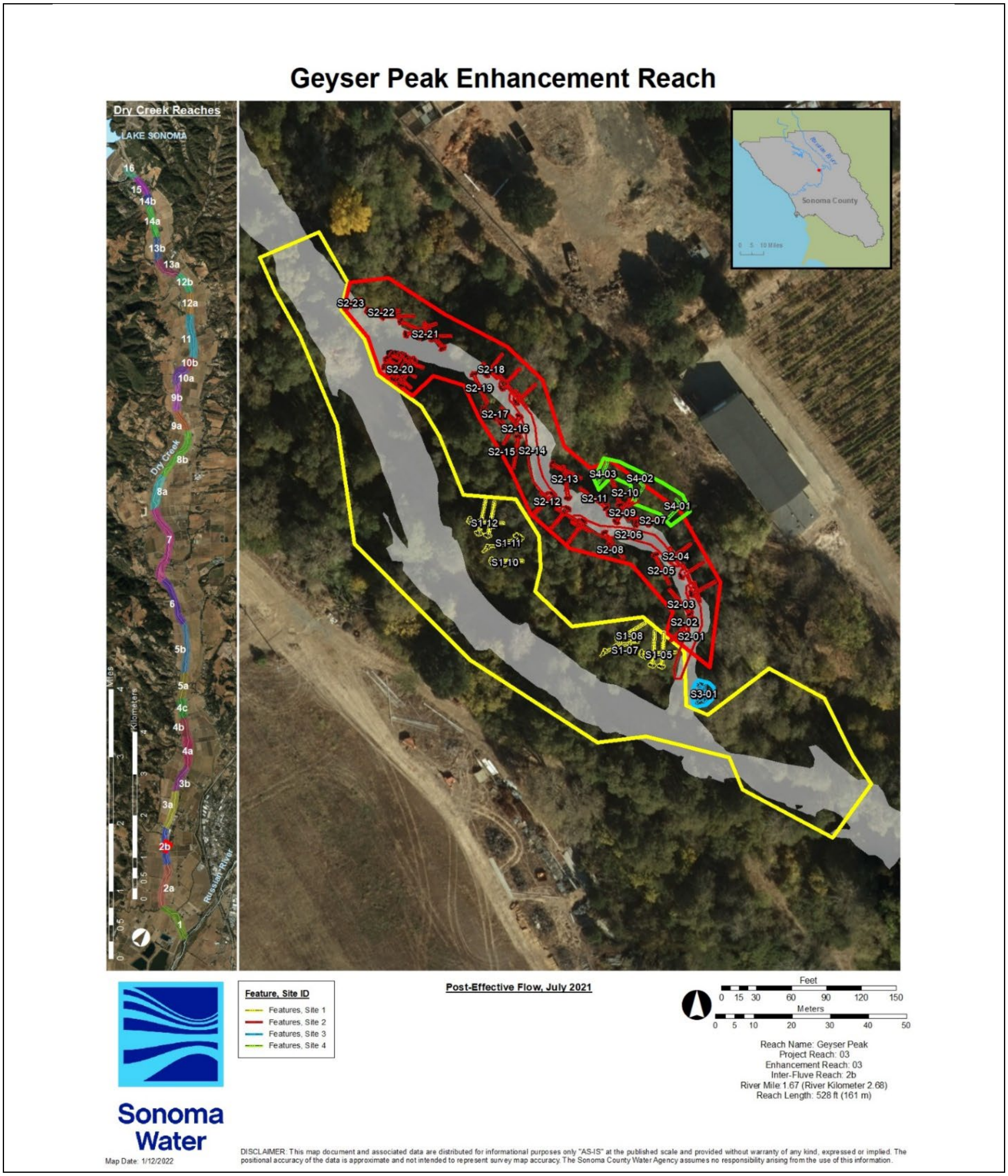

Figure 5.2.56. Enhancement sites and features within the Geyser Peak enhancement reach, July 2021.

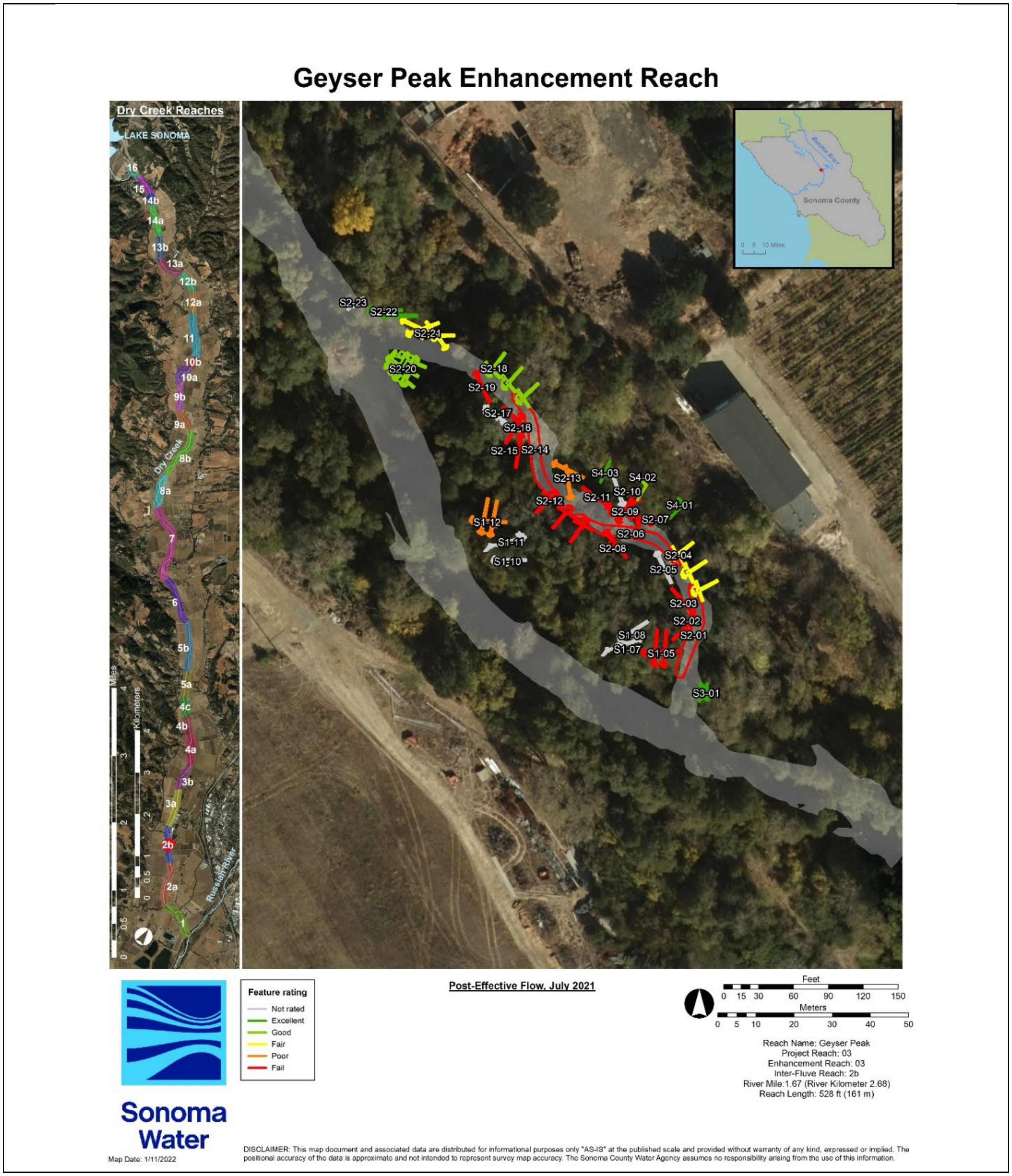

Figure 5.2.57. Feature ratings for the Geyser Peak enhancement reach, July 2021.

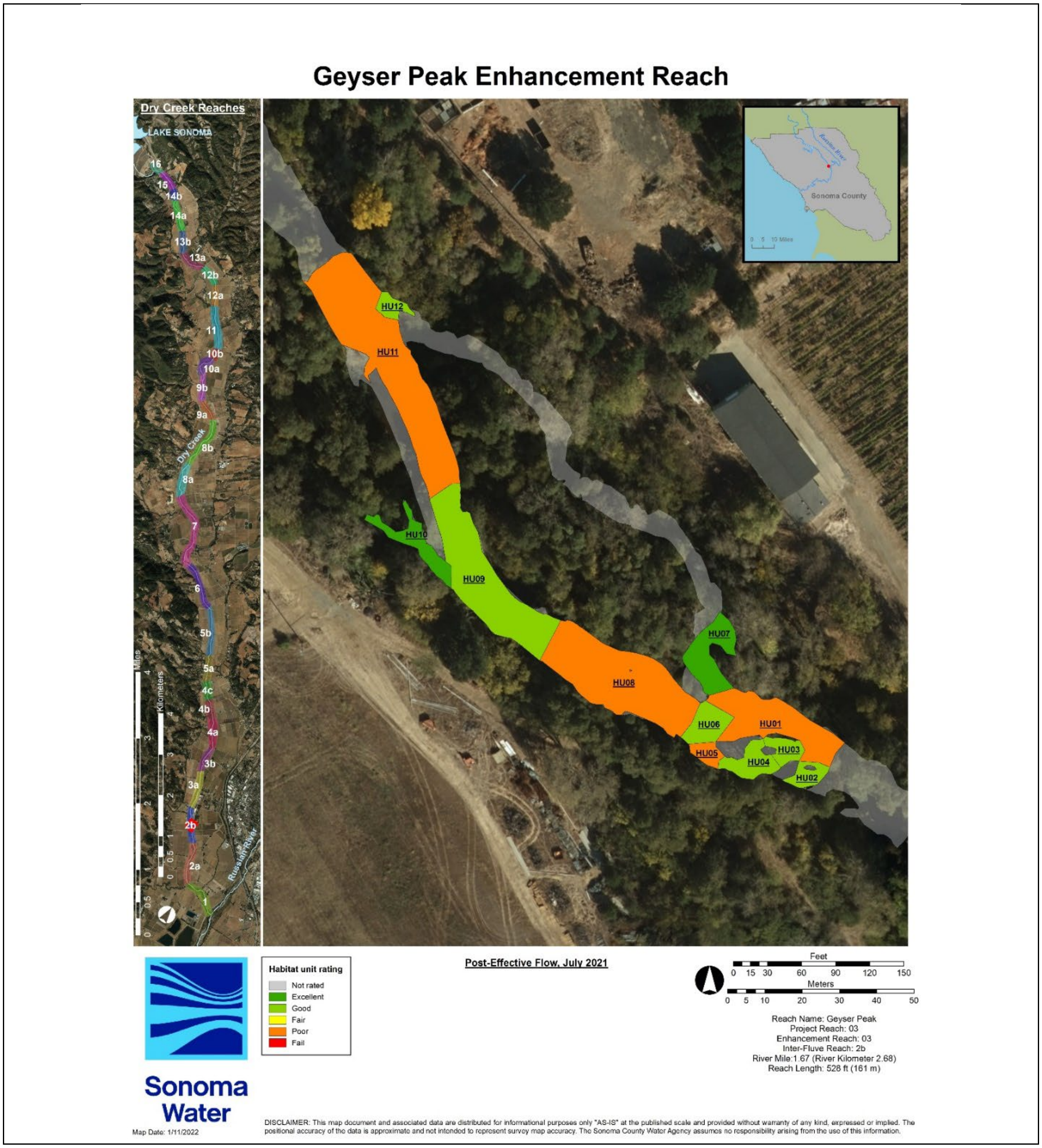

Figure 5.2.58. Post-effective flow habitat unit rating for the Geyser Peak enhancement reach, July 2021.

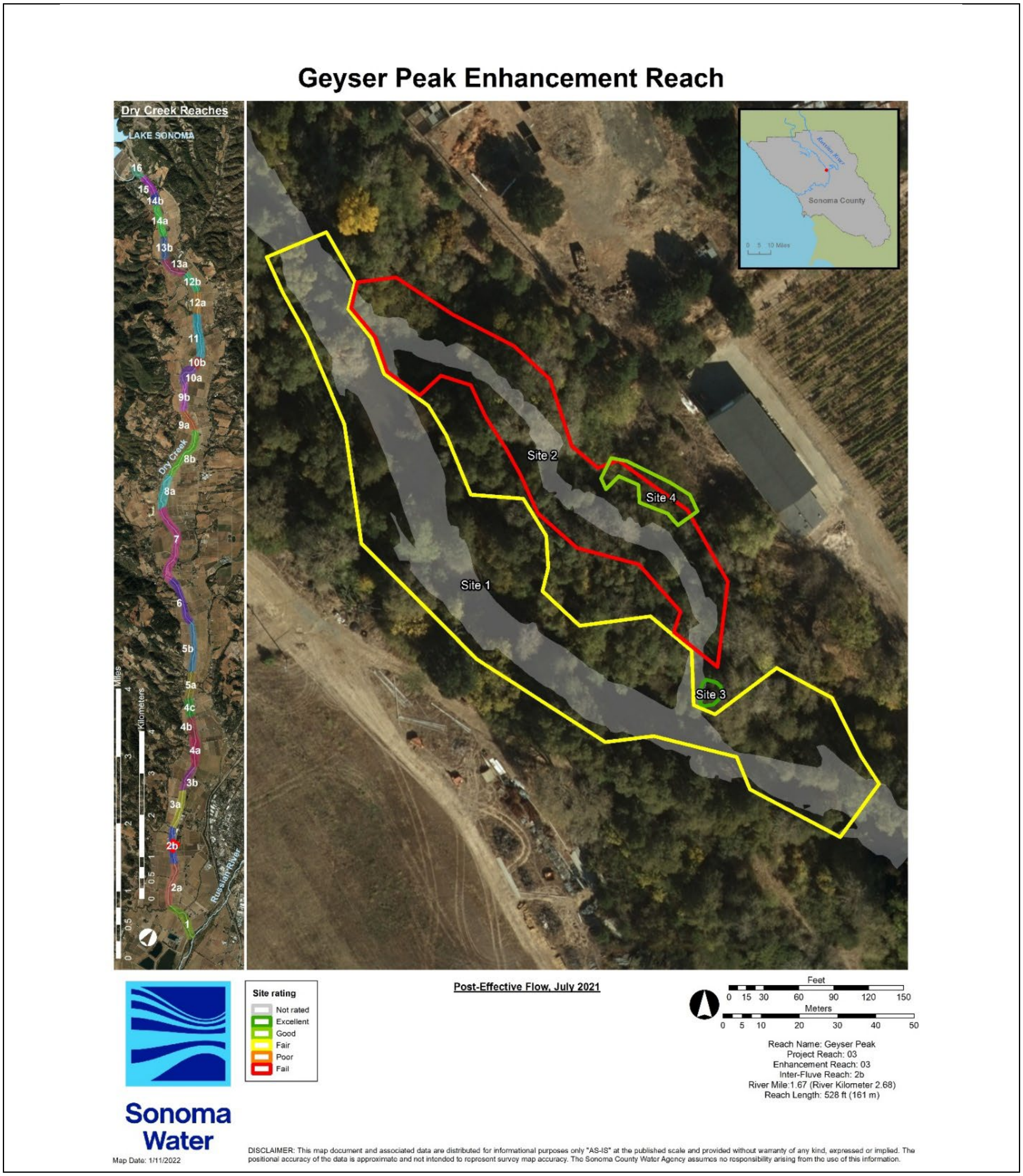

Figure 5.2.59. Post-effective flow site ratings for the Geyser Peak enhancement reach, July 2021.

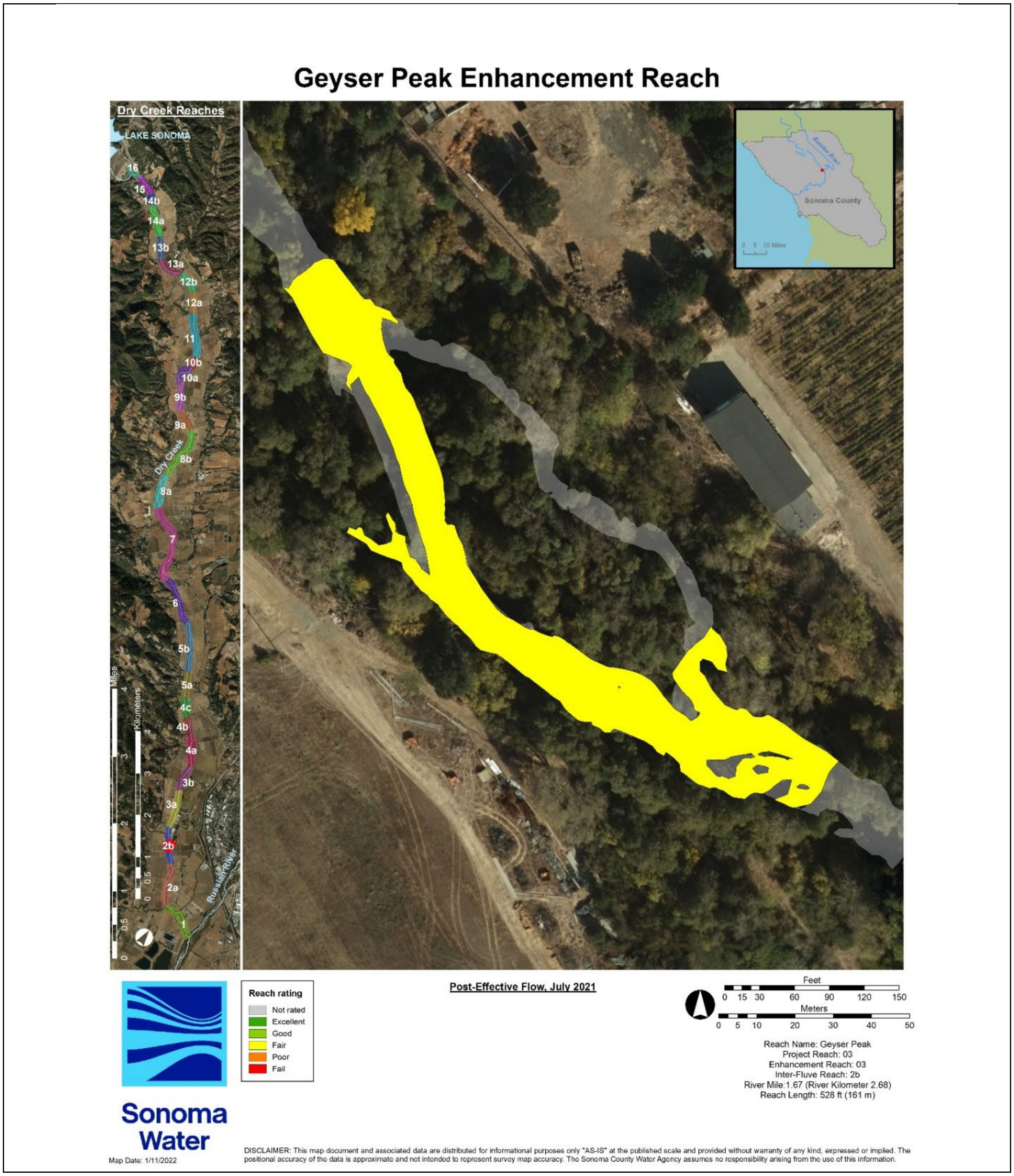

Figure 5.2.60. Post-effective flow reach rating for the Geyser Peak enhancement reach, July 2021.

Spring Flow

Summary

Sonoma Water monitored the spring flow conditions of the Truett Hurst, Meyer, and Carlson Lonestar enhancement reaches in 2021 (Table 5.2.8, Figure 5.2.4). Overall, the enhancement reaches encompassed 49,744 ft^2 within side channel areas, with 51% of the total area meeting optimal depth and velocity criteria (Table 5.2.40). Crews observed 31 habitat units across all enhancement reaches with a total pool to riffle ratio of 12:7 (1.71) and a total average shelter score of 187 (Table 5.2.41). Average shelter score for all habitat types exceeded the optimum shelter score of 80. Spring flow, Truett Hurst, Meyer, and Carlson Lonestar enhancement reaches rated good, good, and excellent, respectively (Table 5.2.42; see below for individual enhancement reach summaries and Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.40. Spring flow areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches surveyed in 2021.

Dry Creek, Spring Flow, 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Side channel area	49,744	25,845	14,021	39,866	33,654	13,960	11,227	25,187
Total area	**49,744**	**25,845**	**14,021**	**39,866**	**33,654**	**13,960**	**11,227**	**25,187**
Side channel % of wetted area	100%	52%	28%	80%	68%	28%	23%	51%
Total % of wetted area	**100%**	**52%**	**28%**	**80%**	**68%**	**28%**	**23%**	**51%**

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.41. Spring flow habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches surveyed in 2021.

Habitat Type	# of Habitat Units	Shelter Score
Riffle	7	109
Pool	12	194
Flatwater	9	218
Alcove	3	252
Pool: riffle	**12:7 (1.71)**	**Avg: 187**

Reach ratings

Table 5.2.42. Spring flow ratings for Dry Creek enhancement reaches surveyed in 2021.

Enhancement Reach	Spring Flow Rating
Truett Hurst	Good
Meyer	Good
Carlson Lonestar	Excellent

Truett Hurst Enhancement Reach

Sonoma Water monitored the spring flow condition of the Truett Hurst enhancement reach in May 2021. Crews also monitored the post-effective flow condition of the Truett Hurst enhancement reach in April 2021 (Table 5.2.20; see Post-effective Flow section above for results).

The 2021 spring flow monitored area encompassed 27,458 ft^2 within side channel areas with 36% of the total area meeting optimal depth and velocity criteria (Table 5.2.43, Figure 5.2.61). The monitored area included 20,006 ft^2 of side channel and 7,453 ft^2 of side channel alcove area, of which 40% and 24%, respectively met optimal depth and velocity criteria, but did not include main channel area as crews were unable to survey the main channel. Thirty habitat units composed the enhancement reach spring flow 2021, with a pool to riffle ratio of 9:11 (0.82) and an average shelter score of 172 (Table 5.2.44, Figure 5.2.62, Figure 5.2.63). Twenty-one 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 5.2.45, Figure 5.2.64) that received fair to excellent site average feature ratings (we did not rate enhancement site 1 [main channel] as crews were unable to survey), and good site average habitat unit ratings (Table 5.2.45, Figure 5.2.65, Figure 5.2.66). Enhancement site ratings ranged from fair to good, with the main channel site (site 1) receiving no rating, the two alcove sites receiving excellent and fair ratings, and the side channel and bank sites receiving good and excellent ratings (Table 5.2.45, Figure 5.2.67). Overall, the Truett Hurst enhancement reach received a good effectiveness monitoring rating (Table 5.2.45, Figure 5.2.68; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.43. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Truett Hurst enhancement reach, May 2021

Truett Hurst, Spring flow, May 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	0	0	0	0	0	0	0	0
Side channel area	20,006	11,488	3,482	14,970	11,967	5,467	2,507	7,975
Side channel alcove area	7,453	5,007	207	5,215	3,706	1,596	201	1,797
Total area	**27,458**	**16,496**	**3,689**	**20,185**	**15,673**	**7,064**	**2,708**	**9,772**
Main channel % of wetted area	0%	0%	0%	0%	0%	0%	0%	0%
Side channel % of wetted area	73%	57%	17%	75%	60%	27%	13%	40%
Side channel alcove area % of wetted area	27%	67%	3%	70%	50%	21%	3%	24%
Total % of wetted area	**100%**	**60%**	**13%**	**74%**	**57%**	**26%**	**10%**	**36%**

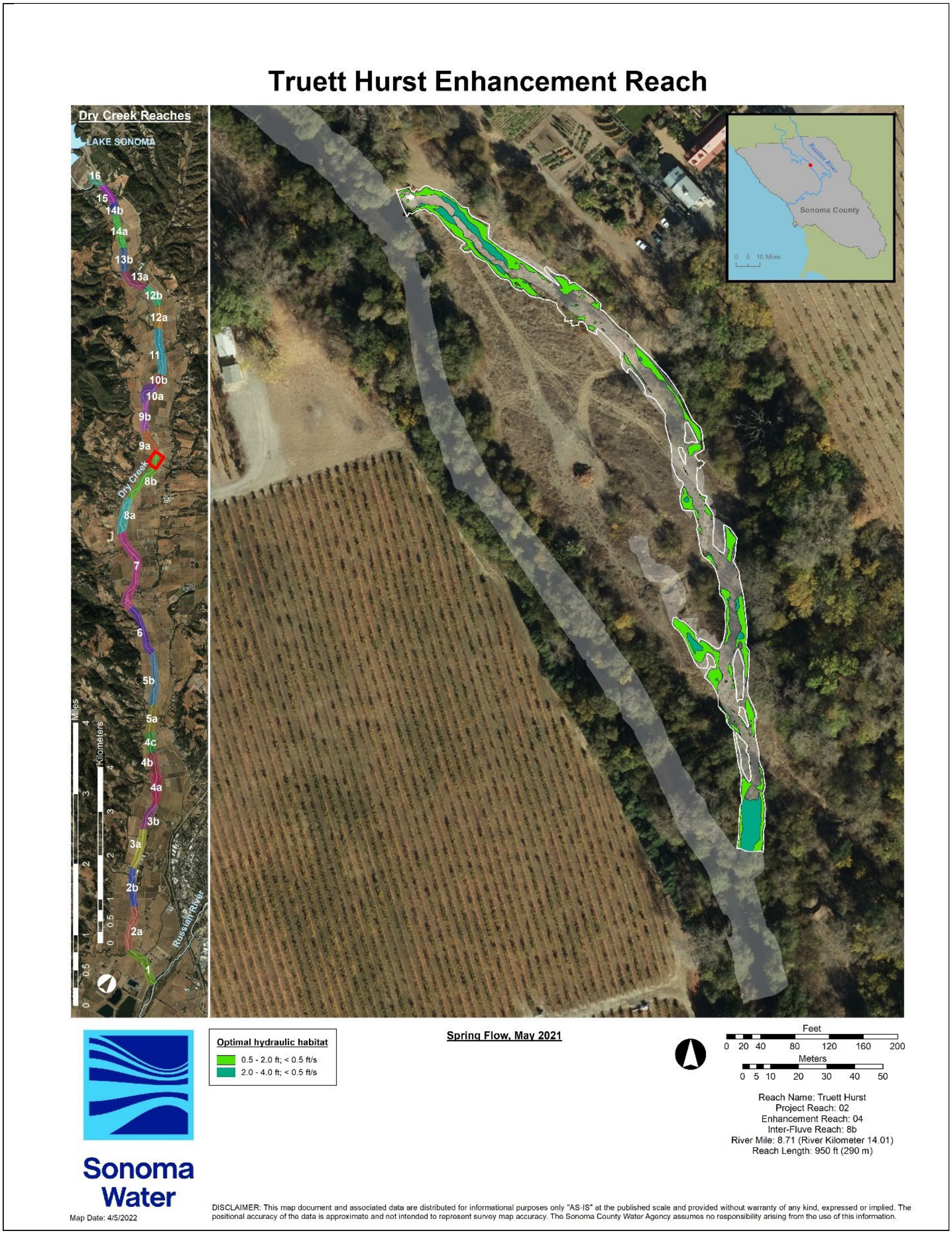

Figure 5.2.61. Optimal hydraulic habitat for fry (<0.5 f/s, 0.5-2.0 ft) and parr (<0.5 f/s, 2.0-4.0 ft) within the Truett Hurst enhancement reach, May 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.44. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Truett Hurst enhancement reach, May 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	85	255
HU02	Riffle	1	90	90
HU03	Pool	2	50	100
HU04	Flatwater	2	90	180
HU05	Riffle	1	20	20
HU06	Pool	3	55	165
HU07	Alcove	2	100	200
HU08	Pool	3	70	210
HU09	Flatwater	3	95	285
HU10	Riffle	3	95	285
HU11	Riffle	3	35	105
HU12	Pool	2	40	80
HU13	Alcove	3	100	300
HU14	Riffle	1	10	10
HU15	Pool	3	50	150
HU16	Riffle	3	55	165
HU17	Pool	3	65	195
HU18	Flatwater	3	80	240
HU19	Flatwater	3	65	195
HU20	Alcove	3	85	255
HU21	Riffle	2	45	90
HU22	Pool	3	75	225
HU23	Pool	3	70	210
Pool: riffle	**9:11 (0.82)**			**Avg= 174**

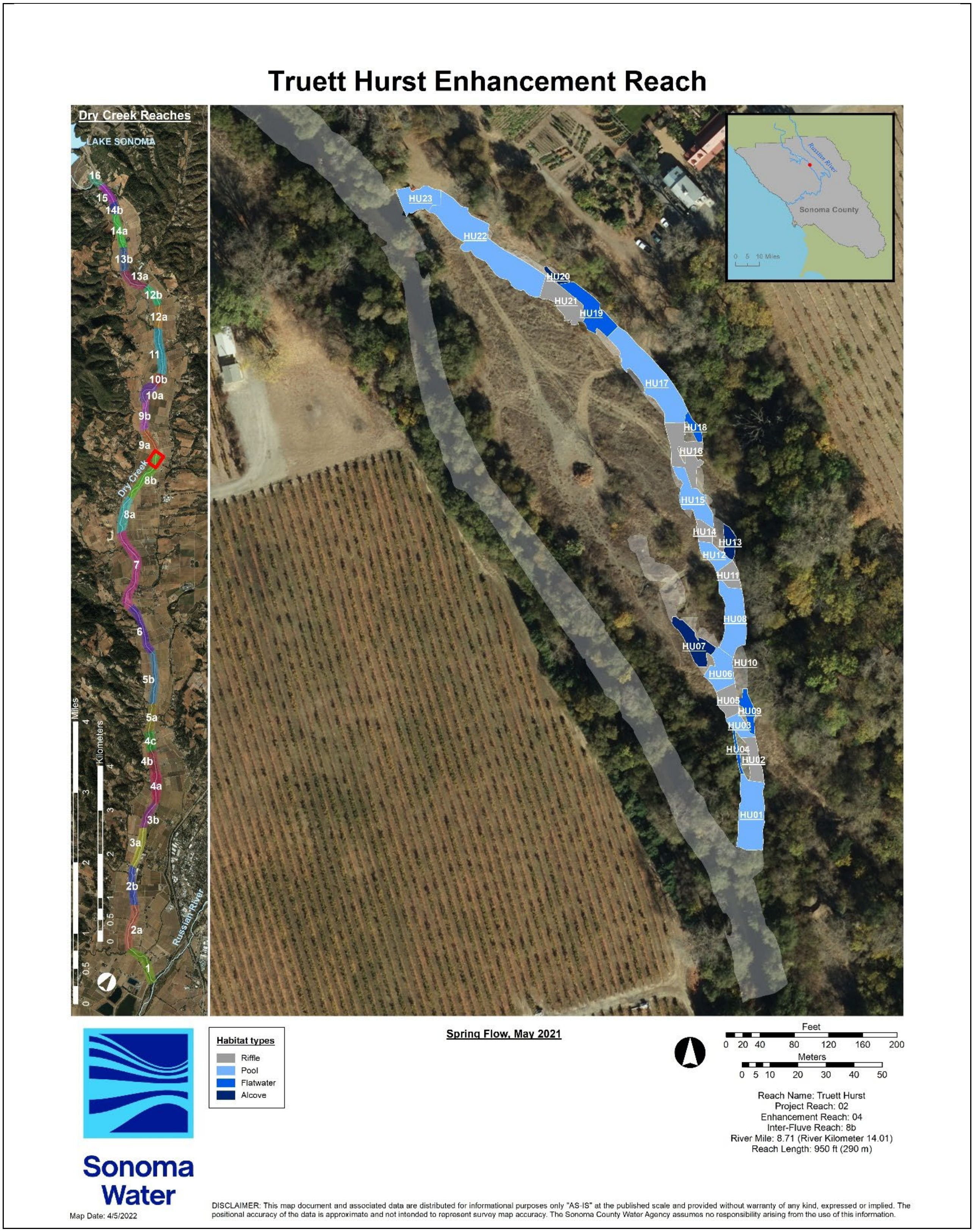

Figure 5.2.62. Habitat unit number and type within the Truett Hurst enhancement reach, May 2021.

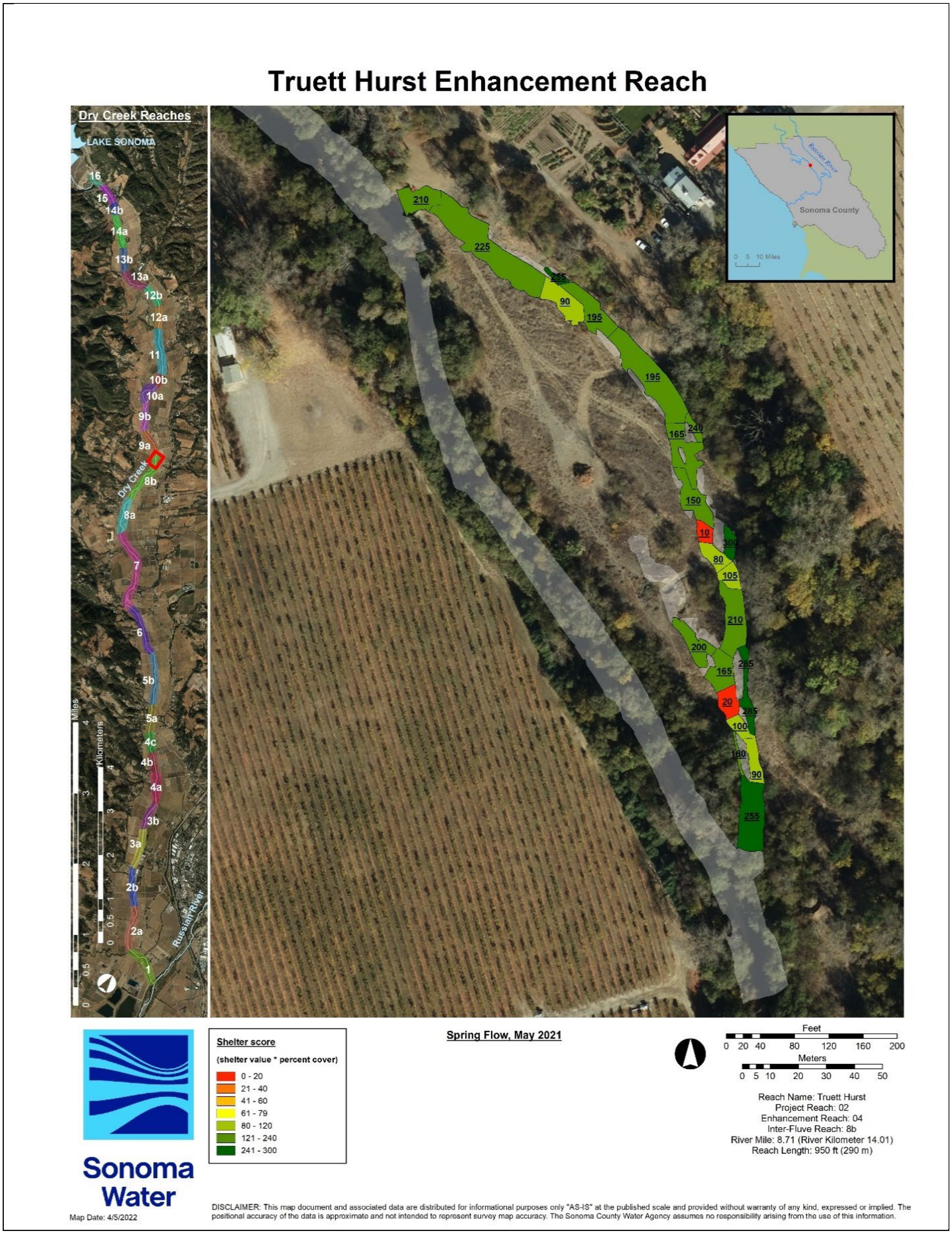

Figure 5.2.63. Habitat unit shelter scores within the Truett Hurst enhancement reach, May 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.45. Spring flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Truett Hurst enhancement reach, May 2021.

Site number	1	2	3	4	5
Site type	Main channel	Side channel	Alcove	Alcove	Bank
Site average feature quantitative rating[a]	0	13	8	12	12
Site average feature qualitative rating[a]	Not rated	Excellent	Fair	Good	Excellent
Site average habitat unit quantitative rating[b]	0	22	26	24	24
Site average qualitative rating[b]	Not Rated	Good	Good	Good	Good
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	0	35	34	36	36
Site qualitative rating[c]	Not rated	Good	Good	Good	Excellent
Enhancement reach quantitative rating (average of site rating)[c]	35				
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)

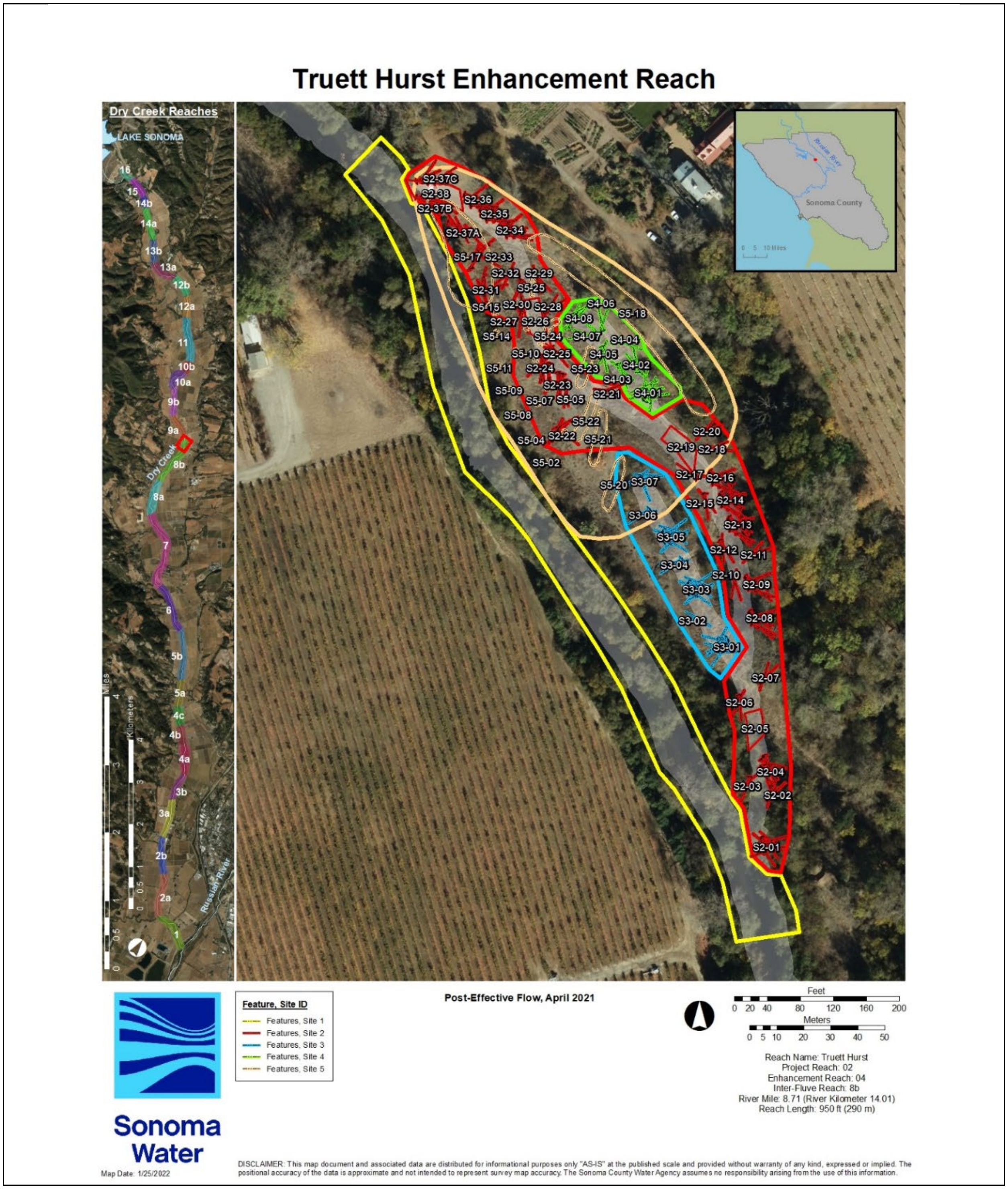

Figure 5.2.64. Enhancement sites and features within the Truett Hurst enhancement reach, May 2021.

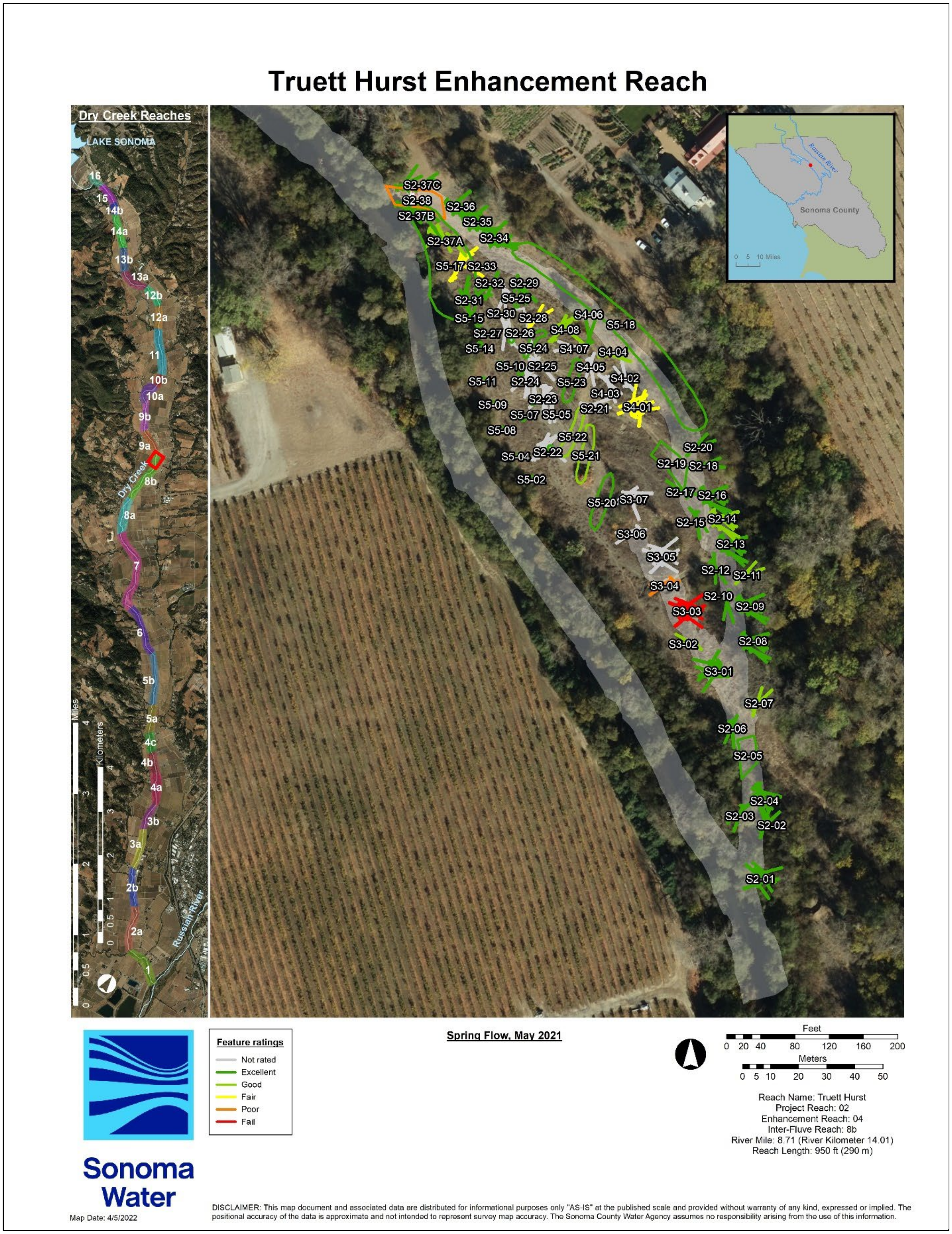

Figure 5.2.65. Feature ratings for the Truett Hurst enhancement reach, May 2021.

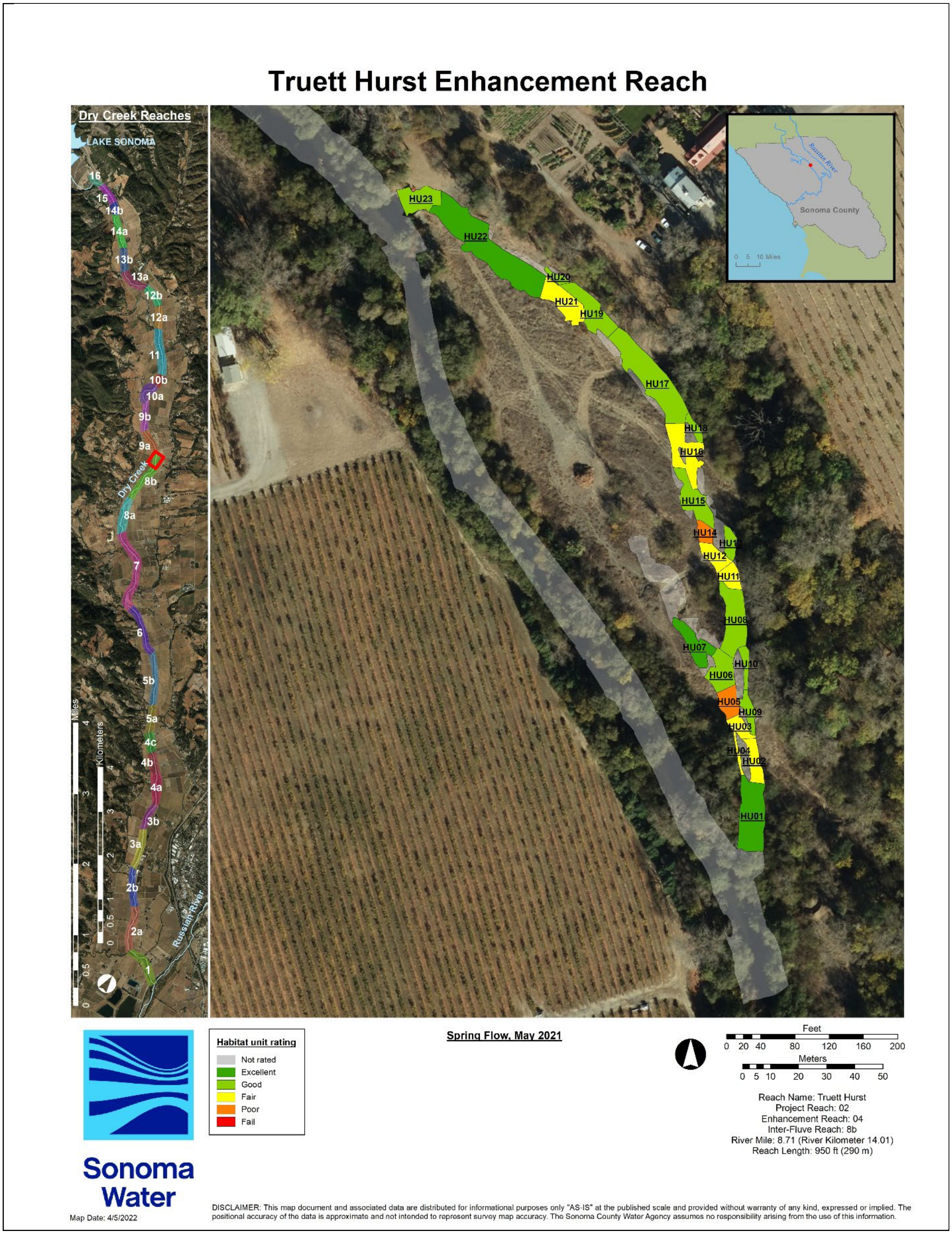

Figure 5.2.66. Habitat unit ratings for the Truett Hurst enhancement reach, May 2021.

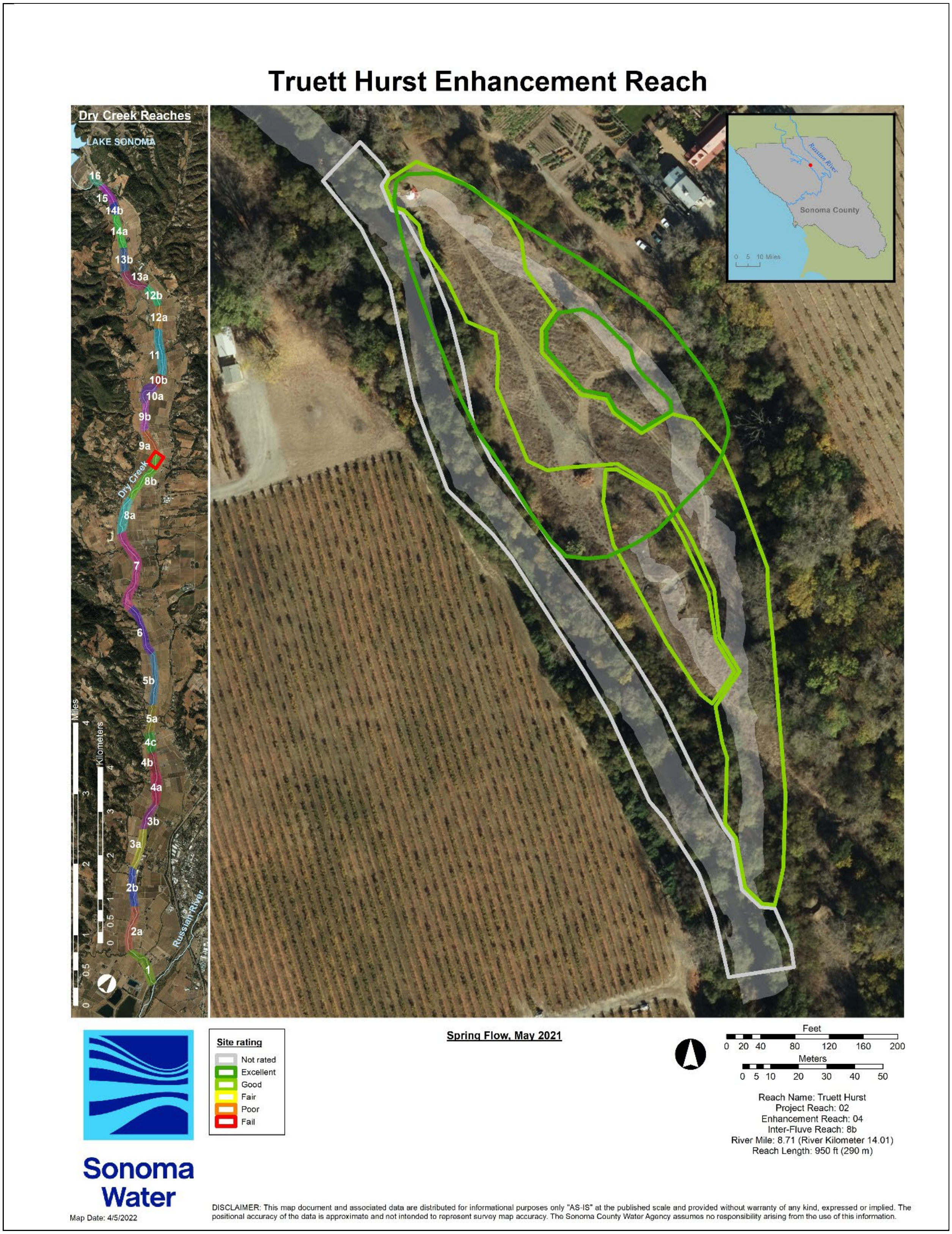

Figure 5.2.67. Spring flow site ratings for the Truett Hurst enhancement reach, May 2021.

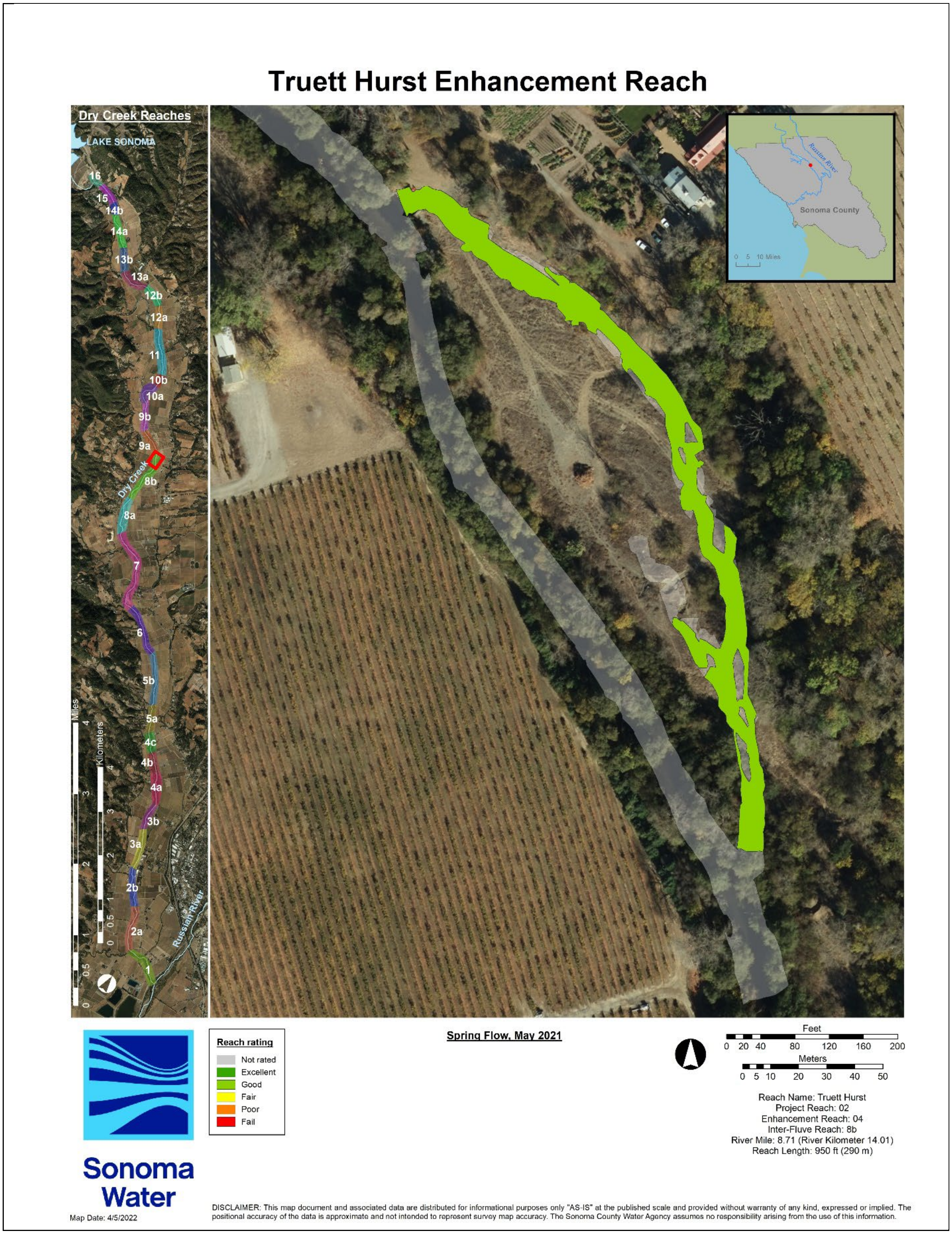

Figure 5.2.68. Spring flow reach rating for the Truett Hurst enhancement reach, May 2021.

Meyer Enhancement Reach

Sonoma Water monitored the spring flow condition of the Meyer enhancement reach in June 2021. Crews also monitored the post-effective flow condition of the Meyer enhancement reach in August 2021(Table 5.2.24; See Post-effective Flow section above for results).

The monitored portion of the reach covered 11,507 ft^2 within the side channel, with 68% of the total area meeting optimal depth and velocity criteria, but did not include the main channel due to the short duration of Warm Springs Dam releases contributing to spring flows (Table 5.2.46, Figure 5.2.69). Four habitat units composed the enhancement reach during spring flow 2021, with two pools and no riffles and an average shelter score of 233 (Table 5.2.47, Figure 5.2.70, Figure 5.2.71). All four habitat units met or exceeded the optimum shelter value of 80. The enhancement reach comprised three enhancement sites (one main channel and two side channels; Table 5.2.48, Figure 5.2.72) that received excellent site average feature rating (we did not rate enhancement site 1 as it contained no features) and sites 2 and 3 (side channel sites) received good and fain site average habitat unit ratings (Table 5.2.48, Figure 5.2.73, Figure 5.2.74). Enhancement sites 2 and 3 receiving good and fair ratings (Table 5.2.48, Figure 5.2.75). Overall, the Meyer enhancement reach received a good effectiveness monitoring score (Table 5.2.48, Figure 5.2.76; see Appendix 5.2 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.46. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Meyer enhancement reach, June 2021.

Meyer, Spring flow, June 2021	**Wetted area (ft^2)**	**0.5 – 2.0 ft (ft^2)**	**2.0 – 4.0 ft (ft^2)**	**Total (ft^2)**	**< 0.5 ft/s (ft^2)**	**0.5 – 2.0 ft, < 0.5 ft/s (ft^2)**	**2.0 – 4.0 ft,< 0.5 ft/s (ft^2)**	**Total (ft^2)**
Main channel area	0	0	0	0	0	0	0	0
Side channel area	11,507	4,502	5,679	10,181	9,125	3,358	4,462	7,820
Total area	**11,507**	**4,502**	**5,679**	**10,181**	**9,125**	**3,358**	**4,462**	**7,820**
Main channel % of wetted area	0%	0%	0%	0%	0%	0%	0%	0%
Side channel % of wetted area	100%	39%	49%	88%	79%	29%	39%	68%
Total % of wetted area	**100%**	**39%**	**49%**	**88%**	**79%**	**29%**	**39%**	**68%**

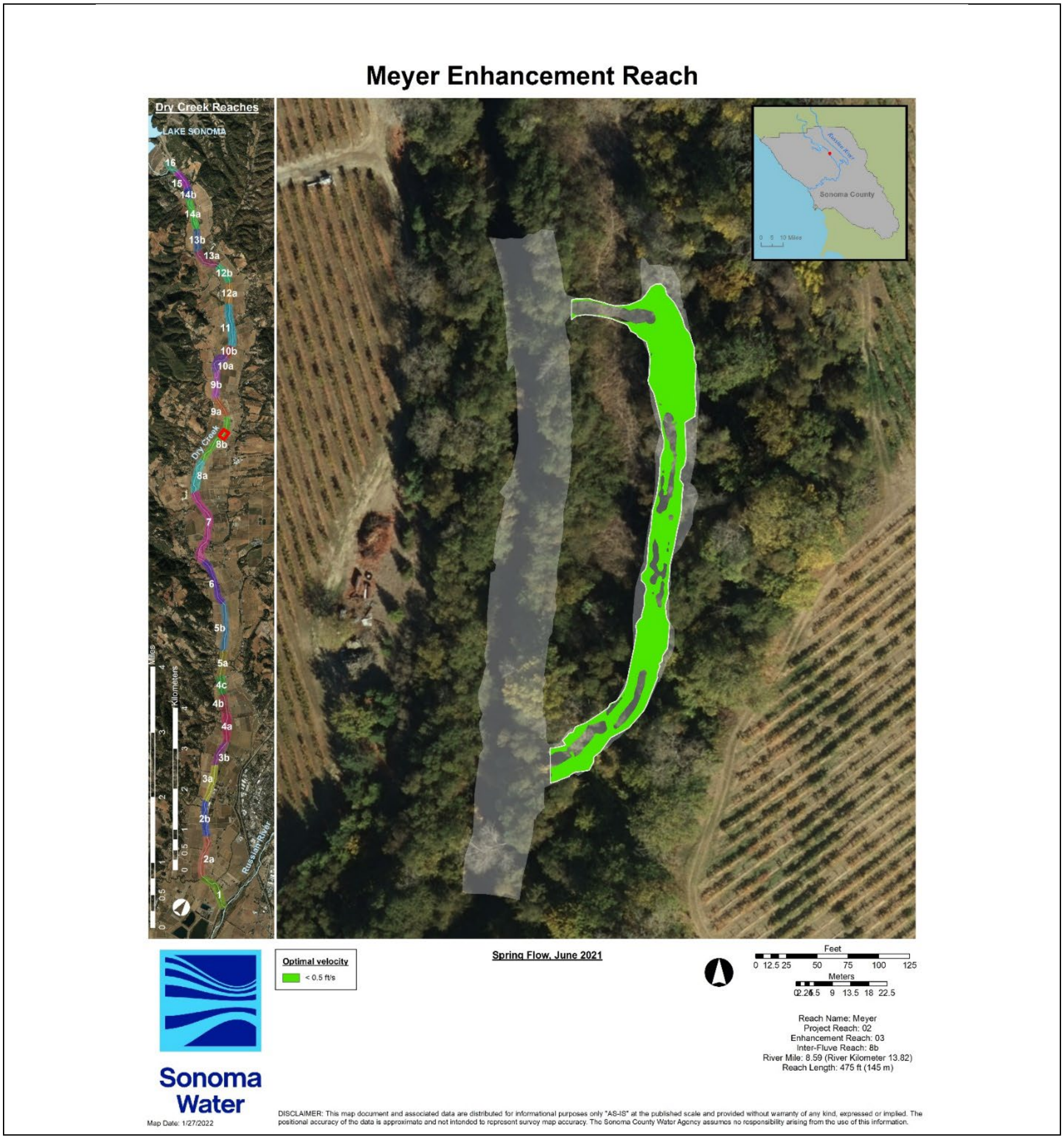

Figure 5.2.69. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Meyer enhancement reach, June 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.47. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Meyer enhancement reach, June 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	3	90	270
HU02	Pool	3	95	285
HU03	Pool	3	95	285
HU04	Flatwater	3	30	90
Pool: riffle	**2:0 (N/A)**			**Avg = 233**

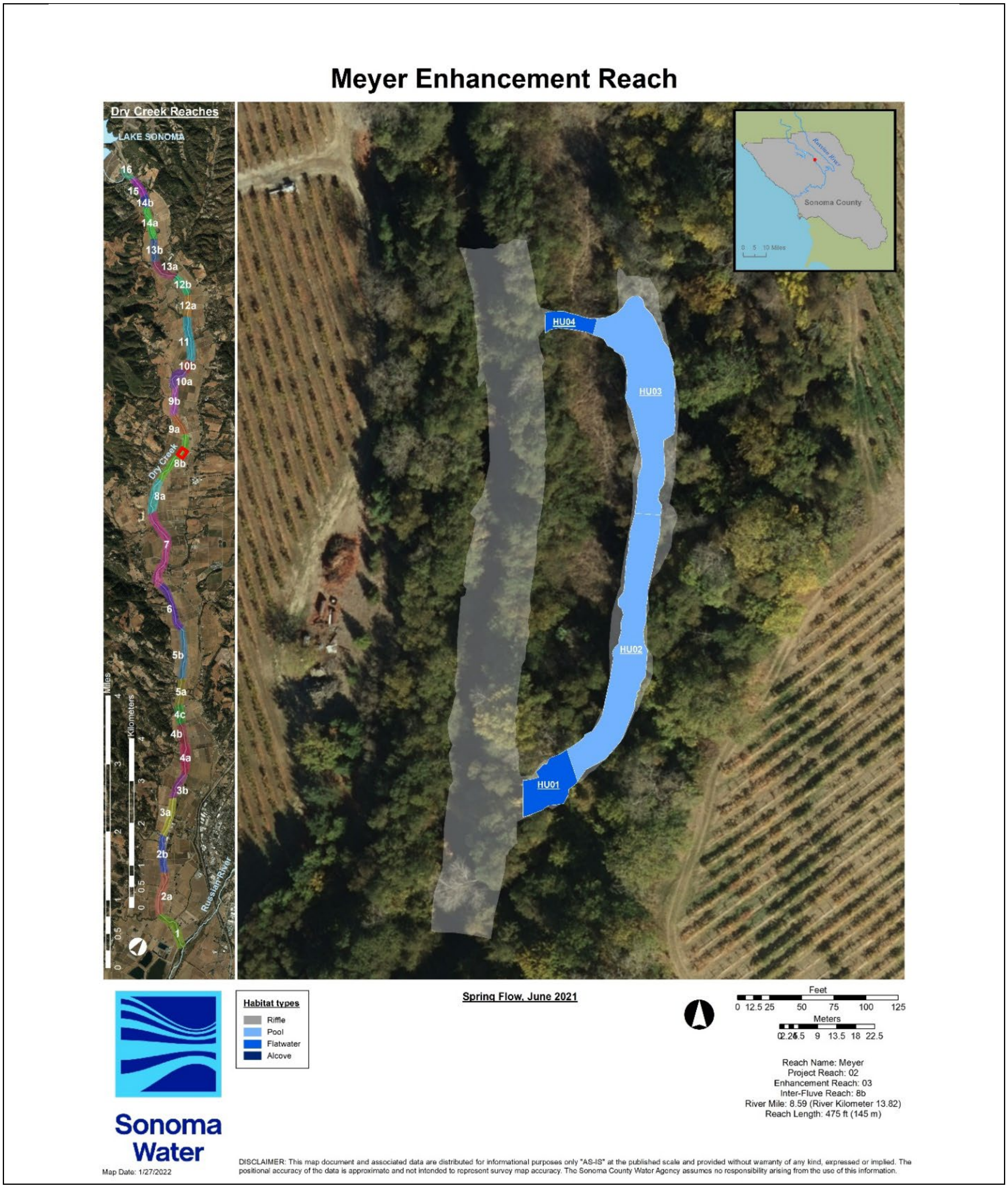

Figure 5.2.70. Habitat unit number and type within the Meyer enhancement reach, June 2021.

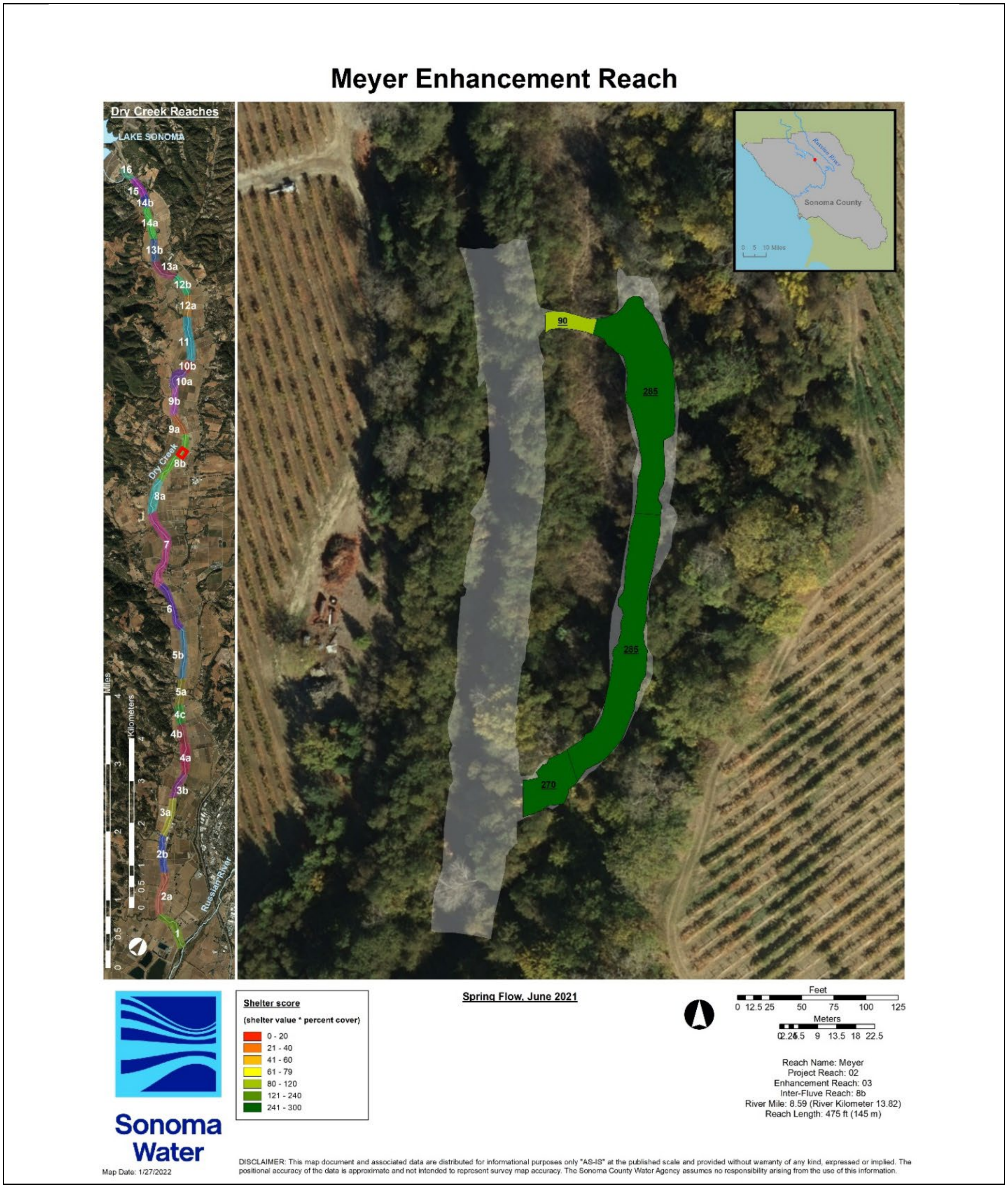

Figure 5.2.71. Habitat unit shelter scores within the Meyer enhancement reach, June 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.48. Spring flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Meyer enhancement reach, June 2021.

Site number	1	2	3	
Site type	**Main channel**	**Side channel**	**Side channel**	
Site average feature quantitative rating	0	13	13	
Site average feature qualitative rating[a]	Not rated	Excellent	Excellent	
Site average habitat unit quantitative rating	0	26	16	
Site average qualitative rating[b]	Not Rated	Good	Fair	
Site quantitative rating (sum of site average feature and habitat unit rating)	0	39	29	
Site qualitative rating	Not rated	Good	Fair	
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)

Meyer Enhancement Reach

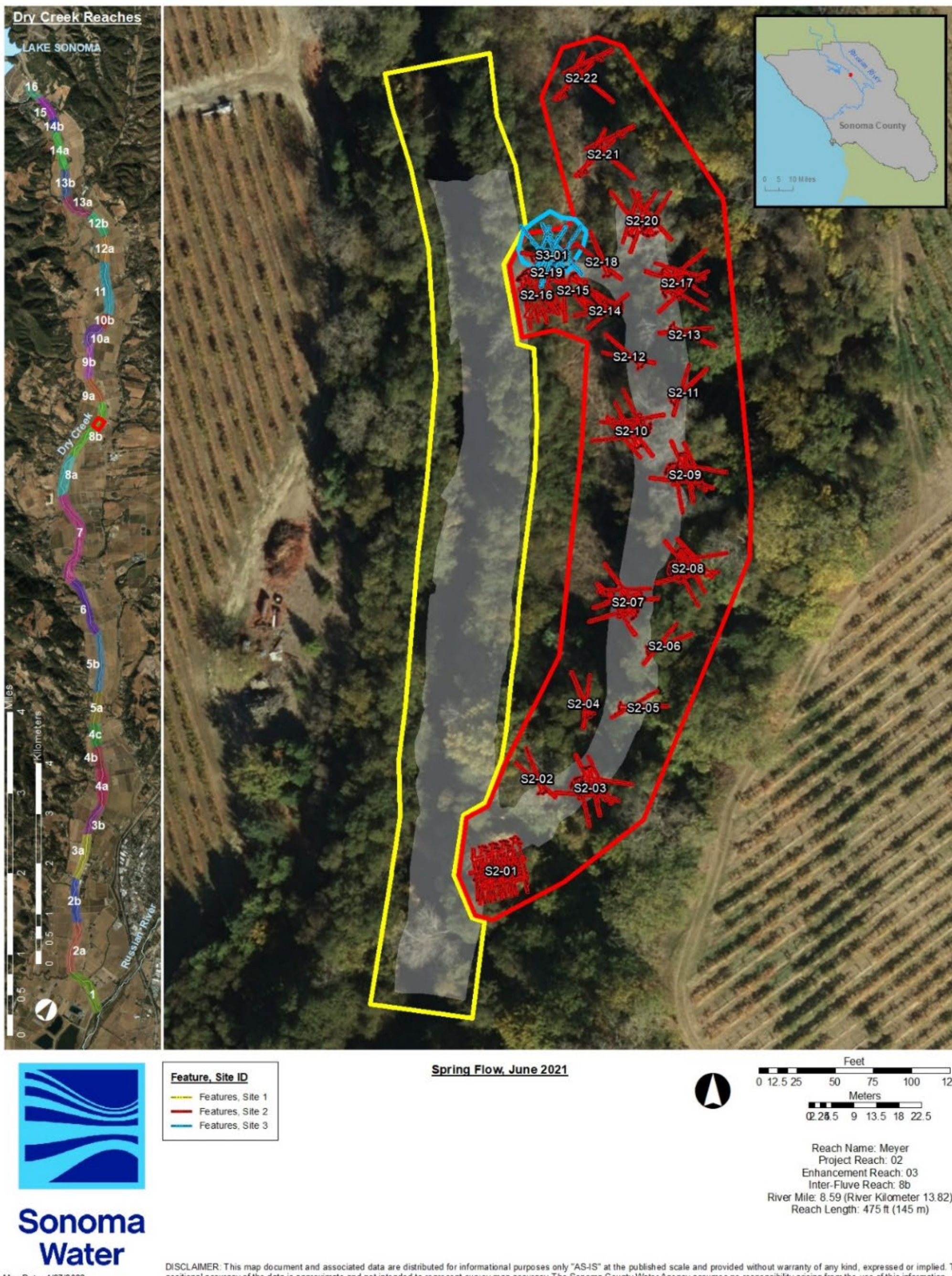

Figure 5.2.72. Enhancement sites and features within the Meyer enhancement reach, June 2021.

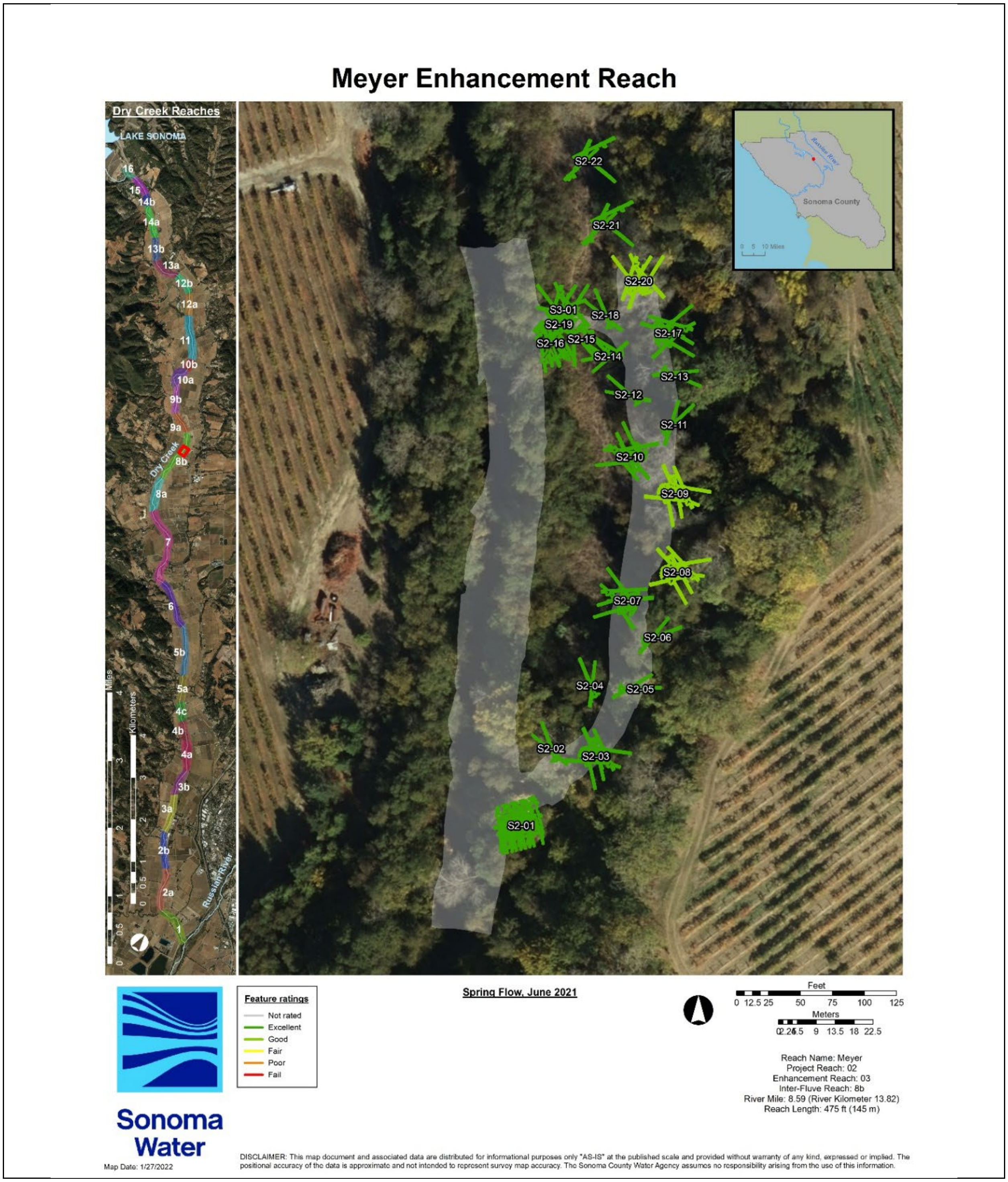

Figure 5.2.73. Feature ratings for the Meyer enhancement reach, June 2021.

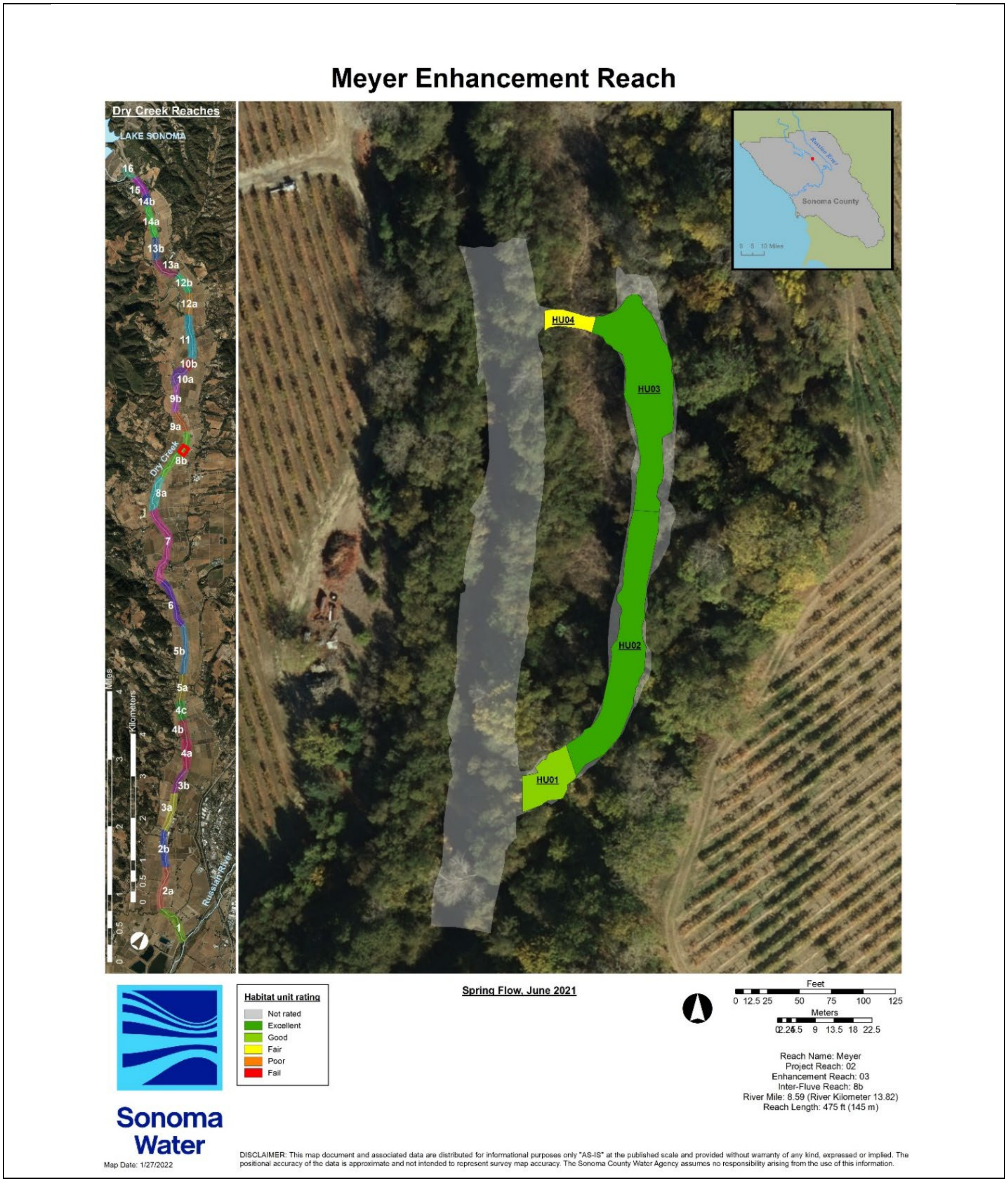

Figure 5.2.74. Habitat unit ratings for the Meyer enhancement reach, June 2021.

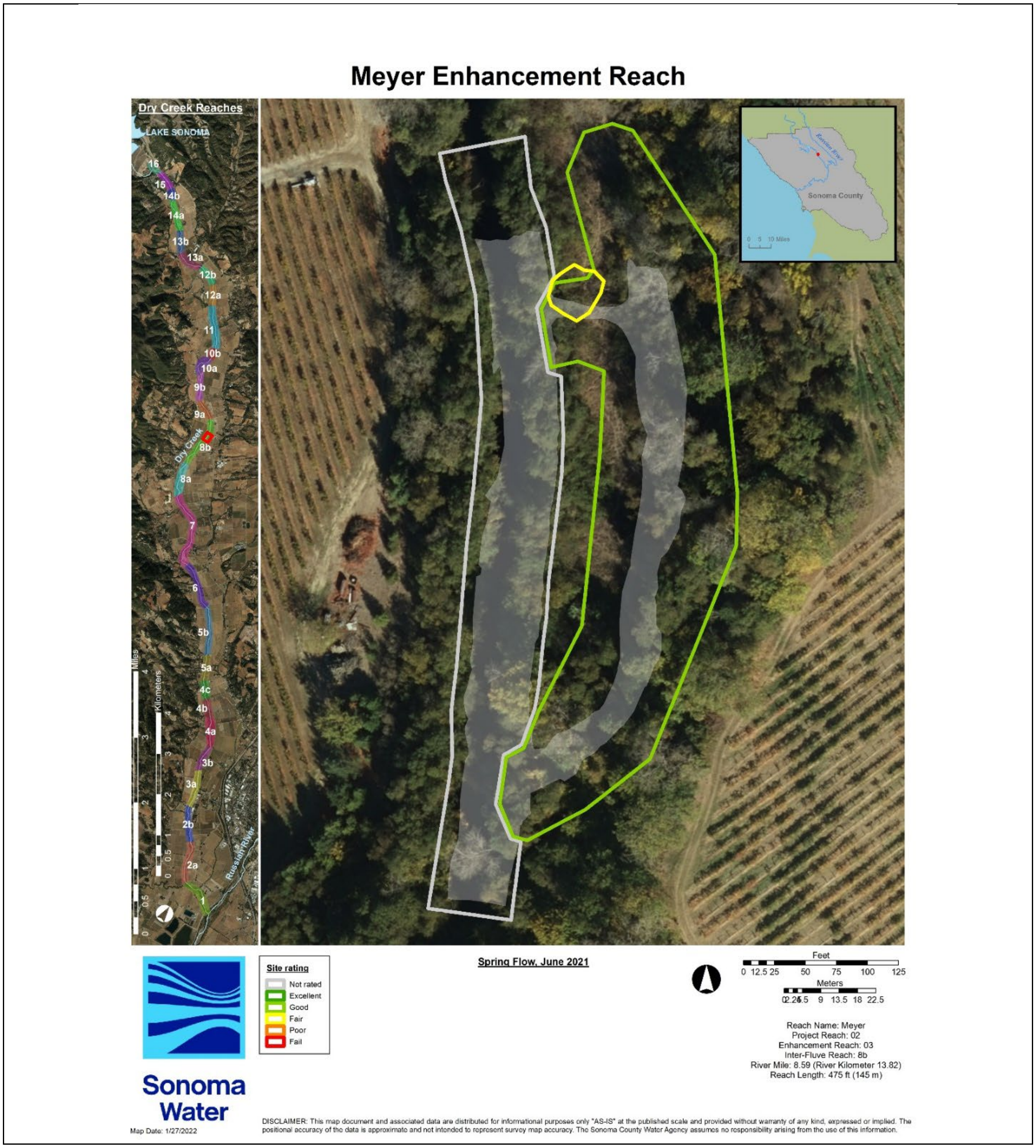

Figure 5.2.75. Spring flow site ratings for the Meyer enhancement reach, June 2021.

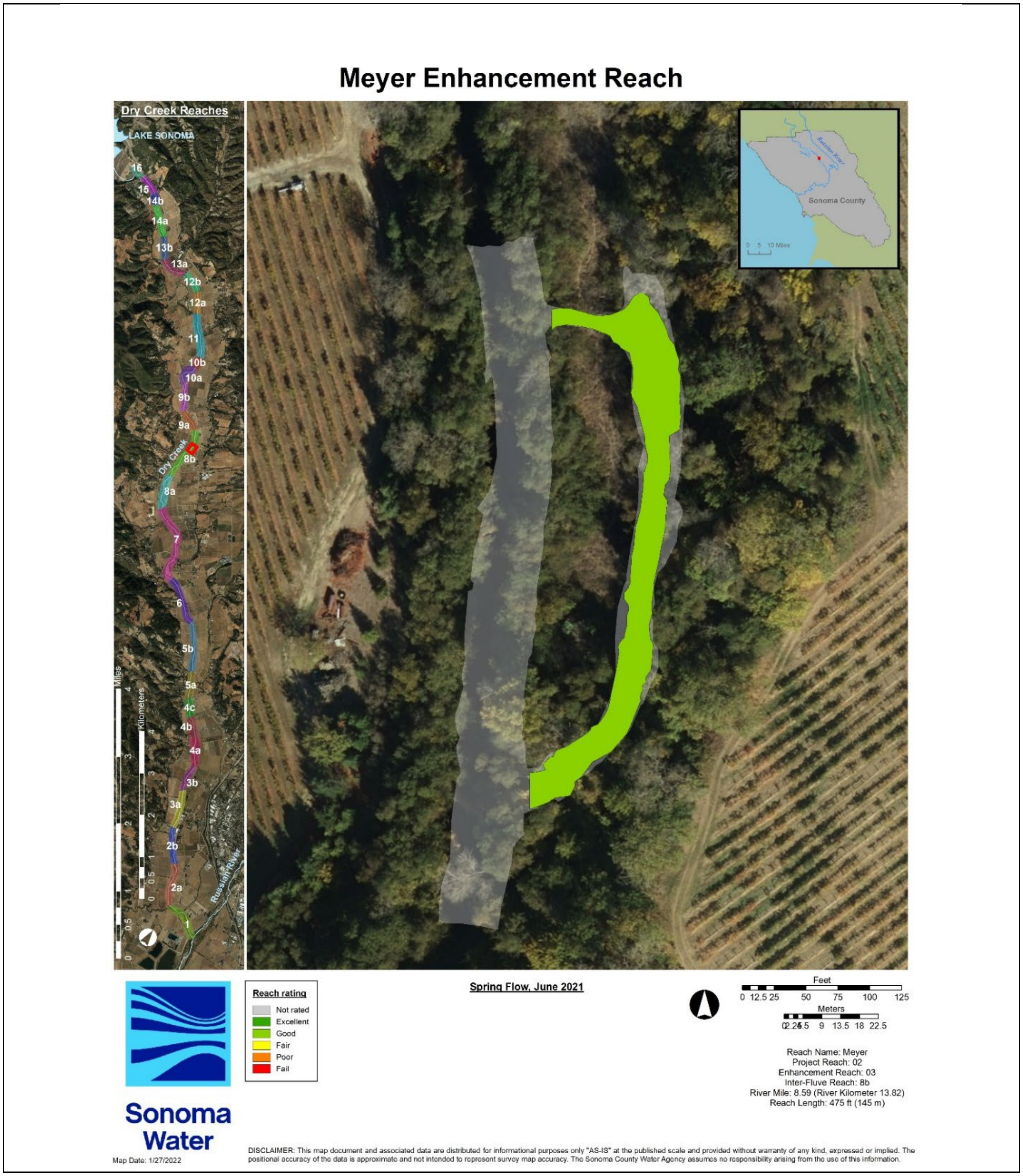

Figure 5.2.76. Spring flow reach rating for the Meyer enhancement reach, June 2021.

Carlson Lonestar Enhancement Reach

Sonoma Water monitored the spring flow condition of the Carlson Lonestar enhancement reach in May 2021. Crews also monitored the post-effective flow condition of the Carlson Lonestar enhancement reach in August 2021 (Table 5.2.28; see Post-effective Flow section above for results).

The 2021 spring flow monitored area encompassed 10,779 ft^2 within the side channel to the east of the main channel, with 70% of the total meeting optimal depth and velocity criteria, but did not include the main channel or the side channel to the west of main channel due to the short duration of Warm Springs Dam releases contributing to spring flows. (Table 5.2.49,Figure 5.2.77). Six habitat units made up the monitored area of the enhancement reach during spring flow, with three pools and zero riffles, and an average shelter score of 240 (Table 5.2.50, Figure 5.2.78, Figure 5.2.79). All six habitat units met or exceeded the optimal shelter value of 80. The monitored side channel received excellent site average feature ratings and excellent site average habitat unit ratings (Table 5.2.51, Figure 5.2.80, Figure 5.2.81, Figure 5.2.82). The side channel enhancement site received an excellent qualitative rating (Figure 5.2.83). Overall, the Carlson Lonestar enhancement reach (excluding the main stem and west side channel) received an excellent enhancement reach rating during spring flow (Figure 5.2.84) (See Appendix 5.2 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.49. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Carlson Lonestar enhancement reach, May 2021.

Carlson Lonestar, Spring flow, May 2021	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	0	0	0	0	0	0	0	0
Side channel area	10,779	4,847	4,653	9,501	8,856	3,539	4,056	7,595
Total area	**10,779**	**4,847**	**4,653**	**9,501**	**8,856**	**3,539**	**4,056**	**7,595**
Main channel % of wetted area	0%	0%	0%	0%	0%	0%	0%	0%
Side channel % of wetted area	100%	45%	43%	88%	82%	33%	38%	70%
Total % of wetted area	**100%**	**45%**	**43%**	**88%**	**82%**	**33%**	**38%**	**70%**

Figure 5.2.77. 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, May 2021.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.50. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Carlson Lonestar enhancement reach, May 2021.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	85	255
HU02	Flatwater	3	90	270
HU03	Pool	3	80	240
HU04	Flatwater	3	75	225
HU05	Pool	3	80	240
HU06	Flatwater	3	70	210
Pool: riffle	**3:0 (N/A)**			**Avg = 240**

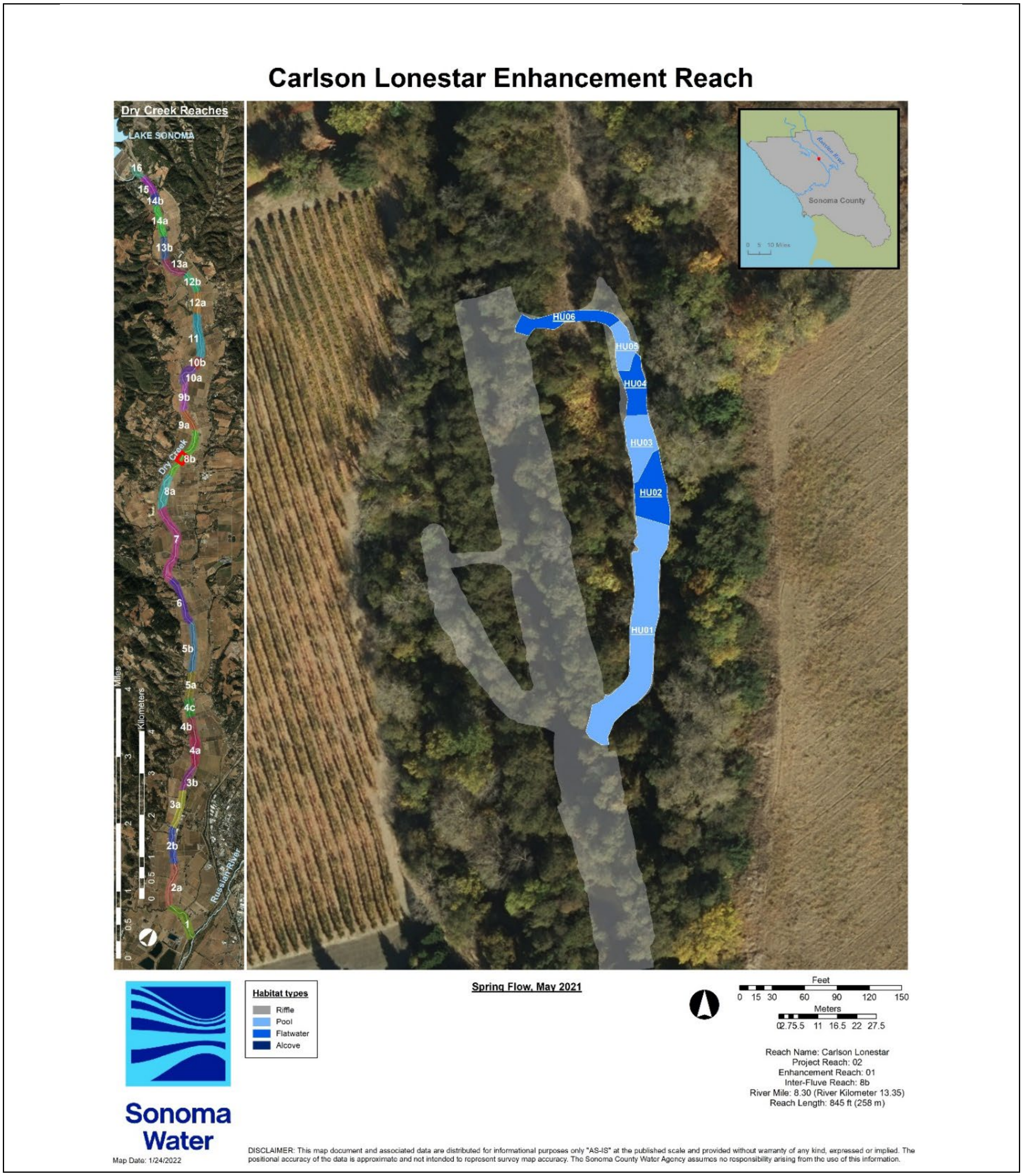

Figure 5.2.78. Habitat unit number and type within the Carlson Lonestar enhancement reach, May 2021.

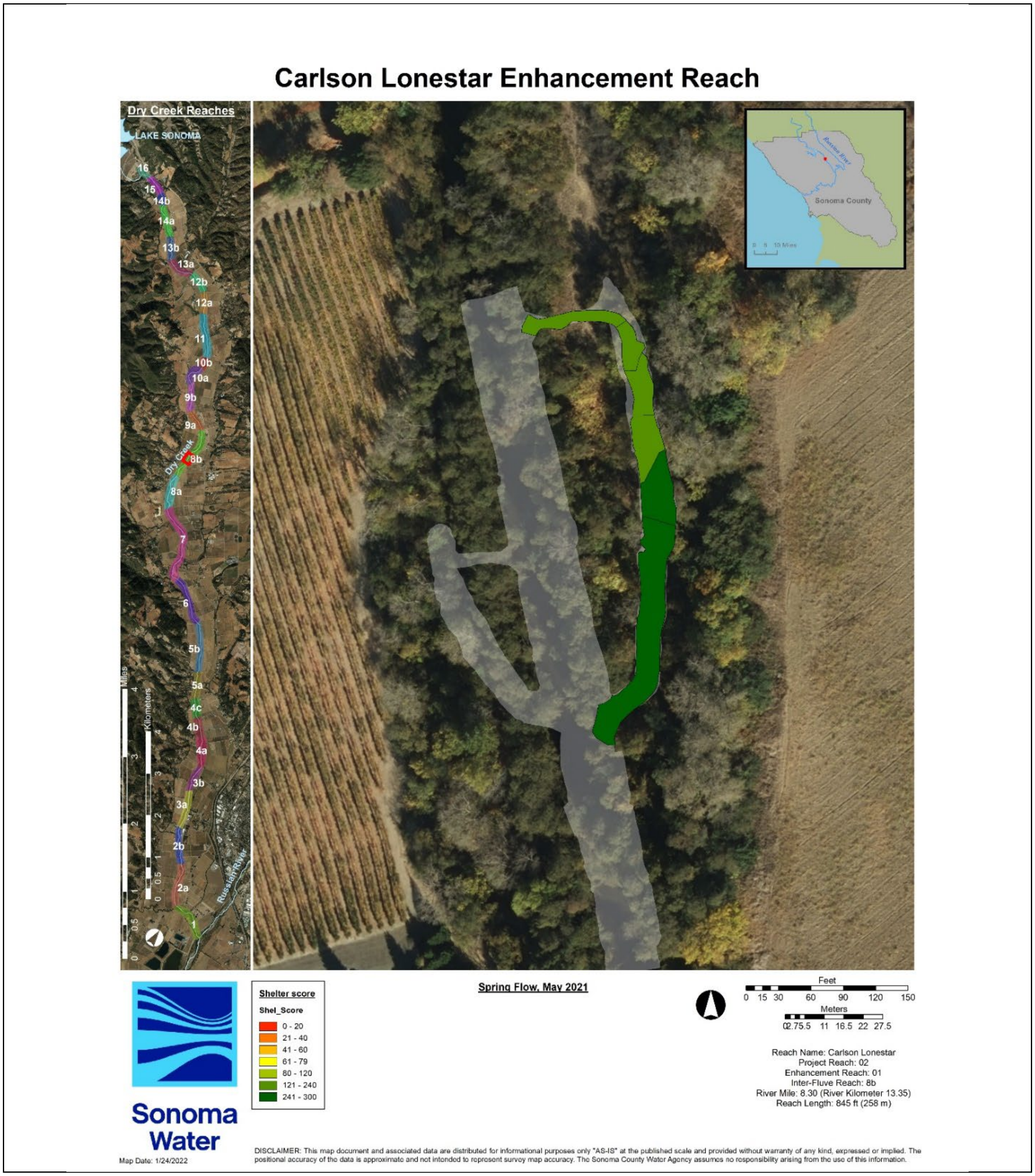

Figure 5.2.79. Habitat unit shelter scores within the Carlson Lonestar enhancement reach, May 2021.

Feature, habitat unit, site, and reach ratings

Table 5.2.51. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Carlson Lonestar enhancement reach, May 2021.

Site number	1	2	3	
Site type	Main channel	Side channel	Side channel	
Site average feature quantitative rating[a]	0	13	0	
Site average feature qualitative rating[a]	Not rated	Excellent	Not rated	
Site average habitat unit quantitative rating[b]	0	30	0	
Site average qualitative rating[b]	Not Rated	Excellent	Not Rated	
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	0	43	0	
Site qualitative rating[c]	Not rated	Excellent	Not rated	
Enhancement reach quantitative rating (average of site rating)[c]	43			
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)

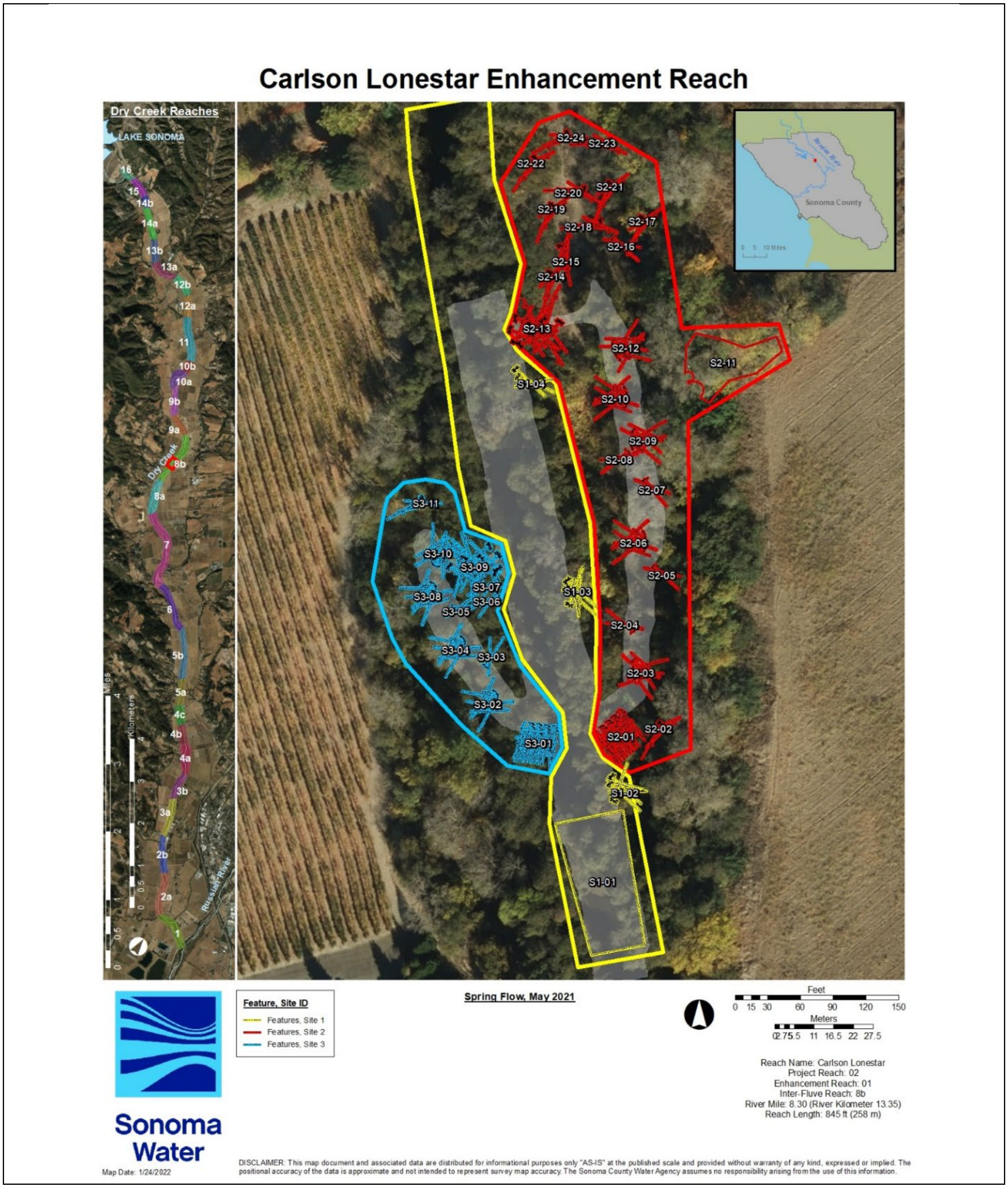

Figure 5.2.80. Enhancement sites and features within the Carlson Lonestar enhancement reach, May 2021.

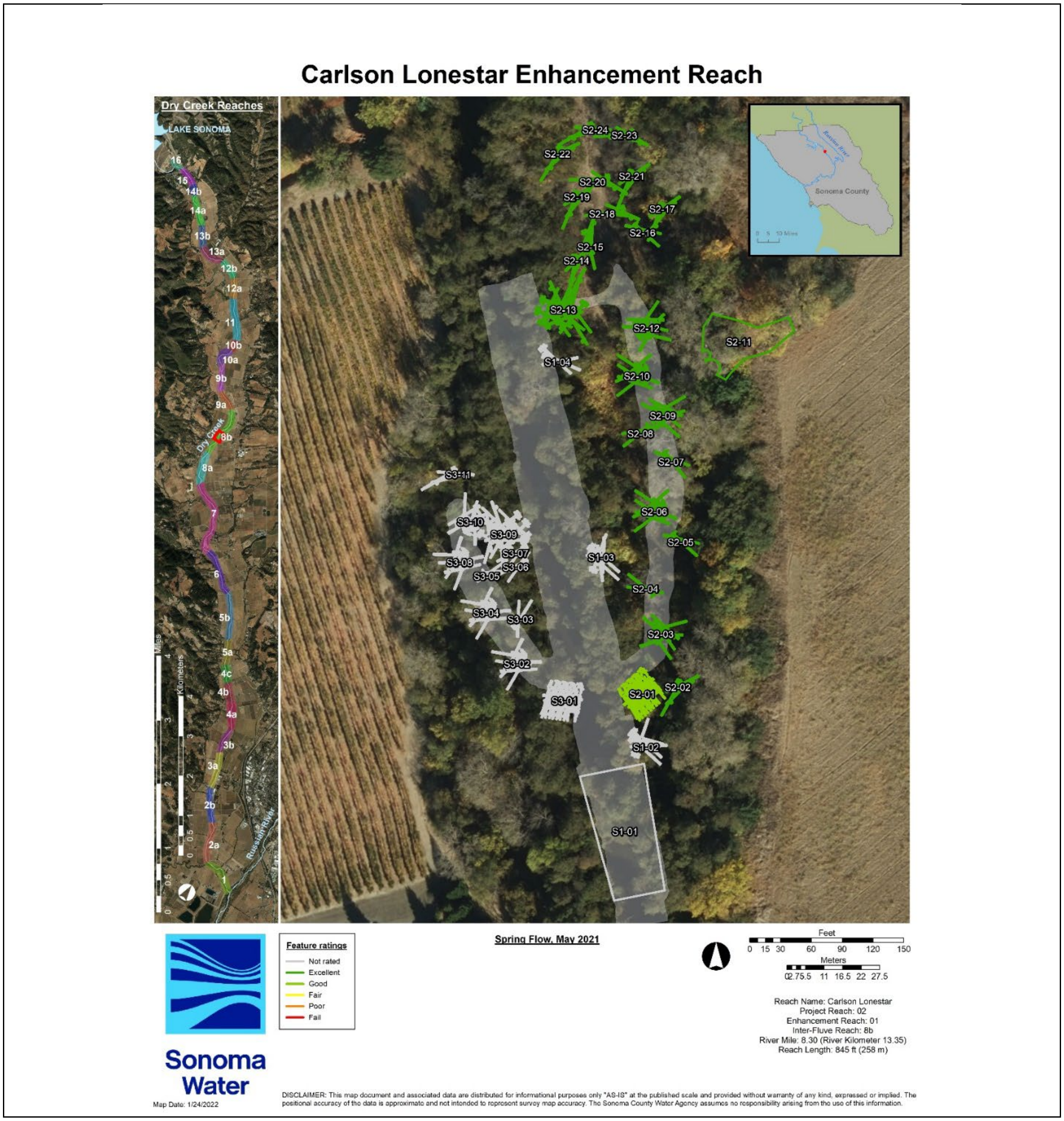

Figure 5.2.81. Feature ratings for the Carlson Lonestar enhancement reach, May 2021.

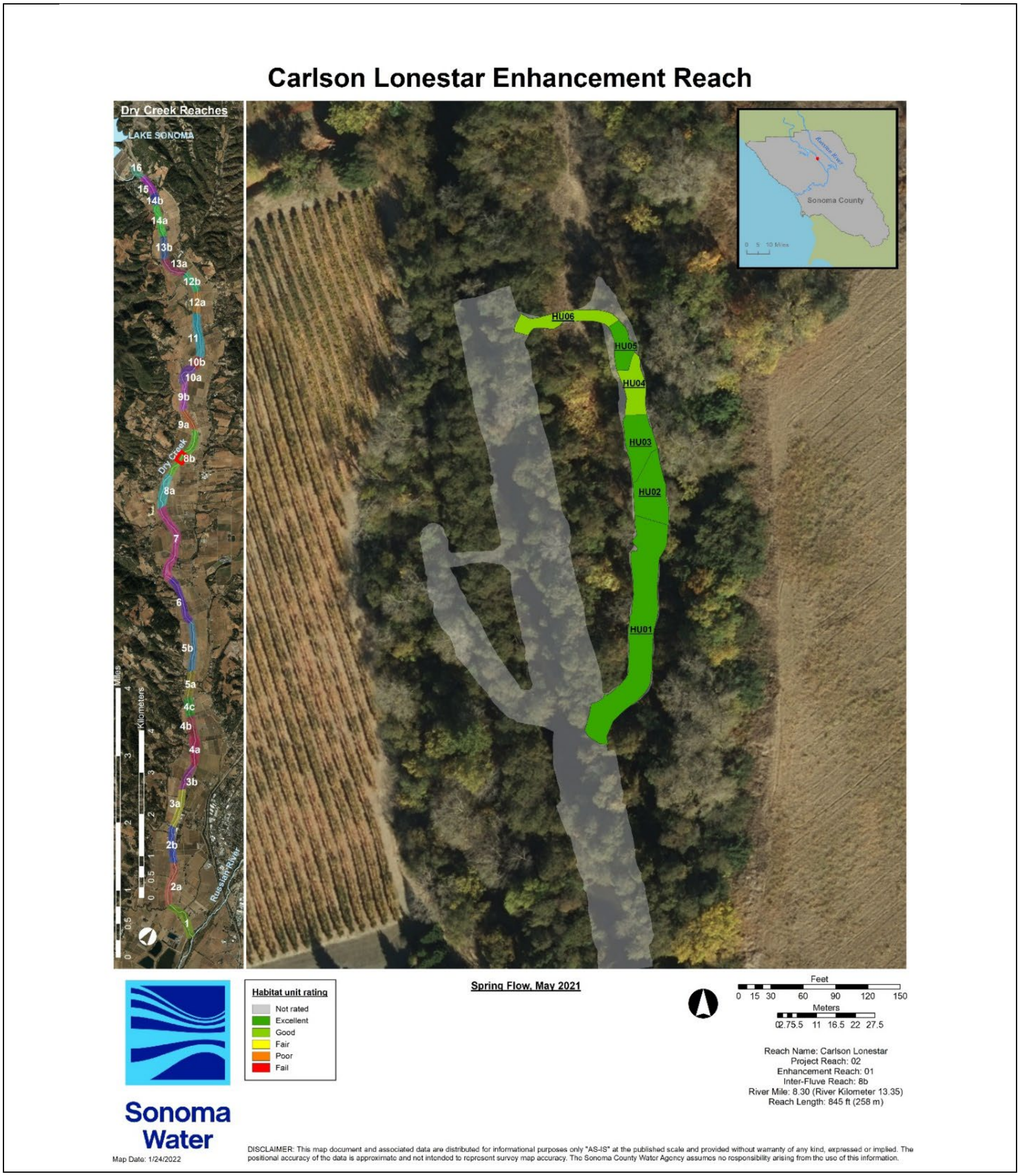

Figure 5.2.82. Habitat unit ratings for the Carlson Lonestar enhancement reach, May 2021.

Figure 5.2.83. Post-effective flow site ratings for the Carlson Lonestar enhancement reach, May 2021.

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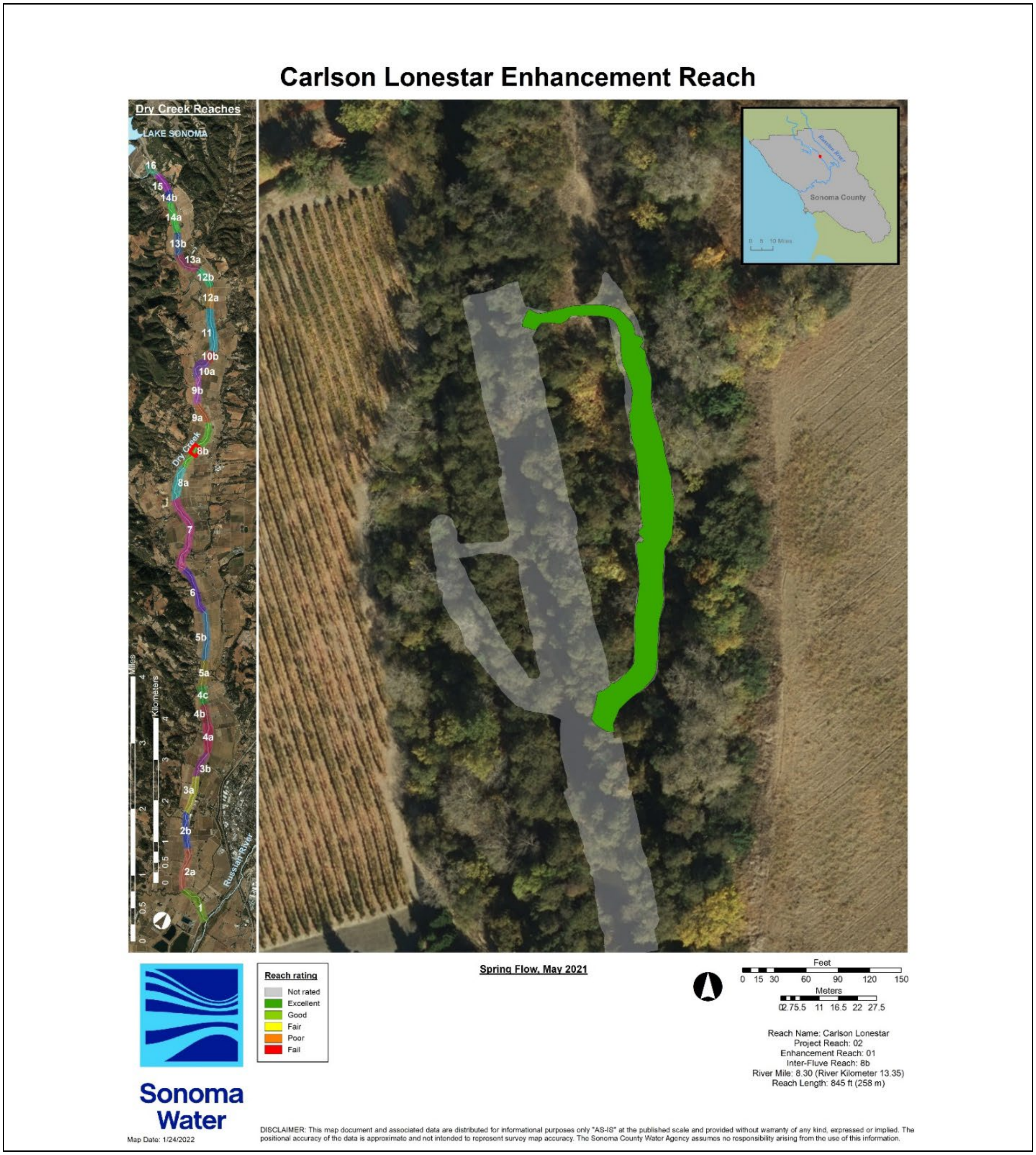

Figure 5.2.84. Post-effective flow reach rating for the Carlson Lonestar enhancement reach, May 2021.

Summary

Enhancement Reach Ratings

Qualitative ratings describe the relative success of habitat enhancement measures within enhancement sites and enhancement reaches, and determine potential future outcomes. 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 should be the most recent post-effective flow ratings. The latest post-effective flow ratings, as of 2021, show two excellent ratings, eight good ratings, three fair ratings, and one poor rating (Table 5.2.52). With 71% (10/14) of ratings either good or excellent, the AMP suggests developing and implementing plans to correct site or metric deficiencies, adding sites/features, and increasing monitoring of sites and features exhibiting negative performance (Table 5.2.2). Sonoma Water is currently implementing the above suggestions, and will continue to monitor habitat units, features, sites, and enhancement reaches according to the AMP. Any future actions will be guided by monitoring data.

Table 5.2.52. 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	2019	2020	2021	Latest post-effective flow rating
Army Corps		Excellent			Good			Good
Army Corps Reach 14					Good			Good
Weinstock					Good	Good		Good
Gallo						Good	Good	Good
Truett Hurst			Poor	Good	Fair	Good	Good	Good
Meyer			Fair	Fair			Good	Fair
Carlson Lonestar				Good			Good	Good
Quivira		Excellent						Excellent
Van Alyea			Good			Excellent		Excellent
Rued	Good							Good
Farrow Wallace			Fair		Good	Good	Good	Good
Ferrari-Carano, Olson					Fair	Fair		Fair
City of Healdsburg Yard				Good	Poor			Poor
Geyser Peak			Poor	Fair	Fair	Fair	Fair	Fair

Depth and Velocity

Effectiveness data from all monitoring time periods in 2021 showed substantial differences in the amount of optimal depth and velocity habitat between main and side channel areas, and between habitat types (Table 5.2.53). Overall, 57% of side channel area supported optimal depth and velocity, compared with 27% in main channel areas. Alcoves supported the greatest area of optimal depth and velocity, regardless of channel location (76%) followed by pools (side channel [62%], main channel [39%]) and flatwater (side channel [45%], main channel [9%]). In the main channel, the percentage of optimal depth and velocity in flatwaters and riffles was substantially lower than alcoves or pools. 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 (>0.5 f/s) and shallower depths (<0.5 ft) at low flows than the optimal depth and velocity conditions recommended by the BO or the AMP. Riffles still perform important ecological roles, such as nutrient retention and food production.

Table 5.2.53. Summary of percent optimal depth and velocity, average shelter score and pool to riffle ratio for all monitoring time periods.

Habitat Type	Side channel % optimal depth and velocity	Main channel % optimal depth and velocity
Riffle	8%	6%
Pool	62%	39%
Flatwater	45%	9%
Alcove	76%	76%
Average	**57%**	**27%**

Shelter Scores

Effectiveness monitoring data from all monitoring time periods in 2021 showed differences in average shelter score between main and side channel areas, and differences in average shelter score between habitat types (Figure 5.2.85). Overall, side channel areas supported an average shelter score of 173, compared with 114 in main channel areas. Alcoves supported the highest average shelter score in both areas, followed by pools. As with the percentage of optimal depth and velocity, average shelter score in flatwaters and riffles was lower than alcoves and pools across both channel locations, but side channel area flatwaters showed substantially higher shelter scores (186) than in the main channel (41). The results reinforce depth and velocity observations (above) that side channels and alcoves are effective at providing habitat conditions recommended in the BO and in the AMP.

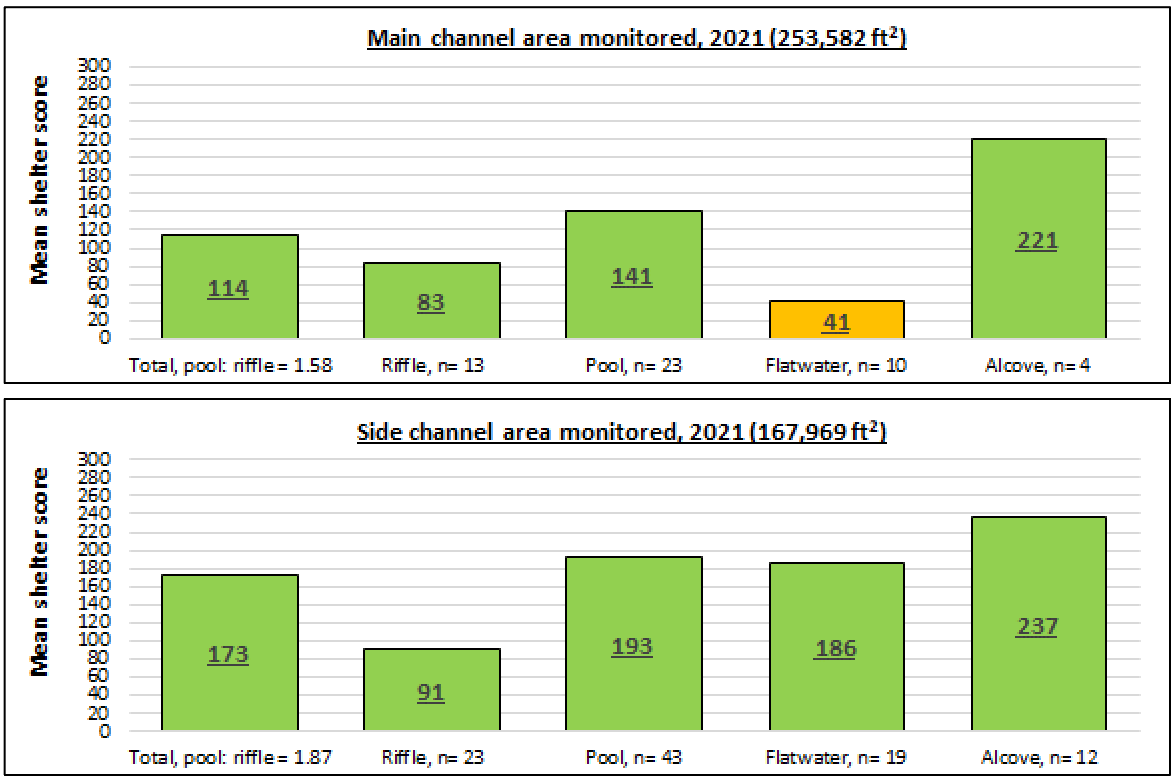

Figure 5.2.85. Average shelter scores within main channel areas (top panel), and side channel areas (lower panel), and across riffle, pool, flatwater, and alcove habitat type.

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Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 2010. California Salmonid Stream Habitat Restoration Manual. Fourth Edition. State of California, the Resources Agency, California Department of Fish and Game, Wildlife and Fisheries Division.

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National Marine Fisheries Service (NMFS). 2008. Endangered Species Act Section 7 Consultation: 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 Improvement District in the Russian River Watershed. Issued September 24, 2008.

Porter, M. D., D. M. Marmorek, D. Pickard, and K. Wieckowski. 2014. Dry Creek Adaptive Management Plan (AMP), Version 0.93. Final document prepared by ESSA Technologies Ltd., Vancouver, BC for Sonoma County Water Agency, Santa Rosa CA. 33 pp. + appendices.

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 2021. These data are part of an ongoing pre- and post-construction monitoring efforts 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 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 observations of Coho in the backwaters and side channels during surveys and observations on PIT antennas within habitat enhancement sites. In 2021 we conducted targeted releases of approximately 50,000 juvenile Coho Salmon in Dry Creek, similar to the phased releases conducted in 2020.

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 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).

Juvenile Coho Salmon hatchery releases

Given the success of the 2020 Coho Salmon broodstock hatchery releases in Dry Creek and the continued dry conditions in tributary streams, the Russian River Coho Salmon Broodstock Committee decided to release approximately 30,000 Coho juveniles in the spring and 20,000 Coho juveniles in the fall of 2021 into Dry Creek. Similar to 2020, Coho juveniles were held in net pens prior to being released into the stream. Net pens were located in the Army Corps Reach 14 (rkm 21.15), Weinstock (rkm 20.62), Gallo (rkm 20.34), and Meyer (rkm 13.88) side channels (Figure 5.3.1). Due to limitations of space and time constraints, approximately 6,000 juveniles from the spring release were placed directly into the Truett Hurst constructed side channel rather than being held in nets pens. Fifteen percent of all Coho were PIT tagged at the hatchery prior to release.

Each net pen was composed of a 12’ X 4’ X 4’ net with ¼” mesh was suspended inside a rigid pen anchored to the bottom of the channel. The net was equipped with a zipper opening to facilitate releasing fish into the net pen and removing fish from the net pen for release into the stream. Spring releases occurred from June 30 to July 21 and fall releases occurred from September 21 to October 26, 2021 (Table 5.3.2). Each release group was held inside the net pens for 3-7 days (median 6 days) before opening the net so they could enter the side channel. The next release group was added to the net pen the following day after the earlier group had left the net pen. If fish remained in the open net pen the following day a diver cleared the fish from the net pen before the next group was released into the net pen.

Residency time and survival

For juvenile Coho Salmon released into constructed off-channel habitats in Dry Creek, we evaluated three metrics: 1) Dry Creek residency time; 2) survival from tagging to the smolt stage at the mouth of Dry Creek; 3) smolt migration survival from the confluence of Dry Creek with the Russian River (rkm 51.64) to the Mirabel dam (rkm 28.14) approximately 24 km downstream. Based on PIT detections near the mouth of Dry Creek, we evaluated Dry Creek residency time as the number of days between release and detection on the stationary PIT antenna located at the mouth of Dry Creek (rkm 0.36) plus PIT-tagged smolts captured at the Dry Creek smolt trap (rkm 3.30). We assumed that the latest detection date of an individual at rkm 0.36 or 3.30 meant that it was leaving Dry Creek.

We were able to use a formal mark-recapture model to estimate survival. The encounter history for the mark recapture input file consisted of 4 encounters: 1) an encounter for release; 2) an encounter for PIT antenna detection at the mouth of Dry Creek (operated year-round); 3) an encounter for PIT antenna detection at the Mirabel dam (operated from April 7 to the end of the smolt emigration season); 4) an encounter for detection at the Mirabel downstream migrant trap (operated from April 7 to the end of the smolt migration season). Survival between the Mirabel PIT antenna and the Mirabel downstream migrant trap (a distance of less than 1 meter) was assumed to equal 1. This resulted in two survival estimates corresponding to the two periods of interest.

Table 5.3.2. Details for 2021 Coho Salmon juvenile spring and fall releases from Warm Springs Hatchery into Dry Creek.

Site	River km	Net pen date	Stream release date	Number of Coho released
Army Corps 14 side channel, net pen	21.15	Jun 30 Jul 8 Jul 15 Sep 21 Oct 20	Jul 7 Jul 14 Jul 21 Sep 28 Oct 26	4,082 4,082 4,082 2,523 2,524
Weinstock side channel, net pen	20.62	Jun 30 Jul 8 Jul 15 Sep 21 Oct 20	Jul 7 Jul 14 Jul 21 Sep 28 Oct 26	2,055 2,055 2,055 2,523 2,523
Gallo side channel, net pen	20.34	Jun 30 Jul 8 Jul 15 Sep 21 Oct 20	Jul 7 Jul 14 Jul 21 Sep 28 Oct 26	2,048 2,008 1,994 2,523 2,523
Meyer side channel, net pen	13.88	Sep 21 Oct 20	Sep 28 Oct 26	2,522 2,524
Truett-Hurst side channel	14.01		Jun 30 Jul 8	3,048 3,075
Total				**50,769**

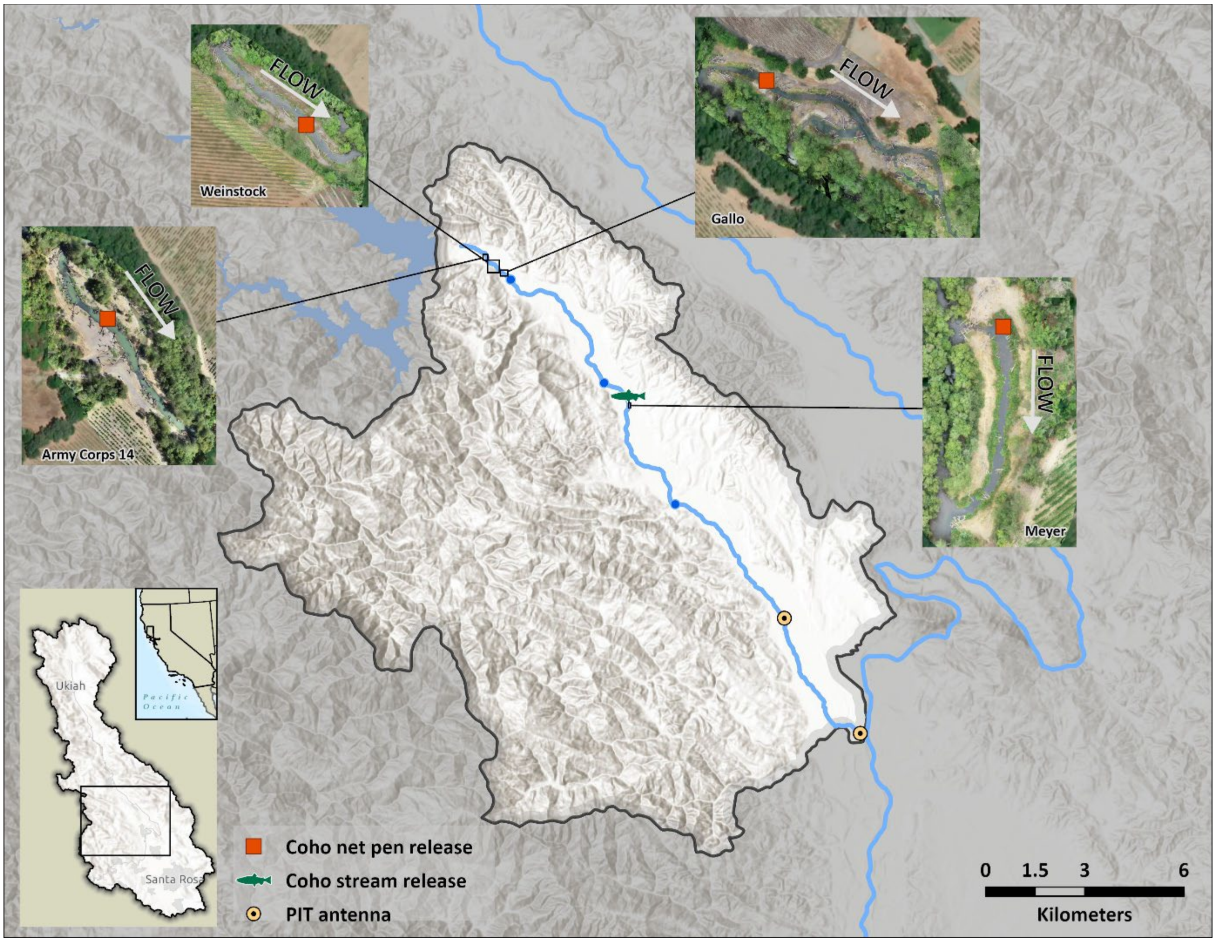


Figure 5.3.1. Location of Coho broodstock juvenile release locations in Dry Creek in 2021. Net pens were located in four constructed side channels (red squares), releases directly into the stream were located in one constructed side channel (green fish) and in-stream PIT antennas were located at river km 5.0 and the mouth of Dry Creek (yellow circles). Blue circles indicate a distance of 5 km along the stream channel.

Habitat utilization

To evaluate habitat use of juvenile salmonids in constructed off-channel habitats along mainstem Dry Creek, Sonoma Water has been operating PIT antennas for a number of years (Figure 5.3.2). During the reporting period, we did not conduct any evaluations of habitat utilization by natural-origin juvenile salmonids in the constructed off-channel habitats. However, we did operate PIT antennas near the mouth of Dry Creek and at rkm ~0.5 for the purpose of evaluating releases of juvenile Coho Salmon in side-channels.

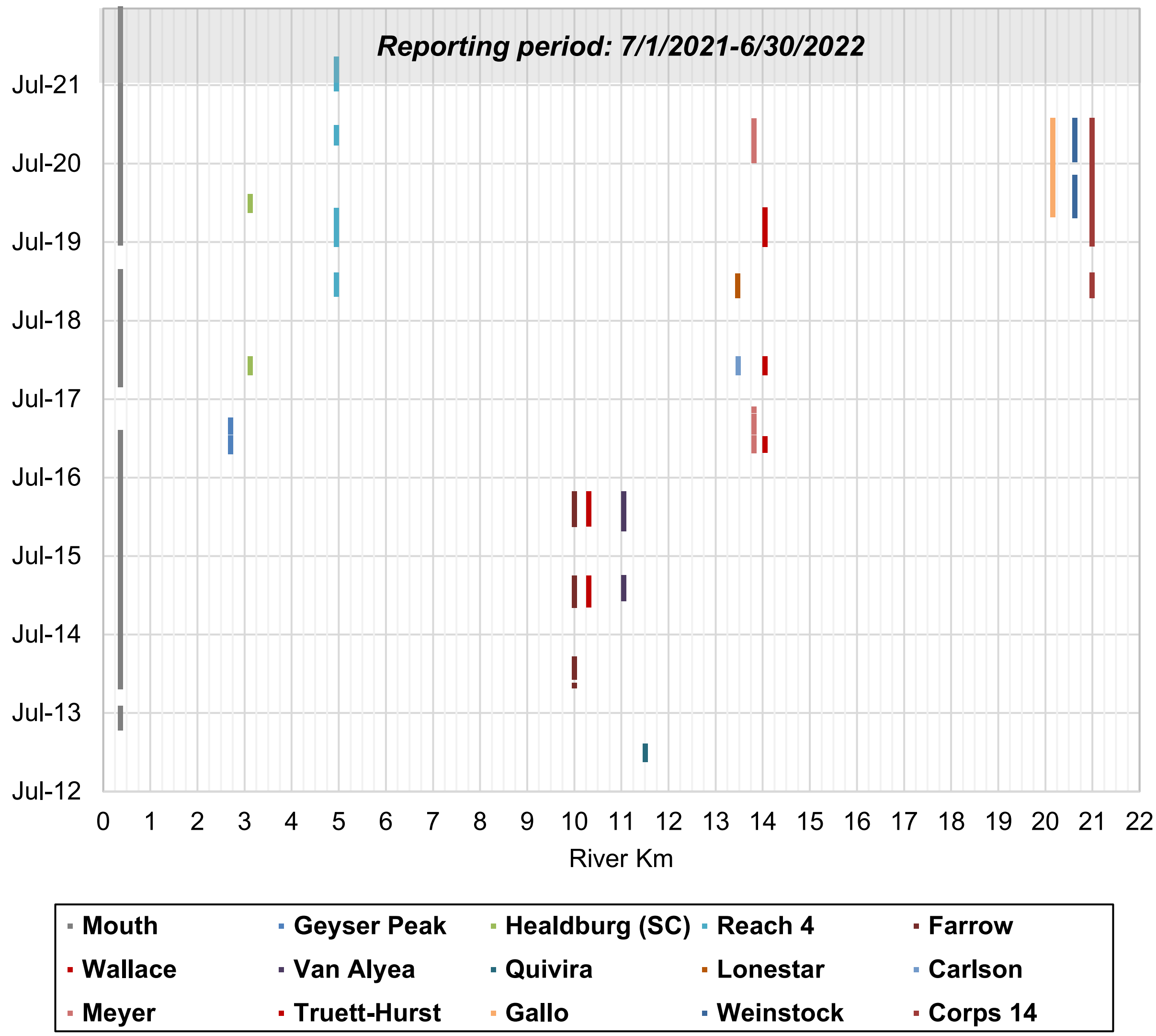


Figure 5.3.2. Period of operation of PIT antennas, July 2012-June 2022 in constructed habitats. Note that the downstream-most antenna near the mouth of Dry Creek (rkm 0.36) is not in constructed habitat and, in some years, the antennas at rkm ~0.5 were in constructed habitats while in other years they were not.

Late summer population density

Site-scale sampling

We conducted sampling to estimate population density in the Truett Hurst (rkm 14.01), Gallo (rkm 20.23), Weinstock (rkm 20.48) and Army Corps Reach 14 (rkm 21.02) constructed side channels in the summer of 2021. A depletion method was used for the Truett Hurst side channel, relying on block nets to temporarily close two sections of the side channel for sampling. Multiple electrofishing passes were conducted through each section on the same day. In order to estimate local population abundance, all fish captured on each pass were counted and temporarily "removed" from the stream by holding them in live cars while subsequent passes were conducted. A seine net was used to sample the Gallo and Army Corps Reach 14 side channels since they were too deep to sample with backpack electrofishers. For the Gallo site a seine was used to make multiple passes on the same sampling event, through a portion of the site isolated by a downstream block net. In the Army Corps side channel sampling was conducted with a single seine pass through a portion of the 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 marked with a PIT tag, released near their capture location, and subject to recapture on day 2. A similar two-pass mark-recapture method was used in the Weinstock side channel, but backpack electrofishing was used, rather than a seine net. We used the Petersen mark-recapture model in Program MARK (White and Burnham 1999) to estimate end-of-summer abundance ($\widehat{N}$). Density estimates were calculated as the quotient of $\widehat{N}$ and wetted area of the sample 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 other factors. To overcome this we sought to place our results in a broader context. We sampled each of the three geomorphically-based reaches identified by Inter-Fluve (2011). Similar to 2020, electrofishing surveys were paired with snorkel surveys to calculate a calibration ratio that would allow us to expand snorkel counts into a population estimate for longer stream sections. This is a modification of the basin wide visual estimation technique of Hankin and Reeves (1988). We have successfully used a similar method in smaller tributary streams as part of CMP life cycle monitoring (Sonoma Water 2020). The ability for divers to sample areas in mainstem Dry Creek that are not suitable for electrofishing is the primary benefit for sampling in this manner. Secondarily, this sample method reduced the number of staff required to work closely together and the frequency of our activities, helping to accommodate the COVID safety protocols in place.

First stage sampling consisted of single pass snorkel sample conducted by three divers swimming side-by-side downstream. Visual identification was used to record the total number of juvenile salmonids by species observed in each of three lanes encompassing the wetted width of the stream channel. Three sections were snorkeled, one each in the lower, middle, and upper reaches. The total length of snorkeled sections varied between 413 and 917 meters. Snorkeled sections were further sub-divided into units that would later be sampled with electrofishing. Electrofishing surveys occurred within 0-7 days of the snorkel surveys. The average ratio of steelhead parr recorded during snorkel and electrofishing surveys was calculated as the calibration ratio. This ratio was then applied to the total snorkel counts of steelhead parr for each snorkeled section to calculate an estimate for the total steelhead parr in that section. Density estimates were calculated as the quotient of $\widehat{N}$ and area of the site.

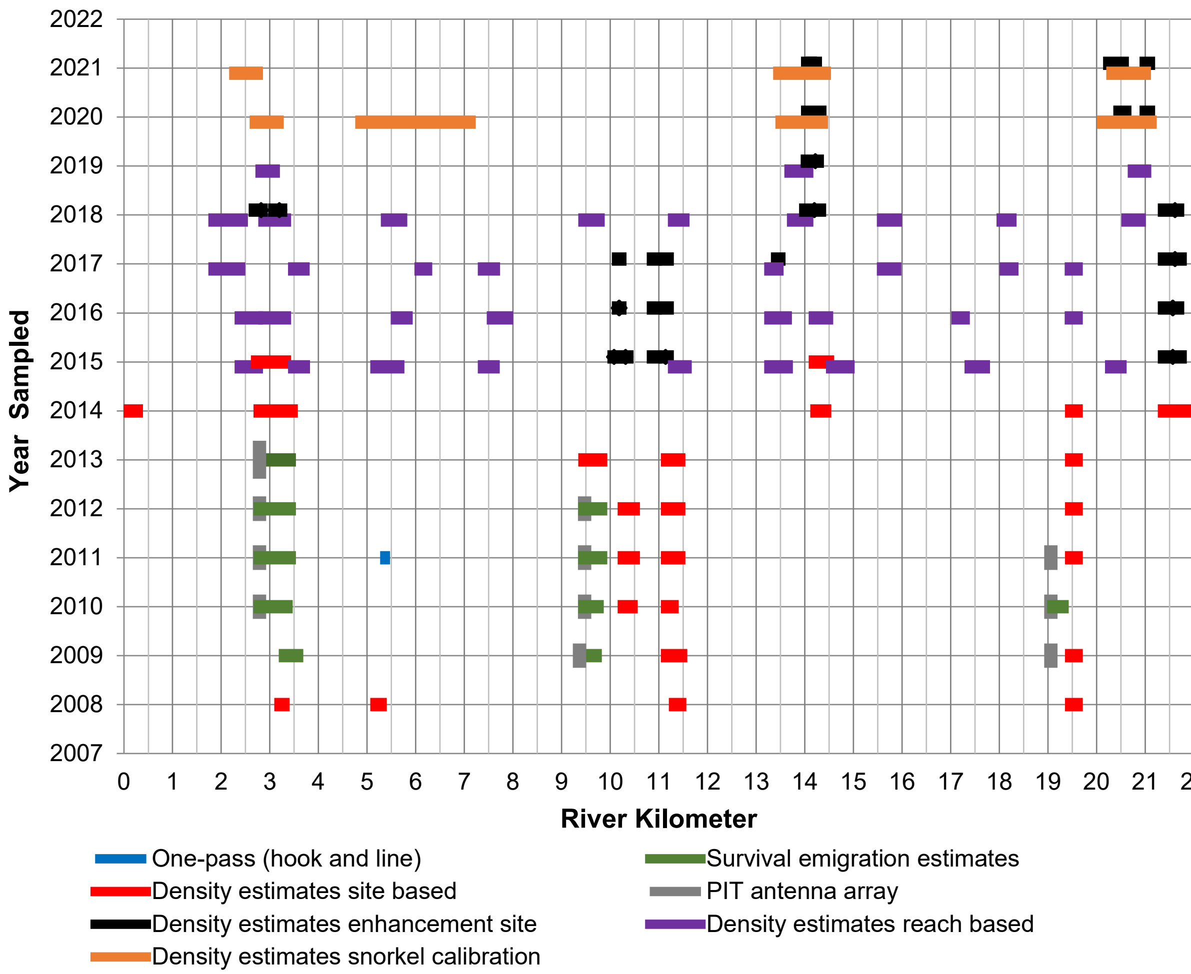


Figure 5.3.3. Years sampled and river kilometer (from the mouth) where juvenile steelhead populations were sampled in mainstem Dry Creek, 2008-2021. Line length for each site is scaled to the length of stream sampled. Data collected at the site scale were analyzed using mark-recapture (either a multiple-pass 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 subsample of each species was anesthetized and measured for fork length (±1 mm) each day, and a subsample of salmonid species was weighed (±0.1 g) 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.

Coho Salmon

Because of the small numbers of Coho Salmon smolts captured in the Dry Creek trap, a population estimate is not possible based on mark-recapture methods available for Chinook Salmon smolts. Therefore, we report trap catch as the minimum count in the Dry Creek trap each year.

Chinook Salmon

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. An upper caudal fin clip was used to mark fish. Marked 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 is based on the period of time that fish were marked and recaptured (March 24--June 24).

Steelhead

Much of the steelhead smolt migration period occurs prior to the time the migrant trap can safely be installed and operated in mainstem Dry Creek; therefore, the catch of steelhead smolts in the trap does not adequately account for the abundance of steelhead smolt emigrating from Dry Creek. To account for this discrepancy, we employed a pre-smolt abundance model that relied on backpack electrofishing in the late summer/early fall and year-round, stationary PIT antenna monitoring to estimate smolts and/or juvenile steelhead leaving Dry Creek. To estimate the number of steelhead emigrants leaving Dry Creek in the 2021 smolt season we relied on the detection of marked individuals on the antenna array located at the mouth of Dry Creek (rkm 0.36). In the absence of trapping and handling steelhead to determine which individuals are smolts, steelhead were classified as smolts if they were detected leaving Dry Creek during the period from November 1, 2020, through June 30, 2021. Based on empirical observations of juvenile steelhead growth, it is reasonable to assume that all or most of these individuals could have reached a size large enough to smolt by the following late winter/early spring.

Juvenile steelhead were PIT tagged in the summer of 2020 during electrofishing surveys in the mainstem of Dry Creek and the Army Corps Reach 14 side channel. The proportion of these individuals that were detected leaving Dry Creek as smolts in 2021 was calculated as a "survival" index, corrected for antenna efficiency. The survival index (si) was then applied to the estimate of juvenile steelhead density ($fish * m^{-1}$) multiplied by the total reach length ($length_r$) to calculate an estimate for the number of smolts from Dry Creek in 2021 ($\hat{Y}$).

$$\hat{Y} = \sum_{i=1}^{r} si(length_r * (fish * m^{-1}))$$

Results and Discussion

Juvenile Coho Salmon hatchery releases

A paired array of antennas was operated at the mouth of Dry Creek from July 1 through October 24, 2021, however, after this point the upper portion of the array was compromised due to a high flow event (Figure 5.3.4). A swim through antenna was operating in the westside Mirabel fish ladder for a brief period in the fall of 2021 and again in the spring of 2022 coinciding with the majority of the Coho smolt emigration season (Figure 5.3.4).

Spring release group

A total of 24,461 Coho juveniles were released into one of four net pen enclosures located within constructed side channels from July 7 through July 21, 2021 (Table 5.3.2). Releases were staged in three groups approximately one week apart with approximately 2,000 Coho released into the enclosers at one time, with each group being held in the net pens for 6 to 7 days before the nets were opened to allow volition release from the pens. Also, during the spring release, a total 6,123 Coho juveniles were release directly into the Truett-Hurst constructed side channel in two groups, on June 30 and July 8, 2021. For the spring release group, the median time of detection at the mouth of Dry Creek was between 298 and 301 days post-release, occurring in May 2022 (Figure 5.3.5).

Of the 4,526 PIT tagged Coho Salmon released in selected side channels in the spring, 208 fish were detected either leaving Dry Creek or in the mainstem of the Russian River during the subsequent smolt migration season, defined as March 1 through June 30, 2022. Only three fish were detected leaving Dry Creek prior to March 1, 2022 (Figure 5.3.5). Estimated percent number of Coho released in the spring detected during the smolt emigration period at Dry Creek ranged from 2% to 5%, while the estimated percent number detected for the same release group to the Mirabel Dam (during antenna operation of April 7 – June 30) was 1% to 4% (Figure 5.3.6).

Fall release group

A total of 20,185 Coho juveniles were released into one of four net pen enclosures located within constructed side channels from September 21 through October 20, 2021 (Table 5.3.2). Releases were staged in two groups approximately four weeks apart with approximately 2,523 Coho released into the enclosers at one time, with each group being held in the net pens for 6 to 7 days before the nets were opened to allow volition release from the pens. The median time of detection at the mouth of Dry Creek was between 196 and 208 days post-release, occurring in April and May, 2022 (Figure 5.3.5).

For the fall release of the 3,073 PIT tagged Coho released into side channels 160 were detected either leaving Dry Creek or in the mainstem of the Russian River during the subsequent smolt migration season. Only seven fish were detected leaving Dry Creek prior to March 1, 2022 (Figure 5.3.5). Estimated percent number of Coho released in the fall detected during the smolt emigration period at Dry Creek ranged from 2% to 5%, while the percent number detected for the same release group to the Mirabel Dam (during antenna operation of April 7 – June 30) was 2% to 3% (Figure 5.3.6).

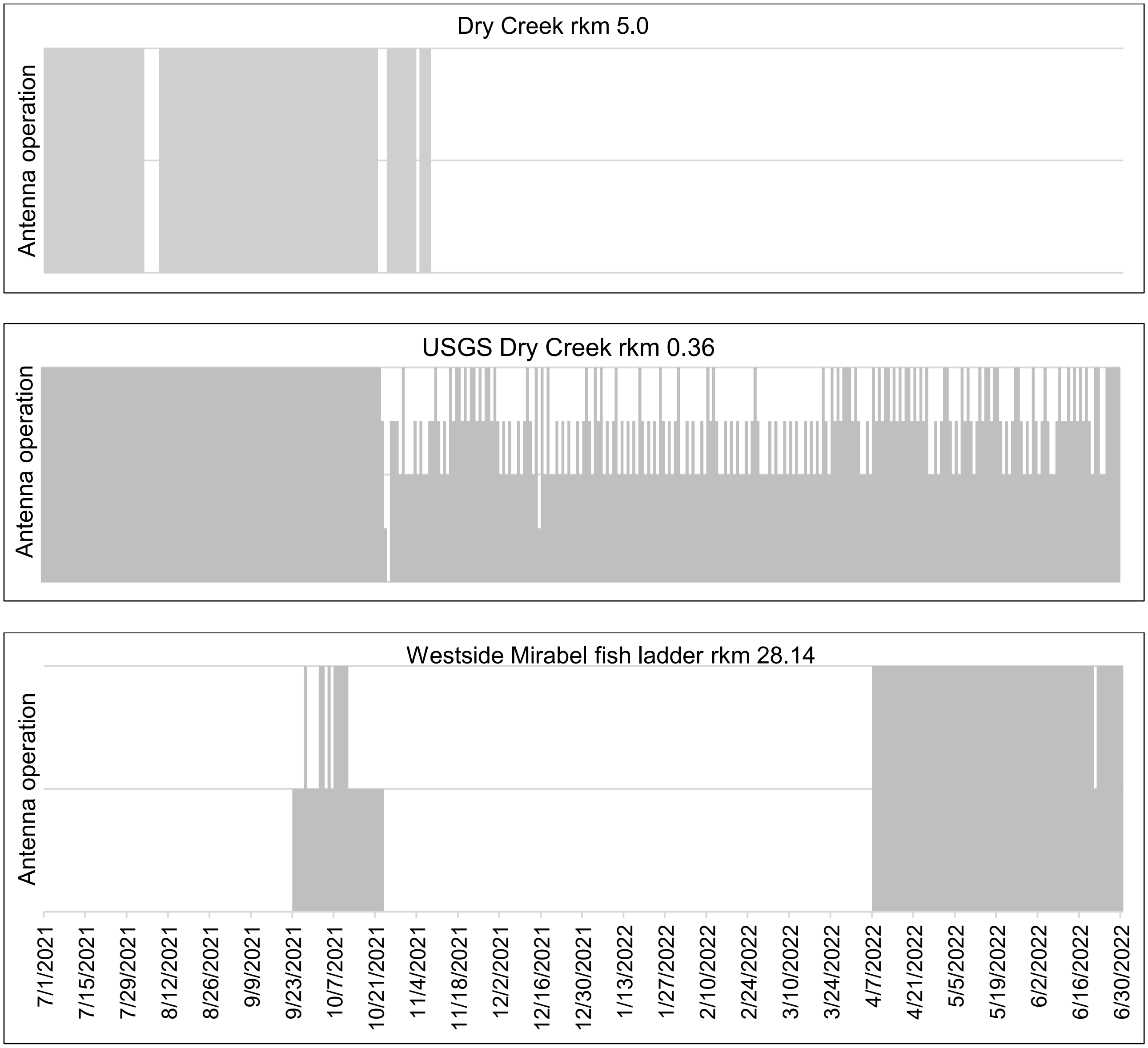
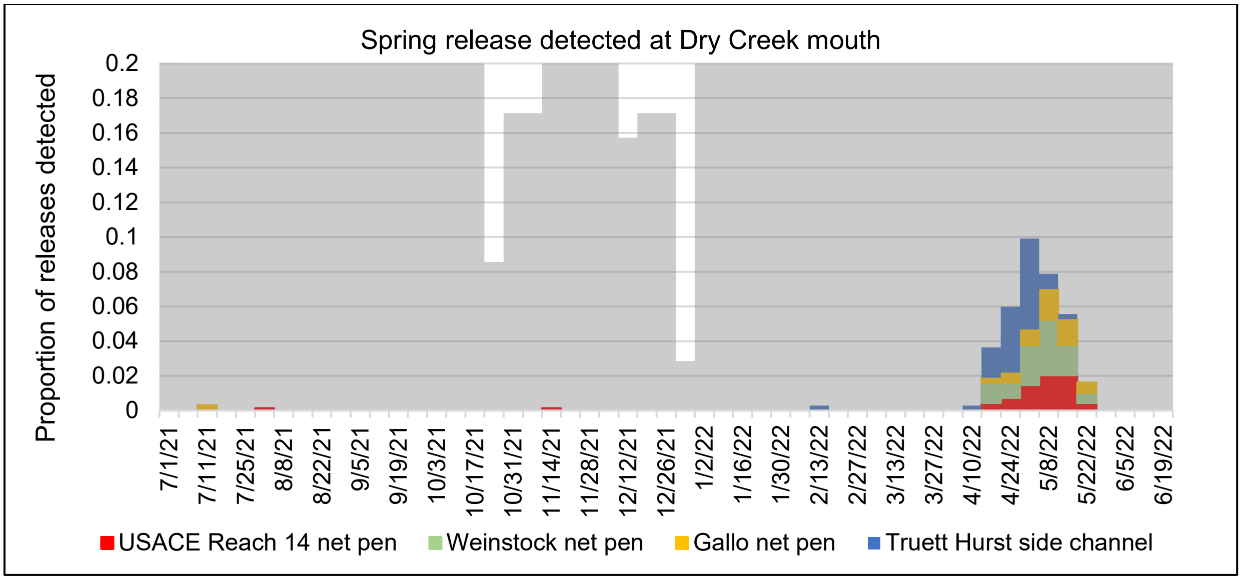


Figure 5.3.4. Antenna operation in lower Dry Creek, the mouth of Dry Creek, and Mirabel fish ladder (Wohler dam) for the period of July 1, 2021 through June 30, 2022. The grey shading indicates the period that antennas were operating during the reporting period.



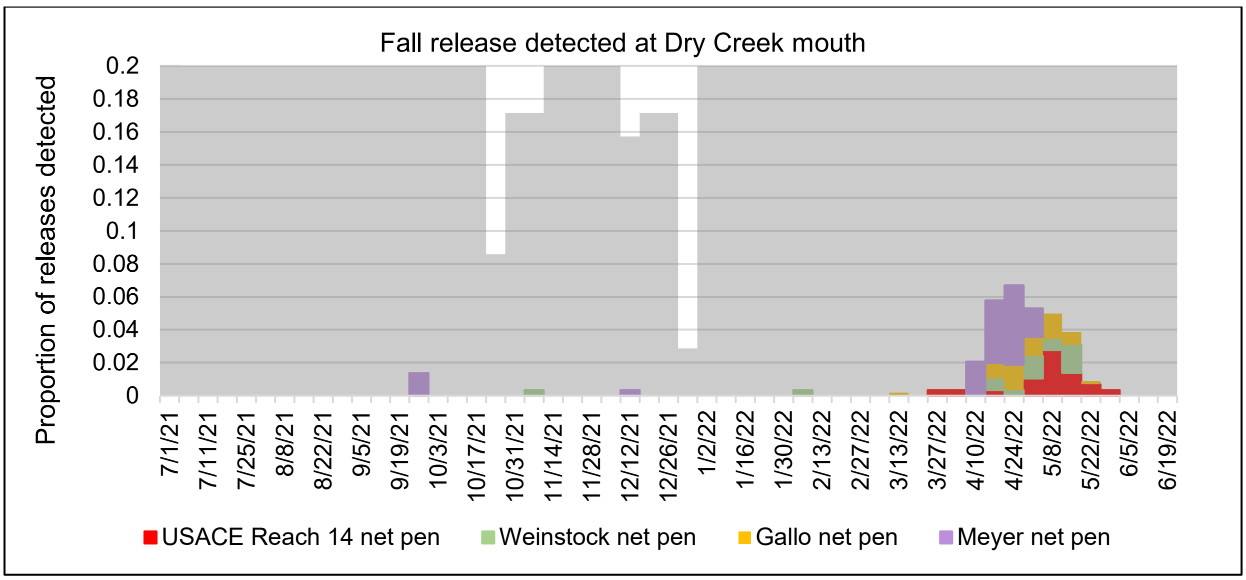


Figure 5.3.5. Proportion of hatchery Coho salmon released into Dry Creek enhancement areas that were subsequently detected at the antenna array located at the mouth of Dry Creek in 2021-2022. The grey shading indicates the period that antennas were operating during the reporting period.

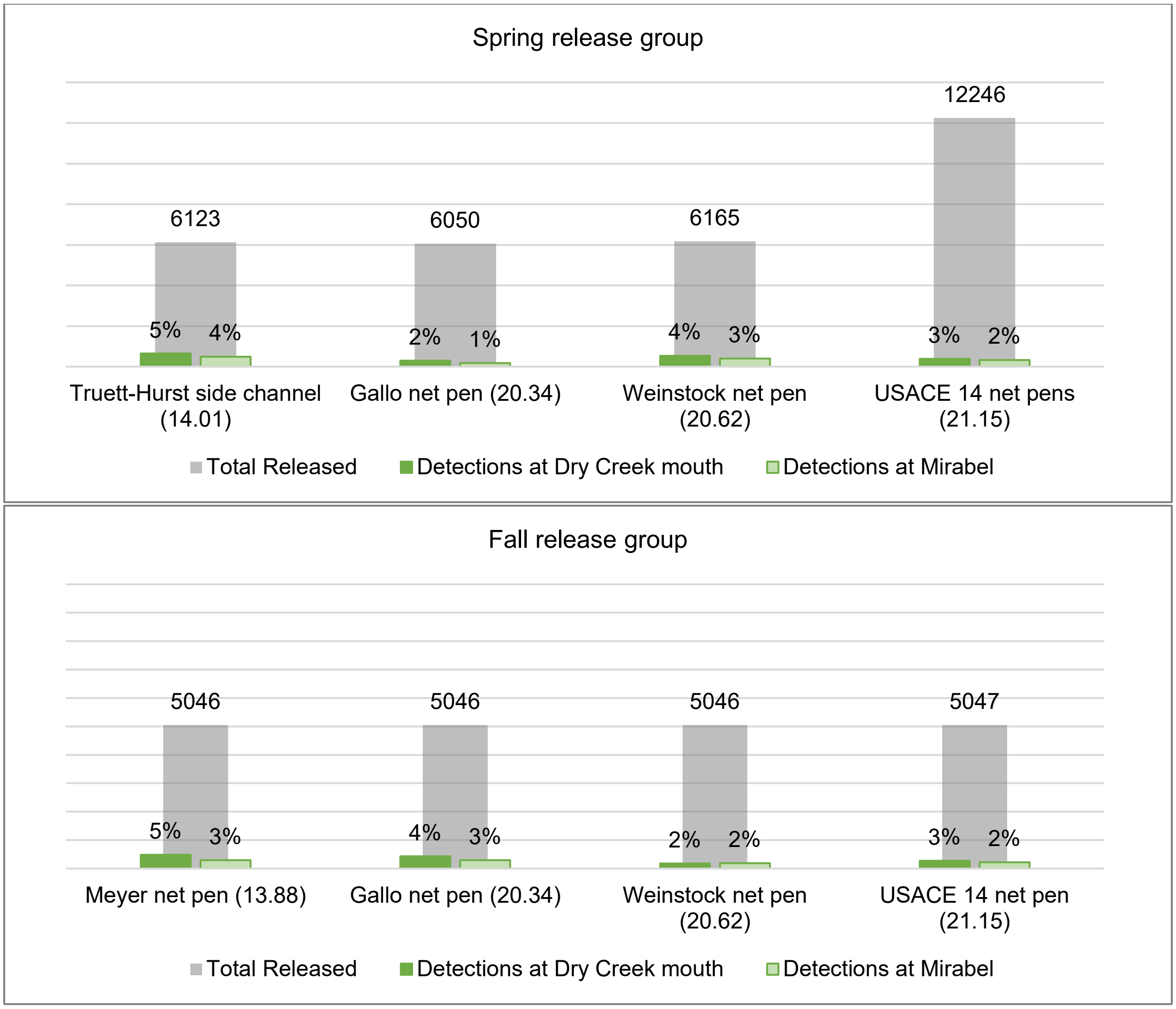


Figure 5.3.6. Estimated percent number of Coho hatchery juveniles released in Dry Creek in 2021 that were detected during the subsequent smolt emigration period at the mouth of Dry Creek (March 1 – June 30) and at the Mirabel dam on the Russian River (April 7 – June 30), by release season and location.

Coho smolt survival estimate

The estimated probability of survival for hatchery-origin juvenile Coho Salmon between release into Dry Creek off-channel habitat and smolting the following spring was low for the 2021 release year for fish released in the spring ($\hat{S}$ = 0.06, 95% confidence limits 0.05 and 0.07) and fall ($\hat{S}$ = 0.11, 95% confidence limits 0.09 and 0.14). Estimated mainstem smolt migration survival from the mouth of Dry Creek to the Mirabel dam was also low for spring, $\hat{S}$ = 0.41 (95% confidence limits 0.30 and 0.52), and fall, $\hat{S}$ = 0.34 (95% confidence limits 0.26 and 0.44), and for both seasons estimated survival for the 2021 release year was slightly lower than 2020 release year (Figure 5.3.7). Notably, in both years the PIT antennas and downstream migrant trap at Mirabel were not installed until the first week in April meaning that an unknown number of Coho smolts passed the dam before installation and were therefore not detected. This likely resulted in a biased downward estimate of survival for both release years.

We suspect that flow may partially explain the difference in survival between years in Dry Creek. An early rain event spiked flows in Dry Creek to 2,770 ft^3/s on October 25. The very next day, 50% of the fish were released. Despite these fish being held in net pens prior to release, we suspect that those that did flee side channels and associated low velocities suffered high mortality. The supposition that a relatively high proportion of fall releases left the side channels is supported by the observation that for fall releases, a proportion 10 times higher than the spring releases were detected on a main channel Dry Creek PIT antenna at river km 5.0 approximately 15 km downstream of the release side channels (Figure 5.3.1, Figure 5.3.2).

We also suspect that flow may partially explain the difference between years in Coho smolt migration mortality from the mouth of Dry Creek to the Mirabel dam. Even though the inflatable dam was raised during the detection period for both release years, there was a substantial rain event during the third week of April 2022 that resulted in significant spill over the dam that did not occur in spring 2021. This likely resulted in a biased downward estimate of survival that was not present in 2020.

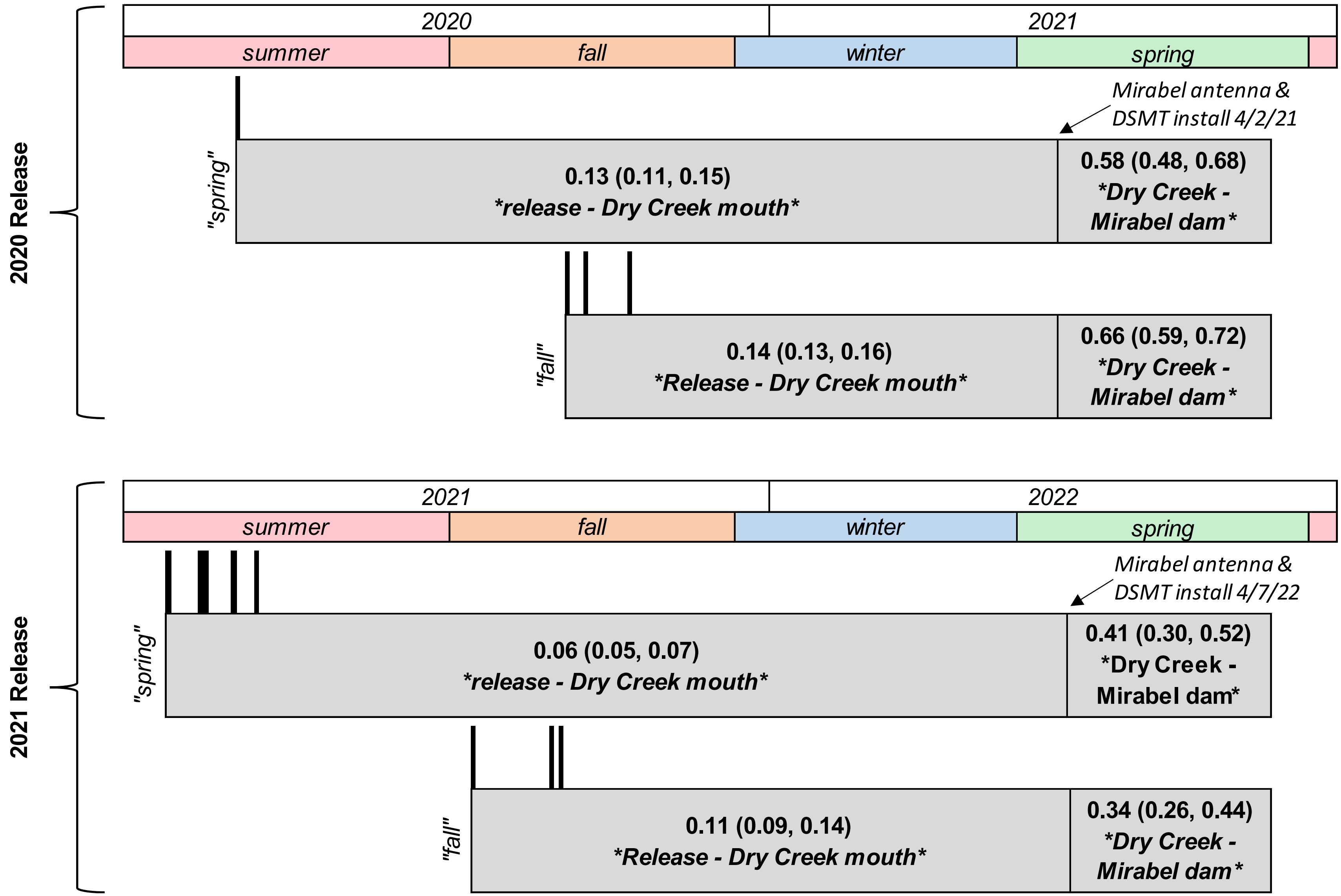


Figure 5.3.7 Estimated Coho Salmon survival from juvenile release to Dry Creek mouth (juvenile to smolt survival) and Dry Creek mouth to Mirabel dam (smolt migration survival) for release cohorts 2020 and 2021. Solid black bars represent release dates.

Late summer population density

Site-scale sampling

The estimated density of juvenile steelhead was greatest in the Truett Hurst side channel (Table 5.3.6). In 2021, since electrofishing was conducted after the release of over 30,000 juveniles in July, we were able to calculate a density for Coho in the Truett Hurst and Army Corps Reach 14 side channels (Table 5.3.3). However, we also encountered a number of non-hatchery origin Coho juveniles in each side channel sampled during the late summer (Table 5.3.3).

Reach-scale sampling

The average density of juvenile steelhead in mainstem sections was 0.10 fish*m^{-2} (range 0.03 fish*m^{-2} to 0.18 fish*m^{-2}). When averaged for all sites within a year, densities in 2021 were the same as the thirteen-year average from 2008-2020 (0.20 fish*m^{-2}). While lower than the previous year, the average population density for enhanced sites was greater than for un-enhanced sites (Figure 5.3.8).

Table 5.3.3. Density of steelhead and Coho juveniles and total non-hatchery-origin Coho in constructed enhancement side channels sampled in the summer 2020. Density of Coho include hatchery and non-hatchery origin individuals.

Enhancement site	River km	Steelhead density (fish * m^{-2})	Coho density (fish * m^{-2})	Number non-hatchery origin Coho observed
Truett Hurst	14.06	0.46	0.30	7
Weinstock	20.48	0.32	NA	3
Army Corps Reach 14	21.02	0.12	0.46	33

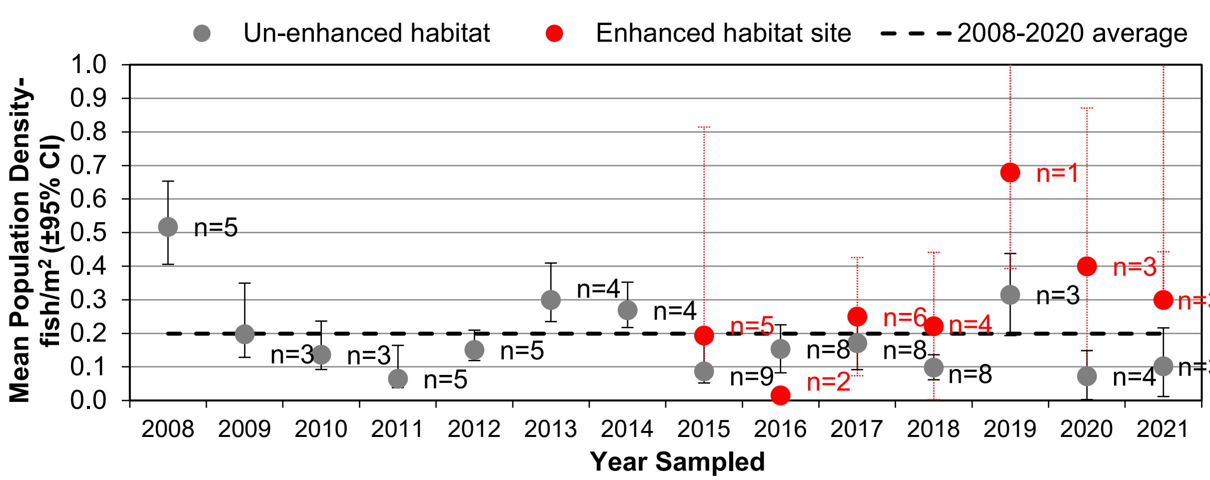


Figure 5.3.8. Mean juvenile steelhead density among all sites sampled within a year in mainstem Dry Creek, 2008-2021. "n" refers to the number of sites sampled per year.

Smolt abundance

We installed the rotary screw trap on March 23 (Figure 5.3.9). 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.

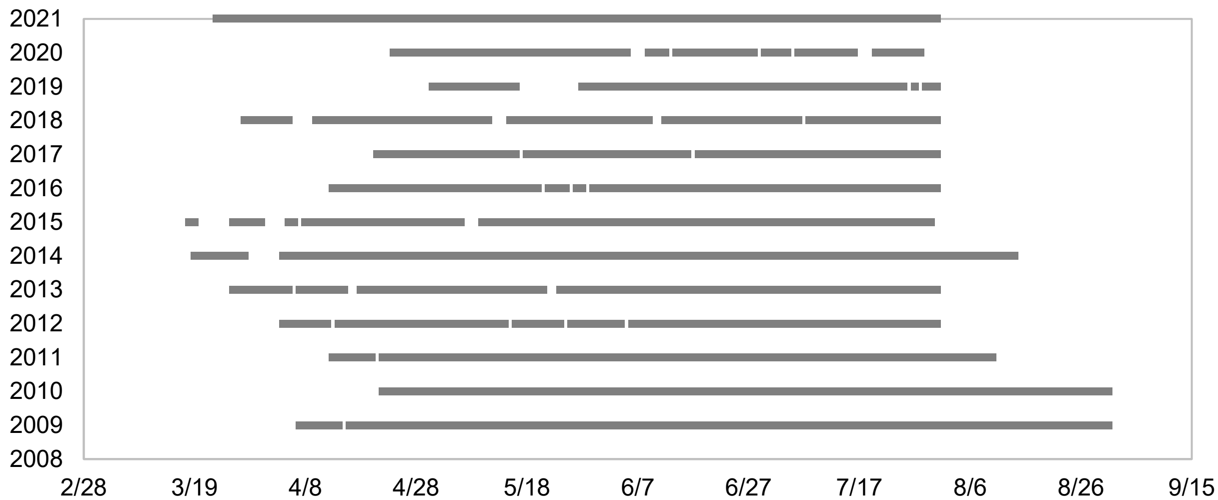


Figure 5.3.9. Begin and end dates and data gaps (spaces in lines) for operation of the Dry Creek downstream migrant trap, 2009-2021.

The peak capture of Chinook Salmon smolts (267) occurred during the week of 4/16 (Figure 5.3.10). Based on the estimated average weekly capture efficiency (range: 5% to 40%), the resulting population size of Chinook smolts passing the Dry Creek trap between March 23 and June 24 was 68,533 (±95% CI: 9,788, Figure 5.3.11).

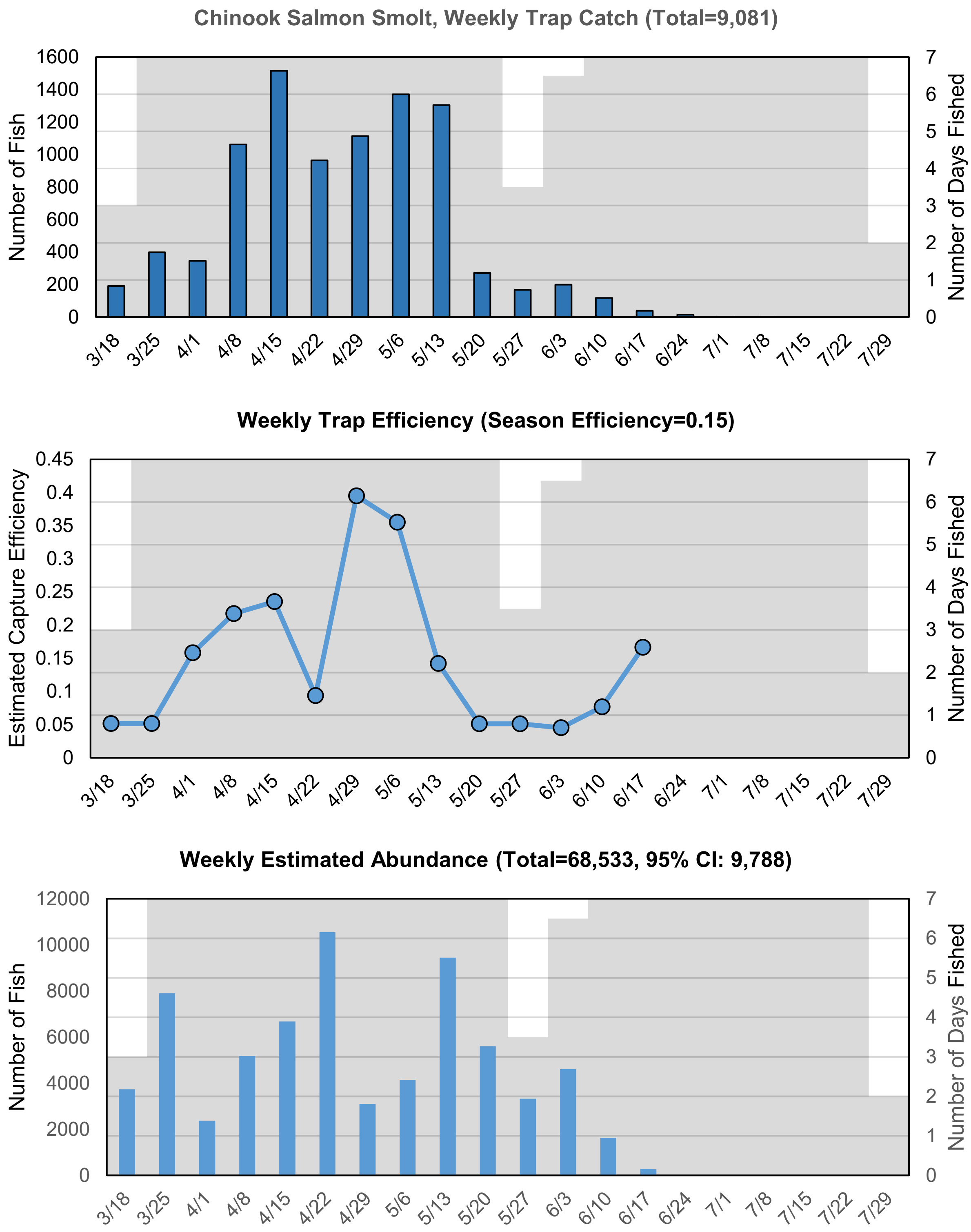


Figure 5.3.10. Weekly trap catch (upper panel), estimated average weekly capture efficiency (middle panel) and population estimate of Chinook Salmon smolts in the Dry Creek rotary screw trap (lower panel), 2021. Estimates are from DARR (Bjorkstedt 2005). The number of days each week the trap was fished is represented by the shaded area.

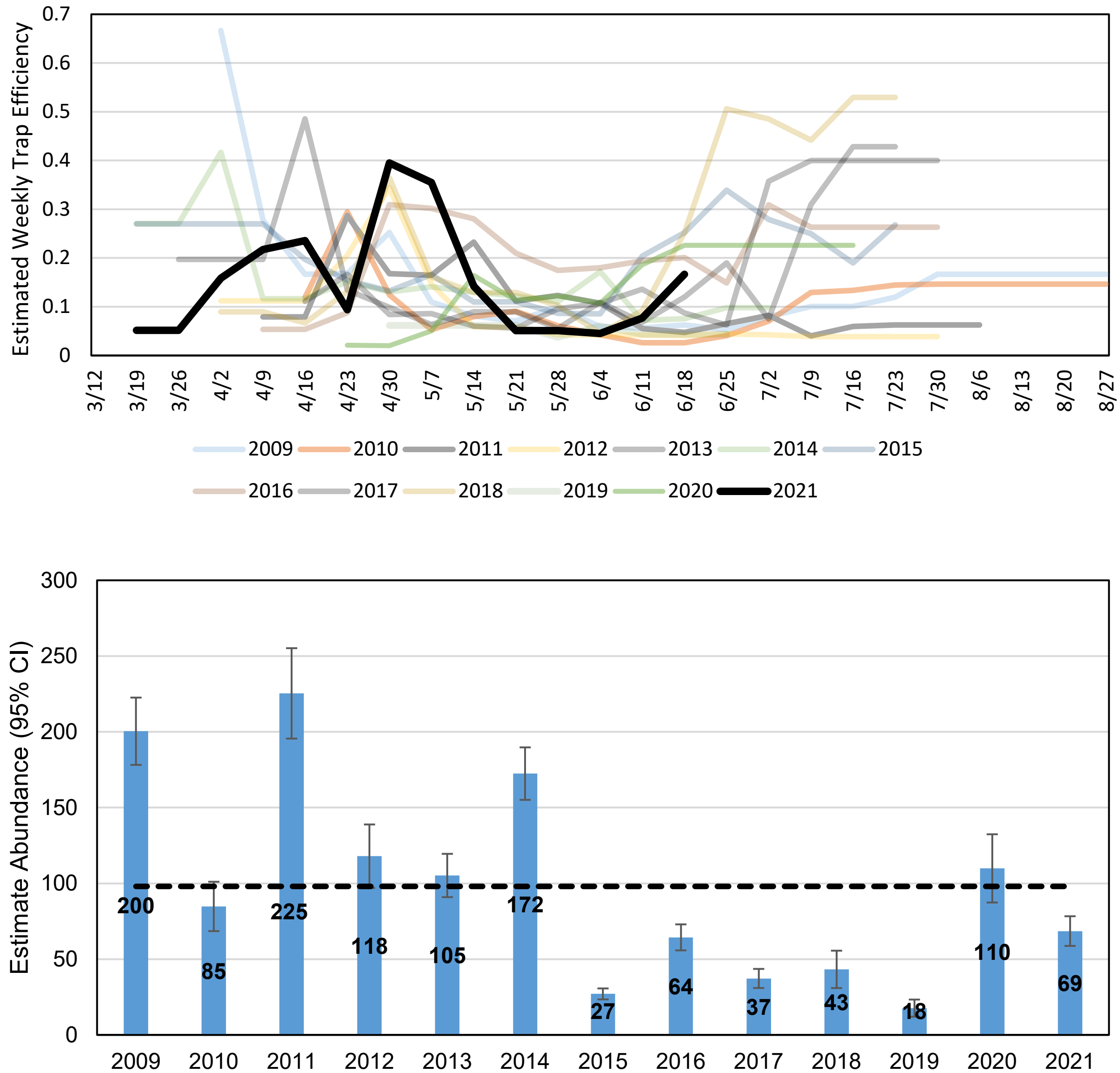
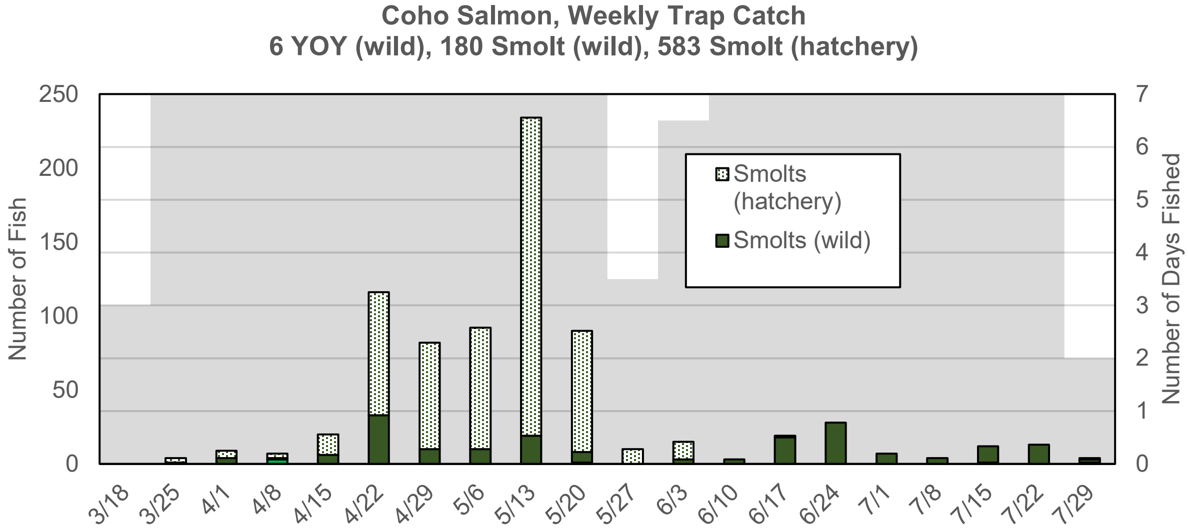


Figure 5.3.11. Estimated average weekly capture efficiency (upper panel) and population estimate of Chinook Salmon smolts (x1000) produced from the Dry Creek watershed upstream of Westside Road smolt trap site (rkm=3.3) (lower panel), 2009-2021. Dashed line is the twelve-year average abundance for all years combined.

Coho Salmon were the least abundant of the three salmonid species captured. Hatchery smolts dominated the catch with a total of 583 individuals captured. Steelhead parr capture was highest in June (Figure 5.3.12).



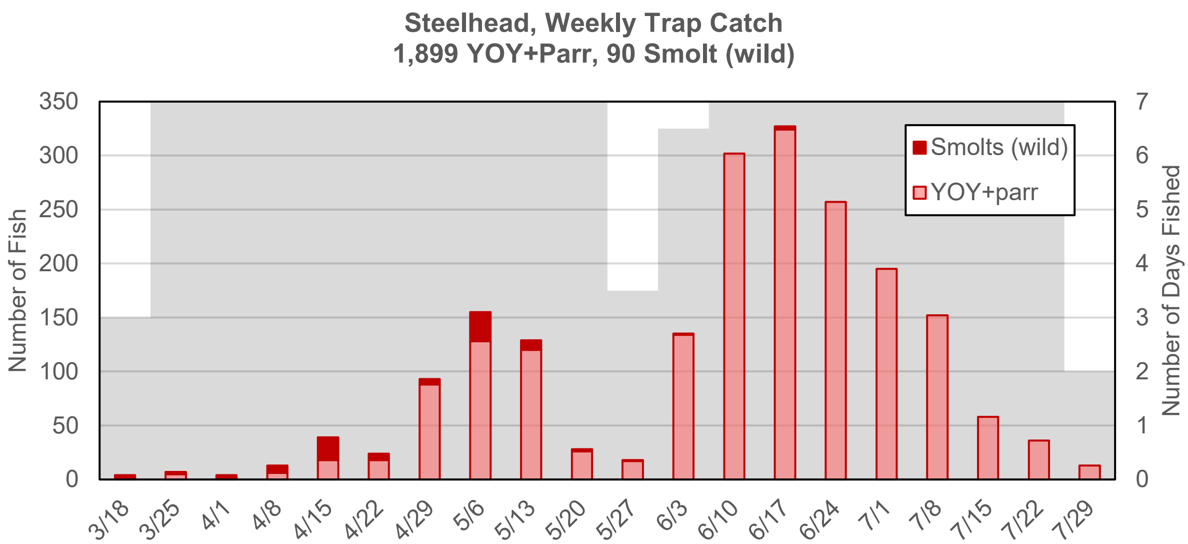


Figure 5.3.12. Weekly trap catch of juvenile Coho Salmon and steelhead in the Dry Creek rotary screw trap, 2021.

Coho smolt trap catch for the season was relatively high and similar to the catch in 2013 and 2014 (Figure 5.3.13). Steelhead smolt and YOY/parr captures (90 and 1,899) were slightly lower than recent years and similar to totals from 2010 and 2011.

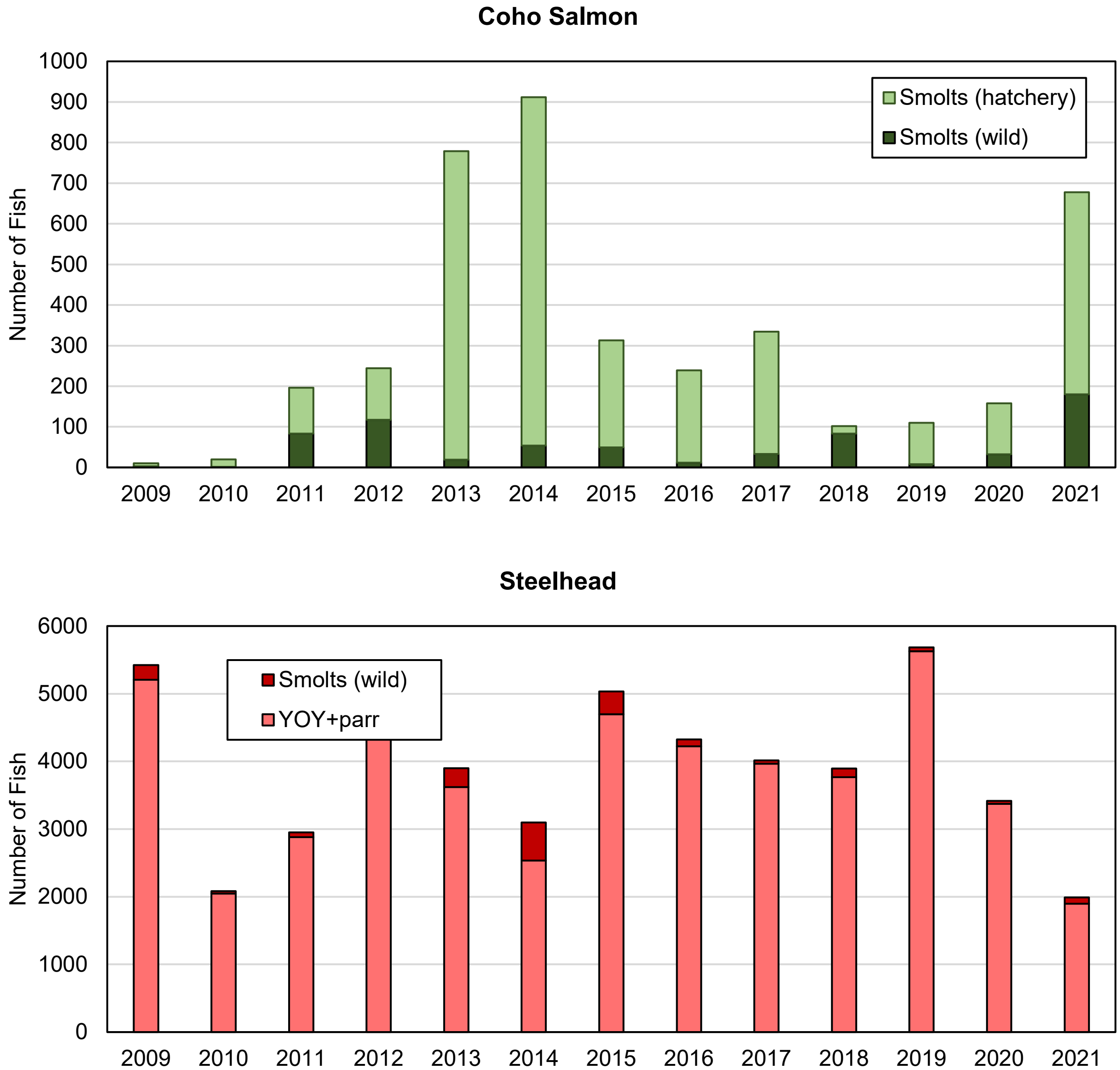


Figure 5.3.13. Trends in trap catch for Coho smolts and steelhead smolts and parr, 2009-2021.

Weekly sizes of all salmonids captured at the Dry Creek trap increased over the course of the trapping season in 2021 (Figure 5.3.14).

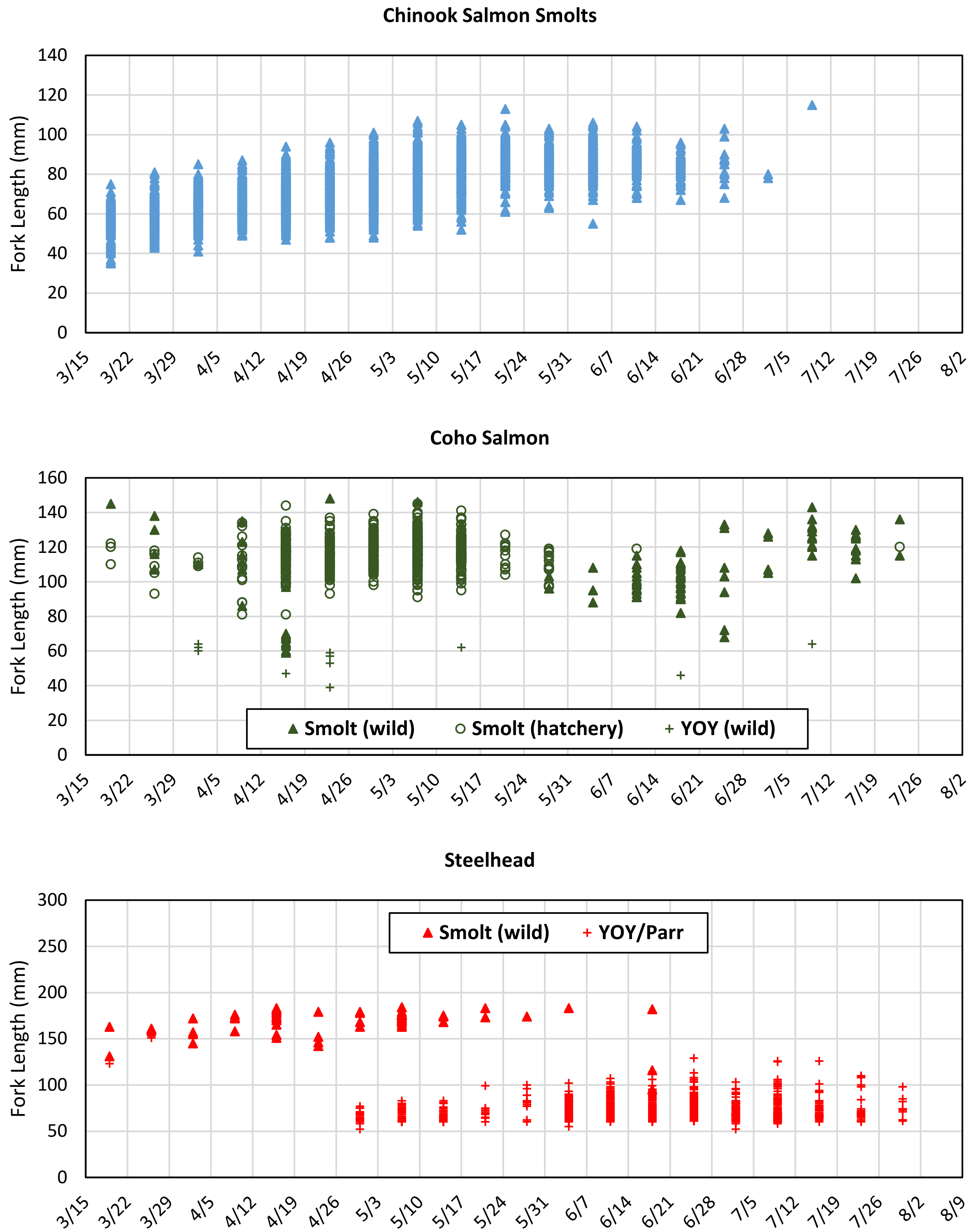


Figure 5.3.14. Fork lengths of juvenile salmonids captured in the Dry Creek rotary screw trap by week, 2021.

Steelhead smolt survival index

Antenna detections of PIT tagged steelhead during the smolt emigration period was used to calculate a survival index for juveniles that left Dry Creek during the subsequent smolt season. Due to the low number of emigrants detected (7) from the total number of steelhead tagged (285), a single survival index was calculated for 2020-2021, and this was applied to the respective expanded population estimates to generate the smolt estimate (Table 5.3.4). The survival index was lower in 2020-2021 compared to the previous year (0.10).

Table 5.3.4. Estimated number of steelhead smolts in Dry Creek in mainstem and side channel reaches for 2021 based on number of juvenile steelhead estimated in summer 2020 and calculated survival index to the 2021 smolt emigration season.

Location	River km	Density (fish * m^{-1})	Expansion estimate (juvenile)	Survival index	Smolt estimate
Lower reach	00.00 – 06.87	1.28	8,832	0.06	530
Middle reach	06.87 – 18.90	1.14	13,749	0.06	825
Upper reach	18.90 – 21.81	0.53	1,563	0.06	94
Total mainstem					***1,449***
Truett Hurst SC	14.01 – 14.30	3.23	937	0.06	56
Weinstock SC	20.48 – 20.53	4.05	1,013	0.06	61
Army Corps Reach 14 SC	21.02 – 21.07	3.20	1,184	0.06	71

Conclusions and Recommendations

As was the case during the 2021 Coho Salmon smolt migration season, flows in Dry Creek and the mainstem Russian River were again extremely low during the 2022 migration season (Figure 5.3.15). While these flows did give us the opportunity to implement monitoring that may not have otherwise been possible, they likely impacted fish populations in in Dry Creek as well as outside Dry Creek. An example of that is the fact that we were able to raise the Mirabel dam and operate PIT antennas and the downstream migrant trap at a time when this is typically not possible (early April).

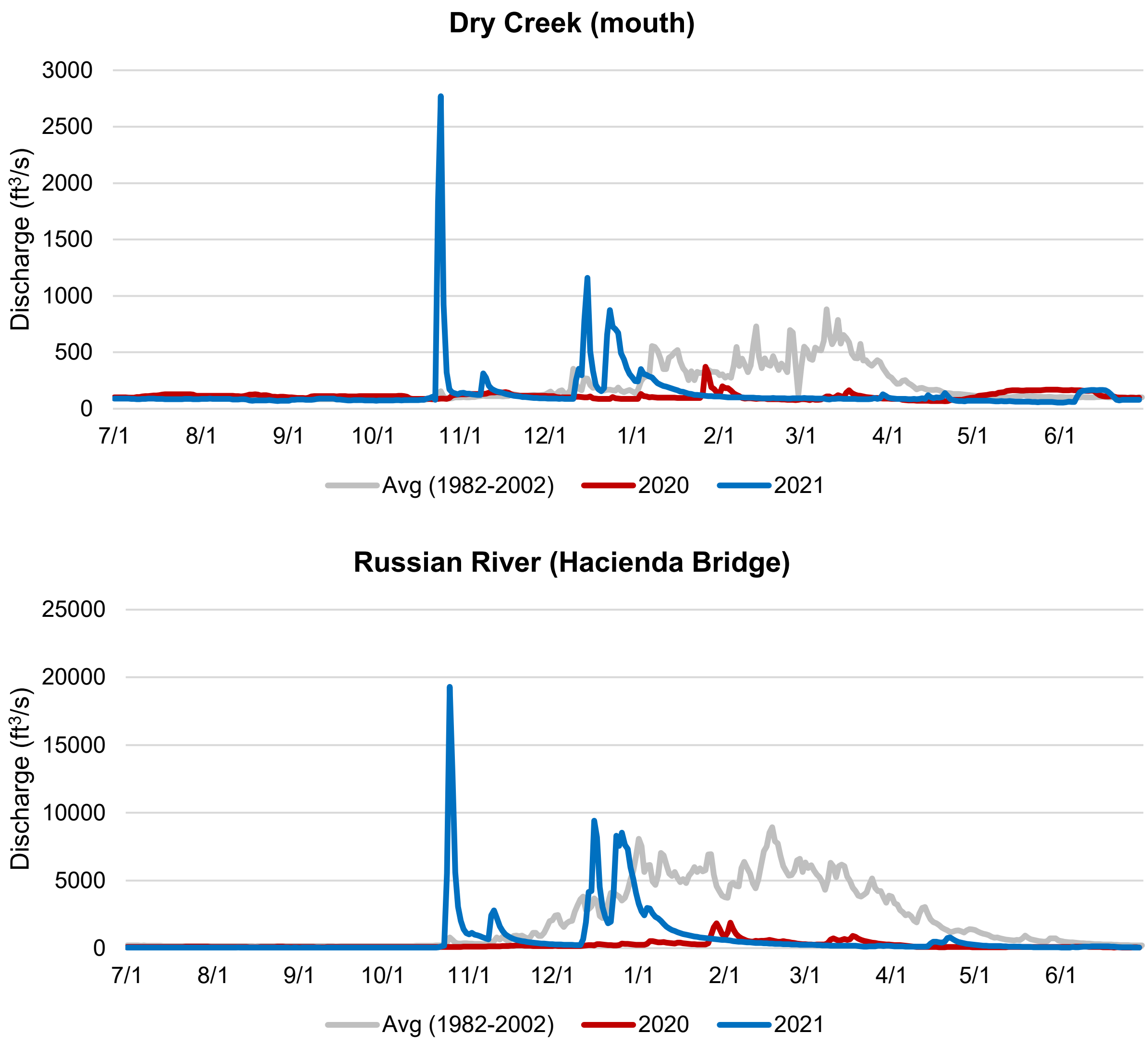


Figure 5.3.15. Stream discharge at the USGS gage station at the mouth of Dry Creek (upper panel) and mainstem Russian River at Hacienda (lower panel).

In typical flow years when PIT antennas remain operable through the spring Coho smolt migration season, we should be able to rely on PIT-tagging and PIT antenna within Dry Creek to estimate survival from juvenile tagging/release to the smolt stage. However, evaluating smolt migration survival as we did in 2021 and 2022 using PIT technology will only be possible during years when we can raise the Mirabel dam. Instead, we will need to turn to other approaches. In 2021, we began evaluating acoustic telemetry as a viable approach and have so far concluded that it will be an effective way to continue evaluating Coho smolt survival through the mainstem Russian River.

Estimating steelhead smolt abundance in Dry Creek remains challenging. Because smolt trapping in Dry Creek is typically not possible until well past the peak of steelhead smolt migration, our approach relies on tagging a suitable number of juveniles in the year prior to smolting, estimating their overwinter survival, then detecting them on PIT antennas as the leave Dry Creek the following winter/spring. However, due to challenges in capturing fish in the main channel as well as off channel locations in Dry Creek, the accuracy of those estimates will be suspect because of small sample size and the fact that large portions of Dry Creek are typically no sampleable with traditional fish capture methods (e.g., backpack electrofishing, seining). We instead recommend moving toward evaluating alternative metrics, such as growth, that may offer a higher chance for success.

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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.

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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 (rkm 39).

Methods

A digital camera and lighting system was installed in the west Mirabel fish ladder. The camera is operated until flow in the river is predicted to raise above 2,000 cfs at which the inflatable dam can no longer be safely operated. Once the dam is deflated the camera system is no longer operational and the camera is typically removed for the season. In previous years a second video camera was operated in the east fish ladder. The east fish ladder which was constructed in the 1970s was in disrepair. Data collected at the Mirabel dam showed that most Chinook used the newly constructed west fish ladder and the east fish ladder was decommissioned in the spring of 2021.

Adult salmonids 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 lumped into 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 2021, the Mirabel fish ladder camera was installed on September 1 (Figure 7.1.1). Unimpaired runoff from a storm in in late October increased stream flow from 120 cfs to over 20,000 cfs. The camera was removed for the season on October 23, 2021. With a few exceptions the camera was operated 24 hours/day after installation until it was removed (Figure 7.1.2).

Adult Salmonids

Counts for Chinook, coho and steelhead will not be reported due to the truncated 2021 monitoring season. Previous years Chinook data are reported in Table 7.1.1).

For Coho salmon we recommend using a different monitoring method to estimate the number of adults returning to the Russian River. 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, Mirabel video counts are not the best indicator of adult

Coho returns to the basin. Instead, we suggest the basinwide redd survey estimate of 227 (95% CI: 104-350) as the most comprehensive and accurate indicator of all adult Coho (hatchery- and natural-origin) returning to the Russian River basin in 2021-22. 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).The number of adult steelhead returning to the Russian River is best estimated using methods other than the Mirabel video camera. Based on hatchery returns, steelhead migrate and spawn in the Russian River primarily between December and March; however, we removed the Mirabel camera in late October before the beginning of the steelhead run. The best indication of steelhead returns to the Russian River basin is the Warm Springs Dam and Coyote Valley Dam fish hatchery counts. For the 2021-22 return year 443 steelhead returned to the Warm Springs hatchery and 549 steelhead returned to the Coyote Valley hatchery (California Department of Fish and Wildlife unpublished data).

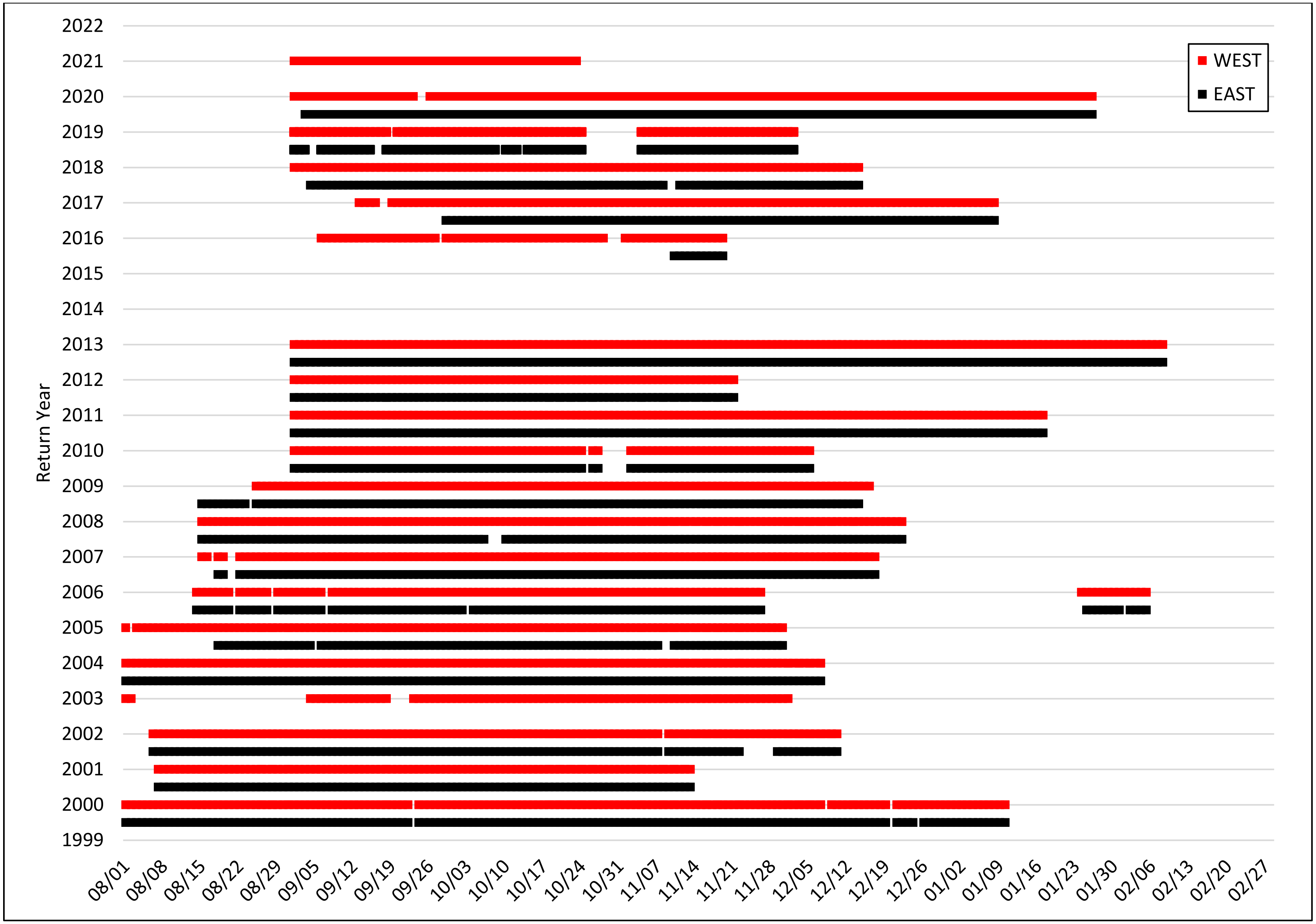

Figure 7.1.1. Period of operation by adult salmonid return year for the video counting station at the Mirabel dam.

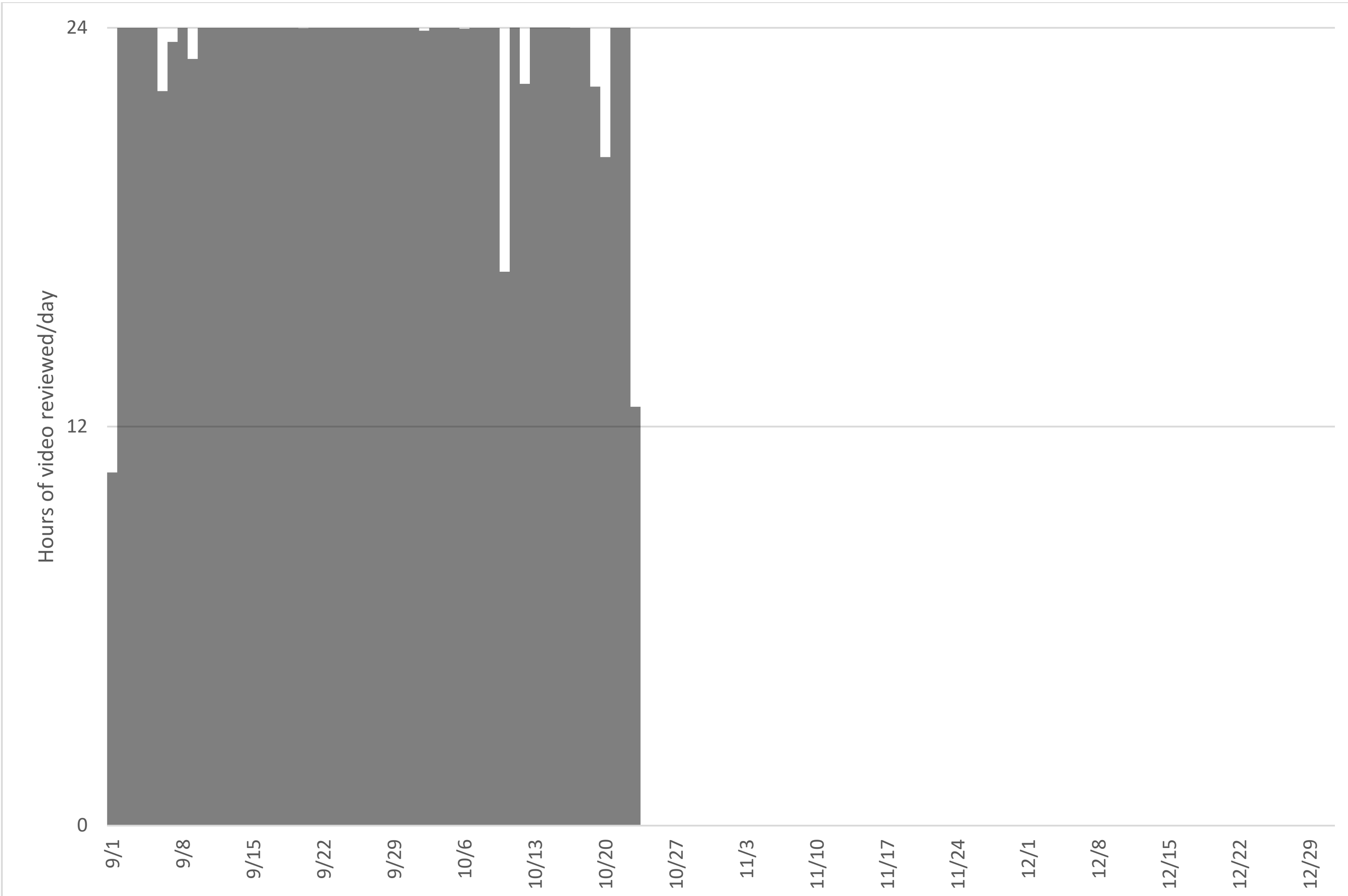

Figure 7.1.2. Number of hours/per day that the west and east fish ladder cameras were in operation at the Mirabel dam in 2021.

Table 7.1.1. Weekly count of adult Chinook salmon at the Mirabel dam fish ladders, 2000-2021. 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	2019	2020	2021
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	0	0	
5-Sep	9	1	18	7	1	4	0	0	0	0	0	0	1	1			0	--	0	0	1	
12-Sep	36	7	19	20	3	14	3	0	2	0	0	0	2	2			0	0	1	0	0	
19-Sep	25	12	65	23	8	14	4	1	17	0	3	1	0	1			0	3	4	4	0	
26-Sep	50	17	1223	181	16	31	8	4	84	0	1	158	70	17			8	2	37	43	12	
3-Oct	31	240	113	146	42	27	317	10	126	78	669	534	51	44			32	91	77	29	3	
10-Oct	115	51	628	515	52	112	87	39	82	562	896	390	551	4			291	50	47	26	0	
17-Oct	81	10	272	232	651	556	532	26	13	177	153	1070	1886	8			392	125	158	52	1	
24-Oct	465	300	153	532	2287	309	114	106	22	285	280	273	996	27			131	81	50	2	80	
31-Oct	64	661	505	2969	185	613	1531	250	511	135	94	223	1654	315			56	612	68	22	40	
7-Nov	23	81	2337	1289	1189	699	298	429	174	335	169	90	619	731			50	366	60	170	135	
14-Nov	182	--	20	47	221	127	459	154	15	38	43	120	851	1063	Not Operated	Not Operated	103	508	145	110	216	Not Reported
21-Nov	201	--	37	95	57	63	53	96	24	129	113	266	50	179			--	71	461	333	64	
28-Nov	110	--	14	45	60	33	--	425	19	24	76	6	--	99			--	82	66	131	9	
5-Dec	19	--	53	--	16	--	--	476	18	9	5	1	--	172			--	24	38	--	14	
12-Dec	15	--	--	--	--	--	--	4	8	28	--	2	--	125			--	24	6	--	36	
19-Dec	17	--	--	--	--	--	--	--	13	--	--	10	--	73			--	16	--	--	2	
26-Dec	1	--	--	--	--	--	--	--	--	--	--	16	--	32			--	27	--	--	4	
2-Jan	0	--	--	--	--	--	--	--	--	--	--	2	--	53			--	11	--	--	5	
9-Jan	0	--	--	--	--	--	--	--	--	--	--	10	--	58			--	--	--	--	3	
16-Jan	--	--	--	--	--	--	--	--	--	--	--	1	--	28			--	--	--	--	2	
23-Jan	--	--	--	--	--	--	0	--	--	--	--	--	--	73			--	--	--	--	0	
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	922	626	--

*Video cameras were reinstalled and operated from 4/1-6/27/2007 but no Chinook were observed.
**Video cameras 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.

Conclusions and Recommendations

In 2021 we were not able to operate the video camera in the fish ladder for the duration of the Chinook migration due to early storms. With the exception of the 2021 return year the Mirabel video system continues to provide useful data on the Russian River Chinook run. We recommend 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 (see CHAPTER 3 Pursue Changes to Decision 1610 Flows of this report). 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.

Background information on the natural history of Chinook salmon in the Russian River is presented in the 2011 Russian River Biological Opinion annual report (Manning and Martini-Lamb 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 Russian River during fall. Typically, the upper Russian River basin and Dry Creek are surveyed. 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. 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. In 2003, the study area was expanded to include 22 rkm of Dry Creek below Warm Springs Dam at Lake Sonoma to the Russian River confluence. The study area is partitioned into six reaches that are demarked by valley sections and the confluence of streams (Figure 7.2.1).

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 searched 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 are cancelled or postponed if increased turbidity from heavy rainfall and subsequent high flows that 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 Ukiah and Canyon study reaches.

Results

Chinook spawning surveys were conducted in the Russian River from the Canyon Reach to Lower Healdsburg Reach between November 17 and 26, 2021. Chinook salmon spawning surveys were curtailed in Ukiah and upper Canyon reaches due to high turbidity from Lake Mendocino water releases. Dry Creek surveys were attempted on November 4, 2021; however, high turbidity from dam releases caused visibility of 0.5 to 1 foot and redd detections was not feasible.

Most of the Chinook salmon spawning typically occurs in the upper Russian River mainstem and Dry Creek (Table 7.2.1). During 2021, there were a total of 39 redds observed in the sampled reaches of the Russian River from the Canyon to Lower Healdsburg. The most productive reach was Alexander Valley with 26 redds observed, which accounted for 67% of all redd observations. However, this redd count for Alexander Valley was the second lowest on record. Although Alexander Valley reach has been relatively productive for Chinook salmon spawning since surveys began in 2002, there has been a long-term decline in redd abundances (Fig 7.2.2). Overall, there has been a substantial decline in the number of Chinook redds in the Russian River watershed since around 2015 (Table 7.2.1).

Conclusions and Recommendations

Although Chinook salmon surveys were restricted to four reaches in 2021, the distribution of redds appear to be similar to other study years. The abundance of Chinook salmon redds have shown a sharp decline since 2015. There are many factors that could be driving this trend. It is likely that several years of severe drought in the region is a major contributor to the low abundance of redds.

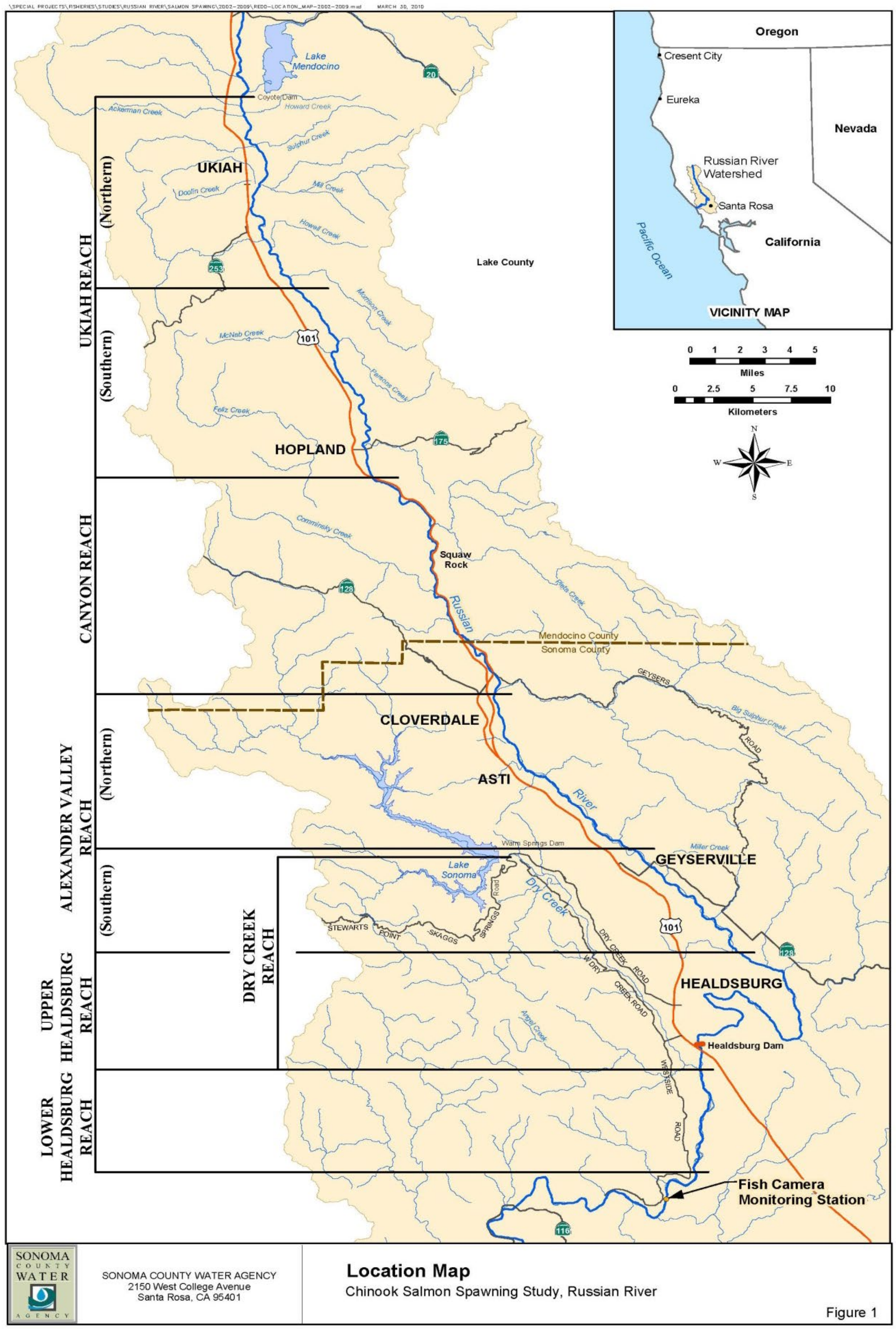

Figure 7.2.1. Chinook salmon spawning survey reaches. Only Canyon (middle and lower sections), Alexander Valley, Upper Healdsburg, and Lower Healdsburg reaches were surveyed in 2021.

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Table 7.2.1. Chinook Salmon redd abundances by reach, upper Russian River, and Dry Creek, 2002-2021. Redd counts are from a single-pass survey conducted during the peak of fall spawning activity. *Survey either not completed or incomplete.

Reach	River km	2002	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	2020	2021
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]	*		*	*	11
Alexander Valley	26.2	163	213	90	*	62	131	65	129	*	97	185	163	*	61[2]	41[2]	39	25	*	29	26
Upper Healdsburg	25.6	79	40	8	*	23	67	48	38	*	66	53	57	*	*	1[2]	14		*	18	2
Lower Healdsburg	8.2	6	0	7	*	1	2	9	30	*	7	4	18	*	*	*	6		*	*	0
Russian River	**113.9**	**1036**	**907**	**558**	*	**402**	**406**	**178**	**273**	*	**170**	**332**	**362**	*	*	*	*	*	*	**47**	**39**
Dry Creek	21.7	*	256	342	*	201	228	65[1]	223	269	229	362	325	*	78	90	112	86	15	91	*

[1]Redd numbers are an estimate.

[2]Redd numbers are presumably an underestimate due to poor survey conditions.

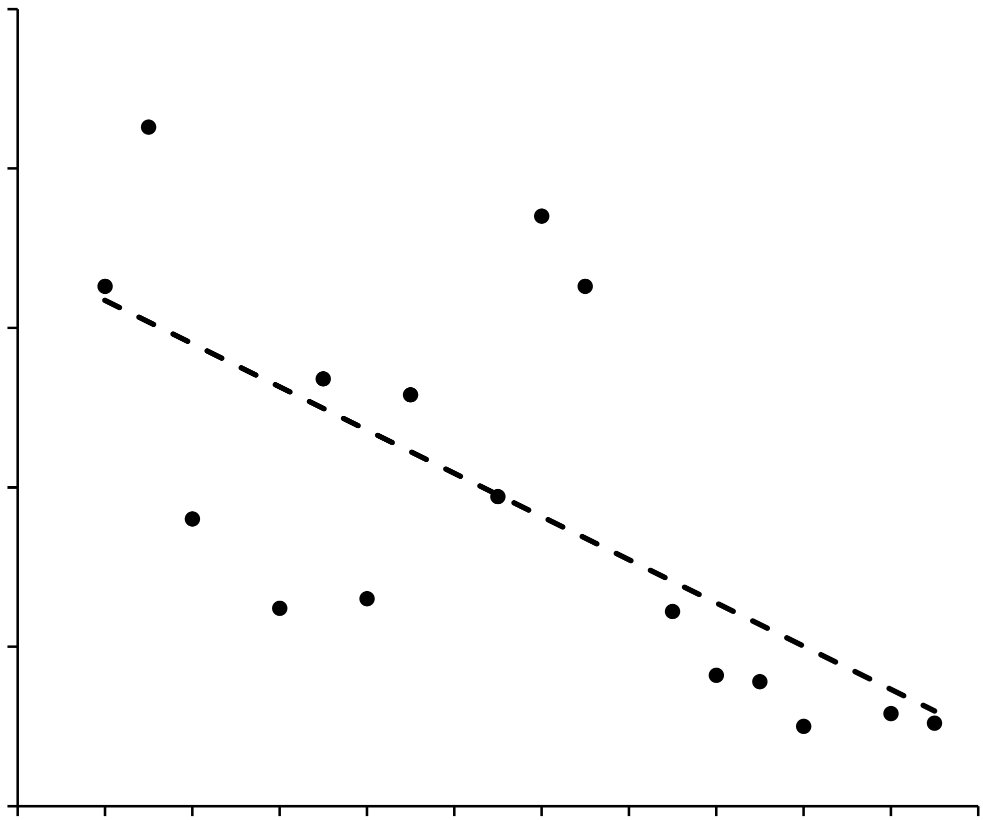

Figure 7.2.2. Chinook salmon redd occurrences in the Alexander Valley reach from 2002 to 2021. No survey conducted, or where incomplete, in 2005, 2010, 2014, and 2019.

References

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