6. Chapter 6: Redwood Creek Action Plan

6.1 Sub-Watershed Overview

Redwood Creek runs through the northwestern portion of the South Fork Eel River sub-basin (SFER) in Humboldt County (Figure 6-1). Redwood Creek is a third order stream with approximately 31 miles of perennial waterways draining a sub-watershed of approximately 23.3 square miles (CDFG 2009b). Elevations range from approximately 250 feet at the mouth of the creek to 1,300 feet in the headwaters. The landscape is dominated by mixed conifer (predominantly redwood and Douglas fir), mixed hardwood forest, and a small amount of grassland and prairie (CDFW 2014).

The sub-watershed is primarily privately owned; the northern portion is dominated by residential land use while the eastern and areas of the southern portion are managed primarily for timber production and, to a lesser extent, grazing. The Redwood Creek sub-watershed is one of the most populated areas in the western SFER and many residents have turned to cannabis cultivation to generate income (Bauer et al. 2015). Between municipal and agricultural water use, water diversion from Redwood Creek is significantly impacting summer flows (Bauer et al. 2015, Cowan 2018, Klein 2017). While land use practices of settlers and modern owners have degraded salmonid habitat in the sub-watershed, Redwood Creek supports a consistent population of Coho Salmon (*Oncorhynchus kisutch*), Chinook Salmon (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss*) (CDFW 2014). Trends in overall habitat suitability indicate conditions are improving, likely due in part to community outreach, improvement in land management including enforced regulations, and restoration actions (CDFW 2014).

The land beneath the Redwood Creek sub-watershed is a diverse and dynamic geology. The sub-watershed is bisected by the Garberville fault and bounded by the Coastal Belt Thrust fault to the north. The underlying bedrock is composed of a mix of Yager terrane and Wildcat Group punctuated by pockets of alluvium and river terrace deposits. The resulting landscape has formed steep forested slopes, cliffs, sharp ridges, and incised canyons with friable soils prone to landslides. The relatively unstable land combined with over 80 inches of annual rainfall and a history of land disturbance makes Redwood Creek prone to erosion (CDFW 2014). Numerous eroded banks and landslides were observed in every California Department of Fish and Wildlife (CDFW[5]) stream inventory conducted in the sub-watershed (1993 - 2017), and aerial imagery reveals numerous landslides and erosion throughout the sub-watershed (CDF 1942, 47, 1965, 1988).

[5] Formerly known as the California Department of Fish and Game (CDFG)

Figure 6-1. Redwood Creek's position in the South Fork Eel River sub-basin.

6.2 History of Land Use and Fish Habitat and Current Salmonid Conditions in Redwood Creek and Tributaries

The history of land use in the Redwood Creek sub-watershed is as variable as its geology. The sub-watershed is within Wailaki ancestral lands, and prior to European settlement tribal members inhabited areas along Redwood Creek and its tributaries. The land and its associated natural resources provided a spiritual connection to the land and sustenance for tribal members. Beginning in the 1850s, settlers and homesteaders of European descent began living in the sub-watershed and by 1878 when a county road was completed between Ferndale and Briceland, the area was the most populated region in Southern Humboldt County (Keter 2017). Briceland, a settlement centered in the Redwood Creek sub-watershed, became a hub of commerce with spur roads to both the seaport at Shelter Cove and the towns of Redway and Garberville. Tanbark extraction was also a major industry of the Southern Humboldt region, and Briceland became the home of a tanoak bark extraction plant established by the Wagner Leather Company in 1903 (Crow 1994). Over 500 employees harvested and processed tanoak bark in the region before shipping the processed material west to Shelter Cove (Crow 1994). The Briceland plant was the largest tanbark business in Humboldt County till its closure in 1920 (Horner 2007). The presence of grasslands and prairies in the sub-watershed have also made the area suitable to livestock; ranching has been consistent in the sub-watershed since the 1880s (California Rangeland Trust 2017). The logging history of the sub-watershed is not precisely known, but the general pattern for the SFER was that late 19th and early and 20th century logging was restricted to redwoods in accessible areas around creek mouths, followed by logging of upper sub-watersheds in the decades following World War II (CDFW 2014). Based on aerial photography, a small amount of logging and rangeland conversion occurred in the lower portion of Redwood Creek and Seely Creek as well as upper Redwood Creek and Somerville Creek up to 1947 (CDF 1942, 1947). By 1965, nearly every tributary in the sub-watershed had been extensively logged and a vast network of haul roads had been constructed (CDF 1965). A portion of the lower sub-watershed was spared from logging and approximately 272 acres of old-growth redwood forest is protected by the CSP at the confluence of Redwood Creek and the South Fork of the Eel River. By the 1960s, most merchantable timber was removed from the land and the timber industry waned. Except for a few family-owned and managed ranches and timber lands, many land holdings were subdivided and sold to “new settlers” (CDFW 2014). To create an income in an economically depressed area, many of these new landowners began cultivating cannabis. This practice dramatically increased in numbers and size of operations in the 2000s and is now popular throughout the sub-watershed (Figure 6-2, Bauer et al. 2015).

Historical and contemporary land uses, as well as a series of devastating floods, have impacted the physical structure of Redwood Creek waterways. The abundant haul roads constructed for timber and tanbark extraction as well as access roads to private residences can contribute substantial sediment loads to nearby streams (CDFW 2014). In a sediment source analysis conducted in the SFER, 46% of sediment loading was attributed to anthropogenic sources including road-related landslides and road crossings (Stillwater Science 1999). The land disturbances due to logging activities exacerbated the slide-prone landscape and left the sub-watershed more vulnerable to erosion. When the sub-watershed was struck by two devastating floods in 1955 and 1964, massive debris and sediment yields were delivered to the Eel River in far greater quantities than observed in the geologic record of the basin (Sommerfield et al. 2002). Landslides and erosion during these events led to the loss of riparian vegetation and rapid aggradation of SFER tributaries (Sloan et al. 2001). In the Redwood Creek sub-watershed, these impacts are clearly visible in 1965 aerial photography of Miller Creek, a heavily logged tributary (CDF 1965, Figure 6-3). Streamside erosion, landslides, and several reaches with highly embedded gravels are still apparent in satellite imagery and stream inventories, though the degree to which these can be attributed to legacy effects or contemporary land use is unknown (CDFG 2009a, CDFG 2009b, CDFG 2009c, CDFW 2017a, CDFW 2017b, CDFW 2017c, CDFW 2017d, Google Earth 2018, Figure 6-4). This history of riparian disturbance has reduced large wood[6] recruitment opportunities and likely contributed to the current low density of large wood throughout the sub-watershed (Figure 6-5). The lack of large wood has reduced hydraulic scouring resulting in shallower pool depths, reduced stream complexity, and vastly diminished connectivity to floodplains (Kaufman et al. 1988, Figure 6-6) that often provide critical habitat refugia during winter flows (Bair 2016).

After the 1974 prohibition on logging in riparian zones, the plant communities have been undergoing disturbance succession. In the Pacific Northwest coastal zones, this succession moves relatively quickly from colonizing herbaceous vegetation to a community dominated by hardwoods including maple and alder species and in the later stages, mature conifers dominate the forest (Naiman et al. 2000). Prior to 1965, aerial photography indicates that much of Redwood Creek's riparian forests had large, mature conifers (CDF 1942, CDF 1947). Contemporary aerial imagery and stream inventories show that the riparian forest is typically dominated by hardwoods (CDFG 1993a, CDFG 1993b, CDFG 2007, CDFG 2009a, CDFG 2009b, CDFG 2009c, CDFW 2017; Google Earth 2018). In 1993, average canopy cover was 63% and only 34% of the riparian forest was coniferous. By 2009 canopy cover had risen to 94% and conifer represented 56% of the riparian forest. Although canopy cover was generally highly rated throughout the watershed, hardwoods generally do not grow large enough, nor remain in streams for long once recruited relative to large conifers (Naiman et al. 2000). The continued succession from a hardwood dominated riparian to a mature conifer riparian forest that can contribute substantial large wood available to alter channel form will likely take many tens to hundreds of years (Gregory et al. 1991).

A relatively dense population and the rise of cannabis cultivation has increased the demand for water during the summer months, which is often drawn directly from riparian sources, diverted

[6] Formally referred to as large wood debris (LWD) in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998). LWD may appear in figures and citations made prior to the adoption of the updated terminology, but it is synonymous with large wood.

from springs, or pumped from wells (Klein 2017). The SHaRP ranking process identified Redwood Creek as having the greatest density of registered water diversions in the SFER sub-basin. Bauer et al. (2015) estimated that cannabis cultivation in the Redwood Creek sub-watershed could demand between 34% and 165% of the summer stream flow depending on the water year. Consistent with this estimation, annual low flow monitoring conducted since 2013 indicates a drastic decline in flow during summer months with several reaches routinely going dry in late August and September (Figure 6-7, Figure 6-8). While the causes of flow reduction are multifaceted and difficult to pinpoint, longitudinal anomalies in flow along the mainstem Redwood Creek and semi-regular fluctuations in discharge measurements throughout the sub-watershed indicate the influence of local water withdrawals (Klein 2017). Additionally, attempts to model and compare unimpaired flows in Redwood Creek to observed flows indicate that Redwood Creek carries a significantly smaller volume of water than it would be expected to (Cowan 2018). Monitoring and regulating water use and stream flow in the sub-watershed are on-going processes and crucial to ensuring salmonid life-cycles can be completed in the sub-watershed.

Despite the history of impacts to the sub-watershed, habitat suitable to salmonids has persisted in Redwood Creek and its tributaries. Based on a review of historical photos and recent stream inventories, riparian vegetation has recovered quickly and is now considered highly suitable along most of the sub-watershed (CDF 1942 - 1988, CDFW 2014, Figure 6-9). Due in part to the persistent canopy cover, stream temperatures are also likely suitable in most of the upper sub-watershed (Figure 6-10). As a result, even in reaches that are intermittently dry, Coho Salmon can temporarily survive in isolated pools (Klein 2017). Low gradient habitats are common in Redwood Creek and often utilized by spawning Coho and Chinook Salmon and steelhead (Figure 6-11). In the SHaRP ranking process, Redwood Creek tied for the highest biological importance score, a composite of all the salmonid spawning and species distribution data available for the sub-watershed.

Currently, the land in the sub-watershed is owned by over 200 private entities, each holding relatively small parcels making restoration projects difficult to implement and opportunistic as opposed to strategic. While the Biological Importance and Habitat Condition of the sub-watershed score relatively high for the SFER basin (1st and 5th respectively), the Optimism, Potential, Integrity, and Risk scores reflect the impacts of relatively high human density in the region (tied for 7th and 11th respectively). Ultimately, Redwood Creek ranked 4th overall in the SHaRP ranking process, making it a priority sub-watershed; however, the difficulties of working with numerous residents will have to be overcome to fully realize the biological potential of Redwood Creek.

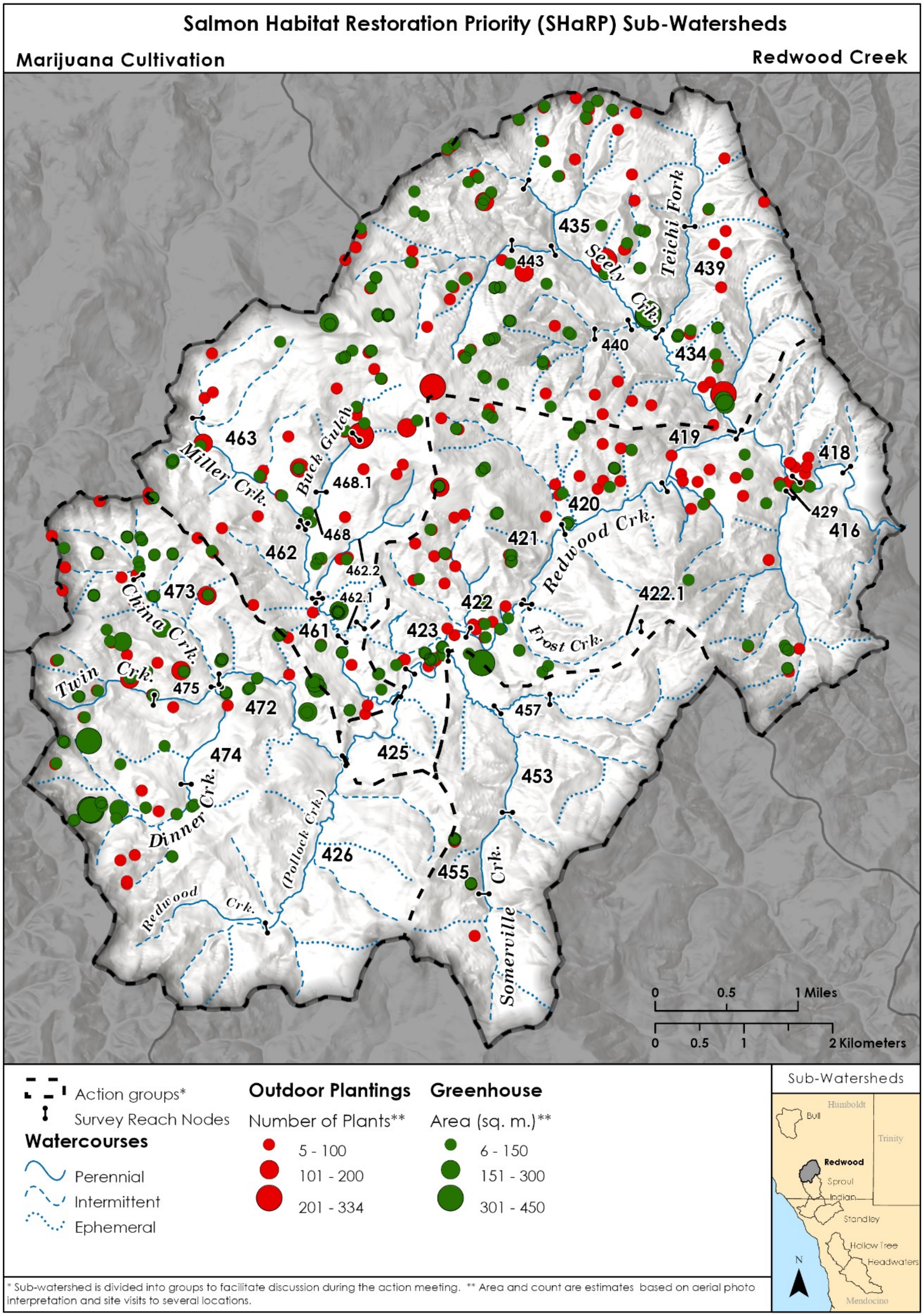

Figure 6-2. Marijuana cultivation in Redwood Creek sub-watershed. Source: Bauer et al. 2015.

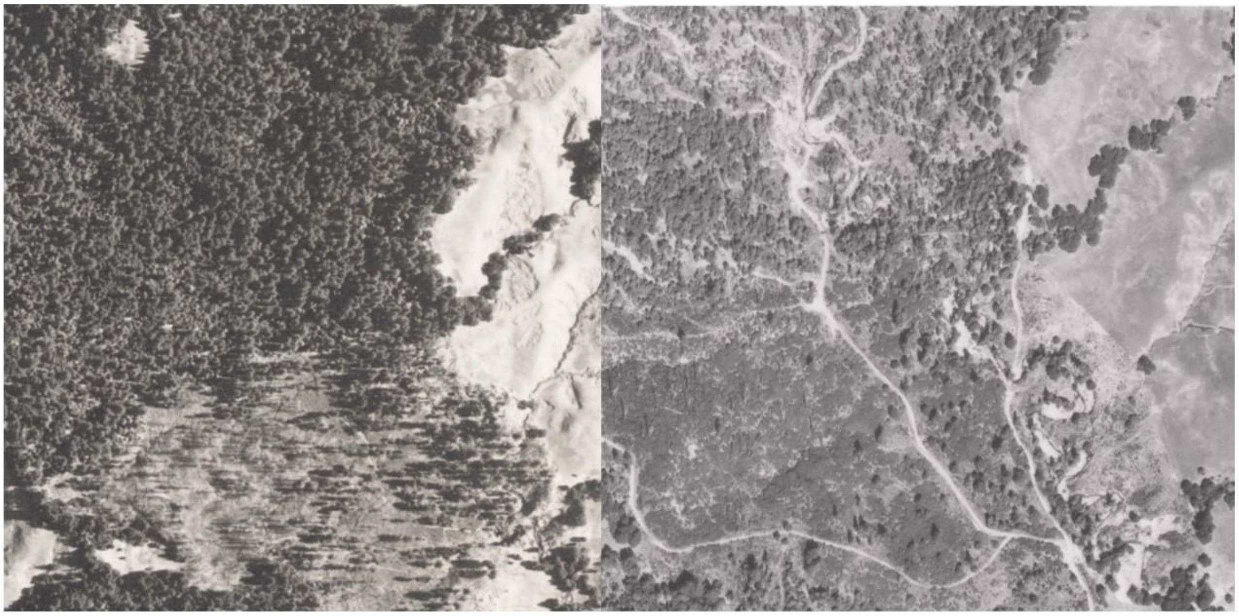

Figure 6-3. Aerial photography of Miller Creek from 1942 prior to most logging activities (left) and 1965 after the area was heavily logged and two major floods washed through the SFER (right). Miller Creek flows from the top center to the bottom right of each frame. A drastic increase in the width and exposure of active inner gorge failures is apparent.

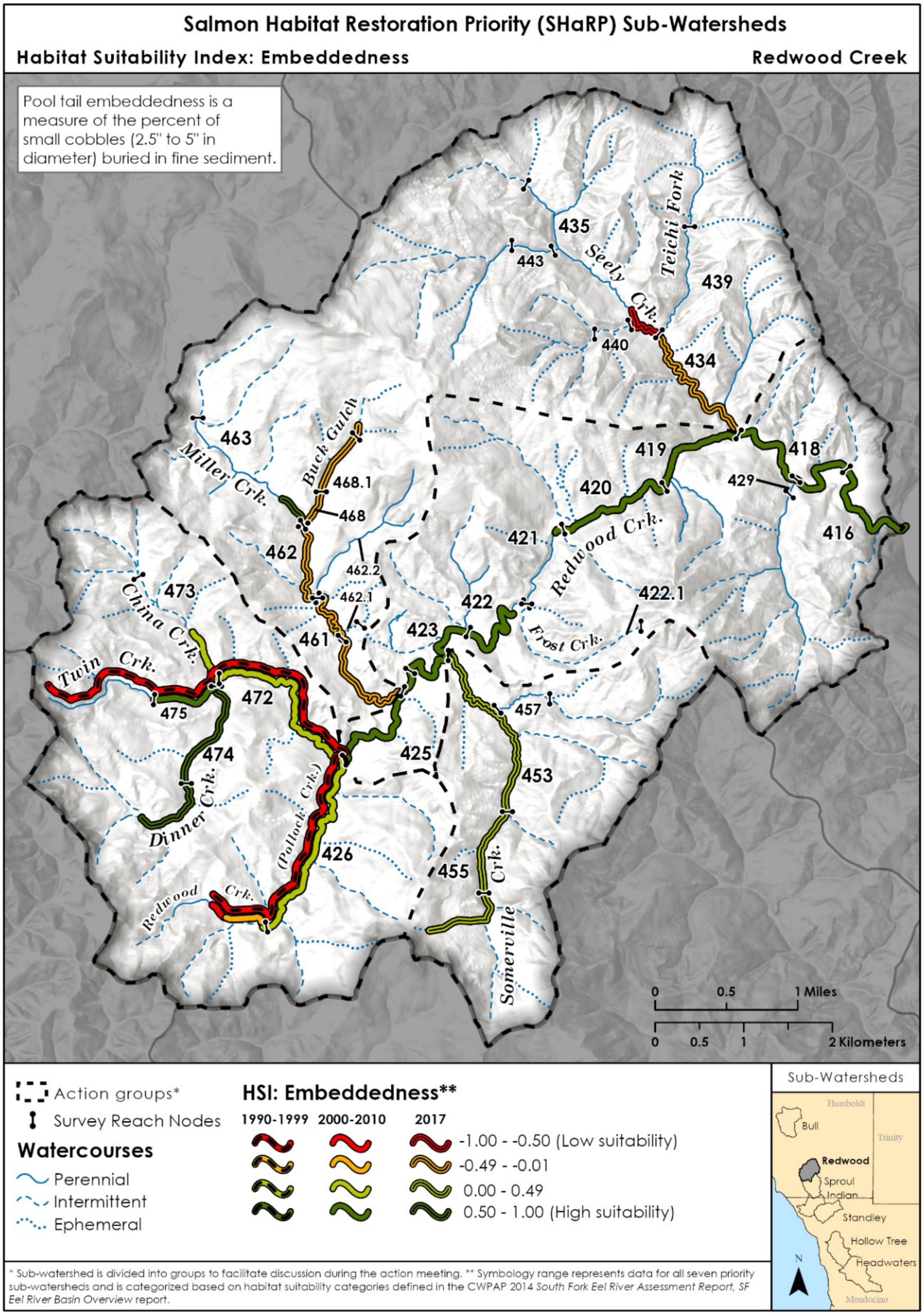

Figure 6-4. Habitat suitability index of gravel embeddedness in the Redwood Creek sub-watershed from CDFW stream surveys derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.

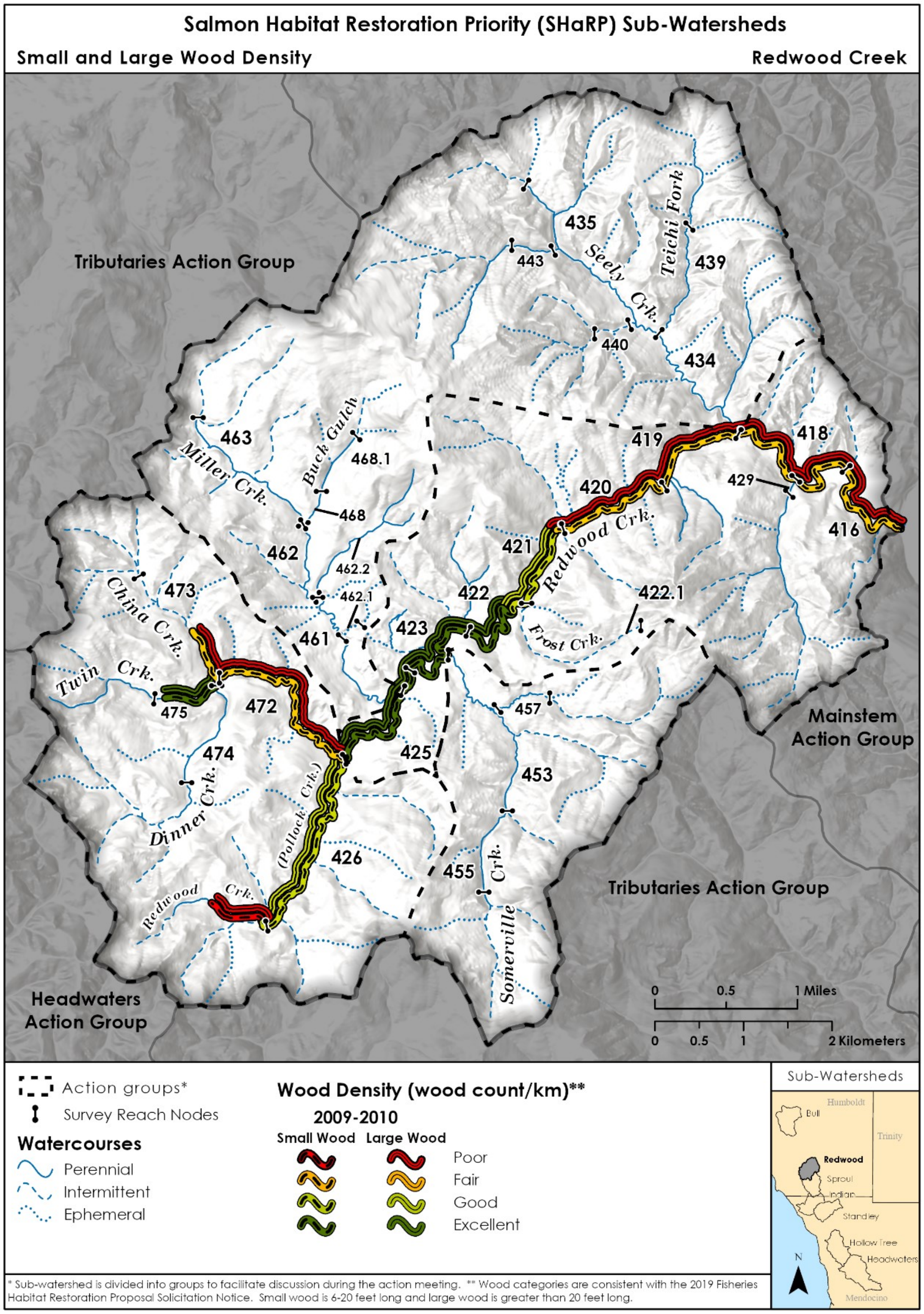

Figure 6-5. Wood densities for small and large wood pieces in the Redwood Creek sub-watershed derived from CDFW stream habitat surveys competed in 2009 and 2010. Large wood is greater than 1 foot in diameter and greater than 20 feet in length. Small wood is greater than 1 foot in diameter and 6 to 20 feet in length.

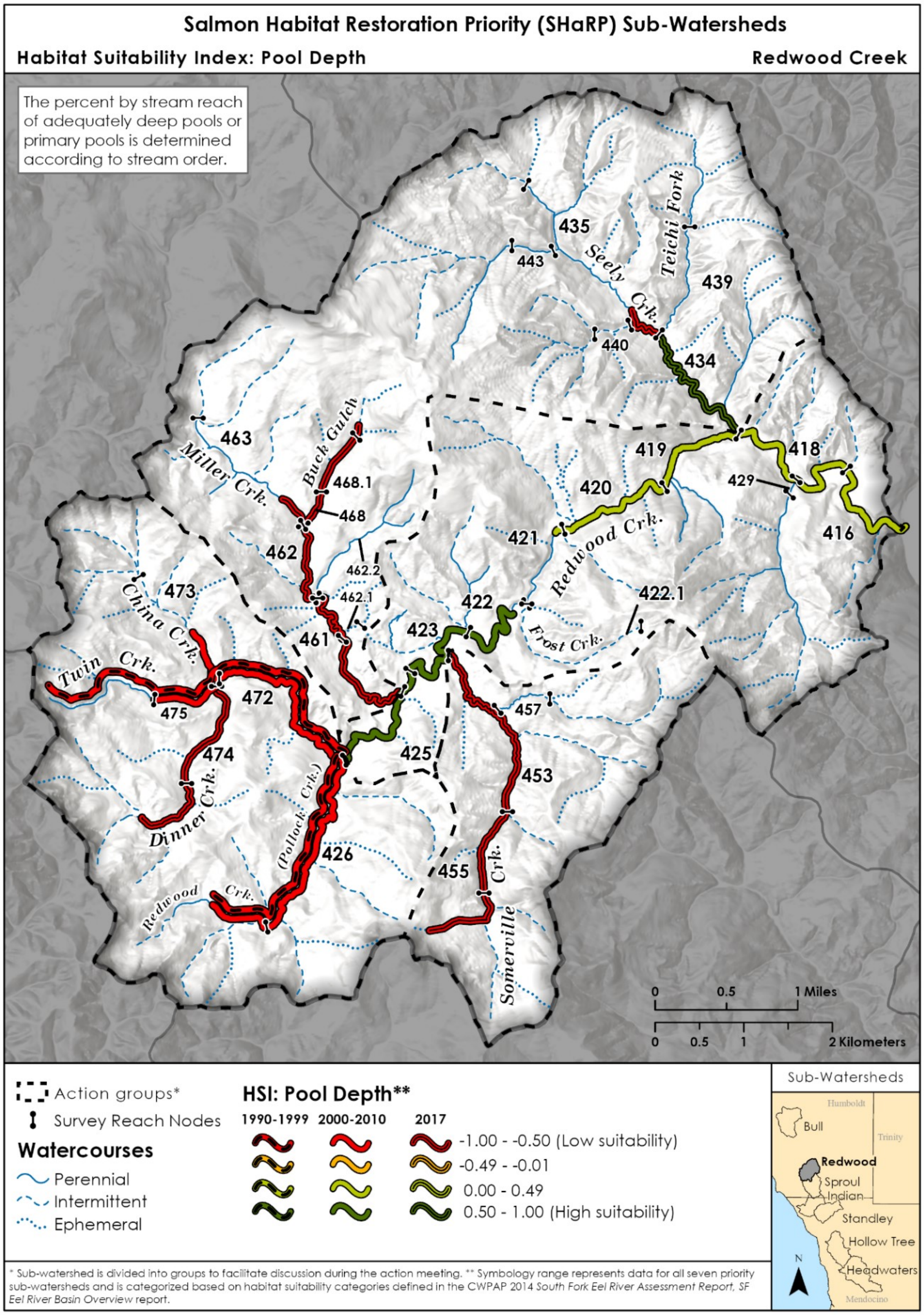

Figure 6-6. Habitat suitability index for pool depth in the Redwood Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.

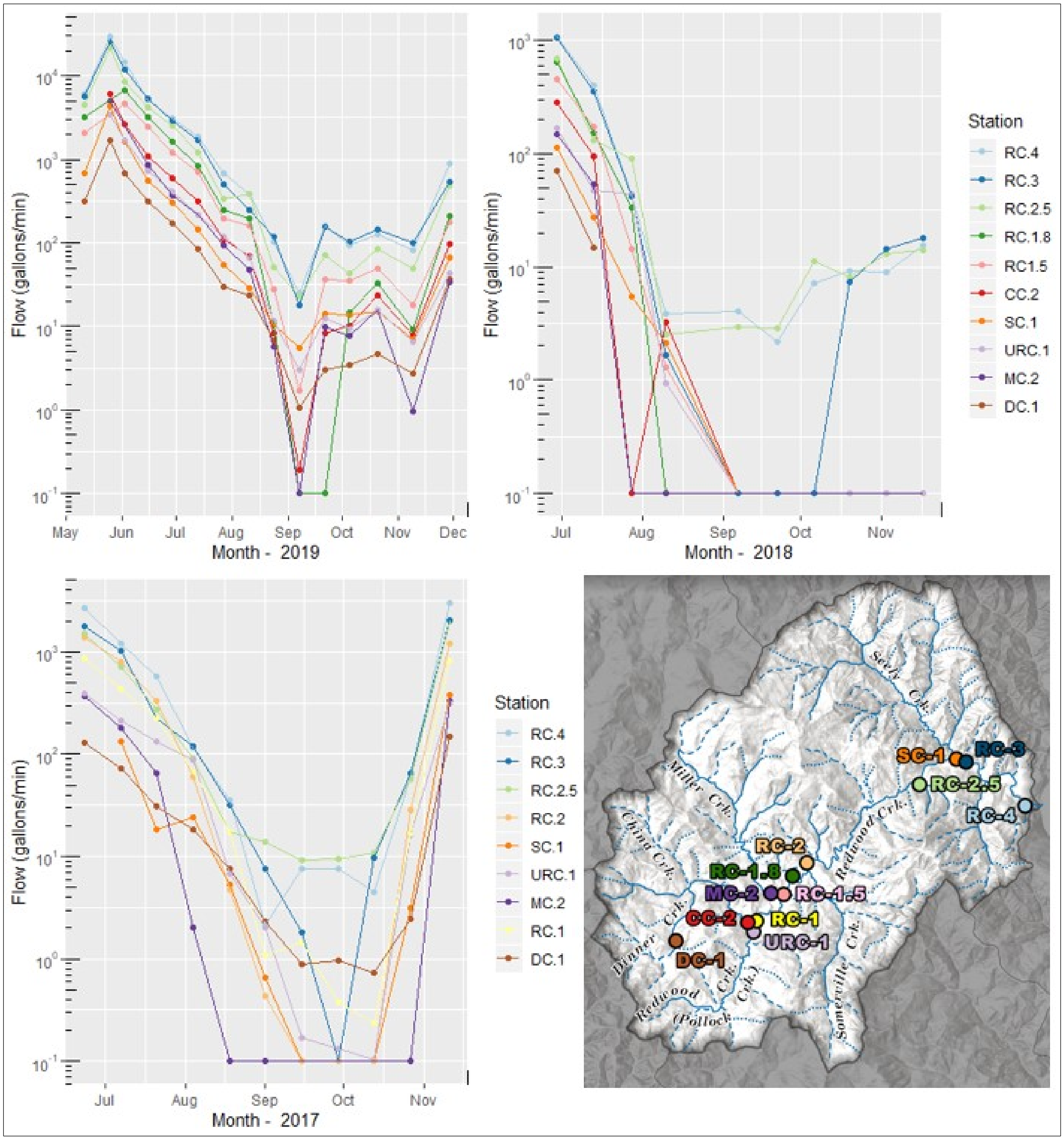

Figure 6-7. Stream flow (gallons per minute) at monitoring stations throughout the Redwood Creek sub-watershed from 2017, 2018, and 2019. Data are plotted on a logarithmic scale; at 0.1 gallons per minute, streams are effectively not flowing. The sub-watershed map in the bottom right panel displays the approximate locations of each monitoring station. Measurements are rounded to the nearest tenth. Source: Salmonid Restoration Federation; 2017 data collection funded by 319h program (State Water Board), 2018-19 data collection funded by Wildlife Conservation Board (SRF 2020).

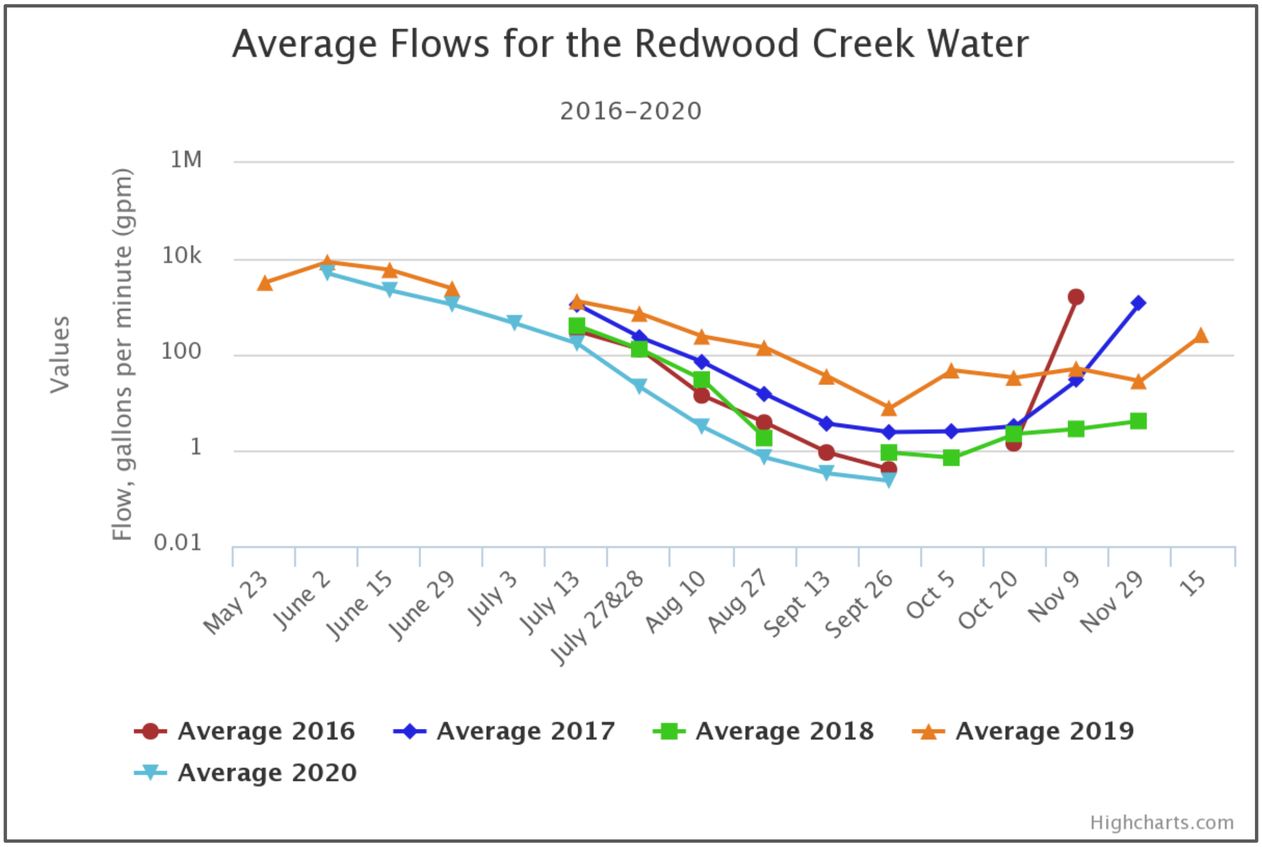

Figure 6-8. Mean flow (gallons per minute) in Redwood Creek during low-flow monitoring seasons 2016 - 2020 (SRF 2020).

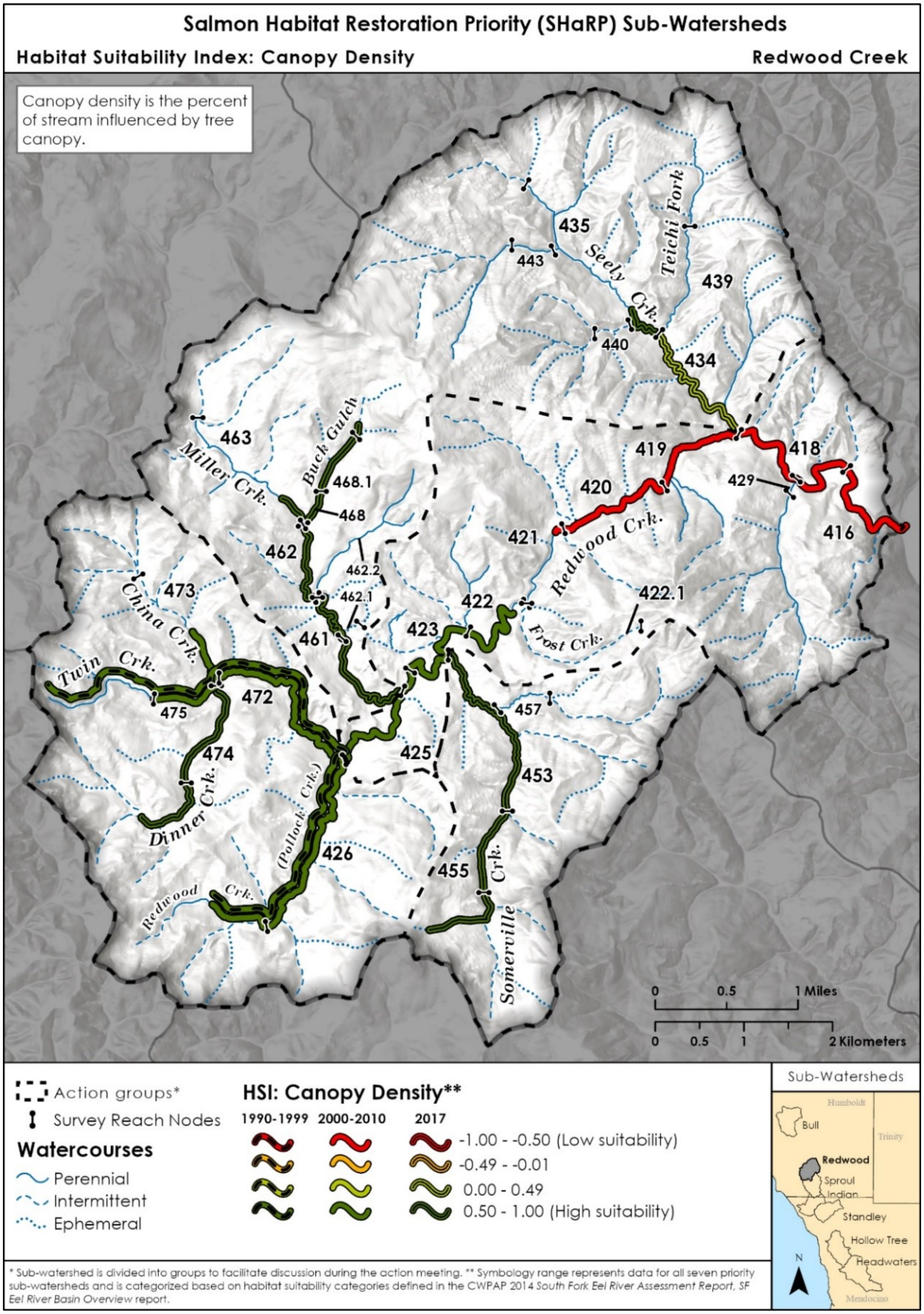

Figure 6-9. Habitat suitability index for canopy density in the Redwood Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.

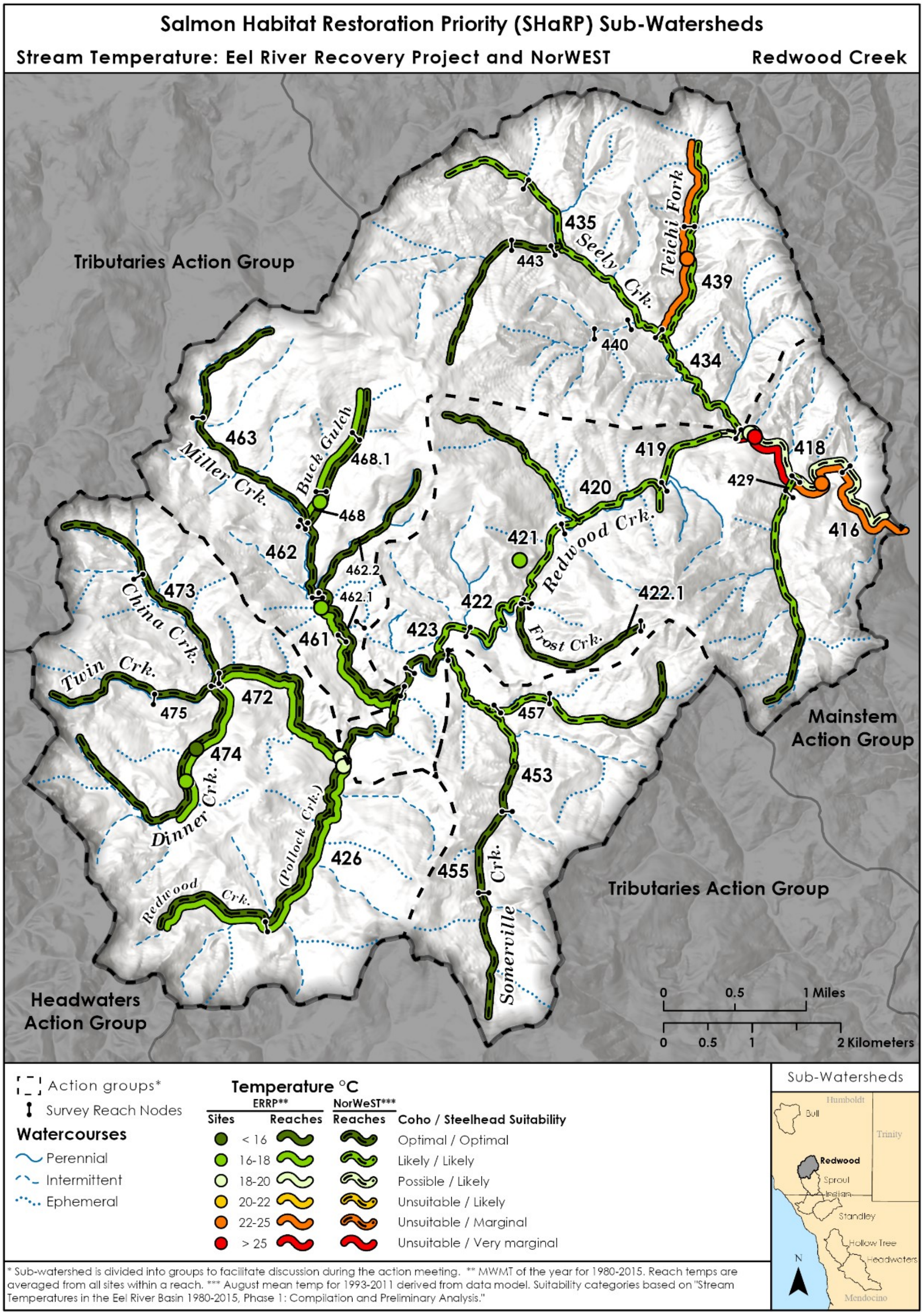

Figure 6-10. Observed and modeled stream temperatures and associated suitability for Coho Salmon and steelhead rearing in the Redwood Creek sub-watershed.

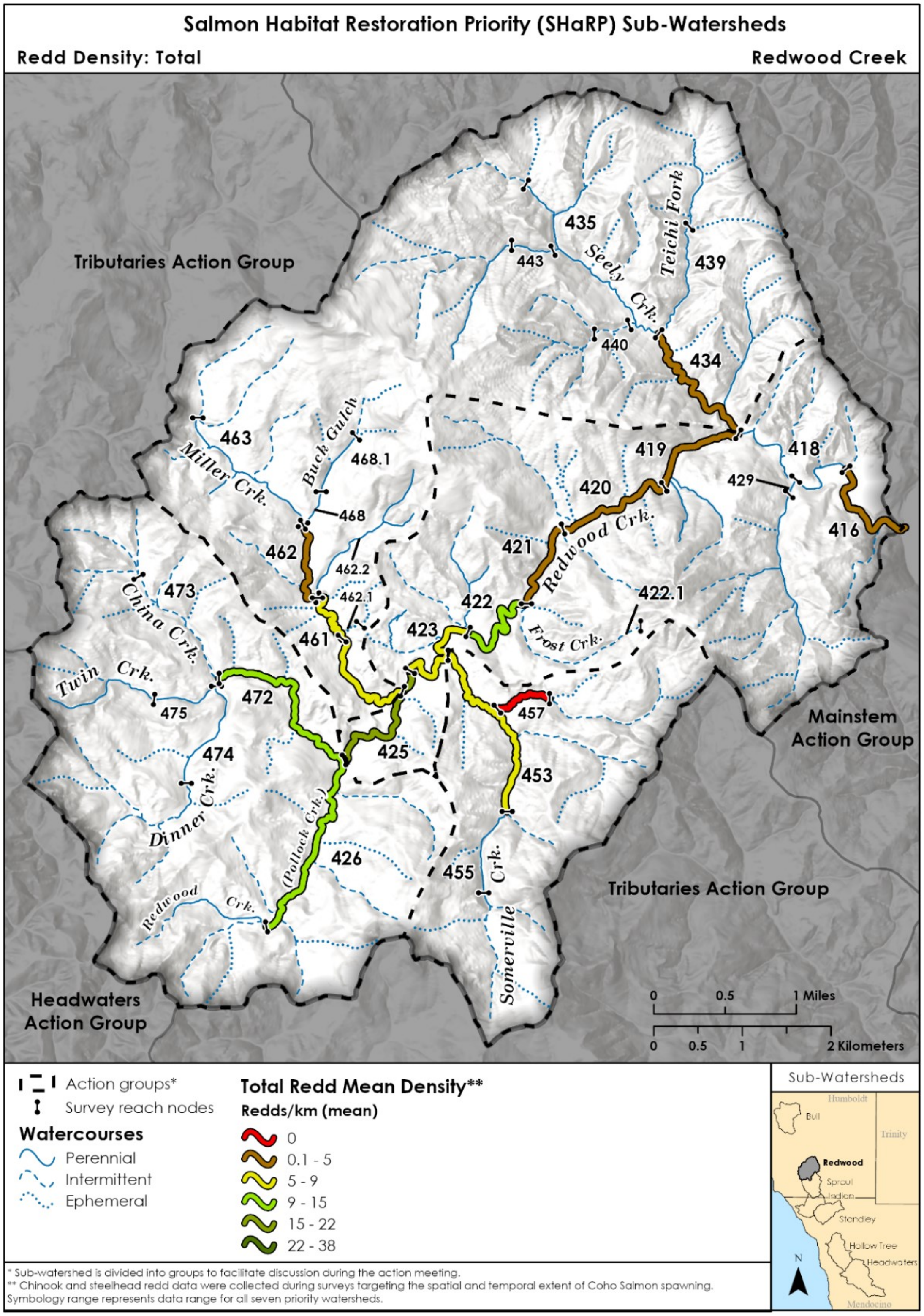

Figure 6-11. Total density of Coho Salmon, Chinook Salmon, and steelhead redds in the Redwood Creek sub-watershed, all years combined (2010-2018), based on CDFW spawner surveys. The redd survey was designed for Coho Salmon, so the duration and extent of the survey do not encompass the full spatial or temporal expression of the Chinook Salmon or steelhead run.

6.3 Historic and Current Restoration Efforts in Redwood Creek

The Redwood Creek sub-watershed has garnered support for restoration from a diverse community of concerned citizens and restoration practitioners. There have been active non-profit organizations (e.g. Salmonid Restoration Federation (SRF), Eel River Watershed Improvement Group (ERWIG), Eel River Salmon Restoration Project, and Trees Foundation), tribal members, community groups, and landowners, but due to a high percentage of private ownership it has been difficult to perform large-scale restoration necessary to have a significant impact on aquatic habitat. Of the 19 sub-watersheds in the SFER, Redwood Creek has the highest human population density and the greatest number of smaller parcels. The result of this is a fewer number of restoration projects and smaller footprint of restoration treatments on the landscape (Figure 6-12).

Due to this high population density and current land use practices (large-scale cannabis cultivation), recent restoration efforts have focused on monitoring stream flow/availability and developing solutions to minimize water extraction and keeping water flowing in streams during critical time periods for salmonids. In 2013, SRF received grant funding to begin monitoring dry season flows in Redwood Creek and its tributaries. Flow monitoring continues to the present through SRF with support of the Wildlife Conservation Board (WCB). As a part of this funding, SRF also initiated a study to determine the feasibility of transferring a voluntary water conservation program from the Mattole River watershed in Southern Humboldt County to the Redwood Creek sub-watershed. Redwood Creek Water Conservation Project was designed to engage rural landowners and stakeholders in a coordinated, community-led water conservation effort. SRF has had some success in landowner participation in these programs, but late-summer stream flows are still highly impacted and detrimental to salmonid growth and survival. In addition to this flow monitoring and conservation project, SRF has also performed other community outreach and watershed education workshops, including water conservation and flow enhancement workshops, water rights clinics, and community stakeholder meetings to build support for coordinated water management concepts and salmon restoration in the sub-watershed. SRF is currently working on two projects in the sub-watershed, both funded by WCB. These include (1) flow enhancement planning throughout the Redwood Creek sub-watershed to identify the highest priority activities needed to increase dry-season stream flow, and (2) the design and permitting of a large-scale flow enhancement project located on the Marshall Ranch near the town of Briceland.

The CDFW Fisheries Restoration Grant Program (see Chapter 4) has provided funding to support a variety of restoration projects in the Redwood Creek sub-watershed. Since 2008, the ERWIG and the California Conservation Corps (CCC) have completed about six instream habitat improvement projects in Redwood Creek from its confluence with China Creek downstream to just below Somerville Creek. These projects have consisted of constructing large wood structures and boulder features to enhance pools, increase gravel sorting and provide habitat complexity. Approximately 30 structures were constructed because of these projects. ERWIG also modified an eight-foot dam along Redwood Creek in 2008 by partially removing the dam to allow for fish passage under various flow conditions. An additional 25 structures along a 2,000-foot reach of Redwood Creek are scheduled to be built in summer of 2020. This ERWIG project will be near the confluence with Somerville Creek and move upstream with the intention of also improving instream habitat and stabilizing stream banks. In the early 2000s, ERWIG and the Eel River Salmon Restoration Project completed separate bank stabilizations projects along Redwood Creek by installing structures at the toe of large slides. These projects stabilized the slides and prevented sediment from entering Redwood Creek.

In the late 1980s and extending through the 1990s, Redwood Creek has been host to a variety of small programs involving the hatching and rearing of salmonids. The Redwood Creek Fish Hatchery located in lower Redwood Creek conducted artificial propagation of Coho Salmon, Chinook Salmon, and steelhead to be distributed in Sproul Creek as well as within Redwood Creek with the intention of producing a greater number of smolts.

Additional restoration projects have been completed in Redwood Creek tributaries and are briefly described in Table 6-1. These projects were also primarily funded through the CDFW FRGP.

Table 6-1. Redwood Creek Tributaries Restoration Projects from early 1990s till 2010*.

Stream	Project Year(s)	Project Type	Project Description
Seely Creek	2006	Sediment Reduction	Restoration Forestry Inc. performed sediment reduction project completed along 300-feet of stream channel.
Teichi Fork (tributary to Seely Creek)	2002	Bank Stabilization	Restoration Forestry Inc. moved road (8-10ft) along Teichi Fork and performed slope work to prevent complete bank failure. Installed willow wall for increased bank stabilization.
	2002	Bank Stabilization and Barrier Modification	Restoration Forestry Inc. installed instream structures to improve bank stabilization as well as grade control structure to improve fish passage.
China Creek	1993	Instream Habitat	Several pre-existing channel spanning logs modified to improve instream habitat.
	2006	Bank Stabilization	ERWIG completed instream bank stabilization project in lower China Creek, which entailed re-sloping 100 feet of hillslope above the bank and armoring it with quarry rock and installing small deflectors and anchor logs.
Dinner Creek	Early 1990s	Instream Habitat	Modification of pre-existing channel scour structures to enhance rearing habitat by deepening and lengthening existing pools.
	2010	Barrier Modification	Two county road crossing (poorly designed culverts) modified to improve fish passage to over 9,400 feet of habitat.
Miller Creek	Early 2000s	Bank Stabilization	Bank stabilizations and riparian and hillside planting of coniferous tree species at active slide locations.

**Table may not reflect all projects that have been completed in the tributaries but intends to describe most of them.*

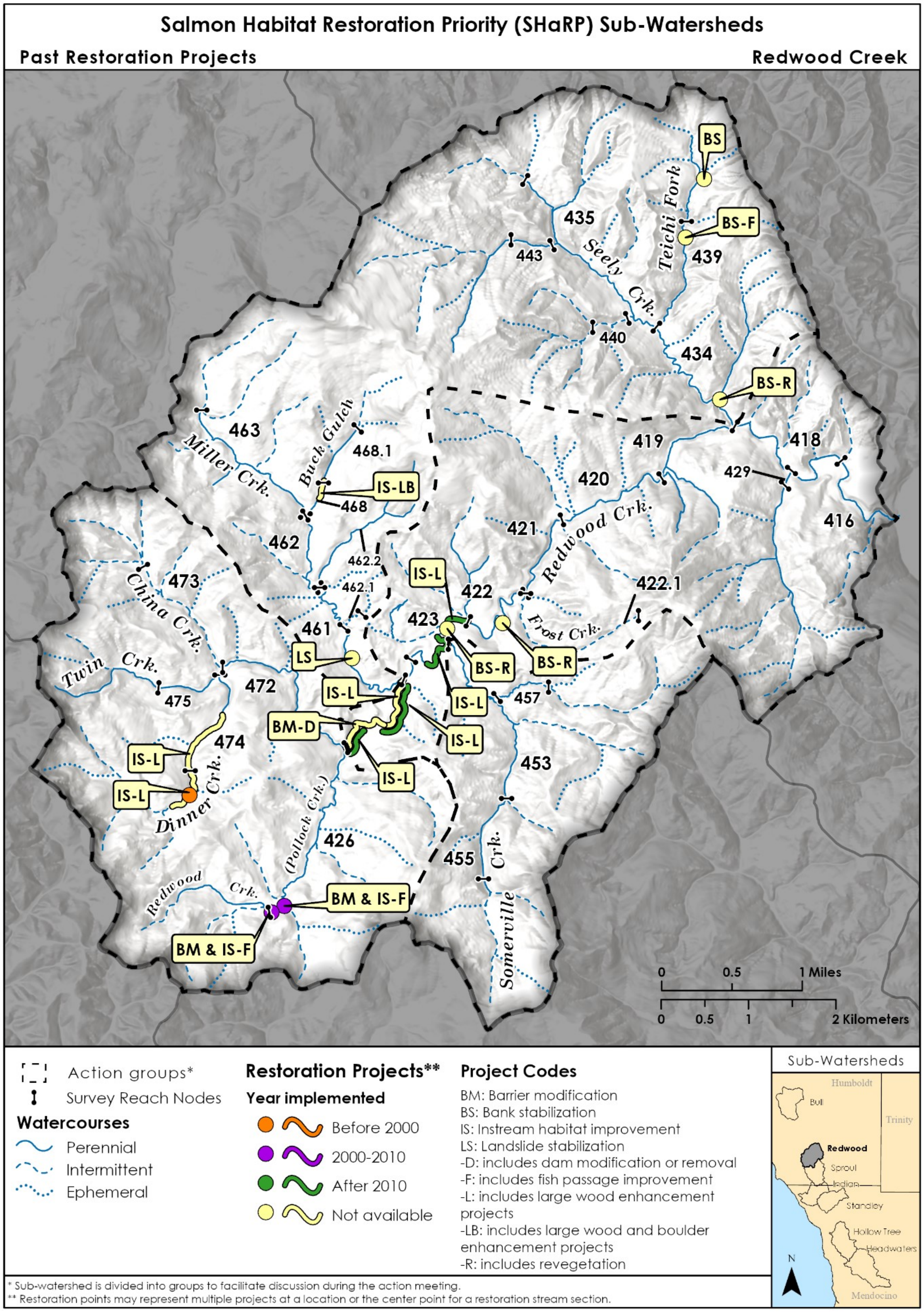

Figure 6-12. Restoration projects implemented in the Redwood Creek sub-watershed.

6.4 Limiting Factors and Threats Affecting Salmonids in Redwood Creek

The Redwood Creek Expert Panelists discussed available data and personal observations of the sub-watershed on June 13, 2019. During this discussion, each participant scored each limiting factor and threat was to each life stage of each species in an interactive process. The resulting limiting factor tables (Table 6-1, Table 6-2) summarize the Expert Panel rankings in three areas of the sub-watershed: the 1) Mainstem Area, 2) Seely, Miller, and Somerville Creeks, and 3) Pollock, China, Twin and Dinner Creeks. The impact of each threat was considered across the entire sub-watershed (Table 6-3). All Expert Panel scores for each factor and life stage were averaged and categorically ranked to indicate how much each factor and threat limits the viability of each life stage of each salmonid. The lower the number, the greater the impact; thus cells scoring less than 2 are red (very high impact), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact). When reviewing the ratings as a group, the Expert Panel considered limiting factors and threats scoring high or very high impact likely need restoration treatment, if possible. The data used during this meeting are available on the SHaRP web site at https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.

Limiting Factors

Table 6-2. Average scores for the impact of each limiting factor on each life stage of Coho Salmon and steelhead in three areas of the Redwood Creek sub-watershed. Scores less than 2 are red (very high impact (most limiting)), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact (least limiting)). When reviewing the ratings as a group, the Expert Panel considered limiting factors and threats scoring moderate or high impact to need restoration treatment.

	Life Stages and Areas											
Coho Salmon and Steelhead	Mainstem Redwood Creek				Seely, Miller, and Somerville Creeks				Pollock, China, Twin, and Dinner Creeks (Upstream of Miller Creek, reach 425)			
Limiting Factor	Eggs	Summer Parr	Winter Parr	Migrating Adults	Eggs	Summer Parr	Winter Parr	Migrating Adults	Eggs	Summer Parr	Winter Parr	Migrating Adults
Barriers		4.7	4.6	4.0		4.1	3.9	3.8		4.3	4.0	3.8
Channel complexity, including pool depth	2.0	1.8	1.3	2.8	1.6	1.5	1.3	2.0	1.9	1.3	1.7	2.0
Dry season flow		1.0				1.0				1.0		
High water temperature		1.7				2.7				3.4		
Large wood recruitment, canopy cover		1.6	1.4	2.9		1.8	2.0	2.1		2.1	2.0	2.4
Off-channel habitat		2.2	1.5			2.7	1.5			3.3	1.8	
Sediment (catastrophic road failures and chronic turbidity)	1.9		2.0		2.2		1.7		2.0		2.0	
Spawning substrate	2.8				2.3				2.8			
Wet season flow (timing and volume)	4.0		3.7	3.3	4.1		3.7	3.8	4.3		3.9	3.4

Table 6-3. Average scores for the impact of each limiting factor on each life stage of Chinook Salmon in three areas of the Redwood Creek sub-watershed.

Chinook Salmon	Life Stages and Areas: Mainstem Redwood Creek			Seely, Miller, and Somerville Creeks			Pollock, China, Twin, and Dinner Creeks (Upstream of Miller Creek, reach 425)		
Limiting Factor	Eggs	Fry	Migrating Adults	Eggs	Fry	Migrating Adults	Eggs	Fry	Migrating Adults
Barriers		4.7	3.8		4.1	4.0		4.0	3.8
Channel complexity, including pool depth	2.1	2.6	2.9	2.2	2.7	2.3	2.6	2.7	2.3
Large wood recruitment, canopy cover		2.9	3.2		3.0	2.4		2.9	2.5
Off-channel habitat		2.3			2.3			2.2	
Sediment (catastrophic road failures and chronic turbidity)	2.1	2.4		2.1	2.2		2.3	2.4	
Spawning substrate	2.6			2.4			2.9		
Wet season flow (timing and volume)	3.7	3.9	3.0	4.0	3.9	3.1	4.2	3.8	2.8

Many of the limiting factors with the highest impacts on Coho Salmon*,* Chinook Salmon, and steelhead in Redwood Creek are related to a relative lack of physical habitat complexity and dry season stream flow and temperature (Table 6-1, Table 6-2). Channel complexity was rated as having a high or very high impact to all life stages of all species in all areas of the sub-watershed. Similarly, the availability of suitable off-channel habitat was rated as having a high or very high impact on all life stages and species except summer parr in the Pollock, China, Twin, and Dinner Creeks Action Group. This is likely due in part to the history of resource extraction in the region, development of roads and residential areas along the riparian corridor, as well is the devastating floods of the 1950s and 60s. The Expert Panel rated dry season flow and high water temperatures as the most limiting factor to Coho Salmon and steelhead summer parr except in the Pollock, China, Twin, and Dinner Creeks Action Group where water temperatures are typically cooler. Due to the relatively dense population of the sub-watershed, as well as the water demands of the local cannabis industry, summer water diversion pressure is high and limiting the summer rearing capacity of the sub-watershed. Large wood recruitment and canopy cover were also rated as an important limiting factor across all life stages of Coho Salmon and steelhead and Chinook Salmon in fry and migrating adults in select areas (Table 6-1, Table 6-2). This is likely due to the role that riparian forests play in creating cooler summer water temperatures and forming complex instream habitat. Sediment was rated as having a high to very high impact on all life stages of the three salmonid species due to the number of heavily used unimproved roads throughout the sub-watershed.

The Expert Panel rated factors related to fish passage as having the least limiting factor on salmonid populations. Natural and anthropogenic barriers were rated as low or very low limiting factors across all species, life stages, and areas, reflecting some of the restoration work that has been completed in the sub-watershed to address fish passage requirements. The timing and volume of wet season flow, as influenced by climate change, was rated low except for migrating adult Chinook Salmon in the Pollock, China, Twin, and Dinner Creeks Action Group. Chinook Salmon, which have a relatively early and narrow spawning period and require larger flow events to occur early in the season in order to access higher reaching tributaries. Increased environmental stochasticity can restrict how often access to those areas is possible for Chinook Salmon.

Threats

Table 6-4. Average scores for the impact of each threat on each life stage of Coho Salmon, Chinook Salmon, and steelhead in the Redwood Creek sub-watershed. Scores less than 2 are red (very high impact (most limiting)), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact (least limiting)). When reviewing the ratings as a group, the Expert Panel considered limiting factors and threats scoring moderate or high impact to need restoration treatment.

	Life Stages and Species						
	Egg		Summer Parr	Winter Parr	Fry	Migrating Adult	
Threat	Coho & Steelhead	Chinook	Coho & Steelhead	Coho & Steelhead	Chinook	Coho & Steelhead	Chinook
Channel, benched road beds	3.1	3.4	1.0	2.7	3.2	4.7	4.0
Culvert, dam	3.0	3.4	2.7	2.0	2.3	3.8	3.8
Diversions	5.0	5.0	4.8	4.7	5.0	4.7	4.9
Land conversion, development	2.0	2.0	1.3	2.0	2.3	3.3	3.1
Pollution	1.6	1.7	2.7	1.8	2.0	4.0	4.2
Riparian zone mgmt.	3.3	3.3	2.1	2.8	3.0	3.8	3.7
Rural and county roads (chronic)	2.8	2.4	2.4	3.1	3.0	3.1	3.0

The effects of a relatively high population density combined with the prevalent cannabis industry in the area are reflected in the Expert Panel rating of threats in the sub-watershed. Water diversion was rated as a very high threat to summer parr in response to the apparent diversion pressure and altered flow regimes (Table 6-3). It is hoped that summer forbearance and diversion rate restrictions that are now required through the State Water Resources Control Board (SWRCB) Cannabis Principles and Guidelines Policy will soon show significant improvements to the summer flow issues in the Redwood Creek sub-watershed. Additionally, the CDFW Instream Flow Program's Redwood Creek study may provide more robust information for the SWRCB and CDFW to apply bypass conditions to Water Right protests or Lake and Streambed Alteration permits. However, until there is a biological response from these actions, diversions remain a very high impact threat to the sub-watershed. The chronic effects of the heavily used private and county roads on watershed hydrology and sediment transport, as well as land conversion and development associated with residences and cannabis cultivation, were also rated as a high to very high impact threat to all egg and juvenile life stages. Pollution from septic systems, illegal dumping, and cannabis cultivation was rated as a high threat for more susceptible life stages including egg and summer parr. Riparian zone management, which was expanded in discussion to include meadow encroachment and the potential effects dense, young forests might have on hydrology, was rated as a high threat for summer and winter parr.

6.5 Recovery Strategy

On June 14, 2019, the Redwood Creek Action Team discussed the outcomes of the Expert Panel meeting and identified restoration actions that would best address the most limiting factors and the highest severity threats. The team collaboratively identified the best locations for these restoration actions (Table 6-4) and delineated project locations on large paper maps of the sub-watershed. Figure 6-13 shows the treatment methods and stream reaches identified by the team, as recorded during the meeting and later interpreted by the steering team.

The recovery strategy for Redwood Creek focuses on increasing summer base flows, improving physical habitat complexity for juvenile fish during summer and winter, reducing sediment delivery, and improving riparian forest cover and composition. To a lesser degree, the strategy also includes increasing the suitable spawning habitat for adults in key spawning reaches (Figure 6-13). This strategy identifies reach-scale regions of the sub-watershed and points identified by expert opinion where treatments can be implemented and will likely have the greatest benefit to salmonids, but specific project locations and the methods of implementation will require further investigation and site-specific design. As more data becomes available based on further assessment and analyses of the sub-watershed, these treatments may be applicable to other reaches in the future.

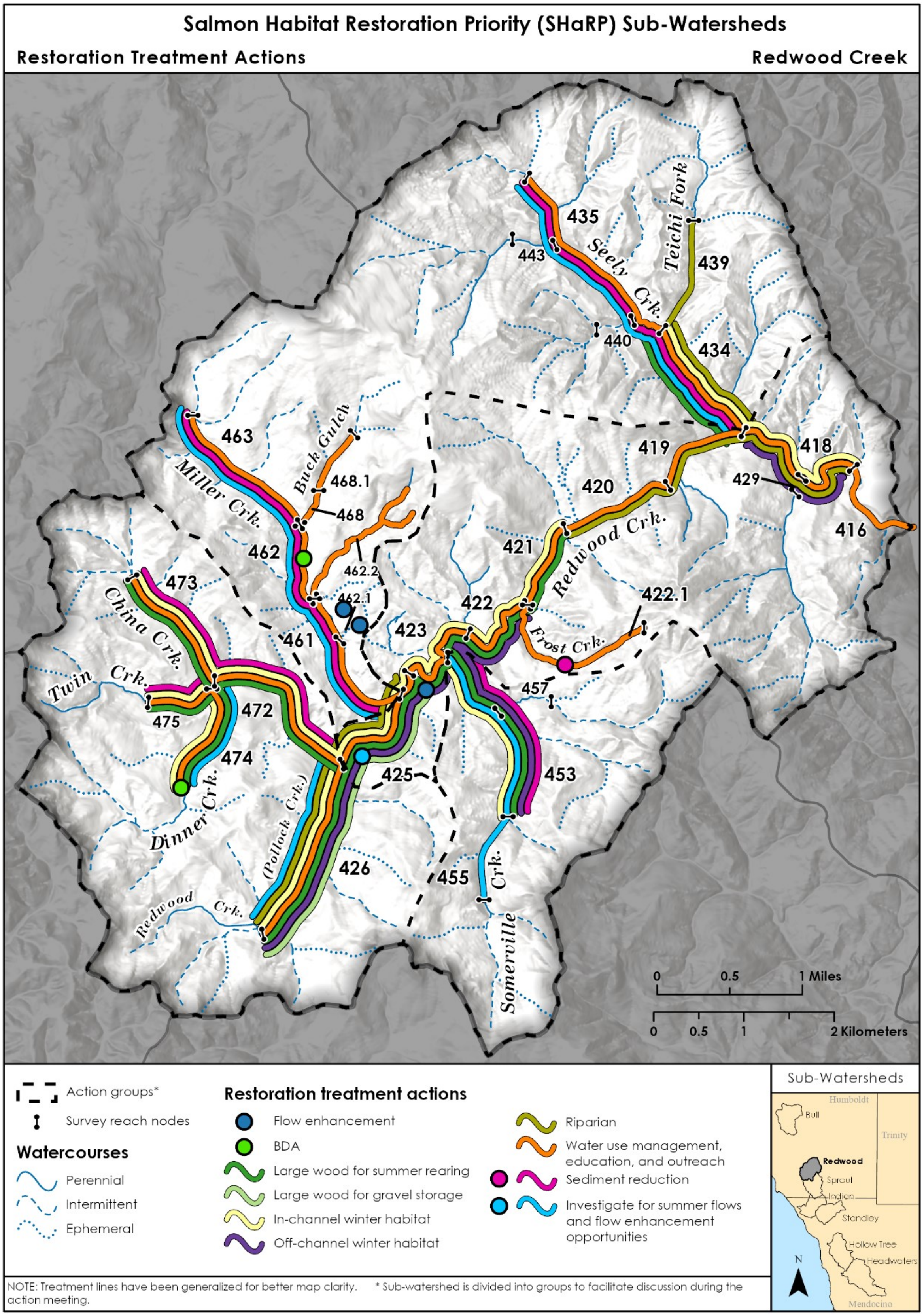

Figure 6-13. Restoration treatments identified by the Redwood Creek Action Team.

Table 6-5. Restoration treatments for the Redwood Creek sub-watershed.

Target	Treatment Description	Stream Name(s)	Survey Reach Code
Winter Juvenile Rearing	In-channel winter habitat	Redwood Creek, Seely Creek, Somerville Creek, China Creek, Dinner Creek, Twin Creek	418, 421, 422, 423, 425, 426, 434, 453, 472, 473, 474, 475
	Off-channel winter habitat	Redwood Creek, Somerville Creek	418, 422, 423, 425, 426, 453
Adult Spawning	Large wood for gravel storage	Redwood Creek	425, 426
Flow Enhancement	Flow Enhancement	Redwood Creek, Miller Creek Tributary	423, 461.2
	Investigate for Summer Flow & Flow Enhancement Opportunities	Redwood Creek, Seely Creek, Somerville Creek, Miller Creek, Dinner Creek	425, 426, 434, 435, 453, 455, 461, 462, 463, 474
	Water Use Management, Education, and Outreach	Redwood Creek, Frost Creek, Seely Creek, Miller Creek, Miller Creek Tributary, Buck Gulch, China Creek, Dinner Creek, Twin Creek	416, 418, 419, 420, 421, 422, 422.1, 423, 425, 426, 434, 435, 461, 462, 462.2, 463, 468, 468.1, 472, 473, 474, 475
	Beaver Dam Analog	Miller Creek, Dinner Creek	462, 474
Summer Juvenile Rearing	Large wood for summer rearing (pools, sorting gravel)	Redwood Creek, Seely Creek, Somerville Creek, China Creek, Dinner Creek, Twin Creek	421, 422, 423, 425, 426, 434, 453, 472, 473, 474, 475
Watershed Processes	Sediment Reduction	Frost Creek, Seely Creek, Somerville Creek, Miller Creek, China Creek, Twin Creek	422.1, 434, 435, 453, 461, 462, 463, 472, 473, 475
	Riparian treatment	Redwood Creek, Seely Creek, Teichi Fork	418, 419, 420, 425, 426, 434, 439

Treatments to Improve Conditions for Winter Parr

To improve habitat for overwintering juvenile salmonids, a key limiting factor identified by the Expert Panel, installation of instream structures was recommended. Stream reaches which were lacking large wood and had poor shelter ratings but had low gradients which could support suitable in-channel refugia were identified as locations to improve in-channel winter habitat. The Action Team also prioritized locations near or below habitats which are frequently utilized for spawning to ensure juveniles born in these areas have nearby winter refugia. In the Redwood Creek sub-watershed, these opportunities exist mostly in the middle and upper reaches of Redwood Creek (reaches 421-423, 425, and 426) and in tributaries of the upper sub-watershed (reaches 453, 472 – 475). There are two reaches in the lower sub-watershed including a section of lower Redwood Creek (reach 418) and lower Seely Creek (reach 434) which may also provide suitable in-channel winter habitat. These lower sub-watershed areas are important for winter rearing as they can be productive for both natal fish emigrating down river and for non-natal fish seeking refuge from the South Fork Eel River (Johnson 2016, Wallace et al. 2015, Rebenack et al. 2015).

The lack of off-channel habitats, including floodplains, alcoves, and backwaters were also identified as limiting for overwintering juvenile salmonids. The Action Team used the same criteria described for in-channel winter habitat to assess suitable locations for off-channel winter habitat with the additional requirement that ideal reaches should have unconfined channels, wide valley widths and/or the observation of existing floodplain habitats that could be enhanced to ensure frequent access to low-velocity habitat during winter base flows. Based on the available data, the Action Team identified one reach in lower Redwood Creek (reach 418), four reaches in middle Redwood Creek (reaches 422, 423, 425, and 426), and one reach of Somerville Creek (reach 453) where opportunities for off-channel winter habitat may exist but field investigation are recommended to locate specific project locations.

Treatments to Improve Conditions for Eggs and Alevin

The Expert Panel identified sediment as a limiting factor affecting the survival of salmonid eggs and alevin in portions of the sub-watershed. Several tributaries in the sub-watershed have legacy logging roads, rural private roads, and bank failures that deliver fine sediment to the sub-watershed. The Action Team identified several areas where investigations are recommended to determine the effect that streamside roads and road crossings are having on sediment delivery. These areas include roads along China and Twin Creeks (reaches 472, 473, and 475), Somerville Creek (453), Seely Creek (434 – 435), Miller Creek (461 – 463), and a single road crossing on Frost Creek (422.1). It was noted that a road inventory had been completed for the China Creek area in 2000 that resulted in upgraded culverts and stream crossings; however, the roads in this area still have chronic sediment issues resulting from poor road surfaces. Because many of these roads are private and used by a diversity of landowners, the Action Team recommended that the community form a road association to pool resources and improve road conditions for all users.

In addition to treating sediment sources, the Action Team recommended installing large wood features to help trap and sort gravel to ensure high quality spawning substrate persists. The upper reaches of Redwood Creek (reaches 425 – 426), which are heavily utilized by spawning salmonids and contain moderate amounts of large wood, were identified as priority treatment locations.

Treatments to Improve Dry Season Flow

Summer base flows are severely impaired in Redwood Creek due in part to the number of water extractions in the sub-watershed as well as the methodology used for water extraction (i.e. the timing of withdrawal, inappropriate extraction volumes, leaky and inefficient equipment). For juvenile salmonids, including Coho Salmon and steelhead parr, a persistent flow of cold, oxygenated water in Redwood Creek is crucial for growth and survival through the summer. To increase the amount of water available for parr throughout the summer months, the Action Team identified treatments to enhance stream flow via off-channel storage and reduce water withdrawal during the summer months through education and community outreach. The Action Team also identified key reaches to focus investigations on flow enhancement feasibility through community outreach and field assessments. Treatment areas were also chosen based on expert opinions of water use in Redwood Creek, as well as the relative feasibility of effectively increasing dry season flows within each area. An additional flow enhancement approach that should be strongly considered is conservation easements and/or land acquisition to protect key areas from further development. The main areas of focus for these approaches are upper Redwood Creek and Dinner Creek, but these approaches could also be extremely beneficial throughout the sub-watershed as opportunities present themselves for reducing development and protecting cold-water inputs.

Improving water use through coordination, education, and community outreach is recommended in Miller Creek, Buck Gulch, China Creek, Twin Creek, Frost Creek, Dinner Creek, Seely Creek, and Redwood Creek (reaches 416-423, 425, 426, 434, 435, 461-463, 468, 468.1, and 472-475). Water use is relatively high along these reaches and the Salmonid Restoration Federation (SRF) have found that many water users in the Redwood Creek sub-watershed have poorly designed and/or leaky water infrastructure which continuously diverts water from springs and small tributaries. With relatively simple updates (e.g., float valves in tanks) and technical assistance, much of the existing infrastructure could be updated to ensure that residents are not diverting more water than needed from Redwood Creek tributaries. Additionally, communicating with residents about the natural resources in their area and encouraging best management practices for water use, such as storage and forbearance, will enable voluntary community actions to improve dry season flow. For instance, Frost Creek was identified as a high-quality perennial source of cold water; however, excessive water drafting from this waterway prevents Frost Creek from making significant contributions to Redwood Creek. Simply engaging the residents of Frost Creek could have immediate returns to salmonids if residents are receptive and responsive.

There is also a critical need for most landowners to increase their storage capacity to reduce their diversion needs during the dry season. While many landowners are currently storing water during the wet season and forbearing diversion during the dry season either on a voluntary basis or as required for commercial cannabis cultivation, there are many landowners in the sub-watershed that do not have the financial resources or expertise to install storage facilities (e.g., tanks or ponds). The population density and number of landowners in Redwood Creek is relatively high throughout the sub-watershed, making it difficult to secure the full cooperation needed to implement projects involving multiple landowners and in key locations that will have the greatest benefits. Therefore, comprehensive education and outreach is needed to accomplish effective restoration. SRF is currently implementing a WCB grant that is funding water conservation planning and community outreach throughout the Redwood Creek sub-watershed. The Action Team recommends continuing this outreach with a focus on key tributaries listed above. Ideally, outreach efforts should include technical assistance to aid water users in updating water infrastructure, with follow-up financial assistance where appropriate. Also, it is recommended that a more formal storage and forbearance program is initiated throughout the Redwood Creek sub-watershed using the Mattole River storage and forbearance project implemented by Sanctuary Forest as a model. It is anticipated that ongoing outreach as well as technical and financial assistance will be required over a prolonged period (decades) to significantly reduce the impacts of human consumptive use.

The Action Team identified several key locations to develop flow enhancement projects that would store wet-season runoff and release the water during the dry season to augment surface flow in Redwood Creek. Through funding primarily by the WCB; the Marshall Ranch, Stillwater Sciences, and SRF are currently collaborating to design and construct a large off-channel pond on the Marshall Ranch property along reach 423 that will deliver cold water to Redwood Creek during the 5-month dry season. The Action Team identified three other specific locations that would be suitable for developing flow enhancement projects utilizing wet-season flow retention and dry season release: two existing on-stream ponds along tributaries to Miller Creek (reach 462.1) and a site along reach 425 with no existing infrastructure. The site along reach 425 has good access, is on low-laying, stable land, and has previously disturbed areas that could be converted to a pond without significant impacts to natural resources. The Action Team recommends working with landowners in these areas to either use existing ponds or develop new off-channel storage to enhance summer stream flows.

Additionally, the Action Team discussed the potential for using beaver dam analogues (BDAs) or log/boulder weirs in small tributaries to slow runoff, facilitate groundwater recharge and increase baseflow during the spring recession and summer dry season. A location was identified on Miller Creek, the stream with the most rapid baseflow recession in the sub-watershed, to investigate the utility of beaver dam analogues. Additional potential sites for these treatment types were also identified in the headwaters of Dinner Creek. BDA structures are a relatively novel approach to restoration; implementation of such projects should carefully consider the geomorphic and hydrologic conditions of a site and designs should build upon the successes and failures of similar projects. Implementation guidance can also be found using the Beaver Restoration Assessment Tool (BRAT), an open source model for assessing beaver restoration potential (Macfarlane et al. 2017).

Several key tributaries were identified for future investigations to identify where and when summer flows become sub-surface and where flow-enhancement opportunities may exist in the landscape. SRF has funding from WCB to conduct this assessment in the summer of 2020. The Action Team identified Redwood Creek, Seely Creek, Somerville Creek, Miller Creek, and Dinner Creek (reaches 425, 426, 434, 435, 453, 455, 461, 462, 463, 474) as areas where the timing and location of flow disconnection is not known. Understanding this pattern will improve our ability to focus instream restoration projects into areas that maintain habitat year-round and where focused community outreach to support summer flow enhancement might be most appropriate. These tributaries, along with the upper reaches of Redwood Creek (reach 426), are also important regions to investigate where springs exist within the sub-watershed and how much potential flow they could provide. Understanding this information could inspire strategic conservation easements or land acquisitions to ensure these springs contribute cold, clean water to Redwood Creek and its tributaries.

Treatments to Improve Conditions for Summer Parr

In addition to low summer flow, the lack of instream complexity, high water temperatures, and large wood recruitment were also identified as limiting factors for juvenile salmonids rearing through the summer months. To address these factors, the Action Team recommends installing large wood structures to augment summer habitat and improving riparian forest cover and composition through planting and conifer release. The Action Team identified priority locations for instream treatments as portions of the sub-watershed which typically provide cold, perennial flows and are in or near well-used spawning habitat. These areas include upper reaches of Redwood Creek, Seely Creek, Somerville Creek, China Creek, Dinner Creek, and Twin Creek (reaches 421-426, 434, 453, and 472-475). Adding large wood features to these locations may create or enhance pool habitat and add cover to provide shelter from predators during low flow conditions. The Action Team recommended riparian planting along temperature-impaired reaches that have poor canopy cover including lower Redwood Creek, Seely Creek, Teichi Fork, and upper Redwood Creek (reaches 418-420, 434, 439, 425, and 426).

If you have questions or would like to collaborate on implementing the actions in this chapter, please contact Julie Weeder, NMFS recovery coordinator (707-825-5168, julie.weeder@noaa.gov) or Allan Renger, CDFW area supervisor (707-725-7194, Allan.Renger@wildlife.ca.gov).