5. Chapter 5: Bull Creek Action Plan

5.1 Sub-Watershed Overview

Bull Creek is the northern most tributary of the South Fork Eel River (SFER) sub-basin in Humboldt County (Figure 5-1). Bull Creek is a fourth order stream with approximately 21.2 miles of perennial waterways draining a sub-watershed of about 44 square miles (Merrill and Vadurro 1999). Elevations range from approximately 160 feet at the mouth of the creek to over 3,000 feet in the headwaters. The landscape is dominated by coastal redwood forest, mixed evergreen, and coniferous forests as well as a small amount of grassland and oak woodland forest (CDFW 2014). The entire sub-watershed is owned and managed by California State Parks (CSP) as part of Humboldt Redwoods State Park. To facilitate discussion of the sub-watershed's characteristics, the sub-watershed has been sub-divided into three areas: 1) Lower Bull Creek (mainstem and Squaw, Miller, Tepee, Harper and Cow creeks), 2) Middle Bull Creek (mainstem and Albee, Mill, Cuneo, and Burns creeks, and 3) Upper Bull Creek (mainstem and Slide and Panther creeks) (see Figure 5-2 for approximate boundaries).

The lower portion of the sub-watershed was purchased to preserve old growth redwood forests in 1931, while the middle and upper portions were not incorporated into the park until after 1964. By that time, over 60% of the forests had been clear cut and the sub-watershed subsequently ravaged by two devastating floods (Jager and LaVen 1981, CSP 2020). Despite early efforts to protect Bull Creek and the surrounding forests, land use practices in the upper sub-watershed and associated flood damage have degraded aquatic conditions throughout the sub-watershed and salmonid populations have declined dramatically (CDFW 2014). Despite the ecological devastation of the mid-20th century, Bull Creek still supports Coho Salmon (*Oncorhynchus kisutch*), Chinook Salmon (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss*), albeit in drastically reduced numbers (CDFW 2014). Trends in overall salmonid habitat suitability indicate conditions are improving, likely due to resource protection and restoration actions taken by CSP and supporting conservation groups (CDFW 2014, CSP 2015). Notwithstanding recent improvements in conditions, aquatic habitat in much of the sub-watershed remains degraded from legacy impacts. Significant restoration actions are needed to accelerate recovery of salmonid populations in Bull Creek.

Figure 5-1. Bull Creek's position in the South Fork Eel River sub-basin.

5.2 History of Land Use and Fish Habitat

The underlying geology of the Bull Creek sub-watershed is dominated by an extensive zone of Yager Terrane, a layered mix of well-consolidated sandstone, argillite, and pebble conglomerate. This geologic feature forms steep, crested ridges and deep valleys that are typically deeply fractured yet stable, giving rise to soils that support lush forests such as the ancient redwood groves of the lower sub-watershed (CDFW 2014, Hahm et al. 2019). Heavily faulted and sheared areas can create zones which are locally weak and prone to landslides and erosion, especially when exposed to precipitation and other surface flow (Brown and Ritter 1971, CDFW 2014). The Bull Creek sub-watershed resides within an area with exceptionally high rates of geologic uplift as well as frequent earthquakes from the nearby faults (Merrits and Bull 1989, Lock et al. 2006). While this geology supported the growth of lush forests, land disturbances associated with unrestricted logging contributed to continuous mass wasting and the rapid aggradation observed during flood events between 1955, 1964, and 1997 (Jager and LaVen 1981, Merrill and Vadurro 1999).

The Bull Creek sub-watershed is located within Wailaki ancestral territory. Prior to European settlement, Wailaki tribal members residing in the sub-watershed depended on seasonal availability of resources including numerous edible and medicinal plants, fibers used in basketry and net making, wild game, salmon, and lamprey. The land and its abundant resources provided a spiritual connection and sustenance for tribal members. The productive timberlands and prairies of the Bull Creek sub-watershed also attracted European settlers to the area. Following the removal and relocation of Wailaki people to the Round Valley reservation in the late 1880's, European immigrants claimed lands in the sub-watershed and established cattle ranches in the open grasslands near Albee Creek.

Ranching persisted as the dominant industry in the small town of Bull Creek until 1946 when small-scale clear cutting began. While Lower Bull Creek was purchased and protected, logging and rangeland conversion continued unabated in Middle and Upper Bull Creek until the mid-1960s (Jager and LaVen 1981). During this time, taxes levied on standing, merchantable timber incentivized the rapid and widespread harvest of timber from forest lands. By 1960, 85% of the privately held land (over 60% of the entire sub-watershed) had been clear cut. Extensive road networks were built to accomplish this feat; road densities in the upper sub-watershed were as high as 20 miles of unimproved road per square mile. Additionally, 4,000 acres of previously forested land was converted to rangeland, typically using fire. Between wildfires and intentional burning, over 8,700 acres of the upper sub-watershed were burnt by 1959 (Jager and LaVen 1981). Standard logging practices of the era included little to no protective measures for waterways and almost no erosion control or reforestation efforts.

Land disturbances due to logging activities exacerbated the slide-prone landscape and left the sub-watershed more vulnerable to erosion. When the area was struck by two devastating floods in 1955 and 1964, massive debris and sediment yields were delivered to the Eel River in volumes approximately three times greater than observed in the geologic record of the Eel River sub-basin

(Sommerfield et al. 2002). These large flood events drastically altered the channel morphology of Bull Creek (Jager and LaVen 1981, Pryor et al. 2011). Landslides, erosion, and unprecedented stream flows during these events severely aggraded the stream channel and floodplains and damaged the town of Bull Creek. Debris from the settlements such as portions of houses, cars, logging materials, and even coffins were transported and deposited throughout the lower sub-watershed (Jager and LaVen 1981). These floods also eroded stream banks along the portions of the stream owned by the state, taking with them over 850 of the treasured redwoods (Jager and LaVen 1981). All of the tributaries in Upper and Middle Bull Creek were filled by landslide and flood debris; the cumulative aggradation from the 1955 and 1964 events reached up to 15 feet in height in tributaries such as Cuneo Creek (Pryor et al. 2011). Subsequent sediment transport carried these sediments from the higher gradient tributaries to depositional areas in Lower Bull Creek, further aggrading the lower reaches and exacerbating erosion and loss of old-growth forest (Jager and LaVen 1981).

In response, CPS developed plans to treat key sources of sediment, minimize bank erosion, encourage sediment transport through lower stream reaches, and store large volumes of sediment in channels and control its release where appropriate. Techniques employed in the mainstem Bull Creek downstream of Albee Creek included channel clearing and shaping, flow spreading, rock gabions, revetments, groins, rock riprap, sediment retention structures, and artificial cascades. Banks lined with large rock riprap after the 1955 flood effectively withstood the 1964 flood and this treatment became the chosen strategy to protect alluvial forest in the lower reaches of Bull Creek (Jager and LaVen 1981). In addition to widespread riprap bank protection, trees that fell into the stream channel were routinely removed to reduce bank erosion potential until 1997, a practice generally referred to as “stream cleaning” (Merril and Vadurro 1999). While these efforts may have been successful in conserving the surrounding forests, they are now considered detrimental to natural river channel formation processes necessary for fish habitat formation and maintenance.

The combined effects of flood damage, logging disturbances, excess sediment yield, channel alterations to improve sediment conveyance, and wood removal (e.g. stream cleaning) have all contributed to poor stream complexity and low habitat suitability scores for salmonids in Bull Creek. Stream inventories conducted between 1991 and 2007 indicate that pool quality (a metric of both pool depth and shelter) is poor throughout the sub-watershed (CDFG 1991, CDFG 2007, Figure 5-2). This is likely due to the combination of excessive sediment delivery from land disturbance, flooding, and a lack of instream structure such as large wood[3], which can scour pools and sort gravels (Figure 5-3). For similar reasons, gravel embeddedness ratings are moderate to

[3] 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.

poor throughout the middle and lower reaches of Bull Creek, but the upper reaches have shown improvement (Figure 5-4). Stream cleaning to remove large wood has likely hindered natural recovery processes leading to poor salmonid habitat (Merrill and Vandurro 1999). While large wood densities are relatively suitable in areas of the sub-watershed with robust, mature forests, most of the reaches in Middle and Upper Bull Creek have low densities of large wood (Figure 5-3). However, it was noted that while Squaw Creek has large wood densities rated at "Excellent," the effects of stream clearing are apparent; many instream pieces of wood have been cut, leaving only the embedded stumps and trunks left in the bank (pers. comm. Brian Starks). It is possible that this has reduced the functionality of the remaining wood pieces, resulting in the poor pool depth ratings in Squaw Creek (Figure 5-2).

Following these dramatic landscape-scale disturbances in the Bull Creek sub-watershed, the upper slopes and riparian zone have been in a process of recovery. The plant community is progressing through ecological succession, aided and accelerated by revegetation projects and road decommissioning. Jager and LaVen (1981) noted after the 1964 flood, portions of the channel in this region widened to over 400 feet and were composed entirely of flood-deposited gravel (1981). Aerial photos of the sub-watershed taken in 1965 clearly show a wide, barren plain where a thickly wooded, narrow stream corridor had once existed (CDF 1942, CDF 1965, Figure 5-5). Initially, the restoration strategy for Bull Creek relied on natural revegetation and vegetation succession (Jager and LeVen 1981). This process was slow to develop and Jager and LeVen (1981) noted this delay likely increased long term monetary and environmental costs (1981).

A 1992 earthquake fractured hillslopes along the Garberville fault and a subsequent flood in 1997 further exacerbated excess sediment delivery in the sub-watershed. Remarkably, the peak flow during the 1997 flood event was higher than peak flows observed during the 1955 and 1964 floods, yet it was much less destructive and the resulting channel aggradation was substantially lower (Pryor et al., 2011). This discrepancy is indicative of progressive watershed recovery, though more proactive measures would be required to prevent further disasters from occurring. In 2012, the second highest peak flow on record (higher than 1955 and 1964) with a recurrence interval of about 25-years did not aggrade the channel. Rather, incision was documented in surveyed areas (Middle Bull Creek), a further indication of an overall reduction in sediment supply and continued watershed recovery. CPS and partners' restoration efforts, described further in the Historic and Current Restoration Efforts section, have likely prevented tens of thousands of yards of sediment from entering streams in the sub-watershed (CSP 2015).

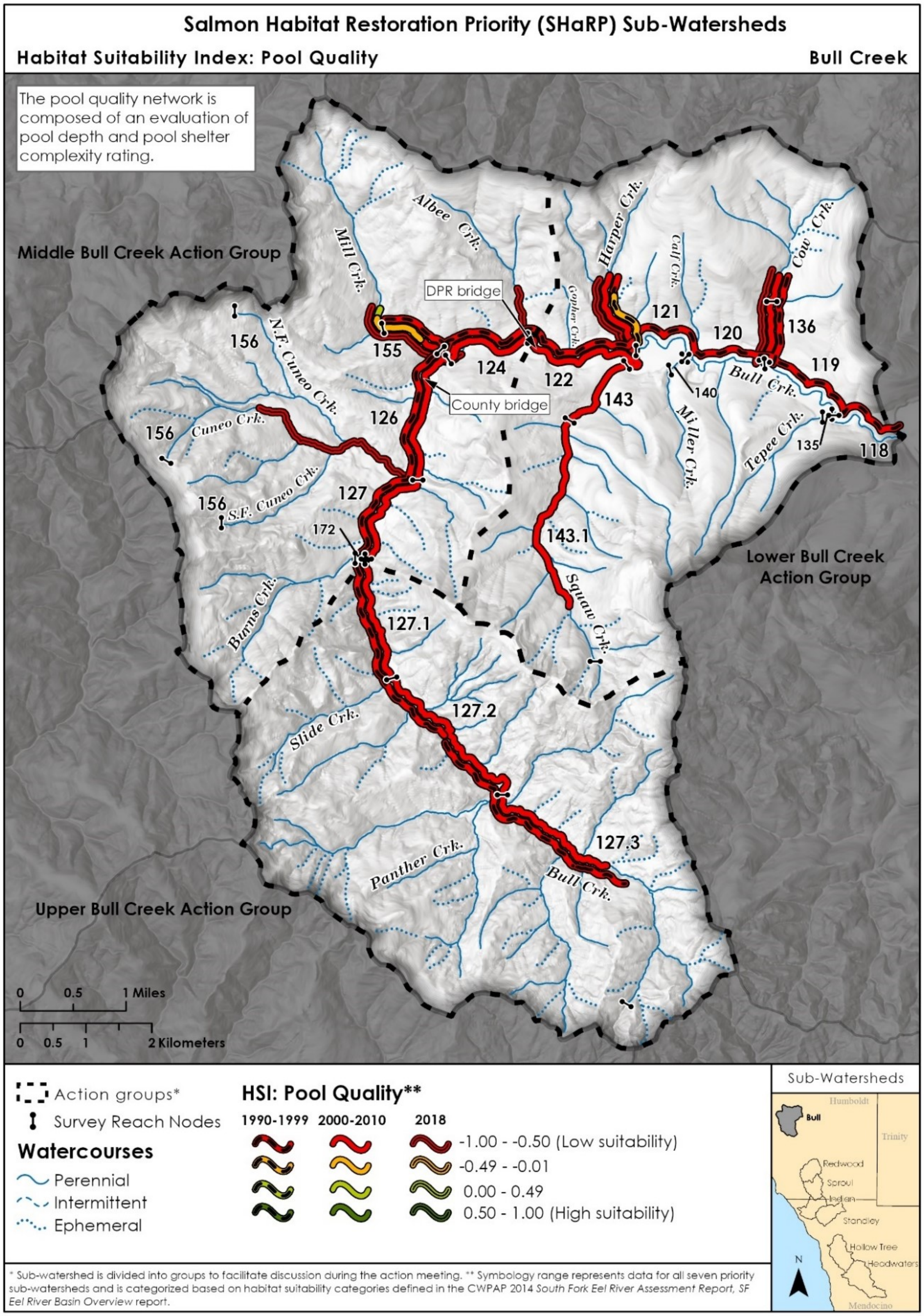

Figure 5-2. Pool Quality Habitat Suitability Index (HSI) scores for pool quality in the Bull Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.

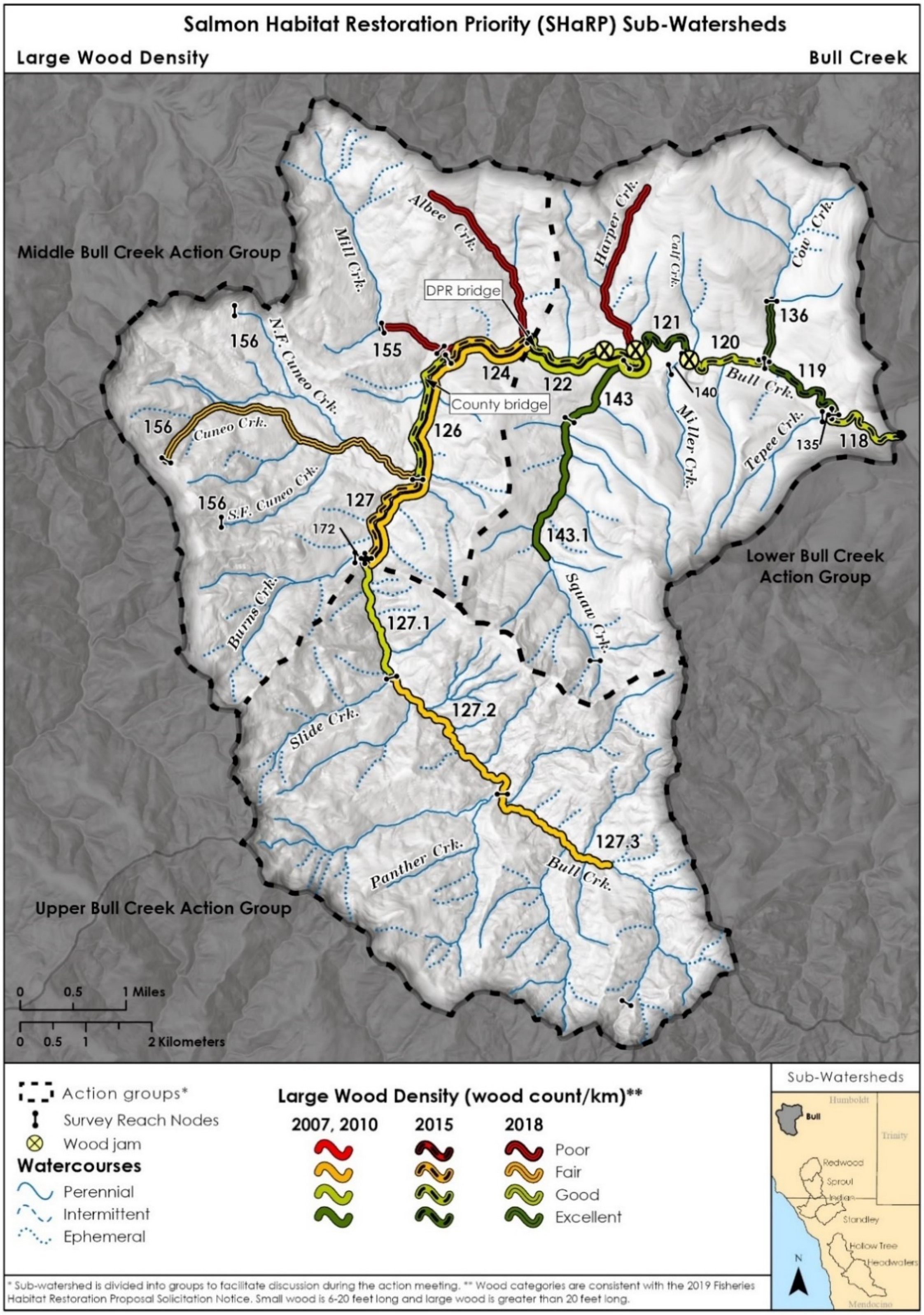

Figure 5-3. Large wood densities in the Bull Creek sub-watershed derived from CDFW stream habitat inventories completed during the following survey years: 2007, 2010, 2015 and most recently in 2018. Surveyed reaches varied each year based on funding and crew availability.

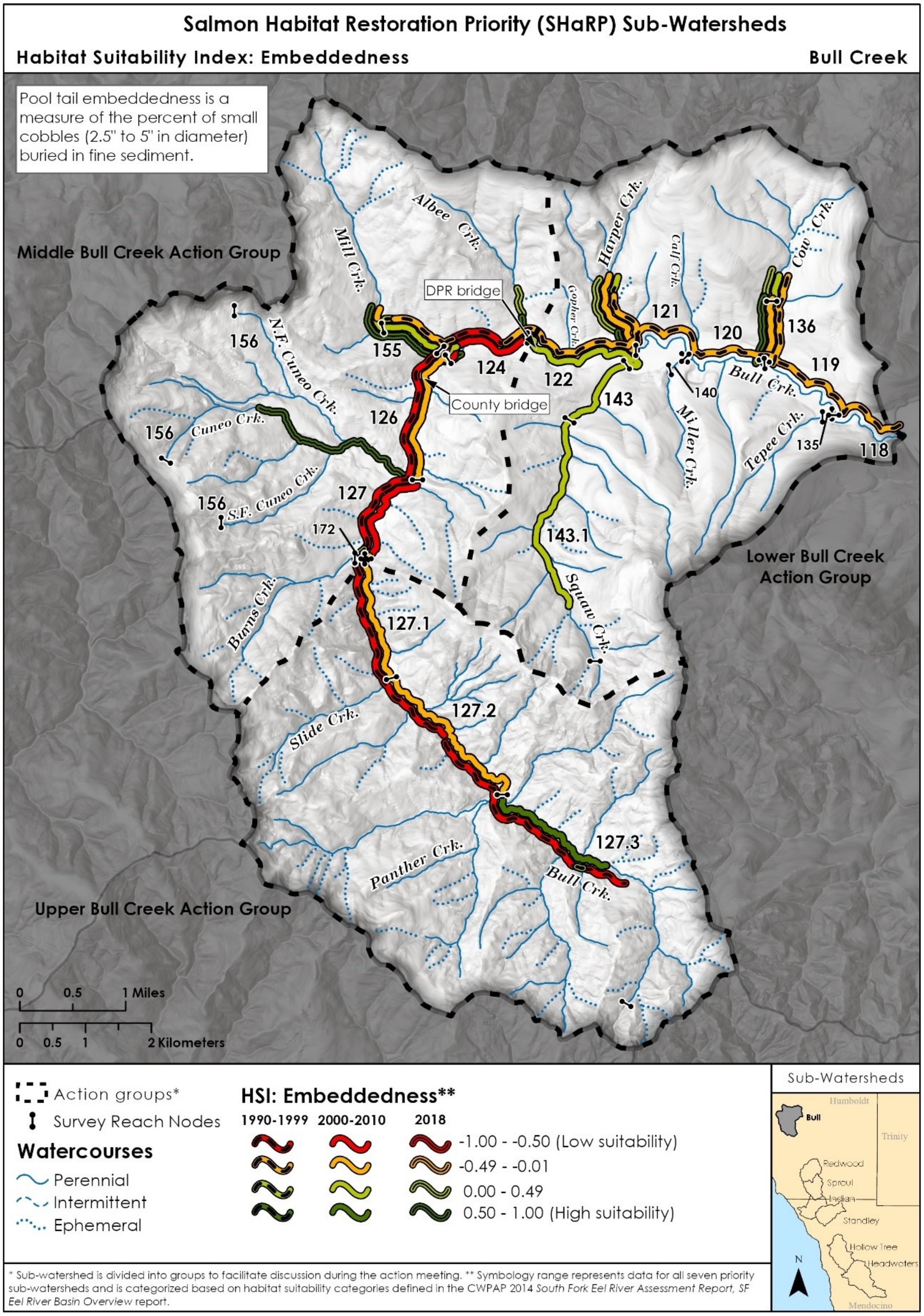

Figure 5-4. Habitat Suitability Index (HSI) scores for gravel embeddedness in the Bull Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.

Riparian canopy densities in Bull Creek from Burns Creek to Mill Creek are still poor, but other reaches have greatly improved (e.g. Upper Bull Creek upstream of Panther Creek) (Figure 5-6). The methods employed to measure canopy density poorly document the old growth redwood riparian forest in Bull Creek below Harper Creek due in part to the widened channel in these reaches. Poor canopy cover increases a stream's exposure to solar radiation, and stream temperature monitoring in Bull Creek indicates reaches with poor canopy cover are associated with marginal to unsuitable water temperatures by late summer (Figure 5-7). Interestingly, in 1937 it was noted Bull Creek "normally runs dry for 3 or 4 miles above the mouth during the summer, so that only a few pools are left. It usually goes dry about July" (CDFG 1937). The continued succession of the plant community to a mature coniferous riparian forest will likely take tens to hundreds of years (Gregory et al. 1991), but active management of the plant community will likely continue to accelerate the recovery process.

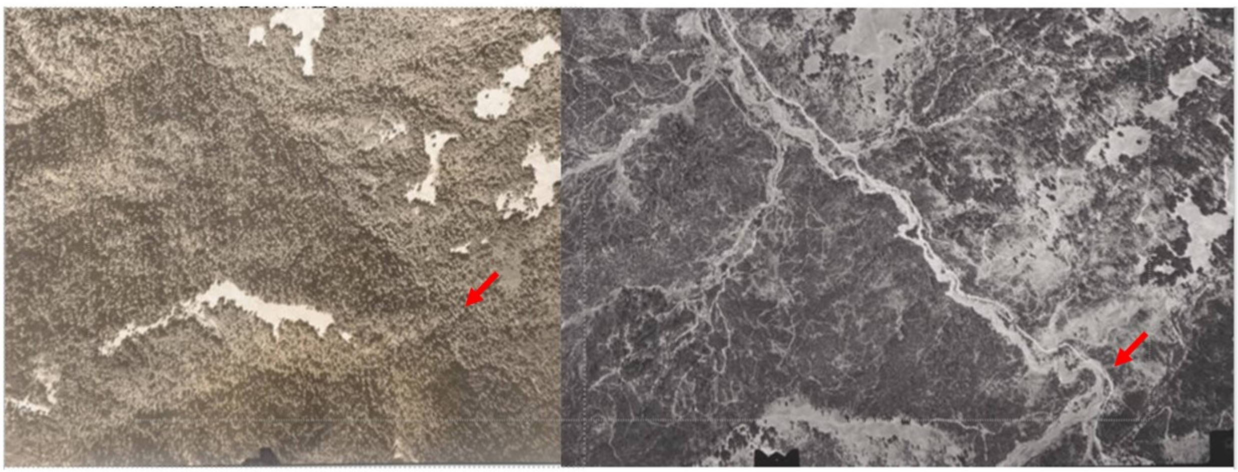

Figure 5-5. Upper Bull Creek from Slide Creek to Panther Creek from 1942 (left) to 1965 (right). The extensive upland road networks, deforestation, and flood damage are shown in stark contrast to the nearly unaltered 1942 landscape. The red arrows indicate the confluence of Panther Creek and Bull Creek.

Formerly thriving salmonid populations in Bull Creek have struggled to persist in this heavily impacted environment. Surveys and records from 1934 to 1938 indicate salmonids were abundant in Bull Creek and natural propagation was "considerable" (CDFG 1934, CDFG 1937, CDFG 1938). However, by 1960 CDFG staff optimism for the salmonid population had waned. A 1956 letter stated that "the possibility of restoring a sizable salmon and steelhead run in Bull Creek appears to be remote" (CDFG 1960). Restoration efforts and protections awarded by state land acquisitions have likely contributed to the persistence of salmonids within the sub-watershed. Though redd densities are low when compared to other sub-watersheds in the South Fork Eel River, Chinook Salmon, Coho Salmon, and steelhead regularly spawn in Bull Creek (Figure 5-8).

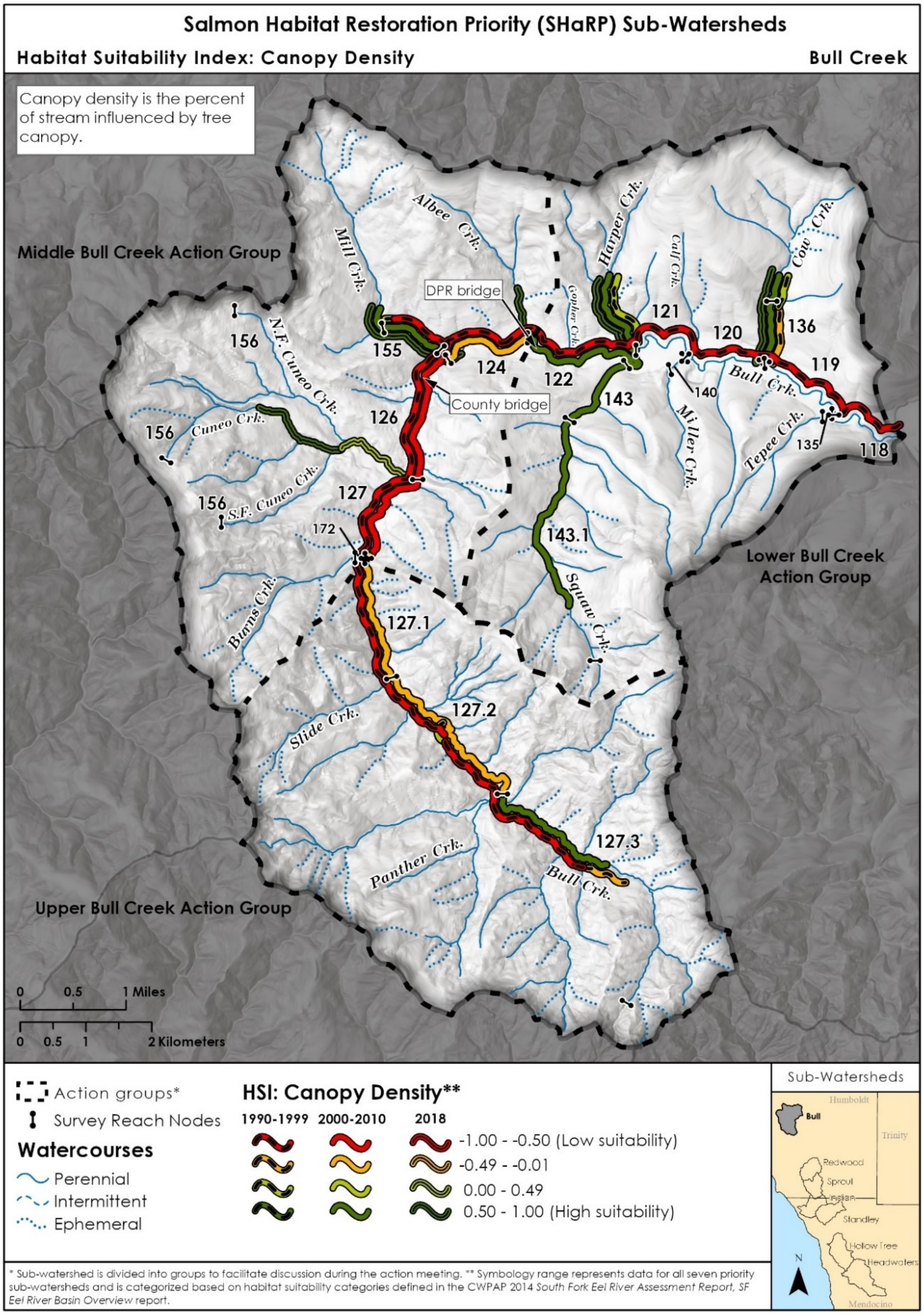

Figure 5-6. Habitat Suitability Index (HSI) scores for canopy density in the Bull Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.

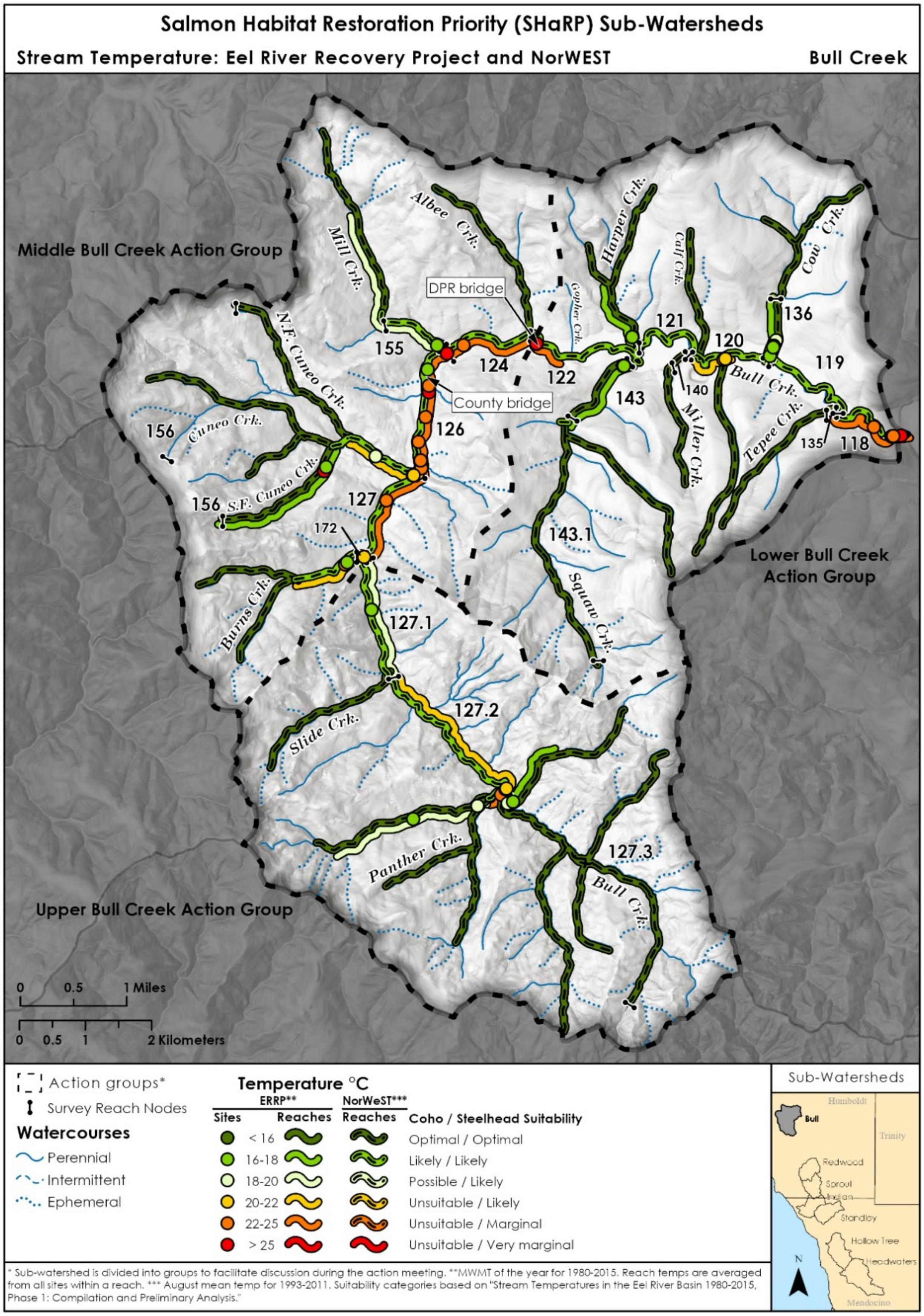

Figure 5-7. Observed mean weekly maximum temperatures (MWMT), the average daily maximum temperature during the hottest seven-day period of the year (ERRP) and modeled mean August temperatures (NorWeST) for the Bull Creek sub-watershed.

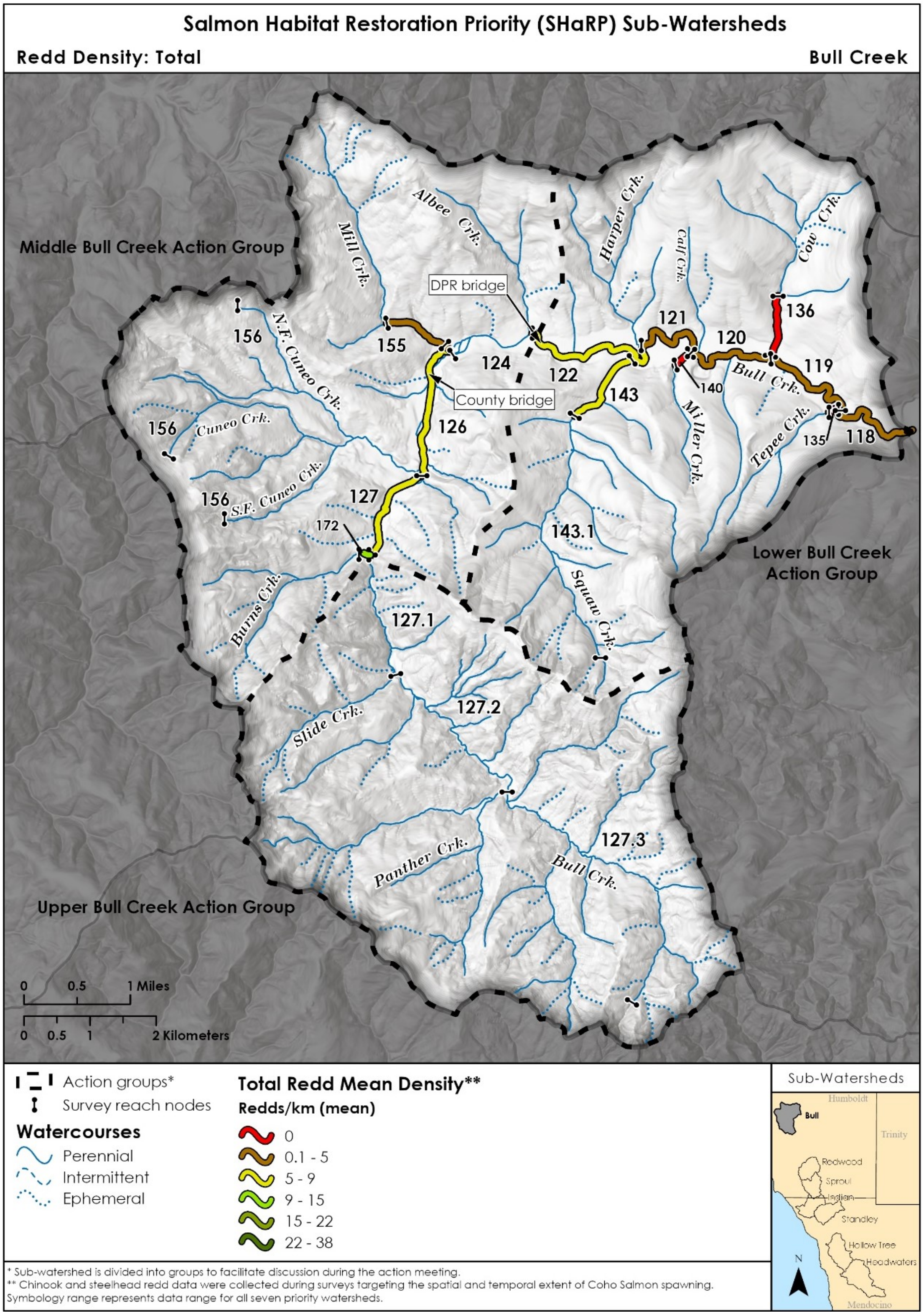

Figure 5-8. Total mean density of Coho Salmon, Chinook Salmon, and steelhead redds in the Bull Creek sub-watershed, all years surveyed (2010-2018). Data were sourced from CDFW spawner surveys (Starks and Renger 2016) designed for Coho Salmon, so the duration and extent of the survey do not encompass the full spatial or temporal extent of the Chinook Salmon or steelhead run.

Bull Creek placed sixth overall in the SHaRP ranking process, with high marks received in categories related to land ownership and restoration potential. Bull Creek scored sixth in Biological Importance, eighth in Habitat Condition, second for Optimism and Potential, and second in Integrity and Risk. While the history of anthropogenic and natural disturbances has acted synergistically to heavily impact salmonids in Bull Creek, the conservation and protection measure bestowed by its ownership is considered an important attribute in Bull Creek's recovery potential.

5.3 Historic and Current Restoration Efforts

Restoration efforts in the Bull Creek sub-watershed differ from the other sub-watersheds in the SFER sub-basin due to the fact it has been under the singular ownership of CSP since the late 1960s. Portions of the sub-watershed were protected under state ownership before any major anthropogenic disturbances took effect. However, historical land uses in unprotected portions of the sub-watershed resulted and drastic changes to the entire sub-watershed, necessitating extensive actions to protect and restore the invaluable natural resources of the park.

As described in the History of Land Use and Fish Habitat section, resource protection efforts of the 1950s and 1960s focused on acquiring the entire Bull Creek sub-watershed as well as measures to prevent the loss of old-growth redwood trees along Bull Creek. This initial management response involved constructing a straight, single-thread channel away from existing infrastructure, installing rock slope protection along the channel, and disposing of instream and floodplain wood accumulations. The projects effectively seized the natural channel forming processes, affecting the morphology of the stream. This was effective in protecting the surrounding forests but ultimately degraded overall habitat suitability for salmonids.

Beginning in the mid- 1990s and expanding in the 2000s, CSP and its restoration partners shifted focus towards reducing upslope erosion and improving riparian and aquatic habitats (Figure 5-9). With support and funding from the California Department of Fish and Wildlife[4] (CDFW) FRGP (including former Senate Bill 271), CSP began conducting upslope restoration projects in problematic areas of the sub-watershed in order to reduce the impacts of large landslides and old, failing logging roads which were contributing large amounts of sediment to streams. CSP completed upslope and road decommissioning work in Mill Creek in the late nineties and early 2000s. These efforts included the decommissioning of 16.7 miles of abandoned logging roads and removing 113 stream crossings to stabilize approximately 80,000 cubic yards of fill/sediment (CSP 2002). During a similar time, abandoned logging roads were also decommissioned and treated in Upper Bull Creek and in the southern portion of Cuneo Creek.

Improving upslope habitat by remediating old logging roads continued through the 2000's (Figure 5-9). During the summers of 2003, 2004, and 2005, upslope restoration projects occurred in Albee and Harper Creeks. Collectively these projects treated 561 acres of previously disturbed sub-

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

watershed by removing 8.1 miles of abandoned logging skid and haul roads and 44 associated stream crossings, effectively stabilizing approximately 21,309 cubic yards of sediment (North Coast Redwoods District 2006). Moreover, road erosion assessment/planning efforts were also developed for Cuneo Creek, which proposed treatment efforts for abandoned logging roads and sediment sources. In 2005 and again in 2007, road rehabilitation projects were completed along Panther Creek. These projects collectively removed approximately 137,000 cubic yards from 81 stream crossings along 16.9 miles of abandoned logging roads (CSP 2008). Riparian revegetation occurred in conjunction with these efforts, focusing in areas where road crossings were removed.

From 2012-2013, the Devil's Elbow Landslide Sediment Reduction Project occurred in the South Fork of Cuneo Creek (Figure 5-9). This project prevented approximately 58,000 cubic yards of sediment delivery to Cuneo and Bull creeks by excavating 11,000 yards of sediment perched at the head of the Devil's Elbow landslide and reduced surface erosion by grading the final surface to promote sheet flow. In an effort to control sediment and stabilize the hillslopes, the project planted over 800 Douglas fir seedlings, 100 redwood seedlings, over 900 coyote bush seedlings, and several other plant species in smaller quantities (Merrill 2013). Prior to project implementation, revegetation of the downslope riparian area and adjacent landslide slopes occurred with matching funds provided through a grant from the State Water Resources Control Board. Several thousand Douglas fir and redwood seedlings were planted from 2008-2010 on the upper slopes and terraces of Bull Creek (Merrill 2013).

From the late 1990s into the 2000s, CSP, Eel River Watershed Improvement Group (ERWIG), and the California Conservation Corps (CCC) through the CDFW's FRGP funding completed several instream habitat restoration and riparian revegetation projects along Bull Creek and in lower Mill Creek (Figure 5-9). CSP installed 14 instream habitat structures in Bull Creek from its confluence with Cuneo Creek downstream to the confluence of the SFER. These structures, mostly consisting of large wood and boulders, were intended to increase habitat complexity and the number of pools in this reach. In 2003, ERWIG improved instream habitat and reduced sediment in a one-mile section of Bull Creek between Burns Creek and Cuneo Creek. The project installed 20 structures consisting of boulder weirs, boulder/log structures, willow pods, and willow baffles. Approximately 1,500 native trees were planted in the riparian area along the entire section for sediment reduction and to improve future canopy conditions (ERWIG 2005). In 2007 and 2008, ERWIG in conjunction with the CCC reduced sediment delivery and improved salmonid habitat on a 1,700-foot section in lower Mill Creek and in Bull Creek (downstream of its confluence with Mill Creek). This FRGP-funded project installed 15 structures consisting of LWD, root wads, and boulders and planted 400 mixed conifers and hardwoods in the project reach (ERWIG 2007). Most recently (2016-2017), CSP removed failing riprap in Rockefeller Forest along Bull Creek and conducted riparian planting through Prop 84 funding.

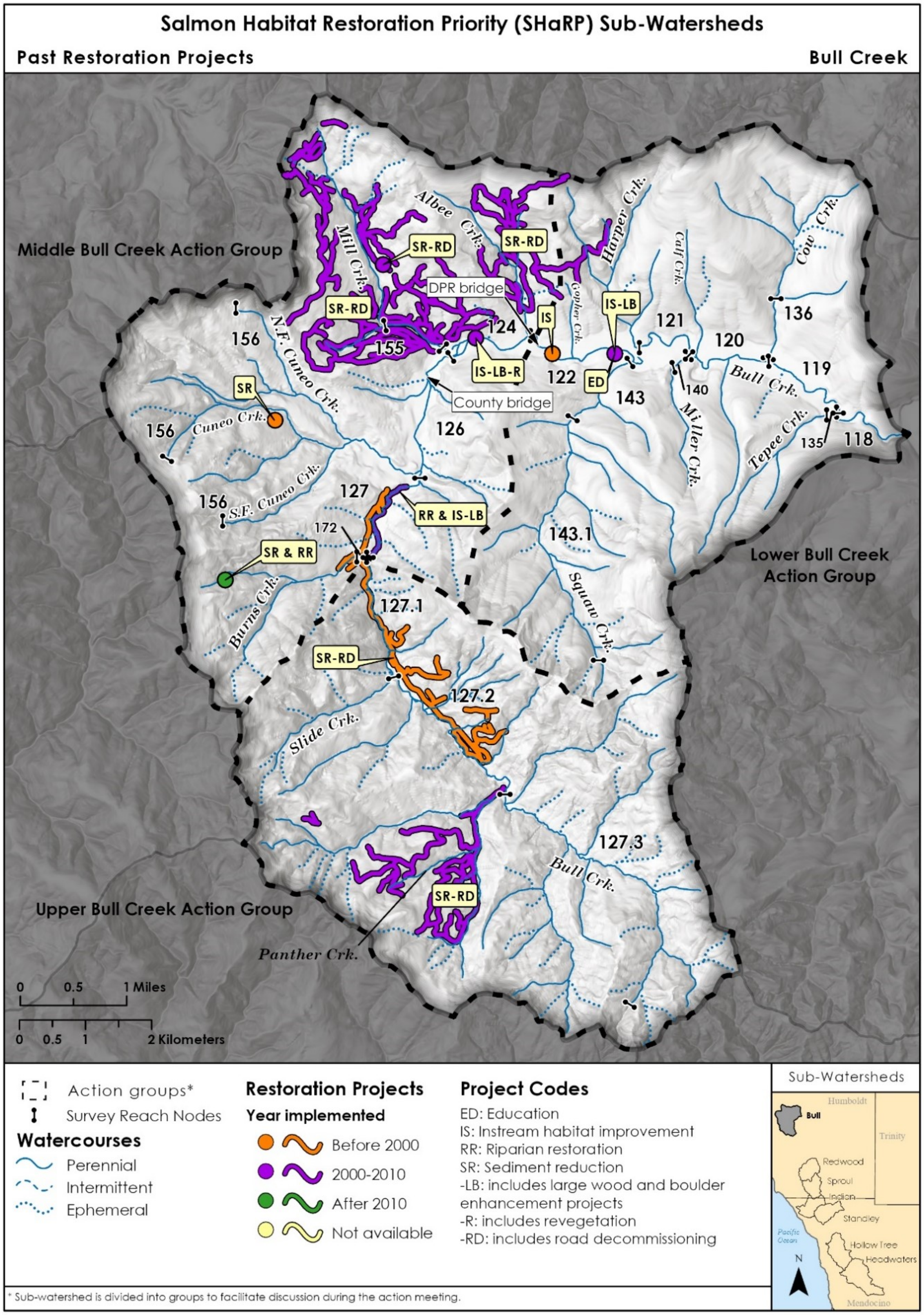

Figure 5-9. Restoration projects implemented in the Bull Creek sub-watershed.

The CSP property contains large tracts of old-growth redwood forests and provides the perfect setting for community-based watershed education opportunities. CSP has led numerous interpretive programs over the years educating park visitors on aspects of salmonid ecology and watershed restoration. In addition, FRGP provided funding for over a decade (late 1990s to early 2010s) for the Watershed Stewards Project (WSP) and ERWIG to organize and host Creek Days in the Bull Creek sub-watershed. This annual week-long event recruits hundreds of local school children, providing education on salmonid biology and the dynamics of healthy watersheds. Creek Days continues to occur and often takes place in the Bull Creek sub-watershed.

5.4 Limiting Factors and Threats Affecting Salmonids in Bull Creek

The Bull Creek Expert Panelists discussed available data and personal observations of the sub-watershed on October 21, 2019. During this discussion, each participant scored the extent to which each potential limiting factor and threat impacts each life stage of each species in an interactive process. 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 severity of impact. 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)). The resulting limiting factor tables (Limiting Factors

Table 5-1 and Table 5-2) summarize Expert Panel rankings in three areas of the sub-watershed: 1) Lower Bull Creek (Bull Creek and Harper, Tepee, Squaw, Miller, and Cow Creeks), 2) Middle Bull Creek (Bull Creek and Albee, Mill, Cuneo, and Burns Creeks, and 3) Upper Bull Creek (mainstem Bull Creek, Slide Creek, and Panther Creek). The threats table (Table 5-3) describes threats to salmonid habitat across the entire sub-watershed. When reviewing the ratings as a group, the Expert Panel considered limiting factors and threats scoring moderate or high impact to 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 5-1. Average scores for the impact of each limiting factor on each life stage of Coho Salmon and steelhead in three areas of Bull Creek. The lower the number, the greater the severity of 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).

	Life Stages and Areas											
	Lower Bull Creek				Middle Bull Creek				Upper Bull Creek			
Coho Salmon and Steelhead	Bull Creek Mainstem and Squaw, Miller, and Cow Creeks				Bull Creek Mainstem and Albee, Mill, and Cuneo Creeks				Bull Creek Mainstem and Slide and Panther Creeks			
Limiting Factor	Eggs	Summer Parr	Winter Parr	Migrating Adults	Eggs	Summer Parr	Winter Parr	Migrating Adults	Eggs	Summer Parr	Winter Parr	Migrating Adults
Barriers (anthropogenic)		4.5	4.5	5.0		4.2	4.9	4.9		4.5	4.8	4.9
Bed material*	2.8		2.9		2.3		2.6		2.1		2.1	
Competition and predation (bullfrog, pikeminnow)		3.5				4.6				5.0		
Dry season flow (including aggraded channels)		3.0				2.3				3.3		
High water temperature		1.3				1.3				3.0		
High wet season flow**	2.8			4.8	2.6			4.6	4.0			4.6
In-stream channel complexity, including pool depth***	1.3	1.3	1.0	1.5	1.3	1.4	1.1	1.4	2.4	2.8	1.2	1.5
Large wood recruitment, canopy cover		2.1	2.3	2.8		1.4	1.5	2.2		2.1	1.7	1.9
Off-channel habitat (floodplain connectivity)			1.0				1.3				1.3	
Riparian inputs (organic material, insects)		3.9				2.4				2.9		
Suspended sediment****	2.4		2.4		2.2		2.4		1.6		2.5	

* Substrate composition and spawning gravel quality

** Redd scour and stability, not due to diversions or climate change or the onset of timing and fall rains

*** For sorting sediment, creating velocity refuge, and predator cover

****Considered for its affects on egg and alevin life stages while residing within a redd

Table 5-2. Average scores for the impact of each limiting factor on each life stage of Chinook Salmon in three areas of Bull Creek.

	Life Stages and Areas								
	Lower Bull Creek			Middle Bull Creek			Upper Bull Creek		
Chinook Salmon	Bull Creek Mainstem and Squaw, Miller, and Cow Creeks			Bull Creek Mainstem and Albee, Mill, and Cuneo Creeks			Bull Creek Mainstem and Slide and Panther Creeks		
Limiting Factor	Eggs	Fry	Migrating Adults	Eggs	Fry	Migrating Adults	Eggs	Fry	Migrating Adults
Barriers (anthropogenic)		4.7	5.0		5.0	4.9		5.0	4.8
Bed material*	2.7	3.2		2.3	3.0		2.0	2.0	
High wet season flow**	2.7		4.5	2.9		4.6	3.7		4.6
In-stream channel complexity, including pool depth***	1.5	1.2	1.6	1.4	1.1	1.6	2.4	1.2	1.9
Large wood recruitment, canopy cover		2.6	3.0		1.5	2.3		1.8	2.0
Off-channel habitat (floodplain connectivity)		1.6			1.3			2.3	
Suspended sediment****	2.2	3.1		2.2	2.9		1.8	3.0	

* Substrate composition and spawning gravel quality

** Redd scour and stability, not due to diversions or climate change or the onset of timing and fall rains

*** For sorting sediment, creating velocity refuge, and predator cover

****Considered for its affects on egg and alevin life stages while residing within a redd

Many of the limiting factors with the highest impacts to Coho Salmon, Chinook Salmon, and steelhead in Bull Creek are related to a deficiency of physical habitat complexity (Limiting Factors

Table 5-1 and Table 5-2). Channel complexity and off-channel habitat were rated high to very high for all life stages of all species in all areas of the sub-watershed. This reflects the history of poorly regulated timber harvest, large scale disturbance events, and subsequent actions to prevent further damage to the old growth forests (see History of Land Use and Fish Habitat above). Anthropogenic land disturbances and large flood events aggraded stream channels and destroyed riparian vegetation. Subsequent channel incision in the absence of large wood and other channel obstructions have left active channels simplified and disconnected from aggraded floodplains (Pryor 2011). Similarly, the Expert Panel also rated large wood recruitment and canopy cover as high to very high for all species and life stages in middle and upper Bull Creek, where timber extraction and floods had the greatest impact on the riparian zone, and moderate to high in lower Bull Creek. In discussion, the Expert Panel linked the loss of large wood recruitment and a mature riparian forest as well as issues with stream temperature and floodplain connectivity to the lack of instream complexity.

Other physical and biological characteristics of salmonid habitat including temperature, stream bed material, riparian inputs, and suspended sediment were rated as high to moderate impacts to Coho Salmon, Chinook Salmon, and steelhead in Bull Creek. The Expert Panel rated high water temperature as very high impact for summer parr in middle and lower Bull Creek. Widened channels and poor canopy cover in the middle reaches leave surface flow exposed to solar radiation and increased stream temperatures from this area persists through the lower reaches. Due to improving canopy cover in upper Bull Creek, high water temperatures were only rated as a moderate impact for applicable life stages in this area. The state of riparian vegetation in the sub-watershed also led the Expert Panel to rate riparian inputs, including leaf litter and terrestrial insects, as high impact for summer parr in upper and middle Bull Creek and moderate impact for summer parr lower Bull Creek. The availability of suitable spawning gravels was rated as high impact for most egg and fry life stages of all species in all areas except Chinook Salmon fry in lower and middle Bull Creek where impacts were rated moderate. In many of the mainstem reaches of Lower Bull Creek, channel simplification has led to a lack of sorting of stream bed material and armoring of the stream bed, which is often too coarse for spawning. Additionally, sediment input from large landslides and catastrophic road failures lead to chronic turbidity. This is problematic for egg and fry (alevin) life stages which depend on gravel permeability for survival. The Expert Panel rated suspended sediment as high to very high impact for steelhead and Coho Salmon eggs and fry in all locations and moderate to very high for Chinook Salmon, depending on the location and life stage.

Factors which were rated from low to high include anthropogenic barriers, wet season flow, and interactions with non-native species. Anthropogenic barriers were rated as having low or very low impact across species, life stages, and areas, reflecting the relative lack of human infrastructure in the sub-watershed and the effect of past restoration work. In middle and lower Bull Creek, high wet season flow was rated as a high impact for eggs of all species in middle and lower Bull Creek and was rated moderate to low impact in Upper Bull Creek. Large flow events regularly occur in Bull Creek and the simplified channel is conducive to scouring the stream bed, including any salmonid redds. The Expert Panel noted warmer summer water temperatures in the Bull Creek sub-watershed are attracting non-native competitors and predators including Sacramento Pikeminnow *(Ptychocheilus grandis)* and American bullfrogs *(Lithobates catesbeianus)*; however, their impact on salmonid populations is perceived to be relatively small with a moderate impact in the warmer lower Bull Creek and a low impact in the middle and upper Bull Creek.

Threats

Table 5-3. Average score for the impact of each threat on each life stage of Coho Salmon, steelhead, and Chinook Salmon in across the Bull Creek sub-watershed.

	Life Stages and Species						
	Egg		Summer Parr	Winter Parr	Fry	Migrating Adult	
Threat	Coho & Steelhead	Chinook	Coho & Steelhead	Coho & Steelhead	Chinook	Coho & Steelhead	Chinook
Channelization (roads, levee, bank protection)	1.2	1.7	1.5	1.0	1.6	2.1	2.4
Climate change	2.7	2.6	1.9	2.6	2.2	2.7	2.7
Culvert	4.9	5.0	4.1	4.3	4.8	4.5	5.0
Current roads (chronic)	2.3	2.6	3.5	3.3	3.4	4.1	4.4
Diversions	5.0	5.0	4.7	5.0	5.0	5.0	5.0
Land conversion, development	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Legacy land mgmt. (roads, timber mgmt. practices)	1.3	1.4	1.3	1.3	1.6	2.2	2.8
Legacy riparian mgmt.	1.7	2.5	2.0	2.0	2.5	3.0	4.3
Vegetation mgmt. (deferred maint.)	2.9	3.5	2.7	2.0	2.8	4.5	4.5

The Expert Panel rated threats related to the effects of roads, land management, and climate change to have the highest potential impacts to salmonids in the Bull Creek sub-watershed (Table 5-3). Channelization due to roads and stream bank stabilization and legacy land management practices including haul road construction and timber harvest management were rated as very high impact for all juvenile salmonids and high impact for adult salmonids. Historical land uses in the sub-watershed as well as early efforts to protect the terrestrial resources of the State Park continue to impact stream habitat by maintaining simplified channels, restricting sources of large wood, and contributing to chronic sedimentation. Similarly, legacy riparian management including efforts to protect the old growth forests of lower Bull Creek were rated as having a high to very high impact for juvenile salmonids and moderate to low impact to migrating adults. Deferred maintenance of upslope and riparian vegetation was also rated as a high impact for most juvenile salmonids as the lack of maintenance has prolonged the habitat recovery process. The impacts of contemporary roads were only rated as high impact to egg life stages where any additional sediment contributions were thought to have an impact. Generally, most of the contemporary roads in the sub-watershed are well maintained and have been improved in recent decades; thus the Expert Panel rated them as moderate to low impact for the remaining life stages.

In contrast, the remaining threats related to land development were of least concern to the Expert Panel. Water diversion, culverts, and land conversion and development were all rated as low impact to all life stages and species. The sub-watershed is entirely owned and managed by CSP for recreational use, ensuring preservation and protection from future land development and resource extraction. Diversions were rated a very low threat in the Bull Creek sub-watershed because there are no existing diversions for household water use. For the same reason, land conversion and development were rated very low. Culverts were rated a low threat due to CSP's land stewardship efforts, upslope restoration, and fish passage improvements.

5.5 Recovery Strategy

On October 22nd, 2019, the Bull Creek Action Team discussed the outcomes of the Expert Panel meeting, as presented in Limiting Factors

Table 5-1, Table 5-2, and Table 5-3, 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 by reviewing spatial data on printed maps and identifying locations known to the experts of the panel. Figure 5-10 and Table 5-4 below show the treatment types and locations identified by the Action Team during the meeting and later interpreted by the steering team.

The recovery strategy for Bull Creek focuses on improving physical habitat complexity for juvenile fish during summer and winter, increasing dry season flow and lowering water temperature, treating upslope sources of sediment in impacted areas, and increasing available spawning habitat through gravel retention. This strategy identifies reach-scale regions of the sub-watershed where treatments will likely have the greatest benefit to salmonids. In some cases, more specific project locations were suggested based on high resolution data or available restoration plans. For most of these recommendations, specific project locations and methods of implementation will require further investigation and site-specific designs. Where high resolution data were available or members of the Expert Panel and Action Team had precise knowledge of treatment areas, specific project locations were identified for treatments; however, partners may require further designs to appropriately implement the recommendations. Additionally, where site-specific designs have been developed, the reports and materials which specify those designed have been identified in the text below and should be referenced for more specific guidance on locations and designs. The materials used by the SHaRP Action Team may be useful to the restoration community in more detailed project planning. 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.

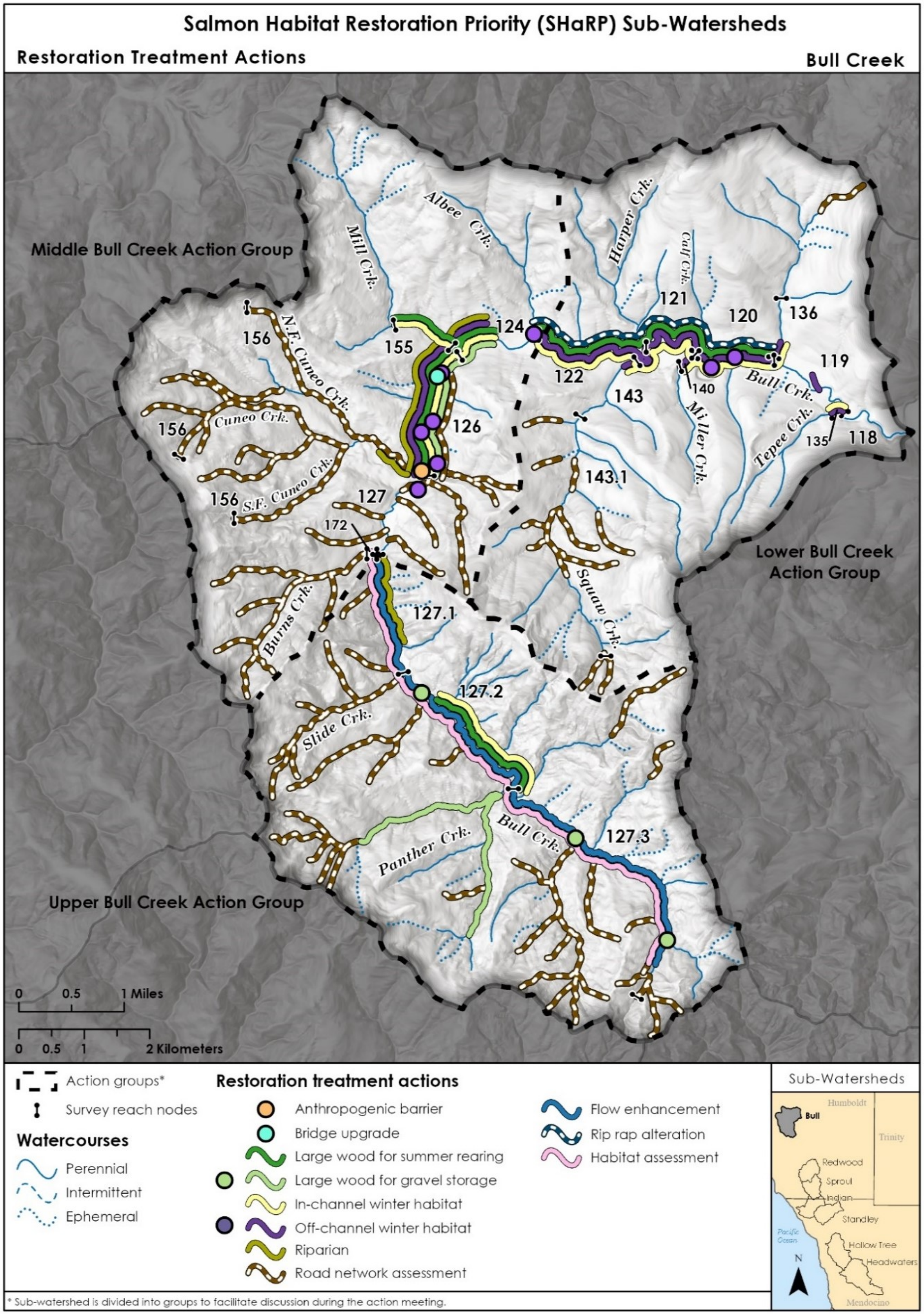

Figure 5-10. Restoration treatment actions recommended by the Bull Creek Action Team.

Table 5-4. Recommended restoration treatments for Bull Creek.

Target	Treatment Description	Stream Name(s)	Survey Reach Code
Summer Juvenile Rearing	LWD for summer rearing (pools, sorting gravel)	Bull Creek, Mill Creek	120, 121, 122, 124, 126, 127.2, 155
Winter Juvenile Rearing	In-channel winter habitat	Bull Creek, Tepee Creek, Cow Creek, Miller Creek, Squaw Creek, Mill Creek, Tepee Creek, Cow Creek, Miller Creek, Squaw Creek, Mill Creek	120, 121, 122, 124, 126, 127.2, 135, 136, 140, 143, 155
	Off-channel winter habitat	Bull Creek, Tepee Creek, Cow Creek, Miller Creek, Squaw Creek, Mill Creek, Tepee Creek, Cow Creek, Miller Creek, Squaw Creek	119, 120, 121, 122, 124, 126, 127, 135, 136, 140, 143,
Adult Spawning	LWD for gravel entrainment	Bull Creek	124, 126
Watershed Processes	Riparian Treatment	Bull Creek, Cuneo Creek	124, 126, 127.1, 156
	Groundwater and flow enhancement	Bull Creek	127.1, 127.2, 127.3
	Road decommissioning	Burns Creek Watershed, Cuneo Creek Watershed, N.F Panther Creek Watershed	N/A, N/A, N/A
	Accelerated wood recruitment	Bull Creek, Panther Creek, N.F. Panther Creek, S.F. Panther Creek	127.2, 127.3, N/A, N/A, N/A
	Bridge upgrade	Bull Creek	126
	Habitat assessment	Bull Creek	127.1, 127.2, 127.3
	Riprap alteration	Bull Creek	120, 121, 122

Treatments to Improve Habitat for Winter Parr and Fry

Channel complexity and off-channel habitat for overwintering juvenile salmonids were key limiting factors identified by the Expert Panel. Treatments to increase the amount of low velocity habitat and increase the frequency of floodplain inundation were recommended. Stream reaches which were typically low gradient but lacking large wood and other refugia were selected by the Action Team as locations that could support suitable in-channel winter habitat if large wood or other flow-obstructing structures were recruited or installed. These areas were also near frequently used spawning habitat and are expected to be occupied in winter by natal and non-natal parr and fry. The Action Team identified potential areas to improve in-channel winter habitat throughout the sub-watershed including Bull Creek and the downstream portions of Cow Creek, Miller Creek, Squaw Creek, Mill Creek, and Tepee Creek (reaches 120, 121, 122, 124, 126, 127.2, 135, 136, 140, 143, and 155).

The Action Team also recommended instream structure treatments in Lower Bull Creek should be done in conjunction with removal or alteration of riprap, which was installed to prevent flood damage (reaches 120-122). Riprap in these reaches is holding the form of the channel in a relatively static state and encouraging the channel to convey sediment through a constrained channel. This limits the creation of undercut banks and natural recruitment of wood to the channel. To restore natural processes of channel migration and improve instream complexity to create more low velocity habitat, it is recommended that riprap be removed or altered where it is safe and feasible, banks should be contoured to match natural grades, and in-channel structures should be installed to complement this work. This includes installing features that extend from the active channel past the top of bank to capture sediments and create naturally contoured inset floodplains. This will help restore inset floodplains and natural stream banks lost to the 1955 and 1964 floods and subsequent mechanical re-shaping of the river channel to maximize sediment conveyance. This work should be done with great consideration for the invaluable terrestrial resources on the Bull Creek floodplain.

The criteria described above were also used to assess suitable locations for off-channel winter habitat with the additional requirement that ideal reaches should have unconfined channels, wide valley widths, the presence of anchor habitat, and/or the observation of existing floodplain habitats that could be inundated more frequently or enhanced to provide suitable winter refugia. LiDAR mapping was made available to the Action Team and digital detrending of the channel slope was used to identify locations that may be inundated at average winter elevations (~1-2m). The Action Team identified potential areas to create or improve off-channel habitat on the mainstem of Bull Creek, from Cuneo Creek to Tepee Creek, and at the downstream portions of Tepee Creek, Cow Creek, Miller Creek, Squaw Creek, and Mill Creek (119, 120, 121, 122, 124, 126, 127, 135, 136, 140, and 143). Site specific locations for off-channel habitat were recommended in the mainstem of Bull Creek from just downstream of Cuneo Creek to Mill Creek and from Squaw Creek to Tepee Creek (reaches 124, 126, 127, 120, 121, and 122). Recommendations for the location in reach 126 include modification of the existing "reef barrier," a channel-spanning boulder structure which was placed at the outlet of a large sediment basin constructed in the mid-1980's. The construction of this feature and the alteration to the adjacent terrace have constricted the stream channel and prevented natural channel evolution. Widening the channel, lowering the terrace, and adding large wood will allow channel migration, more frequent floodplain inundation, expansion of the riparian corridor, and improve habitat complexity and connectivity. Recommendations at locations in reaches 126 and 127 include adding large wood, lowering aggraded floodplains, and construction of side channels and off-channel pond habitats. Detailed plans and design are available in documents previously completed for these areas (NHE et al. 2018, Appendix F, CalTrout et al. 2017a, 2017b, 2017c, and 2017d). Recommendations for locations in reaches 120-122 are to investigate the feasibility of creating or augmenting off-channel habitat in relic alcoves and oxbows. Based on inundation mapping, these areas are near elevations that may inundate at average winter flows but may need to be lowered or enhanced with structures to improve their suitability for salmonids.

Treatments to Improve Summer Conditions for Parr and Fry

The Expert Panel identified that summer parr may be most limited by the lack of instream complexity throughout Bull Creek as well as high temperatures in the middle and lower reaches of Bull Creek. To address the limitations of channel complexity, the Action Team recommended several reaches that would likely support juvenile salmonids during the summer months but would greatly benefit from greater pool depth and increased pool cover. Treatments to install instream structures which would create deeper pools under scouring flows and complex cover under summer base-flow conditions were recommended in reaches with cooler water temperatures near frequently used spawning habitat. Recommended areas typically had lower gradients prone to deposition of sediments in the absence of channel obstructions such as large wood. The recommended reaches include portions of the main stem of Bull Creek and Mill Creek (120, 121, 122, 124, 126, 127.2, and 155). The Action Team noted Mill Creek provides cold water throughout the summer months and may create a crucial refuge for fish at the confluence with mainstem of Bull Creek, which regularly exceeds temperature thresholds in the summer months. However, lower Mill Creek generally lacks the channel complexity needed to support large populations of over-summering fish.

The Action Team identified several regions of the sub-watershed where summer water temperatures are likely limiting the summer rearing potential of parr. Due to excessive solar exposure in the middle reaches on Bull Creek, water temperatures in this region may often exceed the tolerances of salmonids during the summer and limit the summer rearing capacity of the sub-watershed. Salmonid fry and parr typically redistribute from upstream natal areas in the spring to seek productive habitats downstream of spawning sites (e.g. Hall et al. 2016, Soto et al. 2016). Since temperatures in the mainstem of Bull Creek in the middle portion of the sub-watershed typically become too hot to support rearing Coho Salmon fry and parr, the Action Team recommends treatments to lower water temperature in this important rearing reach. The Action Team recommends planting riparian vegetation along Bull Creek from approximately halfway between Albee Creek and Mill Creek to Cuneo Creek, and from Burns Creek to just downstream of Slide Creek, as well as the downstream portion of Cuneo Creek (reaches 124, 126, 127.1, and 156). Detailed plans for these treatments are available in previously completed planning documents (NHE et al. 2018). Additionally, the Action Team recommends exploring groundwater and flow enhancement in Bull Creek above the temperature impaired reaches from the headwaters to Burns Creek (reaches 127.1, 127.2, and 127.3). The Action Team suggested the installation of beaver dam analogues or similar structures where feasible as one possible treatment to increase groundwater recharge, enhance summer flows, and regulate temperature in downstream habitat. These treatments are recommended for the same locations as the large wood for gravel storage and accelerated wood recruitment in the upper portions of the sub-watershed where these treatments could all work synergistically (see *Treatments to Improve Watershed Processes* below).

Treatments to Improve Adult Salmonid Spawning Distribution

The Action Team recommended adding instream structures such as large wood to aid in the capture and sorting of gravels to improve spawning habitat for adult salmonids. Instream complexity, including instream wood and boulders to sort sediments and regulate water velocities, was listed as one of the most limiting factors preventing the success of egg and alevin life stages throughout Bull Creek. In response, the Action Team recommended the installation of large wood features in habitats lacking large wood with gradients suitable for spawning, accessible to migrating adults, and near suitable summer rearing habitat. There is an abundant supply of suitable spawning gravel in the sub-watershed but does not sort well and often becomes too embedded for spawning. Spawning success will improve by increasing gravel permeability and reducing embeddedness through sediment sorting using large wood and other instream structures. Recommended treatment areas include the mainstem of Bull Creek from Cuneo Creek downstream to the left bank unnamed tributary after Mill Creek (reaches 124 – 126). The Action Team also noted the success of this type of project will be more effective if combined with treatments to reduce sources of fine sediment, including improved floodplain connectivity and road network assessment. See *Treatments to Improve Habitat for Winter Parr and Fry* above and *Treatments to Improve Watershed Process* below for descriptions and locations of recommended treatments to improve floodplain connectivity and reduce fine sediment sources throughout the sub-watershed.

The Action Team also recommended in-channel treatments in Bull Creek for improving winter refuge for juvenile life stages could benefit migrating adults. Immigrating adult salmonids will utilize low velocity habitat as holding and resting areas while in route to spawning habitat upstream. See *Treatments to Improve Habitat for Winter Parr and Fry* above for recommended treatments and location details.

Treatments to Improve Watershed Processes

To address processes that have been drastically altered or anthropogenically disrupted, the Action Team recommended several treatments to help to restore watershed function, alleviating limitations across multiple life stages.

Channel Migration

As previously described, much of the downstream portion of Bull Creek and portions of Middle Bull Creek was armored with riprap to encourage the conveyance of sediment and prevent bank erosion. In addition, channel straightening, and installation of channel spanning boulder weir structures installed in Middle Bull Creek further stabilize the channel. These actions have largely disrupted channel migration, floodplain connectivity, and has greatly reduced the complexity and suitability of habitat in this area. As described in the *Treatments to Improve Habitat for Winter Parr and Fry* section above, to restore the natural processes of channel migration and improve instream complexity to create more low velocity habitat, it is recommended riprap should be removed or altered where it is safe and feasible, banks should be contoured to match natural grades, and in-channel structures that do not promote channel stabilization, except where necessary, should be installed to complement this work.

Sediment

To address chronic sedimentation, a key limiting factor across multiple life stages, the Action Team recommended conducting road network assessments in sections of the sub-watershed where legacy logging roads have not yet been treated. California State Parks has carefully analyzed the available GIS data and determined unstable slopes and numerous logging roads are interacting through altered hydrology to create very large sources of sediment and increased risk of slope failure in all untreated portions of the sub-watershed (Fiori et al. 2002). However, site-specific information on treatment locations and the appropriate treatment methods will need to be determined through field investigations and subsequent prioritization. The Expert Panel recommends conducting road network assessments in all the “plan areas” detailed in California State Parks’ sediment source module (Fiori et al 2002). These areas include a portion of middle Bull Creek upstream from Squaw Creek, the headwaters of Bull Creek, the headwaters of Cow Creek, portions of Squaw Creek, unnamed tributaries between Mill Creek and Cuneo Creek, and untreated portions of Cuneo Creek, Burns Creek, Slide Creek, and Panther Creek (reaches 126, 127.3, NA, 143-143.1, 156, 172, NA, NA, NA) (Figure 5-10). Once high and moderate priority sites are identified in these areas, the appropriate road treatment should be applied.

The Action Team also noted there are numerous unstable slopes throughout the upper portion of the Bull Creek sub-watershed and slope failures are likely in this area. Due to the lack of instream structures such as large wood, Bull Creek lacks capacity to store and meter sediments and large volumes of sediment rapidly entrain and transport downstream. Rather than being deposited on the floodplain or stream banks, entrained sediment deposits in pools and low-gradient stream reaches where it can smother important salmonid habitat. The Action Team recommended implementing accelerated large wood recruitment methods in key areas of the sub-watershed to increase the streams' capacity to store and meter sediments. These areas include accessible portions of upper Bull Creek and the North Fork, South Fork and mainstem of Panther Creek (reaches 127.1, 127.2, and Panther Creek) (see Figure 5-10 above for more precise locations along Bull Creek).

Assessment and Investigation

The Action Team also recommended two distinct investigations to better understand fisheries resources in upper Bull Creek and the costs and benefits associated with upgrading the County bridge over Bull Creek. The most recent habitat surveys completed in the upper Bull Creek are over 12 years old and very little is known about the fish population using this portion of the sub-watershed. The Action Team recommends conducting a new habitat assessment as well as fisheries surveys of upper Bull Creek (reaches 127.1, 127.2, and 127.3). This was identified as a large data gap in our understanding of salmonid distribution and habitat use in the sub-watershed.

To better understand and plan for restoration projects occurring upstream of the County bridge located approximately half-way through reach 126 on Bull Creek, the Action Team recommends investigating an upgrade to the County bridge. The current bridge has supporting structures within the active channel which often collect large wood. The County currently cuts free any wood which becomes lodged against the bridge, disrupting the transport process of large wood in Bull Creek. Additionally, instream restoration projects above this bridge will likely need to consider the liability of the bridge, thus increasing the cost of engineering installed features. The Action Team recommends pursuing a cost-benefit analysis of upgrading the County bridge to a stream-spanning structure considering reduced costs of future restoration projects and increased ecological benefits. Additionally, improving coordination between CSP and the County to change how wood is managed could help maintain wood transport and wood retention for stream habitat while the current bridge is in place.

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).