SF Eel River Western Subbasin

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Western Subbasin

Introduction

The Western Subbasin of the South Fork (SF) Eel River Basin is the second largest of the three subbasins, covering an area of 220 square miles, or 32% of the total basin area (*Table 1*). This subbasin begins at the Northern Subbasin boundary at the confluence of Ohman Creek and the SF Eel River (RM 23) and extends to its headwaters south of Laytonville (RM 105). The subbasin includes 82 miles of the SF Eel River mainstem and 312 miles of tributary streams (172 miles of perennial and 140 miles of intermittent stream habitat) west of the mainstem SF Eel River. The Humboldt/Mendocino County line runs directly across the subbasin at Cooks Valley, just north of Piercy; tributaries to the north are located in Humboldt County, and those to the south are in Mendocino County. Only 13% of the SF Eel River population lives within the boundary of the Western Subbasin; the largest towns are Briceland and Hale's Grove.

The primary land use (75% of total subbasin area) is commercial timber harvest. The rest of the land is mostly private parcels less than 40 acres in size, managed primarily for small-scale timber production, ranching, grazing and small-scale agriculture. The climate is dominated by the coastal marine layer, with mild, foggy summers and wet winters.

This subbasin is characterized by a forested landscape of rugged, steep, sharp-crested ridges and narrow stream valleys. Stream elevations range from approximately 223 feet at the confluence of the SF Eel River with Ohman Creek to approximately 2,560 feet in the headwaters of the tributaries near Elkhorn Ridge (elevation 2975 feet). Streams are generally low gradient in valleys, becoming higher (>10%) in headwaters of tributaries, and are surrounded by predominantly mixed conifer and hardwood forest vegetation with relatively cool summer temperatures (*Figure 1*).

Large tributaries with documented salmonid distribution include Redwood (near Redway), Sproul, Indian, and Hollow Tree Creeks. Chinook and coho salmon, and steelhead trout are more widely distributed in Western Subbasin streams than in Northern or Eastern Subbasin tributaries.

General attributes of the Western Subbasin are listed in *Table 1*. *Figure 2* is a map of the subbasin location in relation to other subbasins within the SF Eel River watershed.

Table 1. Attributes of the SF Eel River Western Subbasin.

Area (square miles)	220
Privately Owned (square miles)	201
Publicly Owned (square miles)	19
Predominant Land Use	Timber harvest
Predominant Vegetation	Mixed conifer and hardwood forest
Mainstem Miles	82 (RM 23-105)
Tributary Miles	312
Total Stream Miles	394
Low Elevation (feet)	223
High Elevation (feet)	2,560

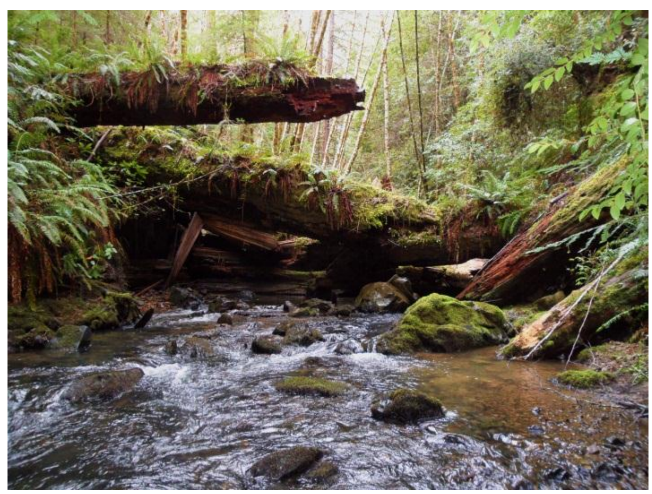

Figure 1. Anderson Creek in the SF Eel River Western Subbasin.

Figure 2. South Fork Eel River Basin and Northern, Eastern, and Western subbasins.

Hydrology

The Western Subbasin is made up of 27 CalWater Units (*Figure 4*). There are 73 named and 103 unnamed tributaries with more than 247 perennial and 140 intermittent stream miles in this subbasin (*Figure 5*). The mainstem SF Eel River is a fifth order stream using the Strahler (1964) classification system. The tributaries are first through fourth order streams. Stream drainage areas range from less than one square mile to 42 square miles (*Table 2*). Hollow Tree Creek is the largest tributary to the SF Eel in the Western Subbasin, with a drainage area of approximately 42 square miles and a stream length of 23 miles (*Figure 3*).

Annual precipitation in the Western Subbasin ranges from approximately 60 inches near Hale's Grove in the Hollow Tree Creek drainage to over 80 inches west of Briceland in the Redwood Creek drainage.

During events that cause large amounts of sediment to enter streams, (e.g. 1955, 1964, 1997 floods, seismic activity, sediment accumulation, land use, water diversion, changes in hydrologic connectivity, change in vegetation, climate, drought, changes in land use, etc.) streams that have historically been mapped as perennial may change to intermittent.

There are two USGS stream gauges located in the Western Subbasin; one near Phillipsville (RM 24), and one near Leggett (RM 66) in the mainstem SF Eel River. The Leggett gauge is fed by all streams in the SF Eel River Basin upstream from this point (78% of the total SF Eel River drainage area, or 537.5 square miles). Average annual discharge data were available from 1966-2010, with missing or incomplete data for water years 1995-1999 and 2005-2007 (*Figure 6*). Peak discharge (>1700 cfs) occurred in 1974 and 1983, and minimum discharge (70 cfs) was recorded in 1977. These data were consistent with those recorded at other stations throughout the SF Eel River Basin, including the Phillipsville gauge, which is discussed in the Northern Subbasin section of this report.

Figure 3. Hollow Tree Creek, tributary to the SF Eel River, located in the Western Subbasin.

Figure 4. Calwater planning watersheds in the SF Eel River Western Subbasin.

Figure 5. SF Eel Western Subbasin Streams.

Table 2. Western Subbasin tributaries and statistics (int. = intermittent stream).

Stream	Tributary to:	Length miles	Perennial miles	Intermittent miles	Drainage Area (sq miles)	Stream order
South Fork Eel River	Eel River	76	76	0	219	5
Hooker Creek	S.F. Eel River	1.9	1.3	0.6	1.8	1
Leggett Creek	S.F. Eel River	4.5	3.6	0.9	5.2	2
Redwood Creek (Briceland)	S.F. Eel River	10.0	9.6	0.4	23.3	3
Seeley Creek	Redwood Creek (Briceland)	3.4	2.8	0.6	5.8	2
Frost Creek	Redwood Creek (Briceland)	1.2	0.0	1.2	0.3	int.
Tank Gulch	Redwood Creek (Briceland)	0.5	0.4	0.1	0.6	1
Somerville Creek	Redwood Creek (Briceland)	3.0	1.9	1.1	3.1	2
Miller Creek	Redwood Creek (Briceland)	4.3	3.3	1.0	3.7	3
Buck Gulch	Miller Creek	1.1	0.7	0.4	0.9	1
China Creek	Redwood Creek (Briceland)	2.9	2.5	0.4	3.9	2
Dinner Creek	China Creek	2.2	1.2	1.0	1.5	1
Connick Creek	S.F. Eel River	3.3	2.3	1.0	2.7	1
Sproul Creek	S.F. Eel River	8.6	8.1	0.5	24.0	3
Little Sproul Creek	Sproul Creek	3.3	2.5	0.8	1.8	1
Warden Creek	Sproul Creek	2.1	1.6	0.5	1.8	1
West Fork Sproul Creek	Sproul Creek	5.9	5.1	0.8	8.5	2
La Doo Creek	West Fork Sproul Creek	2.5	1.9	0.6	1.5	1
Cox Creek	Sproul Creek	2.1	2.1	0.0	1.5	1
Sawmill Creek	S.F. Eel River	2.5	1.0	1.5	1.9	1
Laurel Creek	S.F. Eel River	0.7	0.0	0.7	0.2	int.
North Creek	S.F. Eel River	0.7	0.0	0.7	0.2	int.
Durphy Creek	S.F. Eel River	2.5	2.5	0.0	2.4	2
Hartsook Creek	S.F. Eel River	1.5	1.5	0.0	1.0	1
Indian Creek	S.F. Eel River	14.0	13.0	1.0	27.0	2
Jones Creek	Indian Creek	2.4	0.4	2.0	2.2	1
Parker Creek	Indian Creek	1.7	0.0	1.7	0.9	int.
Moody Creek	Indian Creek	2.8	1.0	1.8	2.2	1
Sebbas Creek	Indian Creek	3.8	3.3	0.5	2.8	1
Coulborn Creek	Indian Creek	2.6	0.7	1.9	2.5	1
Anderson Creek	Indian Creek	5.5	0.0	5.5	4.3	int.
Piercy Creek	S.F. Eel River	5.1	1.5	3.6	3.6	1
Standley Creek	S.F. Eel River	5.2	4.7	0.5	7.3	1
Bear Pen Creek	S.F. Eel River	4.0	3.4	0.6	5.0	2
Cub Creek	Bear Pen Creek	0.5	0.5	0.0	0.3	1
Wildcat Creek	S.F. Eel River	4.3	1.9	2.4	6.0	1
Mill Creek	S.F. Eel River	3.0	2.1	0.9	2.4	1
Hollow Tree Creek	S.F. Eel River	23.1	22.0	1.1	42.0	4
South Fork Creek	Hollow Tree Creek	2.5	0.9	1.6	3.3	2
Mule Creek	South Fork Creek	3.4	1.9	1.5	3.3	2
Middle Creek	Hollow Tree Creek	2.4	2.0	0.4	1.7	1
Islam John Creek	Hollow Tree Creek	2.1	1.7	0.4	1.0	1
Lost Man Creek	Hollow Tree Creek	2.0	1.3	0.7	1.1	1
Lost Pipe Creek	Hollow Tree Creek	1.5	0.6	0.9	0.7	1
Walter's Creek	Lost Pipe Creek	1.3	1.3	0.0	1.8	1
Bear Creek	Hollow Tree Creek	1.8	1.4	0.4	1.0	1
Redwood Creek	Hollow Tree Creek	3.1	1.1	2.0	3.4	2
S.F. Redwood Creek	Redwood Creek	1.9	1.9	0.0	1.4	2
Bond Creek	Hollow Tree Creek	4.7	3.9	0.8	6.5	2
Michael's Creek	Hollow Tree Creek	3.3	2.8	0.5	4.7	2
Doctor's Creek	Michael's Creek	1.5	1.0	0.5	1.7	2
Lynch Creek	Michael’s Creek	0.7	0.7	0.0	0.8	1

Stream	**Tributary to:**	**Length** miles	**Perennial** miles	**Intermittent** miles	**Drainage Area** (sq miles)	**Stream** order
Waldron Creek	Hollow Tree Creek	2.3	0.3	2.0	3.2	1
Bear Pen Creek	Hollow Tree Creek	0.8	0.5	0.3	1.0	1
Huckleberry Creek	Hollow Tree Creek	1.8	1.8	0.0	2.8	1
Bear Wallow	Huckleberry Creek	2.3	1.5	0.8	1.4	1
Little Bear Wallow Creek	Huckleberry Creek	0.8	0.0	0.8	0.3	int.
Butler Creek	Hollow Tree Creek	2.8	2.8	0.0	2.6	2
Mitchell Creek	Hollow Tree Creek	0.9	0.0	0.9	0.4	int.
Low Gap Creek (Leggett)	S.F. Eel River	3.1	2.0	1.1	3.9	2
Little Low Gap Creek	Low Gap Creek	1.0	1.0	0.0	0.6	1
Surveyors Canyon	S.F. Eel River	1.2	1.2	0.0	1.6	1
Jack of Hearts Creek	S.F. Eel River	3.5	3.1	0.4	3.8	2
Dark Canyon	Jack of Hearts Creek	1.1	0.8	0.3	0.7	1
Little Charlie Creek	S.F. Eel River	1.4	0.7	0.7	0.9	1
Dutch Charlie Creek	S.F. Eel River	4.7	4.7	0.0	4.3	2
Thompson Creek	Dutch Charlie Creek	1.1	0.5	0.6	0.6	1
Eagle Creek	Dutch Charlie Creek	1.0	0.7	0.3	0.6	1
Redwood Creek (Branscomb)	S.F. Eel River	3.2	0.7	2.5	4.4	2
N.F. Redwood Creek	Redwood Creek (Branscomb)	1.1	1.1	0.0	0.8	1
Haun Creek	S.F. Eel River	0.9	0.0	0.9	0.7	int.
Section Four Creek	S.F. Eel River	2.5	1.9	0.6	1.2	1
Middleton Creek	S.F. Eel River	1.1	1.1	0.0	0.8	1

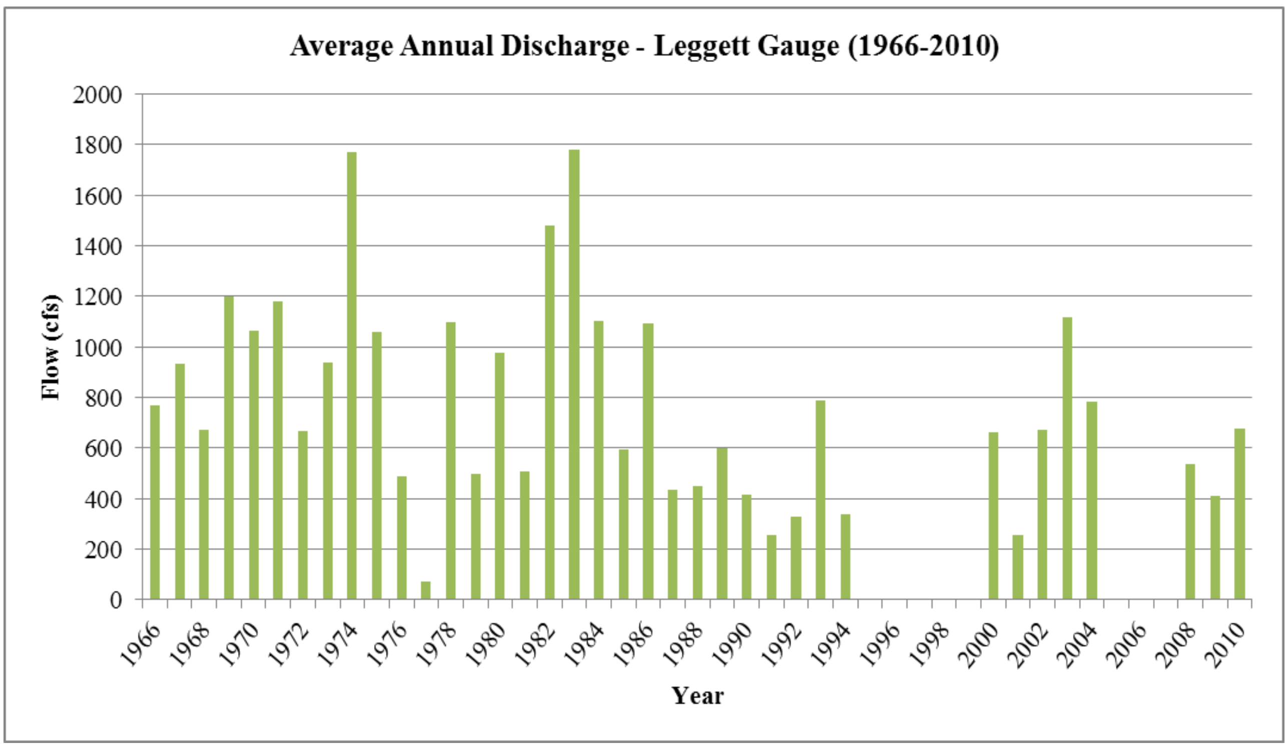

Figure 6. Average annual discharge at the Leggett gauge, located at RM 66 on the mainstem SF Eel River.

Floods

Large floods occur nearly every decade in the SF Eel River drainage. The most devastating floods in recent history occurred in 1955 and 1964. The effects of these floods on the watershed was exacerbated by extensive logging due to the advent of post-WWII tractor technology, changes in local vegetation caused by timber harvest and land use activities, and prior seismic events that further destabilized the hillslopes. The extensive road network also disrupts natural runoff rates and routes. The 1964 flood also involved the melting of a large accumulation of snow in the higher elevations by a warm storm with sustained, heavy rains. Landslides and resulting sedimentation of the streams were unprecedented - these floods washed away entire towns, reset river patterns, and changed stream morphology for decades. In some cases, the lingering effects are still apparent upon the landscape and in streams throughout the basin.

In the SF Eel River Basin the 1955 flood had a peak flow (at Miranda, just north of the subbasin boundary) of 173,000 cubic feet per second (cfs). This flood exceeded 22 million dollars in damages, flooded 43,000 acres, and killed at least one person in the Eel River Basin. The 1964 flood had a peak flow (at Miranda) of 199,000 cfs, exceeded 100 million dollars in damages, and killed at least 19 people in the Mad and Eel River Basins (Dyett and Bhatia 2002).

Dams, Diversions, and Hydrologic Disturbances

There are presently no functioning, legal, man-made dams on the streams of the Western Subbasin. The Benbow Dam is located on the mainstem of the SF Eel approximately ¼ mile downstream from the confluence with the East Branch SF Eel River (*Figure 7*). This dam has not been in use since 2008 and is presently being considered for removal.

As with most watersheds in Humboldt and Mendocino County, there is a significant number of illegal water diversions associated with covert marijuana cultivation practices that remove water from the streams, especially during the dry times of the year. A number of shallow groundwater wells in this subbasin supply water for rural residential and agricultural uses. The groundwater that these wells draw from is considered "surface water underflow", or water that has permeated through the soil layer into the weathered bedrock layer atop the coherent bedrock. This water is critical to providing dry-season base flow to the streams.

Figure 7. Aerial view of Benbow Dam in 2012 (Google Earth (8/23/2012) 40˚03'56.98" N 123˚48'03.77" W, elev 366 ft, eye alt 826 ft. Google 2014).

Geology

Bedrock

The Western Subbasin is composed of metamorphic, marine sedimentary, and igneous rock types of the Franciscan Complex and associated overlap assemblage of sediments and sedimentary rock types. The Costal Belt dominates the geology of this subbasin, the majority of which is occupied by the Coastal Terrane, followed by the Yager Terrane. Also present is a minor amount of the Central Belt, juxtaposed along the Coastal Belt Thrust (fault). Descriptions of bedrock composition, depositional history, landscape morphology, strength, and erosional characteristics of each rock type represented on the geology map (*Figure 8*) will be briefly discussed below in order of abundance within the subbasin. *Table 3* contains a brief summary of Western Subbasin geology types and attributes.

Coastal Terrane

The Coastal Terrane, which occupies approximately 59 percent of this subbasin, is a division of the Coastal Belt of the Franciscan Complex. It consists mainly of slightly metamorphosed, interbedded argillite and sandstone with pebble conglomerate in some places. The Coastal Terrane has been folded, faulted, sheared and shattered in places, sometimes to such an extent that it is considered to be a mélange. Mélange is a highly, penetratively sheared matrix of argillite and sandstone containing blocks of basalt (pillow flows, tuffs, flow breccias, and rare intrusives), limestone (which commonly overlies basalt), and blueschist (McLaughlin et al. 2000).

The sedimentary sequences of sandstone, argillite, and conglomerate are interpreted to be turbidites (sedimentary deposits left from sub-aqueous landslides) and other mass-flow type deposits that punctuated the calm oceanic deposition of mud that accumulated in an east-dipping subduction zone along the western margin of North America between 140 and 28 million years ago. In contrast, the limestone units and exotic blocks are interpreted to be the remnants of rocks and sediment that were carried into the trench and faulted into place within the Coastal Terrane sediments (Aalto 1981).

Sandstone/argillite/conglomerate of the Coastal Terrane tends to form sharp-crested ridges with well-incised sidehill drainage and is susceptible to debris sliding especially upon steep stream banks and inner gorge areas.

Mélange of the Coastal Terrane tends to form a rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows as well as secondary debris flows.

Yager Terrane

The Yager Terrane composes nearly 23 percent of this subbasin. It consists of highly folded and faulted interbedded layers of well consolidated sandstone, argillite, and in some places pebble conglomerate.

This terrane was named by Burdette Ogle in the early 50's because of its excellent exposure along Yager Creek in the Van Duzen River drainage. It is considered a tectonostratigraphic terrane that has been faulted into its current location by tectonic processes as part of subduction and translation at the margin between the North American and the Farallon plates in the accretionary wedge. This terrane contains a stratigraphic history of deposition, age, and metamorphic grade that sets it apart from neighboring terranes.

Sediments of the Yager Terrane were originally deposited between 65 and 34 million years ago and were transported by ancient river systems from as far away as Idaho (Underwood and Bachman 1986). The sediments accumulated along the continental shelf to the deep ocean floor. The accumulation of sediment composing the Yager Terrane is likely more than 10 thousand feet thick in places (Ogle 1953). The sequence of interbedded argillite and sandstone represents stages of calm, marine deposition of sediments punctuated by large underwater landslide events which deposited sand and gravel, the lithified remnants of which are known as turbidites.

These subaqueous landslides were likely triggered by large seismic events, tsunamis, storm wave loading, and sediment loading (Goldfinger et al. 2003), attesting to the abundance of seismic activity and sediment deposition/erosion in this region.

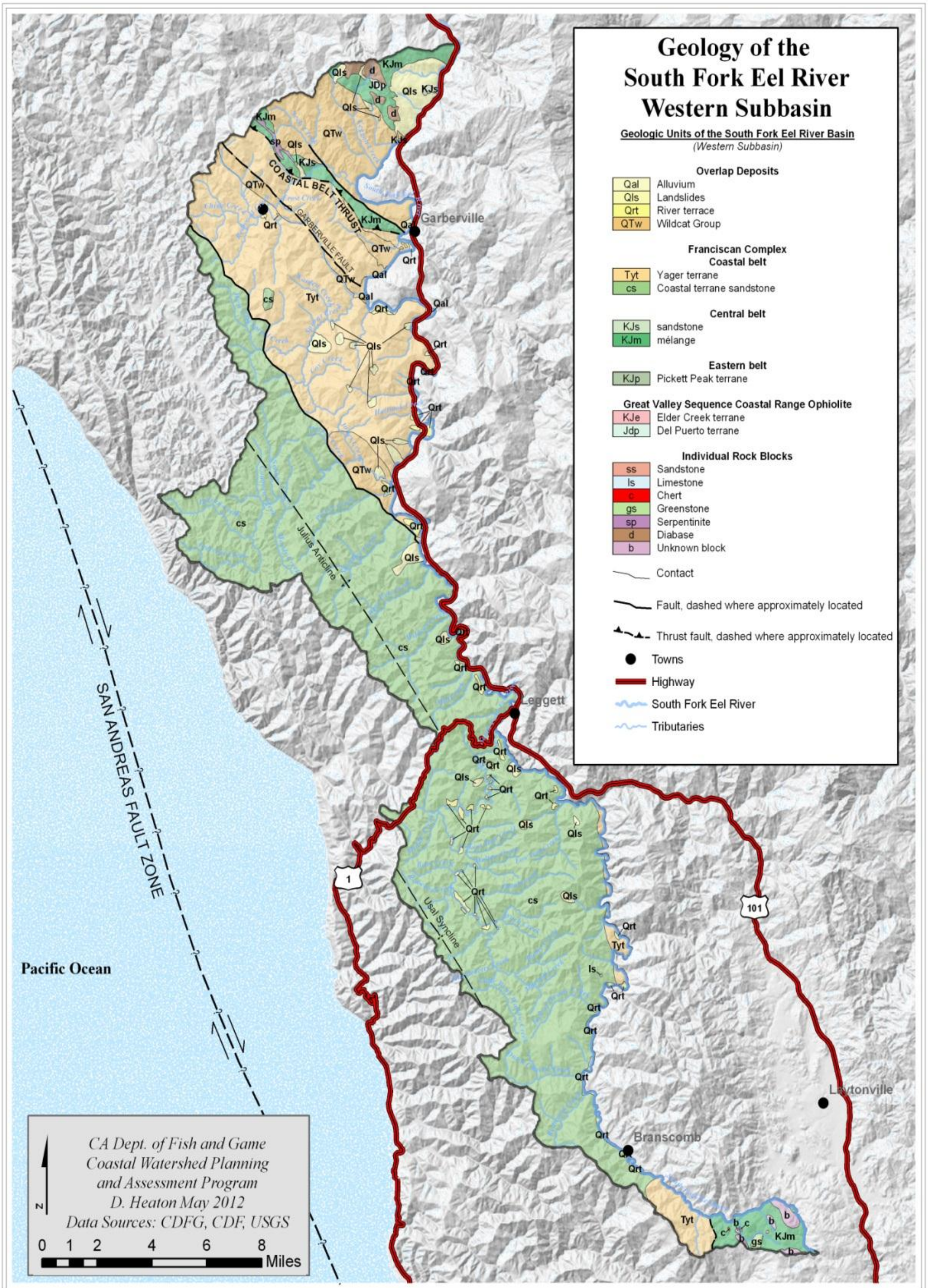

Figure 8. Geologic Map of the Western Subbasin.

Table 3. Western Subbasin bedrock descriptions (ma = millions of years before the present).

Unit	Belt/Rock Type	Formation / Terrane	Composition	Morphology/Erosion	Age (ma)	% Sub-basin Area
Overlap Deposits	Alluvium		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay.	Flat to gently sloping, bare river banks, beds, and floodplanes. Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes.	0-0.01	0.3
	Landslide		Large, disrupted clay to boulder debris and broken rock masses.	Rumpled, disordered hillslopes. Shallow debris slides. Rotational slumps on steep slopes or eroding toes. Surface erosion and gullying where vegetation is bare.	0.01-2	2.7
	River Terrace		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel.	Flat to gently sloping, vegetated, uplifted terrace benches bordering streams. Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes, gullying, debris slides, small earthflows.	0.01-2	1.1
	Wildcat Group	Carlotta Formation	Partially indurated, nonmarine conglomerate, sandstone, and clay. Minor lenses of marine siltstone and clay.	Steep slopes/cliffs and prominent "Flat Irons". Shallow landslides, debris slides, and block slides along inward dipping bedding planes. Toppling along joints. Some rock-falls and ravel.	0.78-1.8	8.5
		Scotia Bluffs Sandstone	Shallow marine sandstone and conglomerate.	Steep slopes/cliffs. Friable; typically fails in numerous small debris slides.	1.8-3.6	
		Rio Dell Formation	Marine mudstone, siltstone, and sandstone.	Steep slopes/cliffs. The Rio Dell Formation is one of the most susceptible to landsliding. Especially in zones between mudstone and sandstone beds with inward dip during saturation.	1.8-3.6	
		Eel River Formation	Marine mudstone, siltstone, and sandstone.	Steep slopes/cliffs. Debris slides/flows, slaking.	3.6-5.3	
		Pullen Formation	Marine mudstone, siltstone, and sandstone.	Steep slopes, forested and highly dissected with sharp ridge crests and V-shaped canyons. Debris slides/flows, rotational slides, slumps, slaking.	5.3-11.6	
Franciscan Complex	Coastal Belt	Coastal Terrane	Slightly metamorphosed, interbedded arkosic sandstone and argillite with minor pebble conglomerate, limestone lenses, and exotic blocks of rock.	Sandstone/argillite/conglomerate of the Coastal Terrane tends to form sharp-crested ridges with well-incised sidehill drainage and is susceptible to debris sliding especially upon steep stream banks. Mélange of the Coastal Terrane tends to form a rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows as well as secondary debris flows.	1.8-99.6	59.3
		Yager Terrane	Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate.	Steep, straight forested slopes, sharp ridge crests, V-shaped canyons and low drainage density. Prone to debris slides along stream banks. Translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers.	33.9-65.5	23
	Central Belt	Sandstone	Large blocks of metasandstone and metagraywake, interbedded with meta-argillite.	Moderate to steep, straight to convex slopes, sharp ridge crests, V-shaped canyons, and densely forested. Generally stable but prone to debris sliding along steep stream banks and in steep headwater	65.5-161.2	0.1

				drainages.		
		Mélange	Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, and metachert.	Rolling, hummocky terrain. Boulders protrude from surrounding mélange forming knockers. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation.	1.8-65.5	4.0
Great Valley Sequence	Coast Range Ophiolite	Del Puerto Terrane	Mudstone, highly sheared locally, containing carbonate concretions and nodules.	Present locally in very limited areas in the northern part of the subbasin.	161.2 - 145.5	0.1
			Dismembered Ophiolite: chert, basalt, diabase, serpentinite mélange, and serpentinized peridotite. Diabase intrusions and gabbro below basalt flows.	Correlated with a more extensive ophiolite 300 km to southeast, in the Del Puerto Canyon area near San Jose, California and forms Bear Buttes, approximately 6 miles northwest of Garberville.	145.5 - 175.6	
Sources: Kilbourne, 1985, Ogle, 1953, McLaughlin, 2000, Kelsey and Allwardt 1975, Kilbourne 1985.						

The Yager Terrane forms steep, sharp-crested ridges and associated valleys that give the landscape a steep and rugged appearance. The relative stability of the Yager Terrane develops soils that typically support lush forest growth.

The Yager Terrane is relatively stable, however, it is faulted and/or sheared in many areas, which typically causes zones of weakness within the bedrock that are prone to large-scale landsliding. Furthermore, the argillaceous interbeds of the Yager Terrane tend to crumble when exposed to repeated cycles of wet and dry (such as in the zone between high water and low water along a stream). This typically leads to undercutting of the stream bank along bedrock reaches, and may cause movement along bedding planes, resulting in translational landslides and rock falls. Excessive crumbling of argillite can also be a source of fine sediments in streams. The beds of the Yager Terrane are tilted by folding and faulting of this region. In areas where the dip of the beds inclines with the hillslope into the stream valley, large translational block landslides are more likely to occur. Yager Terrane is especially prone to debris sliding on steep stream banks (Kelsey and Allwardt 1975).

Wildcat Group

Overlapping the Franciscan Complex is a relatively soft marine mudstone, siltstone, and sandstone layer grading upwards through the non-marine sandstone and conglomerate. This layer, known as the Wildcat Group, makes up approximately 9 percent of this subbasin.

The sediments of the Wildcat Group were deposited within the last 11 million years in environments ranging from a deep to shallow sea and finally to estuaries and river systems.

The Wildcat Group, located downstream of the confluence of the SF Eel River, was originally divided into the Pullen Formation, Eel River Formation, Rio Dell Formation, Scotia Bluffs Sandstone, and Carlotta Formation by Burdette Ogle in the early 1950s. These divisions of the Wildcat Group did not carry over into the SF Eel River Basin, and are mapped in this basin as either "Wildcat undifferentiated" or "Tertiary marine deposits".

The bedrock of the Wildcat is loosely cemented and friable, meaning that the sediment crumbles under light pressure. It is highly prone to erosion, especially when disturbed by land use. Erosion of the soft, fine-grained, sedimentary rock types of the Wildcat contribute fine sediments to stream channels. Landsliding is most common in zones between mudstone and sandstone beds with inward dip, especially during episodes of saturation by heavy rain.

Streams within Wildcat bedrock tend to form steep to vertical canyon walls (*Figure 9*), which are prone to undercutting and subsequent rock falls, and translational rock-block sliding.

Figure 9. Vertical wall in Wildcat Group.

Central Belt Mélange

Mélange of the Central Belt is present in four percent of the Western Subbasin. Mélange is a completely sheared matrix of argillite and sandstone containing very small (gravel sized) to very large (city block sized) mappable blocks of sandstone, limestone, blueschist, greenstone, serpentinite, and chert.

The Central Belt mélange formed from 65.5 through 199.6 million years ago within the subduction trench between the Farallon and North American plates, as material from the oceanic crust and its overlying sediments were tectonically mixed with sediments washing off the continent (Aalto 1981). This mixture was then accreted to the western edge of the continent beginning around 88 million years ago (McLaughlin et al. 2000). Mélange has undergone such a degree of internal shearing during its accretionary/tectonic history that is quite weak and tends to behave as an extremely viscous liquid, slowly “flowing” over time and leaving more coherent rock-blocks within its matrix exposed as “Franciscan Knockers”.

Central Belt mélange creates a hummocky, rolling landscape with grasslands and prairies existing within the most unstable areas with more resistant exotic rock-block protrusions creating large knobs or buttes.

The Central Belt mélange is considered one of the most unstable rock types in the subbasin and is highly prone to erosion and mass movement, especially when saturated with water and/or disturbed by land use. Mélange is especially prone to earthflows and secondary debris flows.

Quaternary Landslides

Large landslide features (tens to hundreds of acres) are present in this subbasin, covering roughly three percent of its surface (based on GIS mapping). Landslide deposits are typically a jumble of debris, soil, and underlying bedrock consisting of clay to boulder-size debris and broken rock masses that have moved down slope within the last 2 million years.

Landslide deposits produce rumpled, jumbled hillslopes and may develop debris slides and rotational slumps on steep slopes or eroding toes. Where vegetation has been stripped, surface erosion and gullying typically occur (McLaughlin et al. 2000).

Landslides have the potential for continued sliding and are sensitive to land use because the coherency of the slide material has been disrupted. The toes of these landslides are typically eroded by stream channels causing subsequent, prevalent small-scale sliding and bleeding of fine sediments into the river system. If the toes erode enough, become saturated by heavy seasonal rain, or if there is a large, local seismic event, the landslide may reactivate.

Earthflows usually form in mélange due to its very low shear strength, and they are capable of contributing large amounts of sediment. Large scale GIS mapping shows only a small percent of the probable extent of landslides within this subbasin. It is estimated based upon topographic diversity that much more material has likely moved over time (Ellen et al. 2007).

River Terrace Deposits

River terrace deposits blanket about one percent of this subbasin. They consist of unconsolidated through poorly consolidated cobbles, gravels and fine sediments.

These terraces were once river-channel and flood-plain deposits, which were subsequently raised during the last 2 million years by regional tectonic uplift above the hundred-year-flood level.

Alluvium

Alluvium covers less than one percent of this subbasin. Alluvium includes any active stream channel sediments as well as unconsolidated bank deposits and floodplain deposits. Alluvium forms flat to gently sloping river beds, banks, flood-plains, and fan-plains.

Faults and Shear Zones

The Western Subbasin is located to the east of the north-northwest trending boundary between the Pacific Plate and North American Plate. At present, most movement consists of the plates grinding past one another at a rate of approximately 5 centimeters per year. The plate boundary also has a component of compression that causes uplift, which forms mountain ranges. The plate boundary is not a single or narrow seam but is a region of crustal deformation approximately 65 miles wide. The Western Subbasin lies within this region of deformation and is located between two of the most active fault rupture zones in north coastal California: the San Andreas that lies just off the coast to the west and the Maacama fault zone at the southern end of this subbasin. Both of these faults are right-lateral strike slip faults and are considered active by the State of California (they exhibit evidence of displacement within the past 11,000 years). Estimations of the recurrence interval between large seismic events for the northern segment of the San Andreas fault range from about 250–100 years. The Western Subbasin is underlain by major, mapped, active faults including the Garberville fault and the Briceland fault. Ground displacement is therefore possible within the basin. Strong seismic shaking should be anticipated to occur if these faults rupture.

A brief description of faults within the Western Subbasin follows, with summary information included in *Table 4*.

San Andreas Fault (Northern Segment)

The San Andreas is an active, right-lateral fault that runs just off shore to the west of this subbasin. It is capable of large (magnitude (M) 7 and greater) earthquakes that can significantly affect the basin with seismic shaking and widespread landsliding. The earthquake of 1906 (the San Francisco earthquake) caused significant damage to the surrounding communities, triggered multiple landslides, and caused liquefaction of low-lying, saturated sediments.

Maacama Fault

The Maacama is an active right-lateral fault zone that runs north by northwest through the southern portion of this subbasin. It is related to translational plate boundary tectonics between the Pacific and North American plates. The Maacama fault is capable of producing earthquakes of up to approximately M 7.1 and has an estimated reoccurrence interval of about 220 years (Hart and Bryant 2001). Over half an inch of right-lateral movement is taken up by the Maacama fault per year on average, more than half of which is accommodated by aseismic creep, meaning that the fault slowly and steadily moves without producing perceptible earthquakes. Approximately 0.26 inches of creep per year were measured in the town of Willits spanning a 10-year period (Galehouse and Lienkaemper 2003).

Garberville Fault

The Garberville fault zone consists of several widely spaced, steeply dipping reverse faults with components of dextral slip that bound elongated northwest-oriented slivers of marine and nonmarine overlap assemblage strata. Earthquakes along the Garberville fault have deep epicenters (greater than 10-12 km) and may be generated from the underlying Gorda plate (McLaughlin et al. 2000).

Briceland Fault

The Briceland fault is thought to be an extension of the Garberville fault, and is a series of steeply dipping reverse faults with components of dextral slip that bound elongate northwest-oriented slivers of marine and nonmarine overlap assemblage strata.

Coastal Belt Thrust

The Coastal Belt Thrust fault cuts through the northern end and the tip of the southern end of this subbasin, juxtaposing the Coastal Belt and the Central belt of the Franciscan Complex.

The Coastal Belt thrust is most likely the zone which accommodated movement between the subducting Farallon plate and the North American plate before accretion of the Coastal Belt when the active subduction moved west to its present location along the Cascadia Megathrust.

Table 4. Western Subbasin fault descriptions. M = magnitude; R. Int. = recurrence interval.

FAULTS WITHIN AND WITH INFLUENCE TO THE SOUTH FORK EEL RIVER BASIN					
	Active Faults:	**Fault Type**	**M**	**R. Int.**	**Description**
SAN ANDREAS FAULT ZONE	San Andreas Fault (Northern Segment)	Dextral	7.3-8.3	200-300	The San Andreas Fault (Northern Segment) is and active dextral fault that runs just off shore, southwest of the Van Duzen River Basin. It is capable of large earthquakes (~M 7) that can significantly affect the basin by seismic shaking, deformation, and associated mass wasting/erosion effects. Although not well documented within the Van Duzen River Basin, the 1906 northern San Andreas Fault seismic event (the San Francisco earthquake) caused significant damage to the surrounding communities, triggered multiple landslides, and caused liquefaction of low-lying, saturated sediments.
	Maacama Fault (Northern Segment)	Dextral	7.1	370-500	Creep rate 7.3mm/year (Galehouse 1995). Slip rate 9mm/year (WGNCEP 1996). Mapped from Laytonville southward into Sonoma County. Interpreted as a right-stepping, northern extension of the Roger's Creek Fault. Most recent event is estimated to have occurred between 1520 and 1650 A.D.
	Brush Mountain Shear Zone	Dextral			Inferred extension of the Maacama Fault.
	Garberville Fault	Dextral	6.9	220	Inferred extension of the Maacama Fault.
	Briceland Fault	Dextral	6.9	220	Inferred extension of the Maacama Fault.
Faults:					
	Coastal Belt Thrust (Freshwater Fault)	Thrust			The Coastal Belt Thrust fault is the major fault that juxtaposes the Coastal Belt and the Central Belt. It trends north by northwest through the Van Duzen River Basin. It is most likely the zone which accommodated movement between the subducting Farallon Plate and the North American Plate before accretion of the Coastal Belt when the active subduction moved west to its present location along the Cascadia Megathrust.
	Piercy Fault				
Sources: USGS website – Quaternary fault and fold database of the US, accessed 2011; McLauglin et al. 2000					

Julius Anticline

The Julius Anticline is a major structure where the bedrock bows upward. This upward fold runs through the Western Subbasin and is caused by localized compression throughout the region (*Figure 10*).

Usal Syncline

The Usal Syncline is a major structure where the bedrock is bowed downward. This downward fold runs through the Western Subbasin and is caused by compression (*Figure 10*). Rock layers that have become tilted towards stream channels or road cuts by syncline or anticline features may increase the likelihood of landsliding.

Ground shaking generated by earthquakes can trigger rock falls and landslides that deliver large amounts of sediment to the streams. Where fault rupture reaches the ground surface it can weaken bedrock, offset streams, and truncate and over-steepen certain topographic landforms, enhancing the erosion and transport of sediment to the streams.

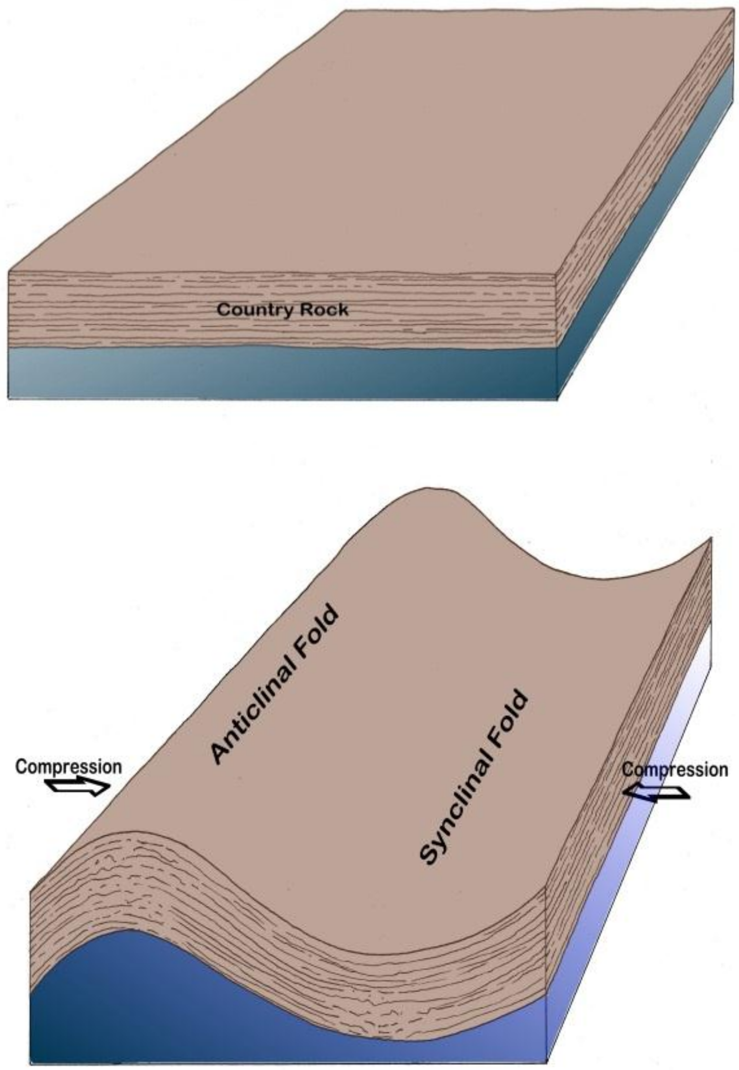

Figure 10. Typical anticline/syncline formation caused by compression.

Landslides and Erosion

The Western Subbasin is predominantly underlain by soft, weak and erodible rock types of the Coastal Belt of the Franciscan Complex, with some areas of Central Belt rock types.

Most of the subbasin is Coastal Terrane. Although the sandstone, argillite, and conglomerate of the Coastal Terrane is relatively more competent than other rock types in the subbasin, it is susceptible to debris sliding, especially on steep stream banks. Mélange of the Coastal Terrane is prone to earthflows as well as secondary debris flows, and contributes sediment at high rates.

The Yager Terrane is prone to debris slides and translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers. Argillite within the Yager Terrane becomes very friable when repeatedly exposed to cycles of wetting and drying and can perpetuate these rock slides as well as contribute fine sediments to the streams. Areas where faults have disrupted the coherency of the bedrock are prone to rockslides, debris flows, and enhanced surface erosion.

The majority of natural sediment entering the streams is produced by landslides. The term "landslide" is used in this report to refer to the various processes of mass wasting of soil, unconsolidated sediment, or bedrock.

There are both positive and negative effects of natural landsliding on fish. On the positive side, landslides typically contribute large woody debris, large boulders, and spawning gravels from the hillsides that increase stream channel diversity by forming plunge-pools, riffles, meanders, and side channels. On the negative side, landslides can contribute an abundance of fine sediments, clear riparian vegetation, decrease channel depth, and fill in pools. Salmonids have evolved over time to thrive in the delicately balanced, highly unstable, natural landscape of this area, but anthropogenic activities may exacerbate the negative effects of natural landsliding throughout the subbasin.

The major factors that tend to increase the likelihood of landsliding include: steep hillslopes, high pore pressure between grains (water saturated ground), bedding planes and/or planes of weakness within the soil or bedrock, undercutting of slopes, poor vegetation cover, seismic shaking, and weak hillslope material. Weak rocks in conjunction with high amounts of rainfall and the dynamic tectonics of Northwestern California create a landscape naturally prone to landsliding. In the past, anthropogenic processes have enhanced the susceptibility of the landscape to landsliding.

Central Belt mélange occurs in the northern most portion of the subbasin. While not widespread, mélange is more susceptible to erosion than other terranes. The amount of internal shearing within mélange has weakened the rock-strength to such an extent that it has become an incoherent matrix of its parent rock types, in this case completely sheared argillite, sandstone, and conglomerate. This sheared matrix, which comprises most of the volume of mélange, has very little internal strength and flows downhill over time via small through very large, deep-seated earthflows. Studies have estimated that while only about 7 to 8 percent of mélange terrain might be active at a given time, approximately 70 to 80 percent of the landscape moves over geologic time (Mackey and Roering 2011). Large, active, deep-seated earthflows are capable of delivering tens of thousands of tons of sediment per square mile of surface area each year (Kelsey 1977). Even when dormant, the toes of these earthflows typically erode, providing a constant source of fine sediments into the streams. If erosion of the toe progrades far enough, if heavy rainfall saturates the earthflow, or if there is local seismic shaking, dormant earthflows may reactivate.

Surface erosion affects recent earthflows by developing rills and gullies, as well as secondary slumps and small debris flows on top of them, which wash additional sediments into the streams.

Three percent of this subbasin has been mapped with large Quaternary landslide features. These landslides reflect only what has been mapped on a large scale without detailed field investigation. Many smaller and/or less obvious landslides most likely exist that have not been mapped or have been mapped as part of landslide inventories at a much more detailed scale.

The largest mapped Quaternary landslide in the Western Subbasin occurs on the flank of Bear Buttes, located north of Redway on the bank of the SF Eel River (*Figure 11*). This landslide occurs in the Central Belt mélange and is drained by Hooker Creek and a few smaller, unnamed tributaries.

Figure 11. Pseudo-aerial-oblique of Bear Buttes earthflow.

Fluvial Geomorphology

The overall fluvial geomorphology of the Western Subbasin may be described by moderately steep tributaries with steeply incised valleys draining into a low gradient mainstem. The relatively resistant geology of this landscape is subject to high rates of tectonic uplift, and the streams incise at similar rates, creating geologically young ridge/valley morphology.

Coastal Belt geology of the Coastal Terrane and Yager Terrane (sandstone, argillite, and conglomerate) dominate this subbasin and typically produce a rugged landscape with steep, sharp ridges and valleys. The trend of these features (~N25°W) is mainly controlled by regional folding and faulting induced by Mendocino triple Junction and San Andreas tectonics.

Mélange geology in the northernmost and southernmost portions of this subbasin typically produces a hummocky topography with rolling hills of oak woodlands and grasslands. Ridge-valley sets of mélange units are more rounded and have lower relief than sandstone units. Exotic rock blocks within mélange protrude from the landscape, forming knockers jutting out from the terrain.

Mélange typically moves via large earthflows. Where active earthflows terminate at a stream, toe erosion delivers large amounts of fine sediment and large boulders of exotic rock types into streams. This creates chronic turbidity as well as boulder-runs and cascade reaches, both of which may become possible barriers to fish passage.

Sediment Transport

Processes of stream sedimentation are controlled by sediment supply and stream power, which is a combination of the stream's discharge and the slope over which it runs (velocity). Streams are typically divided into a source reach (channel gradient of >20%), a transport reach (channel gradient 4-20%), and a depositional reach (channel gradient <4%) in terms of sedimentation based on channel steepness. Sediment is eroded from steep headwater reaches and steepened knick-zones, transported along moderately steep reaches, and deposited within gentle gradient reaches. Although streams are broadly divided into three regions, forms of erosion, transport, and deposition occur on all reaches of a given stream at any given time. Seasonal variations in stream flow and local bedrock morphology alter where and when such processes occur.

The recruitment and transport of most sediment through the system occurs during large storm events. Heavy, long duration rainstorms may completely saturate hillslope soil and trigger landslides and surface erosion. Sediment pulses from large storms migrate slowly downstream and tend to affect the stream for tens of years. Land use can greatly increase the natural rate of erosion and sediment input to streams. Very large storm/flood events mobilize so much sediment that it may take up to a century for the stream to flush out the sediment pulse naturally.

Large flood events can trigger widespread bank erosion and landsliding, recruiting excess sediment into the stream and redepositing it. This can cause aggradation of the stream valleys in decades following the flood event. In time, the channel typically incises through these sedimentary deposits back to its former level, leaving terrace deposits along its banks. Large landslides may block the stream from time to time causing a landslide dam. Water backing up behind the dam typically triggers many smaller streamside landslides, contributing large amounts of sediment which is impounded behind the dam. Eventually the dam is breached and worn away and the stream responds by incising into the impounded deposit, leaving behind terraces along the stream banks.

During high stands of sea-level, base-levels of streams also become raised. Streams usually respond to a raised base-level by depositing sediment and decreasing their slope. Eventually as the seas recede, streams will readjust and incise, leaving behind extensive terrace deposits.

Stream terrace deposits are present at several places along the mainstem of the SF Eel River and some of its tributaries. These deposits have been developed due to their flat morphology, which is easy to build on, as well as the sediment itself, which usually supports good crop growth and forest cover. Portions of the towns of Redway, Garberville, Benbow, Leggett, and Branscomb in the Western Subbasin are built on these terrace deposits.

The tributaries of the Western Subbasin are predominantly bedrock controlled. Bedrock controlled streams create their fluvial-geomorphology from the gradual wearing away of the containing bedrock. As opposed to creating channel morphology from a strict interaction of sediment supply and the transport power of stream-flow, local geology will dictate the creation of these forms. Regional uplift, folding and faulting, and the mechanical strength and behavior of bedrock control the overall morphology of the streams in the Western Subbasin.

Although controlled by bedrock, Western Subbasin streams are also influenced by localized sediment input, typically from landsliding and surface erosion. These processes are often intensified by land use and management activities.

The 1955 and 1964 floods recruited massive amounts of sediment into the streams, aggrading the channels and completely burying bedrock within them. Filling channels with sediment effectively forces the water up and out of the channel, causing extensive bank erosion and channel widening to accommodate increased flow volumes.

Spawning Gravel

Cobble and gravel sized sediment required by salmonids for redd construction, egg emplacement, and rearing, is typically introduced into the stream through landslides, rock-falls, and bank erosion.

In Western Subbasin streams, dominant spawining gravel substrate types are sandstone of the Coastal Belt Coastal and Yager terranes, sandstone of the Central Belt, and resistant rock types found within mélange matrix.

Knickzones

Knickzones are areas of locally steepened stream channel. Major knickzones in the Western Subbasin are formed by regional uplift causing stream incision.

Knickpoints form in series throughout the knickzone and tend to congregate or "bunch up" in areas with limited stream power (Foster 2010). Knickzones provide a record of regional uplift or base-level lowering within the subbasin, and may create gradients steep enough to become obstacles or barriers to fish passage.

The major knickzone in the Western Subbasin is located on the mainstem SF Eel River just upstream from Low Gap Creek and extends upstream approximately eight miles. This knickzone may be the result of cumulative past base-level lowering events stalling near Rattlesnake Creek, which includes about 22% of the upstream drainage area. Studies of stream channel steepness in this area also indicate local uplift (Foster 2010).

CDFW field crews identified the probable end of anadromy on habitat surveys. In 12 Western Subbasin streams, the end of anadromy was associated with a knickzone, usually located near its downstream end.

Bedrock waterfalls marked the end of anadromy for seven mainstem tributaries. All of the waterfall-bearing tributaries were grouped between RM 55 – 65, just downstream of the major knickzone on the mainstem. Five of these waterfalls were easily associated with local stream knickzones and all of them correlate with the major knickzone on the mainstem.

Channel Type

The fluvial geomorphology of individual streams within a system can be used to understand current as well as past fluvial regime changes. Rosgen (1996) defined basic morphologic stream patterns based on entrenchment, sinuosity, and slope of streams (*Figure 12*). The most recent (1983 to 2010) stream surveys of 51 tributaries of the SF Eel River within the Western Subbasin documented A, B, C, E, F, and G Rosgen channel types (*Table 5*).

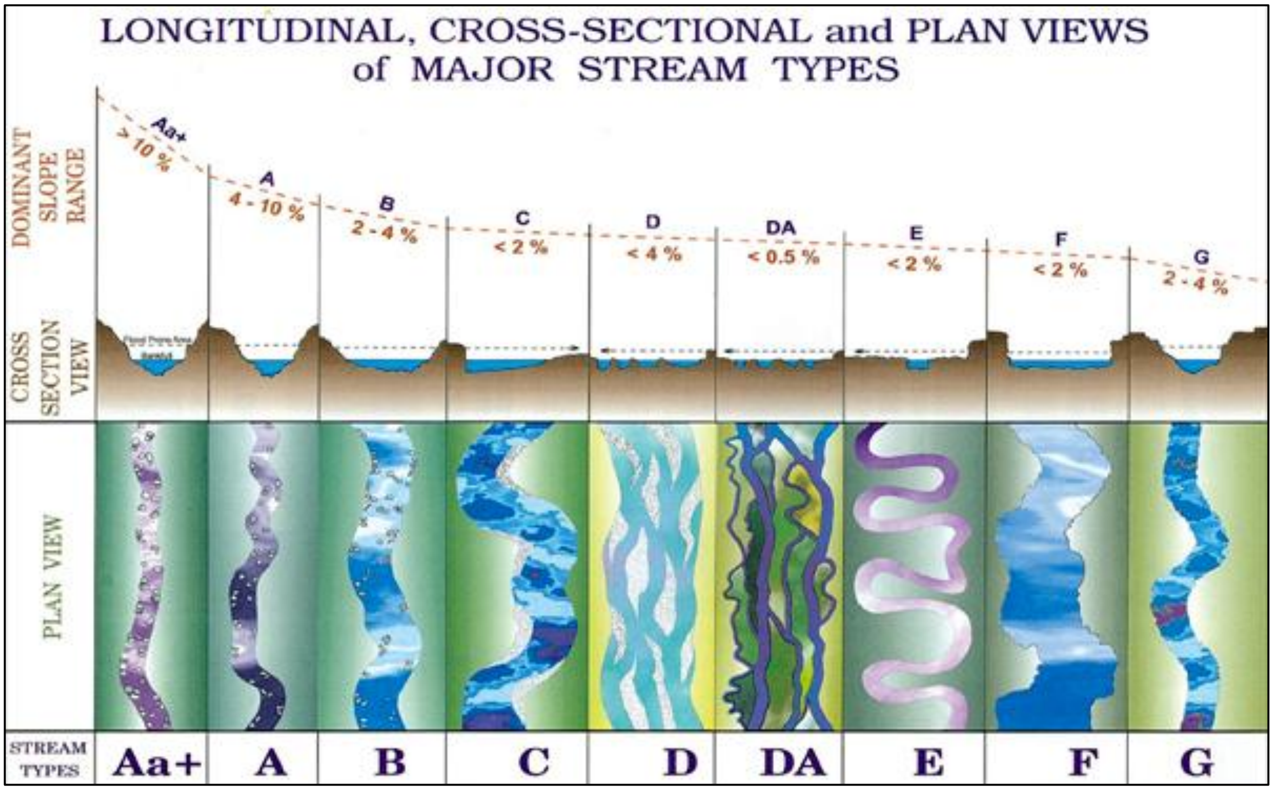

Figure 12. Illustration of channel types A-G (Rosgen 1996, courtesy of Wildland Hydrology).

Table 5. Surveyed channel types by percent of subbasin.

Western Subbasin General Channel Types		
Type	**%**	**Description**
A	2.4%	Type A reaches have a moderate to steep slope (4-10%), flow through steep V- shaped valleys, do not have well-developed floodplains, and have few meanders.
B	22%	Type B stream reaches are wide, shallow, single thread channels. They are moderately entrenched, moderate gradient (2-4%) reaches, which are riffle-dominated with step/pool sequences. Type B reaches flow through broader valleys than type A reaches, do not have well-developed floodplains, and have few meanders.
C	4.3%	Type C stream reaches are wide, shallow, single thread channels. They are moderately entrenched, low gradient (<2%) reaches with riffle/pool sequences. Type C reaches have well-developed floodplains, meanders, and point bars.
E	0.2%	Type E channels are low gradient (<2%), meandering, riffle/pool streams with a gravel, sand, or silt substrate.
F	59%	Type F stream reaches are wide, shallow, single thread channels. They are deeply entrenched, low gradient (<2%) reaches and often have high rates of bank erosion. Type F reaches flow through low-relief valleys and gorges, are typically working to create new floodplains, and have frequent meanders.
G	5.5%	Type G, or gully stream reaches, are similar to F types but are narrow and deep and have a steeper gradient (2-4%). With few exceptions, type G reach types possess high rates of bank erosion as they try to widen into a type F channel. They can be found in a variety of landforms, including meadows, developed areas, and newly established channels within relic channels (Flosi, et al. 1998).

Type F stream reaches (*Figure 13*) were the most common type of channel in surveyed Western Subbasin tributaries, accounting for 59% of the total stream length surveyed.

Type B streams were the second most common channel type in Western Subbasin tributaries (22% of the total surveyed habitat length), followd by G (5.5%), C (4.3%), A (2.4%), and E (0.2%) channel types.In addition to channel type, Rosgen’s system includes a “level II” classification, which describes the size of channel material or D50 (median particle size).

Material size classes include:

- 1 - Bedrock (>2048 mm);
- 2 - Boulder (256-2048 mm);
- 3 - Cobble (64-256 mm);
- 4 - Gravel (2-64 mm);
- 5 - Sand (0.062-2 mm); and
- 6 - Silt/clay (<0.062 mm).

The total distance surveyed by CDFW habitat typing crews in Western Subbasin streams was 565,400 feet. The most common channel types using the level II classification system were F4 (216.519 ft., or 38% of all surveyed habitat) and F3 (96,498 ft., or 17% of surveyed habitat) (*Table 6*).

Figure 13. Type F stream reach in Hollow Tree Creek, in the Western Subbasin.

Table 6. Surveyed channel types of the Western Subbasin by stream reach.

Creek	Length (ft)	Channel Type
Leggett Creek	17,137	F4
Redwood Creek (N)	39,901	F4
Miller Creek	22,411	F3
China Creek	11,635	F4
Twin Creek	2,846	F4
Dinner Creek	751	B1
	693	B3
	8,504	C3
Connick Creek	11,866	C1
Sproul creek	2,887	B2
	31,231	F3
Little Sproul Creek	3,055	A2
	10,018	B3
Warden Creek	609	B2
	1,382	B3
West fork Sproul Creek	4,335	B1
	5,919	B4
	16,350	F4
La Doo Creek	963	B4
Cox Creek	6,799	F3
Durphy Creek	2,065	A2
	7,229	B3
Hartsook Creek	3,316	A2
	3,739	B4
Indian Creek	2,553	F1
	5,616	F2
	43,307	F4
Jones Creek	3,930	B1
Moody Creek	8,707	B1
Sebbas Creek	4,384	B1
	15,899	F3
Coulborn Creek	5,892	B1
	1,638	C3
Anderson Creek	978	E4
	11,191	F3
Piercy Creek	6,479	B3
	5,166	F2
Standley Creek	10,090	G4
Bear Pen Creek	12,631	B4
	2,233	F2
Wildcat Creek	12,207	B3
Mill Creek	1,765	A3
Hollow Tree Creek	18,849	F4
SF Hollow Tree Creek.	1,317	B1
Mule Creek	1,317	B1

Creek	Length (ft)	Channel Type
Middle Creek	715	B1
Islam John Creek	2,428	B1
Lost Man Creek	99	B1
Walter's Creek	4,333	B1
Bear Creek	2,042	C2
Redwood Creek	1,654	B4
	4,700	F3
	909	G4
	3,263	G5
SF Redwood Creek	1,316	B4
	8,528	G5
Bond Creek	811	A2
	1,181	A3
	2,347	B4
	9,558	F4
Michael's Creek	5,890	B4
	7,859	F4
Doctor's Creek	1,603	F3
Lynch Creek	996	F4
Waldron Creek	550	F3
	6,399	F4
	672	G1
Bear Pen Creek	12,631	B4
	2,233	F2
Huckleberry Creek	1,042	F1
	4,141	F4
	2,161	G4
	747	G6
Bear Wallow Creek	630	F3
	5,718	F4
	4,951	G4
Butler Creek	7,531	F4
Low Gap Creek	13,256	B3
Little Low Gap Creek	1,085	A3
Jack of Hearts Creek	16,258	B3
Dutch Charlie Creek	689	B2
	1,484	F3
	13,027	F4
Redwood Creek (S)	11,285	F4
	1,569	F6
Middleton Creek	5,540	B4

Stream Channel Geometry

Longitudinal Stream Profiles

Over time, in ideal conditions, a stream will carve into the landscape and form a channel slope in relative balance to its erosive stream power, sediment availability, and strength of bedrock, eventually reaching a steady state. A stream in a topographically steady state of slope (at equilibrium) tends to form a topographically smooth, concave slope that gets exponentially steeper towards the headwaters. A stream that is out of equilibrium deviates from this basic pattern along various portions of its length. In Western Subbasin streams, typical divergence from this pattern is caused by changes in underlying geology, regional uplift, movement along stream-crossing faults, large landslides, and large amounts of sediment (aggradation) within the stream channel.

These processes cause the longitudinal profile of a particular stream to become progressively convex (*Figure 14*), or form prominent knickzones that migrate upstream over time due to headwater erosion. Changes in the natural resistance of the bedrock to erosion may also cause variations in the longitudinal profile. Sections of the stream channel that are significantly out of equilibrium may become too steep (>10% channel slope) to allow passage of fish and will decrease the length of anadromy. In the Western Subbasin, only three out of 20 (15%) of the surveyed tributaries of the SF Eel River with identified ends of anadromy have profiles that are consistent with the basic pattern of equilibrium. Uplift or basal lowering has created multiple knickzones that are apparent on longitudinal stream profiles and are out of equilibrium. Knickzones are sensitive to disturbance and may limit fish passage over time. Land use and management practices should be studied closely when planning activities that may alter the fluvial morphology or regime of each stream.

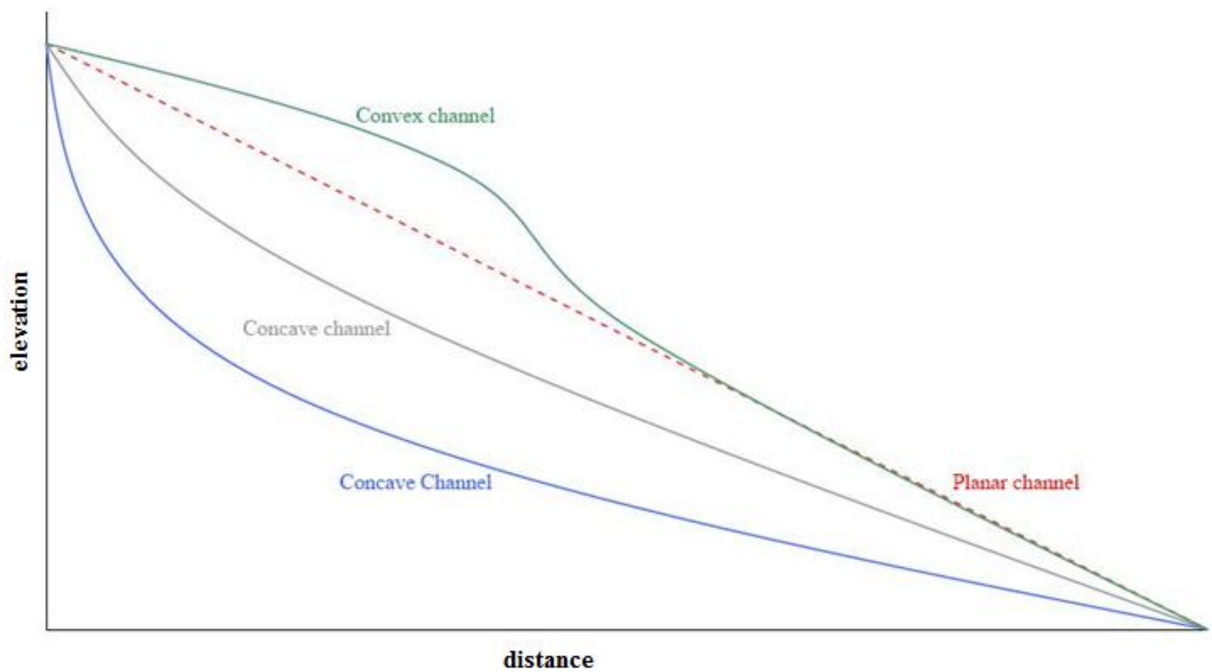

Figure 14. Basic channel profile shapes.

Profiles of Western Subbasin Streams

Stream profiles were completed for 26 Western Subbasin streams (*Figure 15*). Six streams had profiles that were near equilibrium and 24 had profiles that were clearly out of equilibrium. Knickzones and ends of anadromy (EOA) were included on profiles where applicable. Twenty of the 26 streams had EOAs identified on habitat typing reports. Of these 20, 75% had EOAs associated with knickzones, and 55% of EOAs were located at the downstream end of a knickzone.

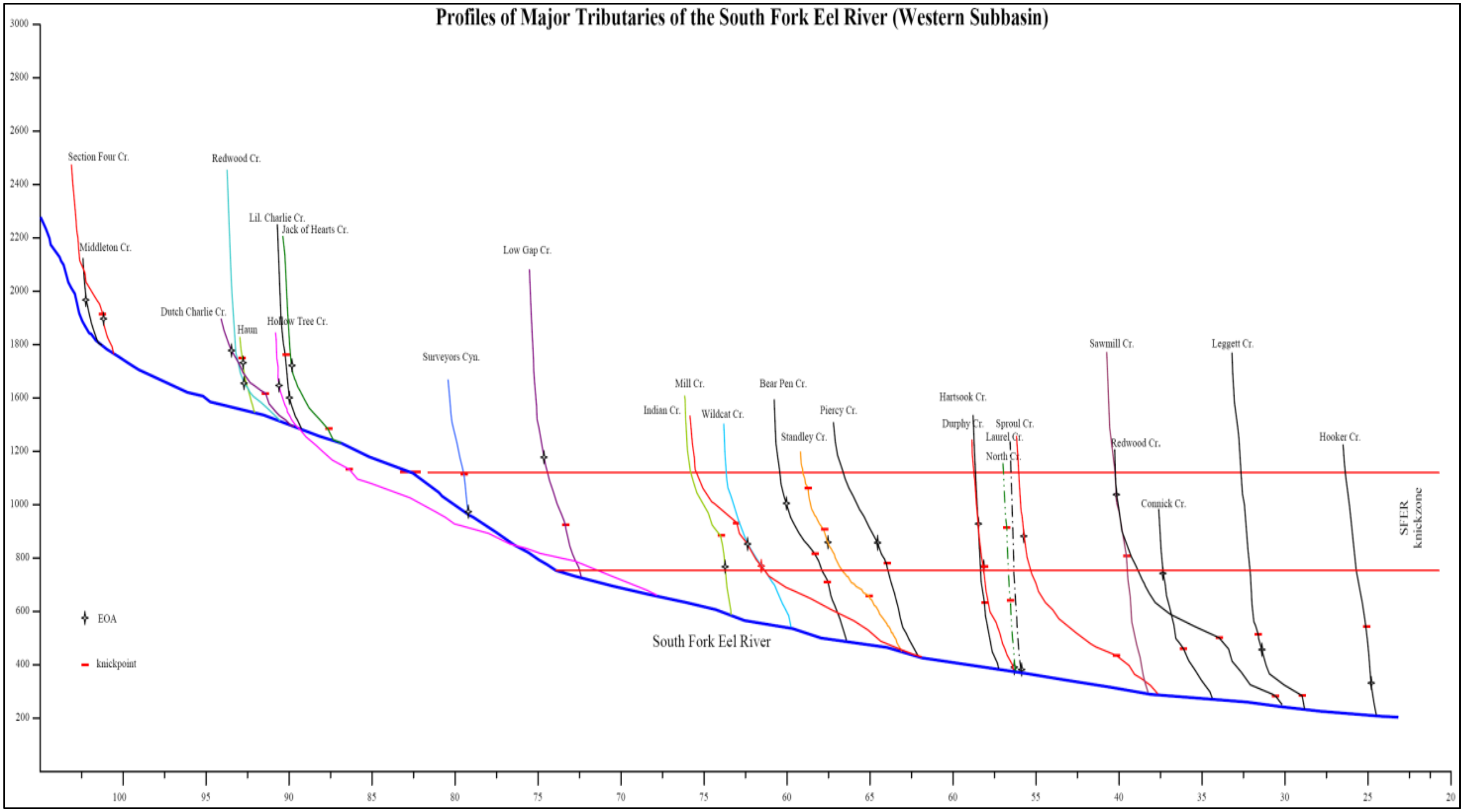

Figure 15. Longitudinal stream profiles of SF Eel River Western Subbasin streams.

Soils

In this assessment, the term "soil" refers to any loose material derived from the weathering of bedrock and mixed upward by biogenic and/or mechanical processes. Like the other SF Eel River subbasins, bedrock of the Western Subbasin is mantled with unstable soils.

The majority of bedrock in the subbasin is composed of sedimentary rock types of the Coastal Belt – Coastal Terrane, which produce soil types (loam to extremely gravely sandy loam) that are prone to mass wasting, hillslope erosion, and transport by fluvial processes. The dominate soil series in the Western Subbasin is Wohly-Holohan-Casabonne which covers approximately 52% of the subbasin area (*Figure 16*). The Wohly-Holohan-Casabonne soil series predominantly mantles steep, rugged ridges and valleys of Central Belt sandstone and the Coastal and Yager Terrane bedrock (sandstone, shale, and conglomerate) of the Coastal Belt (*Table 7*).

The Western Subbasin receives high levels of rainfall between October and May. Rainfall-initiated soil movement varies with storm intensity. As soil becomes saturated, pore pressure between grains increases, which lowers its ability to resist downslope movement. Gradual downslope movement of soil caused by gravity, weathering, saturation, rain-splash, and biogenic activity (soil creep) is evident throughout this subbasin, and delivers large amounts of sediment to Western Subbasin streams (Stillwater Sciences 1999).

A healthy cover of forest vegetation helps stabilize and reinforce the strength and stability of hillslope soils. Roots mechanically reinforce the soil by transfer of shear stress in the soil to tensile resistance in the roots (Menashe 2001). A mesh of intertwining roots also increases cohesion of the soil. Roots decrease the likelihood of saturation-related slope failure by drawing water out of the soil, which can prevent or at least delay soil saturation. Tree cover on hillslopes can increase the soil shear-strength by more than 50% (O'Loughlin and Ziemer 1982), sometimes as much as 100% (Waldron 1977). The soils in this subbasin support a lush growth of Redwood and Douglas-fir, and Tan-oak in second-growth forests (Stillwater Sciences 1999).

A significant portion (nearly 75% of the total area) of the Western Subbasin is managed for industrial timber production. When trees are removed from a slope, the roots tend to decay and lose their stabilizing influence, predisposing soils to failure (O'Loughlin and Ziemer 1982). Soil compaction associated with logging access roads, landings, and skid-trails, and the removal of vegetative cover through timber harvest affect soil hydrology and erosion within this subbasin.

Roads are listed as the most significant source of anthropogenic sediment within the South Fork Eel River Basin (USEPA 1999). Input of soil from roads in Western Subbasin streams will be discussed in detail in the Roads and Railroads section of this report.

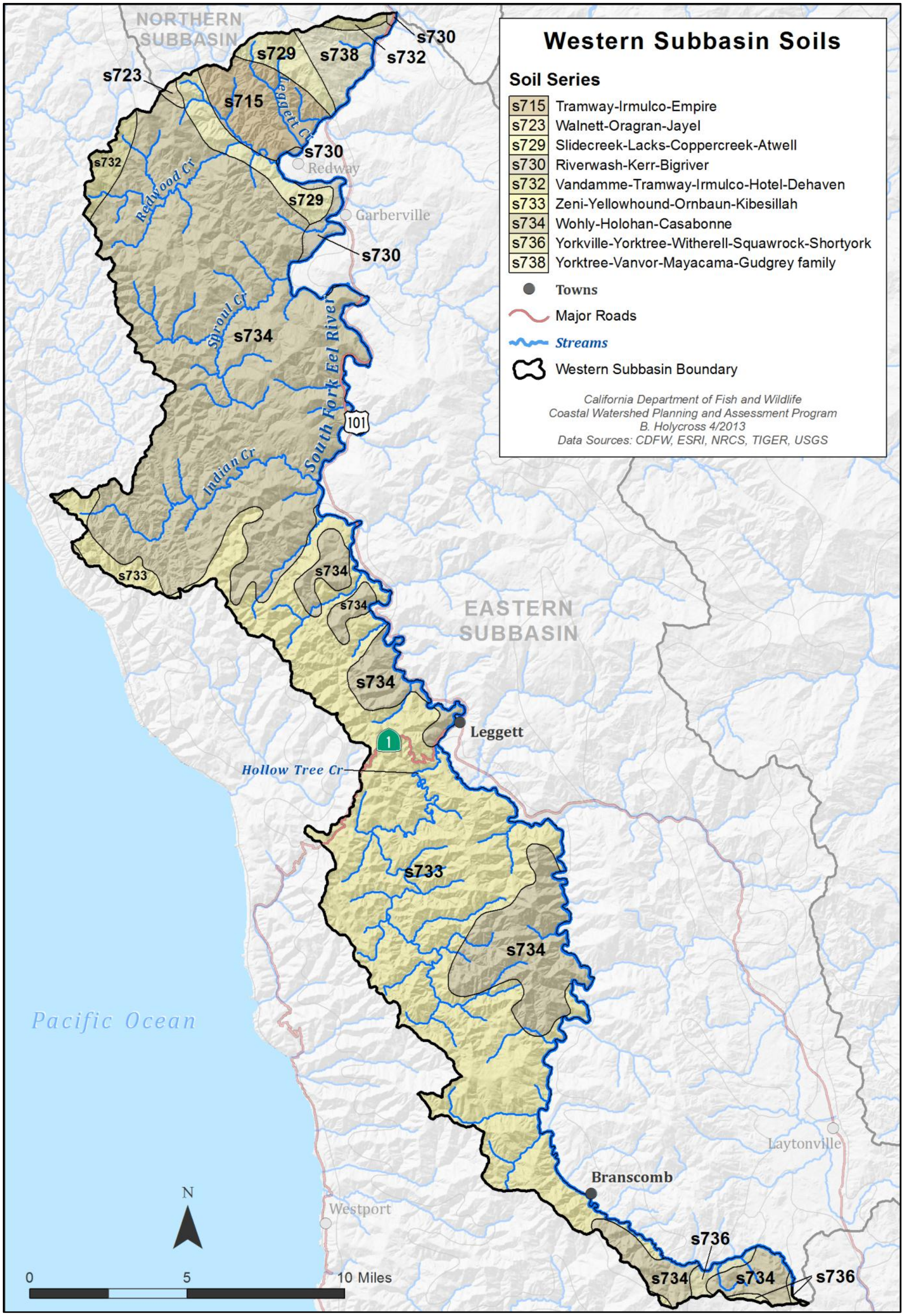

Figure 16. Soils map of the Western Subbasin.

Table 7. Western Subbasin soil descriptions.

Soil series	Texture	Description	Parent Bedrock	Slope %
Wohly-Holohan-Casabonne (52%)				
WOHLY	loam	Very deep, well drained soils that formed in residuum weathered from sandstone and shale.	Central Belt mélange and sandstone. Coastal Belt Coastal and Yager Terrane.	9 - 75
HOLOHAN	extremely gravelly sandy loam	Very deep, well drained soils formed in colluvium weathered from sandstone.		9 - 75
CASABONNE	gravelly loam	Very deep, well drained soils formed in colluvium and residuum weathered from sandstone or shale.		9 - 75
Zeni-Yellowhound-Ornbaun-Kibesillah (37%)				
ZENI	loam	Moderately deep, well drained soils formed in material weathered from sandstone or mudstone.	Coastal Belt Coastal Terrane	9 - 75
YELLOWHOUND	gravelly loam	Deep, well drained soils formed in material weathered from sandstone or conglomerate.		9 - 99
ORNBAUN	loam	Deep, well drained soils formed in material weathered from sandstone and mudstone.		9 - 75
KIBESILLAH	very gravelly loam	Deep, well drained soils formed in material weathered from sandstone.		9 - 99
Tramway-Irmulco-Empire (4%)				
TRAMWAY	loam	Deep, well drained soils formed in material weathered from sandstone.	Wildcat group.	9 - 75
IRMULCO	loam	Deep or very deep well drained soils formed in material weathered from sandstone.		9 - 75
EMPIRE	loam	Moderately deep, well to moderately drained soils formed in material derived from soft sedimentary rocks.		10-40
Slidecreek-Lacks-Coppercreek-Atwell (3%)				
SLIDECREEK	gravelly loam	Very deep, well drained soils that formed in colluvium and residuum weathered from sandstone and mudstone.	Central Belt mélange.	9 - 75
COPPERCREEK	loam	Very deep, well drained soils that formed in colluvium and residuum from schist, sandstone, and mudstone.		9 - 75
ATWELL	silt loam	Very deep, moderately well drained soils formed in material from sheared sedimentary rocks		15 - 50
Yorktree-Vanvor-Mayacama-Gudgrey family (2%)				
YORKTREE	loam	Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone.	Central Belt sandstone.	15 - 75
VANVOR	very gravelly sandy clay loam	Moderately deep, well drained soils on mountains. These soils formed in colluvium from metavolcanic rock.		30 - 75
MAYACAMA	very gravelly sandy loam	Moderately deep, somewhat excessively drained soils formed in material derived from sedimentary and metasedimentary rocks.		9 - 75
GUDGREY	gravelly sandy clay loam	Deep, well drained soils formed in material weathered from sandstone, schist or shale.		8 - 75
Vandamme-Tramway-Irmulco-Hotel-Dehaven (1%)				
VANDAMME	loam	Deep, well drained soils formed in material weathered from sandstone or mudstone.	Coastal Belt Yager	2 - 75

TRAMWAY	loam	Moderately deep, well drained soils formed in material weathered from sandstone.	Terrane.	9 - 75
IRMULCO	loam	Deep or very deep well drained soils formed in material weathered from sandstone.		9 - 75
HOTEL	very gravelly loam	Moderately deep, well drained soils that formed in material weathered from sandstone.		30 - 100
DEHAVEN	gravelly loam	Deep, well drained soils formed in material weathered from sandstone.		30 - 99
Riverwash-Kerr-Bigriver (1%)				
RIVERWASH	N/A	Barren alluvial areas of unstablilized sand silt, clay or gravel reworked by frequently by stream activity.	Alluvium and river terrace deposits.	0 - 5
KERR	loam	Dark olive gray recent moderately well drained alluvial soils without profile development that are formed in material derived mainly from micaceous schists.		0 - 5
BIGRIVER	loamy sand	Very deep, well drained soils formed from alluvium derived from mixed sources.		0 - 5
Yorkville-Yorktree-Witherell-Squawrock-Shortyork (1%)				
YORKVILLE	loam	Very deep, well drained soils that formed in material weathered from chloritic schist and other sedimentary and metamorphic rocks.	Central Belt Sandstone and Mélange.	5 - 75
YORKTREE	loam	Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone.		15 - 75
WITHERELL	loam	Very deep, somewhat excessively drained soils formed in material weathered from sandstone.		5 - 75
SQUAWROCK	cobbly loam	Moderately deep, well drained soils formed in material weathered from sandstone or graywacke.		15 - 75
SHORTYORK	gravelly loam	Very deep, well drained soils formed in material weathered from sandstone, schist, shale and graywacke.		8 - 75
Walnett-Oragran-Jayel (<1%)				
WALNETT	stony loam	Very deep, well drained soils formed in material weathered from serpentinized peridotite.	Central Belt Mélange – peridotite block	5 - 75
ORAGRAN	very stony loam	Shallow, well drained soils formed in material weathered from peridotite or serpentinite.		5 - 75
JAYEL	stony clay loam	Moderately deep, well drained soils formed in material weathered from serpentinized peridotite.		5 - 75

Vegetation

Two of the main factors for the decline of salmonids throughout the South Fork Eel River Basin over the past century have been an overabundance of fine sediments entering streams and an increase in stream temperatures. Vegetation on the landscape directly influences both of these conditions. Hillslope vegetation intercepts and slows the velocity of rainwater and provides leaf-litter and duff layers to the surface of soils, which intercepts and disperses rainwater and increases resistance to surface erosion. Leaf and duff layers also provide an intricate irregular, permeable interface that allows surface water to pond and be absorbed rather than flow downhill as runoff. Vegetation also increases transpiration, decreasing pore pressure between soil grains during heavy rains and thereby reducing slope failure. Root systems increase the tensile slope strength of unstable soils, reducing landslides, erosion and sedimentation.

Riparian vegetation shades streams and reduces solar radiation, both of which lower stream temperatures. Stream bank roots and low hanging branches provide cover for fish. Large woody debris generated by riparian vegetation and recruited by streams provides habitat and increases stream channel diversity. Stream bank root systems increase the tensile slope strength of unstable soils, reducing bank failure and subsequent sedimentation.

In the Western Subbasin, the predominant vegetation cover type as described by the USFS CALVEG data is mixed conifer and hardwood forest, covering approximately 73 percent of the subbasin area (*Figure 17*, *Table 8*). This vegetation type consists of forests and woodlands where conifers are the primary vegetation and hardwoods are present secondarily. Conifers are prevalent throughout this subbasin and are found in nearly all areas except river floodplains, and some river terrace low lands and hillside meadows where the underlying geology is too unstable to support forest growth.

Conifer forest is the next most abundant vegetation in this subbasin, covering approximately 11 percent of the subbasin. Similarly, hardwood forest vegetation cover classification composes just less than 11 percent of the subbasin area.

Grassland/prairie (herbaceous) vegetation is the fourth most abundant vegetative cover type, making up three percent of the total area. This vegetation type is found in small, interspersed hillside prairies in the northern and extreme southern part of the subbasin, overlying earthflows and unstable soils within geology of the Central Belt mélange. Herbaceous vegetation is also found along some of the low-lying areas on the mainstem SF Eel River.

Historically, grasslands were composed of native prairie bunch grasses with relatively deep root systems. In the late 1800's ranchers began seeding European short-rooted annual grasses for grazing that soon replaced the native bunch grasses. Replacement of the more deeply rooted grasses with the shallower rooted annual grasses is believed to have increased surface erosion and hillslope soil stability (Kelsey 1980).

GIS data indicate that less than one percent of this subbasin is covered by agriculture, however this may be an under-representation because pastures used for livestock grazing may not be included in this vegetation designation since land use is often difficult to determine remotely. For this reason, it can be assumed that areas mapped as grassland/prairies may also be agricultural in nature and the overall percentage of agricultural lands is likely to be greater than depicted. Agricultural lands in this subbasin are primarily located on the low-lying river terraces near Garberville and Redway.

Undocumented marijuana cultivation is also not represented in these figures but can have a significant impact on the subbasin's natural resources. Both legal and illegal marijuana cultivation are becoming large scale problems when considering water diversion and water contamination in subbasin streams. Illegal grow sites are established in remote residential areas and on privately owned timber company land.

To supply a constant, reliable source of water to their plants, growers will typically divert water from a nearby stream or spring through plastic pipes to their cultivation sites. The warm, dry season is when plants require the most water, both natural vegetation and cultivated plants. This is the same time period when stream base flows are at their lowest. When low base-flow conditions exist, suitable stream habitat diminishes, and stressors on

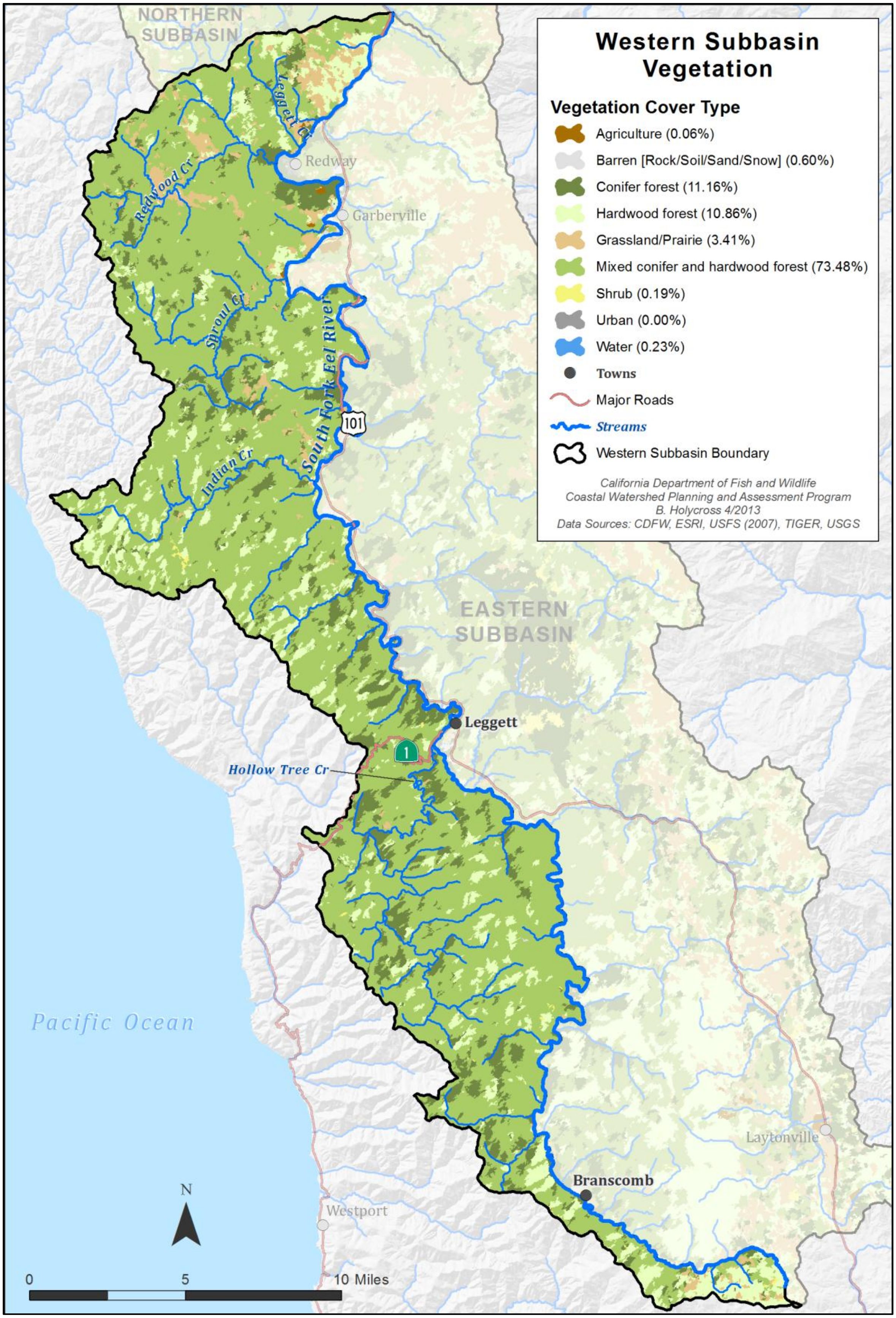

Figure 17. Vegetation map of the Western Subbasin.

Table 8. Vegetation of the Western Subbasin (USFS CALVEG).

Vegetation Cover Type	% of Basin	Primary Vegetation Type	% of Type
Mixed conifer and hardwood forest/woodland	73.48	Pacific Douglas-Fir	58.83
		Redwood - Douglas-Fir	41.05
		Redwood	0.05
		Douglas-Fir Ponderosa Pine	0.01
Conifer forest/woodland	11.16	Redwood - Douglas-Fir	47.01
		Pacific Douglas-Fir	46.00
		Redwood	6.78
		Jeffrey Pine	0.21
Hardwood forest/woodland	10.86	Tanoak (Madrone)	78.92
		Oregon White Oak	14.12
		California Bay	4.48
		Canyon Live Oak	1.89
		Madrone	0.39
		Black Oak	0.15
		Riparian Mixed Hardwood	0.03
		Willow	0.02
Grassland/Prairie	3.41	Annual Grasses and Forbs	99.99
		Perennial Grasses and Forbs	0.01
Barren	0.60	Barren	74.33
		Urban-related Bare Soil	25.36
		Dune	0.32
Shrub	0.19	Blueblossom Ceanothus	75.80
		Manzanita Chaparral	12.12
		Scrub Oak	11.92
		Willow (Shrub)	0.12
Agriculture	0.06	Agriculture (General)	100.00
Statistics exclude classification of water			

salmonids increase. During these times when water flow is minimal (usually in the late summer through early fall), even a single diversion can significantly reduce stream flow. Because these diversions are purposefully concealed, especially when grows are located on public lands or industrial timberland, they cannot be managed. Sedimentation and pollution associated with grow operations are also increasing and becoming a greater concern. Illegal marijuana cultivation will be discussed further in the Industrial Marijuana Agriculture section of this report.

Fire

Historically, fire has shaped ecosystems throughout California, and there are three periods where human influences have managed both fire and fire environments differently: 1) prior to European settlement (before 1700); 2) the settlement period (1700 to 1920); and 3) the suppression era (1920 to present). Fire patterns in pre-European times resulted in many millions of acres burning in California each year, with fire acting as a major cause of ecosystem change (CalFire 2003). Fires renewed mature vegetation communities that required fire to restore vegetation life cycles.

Habitat structure and composition, climate, weather, prior fire history, land management activities, and physical properties such as elevation and aspect influence the frequency, size, and severity of fires (Flannigan et al. 2000, Pilliod et al. 2003). Most fires are effectively suppressed using advanced technology and increased early efforts to protect resources, commodities, and people. To reduce the potential for severe, widespread fires, fuel treatments are considered the only practical means of altering potential wildfire behavior (CalFire 2003). In some areas where cutting and removal of fuel is controversial, infeasible, or prohibitively expensive, fire has been used as a tool to reduce fuel loads. These prescribed burns may limit the extent, effects, and severity of subsequent fires (Collins et al. 2008).

Fire is one of the primary natural disturbance factors influencing vegetation structure in the Western Subbasin. Natural post-fire stands are usually a mosaic of burn severities, from unburned to stand-replacing, within a watershed. Historically, Native Americans and settlers used fire to manage grasslands and prairies, and to maintain the ratio of conifers to oaks in tanoak stands (USBLM et al. 1996).

Modern land use practices have influenced the likelihood and effects of wildfire throughout the subbasin. Logging on highly erodible hillslopes has altered the natural hydrology, and construction of roads and stream crossings causes additional erosion and sediment runoff at greater levels than would have occurred naturally. This is a particular concern in Western Subbasin streams, where industrial timber harvest is the predominant land use, (occurring on nearly 75% of the subbasin area) and road density is extremely high (4.8 miles/square mile).

Human settlement has also affected wildland fire patterns and occurrences. Areas where residential communities border parklands or industrial timberlands are known as the wildland-urban interface. In this interface, a combination of fuel, weather, and topographical conditions may create an environment of increased wildland fire risk.

Twenty two percent (48 square miles) of the Western Subbasin has burned since the early 1900s (*Figure 18*). The largest area burned prior to 1950 (38 square miles, or 17% of the total subbasin area), with most fires burning near the town of Leggett (RM 66). The most recent fires (encompassing 4 square miles, or less than 2% of the subbasin area) occurred between 1990 and 2012 in the upper Hollow Tree Creek watershed. The Western Subbasin had fewer fires (16) than either the Northern (19) or Eastern (35) subbasins, but the percentage of subbasin area burned was similar to the two other subbasins (23% of Northern and 20% of Eastern subbasin area burned).

Fire behavior is strongly influenced by vegetation type and fuel moisture content. Large fires in the Western Subbasin burned in the Hollow Tree Creek, Mill Creek (Leggett), and Low Gap Creek drainages (*Figure 18*) where vegetation types are a mix of conifer, mixed conifer and hardwood forest, and hardwood forest.

Fire-fighting practices may directly affect the landscape and streams within the subbasin. Actions and their effects include the following:

- Construction of fire roads and fire breaks, which may increase erosion and sediment input to streams;
- Aerial application of fire retardant in upslope and riparian areas (and directly in streams when mis-applied), which may result in the input of toxic chemicals to stream habitats;
- Prescribed burning, which may affect LWD recruitment, soils, and stream habitat (Pilliod et al. 2003).

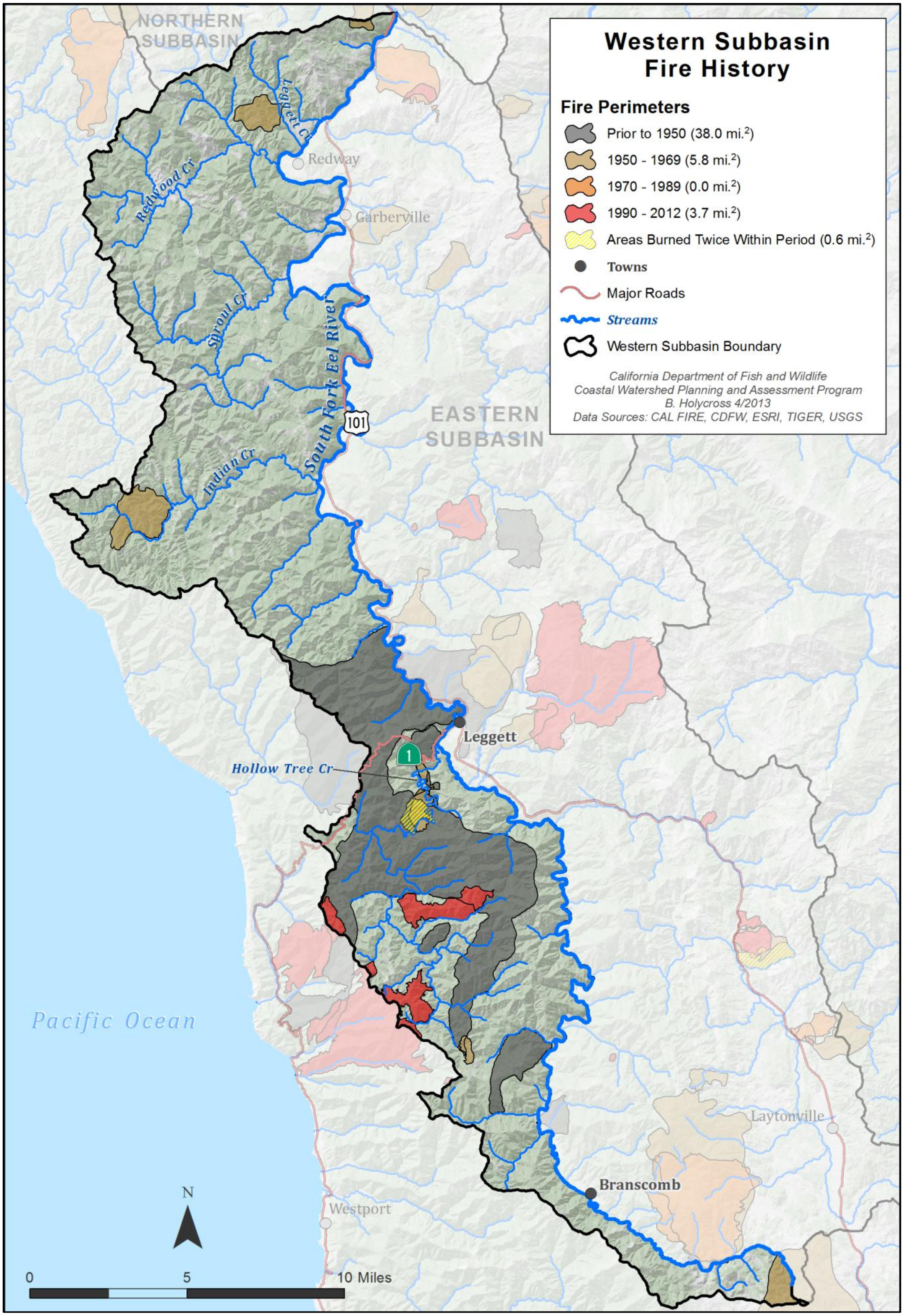

Figure 18. SF Eel River Western Subbasin fire history, with total square mileage burned within each time period.

Climate change has the potential to affect fire behavior, fuels, ignition, season duration, and management strategies. Global climate change models predict drier conditions for northwestern California, which will result in an increased probability of large fires (Westerling and Bryant 2008). Drier conditions, including warmer temperatures and reduced precipitation, will lead to decreased fuel moisture and increased flammability, both of which increase wildfire spread rate, intensity, and duration. Increased fuel flammability may also result in greater fire frequency in wetter, forested areas like the Western Subbasin, and higher temperatures will extend fire seasons, resulting in larger total burn areas from fires occurring both earlier and later than expected (Fried et al. 2004, McKenzie et al. 2004). Fire behavior will also be less predictable due to changes in temperatures, precipitation, fire frequency and fire severity (Tetra Tech 2013). Resource management strategies such as the modification of vegetation structure and fuels can help mitigate the effects of climate change throughout the subbasin.

Reduced rainfall and drier conditions resulting from climate change may also affect the natural fire regime (Flannigan et al. 2000, Fry and Stephens 2006). The fire season in Humboldt County generally begins in June, peaks in August, and ends in October, but this may vary with local geography. According to the County of Humboldt (2012), the western half of the county has a fire season that is generally shorter than the eastern half due to:

- The western half of the county receives more rainfall;
- The west has spring seasons that are wetter and cooler than the east;
- Temperatures in the eastern portion of the county are much higher in the summer months; and
- Much of the precipitation received in the east is snow that falls during winter.

Despite the generally damp climate prevailing in the county's forests, studies have suggested a fire return interval of 50 to 100 years in the northern part of the county, and 12 to 50 years in the south (CalFire 2005).

The effects of wildfire in watersheds may include:

- Loss of vegetative cover;
- Increased runoff;
- Hydrophobic (water repellent) soils;
- Severe erosion; and
- Increased sediment production.

Post-fire erosion may increase sediment loads in both streams and riparian areas. In some areas where large-scale forest fires have occurred, accelerated sediment production has been documented (Humboldt County 2012). Increased erosion and sediment production following fires are of particular concern in the Western Subbasin due to very high natural and anthropogenic sediment input that already exists.

Depleted vegetation in riparian areas following wildfires reduces instream shading, resulting in increased water temperatures that threaten fish and other aquatic life (Pilliod and Corn, 2003). Increased water temperatures during low flow times are already a major concern for salmonids in many areas of the Western Subbasin. Low flows occur during late summer and early fall, which correspond to the times of highest fire danger. Post fire monitoring and the development of management strategies are essential for areas where the loss of riparian vegetation and associated shade results in elevated instream temperatures. Active fuels management in riparian zones, including hazardous fuels reduction and habitat restoration, is increasingly common among land managers (Dwire et al. 2011).

The most recent large fires in the Western Subbasin occurred in areas of moderate to very high fire threat (*Figure 19*). Approximately 66% of the land in the subbasin is classified as either as very high or high fire threat. In a high fire threat area, all fine dead fuels ignite readily and fires start easily from most causes; fires spread rapidly and high intensity burning may develop on slopes or in concentrations of fine fuels; and fires may become severe and their control difficult unless they are attacked successfully while small (National Wildfire Coordinating Group 2002). Thirty three percent of the subbasin area is classified as moderate fire threat, and one percent as low threat (agricultural regions). Threat rankings address wildfire related impacts on ecosystem health, with ecosystems defined as unique vegetation types by tree seed zones (http://www.fire.ca.gov/index.php).

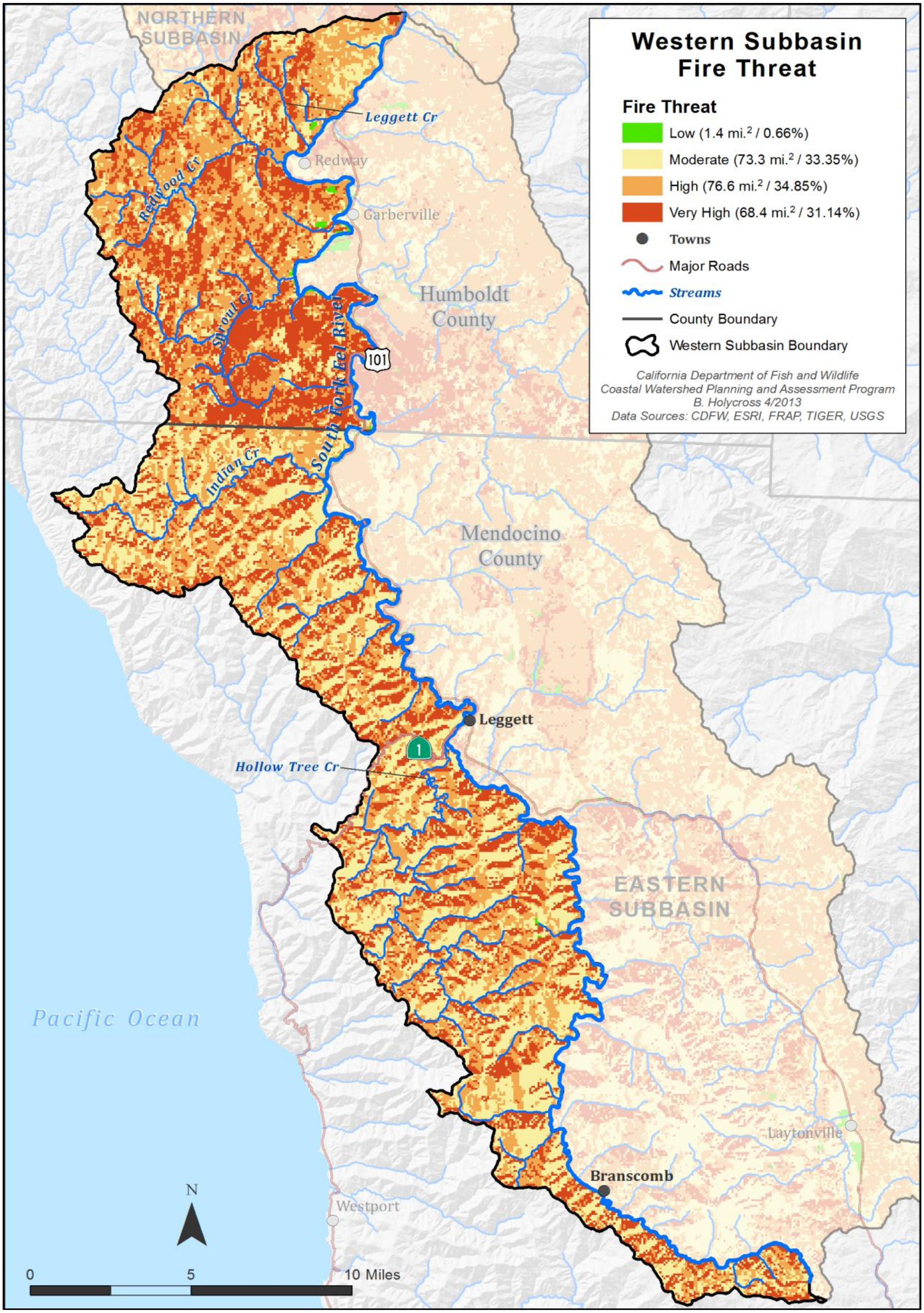

Figure 19. SF Eel River Western Subbasin fire threat, with percentage of total Basin area in each threat category.

CalFire's Fire and Resource Assessment Program (FRAP) data used to produce fire threat maps are related to:

- stand-level data: estimated fire frequency and fire behavior characteristics at a fine scale, and
- landscape-level data: the risk of widespread landscape-level damage to an entire ecosystem, based on the percentage of an ecosystem at risk of losing key ecosystem components or functions.

Sudden oak death (SOD) has spread throughout southern Humboldt, and cases have been confirmed in the SF Eel River Basin. In one SOD hot spot north of Garberville, the rate of expansion of diseased areas was approximately1,500 acres per year from 2004 through 2010 (Valachovic 2011). The OakMapper website (Kelly et al. 2004; http://www.oakmapper.org/oaks/index/4132) shows two clusters within the SF Eel River hot spot area (*Figure 20*). The southernmost cluster near Garberville is within the boundary of the Western Subbasin. Affected stands can detrimentally affect fuel loading and fire behavior because SOD causes 100% mortality in tanoak, and infected areas have higher fuel loads and trees that are prone to rapid failure during fires (CalFire 2012). The duration of infection in stands is also important when considering fire behavior; late-phase (>8 years) diseased forests may show increased rates of fire spreading, flame length, and fireline intensity, which reduces the effectiveness of firefighting strategies and techniques (Valachovic et al. 2011).

In summary, fire is a natural and important part of the disturbance regime of the Western Subbasin. Direct effects to salmonids, particularly increased sedimentation and reduced riparian canopy resulting in increased stream temperatures, may be compounded in areas where human activities have resulted in increased sedimentation and higher instream temperatures, and where sediment input from roads, land use practices, and unstable geology are already concerns.

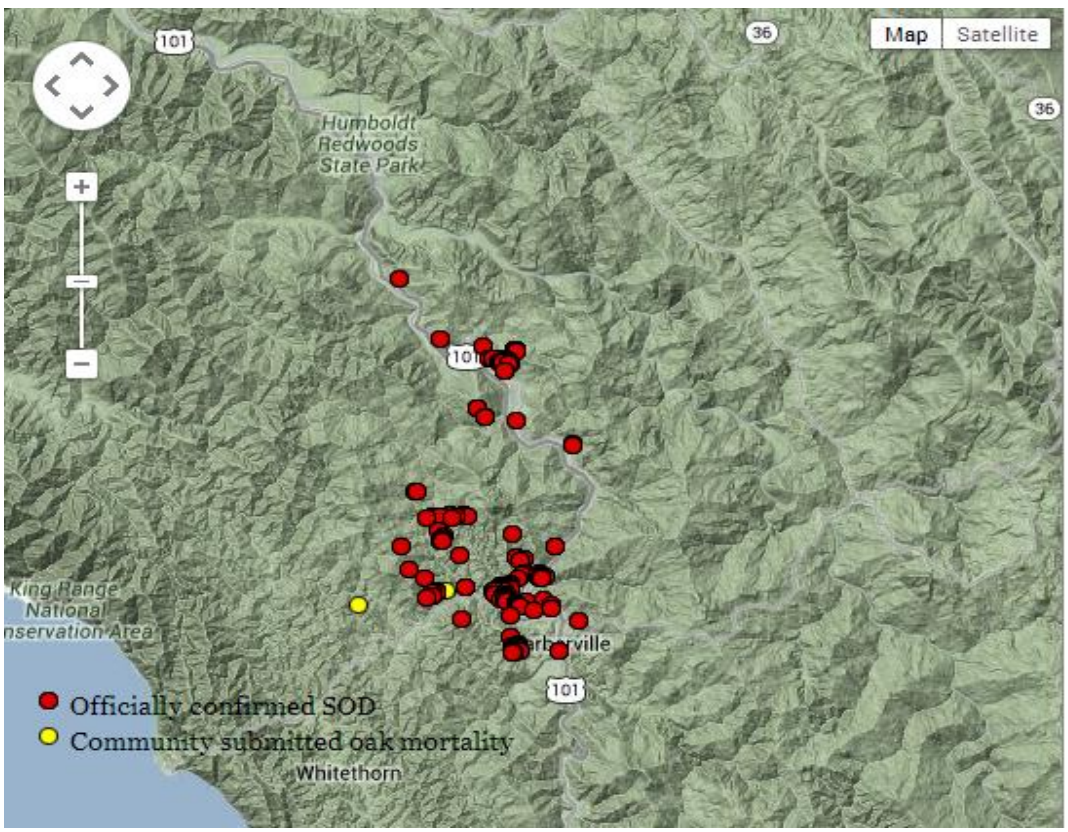

Figure 20. Confirmed (red) and reported (yellow) cases of Sudden Oak Death (SOD) in the SF Eel River Basin, from Oak Mapper website (accessed 2/27/2014).Confirmed locations west of the SF Eel River are located within Western Subbasin boundaries.

Land and Resource Use

Historic Land Use

The first Native Americans inhabiting the Western Subbasin of the SF Eel River Basin were the Sinkyone and Cahto, two subgroups of the Coastal Southern Athabaskans (USBLM et al. 1996). They subsisted primarily on anadromous fish, with secondary resources including upland game and acorns. The Sinkiyone occupied the northern part of the Western Subbasin and the Cahto were found in the southern portions, northwest of Laytonville (USBLM et al. 1996). Native American land use practices such as hunting, gathering, use of fire, and establishment of villages had some influence on the ecosystem, however, the cumulative impact on the environment and natural resources of the Western Subbasin was relatively minor (Yoshiyama and Moyle 2010). Native Americans occupied the North Coast Ranges for at least 4,000 years, possibly as many as 10-15,000 years, prior to the arrival of the first European settlers in the early 1850s (Jack Monschke Watershed Management (JMWM) 2000). Most of these early settlers were trappers, encouraged by the Homestead Act of 1862 which allowed them to purchase affordable land. By the late 1860s, most Native Americans had disappeared from the basin due to violence, disease, and relocation (JMWM 2000). Homesteaders trapped, farmed, harvested timber, and grazed livestock throughout the Western Subbasin.

Historically, logging was most intense in the Northern and Western Subbasins of the SF Eel River Basin, where old growth redwood was relatively abundant. Early logging efforts resulted in the removal of nearly all accessible old growth redwoods along the creek mouths. Prior to WW II, Douglas-fir was considered unmerchantable timber, but after the war, nearly all of the Douglas-fir was harvested in an effort to keep up with the post-war building boom (USBLM et al. 1996). The development of new technologies and additional transportation options made access to remote areas with steep terrain possible, and resulted in an increase in the number and magnitude of logging operations throughout the subbasin. In the 1950s, many small mills were set up throughout the basin, including "brush mills", small temporary mills set up close to stands so that trees could be cut and skidded to the mills easily. Brush mills were dismantled and moved to new locations when stands were depleted (JMWM 2000). Roads, skid trails, and landings were often located in creeks so logs could be skidded downhill easily. During this time, extensive damage to streams and poor road building techniques combined with unstable geology led to increased sedimentation in streams throughout the subbasin (JMWM 2000).

In addition to improvements in timber harvest techniques and equipment, the Humboldt County Board of Supervisors levied a tax on standing timber in 1956, which led to an increase in the amount of timber harvested in the county because many landowners were forced to harvest timber rather than leave it standing for financial reasons (O'Hara and Stockton 2012). Peak timber production years were 1956 in Mendocino County and 1959 in Humboldt County, and although timber harvest levels have declined recently, the timber industry is still an important component of the economy in both counties (Downie 1995).

The major flood events of 1955 and 1964 exacerbated the impacts of intensive timber harvest and poor road building practices in a naturally fragile landscape, resulting in large-scale soil erosion and sedimentation throughout the SF Eel River Basin (Yoshiyama and Moyle 2010). Major aggradation during the floods also buried or destroyed natural armoring of stream banks, allowing high flows to scour banks, causing an increase in bank failures and slides (JMWM 2000). During the 1955 flood, peak flow at Miranda was 173 thousand cubic feet per second, and during the 1964 flood, peak flow was 199 thousand cubic feet per second, (Humboldt County Sheriff's Office 2012). These flows, combined with the unstable geology, steep terrain, high road density, and extensive timber harvest resulted in substantial sediment input during these flood events in streams throughout the Western Subbasin.

Nearly all merchantable timber had been removed from the Western Subbasin by the late 1960s, and land developers bought up large tracts of land, subdivided the smaller parcels (40-80 acres), and sold them to "back-to-the-landers", also known as "new settlers". Significant changes to the watershed from these activities included the development of roads or the increased use of existing seasonal roads to access every parcel, an increase in the number of diversions, and an increase in the total amount of water diverted from streams in the basin to supply additional residences. Many of these "back-to-the-landers" also started cultivating marijuana, and these operations have expanded in both size and number; development of this underground industry in the 1970s provided a boost to the economy throughout the SF Eel River Basin (JMWM 2000). These activities and their impact on the ecosystem and economy are discussed in greater detail in the Industrial Marijuana Agriculture section of this subbasin report.

Current Land and Resource Use

The four principal land uses as of June, 2012 in the SF Eel River Western Subbasin were commercial timber production, residential, open space/parks, and grazing/timber (*Table 9*).

Table 9. Four principal land uses in the Western Subbasin.

Land Use	square miles	acres	% of total area
Timber production	165	105,600	75
Residential	24	15,360	11
Open space/parks	20	12,800	9
Grazing/Timber	10	6400	5

Timber production occurs throughout the subbasin, open space/park land is concentrated in the Southern portion of the subbasin (and at points along the mainstem SF Eel River) between Leggett and Branscomb, and residential development is located primarily in the northern part of the subbasin near Garberville and Redway (*Figure 21*).

Timber Production

Commercial timber production is the primary land use in the Western Subbasin, occurring in 75% of the total subbasin area (*Table 9*). Based on CalFire data collected between 1995 and 2012, timber harvest occurred throughout the subbasin, with the most recent activity occurring along the western edge of the subbasin, southwest of Piercy, west of Leggett, and south of Branscomb in Mendocino County (*Figure 22*). More than half of the land in the Western Subbasin is in Mendocino County, which was ranked fifth among California counties in 2006 in timber harvest, after Humboldt, Siskiyou, Shasta, and Plumas counties; however, it ranked second in total timber value, due to the high value of redwood. The most productive timber forests in Mendocino County are Douglas-fir and redwood forests, with high growth rates resulting from local soil and climate conditions (Mendocino County 2009; Chapter 4).

Timber harvest activities require the development of plans detailing the amount and method of planned harvest. There are different plans based on the area of timberland owned and whether or not the landowner is an individual/family or a corporation. Non-industrial timber management plans (NTMPs) were established in 1989 to allow non-commercial landowners with less than 2,500 acres of timberland to develop harvest plans that were not as expensive and time-consuming as THPs (CalFire 2003). Once an NTMP has been approved, the actual harvest is reported in a notice of timber operations (NTO). Commercial harvest by timber companies and private landowners with more than 2,500 acres of timberland requires the development of a timber harvest plan (THP). Based on CalFire data collected between 1995 and 2012, most timber harvest in the Western Subbasin is commercial (THPs), as opposed to non-commercial (NTOs) (*Figure 22*).

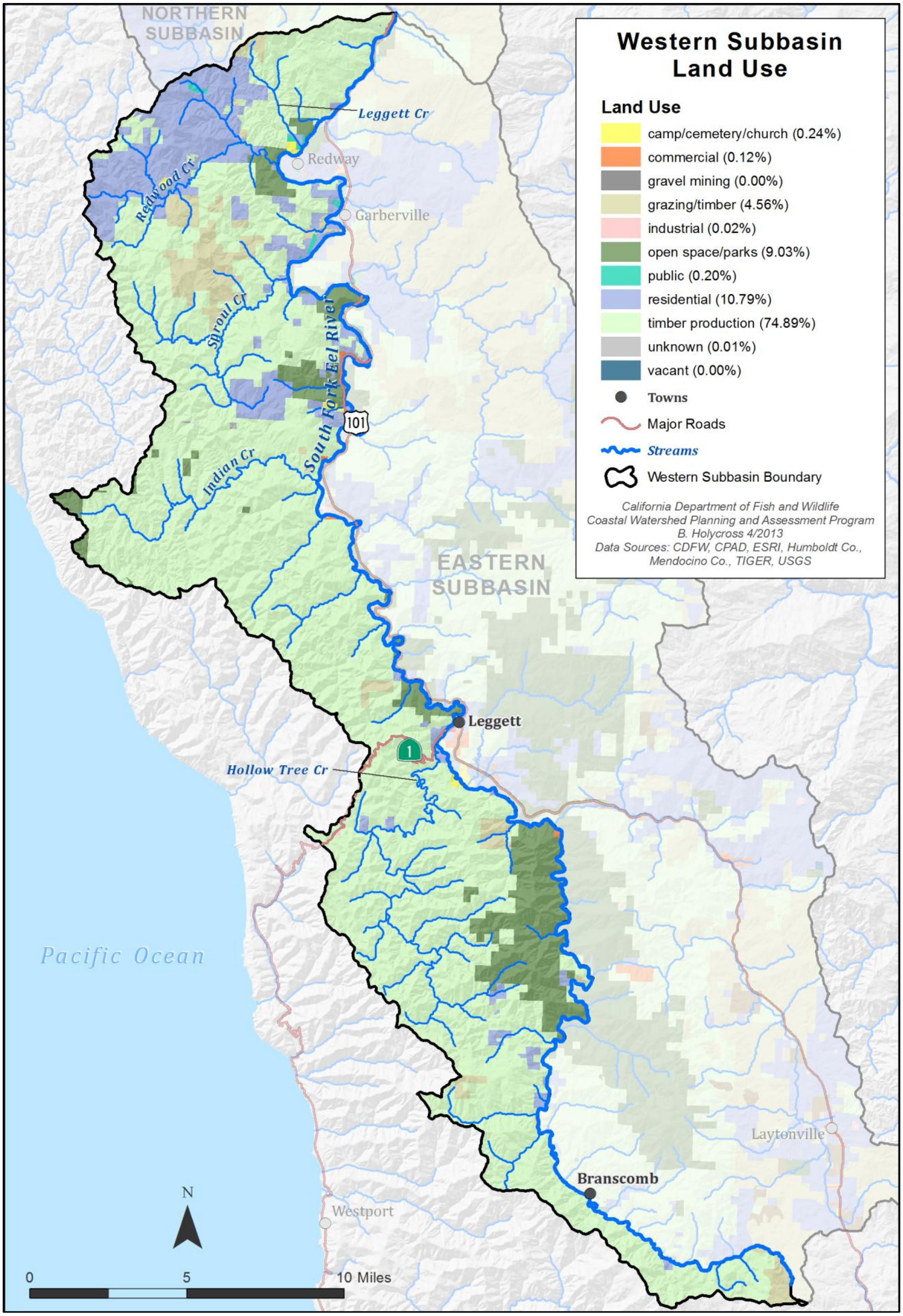

Figure 21. Land use in the Western Subbasin of the SF Eel River Basin.

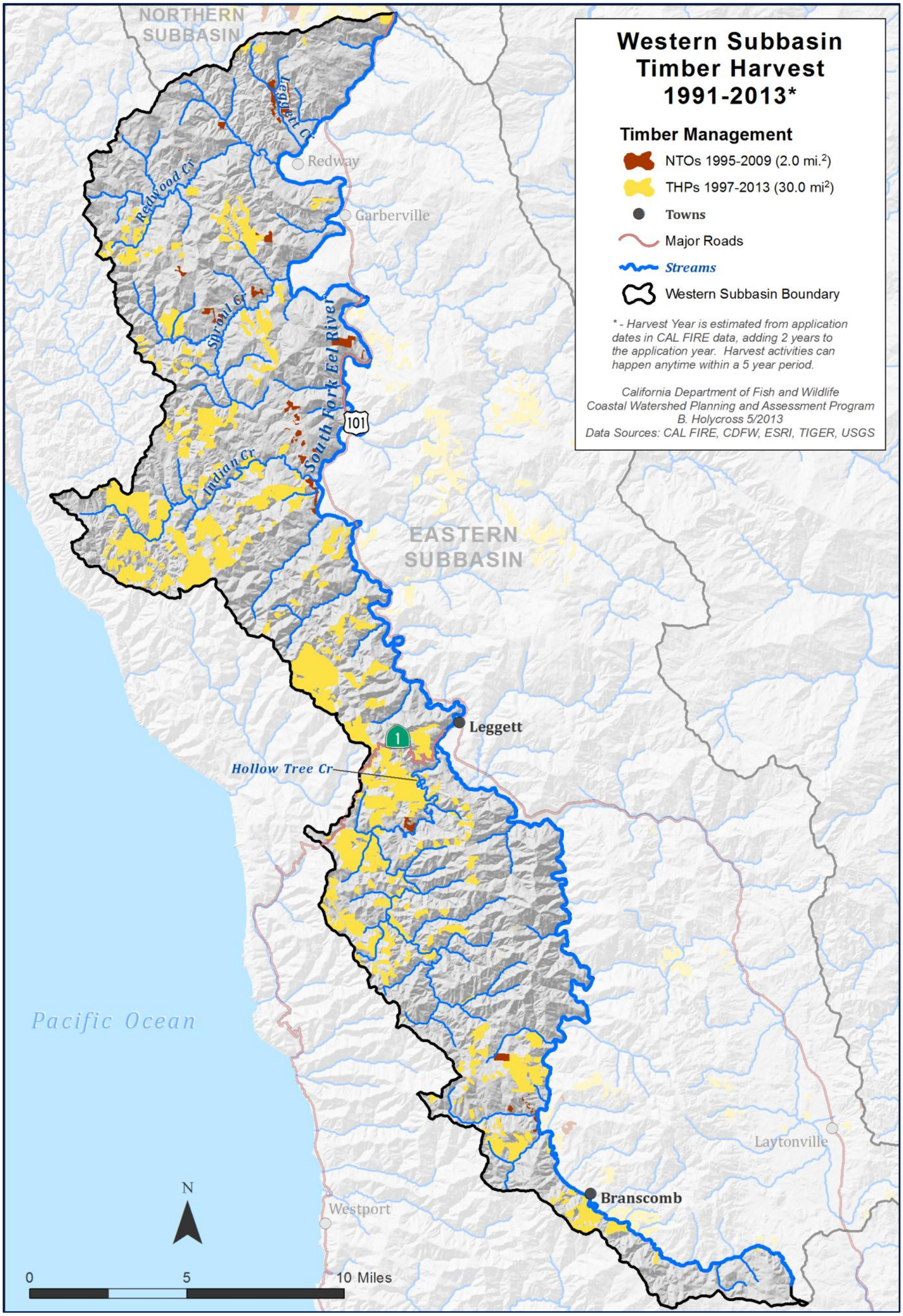

Figure 22. Timber Harvest (NTOs and THPs) between 1995 and 2012 in the SF Eel River Western Subbasin.

The Western Subbasin had the largest number of acres harvested compared to the other subbasins, with almost twice as much as the Northern Subbasin and more than three times as much as the Eastern Subbasin. The total area of timber harvested in the Western Subasin was 21,111 acres: 4,343 acres in Humboldt County and 16,768 acres in Mendocino County (*Table 10*). The total acreage harvested under THPs was 19,937 acres (3,544 acres in Humboldt County and 16,393 acres in Mendocino County) and individual operations ranged in size from 807 acres to less than one acre. Major landowners and harvesters include Barnum Timber Company, Hawthorne Timber Company, Mendocino Redwood Company, and Usal Redwood Forest Company. NTO harvest area in the basin totaled 1,174 acres (799 acres in Humboldt County and 375 acres in Mendocino County) and harvest areas ranged in size from 97 acres to less than one acre.

Table 10. Timber harvest by plan type (THP or NTO) for the SF Eel Western Subbasin (data from CalFire 2012).

Western Subbasin	Plan Type	Acres	County
	THP	3544	Humboldt
	THP	16393	Mendocino
	Total THPs	**19937**	
	NTO	799	Humboldt
	NTO	375	Mendocino
	Total NTOs	**1174**	
	Subbasin Total	**21111**	

The primary silviculture methods used in the subbasin from 1991-2011 were: seed tree removal cut (33% of harvested area); alternative prescription (14% of harvested area); and clearcut (13% of harvested area) (*Figure 23*). Seed tree removal cuts are defined as the cutting of widely dispersed seed trees after regeneration is established (Adams et al. 1994). Alternative prescriptions are modifications of a recommended practice when an alternative could provide better results for forest resource stewardship; harvest techniques differ on a case-by-case basis. Each alternative prescription requires a written analysis of pre- and post-harvest timber stand conditions, and a description of silvicultural practices and systems to be used in lieu of standard methods (CalFire 2012). Clearcutting is defined as the removal of all trees in one operation, producing a fully exposed microclimate for the development of a new age class/even-aged stand (Adams et al. 1994). Following a clearcut, the remaining slash and ground vegetation is usually burned to prepare the site for artificial regeneration.

Each type of silvicultural and yarding technique results in different levels of landscape disturbance and modified stream flows (Harr et al. 1979, USFS 1985, Keppeler and Ziemer 1990). In general, clear-cutting has the highest level of disturbance of any silviculture method (USFS 1985). This includes both a terrestrial disturbance component (soil exposure and instability due to tree removal), and an aquatic disturbance component (removal of shade and reduced contribution of large woody debris). The least disturbing method of timber harvest is commercial thinning (USFS 1985), where trees are felled and cut into segments (bucked), either manually or, where the terrain is not too steep, by machine.

Water drafting as a road dust/sediment control measure is an important consideration due to the amount of water diverted and the possible direct and indirect effects of this practice on salmonids. This will be discussed further in the Water Use: Diversions, Dams, and Hydrologic Disturbances section of this report.

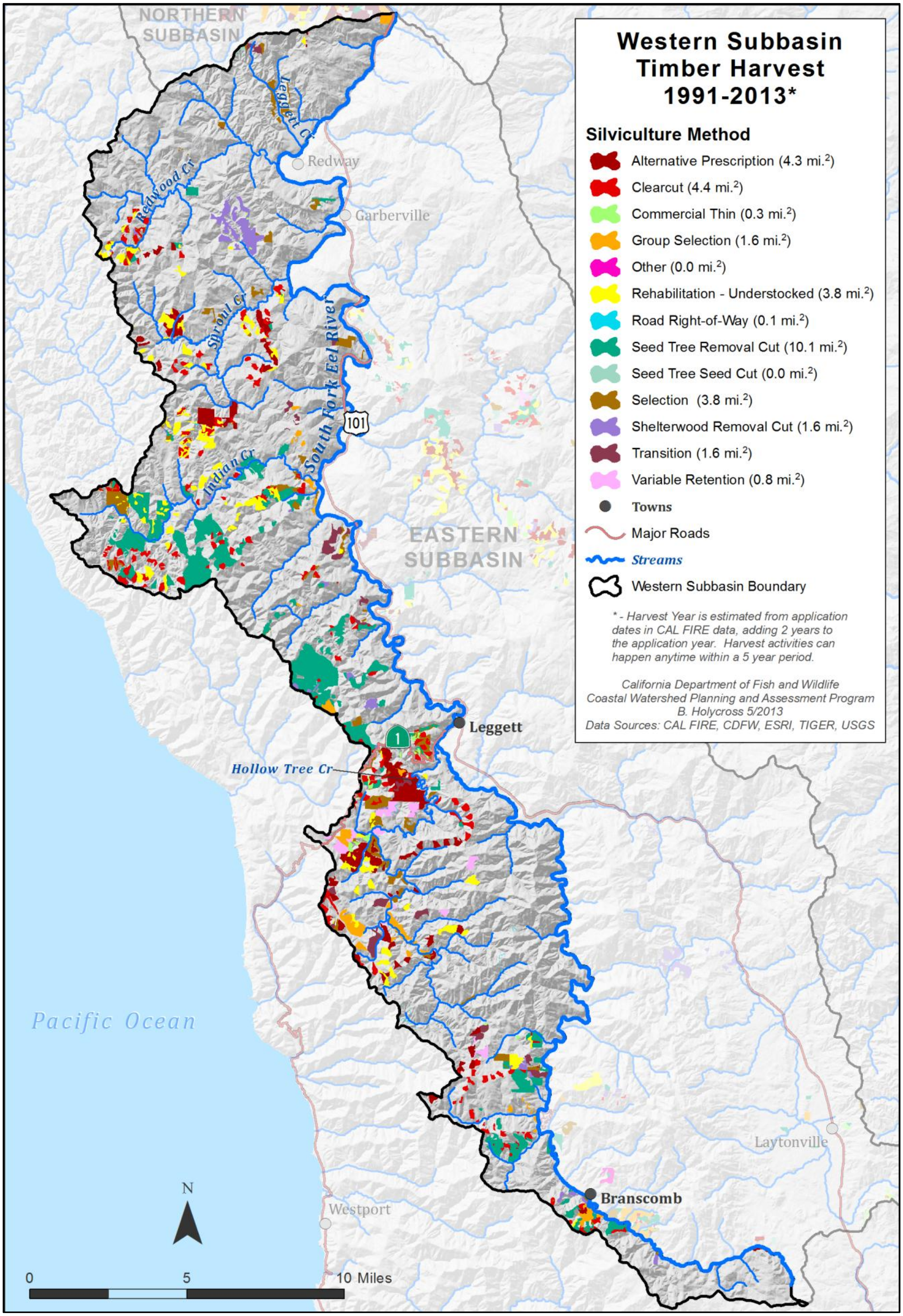

Figure 23. Timber harvest activity by silvicultural method in the SF Eel River Western Subbasin.

Residential

Approximately 13% of the population in the SF Eel River Basin lives in the Western Subbasin, and the population density is the lowest of all three subbasins (5.37 people/square mile). This population estimate was obtained by looking at all of the census blocks within the Western Subbasin boundary, adding the population in those blocks that were fully contained within the boundary, then identifying any blocks with areas outside the subbasin boundaries ("straddling blocks"). The population in these straddling blocks was estimated proportionally based on the amount of each block area that was within the subbasin boundary, and was added to the total population estimate.

Population density in this subbasin is low because there are very few towns, and most of the land (68% of the subbasin area) is owned by industrial timber companies. Of the 23% of the Western Subbasin that is privately owned, 18% are parcels >40 acres, and 5% are ≤40 acres in size. Most residential development is located in the northern area of the subbasin, in the Redwood Creek drainage (*Figure 21*).

Compared to other parts of California, major development of water resources has not occurred in either Humboldt or Mendocino County. No major surface water storage exists; existing water projects include surface water diversions, some small dams and reservoirs, and many small stock watering ponds (Mendocino County 2009; Chapter 3). In both counties, marijuana cultivation operations are rapidly increasing in both number and magnitude. These operations often occur in residential areas, and they require extensive amounts of water. Growers rely on illegal diversion from streams and groundwater reserves to support these operations. Marijuana cultivation and its impacts on the environment in the SF Eel River Basin will be discussed further in the Industrial Marijuana Agriculture section of this report.

The Western Subbasin normally receives substantial wintertime precipitation, but relies on a combination of groundwater and surface water to supply residences outside of the larger communities during the hot summer months. There are four water service providers in the Western Subbasin (*Table 11*). The Garberville Sanitation District and the Redway Community Services District provide both water and wastewater services.

Table 11. Water and wastewater service providers in the SF Eel River Western Subbasin (Humboldt County General Plan Update Draft EIR 2012 and Mendocino County General Plan 2009).

Water Provider	Connections		Capacity			Usage	
	Existing	Available	Supply (mgd)	Treatment (mgd)	Storage (mg)	Peak Day (mgd)	Connection (gpd)
Briceland Community Services District	26	0	0.010	Unknown, but not limiting	0.042	0.040	1,538
Redway Community Services District	600	180	0.838	0.460	0.375	0.475	792
Benbow Water Company	113	0	0.327	0.200	0.150	0.382	3,381
Garberville Sanitation District	396	25	0.461	0.330	0.270	0.310	787
Wastewater Service Provider	**Subbasin Served**	**Connections**		**Permitted Capacity (mgd)**		**Flows (mgd)**	
		Existing	**Available**	**Dry Weather**	**Wet Weather**	**Existing Dry Weather**	**Peak Wet Weather**
Garberville Sanitation District	Eastern, Western	420	180	0.162	0.235	0.140	0.55
Redway Community Services District	Eastern, Western	524	175	0.186	0.64	0.140	0.43
From Humboldt County General Plan Draft EIR (2012) and Mendocino County General Plan (2009)							

The Garberville water system supplies approximately 396 active connections (*Table 11*), and consists of a treatment plant, four water tanks, three booster stations, and two sources: surface water from the SF Eel River (Eel River Infiltration Gallery) and a shallow well located in downtown Garberville (Humboldt Lafco and GSD 2011). The water treatment plant holds a current water diversion permit from the SWRCB, which allows them to divert a maximum of 430 acre feet/year from the SF

Eel River, and the Tobin Well has a limited capacity of 40-70 gallons per minute. Service areas outside the district boundary include: Leino Road and Sproul Creek Road (8 connections), Southern Humboldt Community Park/Buck Mountain Ranch/River Ranch Homes (4 connections), Connick Creek Subdivision (8 connections), and Kimtu (20 connections). The total storage capacity for the system is approximately 300,000 gallons and is adequate to meet the maximum daily demand of 262,398 gallons per day recorded in July 2009 (Humboldt Lafco and GSD 2011). A CEQA initial study was completed in 2013 for a GSD upgrade to replace the existing 30,000 gallon storage tank with a 200,000 gallon tank (LACO Associates 2013).

The Garberville Sanitation District (GSD) also provides wastewater services to some areas in the Western Subbasin, and the wastewater treatment plant (WWTP) is located on the west bank of the SF Eel River (*Figure 24*). The treatment plant was upgraded in 2011 to include three oxidation ponds, four wetland treatment ponds, an onsite chlorination system, improved percolation ponds, and an on-site operations and maintenance building. The district uses naturally occurring processes in created lagoons and wetlands, providing habitat for wildlife while processing the community's wastewater (Humboldt Lafco and GSD 2011).

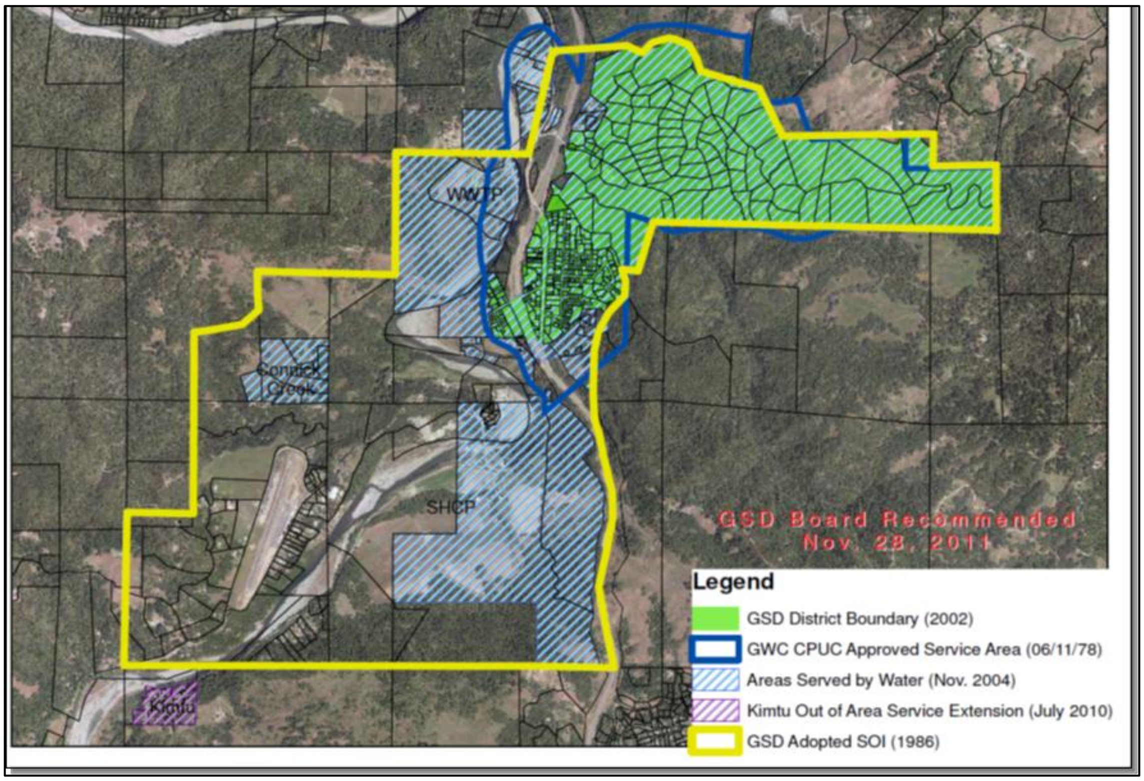

Figure 24. Garberville Sanitation District service area district boundary and sphere of influence (from Humboldt Lafco and GSD 2011).

Other water service providers in the Western Subbasin that draw water directly from the SF Eel River include the Redway Community Services District and the Benbow Water Company. The Benbow Water Company is permitted to divert up to 30 acre feet/year, and also claims a riparian right to divert directly from the East Branch SF Eel River. The State Water Resources Control Board recently (Nov. 26, 2013) ordered the company to stop the sale of bulk water outside the service area, citing possible negative impacts to fish and wildlife.

Open Space/Parks

Nine percent of the land (20 square miles; 12,655 acres) in the Western Subbasin is open space/parkland (*Figure 21*). The largest area is part of the Elkhorn Ridge Wilderness (11,271 acres), managed by the USBLM and located in the southern part of the subbasin between Leggett and Laytonville. This wilderness area is located in both the Eastern and Western subbasins, with approximately half of the acreage in each subbasin. Other open space/parkland is located mainly along the mainstem SF Eel River and includes: Humboldt

Redwoods, Benbow Lake, Richardson Grove, and Standish Hickey State Parks. Other small areas of public land include the Angelo Coast Range Reserve, part of the University of California Natural Reserve System, near Branscomb, and a small area in the headwaters of the Indian Creek drainage that is within the boundaries of Sinkiyone Wilderness State Park.

Grazing/Timber

Approximately 5% of the land in the Western Subbasin is utilized for livestock grazing and small timber operations. These differ from the commercial timber production operations because they are small, usually family-owned ranches that manage their lands using a variety of techniques and schedules. Most of these small grazing/timber operations are located in the northern part of the subbasin, south and east of Garberville, with some isolated operations in the central and southern parts of the subbasin near Leggett and in the headwaters south of Laytonville. The small percentage of land dedicated to grazing and small timber operations in this subbasin is due to a lack of grassland habitat (3.41% of the total area), and a relatively small amount of land owned by private landowners.

Roads

There are approximately 1,048 miles of road within the Western Subbasin (road density = 4.76 miles/square mile). This subbasin has the highest road density of the three subbasins in the SF Eel River drainage. Cal Fire categorizes roads based on capacity, surface material, and frequency of use. Permanent roads include primary (4+ lanes) and secondary (2-3 lanes) paved roads and rocked (improved) roads; seasonal and temporary roads are considered unimproved. Eighty one percent (852 miles) of the roads in the Western Subbasin are seasonal roads, followed by 8% (90 miles) permanent roads and 4% (44 miles) proposed seasonal roads (*Figure 25*).

Most of the roads in the Western Subbasin are seasonal roads used for hauling timber, but many are also used to access residential and agricultural areas, particularly in areas such as Redwood Creek, where marijuana cultivation operations are abundant in areas of residential land use. Road density and type are a reflection of the primary land use in the subbasin (*Table 9*). The Western Subbasin has the highest overall road density, the highest percentage of seasonal roads, and the highest percentage of land allocated for commercial timber harvest (75% of the subbasin) of the three subbasins.

Highway 101, the only primary road in the basin, follows the SF Eel River from north of Weott to south of Leggett, then up the Rattlesnake Creek drainage and south to Laytonville (*Figure 25*). The highway was built from 1909 to 1923 and crosses the SF Eel and many of its tributaries throughout the Basin. The highway follows the river mainly along the eastern side (within the Eastern Subbasin boundary), so the amount of primary road located within the Western Subbasin boundary is relatively small (4.8 miles).

Many of the smaller roads and railroads built in the subbasin either cross streams or run alongside them. Both of these types of roads can affect stream condition and site condition; therefore, road location and road design should be considered when constructing roads to reduce sediment input (Amaranthus et al. 1985, Cafferata and Spittler 1998). Stream crossings may create fish passage barriers or sediment sources (Cafferata et al. 2004), and roads that run along streams can also act as sediment sources and limit the migration of stream channels across floodplains. In addition to these legacy effects, many roads added large amounts of sediment to streams as they were built.

Logging roads contribute more sediment to streams than any other land management activity (Gibbons and Salo 1973, Meehan 1991). Throughout the SF Eel River Basin, major anthropogenic sediment sources were found to be road-related, including roads associated with timber harvest. Specific issues identified as concerns for sediment loading in the Western Subbasin include the following: road surface erosion, road crossing failures and gullies, skid trails, and landslides from roads and harvest (Dyett and Bhatia 2002, MRC 2004).

In the sediment source analysis for the SF Eel River TMDL (Stillwater Sciences 1999), average sediment delivery in the basin was approximately 700 $t/km^2/yr$, with 46% of the total loading contributed by anthropogenic sources. Road-related landslides, road crossings, and gully erosion were the largest anthropogenic sources of sediment.

Stillwater Sciences' (1999) study area was located southeast of Leggett and included the Hollow Tree Creek Basin and adjacent tributary basins (Low Gap

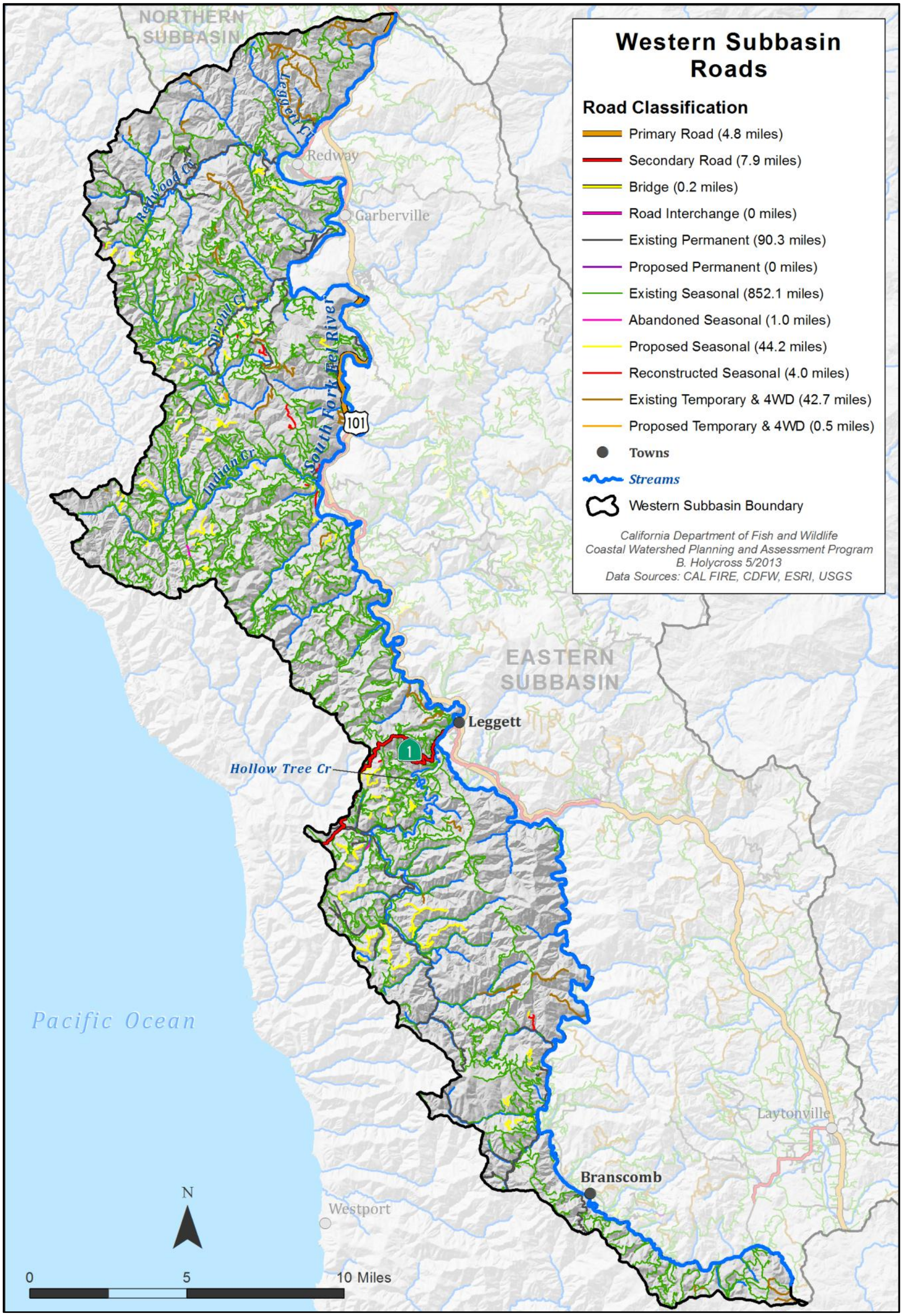

Figure 25. Roads in the SF Eel River Western Subbasin.

and Mill Creek), with a total area of 61 square miles. More than half of the Hollow Tree Creek study area is owned by MRC, and was logged intensively in the 1970s, with decreased levels of timber harvest in the 1980s and 1990s (Stillwater Sciences 1999). MRC mapped 177 landslides between 1966 and 1978 and 206 landslides between 1978 and 1996. Stillwater Sciences analyzed their sediment input data and determined that approximately half of the sediment delivered to Hollow Tree, Low Gap, and Mill Creek was road-related, with 239 tons/square kilometer/year delivered between 1966 and 1978, and 131 tons/square kilimeter/year delivered between 1978 and 1996. MRC also completed a skid trail assessment in the study area and concluded that there is very little sediment (16 tons/square kilometer/year on MRC land) delivered to streams from skid trails under current conditions. However, between 1966 and 1978, there were high rates of sediment delivery to streams (107 tons/square kilometer/year) due to intensive tractor logging and construction of skid trails near streams (Stillwater Sciences 1999). Current logging practices require fewer new skid trails and most sediment input is attributed to legacy effects of old skid trails adjacent to streams in the study area (Stillwater Sciences 1999). As a result, many current restoration and management projects focus on legacy road rehabilitation.

Stillwater Sciences (1999) also studied the Sproul Creek basin during two time periods: 1966-1981 and 1981-1994, as part of their sediment source analysis. This study area is located west of Garberville and is 24 square miles in size. Barnum Timber owns 65% of the basin, and Wagner Timber Company owns most of the remaining. Average sediment loading was higher in the 1966-1981 time period (866 tons/square kilometer/yr) than in the 1981-1994 time period (552 tons/square kilometer/yr), but the ratio of anthropogenic to total inputs was greater for the recent period (0.76) than for the earlier period (0.51). This may be due to an increase in timber harvest, and to drier climatic conditions and reduced natural sediment production in recent years (Stillwater Sciences 1999). The Sproul Creek Basin had the lowest sediment input volume of all studied basins, primarily due to the absence of active earthflows; most of the sediment in this basin is produced by road crossings and gully erosion.

Erosion from rural and logging roads includes two components: chronic erosion of fine sediments and catastrophic failure of roads prisms during winter storms. The geologic setting – steep slopes, rapid uplift, and unstable soils – in which logging occurs in the Western Subbasin creates more erosion from acceptable logging practices and from legacy and new logging roads relative to those in more stable geologic locations (*Figure 26*).

Figure 26. Example of legacy road failure in the SF Eel River Basin.

In 2004, MRC completed a watershed assessment report for Hollow Tree Creek watershed assessment unit (WAU). The WAU included 6 planning watersheds (32.9 square miles total), with Lower, Middle, and Upper Hollow Tree Creek watersheds comprising nearly 90% (29.5 square miles) of the total WAU area. MRC determined that between 1969 and 2000, the average estimated sediment input for the WAU was 1260 tons/square mile/year. Fifty seven percent of all sediment input in the watershed was road related, and when skid trails were included in the analysis, the proportion of sediment input increased to 63% (MRC 2004). MRC collaborated with CDFW, USFWS, and Trout Unlimited on a collaborative restoration program beginning in 2003 that included road improvement, road decommissioning, and instream habitat improvement. Monitoring is ongoing in the Hollow Tree WAU, and is designed to determine if management created mass wasting has been reduced and to determine the effectiveness of erosion control measures on roads and landings.

Surfleet (2007) completed a sediment source analysis for MRC lands in coastal Mendocino (including the Hollow Tree Creek watershed) and Sonoma Counties and determined that 73% of the total sediment input in the last 30-40 years was related to road and skid trail erosion. Thirty percent of the total input was associated with road and skid trail mass wasting, 32% with surface and point source erosion from roads, and 11% with surface and point source erosion from skid trails. At the time this study was completed, MRC had decommissioned approximately 10 miles of streamside logging roads, and was committed to upgrading its entire road network, a process that was expected to take approximately 30 years (Surfleet 2007).

MRC also developed a comprehensive monitoring program to determine whether aquatic habitat and resource conditions are improving as a result of their policies and restoration efforts. From 1998-2012, MRC reported that 993,216 cubic yards of sediment have been prevented from entering streams, and more than 20 million dollars has been contributed by MRC and their funding partners to complete road improvement, road decommissioning, and culvert upgrade or removal projects (http://www.mrc.com/monitoring/forest-and-road-restoration/).

When developing restoration initiatives, NMFS (1996) classified basins with road densities of <2 mi/mi^2 with no valley bottom roads as "properly functioning", those with densities of 2-3 mi/mi^2 with some valley bottom roads as "at risk", and those with densities of >3 mi/mi^2 with many valley bottom roads as "not properly functioning". According to this classification system, the Western Subbasin is "not properly functioning", and road rehabilitation projects for both legacy and current roads should be a high priority for managers. Specific road rehabilitation projects will be discussed in the Restoration Projects section of this report.

Gravel Mining

Gravel mining operations are permitted by the US Army Corps of Engineers (USACE), and SF Eel River operations listed in *Table 12* are authorized under LOP (letter of permission) 2004-1 (USACE 2004). In 1992, the Humboldt County Board of Supervisors appointed the County of Humboldt Extraction Review Team (CHERT) to provide scientific oversight and recommendations on extraction designs for sites on the Mad River, and their role was expanded to include the review of operations on most Humboldt County rivers in 1996. CHERT's recommendations are based on the need to minimize potentially cumulative effects by ensuring that sustainable volumes are harvested, and that site-specific extraction methods protect local habitat (Klein et al. 2011). Annual cross section surveys are used to monitor and evaluate river conditions, and individual operations are reviewed to reduce or eliminate impacts and develop protection/mitigation strategies. Surface Mining and Reclamation Act documents related to gravel mining in the SF Eel River, including CHERT's post extraction reports from 1998-2013 are available at: http://co.humboldt.ca.us/planning/smara/default.asp?inc=slm.

Gravel mining occurs in two relatively isolated locations on four bars in the SF Eel River Basin between Cooks Valley (± RM 50) and Garberville (RM 33.5) (*Table 12*). Sites are located on the banks of the mainstem SF Eel River, which is the dividing line between the Eastern and Western Subbasins.

Table 12. SF Eel River gravel extraction sites, locations, and lengths. RM = river mile.

Gravel Bar Site Name	Location (RM)	Length (ft)
Cook's Valley	Humboldt/Mendocino County line (49.5)	809
Home Bar	Garberville (34.0)	1218
Tooby Park Bar	Garberville (34.0)	2097
Wallan and Johnson Bar	Between Redway and Garberville (33.5)	1854

Two of these sites are located southwest of Garberville at Tooby Park (*Figure 27*). The total extracted volume at all SF Eel River sites from 1997 to 2010 averaged 49,578 cy per year, and ranged from a high of 75,900 cy in 1999 to a low of 24,833 cy in 2008 (*Table 13*). Extracted totals averaged 71% of the annual percent approved, ranging from 110% in 1997 to 38% in (Klein et al. 2011). The average extracted volume for the SF Eel River is relatively low compared to other north coast streams (*Table 14*). The Lower Eel River had the highest average extracted volume per year (198,923 cy), followed by the Mad River (149,300 cy) and Van Duzen River (107,580 cy). The percent extracted versus percent approved each year ranged from a high of 91% for the Mad River to a low of 64% on the Lower Eel River. The average volume extracted from the Lower Eel River is more than four times the volume extracted from the South Fork, and the amount extracted would have been more than six times greater if the approved volume had been removed from the Lower Eel River sites.

Figure 27. Two gravel mining operations at Tooby Park, near Garberville, in the SF Eel River Western Subbasin.

Table 13. SF Eel River Annual Extraction (1997-2010) (Klein et al. 2011).

Year	Recommended Volume (cy)	Extracted Volume (cy)	Percent of recommended volume extracted
1997	67,700	74,700	110%
1998	75,400	70,100	93%
1999	85,400	75,900	89%
2000	75,700	53,700	71%
2001	66,000	43,100	65%
2002	58,163	48,122	83%
2003	87,060	54,660	63%
2004	80,730	50,745	63%
2005	82,770	36,480	44%
2006	92,000	35,075	38%
2007	90,737	73,956	82%
2008	32,358	24,833	77%
2009	40,170	24,986	62%
2010	42,864	27,732	65%
Totals	894,018	641,371	72%
Average	**69,789**	**49,578**	**71%**

Gravel mining can have serious impacts on stream channels, with possible effects including:

- Altered channel morphology and instability;
- Increased sediment input;
- Modified channel hydraulics;
- Loss of riparian vegetation; and
- Reduced groundwater elevations (NOAA 2004).

These effects on stream channels can also influence aquatic life. Gravel mining has been shown in studies and in practice to negatively affect salmonid habitat for both spawning adults and rearing juveniles (Brown et al. 1998, Laird et al. 2000). Direct effects on salmonids can include harming juveniles during mining operations, destruction of spawning and rearing habitat, loss of deep holding pools for adult and juvenile migration, and creating the potential for fish entrapment (Packer et al. 2005).

Additional impacts to salmonids can occur due to destruction of riparian zones, decreased food (macroinvertebrates) in stream channels, and toxic chemical spills that could occur during mining activities (Packer et al. 2005). Increased stream temperatures due to gravel mining activities that result in shallowing or reduced pool habitat and decreased riparian cover may also adversely affect adult and juvenile salmonids (Spence et al. 1996). The USACE (2004) recognized that the SF Eel River sites provided habitat for Chinook, coho salmon, and steelhead (particularly spawning habitat for Chinook), and recommended the use of alternative extraction techniques such as horseshoe extractions, wetland pits, trenches, and dry trenches, as opposed to traditional skimming techniques. Extraction methods currently used at SF Eel River sites include wide offset and shoreline skim, and wet trench (Klein et al. 2011).

Table 14. Historical extraction volume summaries for selected rivers in Humboldt County from 1992 - 2010. Mad River data from 1992-2010; all other river data from 1997-2010 (Klein et al. 2011). cy = cubic yards.

River		Approved volume (cy)	Extracted volume (cy)	Percent extracted vs approved
South Fork Eel River	Total (all years)	894,018	641,371	72%
	Average (annual)	69,789	49,578	71%
Lower Eel River	Total	3,923,757	2,489,719	63%
	Average	311,531	198,923	64%
Middle Eel River	Total	1,013,087	744,292	73%
	Average	72,363	53,164	73%
Van Duzen River	Total	1,968,094	1,362,964	69%
	Average	165,162	107,580	65%
Mad River	Total	3,037,319	2,751,126	91%
	Average	164,814	149,311	91%
Trinity River	Total	570,437	397,368	70%
	Average	42,936	28,504	66%

Water Use: Diversions and Hydrologic Disturbances

Diversions

Water sources in the Western Subbasin include both groundwater and surface water. Groundwater is part of a dynamic flow system that moves into and through aquifers from areas of high water-level elevation to areas of low water-level elevation (NC DWR, available at: http://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/Interaction/). Surface water and streamflow is influenced by precipitation, and by the interaction between surface water and groundwater. The interaction of groundwater and surface water is affected by the interchange of local and regional ground-water flow systems with the rivers and by flooding and evapotranspiration (Winter et al. 1998). Groundwater-level fluctuations due to aquifer storage changes involve either the addition or extraction of water from the aquifer, both through natural means and human involvement.

Water rights are defined as “the legal entitlement authorizing water to be diverted from a specified source and put to beneficial, nonwasteful use” (SWRCB 2013). There are many types of water rights in CA, including: appropriative (for commercial use), registered (for small domestic or livestock use), and riparian (for use on land adjacent to the water body). Appropriative rights require an application, environmental review, public notification, permit issuance, and finally licensing, providing “beneficial use” of the requested amount has been demonstrated. Registered users divert water from streams for use in non-riparian areas, and are permitted to use a specific amount of water. Riparian rights have a higher priority than appropriative rights, and there are no required permits, licenses, or government approvals. Riparian rights apply to water that would naturally flow in the stream, and users are not entitled to divert water for storage, for use during the dry season, or to use on land outside the watershed (SWRCB 2013). Beginning in 2010, riparian users were required to file a statement of use with the SWRCB, but few have complied and the magnitude of the diversions and the impact on fish and wildlife in the Western Subbasin remains unknown. For more information on water rights and diversions, go to: http://www.calsalmon.org/srf-projects/water-rights-education.

Most water rights in the Western Subbasin are for direct diversions, and diverted water is used for municipal and domestic purposes, irrigation, fire protection, recreation, and stock watering. The Western Subbasin contains the fewest permitted diversions and the smallest amount of diverted water of the three SF Eel River subbasins. There are only 3 licensed, permitted, or pending water rights within the Western Subbasin, with a maximum total diversion of 47 acre feet/year (afy) (*Table 15*). In addition to these diversions, there are 11 diversions, with a maximum total diversion of 1,404 afy, located along the mainstem SF Eel River, which is the dividing line between the Eastern and Western subbasins. *Table 15* does not include riparian users

Table 15. Water rights in the SF Eel River Western Subbasin.

Creek	Application Number	Direct Diversion	Maximum Application Direct Diversion	Diversion Storage	Purpose
UNST, Redwood Creek	A010198	12,000 gpd	13.4 afy		Domestic and irrigation
Durphy Creek	A014652	0.046 cfs	33.3 afy		Standby emergency domestic and fire protection
Connick Creek	A025864	1600 gpd	0.1 afy		Domestic
TOTAL (n = 3)			**46.8 afy**		
On boundary line between Eastern and Western subbasins (Mainstem SF Eel)					
SF Eel River	A005317	0.15 cfs	41.4 afy		Domestic and irrigation
SF Eel River	A009686	0.155 cfs	112.2 afy		Municipal
SF Eel River	A011876	0.223 cfs	161.5 afy		Domestic
SF Eel River	A016088	0.14 cfs	34.2 afy		Irrigation (2 sites)
SF Eel River	A023691	0.337 cfs	81 afy		Irrigation, domestic, stock watering
SF Eel River	A023017	1.05 cfs	441 afy		Municipal and domestic (use by 12/1995)
UNSP, SF Eel River	A023018	0.123 cfs	52 afy		Municipal and domestic (use by 12/1989)
UNST (AKA Marshall Creek)	A025436	0.04 cfs	13.5 afy		Domestic
UNSP, Rancheria Creek	A025693B	420 gpd	0.1 afy		Domestic
SF Eel River	A029329		37.5 afy		Industrial and mining (use by 12/1997)
SF Eel River	A029981		430 afy		Municipal (use by 12/1999. 2 sites)
TOTAL (n = 11)			**1404.4 afy**		

and other diversions that are not registered with the State Division of Water Rights, including illegal diversions for domestic use and industrial marijuana grow operations.

Water Drafting for Dust Abatement

The following section is based on information provided by the North Coast Regional Water Quality Control Board (NCRWQCB) in June of 2014 (J. Burke, Senior Engineering Geologist, Southern Timber Unit, NCRWQCB, personal communication 2014).

Water is used for dust abatement/sediment control on timber company roads throughout Humboldt and Mendocino counties between May 15th and October 15th. Timber companies draw water from streams near active harvest operations and apply it to unpaved roads to maintain safety and visibility, minimize input of fine sediment to adjacent streams, and to maintain infrastructure. The amount of water used may be substantial at a time when stream flow is already low. Estimates for the amount of water used each harvest season range from 2,000 to 4,000 gallons/mile/day (treating two times each day). Quantities vary depending on the volume of traffic, road surface, exposure/aspect (east side roads tend to be drier and require more treatment than west side roads), and the use of additional treatments such as magnesium chloride, which may reduce the amount of water required by approximately 50%. It is difficult to make generalizations about the amount of water used, but one timber company with approximately 400,000 acres located in Northwestern California estimated an annual use of two million gallons for dust abatement.

Regulations and limitations currently exist for surface water drafting, including the following:

- Lake and Streambed Alteration Agreements – any landowner that is drafting water must notify CDFW and develop a Streambed Alteration Agreement. These agreements generally contain requirements pertaining to water depth, bypass stream flow, and stream velocity. However, there are no consistent region- or state-wide standards regarding the specific conditions of these agreements;

- Anadromous Salmonid Protection (ASP) Rules – these stipulate the following conditions:
    - Bypass flows during drafting shall be at least 2 cubic feet per second;
    - Diversion rates are limited to 10 percent of surface flow; and
    - Pool volume reduction shall not exceed 10 percent.
- Board of Forestry Emergency rules for water drafting – these require users to comply with CDFW Streambed Alteration Agreements, but do not include specific recommendations for bypass flows;
- Statement of Water Diversion and Use – these are required by the State Water Board for all individuals or organizations that divert surface water or pump groundwater. Beginning January 1, 2012, users are required to measure and report the amount of water diverted each month.

Until recently, the amount of water used and the timing and location of withdrawals has not been carefully documented by industrial timber companies. Drought conditions in California, which are expected to persist through the 2014 logging season, will result in reduced water availability in areas throughout the SF Eel River watershed. In February 2014, staff from timber harvest review agencies including CDFW, CalFire, State and Regional Water Quality Control Boards, and the California Geologic Survey met to discuss water drafting on industrial timber harvest lands, limitations associated with these activities that further reduce instream flows, and the impacts of these activities in relation to current drought conditions. The interagency group developed a list of actions that could be developed to ensure the efficient use of water for dust control, including the following:

- Investigate current scope of use by requesting information from large landowners in an effort to quantify amounts used and specific data available on withdrawal locations and applications. This information will be used to determine if current use is significant to warrant changes in practices;
- Education and outreach to address efficient water use and alternatives to current drafting methods;
- Establish a list of best management practices (BMPs) to present in timber review correspondence;
- Develop regulatory solutions and recommendations; and
- Evaluate prudent use of alternatives to water for dust abatement, especially in areas with existing high industrial or agricultural runoff rates.

Existing ASP rules and regulations specifying minimum bypass flows and diversion rates may be adequate to minimize the impacts to water supplies solely from water drafting for industrial timber harvest operations in most situations. However, additional regulations/actions may be required in watersheds throughout the SF Eel River Basin where significant volumes are already diverted in response to high water demands from industrial marijuana cultivation and residential use.

Industrial Marijuana Agriculture

The permitted water diversions discussed above do not include illegal diversions from the recent proliferation of industrial marijuana agricultural operations in the SF Eel River Basin. During the late 1960s and early 1970s, a large influx of "back to the landers" came to the SF Eel River Basin in search of an independent, peaceful, and rural lifestyle (USBLM et al. 1996). With the decline of the timber and fisheries industries, also in the 1970s, the local economy began to dwindle. With favorable climate conditions and available land, back to the landers, displaced forest workers, and successive generations of homesteaders turned their ingenuity and agricultural talents to cultivating marijuana to accommodate the rising demand both locally and throughout the state. Mendocino and Humboldt Counties are home to the largest marijuana growing operations in the state, and these operations are increasing in both size and number, with a corresponding increase in local revenue currently accounting for nearly two-thirds of Mendocino County's economy (Evers 2010).

Since the passage of Proposition 215 in 1996 and SB420 in 2003 in California, CDFW field staff, local law enforcement agencies, and other state and federal agency representatives have discovered increasing numbers of large marijuana grows on private lands, presumably for medical purposes.

During an August 29th, 2012 flight over several watersheds in the SF Eel River Basin, Third District Supervisor Mark Lovelace and CDFW staff observed many growing operations that showed evidence of illegal and unpermitted clearcutting, road building, and water diversion (S. Bauer, CDFW, personal communication 2013, www.arcataeye.com). In the Salmon Creek and Redwood Creek watersheds (*Figure 28*, *Figure 29*), two coho salmon strongholds in the SF Eel River Basin, CDFW Environmental Scientist Scott Bauer used satellite photography to assess the number of indoor and outdoor grows, then estimated the number of plants grown in greenhouses, and the total amount of water necessary to supply these operations during each growing season (Easthouse 2013).

Bauer identified 567 grows (281 outdoor and 286 indoor/greenhouse) in the Salmon Creek drainage and 549 grows (226 outdoor and 323 indoor) in the Redwood Creek watershed (*Figure 28*, *Figure 29*). The total number of plants estimated to be associated with these grow operations was: 20,000 (8,700 in greenhouses and 11,300 outdoors) in Salmon Creek; and 18,500 (8,100 in greenhouses and 10,400 outdoors) in Redwood Creek. Bauer estimated that grow operations in Salmon Creek are consuming more than 18 million gallons of water per growing season and more than 16.5 million gallons per season in Redwood Creek. This usage during the growing season is nearly 30% of the total streamflow in these basins (Easthouse 2013). Although Salmon Creek is located within the boundaries of the Northern Subbasin, information on grows in this watershed was included in this section because it demonstrates how marijuana cultivation impacts local watersheds throughout the SF Eel River Basin, particularly in those with high percentages of residential land use.

CWPAP staff documented extremely low flow conditions in Redwood Creek (Redway) in August and September, 2013, as part of a study designed to compare conditions in SF Eel River streams that were heavily diverted with those that were not heavily diverted. Low flow conditions resulted from limited rainfall in the winter and spring of 2012-2013 and an increase in the number of diversions due to extensive marijuana cultivation operations (*Figure 29*). Other Western Subbasin streams that were affected extensively by diversion were Twin, Sproul, Little Sproul, Jack of Hearts, and Little Charlie (*Figure 30*) creeks. Flows decreased dramatically during the study, due primarily to active diversions supplying water to grow operations throughout the watershed. For a full description of the CDFW study and other low flow projects and results, see the Flow section of this subbasin report.

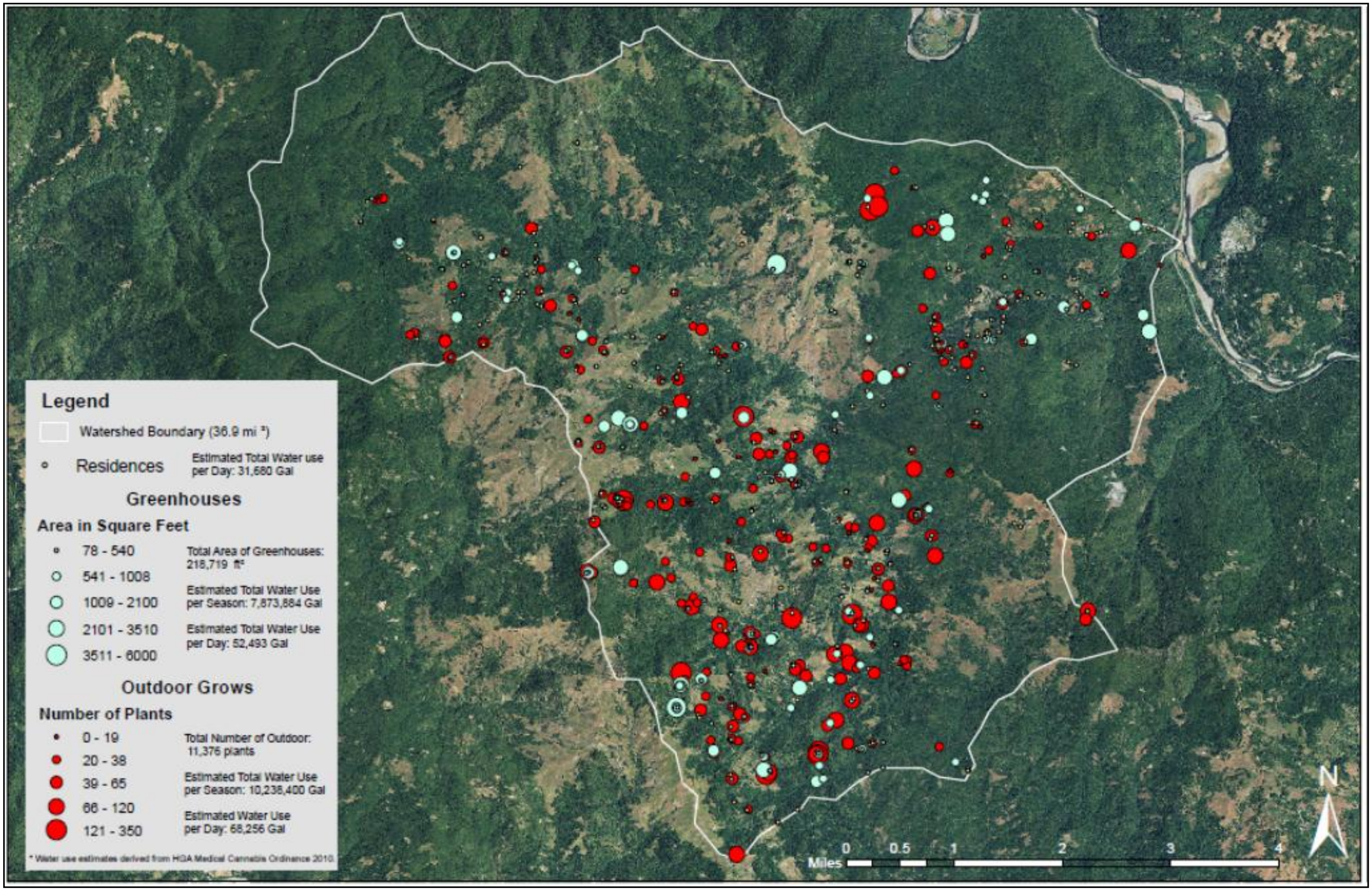

Figure 28. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Salmon Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW, 2013).

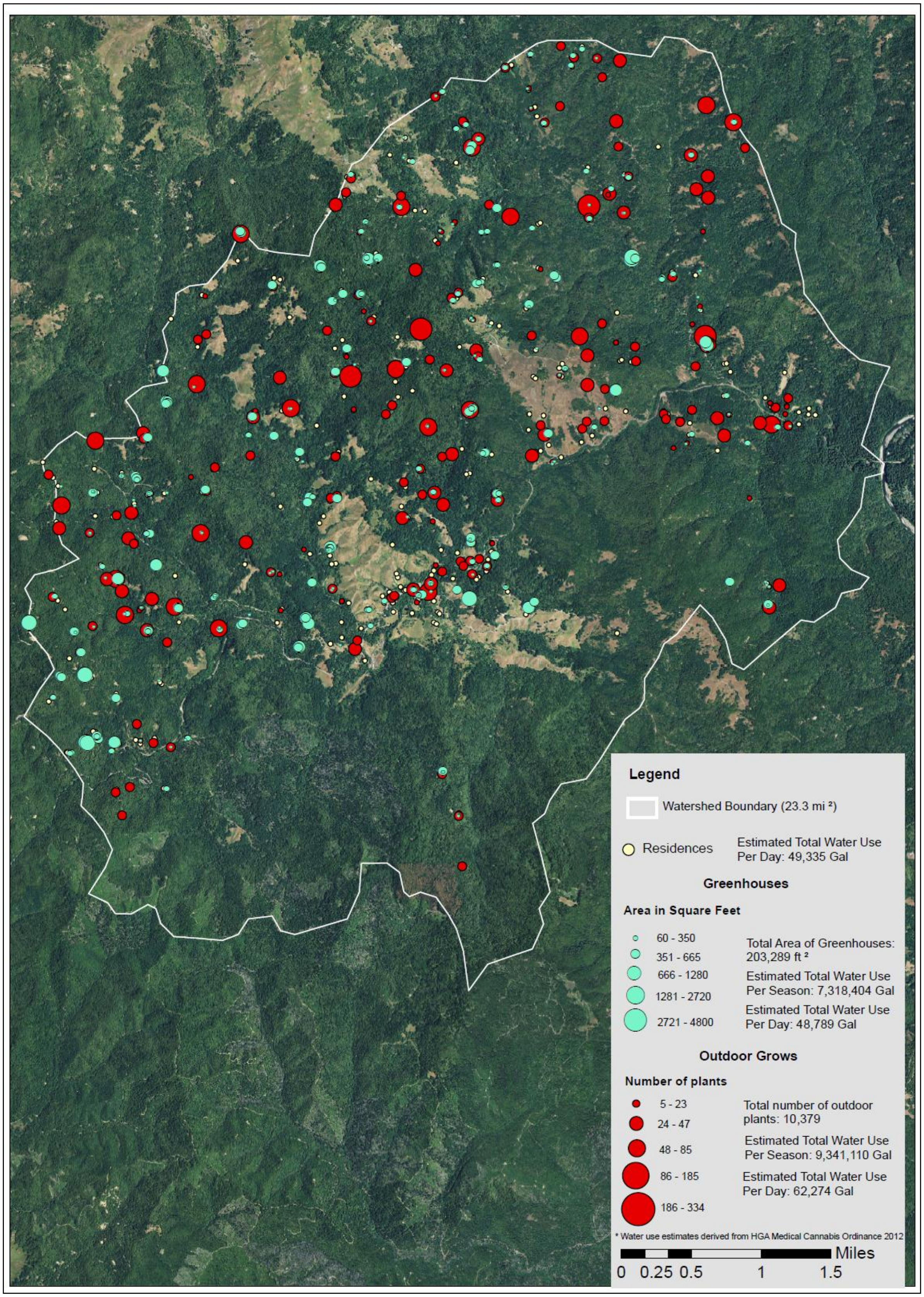

Figure 29. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Redwood Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW, 2013).

Figure 30. Dry streambed in Little Charlie Creek, September 2013.

While numerous factors may be relevant (wet spring vs dry spring, overall summer temperatures, etc.), a 10,000 square foot outdoor marijuana grow operation uses approximately 250,000 gallons of water in a five-month growing season (T. LaBanca, CDFW, personal communication 2012). Considering the number of outdoor and indoor operations within the watershed, this industry is having a significant effect on water flows in the SF Eel River and its tributaries. A recent trend has emerged that shows atypical low flows occurring during the late summer to early fall even during wet weather years (T. LaBanca, personal communication 2012). *Figure 31*, *Figure 32*, and *Figure 33* illustrate this potential trend using flow data from the USGS SF Eel River gauging stations near Miranda (RM 17), Leggett (RM 66, located in the Western Subbasin), and Bull Creek (4 miles up Bull Creek from the confluence of the mainstem SF Eel River). Daily mean discharge (in cfs) for the 2011-2014 water years was plotted along with the median daily statistic (73-year flow average for the Miranda gauge, 40-year flow average for the Leggett gauge, and 52-year flow average for the Bull Creek gauge). 2011 was considered a wet weather year, with above average rainfall throughout Northern California, and 2012 and 2013 were considered a dry years, with less than normal rainfall received. *Figure 31* shows a slight decrease in low flows in September and October 2011 at Miranda compared to the 73 year average, and significantly lower discharge from July through November 2012 and July through December 2013, continuing into January 2014, when compared to the 73 year average.

Figure 32 shows slightly lower flows in September and October 2011 and considerably lower flows in August, September, and October 2012 and 2013 compared to the 40-year average at Leggett. *Figure 33* shows much lower flows in September and October 2011 and 2012, and for nearly all of 2013, compared to the 52-year average flows recorded at the Bull Creek gauge. These atypical low flows (especially during normal water years) support the contention that water diversions by the marijuana industry are affecting streams and tributaries throughout the SF Eel River Basin, by contributing to higher water temperatures, reduced stream flow at critical times for fish rearing and migration, and altering water chemistry in the entire basin.

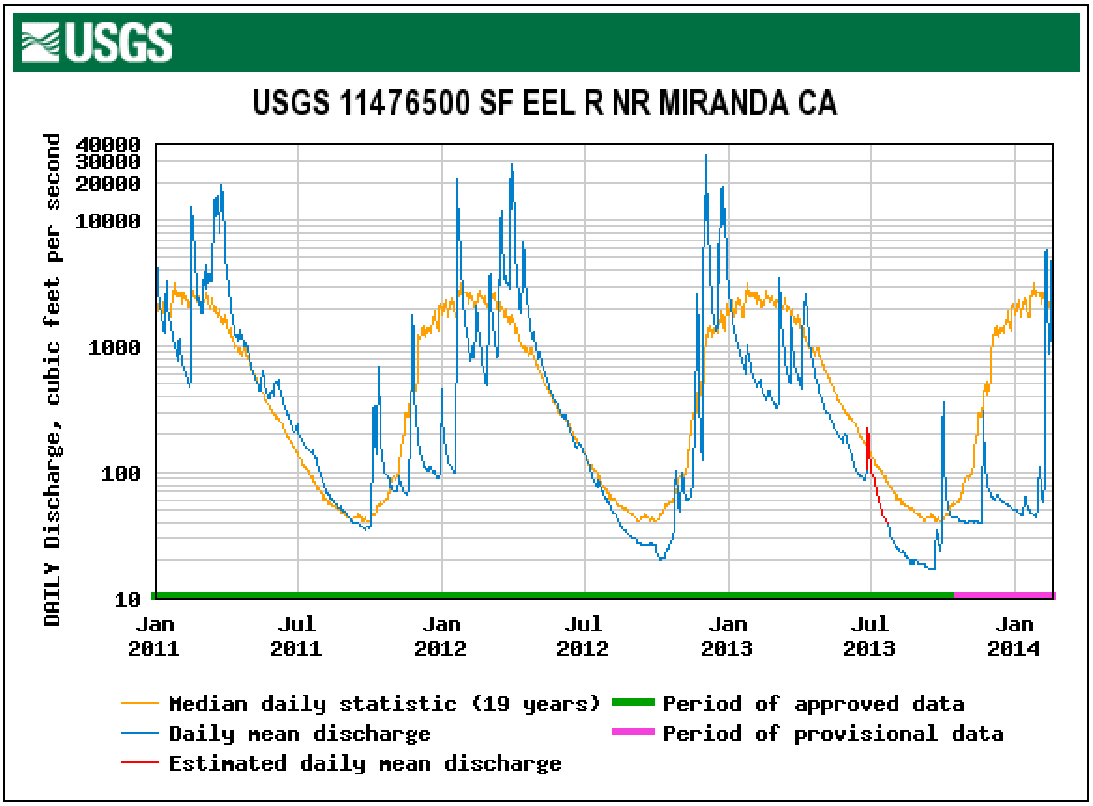

Figure 31. USGS gauging station near Miranda showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (73-year average in cfs).

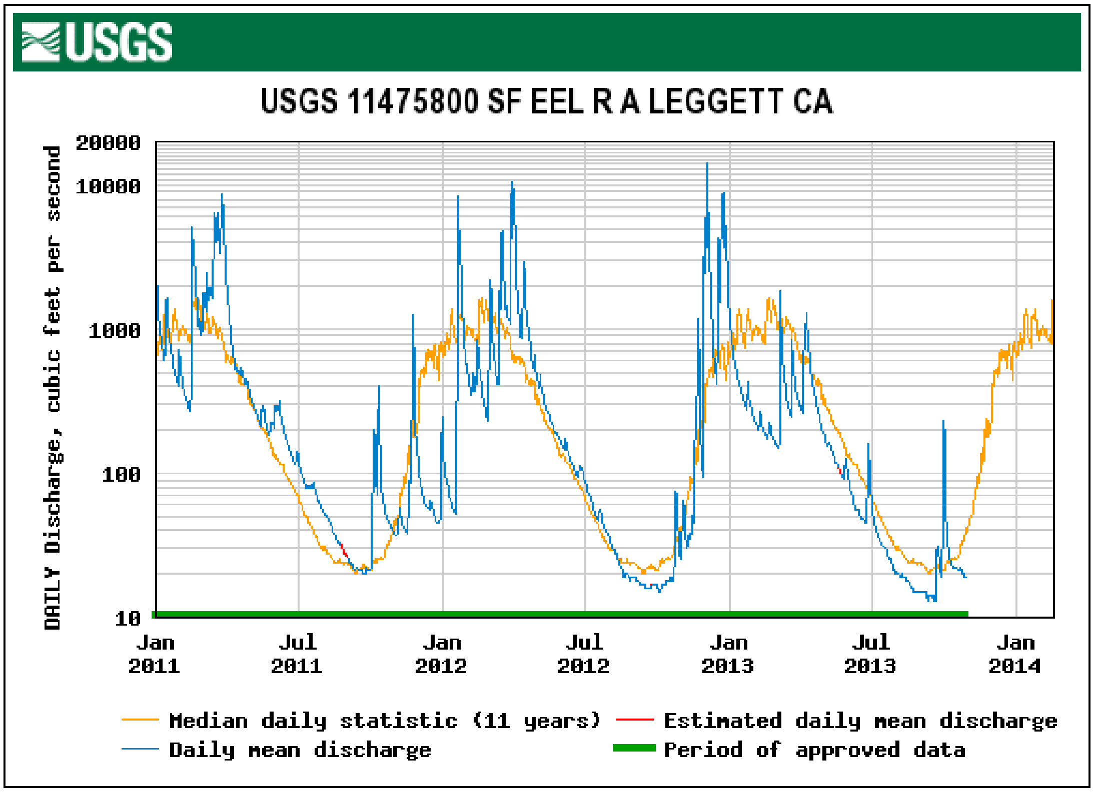

Figure 32. USGS gauging station near Legett showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (40-year average in cfs).

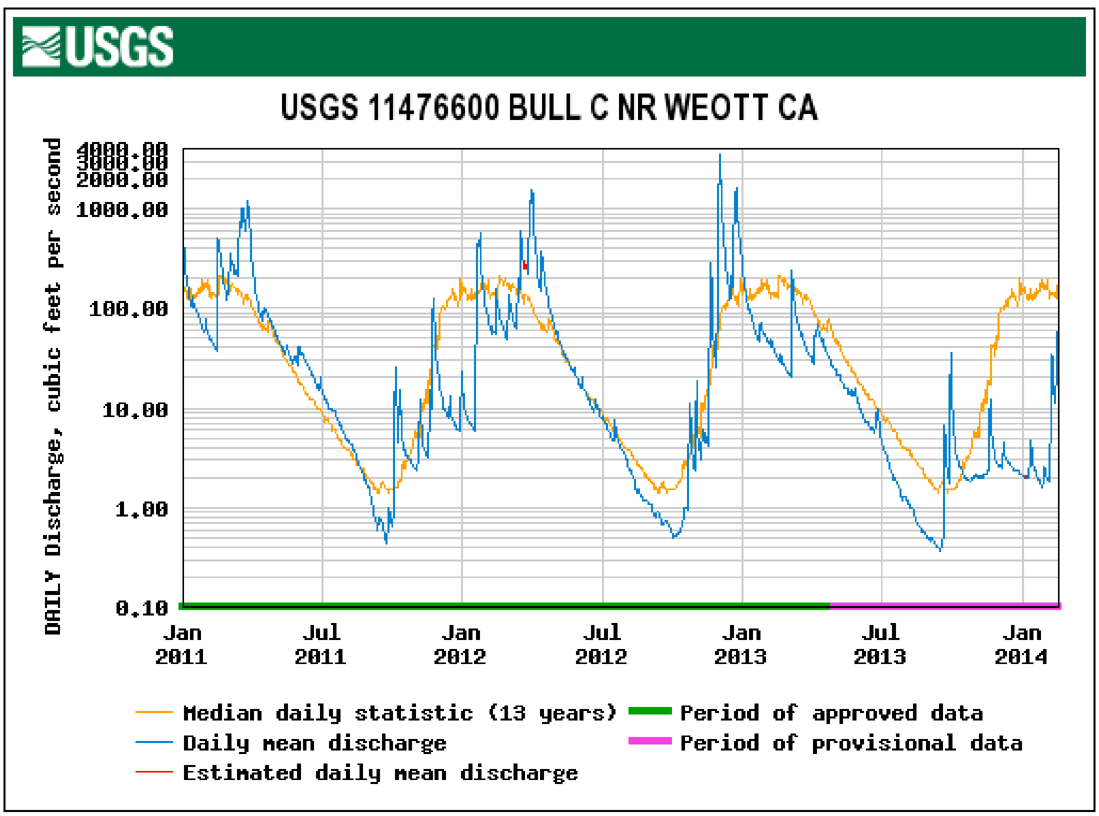

Figure 33. USGS gauging station at Bull Creek showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (52-year average in cfs).

Unlike permitted/licensed water diversions and other regulated land use activities such as legal timber harvesting and/or mining operations, there are no established "best management practices" or any review by agencies like CDFW and the state Water Quality Control Board on industrial marijuana grow sites. Therefore, a wide range of impacts to watercourses and their aquatic resources can be associated with these industrial marijuana agricultural operations. These impacts may include the following (CDFW 2012; T. LaBanca, personal communication 2012):

- Illegal water diversions that draw directly from the streams without screens or bypass, so juvenile fish and amphibian can be pulled from their habitat and die;
- Decreased stream flows due to illegal water diversions, leading to reduced stream depths and diminished pool habitat, possible subsurface flow in streams with excessive sediment recruitment, elevated water temperatures, and concentrated pollutants;
- A wide range of pollutants may be used (*Table 16*), including fuel, fertilizers, herbicides, pesticides, rodenticides, and construction debris. These chemicals and debris may go directly into watercourses or could leach into the soil, eventually being released into the water throughout the year;
- Human waste from camps that could also directly enter or leach into watercourses;
- Sediment from improperly constructed roads and construction around grow sites that enters watercourses throughout the rainy season;
- “Grow trash” such as plastic hose, construction supplies, and gardening waste left on site;
- Conversion and fragmentation of natural wildlife habitat and native ecosystems. Riparian and aquatic habitat may be disturbed or removed, grasslands and hillside habitats cleared and leveled; and
- Unpermitted timber harvests that may occur when an area is cleared for an agricultural grow operation.

In addition, there are many pollutants in fertilizers and pesticides that may enter the stream system from grow operations, but one which poses a particular danger to salmonids is copper. Sorenson (1991, in Woody 2007) determined that copper levels below lethal concentrations have the following potential effects on salmonids:

- Interfere with normal migration;
- Impair salmonids’ sense of smell;
- Impair their ability to fight disease;
- Make breathing difficult;
- Impair their ability to sense vibrations through their lateral line canals, which interferes with their ability to avoid predators;
- Impair brain function;
- Change their blood chemistry and metabolism; and
- Modify natural hatch rates.

Additional research is necessary to determine the concentrations of copper entering the SF Eel River system, and to determine the impacts of other pollutants from pesticides and herbicides on salmonids within this system.

There are some exceptions to the poor land-use practices associated with marijuana cultivation listed above. Local residents with small scale cultivation operations seem to employ more care than larger growers who do not live on site, and may not even own the land. A more comprehensive understanding of the magnitude of the impacts of industrial operations, their effects on fish and wildlife, and consumer and grower education leading to regulation is necessary to address these problems (Weiser 2012).

Although there are no established best management practices for marijuana growing, the Northern California Farmers Guide is a community-based collaborative project that outlines concerns and solutions for many of the issues listed above. This guide is an evolving project that is designed to increase awareness of environmental issues and help cannabis growers protect the environment while growing a high quality, sustainably produced crop. For more information, go to: http://www.norcalfarmersguide.org/.

Table 16. Pollutants associated with marijuana grows and their effects on fish and wildlife (adapted from Greacen 2012).

Pollutant	**Application**	**Result**
Rodenticide	Poison is applied to garden and/or perimeter to keep rodents from harming crop.	Wild animal populations are impacted as poison travels up the food chain. Contamination of fresh stream water.
Insecticide	Poison is applied to garden and/or perimeter to keep insects from harming crop.	Toxic to native insects as well as fish.
Fungicide	Fungicide is applied to plants to keep fungus from harming crop.	Can be toxic to fish and beneficial soil invertebrates. May contain mercury.
Fertilizer	Fertilizer and soil amended with potent nutrients are brought to the grow and used liberally for the growing season then discarded.	Nutrients get into the streams causing problematic algal blooms. Used soil/fertilizer is washed into the streams during the rainy season which adds to the sediment load. Typically leads to a reduction of dissolved oxygen in streams.
Sediment	Tractor/dozer work on larger grows is implemented, often with little or no regard for good road/landscape practices in regard to site stability and erosion.	Sediment from dozer work (roads, landings, gardens) gets into streams.
Reduced flow	Water is taken from a nearby stream by diversion pipe or water truck and used to water crop (individual plants take 3-5 gallons/day).	Evapotranspiration releases most of the water into the atmosphere resulting in a loss of water available to the stream during the driest, hottest part of the year producing extremely low flows downstream of diversion.

Fish Habitat Relationship

Fishery Resources

Historical Distribution

Fish presence has been documented in the Western Subbasin by anecdotal accounts and observations made during stream surveys since 1938. However, stream survey efforts were neither specific nor standardized until 1991 when the *California Salmonid Stream Habitat Restoration Manual (*Flosi et al. 2010) was published. Most observations in stream surveys are not quantitative and have limited use.

Historical salmonid documentation is available for 50 Western Subbasin streams. Information sources include CDFW carcass surveys, stream survey and inventory reports, electrofishing and general field notes, downstream migrant trapping data, fyke net records, and spawning stock and escapement reports (*Table 17*). Coho salmon were found in 28 of the 50 surveyed streams, mostly in those with low gradient and favorable instream and riparian habitat conditions. Large tributaries to the mainstem SF Eel River with documented historical coho salmon presence included: Hollow Tree, Indian, and Redwood (Redway), and Sproul Creeks. Chinook salmon were documented in 17 Western Subbasin streams, and steelhead in 41 of the 50 tributaries. Nine creeks surveyed had no record of Chinook, coho salmon, or steelhead presence, but unidentified salmonids were observed in five of these streams (Butler, Eagle, Hartsook, Hooker, and Sebbas creeks) (*Table 17*).

Table 17. Documented fish presence in surveys from 1938 to 2001 in the Western Subbasin.

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Anderson Creek (tributary to Indian)	6/19/1968	Stream Survey (CDFG 1968)			X	
	April/May 1979	Stream Survey (CDFG 1979)	X		X	
Bear Pen Creek	7/11/1968	Stream Survey (CDFG 1968)			X	
Bear Wallow Creek	9/26/1962	Stream Survey (CDFG 1962)			X	
Bond Creek	7/25/1968	Stream Survey (CDFG 1968)			X	
	9/23 - 9/24/1980	Stream Survey (CDFG 1980)			X	
	10/19/1983, 7/16/1987, 7/27/1988	Electroshocking Survey Summary (CDFG 1988)		X	X	
	12/12/1988	Carcass Survey: Field Note (CDFG 1988)				
	10/17/1991	Stream Inventory Report (CDFG 1991)			X	
	July, Sept, Oct 1992	Stream Inventory Report (CDFG 1992)			X	
Butler Creek	5/10/1979	Stream Survey (CDFG 1979)				X
	1/11/1983	Spawning Stock Survey (CDFG 1983)				
China Creek	6/27/1962	Field Note (CDFG 1962)				X
	9/5/1966	Stream Survey (CDFG 1966)		X	X	
	5/24 -	Stream Survey (CDFG				X

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
	5/26/1982	1982)				
China Creek (con.)	11/28, 12/21/1994	Field Note (CDFG 1994)				
	12/2, 12/11/1997	Spawner Surveys (CDFG 1997)	X			
	2000-2001	Spawner Surveys (CDFG 1997)	X	X		X
Cox Creek	1/5/1994	Field Note (CDFG 1994)				
Dinner Creek	9/1/1966	Stream Survey (CDFG 1966)			X	
	3/20/1985	Field Note (CDFG 1985)			X	
	10/25/1985	Stream Survey (CDFG 1985)				X
	10/5/1990	Biological Inventory Field Form (CDFG 1990)			X	
	1/5/1993	Field Note (CDFG 1993)			X	X
	2/16/1995	Field Note (CDFG 1995)				
Durphy Creek	6/25/1938	Stream Survey (CDFG 1938)	X	X	X	
	1/6/1958	Stream Survey (CDFG 1958)	X	X		
	6/8/1961	Stream Survey (CDFG 1961)				X
	4/1/1968	Field Note (CDFG 1968)			X	
	4/30/1969	Field Note (CDFG 1969)		X	X	
	12/28/1987	Field Note (CDFG 1987)	X			X
Dutch Charlie Creek	7/30/1969	Stream Survey (BLM 1969)		X	X	
	12/9/1982 - 1/17/1983	Spawner Survey (CDFG 1983)	X			
	9/21-25/1992	Stream Inventory Report (CDFG 1992)		X	X	
	9/30/1992	Stream Inventory Report (CDFG 1992)		X	X	
Eagle Creek	2/11/1972	Stream Survey (CDFG 1979)				X
Hartsook Creek	6/13/1961	Stream Survey (CDFG 1961)				X
	4/8/1981	Stream Survey (CDFG 1981)				X
Haun Creek	8/22/1969	Stream Survey (CDFG 1969)		X	X	
Hollow Tree Creek	5/22/1940	Stream Survey (CDFG 1940)	X	X	X	
	7/31 and 8/6/1968	Stream Survey (CDFG 1968)		X	X	

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
	12/12 - 12/13/1979	Carcass Survey: Field Note (CDFG 1979)	X	X		
Hollow Tree Creek (con.)	1983, 1986-1989	Electroshocking Survey Summary (CDFG 1989)		X	X	X
	1/11/1983	Salmon Spawning Stock Survey (CDFG 1983)	X			X
	1/2 - 1/3/1986	Carcass Survey: Memorandum (CDFG 1986)	X	X		X
	1/13 - 1/14/1987	Salmon Carcass Survey (CDFG 1987)	X			X
	2/2 - 2/9/1993	Carcass Suvey: Field Notes (CDFG 1993)	X	X		X
	6/28/1993	Spawning Stock Survey (CDFG 1983)	X			X
	1/12 - 1/13/1994	Carcass Suvey: Field Notes (CDFG 1994)	X	X		X
	12/30/1994	Carcass Suvey: Field Note (CDFG 1995)	X	X		X
Hooker Creek	7/4/1962	Stream Survey (CDFG 1962)				X
Huckleberry Creek	10/29/1968	Stream Survey (CDFG 1968)		X	X	
	7/15/1981	Stream Survey (CDFG 1981)			X	
	1/12/1994	Carcass Survey: Field Note (CDFG 1994)				
Indian Creek	6/18 and 6/25/1938	Stream Survey (CDFG 1938)		X	X	X
	8/11/1938	Stream Survey (CDFG 1938)			X	
	1968	Stream Survey (CDFG 1968)			X	
	11/27/1979	Bid for Andersonia Land (Indian Creek Rehabilitation Project)	X			
	12/14/1988	Salmonid Survey: Field Note (CDFG 1989)	X			
	12/14 and 12/22/1988, 1/5, 1/19, 1/24/1989	Salmonid Survey: Field Note (CDFG 1989)	X	X		X
Jack of Hearts Creek	7/29/1969	Stream Survey (CDFG 1969)		X	X	
	2/11/1979	Stream Survey (CDFG 1979)				X
	10/6/1992	Stream Inventory Report (CDFG 1992)		X	X	
	10/6/1992	Stream Inventory Report (CDFG 1992)		X	X	
	2001	MRC Sampling (CDFG email 2002)		X		
La Doo Creek	7/6/1961	Stream Survey (CDFG 1961)				

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
	10/15/1992	Stream Inventory Report (CDFG 1992)				
Leggett Creek	8/11/1938	Stream Survey (CDFG 1938)			X	
	6/20/1962	Stream Survey (CDFG 1962)				X
	6/21/1973	Electrofishing Field Note (CDFG 1973)			X	
	7/5/1974	Field Note (CDFG 1974)			X	
	8/12/1980	Stream Survey (CDFG 1980)				X
	7/19/1984	Stream Survey (CDFG 1984)				X
	6/16/1989	Electrofishing Field Note (CDFG 1989)			X	
	9/29/1992	Stream Inventory Report (CDFG 1992)		X	X	
	1994, 1995	Spawning Survey Summary (CDFG 1995)			X	
	7/27/2000	Electrofishing Field Note (CDFG 2000)		X	X	
Little Charlie Creek	8/4/1969	Stream Survey (CDFG 1969)		X	X	
	3/19/1979	Stream Survey (CDFG 1979)				
Little Sproul Creek	5/22/1940	Stream Survey (CDFG 1940)			X	
	12/1/1981	Stream Survey (CDFG 1981)				
	3/12/1985	Stream Survey (CDFG 1985)			X	
	6/16/1989	Electrofishing Field Note (CDFG 1989)		X	X	
	3/15/1990	Field Note (CDFG 1990)			X	
	2/11/1991	Field Note (CDFG 1991)			X	
	12/23/1992	Field Note (CDFG 1992)		X		
	2/23/1993	Field Note (CDFG 1993)				
	1/5/1994	Field Note (CDFG 1994)		X	X	X
	12/20/1994 - 2/9/1995	Spawner Survey Summary (CDFG 1995)	X		X	
	3/30/1995	Field Note (CDFG 1995)				
Little Waldron Creek	7/30/1968	Stream Survey (CDFG 1968)		X	X	
Lost Pipe Creek	7/23/1968	Stream Survey (CDFG 1968)			X	
Low Gap	8/11/1938	Stream Survey (CDFG			X	

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Creek		1938)				
	7/4/1962	Field Note (CDFG 1962)			X	X
	6/13/1968	Stream Survey (CDFG 1968)				X
	8/14/1968	Stream Survey (CDFG 1968)		X	X	
	3/26/1979	Stream Survey (CDFG 1979)				X
	1/31/1980	Stream Survey (CDFG 1980)				X
	12/6/1988	Carcass Survey: Field Note (CDFG 1989)				
	1/4/1989	Carcass Survey: Field Note (CDFG 1989)	X			
	7/20/1995	Stream Inventory Report (CDFG 1995)			X	
Lynch Creek	10/30/1968	Stream Survey (CDFG 1968)			X	
Michael's Creek	7/24/1968	Stream Survey (CDFG 1968)			X	
	7/3/1981	Stream Survey (CDFG 1981)		X	X	
Middleton Creek	9/2/1969	Stream Survey (CDFG 1969)				
	3/11/1979	Stream Survey (CDFG 1979)				
Mill Creek (tributary to SF Eel River)	7/12/1968	Stream Survey (CDFG 1968)			X	
Moody Creek	6/18/1968	Stream Survey (CDFG 1968)			X	
	4/20/1979	Stream Survey (CDFG 1979)			X	
Mule Creek	July 1968	Stream Survey (CDFG 1969)		X	X	
Parker Creek	6/17/1968	Stream Survey (CDFG 1968)			X	
Piercy Creek	6/25/1938	Stream Survey (CDFG 1938)		X	X	
	6/24/1968	Stream Survey (CDFG 1968)			X	
	9/27 and 9/28/1977	Stream Survey (CDFG 1977)			X	
Pollock Creek (Upper Redwood Creek)	1988-1989	Spawner Survey Summary (CDFG 1989)	X	X		
	7/8, 7/9/1998	Memorandum (CDFG 1998)			X	
	9/29/1999	Field Sampling Report (CDFG 1999)		X	X	
Redwood Creek (Branscomb)	7/31/1969	Stream Survey (CDFG 1969)		X	X	
	1/3/1979	Stream Survey (CDFG				

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
		1979)				
Redwood Creek (Branscomb) (con.)	1/12/1983	Spawning Stock Survey (CDFG 1983)	X			
	12/15/1988	Carcass Survey: Field Note (CDFG 1989)	X	X		X
Redwood Creek (Hollow Tree)	7/24/1968	Stream Survey (CDFG 1968)		X	X	
	12/12/1988	Carcass Survey Summary (CDFG 1989)	X	X		
	1/12/1994	Carcass Survey (CDFG 1994)		X		X
Redwood Creek (Redway)	6/12/1938	Stream Survey (CDFG 1938)			X	
	1966	Fyke Net Record (CDFG 1966)	X	X	X	
	9/7/1966	Stream Survey (CDFG 1966)		X	X	
	1/7/1969	Spawner Survey Field Note (CDFG 1969)	X			
	1/5 - 1/6/1971	Field Note (CDFG 1971)	X	X		
	7/20 - 7/31/1984	Stream Survey (CDFG 1984)		X	X	
	1983-1990	Trap Summary (CDFG 1990)	X	X	X	
	1984-1985	Spawner Survey Summary (CDFG 1985)	X	X		X
	1985-1986	Spawner Survey Summary (CDFG 1986)	X			
	1986-1987	Spawner Survey Summary (CDFG 1987)	X	X		
	1987-1988	Spawner Survey Summary (CDFG 1988)	X	X		
	1988	Downstream Migrant Trapping Notes (PCFFA 1988)	X	X	X	
	9/11/1989	Electrofishing Field Note (CDFG 1989)		X	X	
	1989-1990	Field Note (CDFG 1990)	X	X	X	
	1990-1991	Spawner Survey Summary (CDFG 1991)	X			
	1/17/1991	Streamwalk Information (CDFG 1991)				
	8/24/1993	Population Estimate Field Note (CDFG 1993)		X	X	
	9/1/1993	Stream Inventory Report (CDFG 1993)		X	X	
	1994-1995	Field Notes (CDFG 1994-95)				
	8/12/1994	Electrofishing Field Note (CDFG 1994)		X	X	

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
	8/23/1995	Electrofishing Field Note (CDFG 1995)		X	X	
Redwood Creek (Redway) (con.)	7/3/1996	Field Note (CDFG 1996)		X	X	
	1999-2000	Spawner Survey Summary (CDFG 2000)	X	X		X
Sawmill Creek	3/30/1939	Stream Survey (CDFG 1938)	X		X	
	7/5/1961	Stream Survey (CDFG 1961)				X
	4/21/1981	Stream Survey (CDFG 1981)				X
Sebbas Creek	3/23/1979	Stream Survey (CDFG 1979)				X
Section Four Creek	9/2/1969	Stream Survey (CDFG 1969)			X	
	1/30/1979	Stream Survey (CDFG 1979)				
Seely Creek	6/11/1961	Stream Survey (CDFG 1961)				X
	9/22/1966	Stream Survey (CDFG 1966)		X	X	
	1/19/1967	Field Note (CDFG 1967)	X			
	1/25/1968	Field Note (CDFG 1968)	X			
	1/7/1969	Field Note (CDFG 1969)	X			
	1/31/1969	Field Note (CDFG 1969)	X			
	1/6/1971	Field Note (CDFG 1971)	X			
	1989	Downstream Migrant Trapping Summary (PCFFA 1989)	X	X	X	
Sommerville Creek	8/1/1938	Stream Survey (CDFG 1938)			X	
	9/25/1966	Stream Survey (CDFG 1966)			X	
Sproul Creek	1963-2001	Spawning Stock Summary Tables, Electrofishing Suumaries (CDFG)	X	X		X
Standley Creek	6/27 - 7/1/1968	Stream Survey (CDFG 1968)			X	X (possibly coho salmon)
	5/10 - 5/11/1976	Stream Survey, Electrofishing (CDFG 1976)		X	X	
	7/27 - 7/28/1977	Electroshocking Memorandum (CDFG 1977)			X	
	1/11/1983	Spawning Stock Survey (CDFG 1983)				X
Surveyors	1975	Stream Survey (BLM				

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Canyon		1975)				
Thompson Creek	3/11/1979	Stream Survey (CDFG 1979)				
Waldron Creek	9/27/1988, 9/15/1989	Electroshocking Survey Summary (CDFG 1989)		X	X	
	1/12/1994	Carcass Survey (CDFG 1994)				
Warden Creek	7/5/1961	Stream Survey (CDFG 1961)			X	
	12/23/1992	Field Note (CDFG 1992)		X		
	10/7/1992	Stream Inventory Report (CDFG 1992)			X	
West Fork Sproul Creek	1987-1996	Electrofishing Field Notes (CDFG 1987-1996)		X	X	
	9/13/1999, 4/7/2000, 8/30/2001	Field Notes (CDFG 1999, 2000, 2001)	X	X	X	
Wildcat Creek	7/15/1968	Stream Survey (CDFG 1968)		X	X	
	1/5/1983	Spawning Stock Survey (CDFG 1983)	X			

There is one long-term salmon and steelhead data set for the Western Subbasin, with data collected at the CDFW fish ladder at Benbow Dam, located at approximately RM 40 on the mainstem SF Eel River near Garberville. Counts were conducted between 1938 and 1975, and they show more than an 80% decline in coho salmon, Chinook salmon, and steelhead trout populations over the span of the last century (*Figure 34*). Linear regression lines for all three species show significant declines in abundance, and it is likely that salmonid populations throughout the SF Eel River Basin declined similarly during this time period.

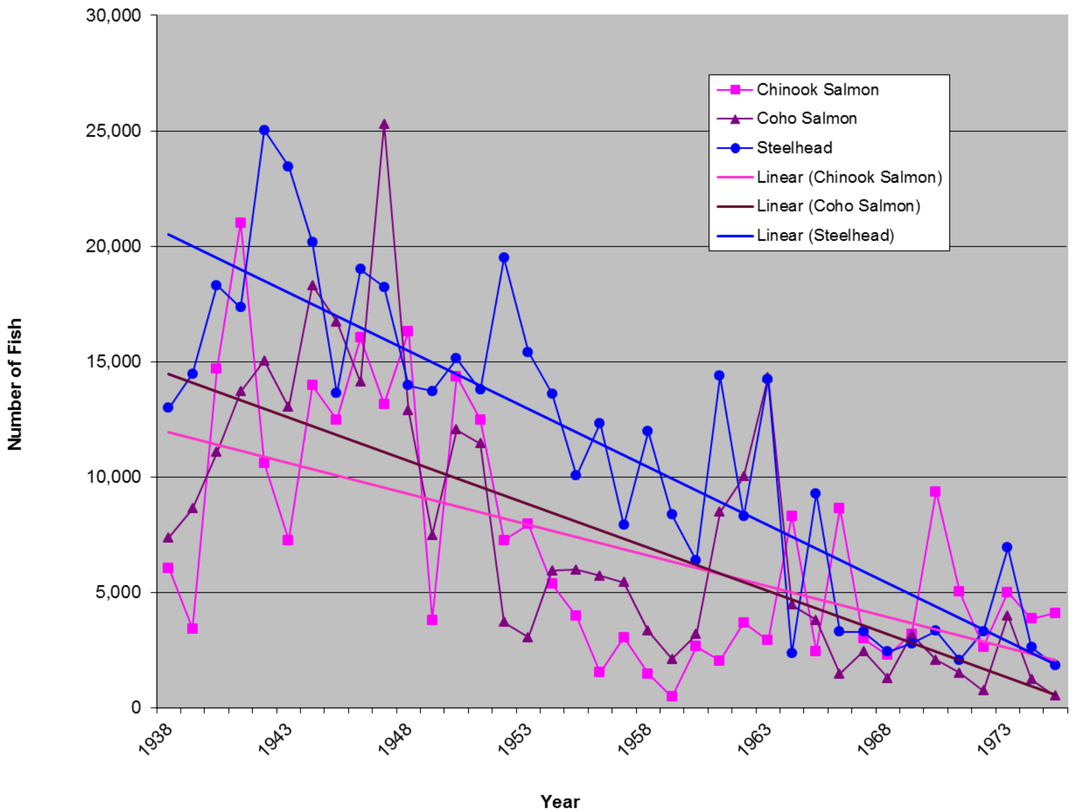

Figure 34. Counts of migrating Chinook salmon, coho salmon, and steelhead at the Benbow Dam fish ladder between 1938 and 1975. Regression lines for all three species show declines over time.

Current Distribution

Current estimated Chinook salmon, coho salmon, and steelhead distributions were based on data collected from a variety of sources (CDFW, USFS, tribal fisheries monitoring, university research, local watershed stewardship programs, and additional fisheries stakeholders) and compiled by the Pacific States Marine Fisheries Commission (PSMFC). Data are available on the CalFish website at: http://www.calfish.org/Programs/ProgramIndex/AnadromousFishDistribution/tabid/184/Default.aspx.

CalFish data is observation-based, meaning that any recorded observation is collected, verified, evaluated, and applied to standard hydrography to develop a linear GIS layer. These layers are overlaid onto local watershed polygons (Calwater Planning Watersheds) to determine distribution ranges, assuming that target species can be found anywhere downstream from the observation point. Distribution layers differ slightly by species:

- Chinook distribution was developed using CDFW reports and the NOAA National Marine Fisheries Service GIS layer, which uses CDFW and PSMFC stream based routed hydrography. This layer was updated in June 2005;
- Coho salmon distribution was developed using CDFW reports and the CalFish observation-based distribution, and was updated in June 2012;
- Steelhead distribution was developed using CDFW reports and the CalFish steelhead distribution layer, and was last updated in June 2012.

Final maps were reviewed by CDFW fishery biologists and distribution lines were added or removed where known distribution was different than gradient and observation-based information. Salmonids in the SF Eel River Basin may be present in areas where they have not been documented due to a lack of data, landowner access issues, or inadequate sampling techniques.

Proportionally, in terms of total number of streams and stream miles, the Western Subbasin contains more documented fish presence than Northern or

Eastern Subbasin streams (*Table 18*), due in part to favorable instream conditions. The Western Subbasin is strongly influenced by the coastal marine layer and defined by morning fog and overcast conditions, which supports coniferous and hardwood forest vegetation. These moderated air temperatures and shady conditions result in cooler summer water temperatures and lush riparian vegetation in Western Subbasin streams, in contrast to the inland Eastern Subbasin where the climate is very hot and dry, and stream temperatures are often unsuitable for Chinook and coho salmon.

Table 18. Number of tributary streams and approximate number of stream miles currently occupied by anadromous salmonids in SF Eel River Basin and subbasins.

Subbasin	**Number of Tributaries**	**Total mainstem miles/tributary miles**	**SFER mainstem miles currently used by anadromous salmonids***			**Number of SFER tributaries/miles currently used by anadromous salmonids**		
			Chinook	**Coho**	**Steelhead**	**Chinook**	**Coho**	**Steelhead**
Northern	109	23 / 190	23	23	23	14 / 27	8 / 13	23 / 50
Eastern	167	82 / 360	80	79	80	27 / 82	17 / 25	44 / 130
Western	175	82 / 312	80	79	80	44 / 86	34 / 99	53 / 128
***** Mainstem SFER is dividing line between Western and Eastern subbasins; mainstem mileage is counted in both Eastern and Western Subbasin totals.								

In the SF Eel River Basin coho salmon have the most limited distribution of all three salmonid species. However, in the Western Subbasin, coho salmon have been documented in 34 tributaries (more than Northern and Eastern subbasins combined) and with generally lower gradients allowing for easier access, they are also found further upstream in Western Subbasin streams than in Northern and Eastern Subbasin tributaries. Western Subbasin tributaries with extensive coho salmon distribution included Redwood (Redway), Sproul, Indian, and Hollow Tree creeks; many tributaries to these larger creeks also had documented coho presence (*Figure 35*).

Chinook salmon have been documented in 44 Western Subbasin streams. Many of these also have coho salmon present, but Chinook are also found in some tributaries to the mainstem SF Eel River with little or no coho salmon presence (e.g. Sawmill, Bear Pen, and Wildcat Creeks).

Steelhead trout are the most widely distributed of the three species, documented in 53 Western Subbasin streams, and are generally found further upstream and in more tributaries than either Chinook or coho salmon (*Table 18*). Steelhead and Chinook have been documented in a similar number of miles of tributary streams in the Eastern and Western subbasins, but they are found in a greater number of tributaries throughout the Western Subbasin.

Both SF Eel River coho salmon and steelhead were selected as “salmon strongholds”, which represent the healthiest wild Pacific salmon populations remaining, and recognize the high value of the habitats occupied by these populations (Wild Salmon Center 2012). Identification of these strong populations is part of a larger conservation effort to complement recovery efforts for salmonids throughout the state. Hollow Tree Creek is particularly important for both coho salmon and steelhead due to high quality habitat and healthy, well-established populations. Land use in this drainage is primarily industrial timber harvest, and most of the land in the Hollow Tree Creek watershed is owned by Mendocino Redwood Company (MRC). Lower Hollow Tree Creek, from the confluence with the SF Eel River upstream to RM 6.3, is used primarily as a migration corridor and is located on Hawthorne Timber Company land. MRC’s (2004) potential salmonid distribution is consistent with CWPAP current salmonid distribution in this watershed.

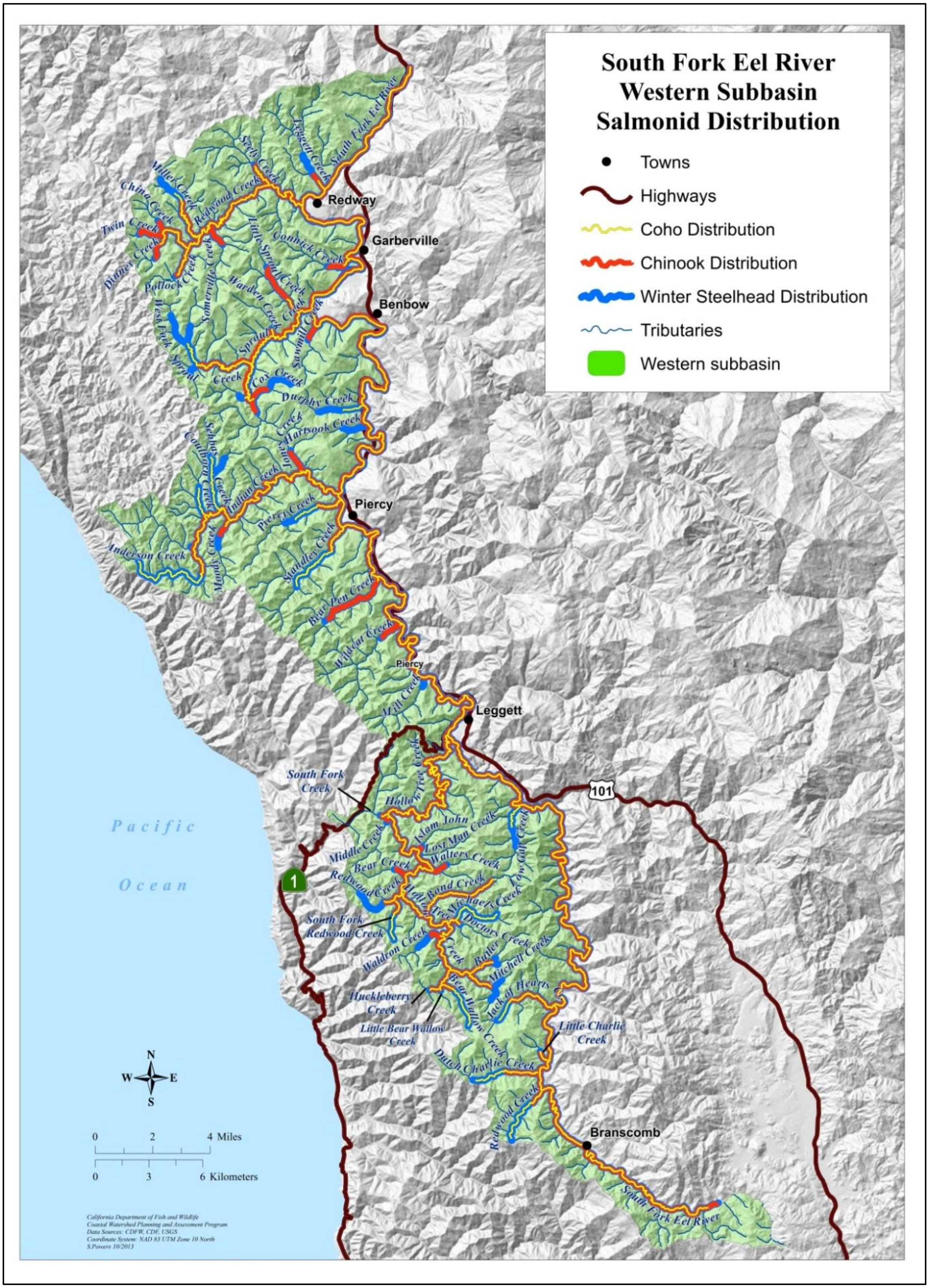

Figure 35. Coho salmon, Chinook salmon, and steelhead trout distribution in SF Eel River Western Subbasin streams.

In addition to salmonids, other native freshwater fish that have been observed in the Western Subbasin include rainbow trout, pacific lamprey, coastrange sculpin (Brown and Moyle 1997, Stillwater Sciences 2010), Sacramento sucker, California roach, and three-spine stickleback (MRC 2004). Invasive species present include Sacramento pikeminnow (*Figure 36*), which have been detected in the mainstem SF Eel River and many of its tributaries (Nakamoto and Harvey 2003). Pikeminnow abundance is increasing and their distribution is expanding due to the species' high tolerance for warm water and low flow conditions, which have become more prevalent throughout the mainstem SF Eel River Basin in recent years. However, Western Subbasin streams are generally cooler than those in the Eastern Subbasin, so pikeminnow are most likely less abundant and present in fewer streams throughout this subbasin.

Figure 36. Juvenile pikeminnow in the mainstem SF Eel River.

CDFW Spawning Ground Surveys

Data on the number of spawning Chinook salmon, coho salmon, and steelhead trout have been collected in SF Eel River streams using two different approaches: index reach sampling (2002 to present) and California Coastal Salmonid Population Monitoring (CMP) program techniques (2010 to present). These methods differ in sampling frequency and intensity, and in the applicability of their conclusions, however, both provide valuable information that can be used to assess the status of salmonid populations in the basin.

Index Reach Sampling

CDFW survey crews have collected data on the number of redds, live Chinook and coho salmon, and salmonid carcasses in 10 SF Eel River stream reaches, six of which were located in the Western Subbasin (the remaining four were located in the Northern Subbasin and are discussed in the Fishery Resources section in that part of the assessment report). Three hundred twenty five surveys were conducted in three Western Subbasin streams (*Table 19*). Sproul Creek sampling reaches included upper, lower, and West Fork locations. Survey sites were not randomly selected; CDFW biologists selected index reaches based on known salmonid (primarily coho salmon) presence in areas with relatively good quality instream and riparian habitat. Annual surveys also differed in sampling duration and effort, and redds were not assigned to species; however, these data provide a continuous record of spawner survey information in select Western Subbasin streams.

Table 19. Index reach sampling streams and survey information for Western Subbasin streams sampled between 2002and 2012.

Stream	Years Surveyed	# of Surveys
Lower Sproul Creek	2002-2012	74
Upper Sproul Creek	2002-2012	74
West Fork Sproul Creek	2002-2012	74
Redwood Creek (Redway)	2002-2010	34
Upper Redwood (Pollock) Creek	2002-2010	35
China Creek	2002-2010	34

Data collected between 2002 and 2012 show relatively large numbers of Chinook (up to 108 live fish and 34 carcasses per season) spawning in Upper, Lower, and West Fork Sproul Creek compared to other streams surveyed. The total number of redds (not identified to individual species) observed was also greatest in the Sproul Creek watershed, with as many as 128 redds counted annually in WF Sproul Creek.

Coho salmon (live fish and carcasses) were present in all of the reaches sampled in the Western Subbasin. West Fork Sproul Creek contained the most live coho salmon (81), coho salmon carcasses (64), and total salmonid redds (128) observed during the 2011-12 sampling season.

Very few steelhead were documented during index reach sampling due to the timing of surveys, which were conducted between November and early March. The peak of steelhead spawning in the SF Eel River usually occurs in late February, but spawning continues through May.

California Coastal Salmonid Monitoring Program (CMP)

Chinook salmon, coho salmon, and steelhead trout spawning ground surveys have been have been completed annually since 2010 in SF Eel River streams, as part of the CMP program. This program is designed to describe the regional status of SONCC coho salmon in coastal watersheds, including the SF Eel River (Adams et al. 2011). The CMP uses the Viable Salmonid Population (McElhaney et al. 2000) concept, with key population characteristics including: abundance, productivity, spatial structure, and diversity, to assess viability. Repeated periodic surveys were conducted on a spatially balanced random sample of stream reaches with possible coho spawning. A total of 818 surveys were completed on 151 stream reaches throughout the SF Eel River drainage between 2010 and 2014 (*Figure 37*). The number of reaches sampled varied slightly by year, and sampling occurred between mid-November and late March.

CMP data were analyzed for the entire SF Eel River Basin, and numbers of live fish, carcasses, redds, and redd estimates were not developed for individual subbasins.

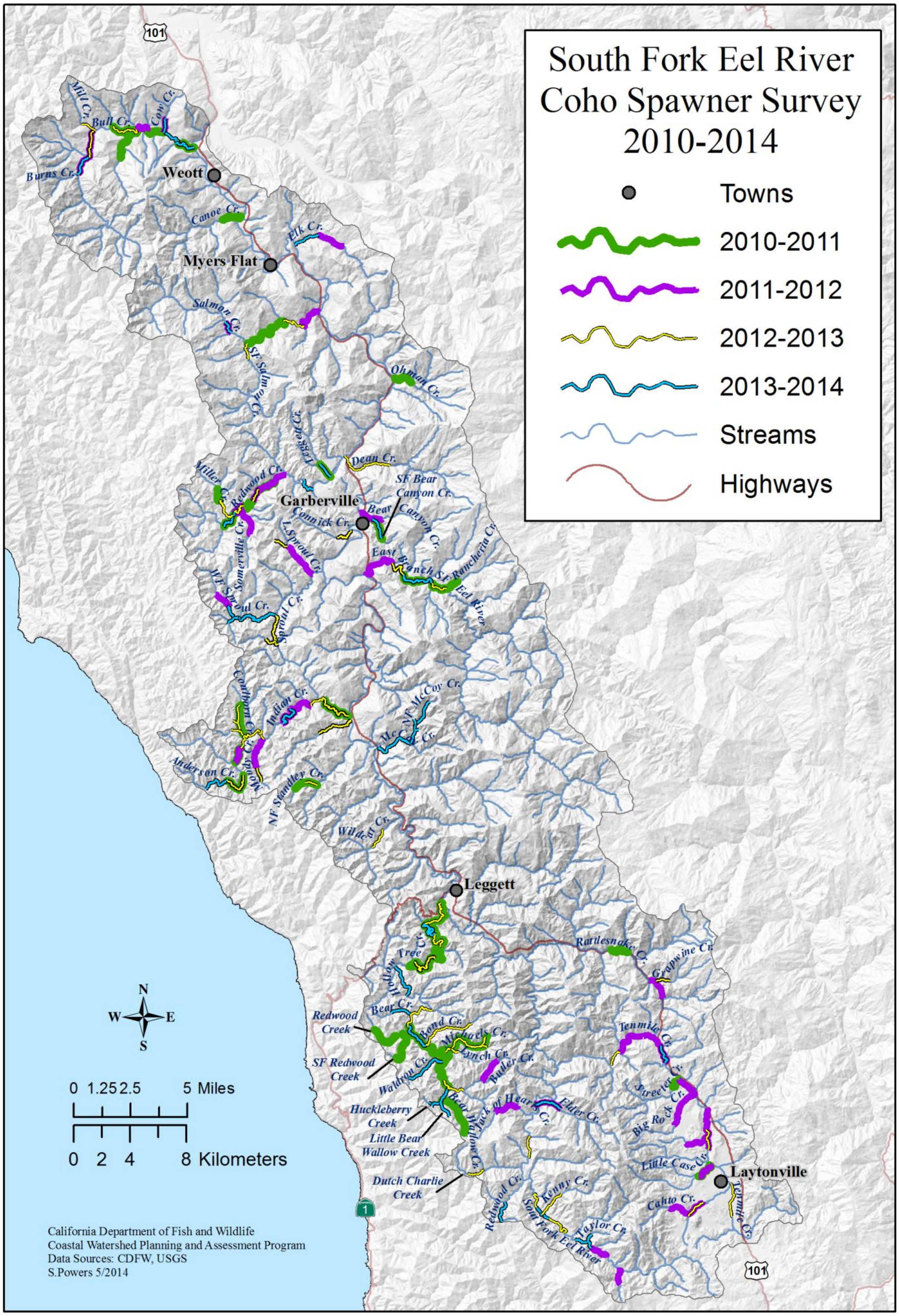

Figure 37. Location of 2010-2014 CMP spawning reaches in the SF Eel River Basin.

Field crews recorded the number of spawning fish, carcasses, and redds observed in each reach, including identifying the salmonid species that constructed each redd where possible (*Table 20*). CDFW biologists then predicted unidentified redds to species using the K-nearest neighbor algorithm (Ricker et al. in review) and estimated the total number of redds constructed across all reaches in the sample frame. Sampling methods and calculations are described in detail in Ricker et al. 2014a - 2014d.

Table 20. Summary of CMP regional spawning ground surveys and estimates of total salmonid redd construction in the SF Eel River (data from Ricker et al. 2014a - 2014d). UI = unidentified salmonids.

	Report Year			
	2010	**2011**	**2012**	**2013**
# of surveys	150	198	224	246
# of stream reaches	31	42	39	39
survey dates	11/17/2010 - 3/9/2011	11/14/2011 - 3/12/2012	11/26/2012 - 2/28/2013	11/14/2013 - 3/25/2014
# live fish				
Chinook salmon	93	63	106	17
coho salmon	39	293	33	178
steelhead	6	41	29	107
UI salmonids	44	142	41	24
# carcasses				
Chinook salmon	0	21	53	4
coho salmon	0	51	25	22
UI salmonids	2	2	0	7
# redds observed	463	495	524	349
# redds assigned to species	38	65	33	51
estimate of redds in sampling area				
Chinook salmon*	1316	569	1045	126
coho salmon	1705	1323	1346	905
steelhead*	160	431	148	736

* Chinook salmon and steelhead redd estimates represent only the time period and area encompassed by the study (Ricker et al. 2014a - 2014d).

Chinook salmon and steelhead spawning is extended both spatially and temporally compared to coho salmon. The range of Chinook and steelhead extends further upstream and in more tributaries than coho salmon, and spawning occurs during different peak times and intervals than coho salmon spawning. Therefore, redd abundance estimates for Chinook salmon and steelhead apply only to the time period and physical sampling area used in the study. Redd estimates for Chinook salmon were also not particularly accurate for the first three years (A. Renger, CDFW, personal communication 2012) due to the following limitations:

- Year 1 (2010-2011) – restricted access from landowners in selected reaches resulted in limited sampling;
- Year 2 (2011-2012) – low flow in tributaries resulted in extensive mainstem and limited tributary spawning;
- Year 3(2012-2013) – heavy rainfall in December, when most spawning occurs, limited spawning surveys (high flow and low visibility in streams).

Population estimates have not yet been developed from redd estimates because there are no redd-to-adult corrections available. These corrections are developed using life cycle monitoring stations, which are established in streams with known coho salmon presence. Essential components of a life cycle monitoring station include:

- A counting station for adults (e.g. a weir);

- Adult escapement surveys in areas above the counting station; and
- Outmigrant juvenile trapping using a fyke net, inclined plane, or rotary screw trap (*Figure 38*).

Counts of adults and outmigrating smolts are recorded, and these counts are used to calibrate spawning ground escapement estimates and freshwater and ocean survival. CDFW submitted a funding request in 2014 to establish a life cycle monitoring station in Sproul Creek in 2015, and information collected at this station will be used to assess the status of SONCC coho salmon in the ESU.

Data will be collected annually as part of the CMP in SF Eel River streams and at the life cycle monitoring station in order to generate more accurate salmonid population estimates, and results will be available in annual CDFW summary reports.

For additional information on the CMP, see Adams et al. (2011) or go to: http://www.calfish.org/Programs/CaliforniaCoastalMonitoring/tabid/186/Default.aspx/.

Figure 38. Rotary screw trap used to sample outmigrant juvenile fish.

Habitat Overview

Historic Conditions

Stream surveys were conducted as early 1938 in SF Eel River Western Subbasin streams; 112 surveys were completed in 41 creeks between 1938 and 1990. Beginning in the 1950s, CDFG (now CDFW) used a standard stream survey form to record data, but it was not until the early 1990s that a standard habitat inventory protocol was developed by Flosi et al. (first published in 1991) and is outlined in the *California Salmonid Stream Habitat Restoration Manual*. The protocol described specific data parameters, methods of data collection, and training procedures that were designed to reduce potential bias and error while collecting field data at a relatively rapid rate (Albin and Law 2006). The manual has been revised three times since 1991, and the current (4th) edition, published in 2010, is available at: http://www.dfg.ca.gov/fish/resources/habitatmanual.asp.

Two major flood events occurred in the SF Eel River Basin: December of 1955 and December of 1964. The flood crest in 1955 was 43 feet (at Weott) and in 1964, it was 46 feet (at Miranda) (CA State Parks 2012). These historic flood events, combined with land use activities (particularly timber harvest and rural residential development) have modified natural stream channels and conditions throughout the subbasin. The most notable changes have been in stream temperatures, flow regimes, and sediment input rates and volumes. These changes from historic stream conditions have resulted in reduced salmonid habitat quality and quantity.

Stream surveys were completed by CDFW on 44 streams in the Western Subbasin (including six reaches on the mainstem SF Eel River), with 120 site visits documented between 1938 and 1990 (*Table 21*). Stream survey efforts were neither specific nor standardized until 1990. Most observations in historic stream surveys are not quantitative and have limited use in comparative analysis with current habitat inventories. However, data from these stream surveys provide a snapshot of conditions, including barriers limiting fish passage at the time of survey. Streams with relatively consistent good habitat ratings were: Anderson (lower reach), Dutch Charlie, Hollow Tree, Little Sproul, Low Gap, Redwood (tributary to Hollow Tree) creeks, and the headwaters of the SF Eel River near Branscomb.

Historic habitat surveys included comments on possible barriers to fish passage; log jams were abundant due the input of material from watershed slopes to streams. Intensive logging practices, road building, and the naturally fragile landscape resulted in large amounts of sediment and logging debris in Western Subbasin streams, particularly after the major flood events of 1955 and 1964. These land use practices and related input of sediment and woody debris resulted in many log jams inventoried as partial barriers and recommended for modification or removal in the “barrier comments” sections of historic stream surveys. Barrier removal can be problematic in these streams due to the large amount of sediment behind barriers that will move downstream after removal. Historically, this has been an issue in streams with limited spawning habitat; barrier removal upstream increases fine sediment loads, which then further diminish spawning habitat quality and quantity of downstream gravels.

Table 21. Habitat observations made in the SF Eel River Western Subbasin from 1938-1990 (ND = no data recorded).

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Anderson Creek	6/19/1968	Stream Survey (CDFG 1968)	Good to excellent spawning gravel in lower areas; good shelter; with creek cleaned of logging debris, some very good spawning water for migratory fish.	Ongoing logging - continual mess of logging debris. Lower 1-2 miles is usable but not above.
	8/5 - 8/7/1978	Stream Survey (CDFG 1978)	Average stream flow conditions; medium shade canopy; invertebrates common.	Three sinks and many log jams. Not total barriers at high water.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Anderson Creek (con.)	Apr, May 1979	Stream Survey (CDFG 1979)	Excellent shelter from alders except in areas of middle reach; good pools and cover (3' depth); spawning gravels in lower reaches best; abundant invertebrates. Lowest three miles would be accessible and good salmonid habitat with barrier modification and erosion control.	Eight log and debris barriers holding sediment - removal or modification recommended for first (largest) barrier.
	8/2/1979	Gravel Sample (CDFG 1979)	ND	
Bear Pen Creek	7/11/1968	Stream Survey (CDFG 1968)	Good spawning areas; pools increased as gradient increased; mainly log shelter in pools.	One log jam should be removed 3 miles upstream from the mouth.
Butler Creek	10/29/1968	Stream Survey (CDFG 1968)	Good shade entire length (alder, tan oaks); generally good spawning areas; average pool depth 1.5'.	Recommend removal of 8 debris jams; jam 0.25 miles up North Fork is complete barrier.
	4/9/1979	Stream Survey (CDFG 1979)	Abundant shelter; average pool depth 1-2' (from upper to lower areas); recommend clearing log jams in lower reach.	
	5/10/1979	Stream Survey (CDFG 1979)	Removal of blockages would open 4 miles of good gravel to spawners; riparian vegetation sparse in some areas; silt is not a problem.	12 log jams.
	4/15/1980	Sediment Analysis (CDFG 1980)	ND	
China Creek	6/27/1962	Stream Survey (CDFG 1962)	70-80% of lower reaches good for spawning; adequate shelter in pools from undercut bedrock and brush.	18 log jams; no total barriers.
	9/5/1966	Stream Survey (CDFG 1966)	Fair to good pools and shelter; scattered areas good for Chinook spawning; more area good for steelhead spawning; low summer flows.	
	5/24 - 5/26/1982	Stream Survey (CDFG 1982)	Pool riffle ratio 1:8 - 1:5; average pool depth 2'; 50% embeddedness; 1-2 invertebrates/square ft; canopy 70-90%.	
Dinner Creek	9/1/1966	Stream Survey (CDFG 1966)	Fair spawning and nursery habitat; limited/intermittent summer flows; pools and cover fair; canopy good; limited aquatic insects.	Several log jams may be partial barriers at low flows.
	5/22/1982	Stream Survey (CDFG 1982)	Pool riffle ratios were 1:3 at beginning, 1:2 in middle, and 1:1 at end of survey; poor bank stability; 60% canopy; abundant aquatic insects.	
Durphy Creek	6/25/1938	Stream Survey (CDFG 1938)	ND	
	6/8/1961	Field Note (CDFG 1961)	Excellent spawning areas below barrier; nursery area lacking - shallow pools and no shelter; canopy cover sparse.	Total barrier 400 yards below first tributary.
	1/6/1968	Survey Notes (CDFG 1958	Erosion evident at logging points above Richardson Grove water supply; mouth of creek spreads out into three different channels, making spawner access difficult; bulldozer scheduled to clean out mouth and make single channel.	
	1/29/1980	Stream Survey (CDFG 1980)	Limited spawning habitat; canopy 80%; riparian vegetation sparse; continuous riffle in lower area, with pool riffle ratio 2:3 above; aquatic insects abundant; slide stabilization necessary.	17 barriers documented; 2 total log jam barriers near end of survey.
Dutch Charlie Creek	6/26/1938	Stream Survey (CDFG 1938)	Excellent spawning areas, pools and shelter, and arboreal shade. Abundant coho salmon and steelhead YOY.	

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Dutch Charlie Creek (con.)	6/30/1969	Stream Survey (CDFG 1969)	Good spawning areas in lower 1.5 miles; fair to poor in upper areas due to siltation; small (1') pools.	Logging debris and small jams; no total barriers. 7' bedrock falls near upper forks is end of anadromy.
	1/24/1979	Stream Survey (CDFG 1979)	Good spawning areas in middle section; good shelter from logs and boulders; shallow (1') pools in lower section, deep (3') resting pools in middle section, sparse pool habitat in upper section.	4 log jams; 2 are total barriers under some flow conditions.
Hartsook Creek	6/13/1961	Field Note (CDFG 1961)	Good spawning gravel available in 800 lineal yards of riffle habitat; good nursery habitat; good shelter and cover.	
	4/8/1981	Stream Survey (CDFG 1981)	Adequate spawning and nursery habitat; 50-70% canopy; pool riffle ratio 1:15 near mouth, 1:3 in middle of survey, and 1:1 at end; 10-30% silt substrate, highest in upper areas.	6 barriers observed; 4 possible low water barriers and one possible complete barrier.
Hollow Tree Creek	5/22/1940	Stream Survey (CDFG 1940)	Excellent pools and shelter. Steelhead, Chinook, and coho salmon present.	
	7/31 and 8/6/1968	Stream Survey (CDFG 1968)	Excellent spawning areas; deep pools (2-10'); poor shelter downstream; good flow; excellent nursery habitat.	
	1/27/1982; 2/1984	Fish Habitat Improvement Completion Form (CDFG 1982, 1984)		Emergency removal of log debris jam that was possible threat to egg collection station.
Hooker Creek	7/4/1962	Field Note (CDFG 1962)	Small area of spawning habitat but good quality; excellent shelter and nursery areas; pool riffle ratio 4:1; flow 1 cfs.	25' waterfall 650' above mouth is complete barrier.
Indian Creek	6/18/1938	Stream Survey and DFG Improvements (CDFG 1938)	Clear passage at old mill pond dam; 2 side channels at mouth improved by diverting them into main channel; excellent shelter; steelhead abundant.	Very large log jam several hundred yards below Moody Creek confluence.
	6/25/1938	Stream Survey (CDFG 1938)	ND	
	8/11/1938	Stream Survey (CDFG 1938)	Good pools and shelter; excellent spawning areas; abundant fish food; school of 250 steelhead, 75 of which were "sick" (fungus).	Removal of debris at old Anderson sawmill site would avert possible waste and barrier to fish passage.
	8/27/1982	Fish Habitat Improvement Completion (CDFG 1982)		Two logs in a waterfall removed with explosives and hand labor on Georgia Pacific land.
Indian Creek and tributaries (Jones, Moody, Coulbourn, and Anderson Creeks)	6/17 - 6/21/1968	Stream Survey (CDFG 1968)	Good spawning and nursery conditions; logging active on slopes; many good pools (up to 6' deep); good shelter in tributaries and upper Indian Creek (above Moody Creek).	15 debris jams in 10-12 mile survey; possibly passable in winter; many jams on tributaries.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Jack of Hearts Creek	3/6/1957	Field Note (CDFG 1957)		Log jam inventory and removal cost estimates. Jam #2, located 0.3 miles upstream, is complete barrier.
	7/29/1969	Stream Survey (CDFG 1969)	Good spawning areas; pools long, narrow, and shallow (1.5'deep); heavy canopy; boulder shelter in lower section; steelhead and coho salmon present.	23 log jams, 3 large in lower region; recommend removal of barriers and brush.
	2/11/1979	Stream Survey (CDFG 1979)	5% of stream area has suitable spawning area; pool riffle ratio 40:60; average pool depth 1.5 feet.	6 log jams; no total barriers but may be deterrents under most water conditions; recommend removal.
La Doo Creek	7/6/1961	Field Note (CDFG 1961)	20' fall at mouth makes creek unavailable to anadromous fish; excessive erosion upstream has increased siltation and decreased spawning and shelter area to a bare minimum.	
Leggett Creek	8/1/1938	Stream Survey (CDFG 1938)	Excellent spawning habitat; scant pools and shelter; extensive juvenile steelhead use.	
	6/20/1962	Field Note (CDFG 1962)	75% of stream area is suitable spawning habitat; pool riffle ratio 1:3; 25% of stream area provides good shelter and nursery area; abundant fish food; flow 3 cfs.	35 log jams observed; jams in gorge area are probable barriers.
	6/21/1973	Field Note (CDFG 1973)	Pool riffle ratio 1:3; logging on slopes on both sides of creek.	
	5/11/1977	Field Note (CDFG 1977)	Considerable logging in this area has resulted in accumulated material (logs and slash) in streambed, and increased siltation; removal of barriers would open up spawning potential but stream bed is heavily silted and not very suitable for spawning.	Log jams are impassable during low flows but probably passable at high flows.
	6/8/1979	Memorandum (CDFG 1979)	Adequate spawning gravel; available gravel slightly to moderately silted.	
	8/12/1980	Stream Survey (CDFG 1980)	Infrequent spawning and rearing habitat; pool riffle ratio 1:3; 50% canopy; high percentage of sand and silt in substrate.	8 barriers observed; one total obstruction at site #7.
	7/19/1984	Stream Survey (CDFG 1984)	Stream flows through narrow gorge 6-12' wide, making log jams a persistent problem; gravels loose and moderately silted; pool riffle ratio 1:4; rearing habitat lacking; canopy 40% in lower, 70% in middle, and 20% in upper sections; abundant instream invertebrates.	12 barriers observed; three were total barriers.
Little Low Gap Creek	8/14/1968	Stream Survey (CDFG 1968)	Steep gradient and debris in creek; poor conditions, low flow; not usable for salmonids.	
Little Sproul Creek	5/22/1940	Stream Survey (CDFG 1940)	Water temperature 62 degrees F. Steelhead and coho common.	
	6/23/1961	Field Note (CDFG 1961)	Good spawning and nursery areas below forks; pool riffle ratio 50:50; adequate shelter and cover; hillsides have been logged so active erosion is occurring but does not seem to be detrimental to the stream.	15 log jams; no complete barriers.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Little Sproul Creek (con.)	12/1/1981	Stream Survey (CDFG 1981)	Good usable habitat for steelhead and possibly salmon; good spawning gravel; pool riffle ratio 1:2; 5% shade canopy; sufficient escape cover.	North Fork: log jam 6' high 20' above confluence is probable barrier to salmonids; South Fork: bedrock chute at confluence with no pools.
	3/12/1985	Field Note (CDFG 1985)	Spawning and rearing habitat declined 200' above each fork confluence.	Log jam 300' downstream from forks (10'H x 50'W x 200-300'L); not a complete barrier.
	7/21 and 9/1/1988	Stream Enhancement Work Plan (CCC 1988)	Long spawning channels could be enhanced by creating pools for resting and escape areas; gravel retention needed to increase spawning material; unstable banks and lack of canopy throughout.	
Low Gap Creek	8/11/1938	Stream Survey (CDFG 1938)	Good spawning areas; good pools and shelter; scant aquatic vegetation; abundant fish food; steelhead YOY abundant.	
	7/4/1962	Stream Survey (CDFG 1962)	Pool riffle ratio 1:9; abundant good spawning gravel; large amounts of fish food; very little shelter (few trees); little existing nursery area is poor quality.	Extensive log jams and debris should be cleared.
	6/13/1968	Stream Survey (CDFG 1968)	Good spawning areas; few pools, most small; poor shelter.	7 log and debris barriers; 40' falls 3.5 miles upstream from mouth is end of anadromy. Numerous log jams in 3 tributaries.
	8/14/1968	Stream Survey (CDFG 1968)	Spawning habitat it lower reaches good, but limited above forks; excellent shelter due to narrow canyon slopes above forks; few large pools (2' deep), limited by gradient.	
	3/26/1979	Stream Survey (CDFG 1979)	Average pool depth 4'; abundant pool shelter; steep walled, sparsely foliated, narrow canyon habitat.	6 log jams; recommend removal of major jams blocking passage.
	1/31/1980	Stream Survey (CDFG 1980)	North and South Forks: shade canopy 60% (alders); good spawning areas; pool riffle ratio 1:2 except at mouth (continuous riffle); invertebrates plentiful; juveniles in side pools and adult steelhead present.	6 log jams; 2 are possible barriers to fish passage.
Lynch Creek	7/24/1968	Stream Survey (CDFG 1968)	Good spawning areas but low summer flow present nursery problems; loose log debris and jams along entire length; removal of litter recommended.	Three barriers between mouth and forks.
	8/24/1972	Aerial Stream Inventory (BLM 1972)		8-10' falls at mouth; deep pool.
Michaels Creek	7/24/1968	Stream Survey (CDFG 1968)	Poor spawning habitat at mouth, becoming good above lower 0.25 mile and excellent upstream; few 3' deep and numerous 1' deep pools; good shelter; lack of water in summer offers poor nursery conditions.	10 log jams in lower 1.5 miles of stream; no total barriers but recommend removal.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Michaels Creek (con.)	7/3/1981	Stream Survey (CDFG 1981)	Good summer flow; large amounts of spawning gravel above Lynch Creek; good canopy; feral pig streambank damage in upper drainage.	Numerous barriers recommended for removal to open 2 miles of anadromous habitat.
Piercy Creek	6/25/1938	Stream Survey (CDFG 1938)	Subsurface flow annually in summer from mouth upstream 250 yards; fish rescue work would be difficult due to snags and rough bottom.	Large log jam 250 yards upstream from mouth causes flow to go subsurface.
	6/24/1968	Stream Survey (CDFG 1968)	Spawning areas good in upper and lower reaches but poor to fair in middle; numerous pools 1.5' deep, better in upstream areas; good shade/canopy in upper reaches; good nursery areas throughout survey area.	Numerous jams, 4 intense and recommended for removal.
	9/27 - 9/28/1977	Stream Survey (CDFG 1977)	40% of lower section, 25% of middle section, and 20% of upper section was good spawning habitat; pools numerous but averaged 6/8" deep; pool riffle ratio 1:4; good nursery habitat; productivity limited by logging (wood input, bedload buildup, and increased siltation resulting in reduced flows).	Numerous log jams are partial barriers.
Redwood Creek (Branscomb)	6/26/1938	Stream Survey (CDFG 1938)	Excellent spawning areas, pools, and shelter.	
	7/31/1969	Stream Survey (CDFG 1969)	Excellent spawning areas in lower reaches decreasing in quality in upstream areas due to low velocity and siltation; average pool depth 1.5', above NF depth 1'; excellent shelter.	27 barriers recommended for removal; heavy jams in firs 1.5 miles of survey.
	1/3/1979	Stream Survey (CDFG 1979)	No spawning areas; average pool depth 1.5'; pool riffle ratio 50:50.	One total barrier (log jam #8); 10 jam areas recommended for removal - none total barriers at time of survey.
	1/4/1979	Stream Survey (CDFG 1979)	Very few spawning areas; hard clay substrate in second half of stream; pool riffle ratio 50:50; average pool depth 2'; some large pools off main stream; water muddy and silty	6 log jams recommended for removal but no total barriers.
Redwood Creek (Hollow Tree)	7/24/1968	Stream Survey (CDFG 1968)	Good spawning area at mouth but diminishing as bottom becomes more clayish where SF enters mainstem; very abundant pools (1.5' depth); heavy undergrowth of alder and tank oak; SF littered with debris and alders but has good flow.	4 intensive jams in first 0.75 miles - all are passable but recommend removal; SF littered with small jams every 100'; main creek above fork is littered entire way.
	11/14/1980	Memorandum (CDFG 1980)		Log jams observed but 50' natural falls found 400' above mouth, so recommended no effort expended to remove log jams.
Redwood Creek (Redway)	6/12/1938	Stream Survey (CDFG 1938)	Good spawning areas, pools, and shelter.	

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Redwood Creek (Redway) (con.)	circa 1962	Field Note (CDFG no date).	Pool riffle ratio 1:9; spawning areas in 7.6 miles of riffle; shelter not abundant in lower area but improves in upstream areas.	16 log jams recommended for removal - no total barriers.
	7/26/1968	Field Note (CDFG 1968)	Low flow and lots of algae; water barely trickling at mouth - may be cut off from SF Eel River in future.	
	7/20/1977	Field Note (CDFG 1977)	Mouth closed, stream intermittent.	
	1/18/1984	Field Note (CDFG 1984)	Redwood and Dinner Creeks have abundant spawning gravels but large amounts of sediment; some areas lacking in adult holding and juvenile rearing habitat.	
	7/20 and 7/30-31/1984	Stream Survey (CDFG 1984)	Pool riffle ratio 1:3; average pool depth 3'; 70% canopy; stream banks unstable and in poor condition in lower areas, but good in middle and upper areas; medium compaction of gravel.	Probable total barrier (log jam) 4500' above China Creek.
Redwood Creek (Redway) - 1000' below Frost creek to mouth.	9/6/1966	Stream Survey (CDFG 1966)	Spawning areas adequate and pools and shelter present but not abundant; limiting factors are low summer flow and associated limited food supply.	
	9/7/1966	Stream Survey (CDFG 1966)	Low flow (0.3 cfs); good pool development with moderate to poor shelter;	
Redwood Creek (Redway) - confluence of China Creek to 1.7 miles upstream.	9/24/1966	Stream Survey (CDFG 1966)	Abundant spawning areas; good pool shelter (undercut banks, logs, and debris); adequate pools.	Numerous log jams from logging operations; no total barriers.
Redwood Creek (Redway) - headwaters.	9/21/1966	Stream Survey (CDFG 1966)	Low flows but good water temperatures; poor food supply.	
Redwood Creek (Redway) UT	9/21/1966	Stream Survey (CDFG 1966)	Intermittent flows at mouth; scarce shelter; limited spawning areas.	
Sawmill Creek	3/30/1939	Stream Survey (CDFG 1939)	Good pools, shelter, and invertebrate food; abundant juvenile Chinook and steelhead.	
	7/5/1961	Stream Survey (CDFG 1961)	Gradual gradient; pool riffle ratio 1:1; several hundred yards upstream from forks, gradient steepens; light siltation; abundant shelter and nursery areas.	20,135 cubic ft of logs and debris recommended for removal; cascading waterfall 2-3 yards upstream from forks.
	4/21/1981	Stream Survey (CDFG 1981)	Suitable spawning gravel; good bank stability; gradient 4-8% at beginning of survey and 23% at end; shade canopy 50% at mouth and 80% upstream; pool riffle ratio 1:3 near mouth and 1:1 in upper half; average pool depth 1.5'.	
	2/5/1983	Field Note (CDFG 1983)	Barnum Timber Co concluded hardwood harvesting - end of commercial timber harvesting in the watershed; reduced turbidity and bedload shift; lack of meander and pools limiting for upstream migrants	Log jam 100' above bridge should be removed for upstream migrants.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Section Four Creek	9/2/1969	Stream Survey (CDFG 1969)	Below forks, spawning areas fair to good; above forks, good; few, small pools (0.5' deep); poor shelter and cover for entire survey length; poor nursery conditions; in summer, no water above forks and slight flow below; poor summer stream.	Below forks, streambed cluttered with logs and litter; short section of steep gradient 1/8 mile upstream may be partial barrier.
	2/18/1979	Stream Survey (CDFG 1979)	Good quality spawning areas below forks; pools average 10" deep; abundant shelter (logs and boulders).	Boulder 1/8 mile from mouth - total drop 30', no pools; 6 log jams between mouth and forks; final barrier is 50' vertical boulder run for 100' of stream.
Seeley Creek	6/11/1961	Field Note (CDFG 1961)	Good spawning areas; good canopy in lower reaches but logging in upper results in decreased canopy cover; pool riffle ratio 1:1.	29 log jams (ongoing restoration projects); temporary culvert will be removed; no natural barriers.
	9/22/1966	Stream Survey (CDFG 1966)	Spawning habitat suitable (available in 13% of stream); riparian vegetation limited; aquatic insects scarce.	
	1/7/1969	Field Note (CDFG 1969)	Fish observed between mouth and 1 mile upstream.	Potential log jam barrier 1.3 miles from mouth.
SF Eel River	6/8, 8/15-8/17, 8/25-8/26, 9/2-9/3, 10/21/1959	Stream Surveys (CDFG 1959)	Multiple survey locations from confluence to headwaters; high water temperatures may be limiting factor; salmonids seeking cooler water throughout survey locations (water temps 70-77 degrees F in many areas); very few fish in large pools; fish present only in pools with thermal stratification; steelhead and coho production greatest near Branscomb (good cover and cooler water).	
SF Eel River - near Branscomb	12/15/1988; 1/18/1989	Field note - carcass surveys (CDFG 1988, 1989)	Typically good; abundant spawning gravels, pools, and canopy. Woody materials lacking. Chinook and coho salmon.	
SF Eel River (100' above Cedar Creek)	9/4/1941	Stream Survey (CDFG 1941)	Good spawning areas, good pools and shelter.	
SF Eel River (Hollow Tree Creek bridge)	5/22/1940	Stream Survey (CDFG 1940)	Good spawning areas, excellent pools and shelter.	
SF Eel River - rock shop to Mud Creek	1/7/1988	Field note - carcass survey (CDFG 1988)	Abundant canopy; pool riffle ratio typically good, but long riffle stretches. Woody materials lacking. Spawning gravel fair to good - lots of fine sediment.	Several debris piles should be re-evaluated.
SF Eel River (mouth of Piercy Creek)	6/25/1938	Stream Survey (CDFG 1938)	Water temperatures too high for stocking steelhead.	Concrete dam at Reynolds Redwoods between McCoy and Red Mountain Creeks not a barrier.
SF Eel River UT (near Benbow)	2/19/1963	Field Note (CDFG 1963)	Virtually no spawning area; slopes logged extensively and much silt deposited; upper portions dry in summer months.	200 yards above mouth is 250-300 foot cascading waterfall - total barrier.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Sommerville Creek	8/1/1938	Stream Survey (CDFG 1938)	10 gpm flow; 69 degrees F.	
	9/25/1966	Stream Survey (CDFG 1966)	Spawning gravel scarce; fair pool development; adequate cover and shade except where active logging is occurring; logging practices damaging stream and hillslopes; severe siltation from logging; recommend removal of road crossings, logs, and debris.	Three log jams may be complete barriers.
Sproul Creek	6/20/1939	Stream Survey (CDFG 1939)	Water temp 60 degrees F; murky; medium to low stream condition.	
	5/23/1940	Velocity Measurement (CDFG 1940)	Good (5%) flow.	
	7/5-7/6/1961	Field Note (CDFG 1961)	Logging in upper regions results in erosion of hillsides and siltation of stream; spawning areas in lower areas plentiful; pool riffle ratio 1:1; nursery and shelter ample; little overhanging vegetation. Logging operations have pushed logs and debris into streams to use as roadbeds.	59 log jams on mainstem and 32 in West Fork. Two natural falls above West Fork are not complete barriers.
	7/26/1968	Field Note (CDFG 1968)	Low flow (1.42 cfs) at time of survey; three dams (probably to provide swimming holes) with bypasses allowing fish passage.	
	6/11 and 6/13-6/14/1984	Stream Survey (CDFG 1984)	47 sites described and considered for restoration; spawning gravel limited and habitat diversity low.	
	6/18-6/20/1984	Stream Survey (CDFG 1984)	Mainstem and tributaries surveyed. Mainstem, Cox, and tributary D contain excellent spawning and rearing habitat; revegetating slides and undercut banks would improve riparian habitat; landslide toe stabilization necessary; summer low flows are a limiting factor.	
Sproul Creek (West Fork)	2/3/1983	Stream Survey (CDFG 1983)	Relatively stable streambanks; canopy 50-80%; pool riffle ratio 1:1; average pool depth 3'; stream clearance recommended. East Branch West Fork: pool riffle ratio 1:1; average pool depth 3'; 0.25 miles upstream is bedrock canyon; 50-80% canopy.	
Standley Creek	6/27 and 7/1/1968	Stream Survey (CDFG 1968)	Good spawning areas; abundant pools 2-6' deep; good shelter from overhanging vegetation, undercut banks, and logs; excellent nursery habitat; frequent landslides from logging roads.	28 log jams on mainstem and tributaries; recommended removal of one jam (#16) and litter clearing on tributary #2.
	5/10-5/11/1976	Stream Survey (CDFG 1976)	Suitable spawning areas in 10% of stream; extensive steelhead spawning activity; large amounts of siltation from logging activities; numerous pools (in 30% of stream, averaging 3' deep); abundant pool shelter; canopy good except at mouth; recommend controlling road building and logging to minimize erosion.	No total barriers but some log jams may be barriers at certain flows. Active slides causing trees to fall into creek and may become barriers.
Surveyors Canyon Creek	9/10/1975	Stream Survey (BLM 1975)	Stream erosion caused by logging in and near stream basin has led to siltation of all gravel beds.	Numerous rock and log falls prohibit steelhead use and make stream uninhabitable for resident trout.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Waldron Creek	7/25/1968	Stream Survey (CDFG 1968)		Log jam at mouth - temporary dam created to collect water for filling tank trucks.
	7/30/1968	Stream Survey (CDFG 1968)	Few deep pools (1.5'); few, fair spawning areas; steelhead and coho YOY.	No total barriers; intensive jam 0.5 miles above mouth recommended for removal.
Warden Creek	7/5/1961	Stream Survey (CDFG 1961)	Spawning areas limited to lower 300 yards of stream; pool riffle ratio 50:50; shelter and nursery area fair.	300 yards upstream from mouth, natural gradient is barrier to migration. 11 log jams recommended for removal.
	6/27/1987	Field Note (BLM 1987)	20% pools; 80% canopy; active logging on side slopes; not adequate salmonid habitat due to lack of spawning areas, pools, and flow.	Falls at mouth prevent fish migration.
Wildcat Creek	7/15/1968	Stream Survey (CDFG 1968)	Spawning conditions fair at mouth and improving to good upstream; numerous pools (2' deep); good pool shelter.	Debris plentiful but no total barriers; jams more numerous and intense in upper areas due to new logging operations.

Current Conditions

A total of 110 habitat inventories were conducted by CDFW in the Western Subbasin between 1990 and 2010 (*Table 22*). Most streams were surveyed twice within that time frame, and survey lengths ranged from 14.82 miles (Hollow Tree Creek 1992) to 0.19 miles (SF Redwood Creek 2003). Survey data were divided into two sampling periods (1990-1999, and 2000-2010) in order to assess changes in habitat factors and suitability of habitat for salmonids over time.

The number of reaches and the total stream length surveyed varied by stream. Habitat typing surveys describe specific stream reaches by Rosgen channel type (see Channel Types section of this report) and sequence. Reaches show characteristics of certain channel types for a minimum distance of 20 bankfull channel widths (Flosi et al. 2010), but are highly variable in overall length.

Some streams were surveyed in multiple years within each sampling period, and if the surveys covered the same area of stream, only the most recent survey information (from 44 streams) was used in the EMDS-based analysis. Only habitat typing surveys completed on perennial streams were used in the analyses. However, some perennial streams contain dry reaches during certain times of the year (usually in late summer) due to variation in annual precipitation, natural aquifer levels, and magnitude of diversion. These dry reaches were categorized as Type 7 (Flosi et al. 2010) in habitat typing reports.

Streams that were surveyed during both time periods were often completed at different times of the year (e.g. Bear Wallow Creek was surveyed in June in 1990 but in September-October in 2002). For a complete list of the month each survey was completed, see *Table 35* in the SF Eel River Basin Overview. Environmental conditions vary by month and year, and may influence habitat suitability values. For example, flow is reduced between mid-July and early- to mid-September in streams throughout the Western Subbasin (due to limited rainfall, evapotranspiration by plants, groundwater levels, and the number and magnitude of diversions), so primary pool values and corresponding scores would most likely be lower in creeks where sampling was completed during this time interval. Variability in rainfall received during wet and dry years may also influence flow, and therefore habitat factors and suitability values. According to records from the USGS gauge at Leggett (RM 66), which is located within the Western Subbasin boundary, annual flow was very high in 1998 and 2006, and very low in 1991 and 2001 (*Figure 6*).

CWPAP staff evaluated habitat typing data using an analysis based on the Ecological Management Decision Support (EMDS) model used in previous CWPAP Watershed Assessments. Rating scores were developed from habitat typing data summarized in *Table 22* and were used in the analysis to evaluate stream reach conditions for salmonids based on water temperature, riparian vegetation, stream flow, and in channel characteristics. Additional analysis details can be found in the Analysis Appendix and in the NCWAP Methods Manual, available at: http://coastalwatersheds.ca.gov/. Calculations and conclusions in the analysis are pertinent to surveyed streams and are based on conditions existing at the time of each survey.

Surveys completed on the same stream during both time periods may also show differences in habitat values because of changing land use practices. For example, in Redwood Creek, there has been a dramatic increase in the number and magnitude of marijuana cultivation operations in the past few decades (see the Industrial Marijuana Agriculture section of this report). Increased diversions from these operations have resulted in lower flows and reduced pool depth suitability in this watershed.

Observer variability and error during habitat typing surveys may also account for changes in habitat variables over time but error and bias can be minimized through use of standards and training. Well-designed sampling schemes, comprehensive observer training, and the use of established operating protocols (e.g. the *California Salmonid Stream Habitat Restoration Manual)* will result in monitoring that effectively detects changing stream conditions (Roper et al. 2002). Because of observer and other error sources, habitat typing is best suited to detecting fundamental changes in Level I or II habitat types (Gerstein 2005), and to identify potential limiting factors for salmonids in specific watersheds for assessment purposes.

Summary values of each factor and the associated target values for these attributes are listed in *Table 22*. Average embeddedness, length of primary pools, and pool shelter ratings for all streams in the subbasin were below target values during each time period. Average canopy density for all Western Subbasin streams was below the target value of 80% in the 1990s, but increased to 88.5% in the 2000-2010 sampling period, which exceeded the target value established by Flosi et al. (2010). The importance of each habitat factor to salmonids, and their effect on habitat suitability will be discussed in detail in the individual factor sections of this subbasin report.

Table 22. Summary of CDFW habitat inventories used in analysis for streams in the SF Eel River Western Subbasin, and associated target values. Averages are weighted by stream length surveyed.

Stream	Survey Year	Survey length (miles)	Mean Canopy Density (%)	Category 1 Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Pool Shelter Rating
TARGET VALUES			**>80**	**>50**	**>40**	**>100**
Anderson Creek	2008	2.29	97.1	64.7	ND	22.4
Bear Pen Creek	1992	3.38	66.5	2.0	5.0	33.2
	2007	2.82	79.4	26.7	6.1	41.6
Bear Wallow Creek	1990	1.41	86.7	78.0	4.76	105.9
	2002	2.14	96.1	29.7	8.7	48.6
Bond Creek	1991	1.83	49.8	9.8	1.9	54.6
Bond Creek (con.)	2003	2.63	92.4	23.8	10.0	62.8
Butler Creek	1990	1.22	76.0	75.6	7.3	112.7
	2002	1.43	96.2	52.0	4.5	34.8
Butler Creek (unnamed left bank tributary)	2002	0.29	97.9	73.0	3.8	43.0
China Creek	1998	2.87	87.9	0.8	12.1	32.6
	2009	2.20	92.9	35.0	18.1	29.7
Cox Creek (SF Eel River)	1993	1.22	72.6	8.0	1.1	44.6
	2004	1.29	96.7	0.0	0.9	27.7

Stream	Survey Year	Survey length (miles)	Mean Canopy Density (%)	Category 1 Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Pool Shelter Rating
Doctors Creek	1991	0.16	66.5	0.0	0.5	68.5
	2003	0.30	96.8	80.0	3.1	56.3
Durphy Creek	2006	1.76	74.2	13.6	0.9	9.1
Durphy Creek (unnamed left bank tributary)	1993	0.43	60.2	5.0	0.0	39.5
	2006	0.49	79.3	38.0	0.1	10.9
Dutch Charlie Creek	1992	3.55	84.7	0.0	18.8	24.9
	2007	2.88	98.1	22.6	20.6	59.1
Hartsook Creek	1999	1.25	88.8	17.0	0.4	5.7
	2009	1.32	89.0	36.8	0.5	24.0
Hollow Tree Creek	1992	14.82	32.5	13.0	22.8	38.2
	2002	1.89	88.8	16.9	10.2	31.9
	2003	3.44	91.9	26.0	13.6	38.3
Huckleberry Creek	1990	1.18	80.9	21.0	17.4	87.7
	2002	1.48	98.5	28.0	14.6	36.4
Indian Creek	1993	11.15	53.7	34.3	23.7	46.6
	2008	9.75	82.0	78.5	34.0	11.5
Jack of Hearts Creek	1992	2.88	84.2	14.0	6.7	49.2
	2005	3.07	93.7	53.0	10.7	37.2
Leggett Creek	1995	2.31	75.8	3.0	7.6	20.6
	2007	3.25	87.6	21.0	5.3	23.1
Little Sproul Creek	1995	1.66	85.9	0.0	8.1	44.8
Little Sproul Creek (unnamed tributary)	2004	0.92	94.2	0.0	ND	41.8
Low Gap Creek	1990	2.71	19.4	10.4	1.7	77.8
	2007	2.51	79.6	31.0	3.4	49.5
Lynch Creek	1991	0.31	67.3	0.0	0.0	42.0
	2003	0.19	94.1	10.0	3.5	62.0
Michaels Creek	1991	1.75	40.1	5.0	4.0	28.4
	2003	2.60	93.2	75.4	8.3	56.8
Mill Creek	2010	0.33	92.4	29.0	10.6	21.2
Moody Creek	1993	1.65	88.5	5.0	2.6	69.3
	2008	1.74	92.6	51.0	11.6	18.2
Piercy Creek	2007	2.21	92.0	14.2	3.2	57.1
Pollock Creek (Upper Redwood Creek)	1998	2.04	90.5	0.0	17.1	28.5
	2009	2.68	95.1	23.5	12.1	35.3
Redwood Creek (Hollow Tree Creek)	2003	1.99	90.8	2.0	41.8	31.5
Redwood Creek (Branscomb)	1993	2.43	81.9	5.6	29.6	36.4
	2007	2.43	96.9	1.9	23.4	75.2
Redwood (Redway)	2009	7.43	66.1	71.8	27.3	20.1
SF Eel headwaters	1996	9.06	82.5	1.0	11.9	42.2
	2007	5.38	94.6	11.0	29.2	47.4
SF Redwood	1991	1.68	87.5	0.0	15.7	69.2
	2003	1.86	92.0	0.0	20.2	24.4
SF Redwood (unnamed tributary)	2003	0.19	90.6	0.0	0.5	5.0
Sproul	2004	6.15	83.3	10.8	18.1	33.7
Sproul (tributary 5)	2004	0.48	99.4	5.0	0.2	16.8
Standley Creek	1992	3.10	61.4	13.0	17.6	46.4

Stream	Survey Year	Survey length (miles)	Mean Canopy Density (%)	Category 1 Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Pool Shelter Rating
	2007	3.04	82.3	5.5	19.0	20.1
	2009	1.91	94.0	56.0	7.3	21.2
Twin (unnamed tributary to China)	2009	0.54	97.4	55.0	0.9	30.3
Waldron	1991	1.38	74.8	1.0	4.7	35.9
	2002	1.44	83.4	40.6	17.8	46.1
Warden	1992	0.38	78.6	0.0	0.2	37.0
	2004	0.38	97.2	18.2	5.1	56.4
WF Sproul	1992	5.52	80.6	0.0	14.4	28.4
	2004	5.04	95.4	12.1	17.2	62.5
WF Sproul (tributary 8)	2004	0.55	98.5	0.0	0.7	63.1
WF Sproul (tributary 9)	2004	1.54	98.4	7.0	6.9	75.4
Wildcat	1992	2.37	64.0	28.2	8.7	44.5
	2007	2.31	93.8	73.0	16.5	53.7
Wood	2002	0.99	84.6	30.5	3.5	14.3
AVERAGES	1990-1999		64.7	12.7	12.5	43.5
	2000-2010		88.5	34.4	14.5	36.4

Overall Habitat Suitability

Four factors (canopy density, pool depth, pool shelter complexity, and substrate embeddedness) were used in the EMDS-based analysis to determine overall habitat suitability using habitat typing data collected from two separate time periods: 1990 to 1999, and 2000 to 2010. Suitability scores were calculated by assessing how measured values compared to target values for each factor. Overall habitat suitability and suitability of each factor used in the analysis were calculated based on a weighted (by reach or stream length surveyed) average for Western Subbasin streams in each time period, and the change in suitability between time periods was compared for streams and for individual reaches.

Suitability scores ranged between +1 and -1, and were divided into four categories:

- 1.00 - 0.50 (high suitability);
- 0.49 - 0;
- -0.01 - -0.49; and
- -0.50 - -1.00 (low suitability).

Scores were weighted by survey length to facilitate comparison of habitats between different tributaries based on sampling effort. For a detailed discussion of the analysis framework and calculation of suitability scores, see the Analysis Appendix.

Overall habitat suitability increased in Western Subbasin streams between the 1990s and early 2000s, but scores were still low (negative values) during both sampling periods (*Table 23*). Overall suitability increased over time mainly due to an increase in embeddedness scores, but also due to a small increase in pool depth scores between the two sampling periods.

Table 23. Overall suitability and suitability by factor in SF Eel River Western Subbasin streams during two sampling periods: 1990-1999 and 2000-2010 (suitability scors range between 1 and -1).

Sampling period	Stream miles surveyed	Overall habitat suitability score	Canopy density suitability score	Pool depth suitability score	Pool shelter suitability score	Pool quality score	Embeddedness suitability score
1990-1999	85.70	-0.75	0.06	-0.71	-0.60	-0.62	-0.44
2000-2010	101.55	-0.39	0.87	-0.61	-0.69	-0.64	0.15

Canopy density scores were higher than any other factor scores used in the EMDS-based analysis. In the model, canopy density (riparian vegetation score) was evaluated with an "in channel score" (a combination of pool depth, pool complexity, and substrate embeddedness factors, all weighted equally), at the final decision node where the lower of the two scores was used to indicate the potential of the stream reach to sustain salmonid populations. In Western Subbasin streams, in channel scores were almost always lower than canopy density scores, therefore, canopy density scores were often not used as the final indicator of a stream's potential to support salmonids. Canopy density scores were lower for data collected in the 1990s than in the 2000s, but were only lower than in channel scores 5 times for data collected during the 1990s and only once using data collected between 2000 and 2010.

Most Western Subbasin streams and reaches showed improvement in overall suitability between the two sampling periods (*Figure 39*). Different stream reaches were sampled in Redwood, Sproul, and Hollow Tree creeks during each time period, but overall suitability scores still increased in these watersheds.

In the Indian Creek drainage, overall suitability increased from the lowest level (-0.79) to the second highest level (0.47) of suitability because of an increase in the percentage of habitat with category 1 embeddedness, and also due to very low canopy scores in the 1990-1999 sampling period. Canopy densities recorded on habitat surveys in Indian Creek in 1993 were very low (53.7%), which resulted in a lower riparian score than in-channel score, and a very low overall suitability score. In 2008, pool depth, cobble embeddedness, and canopy density were excellent in Indian Creek, and only pool shelter was low, resulting in relatively high overall suitability.

Overall suitability in 3 tributaries in the upper Hollow Tree Creek drainage increased in suitability between the two sampling periods (Waldron, Bond, and Michaels), however, overall suitability decreased in Bear Wallow Creek and Butler Creek due to decreases in pool shelter scores. Habitat in the upper mainstem of Hollow Tree Creek (from Redwood Creek upstream to the headwaters) is some of the best salmonid habitat in the Western Subbasin, and coho salmon have been found in more tributaries in this watershed than in any other SF Eel River catchment. Management activities and restoration projects should address the need for increased pool shelter in streams throughout this watershed.

Although overall suitability scores improved over time, most reaches had negative suitability scores, as indicated by red and orange segments, during both time periods (*Figure 39*). In the 1990-1999 sampling period, only Butler and Bear Wallow creeks had positive overall suitability scores.

Although unstable geology, high road density, and active timber harvesting in the Western Subbasin negatively affects pool depth pool and pool shelter (and therefore pool quality), increases in overall suitability may be due to changes in land use and restoration efforts in areas throughout the subbasin. Most of this subbasin was heavily logged in the last century. However, since 1973 with the passage of the Z'Berg-Nejedly Forest Practice Act, environmental regulations have increased and environmental disturbance and the amount of timber harvested have been reduced. Road decommissioning and improvement, instream habitat, and upslope restoration projects are ongoing, especially in Redwood Creek (near Redway) and Hollow Tree Creek watersheds. Reduced disturbance is reflected in increasing habitat suitability, and with time, management practices and restoration projects that improve salmonid habitat may be expressed by factor values approaching target values, with associated increases in suitability scores. Individual factors scores and how they may influence overall scores are discussed in more detail in the following sections.

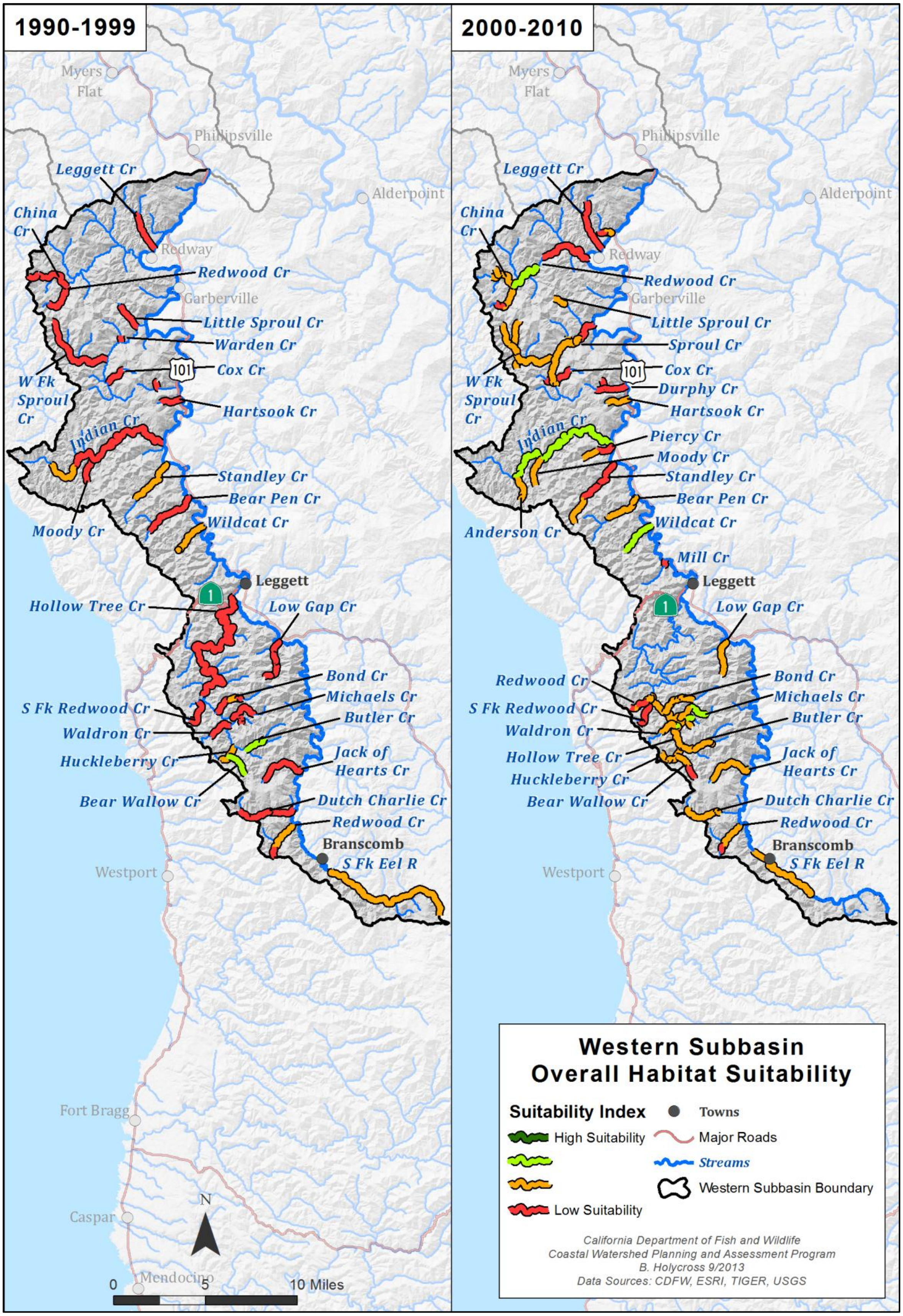

Figure 39. Overall habitat suitability in SF Eel River Western Subbasin streams in two sampling periods: 1990-1999 and 2000-2010.

Canopy Density

Canopy density is one of the measurements estimated during CDFW habitat surveys. These measurements, which are defined as a percentage of shade canopy over the stream, provide an indication of potential recruitment of organic debris to the stream channel, and are a measure of the insulating capacity of the stream and riparian areas during the winter. Canopy density may also contribute to microclimate conditions that help moderate air temperature, an important factor in determining stream water temperature. Stream canopy relative to the wetted channel normally decreases in larger streams as channel width increases due to increased drainage area. The CDFG Restoration Manual established a target of 80% for shade canopy along coastal streams (Flosi et al. 2010). The CDFW recommends areas with less than 80% shade canopy as candidates for riparian improvement efforts.

Canopy density is generally good in Western Subbasin streams, and average values increased in streams between the two sampling periods. Using data collected between 1990 and 1999, 16 streams did not meet the target value of 80%, and four of those were below 50% canopy cover (*Figure 40A*). Habitat typing reports from 2000-2010 showed only 5 streams with canopy densities below target values, and none of these were in the <50% category (*Figure 40B*).

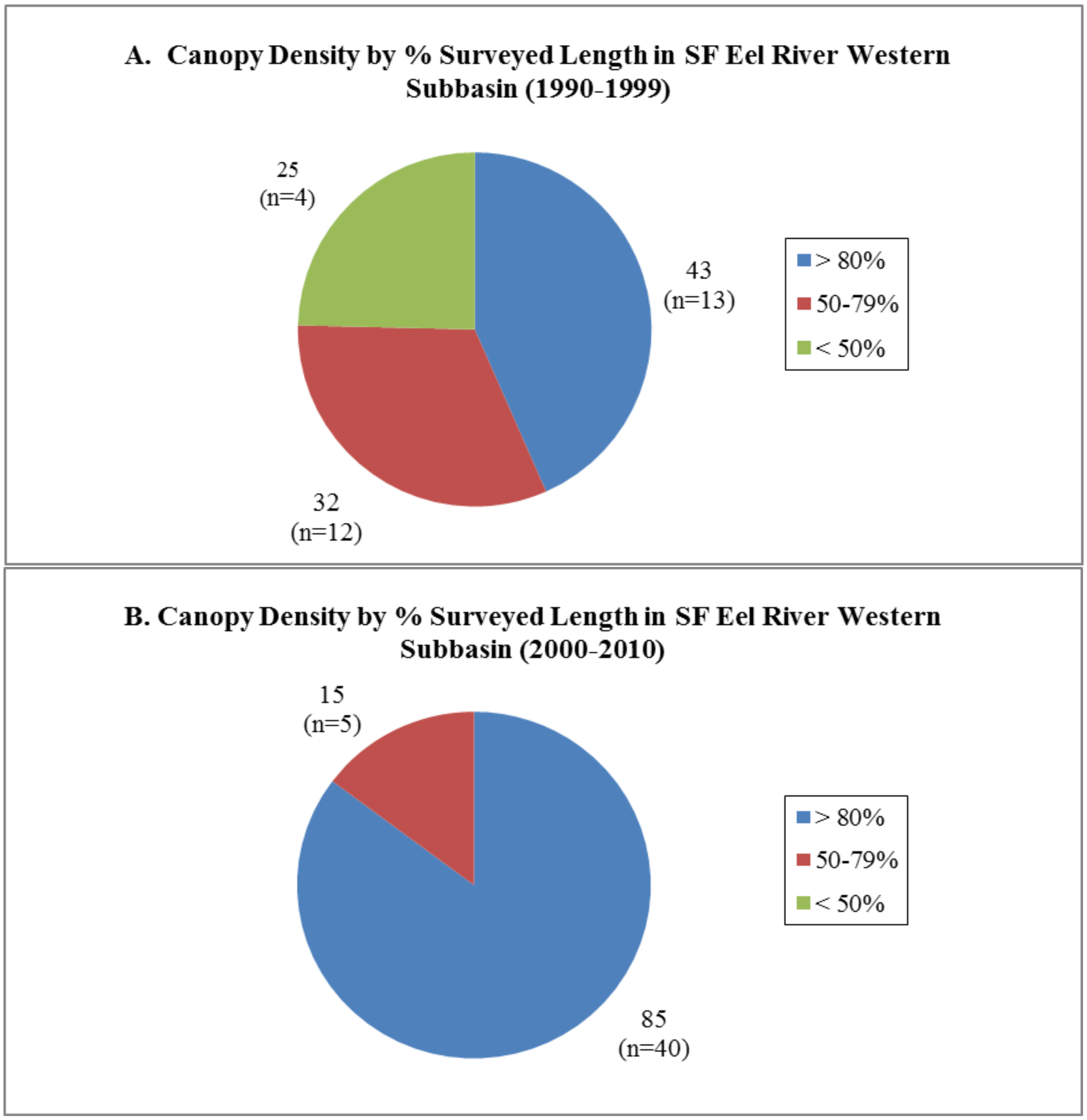

Figure 40A, B. Canopy Density by percent habitat typing survey length in Western Subbasin streams, using data collected from 1990-1999 (A) and 2000-2010 (B); n = number of streams surveyed.

Canopy density suitability scores increased in most Western Subbasin streams between the two sampling periods (*Figure 42*). From surveys completed between 1990 and 1999, the average canopy score for all Western Subbasin streams was 0.06 (*Table 23*). During this sampling period, canopy density was in the lowest suitability category in Indian, mainstem Hollow Tree (below Redwood Creek), Michaels, and Low Gap Creek, and two reaches in Bond Creek.

From surveys completed between 2000 and 2010, the average canopy score for all streams was 0.87. Most streams were in the highest suitability category, and only two reaches in the entire subbasin had riparian vegetation scores that were negative (unsuitable). The lower reach of Redwood Creek (near Redway) had a canopy density score in the lowest suitability category when sampled in 2009, and one reach in lower Sproul Creek had a score in the second to lowest suitability category when sampled in 2008. These reaches were not sampled in the previous decade so there is no quantitative information available to determine how canopy density changed over time.

In Hollow Tree Creek, canopy density was much lower in the earlier sampling period, but surveys in the 1990s were conducted in the mainstem, from the confluence with the SF Eel River upstream to Redwood Creek (*Figure 42*). The stream channel in this lower area of Hollow Tree Creek is relatively wide and lower canopy densities are expected. The lower mainstem is also not used much for spawning; most fish travel upstream to tributaries in the headwaters above Redwood Creek, using the lower reaches of Hollow Tree Creek primarily as a migratory corridor (A. Renger, CDFW, personal communication 2013). Canopy density in upper Hollow Tree Creek, including in Michaels Creek (*Figure 41*) has improved over time due to timber harvest policies promoting streamside canopy and riparian management (MRC 2004) and to the relatively large number of upslope restoration projects completed in tributaries above Redwood Creek.

Canopy density improved over time in Indian Creek, and the same reaches were sampled during both time periods. Most of the land in this watershed is owned by industrial timber companies, and was intensively harvested in the 1990s. Riparian habitat may have grown back by the time habitat crews collected data in 2008.

Figure 41. Example of good canopy density in Michaels Creek.

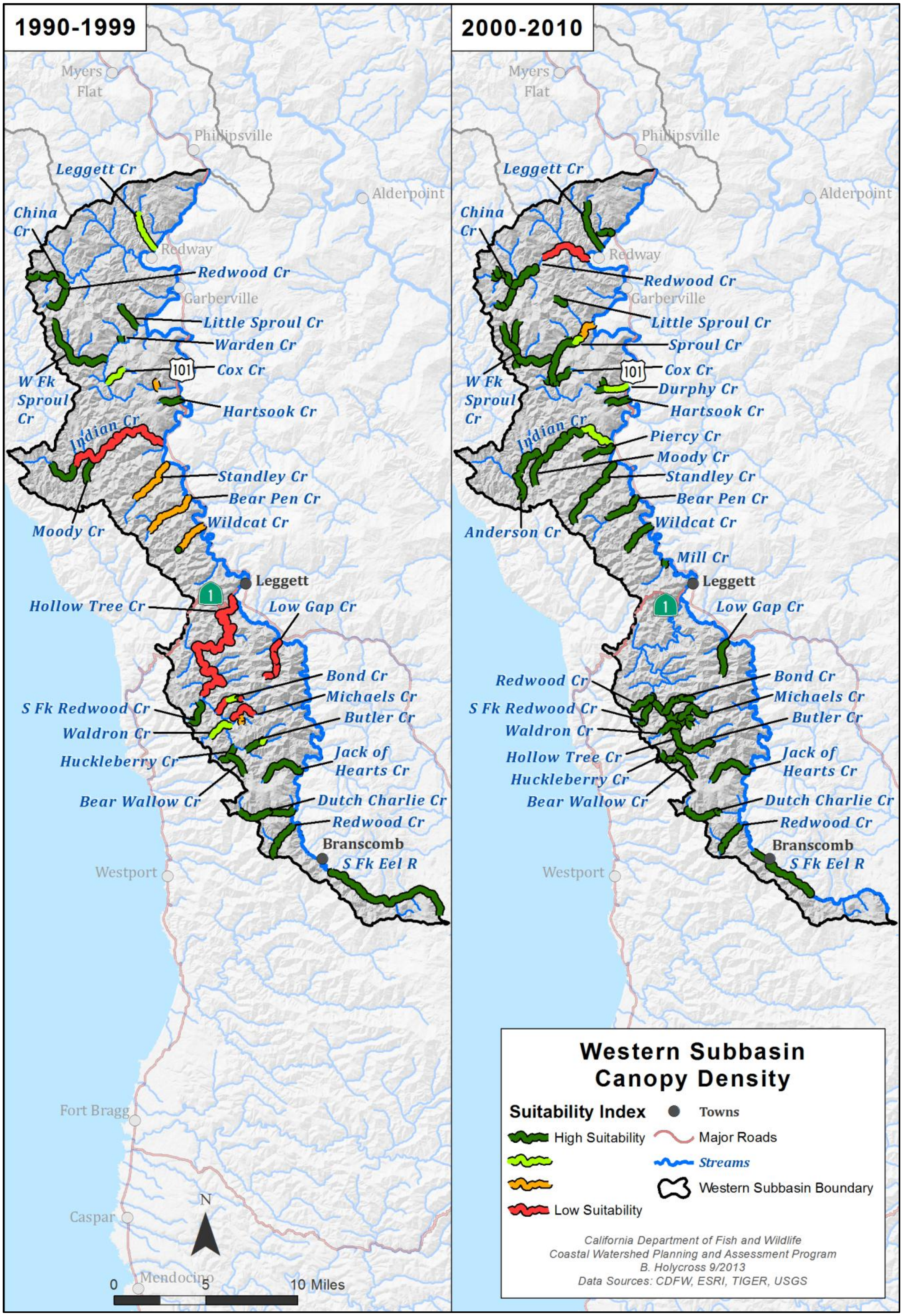

Figure 42. Canopy density suitability for Western Subbasin streams during two sampling decades: 1990-1999 and 2000-2010.

In addition to overall canopy density, it is important to consider the contribution of coniferous and deciduous components in the canopy. Dense deciduous riparian vegetation such as alder and maple trees provide excellent canopy closure and habitat/food for macroinvertebrate production, but do not provide the LWD recruitment potential of larger, more persistent coniferous trees (Everest and Reeves 2006). In Western Subbasin streams, the percent contribution of canopy density from coniferous and deciduous trees was estimated visually during habitat typing surveys.

Coniferous canopy cover was relatively low (< 50%) in most streams in the Western Subbasin. Very low (< 10%) coniferous canopy densities were recorded in Bond (1991), Doctor's (2003), unnamed tributary to Durphy (1993 and 2006), Hollow Tree (1992 and 2003), Michaels (1991), Mill (2010), and Sproul (2004) Creeks (*Table 24*).

For streams with survey data available during both time periods, the average percent of open canopy decreased in all streams over time and the percent coniferous vegetation increased in 50% of streams (*Table 24*). The average percent of deciduous canopy increased in nearly all streams, but decreased slightly in SF Redwood Creek and decreased considerably in Jack of Hearts Creek. Most of the land in this subbasin is used for industrial timber harvest, and although management plans are designed to promote streamside canopy and riparian habitat, reductions in coniferous habitat are expected.

Table 24. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Western Subbasin.

STREAM	AVG%CONIFEROUS	AVG%DECIDUOUS	AVG%OPEN
Anderson Creek 08	45.5	51.6	2.9
Bear Pen Creek 92	23.3	43.2	33.5
Bear Pen Creek 07	17.6	61.8	20.6
Bear Wallow Creek 02	32.6	63.5	3.9
Bond Creek 91	7.5	42.3	50.2
Bond Creek 03	35.7	56.7	7.6
Butler Creek 02	22.2	74.0	3.8
Butler Crk LB Trib 3 02	17.0	80.9	2.1
China Creek 98	12.8	75.1	12.1
China Creek 09	10.2	82.7	7.1
Cox Creek 93	11.6	61.0	27.4
Cox Creek 04	20.9	75.8	3.3
Doctors Creek 91	21.6	44.9	33.5
Doctors Creek 03	6.1	90.7	3.2
Durphy Creek 06	18.4	55.8	25.8
Durphy Creek UT 93	6.7	53.5	39.8
Durphy Creek UT 06	7.6	71.7	20.7
Dutch Charlie Creek 92	13.6	71.1	15.3
Dutch Charlie Creek 07	25.1	72.9	1.9
Hartsook Creek 99	27.4	61.4	11.2
Hartsook Creek 09	16.9	72.1	11.0
Hollow Tree Creek 92	1.6	30.9	67.5
Hollow Tree Creek 02	16.0	72.8	11.2
Hollow Tree Creek 03	6.4	85.5	8.1
Huckleberry Creek 02	24.7	73.4	1.9
Indian Creek 93	16.4	37.3	46.3
Indian Creek 08	16.1	65.9	18.0
Jack of Hearts Creek 92	38.9	45.3	15.8
Jack of Hearts Creek 05	66.3	27.5	6.3
Leggett Creek 95	31.5	44.3	24.2

STREAM	AVG%CONIFEROUS	AVG%DECIDUOUS	AVG%OPEN
Leggett Creek 07	27.9	59.7	12.4
Little Sproul Creek 95	41.8	44.1	14.1
Little Sproul Creek UT 04	15.4	78.9	5.8
Low Gap Creek 07	22.3	57.3	20.4
Lynch Creek 91	22.7	44.6	32.7
Lynch Creek 03	35.5	58.6	5.9
Michaels Creek 91	7.6	32.5	59.9
Michaels Creek 03	18.5	74.7	6.8
Mill Creek 10	3.9	88.5	7.6
Moody Creek 93	19.5	69.0	11.5
Moody Creek 08	15.7	76.9	7.4
Piercy Creek 07	18.0	74.1	8.0
Pollock Creek (aka Upper Redwood) 98	18.0	72.5	9.5
Pollock Creek (aka Upper Redwood) 09	19.5	75.6	4.9
Redwood Creek (Hollow Tree) 03	34.2	56.5	9.2
Redwood Creek (Branscomb) 93	53.1	28.7	18.2
Redwood Creek (Branscomb) 07	39.2	57.8	3.1
Redwood Creek (Redway) 09	14.4	51.7	33.9
South Fork Eel River 96	16.0	66.5	17.5
South Fork Eel River 07	17.8	76.8	5.4
South Fork Redwood Creek 91	34.0	53.5	12.5
South Fork Redwood Creek 03	40.0	52.0	8.0
South Fork Redwood Creek UT 03	58.9	31.7	9.4
Sproul Creek 04	7.1	76.3	16.7
Sproul Creek Trib 5 04	14.3	85.1	0.6
Standley Creek 92	21.2	40.2	38.6
Standley Creek 07	33.8	48.5	17.7
Standley Creek 09	41.7	52.3	6.0
Twin Creek UT to China Creek 09	25.5	71.9	2.6
Waldron Creek 91	27.2	47.6	25.2
Waldron Creek 02	27.1	56.2	16.6
Warden Creek 92	31.4	47.2	21.4
Warden Creek 04	17.5	79.6	2.8
West Fork Sproul Creek 92	15.1	65.5	19.4
West Fork Sproul Creek 04	12.6	82.8	4.6
West Fork Sproul Creek Trib 8 04	21.7	76.8	1.5
West Fork Sproul Creek Trib 9 04	23.9	74.5	1.6
Wildcat Creek 92	11.1	52.9	36.0
Wildcat Creek 07	10.6	83.2	6.2
Wood Creek 02	45.7	38.9	15.4

Pool Depth

Primary pools provide salmonids with escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas. Generally, a stream reach should have 30 to 55% of its length in primary pools to be suitable for salmonids. Good coho salmon streams have >40% of total length in primary pool habitat. According to Flosi et al. (2010), in first and second order streams, a primary pool is described as being at least 2.5 feet deep; in third and fourth order streams, primary pool depths are 3 feet and 4 feet, respectively. Because pools are important salmonid habitat even if they are slightly shallower than the established primary pool guidelines, CWPAP staff adjusted primary pool length data for use in the analysis. This adjustment allowed 25% of the length of pool habitat in the depth category below the minimum for each stream order class to be represented in the analyses. For example, in first and second order streams, where pools ≥ 2.5 feet deep are considered primary, 25% of the length of pool habitat between 2 and 2.5 feet deep was added to the total primary pool length to obtain an adjusted percent of primary pool habitat. For third and fourth order streams, 25% of pool habitat between 2.5 and 3 feet, and 3.5 and 4 feet, respectively, was added to the primary pool length. For a complete description of pool depth categories and details of pool depth calculations, see the Analysis Appendix.

Table 22 lists the percent length of primary pool habitat by stream. Percentages ranged from zero (in Lynch Creek and in an unnamed tributary to Durphy Creek) to 41.8% (in Redwood Creek, tributary to Hollow Tree Creek). Redwood Creek (2003) was the only location sampled where the percent of primary pool habitat met the target value of 40%. Overall percent primary pool habitat (weighted by surveyed length) was 12.5% for habitat surveys completed in the 1990s, and increased slightly to 14.5% for surveys in the early 2000s. These averages are well below target values of >40%.

The percent of primary pool habitat in first through third order streams was very low (10% or less) in both the 1990s and the early 2000s (*Figure 43*). Although the percent of primary pool habitat is low, it increased slightly over time in first and second order streams, and nearly doubled in third order streams.

Lower Hollow Tree Creek was the only 4th order stream habitat sampled in the 1990s, and the percent of primary pool habitat was 22.8% (of 14.8 miles of stream surveyed). This reach was not sampled between 2000 and 2010.

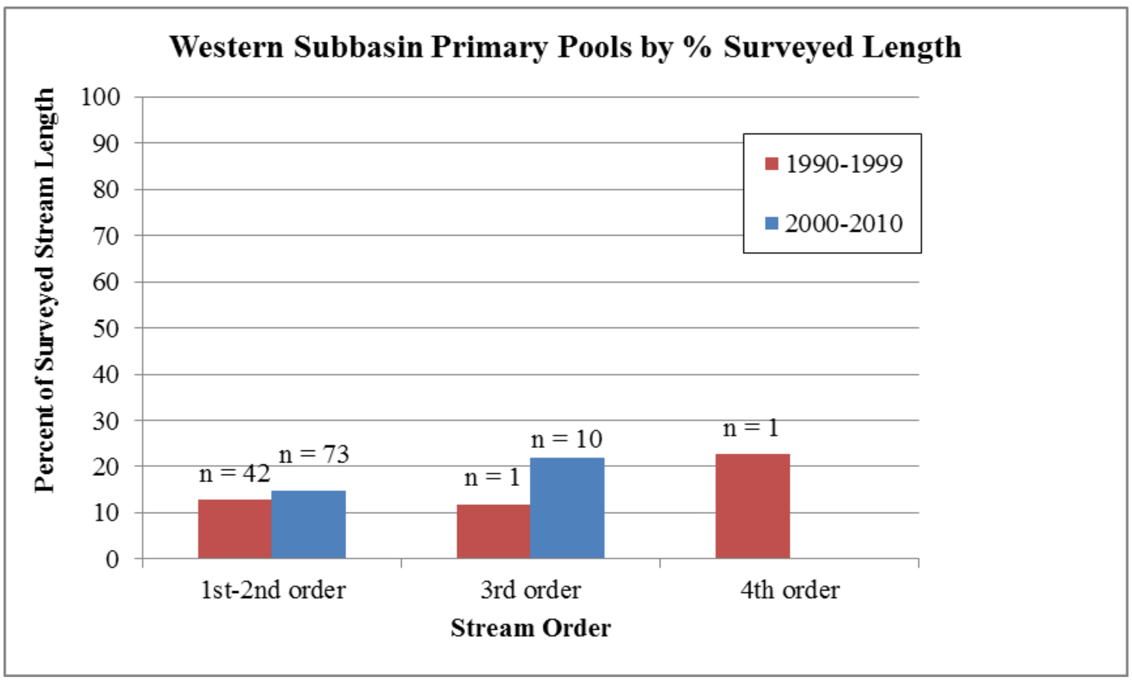

Figure 43. Percent of surveyed habitat in primary pools in the Western Subbasin, using data collected from 1990-1999 and 2000-2010.

Pool depth suitability in Western Subbasin streams was in the lowest category for most streams during both sampling periods (*Figure 44*). Indian Creek and the mainstem SF Eel River headwaters near Branscomb showed considerable improvement between the 1990s and early 2000s. Pool habitat suitability improved in some areas of WF Sproul, Standley, Redwood (tributary to Hollow Tree Creek), and Dutch Charlie creeks between the sampling periods, and deteriorated over time in Redwood Creek (near Branscomb). Tributaries in upper Hollow Tree Creek are important coho spawning and rearing habitats, and most streams had pool depth suitability levels in the lowest category, during both the 1990s and early 2000s. Western Subbasin streams receive a tremendous amount of sediment from both anthropogenic (mainly timber harvest and roads) and natural sources. Heavy

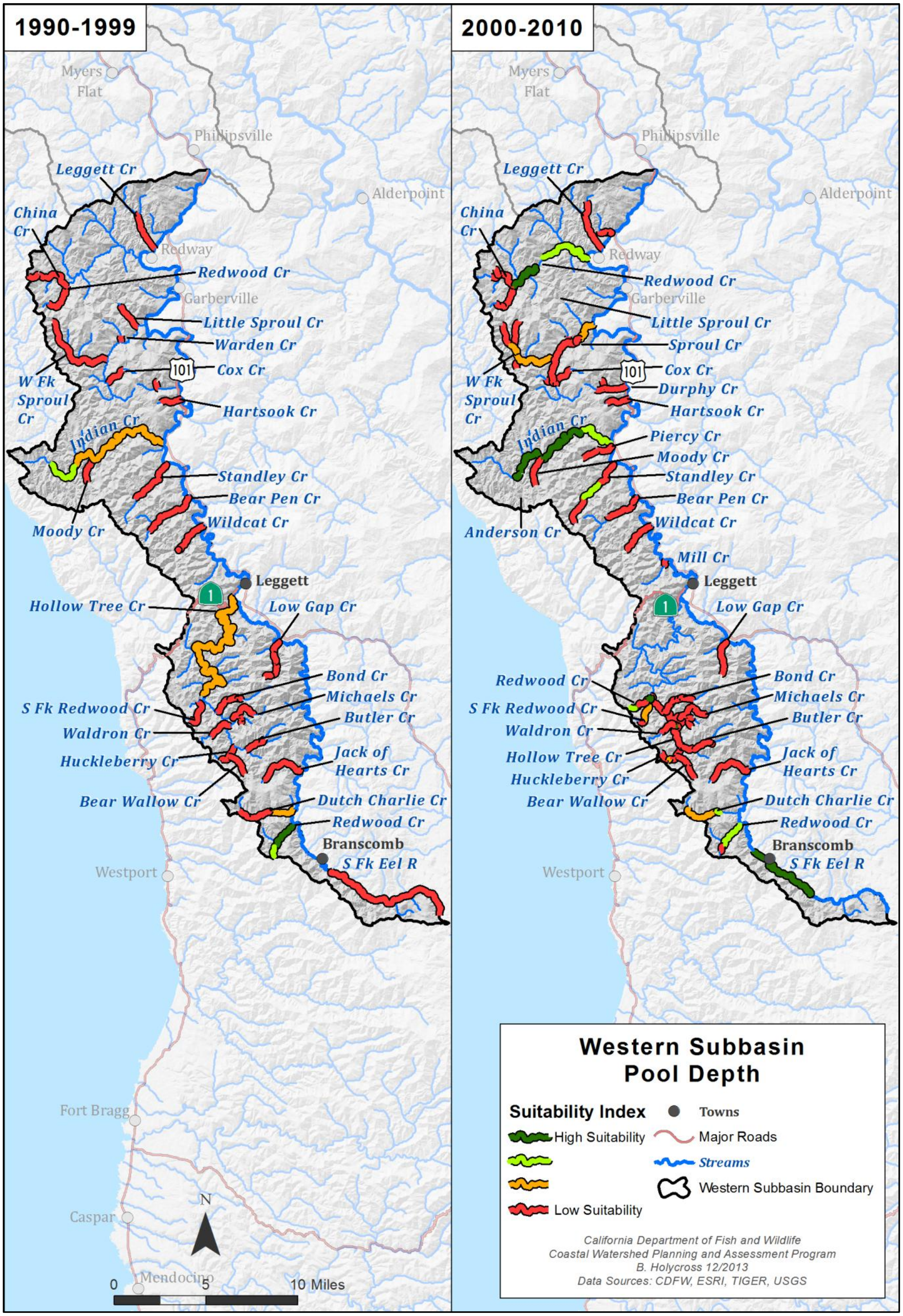

Figure 44. Pool depth suitability in SF Eel River Western Subbasin streams, using data collected between 1990 and 1999, and 2000 and 2010.

sedimentation rates, especially during large flood events such as the 1955 and 1964 floods, have modified stream channels from deep, cool and relatively stable, to shallow and relatively unstable by filling in pool habitat and depositing sediment throughout the channel bed. In their sediment source analysis, Stillwater Sciences (1999) found that earthflow toes and associated gullies were the primary source of sediment input in the Hollow Tree Creek Basin, followed by road related mass wasting, road crossing and gully erosion, and skid trail erosion. In Sproul Creek, the primary source of sediment input was road crossing and gully erosion, followed by inner gorge and upland mass wasting. Overall sediment loads were less in these areas of Coastal Belt geomorphic terrain, compared to mélange terrain in the Northern Subbasin. However, the Western Subbasin has the highest road density (4.76 mi/sq mi) of the three SF Eel River subbasins, and industrial timber harvest is the primary land use, resulting in high anthropogenic sediment loads filling in existing pool habitat. Restoration activities that create additional pool habitat and scour existing shallow pools while reducing sediment input from surrounding hillsides and roads are highly recommended throughout this subbasin.

Pool Shelter

Pool shelter provides protection from predation and rest areas from high velocity flows for juvenile and adult salmonids. The pool shelter rating is a relative measure of the quantity and percent composition of small and large woody debris, root masses, undercut banks, bubble curtains, and submerged or overhanging vegetation in pool habitats. A standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) is assigned according to the complexity of the shelter. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent of pool habitat covered. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream. Shelter ratings of 100 or less indicate that pool shelter/cover enhancement should be considered.

The average mean pool shelter rating for all Western Subbasin streams was 43.5 in the 1990s and 36.4 using habitat data collected between 2000 and 2010 (*Table 22*). Values ranged from a low of 5.0 (unnamed tributary to SF Redwood Creek) to a high of 112.7 (Butler Creek). Only two streams had pool shelter ratings above target values: Butler Creek (1990) and Bear Wallow Creek (1990). Both of these streams had substantially lower pool shelter ratings when sampled in the 2000-2010 period: 34.8 in Butler Creek in 2002, and 48.6 in Bear Wallow Creek in 2002. Pool shelter type in both creeks in the 1990s was mostly LWD and boulders, but in the 2000s, shelter was mainly boulders, with only a small amount of LWD in Butler Creek, and mainly SWD in Bear Wallow Creek. Reductions in LWD and corresponding decreases in shelter values are most likely due to the lack of LWD recruitment in these streams.

Most streams in the subbasin had pool shelter scores in the lowest suitability category (*Figure 45*). A few streams showed some improvement between the two sampling periods, including West Fork Sproul Creek, Wildcat Creek, Redwood Creek (near Branscomb), and some of the tributaries in upper Hollow Tree Creek.

Restoration projects targeting streams with particularly low pool shelter values and potential salmonid presence should be a high priority throughout the Western Subbasin. Because most of the land is owned by timber companies, wood recruitment is low and projects that add LWD to streams are recommended. These projects could be combined with pool habitat creation/enhancement projects, since both primary pool habitat and pool shelter are limiting factors for salmonids in this subbasin.

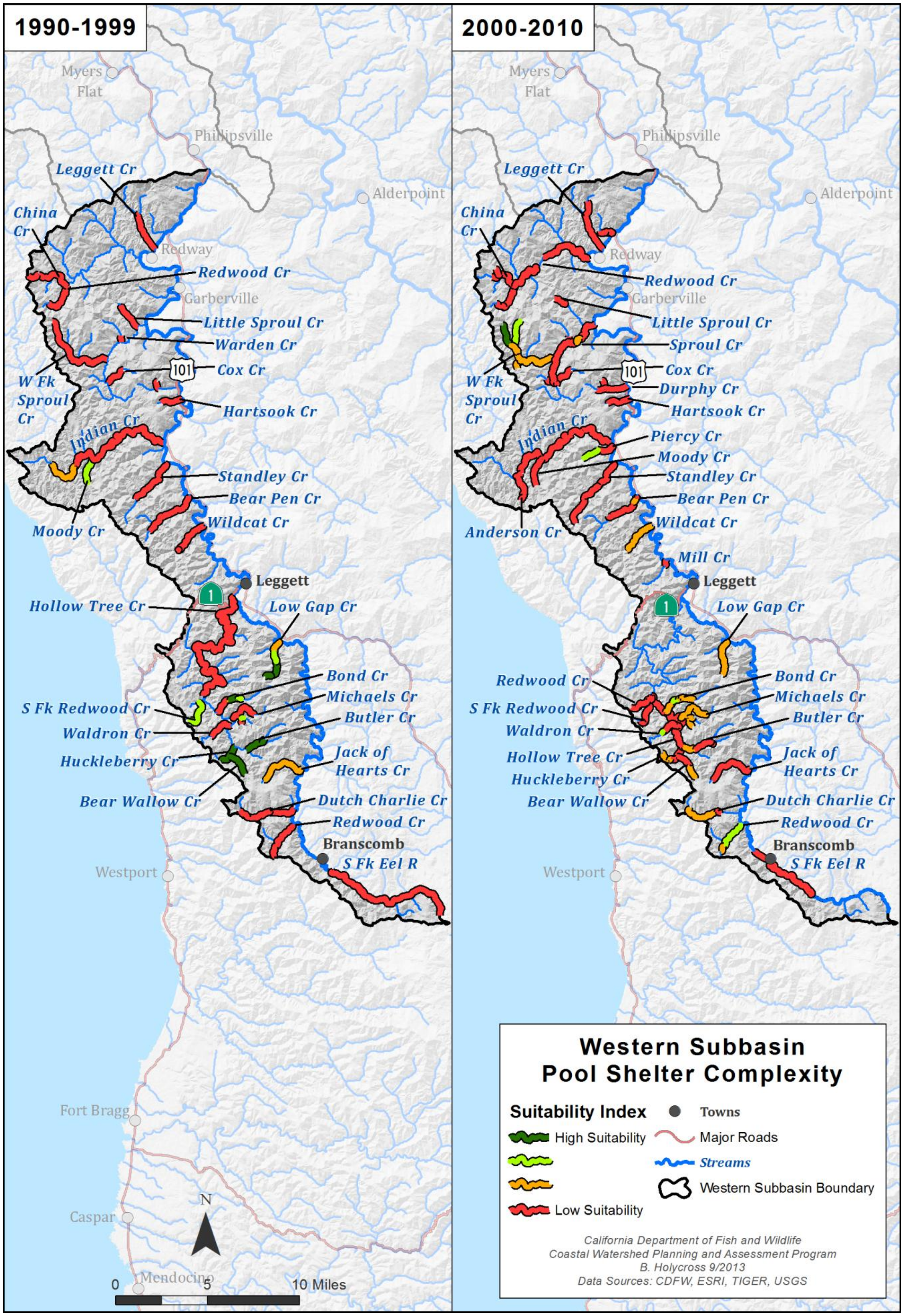

Figure 45. Pool shelter complexity suitability for Western Subbasin streams during two sampling decades: 1990-1999 and 2000-2010.

Substrate Embeddedness

Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments in gravels reduce spawning and incubation success. Substrate embeddedness is the percentage of an average sized cobble piece at a pool tail out that is embedded in fine substrate. Category 1 cobbles are 0-25% embedded, category 2 are 26-50% embedded, category 3 are 51-75% embedded, and category 4 are 76-100% embedded. Embeddedness categories 3 and 4 are not within the fully suitable range for successful use by salmonids. Category 5 embeddedness, represented by the bars furthest to the right in *Figure 46* represent tail-outs deemed unsuitable for spawning due to inappropriate substrate like sand, bedrock, log sills, or boulders, and were not included in the suitability analysis.

Cobble embeddedness condition improved in most Western Subbasin streams over time, with average percent category 1 embeddedness values of 12.7% for data collected in the 1990s and 34.4% for data collected between 2000 and 2010 (*Table 22*).

While subbasin averages are a good overall indicator of embeddedness, it is valuable to consider the changes in each category type over time, since only categories 1 and 2 are suitable for salmonid spawning. The percent of pool tails surveyed in cobble embeddedness category 1 nearly tripled between the 1990s and early 2000s (*Figure 46*). Although nearly 35% of surveyed pool tails were in category 1 in the early 2000s, this is still less than the target value of 50% in category 1 embeddedness established by Flosi et al. (2010).

The percentage of pool tails in category 2 was nearly the same (31-36%), and the percentage of pool habitat in categories 3 and 4 was substantially lower when comparing the two time periods. The percentage of pool habitat in category 5 (unsuitable for spawning) doubled between the two time periods, due to sediment input from both natural and anthropogenic sources.

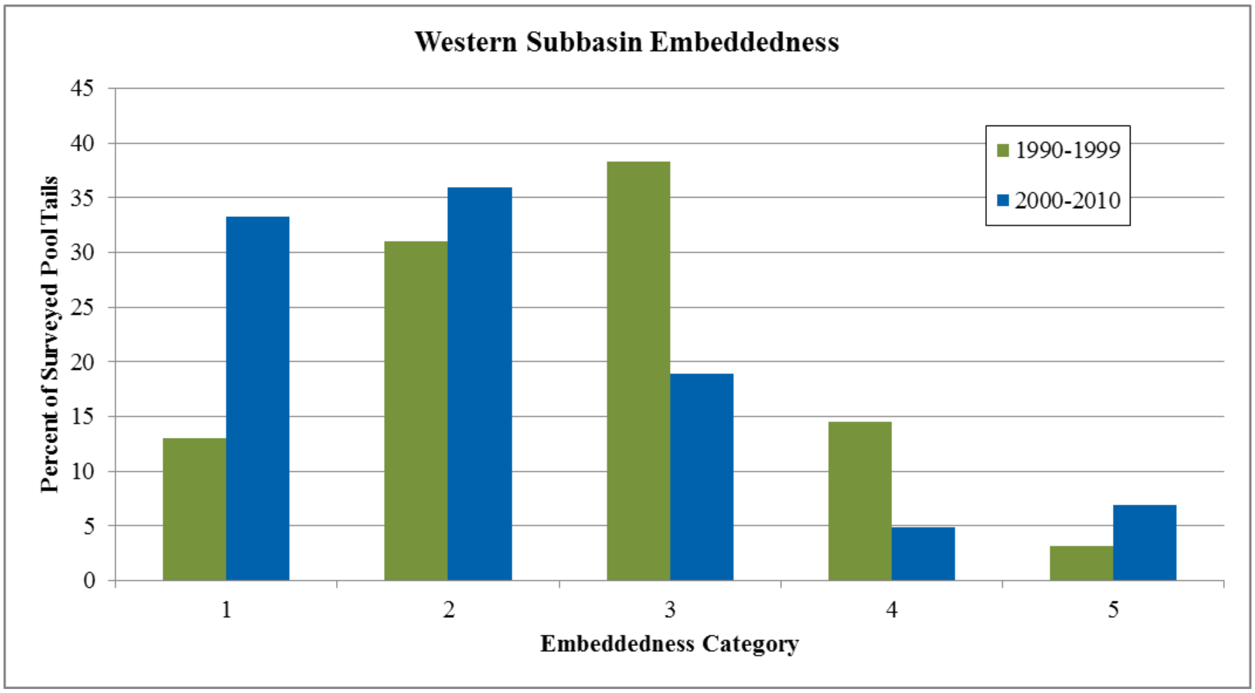

Figure 46. Cobble Embeddedness in the Western Subbasin using data collected from 1990-1999 and 2000-2010.

The EMDS-based model used a weighted sum of embeddedness category scores to evaluate the pool tail substrate suitability for survival of eggs to emergence of fry. The percent embeddedness categories were weighted by assigning a coefficient to each category. Embeddedness category 1 was rated as fully suitable for egg survival and fry emergence and a coefficient of +1 was assigned to the percent of embeddedness scores in category 1. Embeddedness category 2 was considered uncertain and given a coefficient of 0. Embeddedness categories 3 and 4 were considered unsuitable and were assigned a coefficient of -1. Category 5 values were omitted because they are composed of impervious substrate. The values for each category were summed and evaluated in the analysis.

Embeddedness suitability increased in streams throughout the Western Subbasin between the 1990s and early 2000s (*Figure 47*). Most streams were in the lowest suitability category in the 1990s, but by the early 2000s, most streams were in either the highest or second highest suitability category. Indian Creek, Redwood Creek (near Redway), and tributaries in the upper Hollow Tree Creek are some of the more important coho streams with improved embeddedness scores. These improvements are most likely due to sediment from historical floods moving through the system, and due to bank stabilization and upslope watershed restoration projects that have been completed or are in progress throughout the subbasin.

Upslope watershed restoration, including road decommissioning and upgrading projects, are designed to decrease fine sediment input and therefore decrease embeddedness are particularly important in this subbasin because of the high road density (4.76 miles/square mile) and intensive historic and current timber harvest activities, in addition to increased road usage for residential and agricultural purposes. Many road related restoration projects have been completed in Hollow Tree Creek and Standley Creek watersheds, and will be discussed in the Restoration Projects section of this subbasin report.

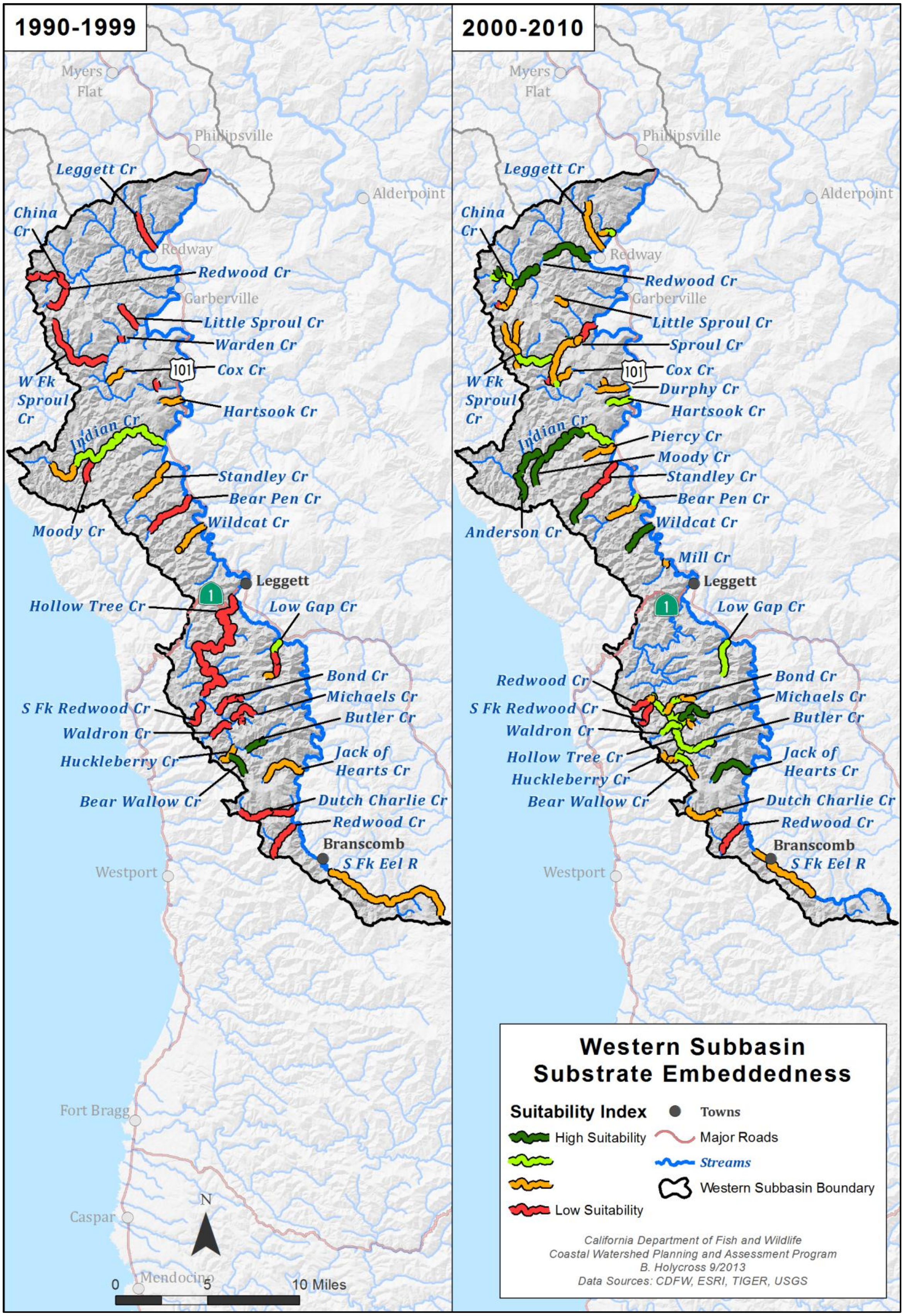

Figure 47. Embeddedness suitability in Western Subbasin streams using data collected during between 1990 and 1999, and 2000 and 2010.

LWD

Wood recruitment processes vary spatially across landscapes due to differences in forest composition and age, climate, stream size, topography, natural disturbances, and land use history (Benda and Bigelow 2011). Large wood shapes channel morphology, helps streams retain organic matter and nutrients, and provides essential cover for salmonids. It also modifies streamflow, adds habitat complexity and structure, and increases pool formation and available habitat for Chinook and coho salmon and steelhead trout at all life stages during both low and high flow times (Snohomish County Public Works 2002). Natural LWD recruitment is lower in areas where industrial timber harvest occurs (Murphy and Koski 1989, Beechie et al. 2000).

CWPAP staff did not develop reference values for frequency and volume of LWD in the EMDS-type analysis. Other models have used values derived from Bilby and Ward (1989), which are dependent on channel size. Most watersheds in the Western Subbasin did not have sufficient LWD surveys and channel size measurements for use in the analysis, but existing data were summarized to determine the frequency of LWD as the dominant shelter type and the percent shelter from LWD in pools.

Boulders were the dominant shelter type recorded in Western Subbasin streams in all subbasin reaches during both time periods (*Table 25*). Large and small woody debris were the next most common shelter types, and the occurrence of both of these types as dominant sources of shelter increased from the 1990s to the early 2000s. This was expected due to the predominance of coniferous and hardwood forest vegetation types (which supply LWD to streams), timber harvest policies promoting streamside canopy and riparian management, and restoration efforts and management strategies designed to encourage natural LWD recruitment and placement in Western Subbasin streams.

Table 25. Dominant pool shelter type by number of reaches surveyed in Western Subbasin streams.

Dominant Shelter Type	**1990-1999**	**2000-2010**
Boulders	32	39
Root masses	0	1
Terrestrial vegetation	2	3
LWD	3	20
SWD	4	14
Aquatic vegetation	0	0
Undercut banks	3	8
Whitewater	0	1
Total number of reaches surveyed	**44**	**86**

The average percent shelter from LWD in pools in Western Subbasin streams was very low during both sampling periods, but increased slightly over time (*Table 26*). These low values may be due to past management practices and land uses. Most of the land in this subbasin has been used for industrial timber harvest historically and currently, and rates of natural LWD recruitment are low. In the 1960s and 1970s, management strategies included aggressive removal of large wood (from landslides, flood events, and logging debris) from channels; these accumulations were thought to be barriers to fish passage. Recent restoration activities have emphasized adding large wood back into streams (Opperman et al. 2006), especially in areas where wood is readily available in close proximity to the stream. Although the average percent shelter from LWD values increased over time, these values were very low (<5%), indicating the need for additional large wood as vital rearing and holding habitat components in streams throughout the Western Subbasin.

Table 26. Total length of pool habitat and average percent shelter from LWD in Western Subbasin streams using data collected during two time periods: 1990-1999 and 2000-2010.

Western Subbasin	Total length of pool habitat (mi)	Avg % shelter from LWD
1990-1999	27.08	3.52
2000-2010	34.35	4.00

Pool-Riffle Ratio

Pool-riffle ratio is a measure of the amount of habitat available to salmonids in a stream, specifically the amount of pool habitat for resting and feeding, and the amount of riffle habitat for food production and spawning. Pool-riffle sequences, ratios, and lengths are dependent on channel gradient, resistance of channel boundaries (bedrock walls and bed material), and discharge (Wohl et al. 1993). A 50:50 (1:1) ratio is usually considered optimal, but streams with a slightly lower percentage of pool habitat compared to riffle habitat (0.4:1 ratio) have also been found to support a high biomass of salmonids (Platts et al. 1983). Flosi et al. (2010) recommended that approximately 40% of anadromous salmonid stream length should be pool habitat. Streams with a high percentage of riffles and few pools are generally low in fish biomass and species diversity (Snohomish County Public Works 2002).

Although pool depth, as measured by the percentage of primary pool habitat in Western Subbasin streams, was below optimal levels during both sampling periods, the ratio of pool to riffle habitat exceeded the recommended 50:50 ratio during both time periods (*Table 27*). A pool-riffle ratio of 60:40 is generally considered to provide suitable holding area and habitat diversity for both juvenile salmonids and benthic invertebrates, which are utilized as prey items by salmonids (Johnson 1985). Aggradation from numerous active landslides and unstable geology, and sediment input from roads may have contributed to a decrease in channel complexity and less than optimal pool depths in this subbasin, and projects designed to enhance pool depths are recommended.

Table 27. Percent pool and riffle habitat, and pool riffle ratios for Western Subbasin streams (from habitat typing data collected between 1990 and 1999, and 2000 and 2010).

DATE	% POOL HABITAT	% RIFFLE HABITAT	POOL:RIFFLE RATIO
1990-1999	32	23	58 : 42
2000-2010	34	23	60 : 40

The ratio of pool to riffle habitat improved slightly in recent years (2000-2010) compared to conditions in the 1990s. This improvement may be due to restoration projects completed in the basin, especially instream and riparian habitat improvement, upslope watershed restoration, and bank stabilization projects, and to large sediment deposits from historic floods moving through the system.

Most pools sampled during both time periods were shallow, resulting in primary pool lengths below target values and corresponding low pool depth suitability scores. This was expected because habitat typing surveys are conducted during summer (relatively low flow) months, and are not a reflection of winter habitat conditions, when flows and pool depths increase. Additional information on pool depths and pool-riffle ratios collected during the winter would be beneficial for future assessments.

Water Quality

Water Temperature

Water temperature is one of the most important environmental influences on salmonids at all life stages, affecting physiological processes and timing of life history events (Spence et al. 1996, Carter 2005). Stressful conditions from high temperatures are cumulative and are positively correlated with both the severity and duration of exposure (Carter 2005). Elevated instream temperatures result from an increase in direct solar radiation due to the removal of riparian vegetation, channels widening and becoming shallower due to increased sedimentation, and the transport of excess heat downstream (USEPA 1999).

The Humboldt County Resource Conservation District (HCRCD), with the cooperation of 21 supporting agencies, individuals, and landowners, completed temperature monitoring and biological sampling in the Eel River Watershed, collecting data during eight field seasons from 1996-2003 (Friedrichsen 2003). They collected maximum weekly average temperature (MWAT) in streams throughout the SF Eel River Basin, including 64 sampling locations (53 in tributaries and 11 in the mainstem SF Eel River) in the Western Subbasin (*Figure 48*). Data loggers were generally deployed from June through October, and not all sites were sampled every year. Some large streams (Redwood and Sproul Creeks) were sampled at more than one location, and site locations are listed for each data point. Friedrichsen (2003) provided X,Y coordinates for most gauge locations, and others were digitized using HCRCD map data where available. Although not all sampling locations are included on the map, most missing data points were located in mainstem areas of larger tributaries (S. Downie, CDFW, personal communication 2013).

The CWPAP staff created suitability ranges for stream temperature based on MWATs, considering the effect of temperature on salmonid viability, growth, and habitat fitness (*Table 28*). This metric was calculated from a seven-day moving average of daily average temperatures. The maximum daily average was used to illustrate possible stressful conditions for salmonids. The instantaneous maximum temperature that may lead to salmonid mortality is ≥75°F; this temperature is potentially lethal for salmonids if cooler refuge is not available.

Table 28. CWPAP-defined salmonid habitat quality ratings for MWATs.

MWAT Range	Description
50-62°F	Good stream temperature
63-65°F	Fair stream temperature
≥66°F	Poor stream temperature

Using Friedrichsen's data and these temperature ranges, 40 sites (on 26 creeks) in Western Subbasin tributaries and one site on the mainstem SF Eel River had good salmonid temperatures (*Table 29*). Eight tributary sites (on seven creeks) and one mainstem site had fair temperatures, and five tributary sites (on four creeks) and nine mainstem sites had poor stream temperatures (*Figure 49*). There were more Western Subbasin streams with good stream temperatures recorded compared to Northern and Eastern Subbasin streams in the SF Eel River Basin, primarily because of good canopy cover, narrow stream valleys, and the location of this subbasin in the coastal fog belt and corresponding cool air temperatures.

Many of the sampling sites with poor stream temperatures were located in the mainstem SF Eel River, and in the lower reaches of large tributary streams (e.g. Hollow Tree, Redwood (Redway), and Sproul creeks). In these areas, increased direct solar radiation from reduced riparian cover and wide channels results in warmer water temperatures than in nearby tributaries. Researchers obtained a maximum daily average reading of 75˚F or greater in two sites in the mainstem SF Eel River (near Piercy at RM 54, and near Sylvandale at RM 25), both of which exceeded the lethal temperature for salmonids if cooler refuge areas (springs and seeps) are not available nearby. Although we expect higher temperatures in mainstem SF Eel River than in tributaries, it is important to capture the duration that salmonids are exposed to these stressful or lethal temperatures, and to document the location and availability of cool water refugia areas near sites where lethal MWAT values have been recorded.

In addition to the HCRCD studies, Higgins (2013) and the Eel River Recovery Project (ERRP) employed a citizen monitoring effort in 2012 to collect water temperature data as an indicator of flow depletion in streams throughout the Eel River Basin. Higgins compared 2012 stream temperatures with data collected at similar locations by HCRCD between

1996 and 2003, and his conclusions were similar to Friedrichsen's: mainstem SF Eel River temperatures in the upper areas near Branscomb were some of the coolest mainstem conditions in the entire Eel River system, and temperatures became progressively warmer downstream. Higgins and ERRP also found temperatures in the mainstem SF Eel River near Piercy were above optimal for salmonids. Fish in these areas may seek refuge in thermally stratified pools or in localized refugia provided by surface and groundwater interactions when mainstem and tributary temperatures reach stressful or even lethal temperatures (Nielsen et al. 1994). These cool water refugia are particularly important in areas where high temperatures result in increased primary productivity (algal blooms), low dissolved oxygen concentrations, and conditions favoring invasive species such as Sacramento pikeminnow. Both spatial and temporal changes in stream temperatures are concerns in some Western Subbasin tributaries. Stressful temperature conditions caused by drawing more water out of streams both during dry years and during dry seasons each year have exposed salmonids to extremes that they would not normally encounter. These extremes are particularly problematic for fragmented populations, which are less resilient to variations in stream temperature and other habitat conditions (Poole et al. 2001).

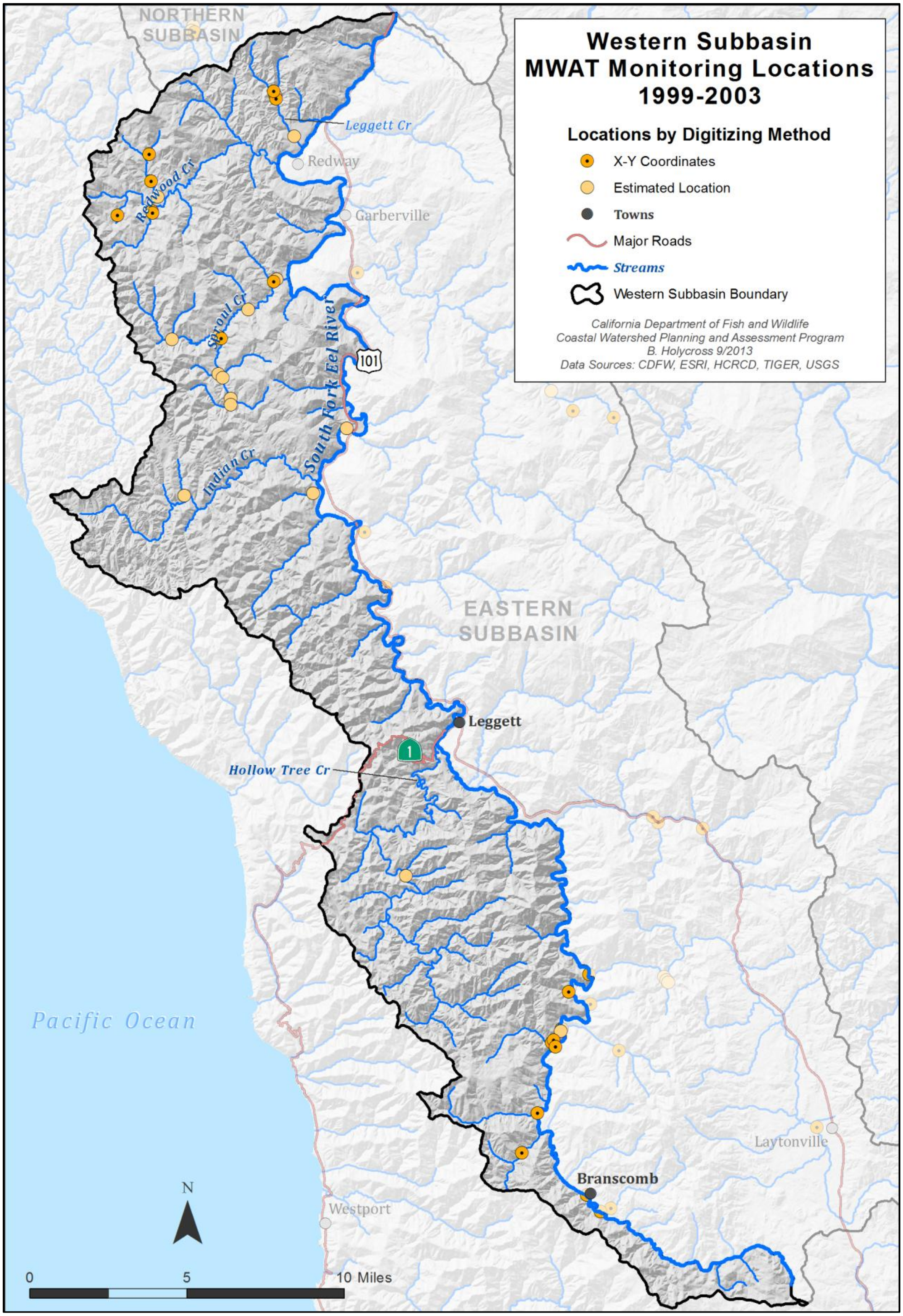

Figure 48. Locations of temperature monitoring sites in the Western Subbasin.

Table 29. Maximum weekly average temperatures (MWATs) and ranges collected in SF Eel River Western Subbasin tributaries from 1999-2003 (data from Friedrichsen 2003).

Creek	Site	MWAT Range (°F)	Average MWAT (°F)	Years of Data
Good Stream Temperature (50-62 °F)				
Bear Creek	1839	57	57	1
Barnwell Creek	8046	61	61	1
Bear Pen Creek	1776	62	62	1
Bond Creek	2150	59	59	1
Buck Gulch	8001	60-63	61	5
China Creek	1525	59-61	60	3
Dinner Creek	8002	60	60	2
Dinner Creek	8003	59-62	60	5
Dutch Charlie Creek	1534	62	62	4
Dutch Charlie Creek	1780	56	56	1
Hollow Tree Creek (Middle)	2142	62	62	1
Hollow Tree Creek (Upper)	2036	55	55	1
Huckleberry Creek	2037	55	55	1
Indian Creek	1770	59	59	1
Indian Creek	1786	62	62	1
Jack Of Hearts Creek	1566	61-64	62	5
Ladoo Creek	1106	58-60	59	3
Legget Creek	8034	61	61	1
Legget Creek	8035	62	62	1
Lost Man Creek	8038	60	60	1
Michael's Creek	2152	60	60	1
Miller Creek	8012	57-60	59	4
Miller Creek	8014	60	60	1
Miller Creek	8032	58-64	61	2
Piercy Creek	1772	61	61	1
Piercy Creek	1606	61-63	62	2
Pollock Creek	1412	58-62	60	3
Redwood Creek	1779	55	55	1
Redwood Creek (Hollow Tree)	2151	58	58	1
Redwood Creek @ Branscomb.Dump	1612	57-61	59	5
Sebbas Creek	1117	60-62	61	2
South Fork Eel River @ Mud Creek (RM 97)	8045	62	62	1
Sproul Creek	1102	58	58	2
Sproul Creek	1103	57-62	59	3
Sproul Creek	1105	61	61	2
Sproul Creek	1136	61	61	1
Sproul Creek	1104	61-62	62	2
West Fork Sproul Creek	1107	58	58	1
West Fork Sproul Creek	1108	59	59	1
West Fork Sproul Creek	1109	59	59	1
Wildcat Creek	1773	62	62	1
Fair Stream Temperature (63-65 °F)				
Jack Of Hearts Creek	8060	63	63	1
Hollow Tree Creek	8063	65	65	1
Leggett Creek (Upper)	1572	62-67	64	4

Creek	Site	MWAT Range (°F)	Average MWAT (°F)	Years of Data
Fair Stream Temperature (63-65 °F) (con.)				
Little Sproul Creek	1477	62-64	63	2
Seely Creek	8061	65	65	1
South Fork Eel River @ Branscomb (RM 95)	1658	63-66	64	5
Sproul Creek	1407	62-64	63	4
Sproul Creek	1408	57-67	64	4
Sproul Creek (West Fork)	1409	63	63	2
Poor Stream Temperature (≥66 °F)				
Hollow Tree Creek	1778	69	69	1
Hollow Tree Creek (Lower)	2029	66	66	1
Leggett Creek 2	8021	65-67	66	4
Redwood Creek (Redway) (Walley's Repair; 0.5 mi upstream from Seeley Creek)	1614	73	73	1
South Fork Eel River (RM 51)	241	73	73	1
South Fork Eel River (RM 54)	249	74	74	1
South Fork Eel River (RM 84)	9636	73	73	1
South Fork Eel River (RM 86)	9637	72	72	1
South Fork Eel River @ Angelo Reserve (RM 88)	8059	69	69	1
South Fork Eel River @ Piercy Creek (RM 54)	1416	75	75	1
South Fork Eel River @ Sylvandale (RM 25)	1634	74-78	76	4
South Fork Eel River above Elder Creek (RM 90)	1657	68-71	70	3
South Fork Eel River above Rattlesnake Creek (RM 76)	1638	74	74	1
Sproul Creek	1137	69-70	69	2

Figure 49. Number of sites in each CWPAP suitability rating category for MWATs collected from 1999-2003 (n=64; 53 tributary and 11 mianstem sites) in the SF Eel River Western Subbasin (data from Friedrichsen 2003).

Temperature data were also collected during the summer of 2013 by UC Berkeley graduate student Keith Bouma-Gregson. Bouma-Gregson sampled cyanotoxins, nutrients (nitrogen and phosphorous), and temperature at seven Eel River Basin sites, including 4 in the mainstem SF Eel River: Phillipsville (RM 22), Richardson Grove (RM 49), Standish-Hickey State Recreation Area (SRA) (RM 66), and Angelo Reserve (RM 89) (*Figure 50*). Of the SF Eel River sites, daily average temperatures recorded were lowest at Angelo Reserve (64.6-74.7˚F) and warmest at Phillipsville (67.1-79.6˚F). These data are consistent with Friedrichsen's and ERRP's findings. Temperatures recorded at Richardson Grove and Standish-Hickey SRA were intermediate between the other two SF Eel River locations. Lethal temperatures (≥75˚F) were recorded on 15 days in July and August at Richardson Grove, and on 9 days in July at Standish-Hickey SRA, both of which are located within the Western Subbasin boundary. At the Phillipsville site, located just north of the Western Subbasin boundary, daily average temperatures were above lethal limits for salmonids on 27 days from mid-July to early September. There were no lethal temperatures recorded at the Angelo Reserve site (Bouma-Gregson, UC Berkeley, personal communication 2014).

Maximum weekly average temperatures are momentary high points, and both MWAT and daily average temperatures are useful for general discussion. However, in order to understand temperature conditions and their effects on salmonids, it would be more informative to capture the duration that salmonids are exposed to stressful or lethal temperatures on a reach by reach basis, and to document the availability of cool water refugia areas near locations where poor MWAT values have been recorded. There are studies in development to address flow and temperature concerns in other parts of the SF Eel River Basin (e.g. Redwood Creek, near Redway (SRF 2013)), but additional studies are necessary in Western Subbasin streams, particularly in tributaries to larger creeks and in locations further upstream in tributaries sampled by Friedrichsen et al., ERRP, and Bouma-Gregson. Studies addressing temperatures during low flow periods are especially important to determine how low flow and diversion are affecting temperatures in tributaries, and the effects of these changes on salmonids throughout the subbasin.

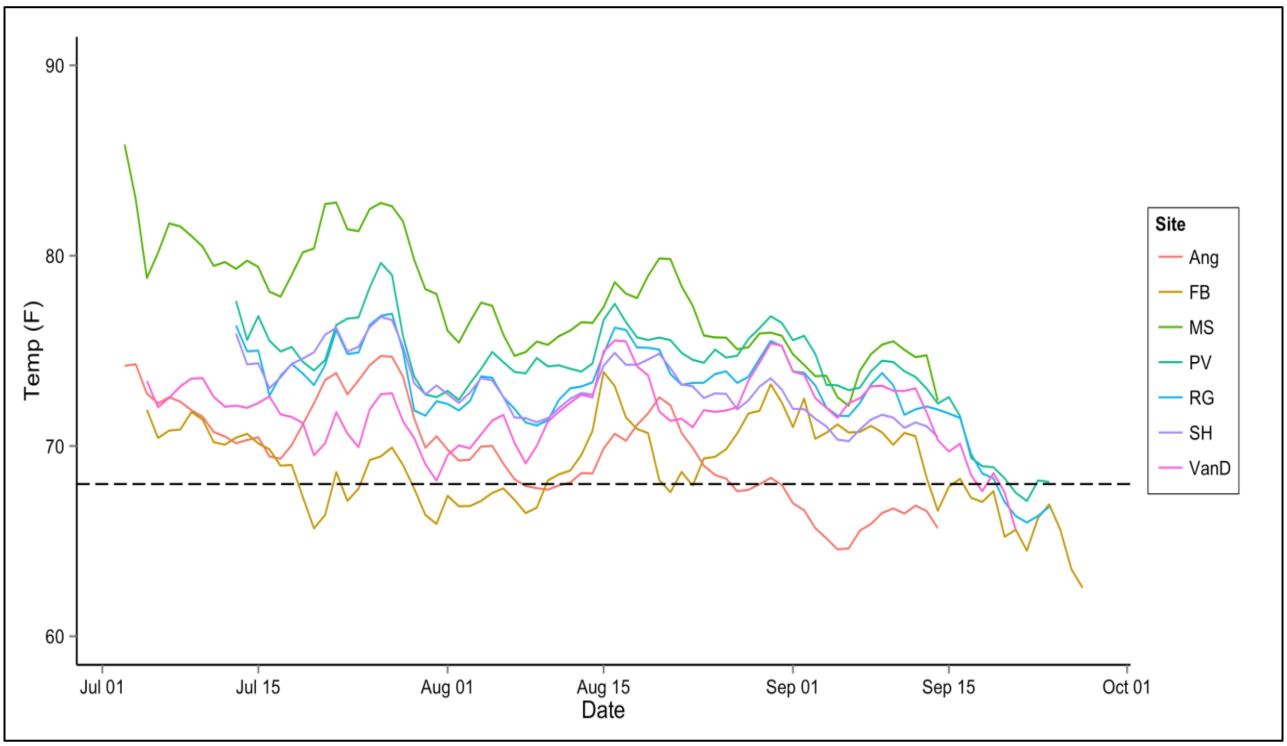

Figure 50. Daily average temperatures (degrees F) from July 3 through September 24, 2013, recorded at 7 sampling locations in the Eel River Basin. Data and graph provided by Keith Bouma-Gregson (UC Berkeley, 2014). Ang = Angelo Reserve; FB = Fernbridge; MS = Mainstem Outlet Creek; PV = Phillipsville; RG = Richardson Grove; SH = Standish-Hickey SRA; VanD = Van Duzen River.

Flow

There are four sources of stream flow in a natural watershed:

- **Groundwater flow** into the channel provides base flow. In perennial streams, the water table is at the height of the stream surface;
- **Interflow** from the soil moisture zone;
- **Direct channel precipitation** at the surface; and
- **Surface runoff** as overland flow (Ritter 2013).

Instream flow is typically measured in cubic feet per second (cfs), and is a measure of how fast the water is moving through a cross-section of the stream. Flow velocity is directly related to the hydraulic radius and channel slope, and inversely related to channel roughness in a stream (Ritter 2013).

River morphology (width, depth, slope, and channel pattern) changes in response to the supply of sediment and water from the surrounding watershed (Pitlick and Wilcock 2001). In Western Subbasin streams, increased deposition and aggradation from high sediment input rates affect flow, particularly during summer months when natural flow sources are significantly reduced and diversion rates are high. These low flows and the predominance of sediment result in streams with subsurface flow during late summer and early fall months, which decreases the quantity and quality of salmonid habitat in many streams by reducing stream depth and available pool habitat, elevating water temperatures, and concentrating pollutants.

The USGS monitors flow at one location in the Western Subbasin (on the boundary line between the Eastern and Western subbasins), in the mainstem SF Eel River near Leggett (RM 66). Records from this gauge show a recently emerging pattern of atypical low flows (compared to the historic running average) occurring during the late summer to early fall months even during wet weather years (*Figure 51).* These low flows may be caused by reduced winter precipitation and an increase in both the number of diversions and the quantity of water diverted from subbasin streams and tributaries for agricultural and domestic uses.

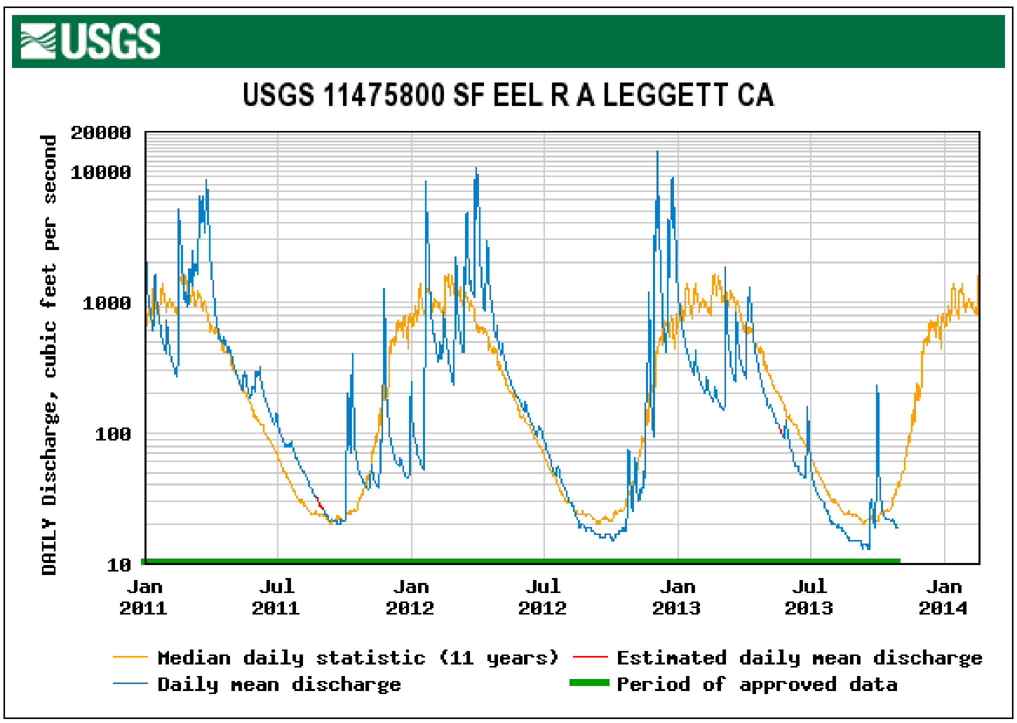

Figure 51. Daily mean discharge (in cfs) and mean daily discharge (40-year average in cfs) for USGS gauging station at SF Eel River near Leggett, showing 2011-2014 data.

Recent Low Flow Studies

In response to the limited rainfall in the winter and spring of 2012-2013 and concern over extremely low flow conditions that were being reported/observed in the SF Eel River Basin, CWPAP staff conducted a brief low flow study in August and September, 2013. The staff collected information at six mainstem SF Eel River sites and in 37 tributaries with known coho distribution. The purpose of the study was to document extremely low flow conditions and its potential impacts on juvenile salmonids (stress, mortality, etc.) while comparing conditions in streams that are heavily diverted (due to marijuana cultivation and residential use) with those those that are not heavily diverted. In streams that were not affected by diversion (n = 15) and in streams that were not heavily diverted (n = 21), flows were typical of those seen in very low water years. In heavily diverted streams, conditions ranged from dry or isolated pools only in some streams, to connected streams with very low flow in others.

Six of the streams that were affected extensively by diversion were located in the Western Subbasin: Redwood (Redway), Twin, Sproul, Little Sproul, Jack of Hearts, and Little Charlie creeks. Of these six, one was dry (Twin Creek), and two were nearly dry, with isolated pools only (Redwood and Little Charlie creeks). CWPAP staff estimated flow rates of 0.5 cfs or less in the remaining three creeks.

In the summer of 2013, the Salmonid Restoration Federation (SRF) initiated a low flow study in Redwood Creek near Redway (RM 30), located within the Western Subbasin boundary. SRF collected baseline streamflow data at eleven sites in the Redwood Creek watershed. The furthest upstream site was located approximately 2.3 miles up Dinner Creek from the confluence of Redwood Creek, and other sampling stations were located on Pollock, China, Miller, Buck, Seely, and Redwood creeks. The furthest downstream site was located approximately 1800 feet upstream from the confluence of Redwood Creek and the SF Eel River. SRF measured flow using a variety of techniques, including a 4-inch diameter pipe, Parshall Flume, and Pygmy Current Meter (although flows were usually too low to get accurate readings with the meter). Findings included:

- Flow was intermittent in most streams from August through September;
- All sites had less than 1 gallon per minute (gpm) flow in mid-September (*Figure 52*);
- Bedrock substrate was the main factor in maintaining pools;
- Groundwater recharge was highly variable. After one inch of rain fell on September 20-21, connectivity was reestablished in China and Pollock Creeks. After three more inches of rain fell on September 28-29, all streams throughout the watershed were reconnected and remained flowing until the next rainstorm on November 18.

SRF staff concluded that flows were extremely low during August and September 2013, with some streams going dry during this time (*Figure 52*). After the first rainfall in in September, connectivity was restored in all monitored streams and flow increased in some streams even though no additional rain fell for 6 weeks. Some of the increased flow or slowed decrease in flow may come from slow moving ground water from the storms finally reaching streams (SRF 2013). SRF is currently seeking funding to develop a more comprehensive instream flow study, and will use the results of current and future research to inform their water diversion and voluntary conservation program discussed below.

SRF's findings most likely apply to other areas throughout the subbasin, particularly in areas with similar land use patterns such as the Sproul Creek watershed, and in streams with residential land use near Garberville, Redway, Leggett, and north of Branscomb.

Water Diversion and Voluntary Conservation

The effects of low flow, diversions, and warm water temperatures on salmonids are major concerns in streams throughout the Western Subbasin. In 2013, the Salmonid Restoration Federation (SRF) and Humboldt State University (HSU) initiated a study to determine the feasibility of implementing a voluntary water conservation and storage program in Redwood Creek. This study is modeled after Sanctuary Forest's water storage tank and forbearance program in the Mattole River headwaters, where participating landowners store water in tanks during high flows for use during low flow times: (http://sanctuaryforest.org/wp-content/uploads/2014/02/FINAL-tanks-and-forbearance-brochure-text-12.5.07.pdf). This

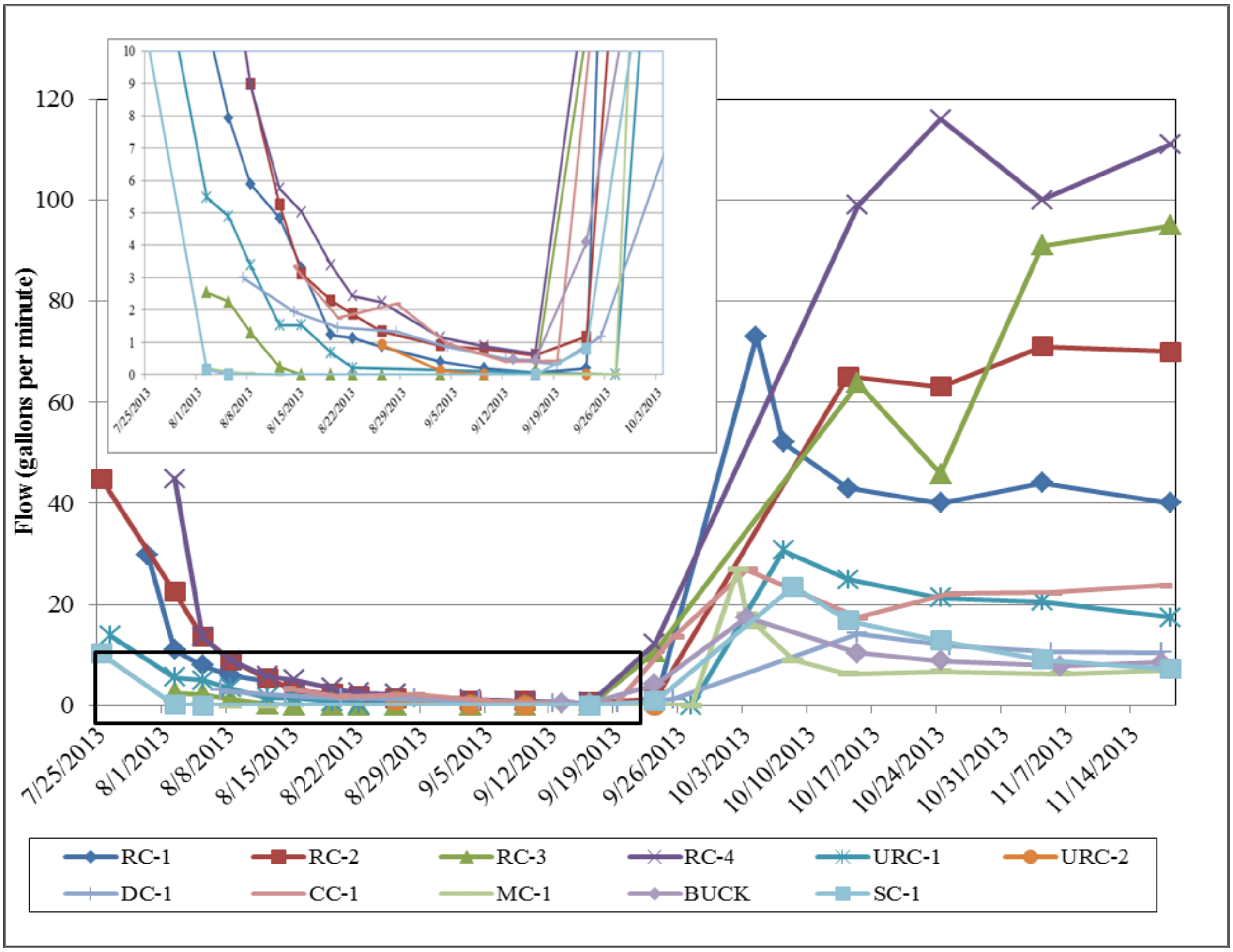

Figure 52. 2013 summer streamflow in Redwood Creek (near Redway), with inset showing low flow from July through September (data and figure from SRF 2013). RC = Redwood Creek; URC = Upper Redwood Creek (Pollock Creek); DC = Dinner Creek; CC = China Creek; MC = Miller Creek; BUCK = Buck Creek; SC = Seely Creek.

storage reduces diversions and increases flows to improve fish habitat and water quality during the low flow season. Due to the success of the program in the Mattole River Basin, SRF and HSU applied a similar design when developing the Redwood Creek Water Conservation Project.

There are two phases in the Redwood Creek study:

1) Surveys and data analysis. A survey questionnaire was sent out in early 2013 to all landowners in the basin (n = ± 400) requesting information on water sources(s), diversion rates, and on-site storage capacities. As of May 2013, 70 people had completed the survey (a 17.5% response rate);
2) Community outreach. Two local meetings were held to provide a forum for input from Redwood Creek residents. A total of 57 people attended the meetings, and discussion topics included: the Mattole Flow Program, designing a low flow study in Redwood Creek, suggestions for water conservation measures, storage tank options, and strategies to increase community awareness and participation (SRF 2013).

Sixty six percent of landowners who responded to the survey reported that they have mechanisms in place to prevent tank overflow, and 26% did not, illustrating the importance of developing affordable and accessible options to help prevent water loss. The survey responses also indicated that residents who valued the aesthetic beauty of the stream environment and habitat for salmon often spoke to others in the community about watershed health, and were more likely to voluntarily participate in water conservation efforts (SRF 2013).

SRF and HSU determined that there are landowners who are willing to take part in a voluntary water conservation program, however there are some obstacles. Tank installation requires a financial commitment, including the purchase of a new tank and additional property taxes when water storage is installed, which are currently financial disincentives for residents interested in participating in the water storage program. Several local non-profit agencies are currently investigating options for a new tax policy to provide financial incentives for residents interested in installing water tanks. Water rights are also problematic in the watershed: many landowners currently divert water for domestic and agricultural purposes, but only two residents have established water rights (SRF 2013). SRF, in cooperation with several local non-profit agencies, established a public forum to educate residents about water rights and compliance issues so that they can legally divert and store water.

The next steps in the study will include interpretation of data collected in additional low flow studies to develop information that will be used to determine how existing diversions are affecting flow, and to expand the community-led water conservation program that will improve habitat and benefit salmonids in the Redwood Creek watershed. For additional information and project updates, go to the SRF website at http://www.calsalmon.org/

This study emphasizes the need for specific information on water diversions and flow, and it is an example of successful community involvement in fisheries habitat monitoring and restoration efforts. Similar voluntary conservation programs could be applied in the future in other Western Subbasin watersheds.

In January 2014, Governor Brown declared a drought State of Emergency in California and directed state officials to take all necessary actions to prepare for water shortages. In March 2014, CDFW and the SWRCB announced that they would expedite the permitting and approval of storage tanks for landowners who currently divert water from rivers and streams in the Northern and Bay Delta regions of CA (CDFW regions 1 and 3). This action, which came under the State Water Board's Small Domestic Use (SDU) registration program, will relieve pressure for in-stream diversions during the drier months when fish need it most. This action was a direct result of suggestions made by local communities, SRF, Mattole River Sanctuary Forest, and Trout Unlimited (CDFW 2014).

Water Chemistry

Sediment

Sediment affects salmonids both directly and indirectly by modifying aquatic habitat. Coarse sediment, fine sediment, and suspended sediment may adversely affect adult and juvenile salmonids by altering channel structure and affecting production.

In 1999, the SF Eel Basin was listed by the USEPA as an impaired water body for sediment. In the TMDL analysis (USEPA 1999), the USEPA interpreted water quality standards, calculated existing sediment loads, set loading capacities, and established load allocations. The most significant sources of sediment found in the watershed included roads, timber harvest related activities, and natural sources. In order to interpret water quality standards and to determine the amount of sediment that will not adversely affect salmonids, USEPA developed a set of indicators: percent fines, turbidity, V star (V*), and the thalweg profile. Stillwater Sciences (1999) then completed a sediment source analysis, which was used to set TMDL loading capacity and allocations for the SF Eel River Basin. TMDL allocations were developed to assess the maximum allowable amount of sediment received by a stream while still meeting water quality requirements (*Table 30*).

Table 30. USEPA sediment indicators and targets for the SF Eel River Basin (USEPA 1999).

Indicator	Target	Purpose
Substrate composition – percent fines	<14%<0.85 mm	Indirect measure of fine sediment content relative to incubation and fry emergence from the redd. Indirect measure of ability of salmonids to construct redds
Turbidity and suspended sediment	Turbidity < 20% above naturally occurring background	Indirect measure of fish feeding/growth ability related to sediment, and impacts from management activities

Indicator	Target	Purpose
Residual pool filling (V*)	<0.10	Estimate of sediment filling of pools from disturbance
Thalweg profile	Increasing variation from the mean	Estimate of improving habitat complexity & availability

The USEPA and Stillwater Sciences did not subdivide the SF Eel River Basin into subbasins, so estimates and recommendations were developed for the entire basin. The USEPA calculated that existing sediment loading was approximately two times the natural rate, or for every ton/square kilometer/year of natural sediment, there was one ton/square kilometer/year of human-induced sediment (USEPA 1999). Stillwater Sciences (1999) found that sediment loading is variable, and roads are the largest anthropogenic contributors of fine sediment to streams throughout the basin.

The total sediment load was calculated to be 704 tons/square kilometer/year or 1.9 tons/square kilometer/day on a 15 year running average (*Table 31*). The ratio of human-induced sediment is approximately 1:1, but slightly more sediment is from natural sources (54% of total) than anthropogenic sources (46% of total). Earthflows are the primary source of natural sediment, and roads are the primary source of anthropogenic sediment in the basin.

Table 31. USEPA basinwide estimates of sediment sources for the SF Eel River Watershed from 1981-1996 (USEPA 1999).

Sediment Source	**Total sediment input (tons/year)**	**Unit area sediment input (tons/square kilometer/year)**	**Fraction of total**
Natural Sediment Sources			
Earthflow toes and associated gullies	478800	269	38%
Shallow landslides	132500	74	11%
Soil creep	62980	35	5%
Subtotal	**674280**	**378**	**54%**
Anthropogenic Sources			
Shallow landslides, roads and harvest	216200	121	17%
Skid trail erosion	21534	12	2%
Road surface erosion	67512	38	5%
Road crossing failures and gullying	276500	155	22%
Subtotal	**581746**	**326**	**46%**
Total	**1256026**	**704**	**100%**

The loading capacity, or the amount of pollution that a stream can assimilate and still meet water quality standards, was set for all stream reaches in the basin based on a 1:4 ratio of human to natural sediment. Using this ratio, the allowable human-induced loading capacity would be 95 tons/square kilometer/year, and the TMDL for the basin would be 473 tons/square kilometer/year. Considerable erosion control measures will be required to meet the TMDL and loading capacity. For example, in order to meet the target ratio, road sediment would need to be reduced from current levels by 80%. Sediment from landslides would then require a 55% reduction in input levels.

In the Water Quality Control Plan for the North Coast Region, NCRWQB established basin-wide regulations that turbidity should not be increased more than 20 percent above naturally occurring background levels (NCRWQCB 2011). Additional prohibitions are included for erosion sources such as logging operations and constructions projects, so that organic material (including soil, bark, slash, sawdust, and other earthen material) from these operations is not directly or indirectly discharged into streams in quantities sufficient to harm fish and wildlife.

Road decommissioning, or the removal and stabilization of unwanted roads to a natural state, is an effective management technique used to reduce sediment input in watersheds with high road densities. McCaffery et al. (2007) found that watersheds with decommissioned roads had lower percentages of fine sediment in streams than those with roads in use. Many CDFW Fisheries Restoration Grant Program (FRGP) projects that have been completed in upslope areas in the Western Subbasin include road decommissioning and erosion control measures.

Pacific Watershed Associates (PWA) completed an evaluation of CDFW road decommissioning protocols and guidelines used on more than 51 miles of road in Northern California between 1998 and 2003 (PWA 2005). They determined that at decommissioned stream crossing sites:

- Sediment delivery was approximately 5% of the original pre-treatment fill volume;
- Unexcavated fill was the most common problem; and
- Protocols were effective but were not being uniformly followed at stream crossing sites.

At landslide sites and road drainages, PWA determined that protocols were effective and were being followed, but protocols for “other” sites were vague and ineffective. When done properly, road decommissioning projects resulted in decreased fine sediment input at most treated sites. Although PWA did not look at specific road decommissioning sites in the Western Subbasin, their findings are important to consider given the high road density and the potential to significantly reduce the amount of sediement input from legacy and failing roads. Other sediment reduction projects completed in the subbasin (see Fish Restoration Programs section) will also contribute to a reduction in overall sediment input, and will be monitored over time.

Nutrients

UC Berkeley graduate student Keith Bouma-Gregson sampled nitrogen and phosphorous concentrations at seven Eel River Basin sites while collecting cyanotoxin and temperature data in the summer of 2013. Three of these sites were located in the mainstem SF Eel River, on the Western Subbasin boundary line: at Richardson Grove (RM 49), Standish-Hickey SRA (RM 66), and Angelo Reserve (RM 89). Bouma-Gregson is currently analyzing data and developing conclusions on the relationship between blue-green algae blooms, toxins, temperatures, nutrient levels, and blue-green algae and green algae associations in SF Eel River streams (K. Bouma-Gregson, UC Berkeley, personal communication 2014).

Aquatic Invertebrates

Aquatic macroinvertebrates are the primary food source for salmonids, and can be used as indicators of stream health because they are directly affected by physical, chemical and biological stream conditions. They may also show effects of habitat loss and short- and long-term pollution events that may not be detected in traditional water quality assessments (USEPA 1997). High instream temperatures, reduced flow, and increased sediment input may result in decreased macroinvertebrate assemblages and abundance, and populations may be further reduced in watersheds where land use activities have intensified these conditions. Cover et al. (2006) documented decreases in invertebrate abundance in streams with increased fine sediment input from unstable hillslopes and land use activities in Klamath mountain streams, where instream conditions and land use practices were similar to those found in many Western Subbasin creeks.

In 1996, Friedrichsen (1998) sampled macroinvertebrate communities throughout the Eel River Basin. Sampling locations were selected by Scott Downie (CDFW) and reviewed by the project’s technical advisory committee. Seven of the sampling sites were located within the SF Eel River Basin boundary, with two locations in the Western Subbasin (Redwood Creek near Branscomb, and Little Sproul Creek). Five metrics (explained in detail by Plafkin et al. 1989) of macroinvertebrate assemblages and community structure were used to assess stream condition:

- The Simpson Index (diversity of taxa and evenness of the community);
- Modified Hilsenhoff Index (tolerance values and number of organisms per taxa divided by the total number of invertebrates in the sample);
- EPT Index (number of species of Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies));
- Percent Dominant Taxa (the total number of organisms in the sample divided by the

number of invertebrates in the most abundant taxa); and

- Richness Index (total number of taxa).

These metrics may indicate if the stream is healthy or impaired, and can be used to determine how invertebrate assemblages respond to human and natural disturbances. Friedrichsen (1998) found that when all metric results were considered, Redwood Creek invertebrate populations were among the healthiest in the SF Eel River Basin. These invertebrate communities had good evenness, and a higher level of representation of taxa associated with cooler summer water temperatures. Conditions have most likely not changed significantly in the Redwood Creek watershed since Friedrichsen's study was completed; this stream is located on MRC land, and the primary concern in this watershed is sediment input from roads and harvest activities. Other streams in this subbasin are heavily diverted, particularly in areas where residential land use is high and water is diverted for illegal marijuana cultivation. In addition to reduced instream flow, water entering the stream near grow operations may be polluted with fertilizers, diesel fuel, rodenticides, human waste, and fine sediment, affecting water quality and, therefore, instream invertebrate communities. More information is necessary to determine invertebrate species tolerance levels for both pollution and elevated water temperatures, to assess the effects of increased diversions on aquatic invertebrate populations, and to determine how changes in invertebrate populations affect salmonid populations.

Food web ecology and aquatic invertebrates that support salmonids have been studied at Angelo Coast Range Reserve near Branscomb, as part of the Eel River Critical Zone Observatory (https://criticalzone.org/images/national/associated-files/Eel/EelRiverCZO_Project_Description.pdf). Scientists and students from UC Berkeley have monitored low flow food web dynamics and explored links between the mainstem SF Eel River and food webs in 12 tributary streams. For more information, and a list of publications, go to: http://angelo.berkeley.edu/angelo/

Blue-Green Algae Blooms

Blue-green algae (cyanobacteria) are naturally occurring photosynthetic bacteria present in warm, slow-moving surface waters during temperate months in the late summer and early fall. Some forms of blue-green algae produce harmful toxins which may attack the liver (hepatotoxins) or the nervous system (neurotoxins). These toxins are released into the environment when cells rupture or die, and may be concentrated during algal blooms (Hoehn and Long 2008, Blaha 2009). The relationship between the timing of blooms and the concentration of cyanotoxins in the water column is currently unknown (K. Bouma-Gregson, UC Berkeley, personal communication 2014).

Cyanobacteria are found throughout the SF Eel River, in the water column, living within the cell walls of diatoms, growing directly on the substrate, and growing on certain types of filamentous green algae such as *Cladophora*. The color of *Cladophora* changes as epiphytic assemblages of diatoms, some containing nitrogen fixing cyanobacteria, develop on filaments. New *Cladophora* growth is green (*Figure 53*), turns yellow when colonized by non-nitrogen fixing diatoms, then turns rusty red colored as assemblages are dominated by nitrogen fixing diatoms (Power et al. 2009).

Figure 53. Cladophora in Elder Creek, June 2013 (photo courtesy of ERRP).

Rapid accumulations of cyanobacteria cells, or algal blooms, occur during warm summer months, under optimal conditions including elevated stream temperatures, high levels of nutrients (phosphorous and nitrogen, and the ratio of the two), increased periods of sunlight, and low flow. Human activities such as inadequate sewage treatment, or activities that result in increased agricultural and sediment input, lead to excessive fertilization (eutrophication) in water bodies. Eutrophication creates favorable conditions for blue-green algae blooms (WHO 2009) and decreased water clarity and reduced dissolved oxygen levels in streams (Trout Unlimited 2013).

Measures to prevent blooms should be designed to control anthropogenic influences that promote blooms, such as the leaching and runoff of excess nutrients. Management practices for nutrient input, specifically nitrogen and phosphorus, should be designed to reduce loadings from both point and nonpoint sources, including water treatment discharges, agricultural runoff, and stormwater runoff (USEPA 2012). This is especially important in Western Subbasin drainages where nutrients, sediment, and/or pollutants are entering streams from large marijuana cultivation operations (e.g. Redwood Creek).

The Humboldt County Department of Health and Human Services (HCDHHS) recently issued warnings notifying recreational users of the SF Eel River to avoid exposure to neurotoxins and liver toxins found in blue-green algae in the river (HCDHHS, Division of Environmental Health, 2011). The County provided the following recommendations for homeowners and land managers to reduce conditions favoring the spread of blue-green algae:

- Minimize the use of water, fertilizers, and pesticides;
- Recycle or dispose of spent soil that has been used for intensive growing – it may still contain high levels of phosphorous and nitrogen;
- Operate and maintain your septic system properly; have the system pumped every 3-4 years;
- Encourage the growth of native plants on riverbanks and shorelines to prevent erosion and filter water, with no fertilizers or pesticides required;
- Keep livestock out of surface waters and prevent surface runoff from agricultural areas; and
- Prevent sediment from roads, construction projects, and logging operations from entering streams.

In recent years, blue-green algae blooms have become more common in the mainstem SF Eel River during the late summer, when flows are at a minimum and air temperatures are high (>100˚F). These conditions are prevalent in the middle mainstem areas of SF Eel River in the Western Subbasin. The ERRP is currently collecting information on algal blooms, flows, pollutants, and temperatures throughout the Eel River Basin, and are currently developing recommendations to improve ecological conditions and reduce pollution. Bouma-Gregson obtained weekly average concentrations of dissolved cyanotoxins, nitrogen, and phosphorous at 7 sites in the Eel River Basin from July-September, 2013 (for a description of sampling locations, see the Temperature section of this subbasin report). The sites with the highest concentrations of toxins were located in the SF Eel River, though cyanobacteria were present at all sites except Fernbridge. *Anabaena* and *Phormidium*, two genera of cyanobacteria that produce cyanotoxins, were frequently observed at all of the monitoring sites except Fernbridge (Bouma-Gregson, UC Berkeley, personal communication, 2014). In the Western Subbasin, cyanobacteria blooms have been reported only in the mainstem SF Eel River. However, additional studies targeting Western Subbasin tributaries are necessary to address the following issues: specific locations of blue-green algae blooms; the relationship between blue-green algae and green algae; levels of nutrients and pollutants present; current sources of nutrient input; and ways to reduce the input of these and other harmful substances in order to improve salmonid habitat.

Fish Passage Barriers

Barriers to fish passage occur on all natural streams, and are usually gradient or flow barriers near the headwaters. Barriers that occur downstream and limit the naturally occurring range and distribution of salmonids can be classified according to the cause of the barrier (natural or anthropogenic), the barrier’s lifespan (temporary or permanent), and the barrier’s effectiveness (partial or total). Natural barriers include gradient, landslide, and log debris accumulations (LDA); manmade barriers include culverts and dams. All types of barriers fragment the habitat available to different life stages of salmonids by reducing access to stream reaches that are used as migratory corridors, and spawning and rearing habitat.

Several fish passage barrier issues have been identified in the Western Subbasin. Most of the barriers are gradient barriers, followed by culvert barriers (6 partial, 4 total, and 2 temporal) (*Figure 54*). Data used to create the map were collected between 1981 and 2012, but additional barriers may occur as conditions change and information is added to the CalFish Passage Assessment Database.

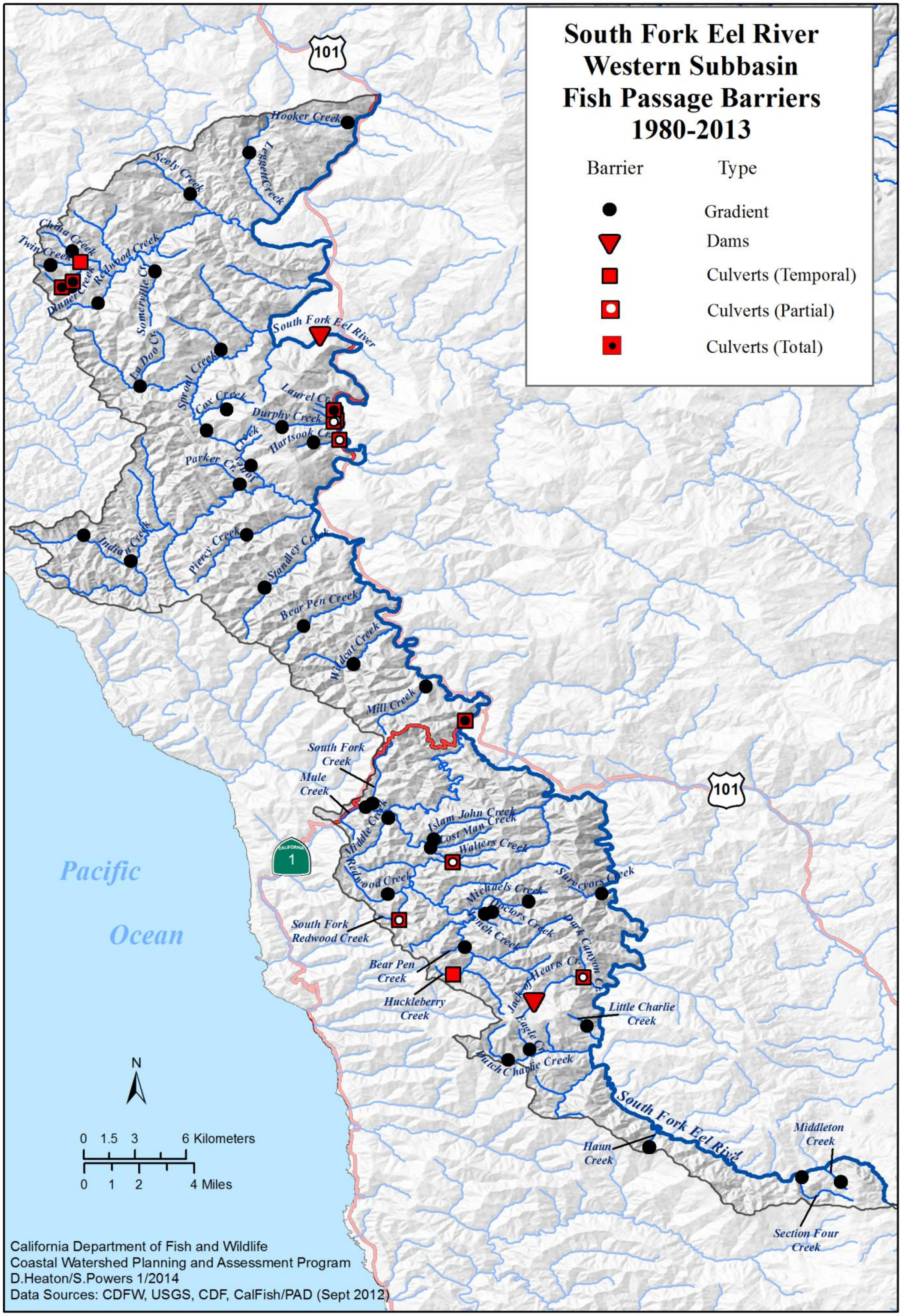

Figure 54. Fish passage barriers in the SF Eel River Western Subbasin.

Improper culvert placement where roads and streams cross can limit or eliminate fish passage (Gucinski et al. 2001). Highway 101, the only primary road in the subbasin, runs along the SF Eel River for the full length of the subbasin, with a secondary frontage road following the highway for most of its length. Many smaller roads, some permanent and some seasonal, connect Highway 101 with headwater areas in most of the larger watersheds. Many roads cross streams multiple times, and at each crossing, passage issues are a possibility. Five culvert barriers (three partial and one total) are located near the mainstem SF Eel River, where Highway 1 (RM 69), and Highway 101 and its frontage road cross tributaries (RM 46-47). Two partial barriers are located on Durphy Creek (*Figure 55*), and one on Hartsook Creek. Other culvert barriers located further up in tributary streams include partial culvert barriers located in the Upper Hollow Tree Creek drainage on MRC land (on Walters and SF Redwood creeks), and on lower Jack of Hearts Creek. Temporal culvert barriers are located on Huckleberry and Twin creeks.

Figure 55. One of two partial culvert barriers located on Durphy Creek.

Ross Taylor and Associates (2005) identified two culverts located on Dinner Creek, both of which are total barriers to fish passage. The first culvert is located 8.3 miles up Briceland Thorn Road from Redway (RM 0.85 from China Creek confluence; *Figure 56*) and the second culvert is located 8.8 miles up Briceland Thorn Road (RM 1.39 from China Creek confluence). Both sites were ranked as high priorities for treatment. The County of Humboldt recently submitted a proposal for FRGP funding to replace both of these culverts, in addition to a smaller culvert approximately 700 feet upstream from the second culvert. In their proposal, the County noted that in May 2012, coho salmon juveniles (YOY) were observed below the first culvert, and steelhead juveniles were observed

Figure 56. Failing culvert on Dinner Creek, tributary to China Creek in the Western Subbasin (photo courtesy of Scott Bauer, CDFW).

between the second and third culverts (S. Bauer, CDFW, personal communication 2014).

There are two dams in the Western Subbasin, only one of which is considered a total barrier. An earthen Dam located on Jack of Hearts Creek is a permanent, total barrier but is located near the headwaters and does not seem to shorten the length of anadromy significantly. Benbow Dam was was identified by CalFish (2012) and included on the barrier map for reference, however, the flashboards are no longer installed each summer to impound water, and it is not considered a barrier to fish passage at this time.

Gradient barriers caused by boulders or bedrock are found throughout Western Subbasin streams (*Figure 54*). Most of the gradient barriers mapped in this subbasin were waterfalls, which are considered extreme examples of gradient barriers. The largest waterfall barrier (38') in the Western Subbasin is located on Middle Creek, a tributary to Hollow Tree Creek, and other streams contain smaller waterfalls that are large enough to act as total barriers. Height or vertical drop of falls, plunge pool area and depth, and the jumping ability of each species must be considered when determining whether a waterfall is a barrier to fish passage (Powers and Orsborn 1985). Other gradient barriers included boulder runs and series of cascades.

Log jams, referred to in this report as LDAs, in streams can also become fish passage barriers. These are noted in CDFW stream inventories. LDAs are usually temporary barriers, because they shift or break apart during large flow events, but some trap sediment and additional material so that they may persist for decades as total barriers. Stream inventories in the Western Subbasin found no total LDA barriers, although many large debris jams were documented in stream surveys, especially following historic flood events. Restoration activities in the past concentrated on removing wood jams, including complete, partial, or potential barriers. These actions, combined with intensive industrial timber harvest activities, resulted in a lack of large wood in streams. Current restoration projects concentrate on adding large wood back into streams to scour pool habitat and provide cover for adult and juvenile salmonids.

Habitat Conclusions

Overall Suitability

CWPAP staff assessed changes in Western Subbasin salmonid habitat using historic data collected on surveys from 1938-1990, and stream habitat typing survey data collected from 1990-2010. Data from older surveys, collected prior to the establishment of a stream survey protocol (Flosi et al. 2010), provided a snapshot of the conditions at the time of each survey. Terms such as excellent, good, fair, and poor were based on the judgment of the biologist or scientific aid who conducted the survey. The results of these historic stream surveys were qualitative and were not used in comparative analyses with quantitative data provided by habitat inventory surveys collected beginning in the 1990s. However, the two data sets were compared to show general trends.

In historic surveys (prior to 1990), spawning habitat was generally good in Western Subbasin tributaries. High water temperatures were noted in the lower reaches of the mainstem SF Eel River. Log jams were the most common barrier type, but most were not classified as total barriers.

Average canopy density and embeddedness scores in Western Subbasin streams increased over time when comparing data collected in the 1990s with data from the early 2000s (*Table 32*). Most primary pool length scores were in the lowest suitability category during both time periods, and pool shelter scores decreased slightly over time. Although some increases in factor values were seen, average values were below target values for all streams except canopy density in the 2000-2010 sampling period. Embeddedness, primary pools, and pool shelter are likely limiting to salmonid populations in this subbasin.

Canopy density was suitable on most surveyed creeks. However, overall canopy density measurements do not take into account differences between smaller, younger riparian vegetation and the larger microclimate controls that are provided by old-growth forest canopy conditions. CWPAP staff considered the contribution of coniferous and deciduous components in the canopy, and found that the average percent of coniferous vegetation increased and percent open canopy decreased considerably in most Western Subbasin streams over time.

Primary pool length was in the lowest suitability category for nearly all streams during both sampling periods. The headwaters of the SF Eel River was the only stream sampled that showed improvement in the length of primary pool habitat over time.

Pool shelter was in the lowest suitability category in most Western Subbasin streams, and in streams that were sampled during both time periods, shelter suitability decreased from suitable to unsuitable in 7 streams (Bear Wallow, Butler, Doctors, Huckleberry, Low Gap, Moody, and SF Redwood creeks). Both pool habitat and pool shelter are likely limiting factors in Western Subbasin streams.

Cobble embeddedness suitability increased in most Western Subbasin streams over time, and went from the lowest to the highest suitability category in Michaels and Doctors creeks. Embeddedness values increased throughout the Hollow Tree Creek drainage over time. This improvement is most likely due to changes in timber harvest regulations, road decommissioning, numerous restoration and instream habitat improvement projects completed in this basin, and sediment from historic floods moving through the system. Although embeddedness suitability scores increased in many streams, average values were still below target values during both sampling periods.

Summer water temperature measurements showed that water temperatures were good for salmonids in headwaters areas above Branscomb (RM 95), but were stressful for salmonids at downstream sites and in larger tributaries. Sampling sites in tributaries with poor temperatures were located in the lower reaches of the largest streams in the subbasin (Hollow Tree and Sproul creeks) and in the mainstem SF Eel River from RM 25-86. Lethal temperatures were recorded in the mainstem SF Eel River at Piercy (RM 54) and Sylvandale (RM 25). Lower Hollow Tree and lower Sproul creeks are wide channels with little riparian canopy cover, and increased direct solar radiation results in higher stream temperatures. Warm water temperatures in Redwood Creek (Redway) are caused by reduced riparian canopy and increased water diversion for

Table 32. EMDS-based Anadromous Reach Condition Model suitability results for factors in Western Subbasin streams (ND = no data available; LB = left bank; UT = unnamed tributary).

Stream	Survey Year	Mean Canopy Density (%)	Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Pool Shelter Rating
Anderson Creek	2008	++	++	ND	--
Bear Pen Creek	1992	-	--	--	--
	2007	++	+	--	--
Bear Wallow Creek	1990	++	++	--	++
	2002	++	+	--	-
Bond Creek	1991	--	--	--	-
	2003	++	-	--	-
Butler Creek	1990	+	++	--	++
	2002	++	+	--	--
Butler Creek (UT - LB)	2002	++	++	--	--
China Creek	1998	++	--	--	--
	2009	++	+	--	--
Cox Creek (SF Eel)	1993	+	-	--	--
	2004	++	-	--	--
Doctors Creek	1991	-	--	--	+
	2003	++	++	--	-
Durphy Creek	2006	+	-	--	--
Durphy Creek (UT - LB)	1993	-	--	--	--
	2006	++	+	--	--
Dutch Charlie Creek	1992	++	--	--	--
	2007	++	-	-	-
Hartsook Creek	1999	++	-	--	--
	2009	++	+	--	--
Hollow Tree Creek	1992	--	--	--	--
	2002	++	+	--	--
	2003	++	+	--	--
Huckleberry Creek	1990	++	-	-	++
	2002	++	+	--	--
Indian Creek	1993	--	+	--	--
	2008	++	++	--	--
Jack of Hearts Creek	1992	++	-	-	-
	2005	++	++	--	--
Leggett Creek	1995	+	--	--	--
	2007	++	-	--	--
Little Sproul Creek	1995	++	--	--	--
Little Sproul Creek (UT)	2004	++	-	ND	--
Low Gap Creek	1990	--	-	--	+

Stream	Survey Year	Mean Canopy Density (%)	Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Pool Shelter Rating
Low Gap Creek (con.)	2007	++	+	--	-
Lynch Creek	1991	-	--	--	--
	2003	++	+	--	-
Michaels Creek	1991	--	--	--	--
	2003	++	++	--	-
Mill Creek	2010	++	+	--	--
Moody Creek	1993	++	--	--	+
	2008	++	++	--	--
Piercy Creek	2007	++	-	--	-
Pollock Creek (Upper Redwood Creek)	1998	++	--	--	--
	2009	++	-	--	--
Redwood Creek (Hollow Tree Creek)	2003	++	--	--	--
Redwood Creek (Branscomb)	1993	++	--	--	--
	2007	++	--	-	+
Redwood Creek (Redway)	2009	-	++	+	--
SF Eel River headwaters	1996	++	-	--	--
	2007	++	-	++	--
SF Redwood Creek	1991	++	--	--	+
	2003	++	--	-	--
SF Redwood Creek (UT)	2003	++	--	--	--
Sproul Creek	2004	++	-	--	--
Sproul Creek (tributary 5)	2004	++	--	--	--
Standley Creek	1992	-	-	--	--
	2007	++	--	--	--
	2009	++	++	--	--
Twin Creek (UT to China Creek)	2009	++	++	--	--
Waldron Creek	1991	+	--	--	--
	2002	++	+	--	--
Warden Creek	1992	++	--	--	--
	2004	++	-	--	-
WF Sproul Creek	1992	++	--	--	--
	2004	++	-	--	-
WF Sproul Creek (tributary 8)	2004	++	-	--	-
WF Sproul Creek (tributary 9)	2004	++	-	--	+
Wildcat Creek	1992	-	-	--	--
	2007	++	++	--	-
Wood Creek	2002	++	+	--	--
Key: ++ = Highest Suitability		**-- = Lowest Suitability**			

residential use and industrial marijuana cultivation operations. Water temperature is likely a limiting factor for salmonids in surveyed streams in this subbasin, and cold water seeps where springs or tributaries enter the mainstem may provide important patches of cooler water for salmonids during late summer months.

Sediment loading in the Western Subbasin is extremely high, and primary input sources include natural landslides and earthflows, road erosion and failure, and logging related erosion from skid trails and road construction. This subbasin has a very high road density, and road decommissioning projects have resulted in decreased fine sediment input at most treated sites, however, considerable erosion control measures will be required to meet the established TMDL and loading capacity. Sediment loading and turbidity conditions may be limiting factors for salmonid production.

Restoration Projects

Increased funding and the associated tracking requirements have facilitated cataloging restoration projects. The California Habitat Restoration Project Database (CHRPD) houses spatial data on CDFW's Fisheries Restoration Grants Program (FRGP) projects and other projects with which CDFW has been involved. The CHRP data is available through CalFish (www.calfish.org) and includes some projects from agencies and programs outside of CDFW. In addition, the Natural Resources Project Inventory (NRPI), available through the University of California, Davis (www.ice.ucdavis.edu/nrpi/), receives information on projects from the CHRPD and other sources. Information presented here includes projects from both of these databases, but are not comprehensive of all restoration projects completed in the Western Subbasin.

There have been 160 restoration projects, totaling more than 13 million dollars in funding, completed from 1982 to the present in the Western Subbasin (*Table 33*). The most common types of projects are cooperative rearing, followed by upslope watershed restoration and instream habitat improvement. Fifty four percent of all funding has been allocated to upslope watershed restoration projects (*Figure 57*) in this subbasin, which is similar to the percentage of total funding allocated for these types of projects in the entire SF Eel River Basin.

Table 33. Western Subbasin restoration project type and funding (1982 to 2013).

Project Type	# of Projects	Total Project Funding
Bank Stabilization	17	$470,741
Cooperative Rearing	39	$1,232,404
Fish Passage Improvements	15	$715,554
Instream Habitat Improvement	30	$1,224,544
Land Acquisition	1	$715,554
Monitoring	4	$308,416
Other *	4	$167,781
Riparian Habitat Improvement	2	$30,843
Upslope Watershed Restoration	34	$7,203,745
Watershed Evaluation, Assessment & Planning	14	$1,206,457
Total	**160**	**$13,276,039**
* "Other" includes education/outreach, training, capacity building and public involvement.		

The majority of restoration projects in this subbasin have been completed in the Hollow Tree Creek basin and in Redwood Creek near Redway (*Figure 58*). In the Hollow Tree Creek watershed, restoration projects are primarily road decommissioning, with some instream and riparian habitat improvement, fish passage improvements, and cooperative rearing projects completed. In the Redwood Creek watershed, the most common project types are bank stabilization, cooperative rearing, and upslope watershed restoration.

Figure 57. Example of upslope watershed restoration project in Hollow Tree Creek before (above) and after (below) treatment (Pacific Watershed Associates 2010).

Additional information about specific projects can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis.edu/nrpi/).

While site-specific projects are important at the reach scale, restoration that addresses land use issues, such as timber harvest and illegal marijuana cultivation that result in degradation and reduction of salmonid habitat on a watershed scale is essential for ecosystem recovery. Current management actions are needed to address diversion, flow, and pollution in residential areas, particularly in the larger watersheds such as Redwood Creek near Redway in the northern part of the subbasin.

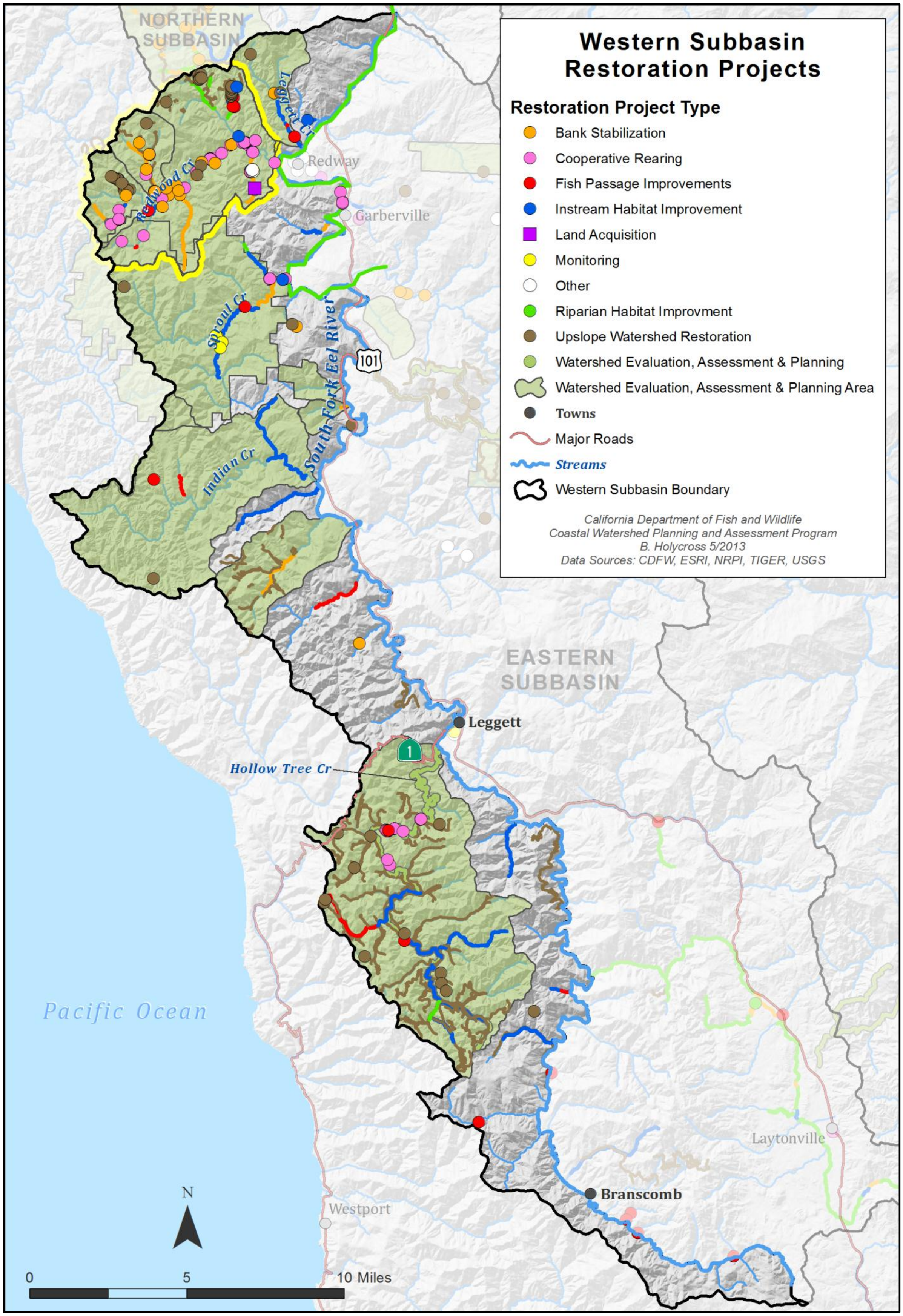

Figure 58. SF Eel River Western Subbasin restoration projects.

Integrated Analysis

Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFW stream inventories provide a list of recommendations that address those conditions that did not reach target values (see the Fish Habitat section of this subbasin). In the Western Subbasin, 62 streams were inventoried (109 surveys; 260 miles total) and recommendations for each were selected and ranked by a CDFW biologist (*Table 34*). The first recommendation in every CDFW stream inventory report is that the stream "should be managed as an anadromous, natural production stream". Because this recommendation is the same for every stream, and because it does not address specific issues, with associated target values, it was not included in the tributary recommendation analysis. The tributary recommendation process is described in more detail in the Synthesis section of the Basin Profile.

In order to compare tributary recommendations within the subbasin, the recommendations of each stream were collapsed into five target issue categories (*Table 35*). The top three recommendations of each stream are considered the most important, and are useful as a standard example of the stream. When examining recommendation categories by occurrence, the most important target issue in the Western Subbasin is instream habitat, followed by erosion/sediment and riparian/water temperature.

However, comparing recommendation categories in the subbasin by number of tributaries can be confounded by differences in the length of stream surveyed in each tributary. Therefore, CWPAP staff calculated the number of stream miles within the subbasin assigned to various recommendation categories (*Figure 59*). By examining recommendation categories by number of stream miles, the primary target issue remains instream habitat, followed by erosion/sediment and riparian/water temperature recommendations as the next most important target issues in Western Subbasin streams. Because of the high number of recommendations dealing with these target issues, high priority should be given to restoration projects that emphasize instream habitat restoration and improvement, in addition to sediment reduction and bank stabilization projects designed to reduce input from both natural and anthropogenic sources.

Table 34. Occurrence of stream habitat inventory recommendations for streams in the SF Eel River Western Subbasin.

Stream	Survey Length (miles)	Bank	Roads	Canopy	Temp (A=study required)	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Anderson Creek (1993)	5	4	5			1	2		3		
Anderson Creek (2008)	2.3		3		A1		2				
Barnwell Creek (1992)	0.5	4			A1	2	3		5		6
Bear Creek (1992)	0.4								1		
Bear Pen Creek (1992)	3.4	4		5	A1	2	3		6		
Bear Pen Creek (2007)	2.8	2			A3		1				
Bear Wallow Creek (1990)	1.5	2					1		3		
Bear Wallow Creek (2002)	2.1	3	4		A1		2				
Bond Creek (1991)	1.8	4	5	3		1	2				
Bond Creek (2003)	2.6	2	3		A1	4	5				
Butler Creek (1990)	1.2					2	1				
Butler Creek (2002)	1.4		4		A1	2	3				

Stream	Survey Length (miles)	Bank	Roads	Canopy	Temp (A=study required)	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Butler Creek Unnamed Tributary 1 (2002)	0.3		3		A1		2				
China Creek (1993)	1.8	1	2	3							
China Creek (1998)	2.9	4	3	5	A1		2				
China Creek (2009)	2.2	3			A1		2				
Connick Creek (1993)	2.2	2		6	A1	3	4		5		
Coulborn Creek (1993)	1.4	3	4			1	2		5		
Cox Creek (1993)	1.2	3	4			1	2				
Cox Creek (2004)	1.3	4			A1	2	3		5		
Dinner Creek (1993)	1.9	2				3	1				
Doctors Creek (1991)	0.2	2				3			1		
Doctors Creek (2003)	0.3				A1	2	3				
Durphy Creek (1993)	1.6	3		4		1	2				
Durphy Creek (2006)	1.8	4	5	7	A1	2	3				6
Durphy Creek Unnamed Tributary (1993)	0.4	4		5		2	3				1
Durphy Creek Unnamed Tributary (2006)	0.5	2			A1						
Dutch Charlie Creek (1992)	3.5		4		A2	3	1			5	
Dutch Charlie Creek (2007)	2.9	2			A3		1				
Hartsook Creek (1994)	1.3	3	4			1	2				5
Hartsook Creek (1999)	1.3	4			A1	2	3				
Hartsook Creek (2009)	1.3				A1	2	3				
Hollow Tree Creek (1990)	2.1						1				
Hollow Tree Creek (1991)	4.7	3		4		2	1				
Hollow Tree Creek (1992)	14.8	3	4	5	A1		2				
Hollow Tree Creek (2002)	2.6	3	4		A1		2				
Hollow Tree Creek (2003)	3.6	3			A1		2		E4		
Hollow Tree Creek, SF (1992)	0.3		4			1	2		3		
Huckleberry Creek (1990)	1.2						1		3		2
Indian Creek (1993)	11.1	6	7	2	A1	4	3	5			
Indian Creek (2008)	9.8		3		A1		2				

Stream	Survey Length (miles)	Bank	Roads	Canopy	Temp (A=study required)	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Islam John Creek (1992)	0.5	5		6		2	3		4		1
Jack of Hearts Creek (1992)	2.9	3	4			1	2		5		
Jack of Hearts Creek (2005)	3.1	4	5	6	A1	2	3	7	8		
Jones Creek (1993)	0.7				A1	2	3	4			
La Doo Creek (1992)	0.2										1
Leggett Creek (1992)	3.2	3				1	2				
Leggett Creek (1995)	2.3	2	1			3	4				
Leggett Creek (2007)	3.3	3	4		A5	2	1				
Little Sproul Creek (1989)	1.9	1		2			4				
Little Sproul Creek (1991)	1.9	5		2	A1	3	4				
Little Sproul Creek (1995)	1.7	1	4			2	3				
Little Sproul Creek (2004)	2.5	4	5	6	A1	2	3	7	8		
Little Sproul Creek Unnamed Tributary (2004)	0.9	3			A1		2				
Lost Man Creek (1992)	0.02										1
Low Gap Creek (Leggett) (1990)	2.7	2					1		3		
Low Gap Creek (Leggett) (2007)	2.5	3			A4	1	2				
Lynch Creek (1991)	0.3	2				4	3		1		
Lynch Creek (2003)	0.2				A1	2	3				
Michaels Creek (1991)	1.7	1				4	3		2		
Michaels Creek (2003)	2.6				A1	2	3				E4
Middle Creek (1992)	0.3	4				1	2		3		
Middleton Creek (1996)	1		4	5	A1	2	3				
Mill Creek (Leggett) (1992)	0.3			1		3	4				2
Mill Creek (Leggett) (2010)	0.3				A1		2				
Miller Creek (1995)	4.3		3		A1	4	2				
Moody Creek (1993)	1.6	3	4			1	2		5		
Moody Creek (2008)	1.7		3		A1		2		4		
Mule Creek (1992)	0.2		4			1	2		3		

Stream	**Survey Length (miles)**	**Bank**	**Roads**	**Canopy**	**Temp** (A=study required)	**Pool**	**Cover**	**Spawning Gravel**	**LDA**	**Livestock**	**Fish Passage**
Piercy Creek (1990)	3.2	2					1		3		
Piercy Creek (2007)	2.2		4		A3	2	1				
Pollock Creek, aka Upper Redwood (1993)	2.4	1	2			4			3		
Pollock Creek (1998)	2	3	4	5	A1		2				
Pollock Creek (2009)	2.7	3			A1		2				
Redwood Creek (Branscomb) (1993)	2.4	2	3		A1		5		4		
Redwood Creek (Branscomb) (2007)	2.4		1		A3		2				
Redwood Creek (Hollow Tree) (1991)	2.7	4					3			2	1
Redwood Creek (Hollow Tree) (2003)	2		3		A1		2				
Redwood Creek (Redway) (1993)	7.9	2	1	5	A4	3					
Redwood Creek (Redway) (2009)	7.4	3		4	A1		2				
Redwood Creek, SF (1991)	1.7	3					2		1		
Redwood Creek, SF (2003)	1.9	3	4		A1		2				
Redwood Creek, SF Unnamed Tributary (2003)	0.2		2		A1				3		
Sebbas Creek (1993)	3.8	4	5			1	2		3		6
SF Eel River Headwaters (1996)	9	1	2		A7	5	3		6	4	
SF Eel River Headwaters (2007)	5.4				A2		1				
Somerville Creek (1993)	1.9	1		5		3	4			2	
Sproul Creek (1992)	7.2		4	2	A1	6	3	5			
Sproul Creek (2004)	6.1	3		4	A1		2				
Sproul Creek Unnamed Tributary 5 (1992)	1.4					1	2		3		
Sproul Creek Unnamed Tributary 5 (2004)	0.5	4	5		A1	2	3				
Sproul Creek, East Branch of WF (1992)	1.3	1				4	3		2		
Sproul Creek, WF (1992)	5.5	1	2			4	3		5		
Sproul Creek, WF (2004)	5	4	5		A1	2	3				

Stream	Survey Length (miles)	Bank	Roads	Canopy	Temp (A=study required)	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Sproul Creek, WF Unnamed Tributary 8 RB (2004)	0.6				A1	2	3		4		
Sproul Creek, WF Unnamed Tributary 9 LB (2004)	1.5	4			A1	2	3				
Standley Creek (1992)	3.1	3	5	4		1	2		6		
Standley Creek (2007)	3	3	2		A4		1				
Standley Creek (2009)	1.9				A1		2				
Twin Creek (1993)	0.9	4				1	2				
Twin Creek (2009)	0.5	3			A1		2				
Waldron Creek (1991)	1.4	3	4			1	2				
Waldron Creek (2002)	1.4	3	4		A1		2				
Walters Creek (1992)	0.8		5		A4	1	2		3		6
Warden Creek (1992)	0.4	1	2			4	5				3
Warden Creek (2004)	0.4	5			A1	3	4				2
Wildcat Creek (1992)	2.4	3				1	2				
Wildcat Creek (2007)	2.3	3			A1		2				
Wood Creek, SF Unnamed Tributary (2002)	0.8	4			A1	2	3				

Canopy = shade canopy is below target values; **Bank** = stream banks are failing and yielding fine sediment into the stream; **Roads** = fine sediment is entering the stream from the road system; **Temp** = summer water temperatures seem to be above optimum for salmon and steelhead; **Pool** = pools are below target values in quantity and/or quality; **Cover** = escape cover is below target values; **Spawning Gravel** = spawning gravel is deficient in quality and/or quantity; **LDA** = large debris accumulations are retaining large amounts of gravel and could need modification; **Livestock** = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; **Fish Passage** = there are barriers to fish migration in the stream.

Table 35. Top three ranking recommendation categories by number of tributaries in the Western Subbasin.

Western Subbasin Target Issue	Related Table Categories	Count
Erosion / Sediment	Bank / Roads	72
Riparian / Water Temp	Canopy / Temp	64
Instream Habitat	Pool / Cover	145
Gravel / Substrate	Spawning Gravel / LDA	19
Other	Livestock / Barrier	11

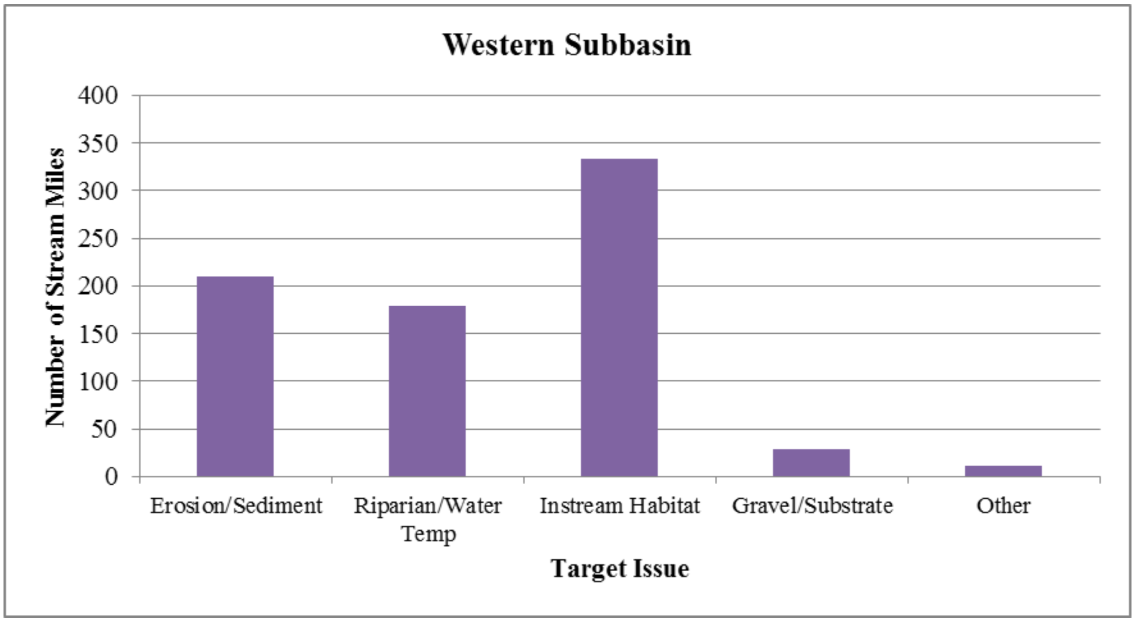

Figure 59. Recommendation target issues by stream miles for the Western Subbasin.

Refugia Areas

The interdisciplinary team identified and characterized refugia habitat in the Western Subbasin using professional judgment and criteria developed for north coast watersheds. The criteria included measures of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. The team also used results from information processed by the EMDS-based analysis at the stream reach scale.

A total of 57 Western Subbasin streams were designated as salmonid refugia areas and were rated into one of the four refugia categories. Refugia categories were defined as:

- **High Quality** – relatively undisturbed habitat, with the range and variability of conditions necessary to support species diversity and natural salmonid production;
- **High Potential** – diminished but good quality habitat with salmonids present, currently managed to protect natural resources with the possibility to become high quality refugia;
- **Medium Potential** – degraded or fragmented instream and riparian habitat, with salmonids present but reduced densities and age class representation. Habitat may improve with modified management practices and restoration efforts;
- **Low Quality** – highly impaired riparian and instream habitat with few salmonids (species, life stages, and year classes). Current management practices and conditions have significantly altered the natural ecosystem and major changes are required to improve habitat.

The most complete data available in the Western Subbasin were for tributaries surveyed by CDFW. However, many of these tributaries were still lacking data for some factors considered. Five streams were rated as high quality refugia, 38 as high potential refugia, 12 as medium potential refugia, and 2 as low quality refugia habitat.

Three of the largest streams in the subbasin were divided into two sections because of significant differences in conditions and salmonid use between lower and upper areas:

- Hollow Tree Creek - the area below the old hatchery (downstream from the confluence of South Fork Creek) was rated medium potential, and the area above the hatchery was rated high quality, with some of the best salmonid habitat in the entire SF Eel River Basin;
- Connick Creek – the lower section (1 mile up from confluence of the SF Eel River) is

medium potential, and the upper section is low quality;

- Redwood Creek (Redway) – the lower section (below Sommerville Creek) is medium potential, and the upper section (also known as Pollock Creek) is high potential refugia habitat.

Five streams were rated as high quality refugia habitat: Indian, Moody, Anderson, Low Gap, and Upper Hollow Tree creeks. Moody and Anderson creeks are located in the upper Indian Creek watershed. This basin is owned primarily by Hawthorne Timber Company, and habitat is relatively good, with excellent canopy condition, good instream temperatures, good spawning gravels, and few diversions. The Upper Hollow Tree Creek drainage and most of the land surrounding Low Gap Creek is owned by MRC, and contains excellent spawning habitat, with cool stream temperatures, good canopy coverage, and adequate flow even during the late summer months.

The majority of Western Subbasin streams were rated as high potential habitat. The climate in this subbasin is relatively cool throughout out year due to the influence of the coastal marine layer, and the topography includes many steep walled canyons and relatively narrow valleys compared to Eastern Subbasin topography. These conditions, along with the resulting cool instream temperatures in most tributaries provide good overall conditions, but road related sediment input and timber harvesting activities have resulted in diminished high quality habitat. Current forest practice rules and practices, combined with restoration (especially road decommissioning) projects may lead to some of these streams becoming high quality refugia areas in the future.

Only two creeks in the entire subbasin were rated low quality: Little Charlie Creek and Connick Creek (*Figure 60*). These creeks are heavily diverted, with corresponding high impacts to salmonid habitat and populations from low flow and poor water quality.

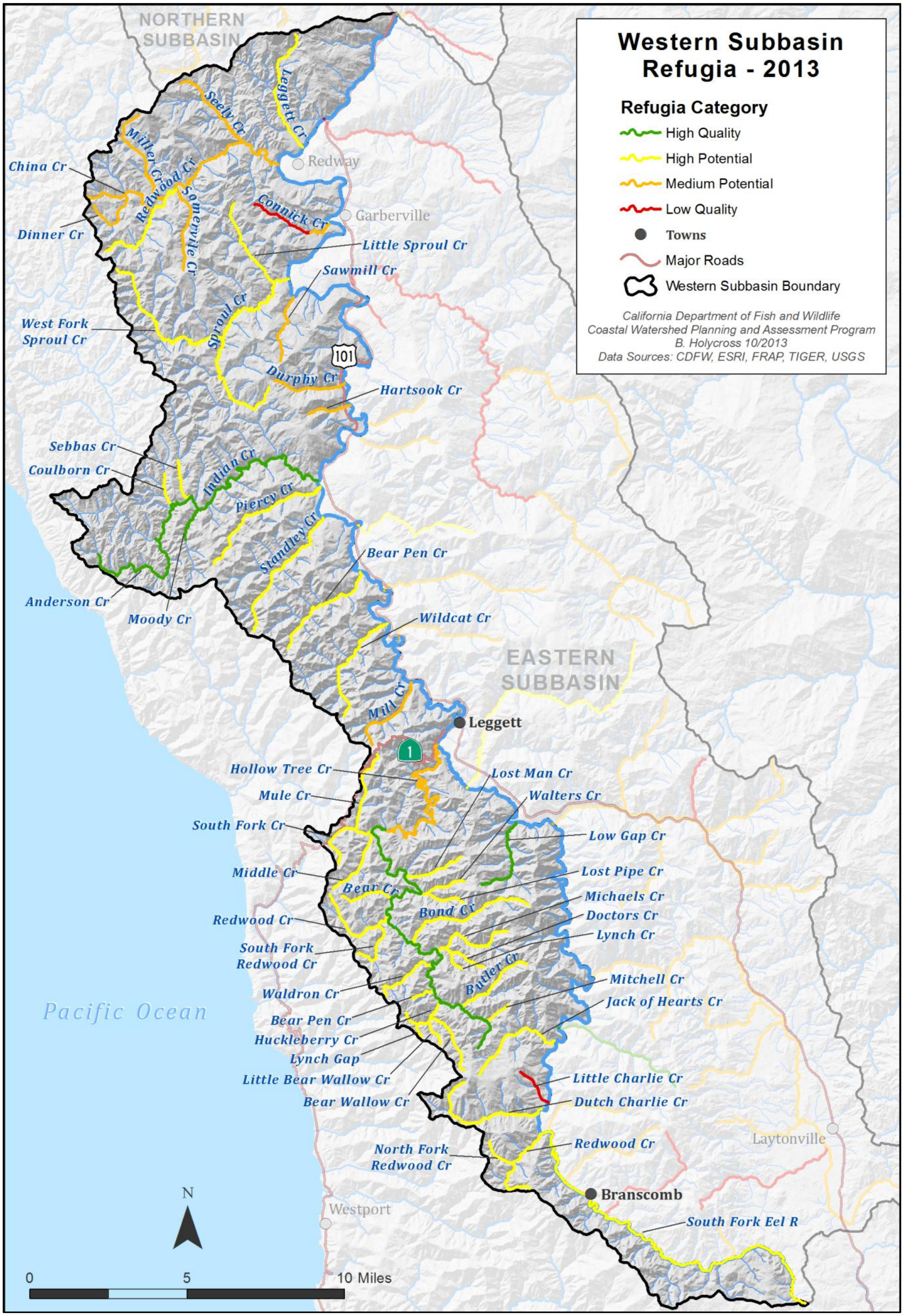

Figure 60. Refugia ratings in SF Eel River Western Subbasin streams.

Key Subbasin Issues

- High levels of fine sediment input related to very high road density and timber harvest activities on unstable soils;
- Altered flow regimes, particularly during low flow periods in late summer, resulting from diversion and reduced winter precipitation patterns;
- Addition of fertilizers, pollutants, and sediment to streams from marijuana cultivation operations in watersheds with high residential land use (e.g. Redwood Creek);
- Erosion from landslides, roads, construction waste, and ground disturbance;
- Poor quality pool habitat (depth, shelter, and quality) in most Western Subbasin streams;
- Medium potential refugia habitat in lower Redwood Creek (Redway), which was historically a productive coho and Chinook salmon and steelhead trout stream;
- High instream temperatures in many streams, with above lethal temperatures recorded in the late summer in the mainstem SF Eel River;
- Sacramento pikeminnow documented in mainstem SF Eel River and in some Western Subbasin tributaries.

Responses to Assessment Questions

What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Western Subbasin?

Findings and Conclusions:

- The Western Subbasin supports populations of Chinook salmon, coho salmon, and steelhead trout;
- Using data from one long term data set for salmonid populations in the SF Eel River Basin (Benbow Dam counts occurring from 1938-1975), trend lines for Chinook salmon, coho salmon, and steelhead trout abundance all show significant decreases throughout the sampling duration. These trends are most likely similar for salmonid populations throughout Western Subbasin streams;
- Populations of all three salmonids appeared to decline abruptly following the 1955 and 1964 floods;
- Current salmonid populations are not only less abundant, but they are less widely distributed than they were historically:
    - Historical and anecdotal accounts in 50 Western Subbasin streams dating back to the late 1930s indicate the presence of presence of Chinook salmon in 17 tributaries (34% of streams sampled), coho salmon in 28 tributaries (56% of streams sampled), and steelhead trout in 41 tributaries (82% of streams sampled) in the Western Subbasin;
    - Current salmonid distribution, based on data collected in 175 streams from a variety of sources (CDFW, USFS, tribal fisheries monitoring, university research, local watershed stewardship programs, and additional fisheries stakeholders) indicate the presence of Chinook salmon in 44 tributaries (25% of surveyed streams), coho salmon in 34 tributaries (19% of surveyed streams), and steelhead trout in 53 tributaries (30% of surveyed streams) in the Western Subbasin;
- Historically and currently, steelhead trout have been found in more tributaries and in areas further upstream than both Chinook and coho salmon. This is due to their preference for habitats that are located farther inland, in smaller streams than Chinook and coho salmon (Moyle et al. 2008), their ability to tolerate a broader range of instream conditions, and their comparatively superior jumping abilities;
- Non-native Sacramento pikeminnow have been documented in most surveys beginning in the late 1990s and are now common in areas of the mainstem SF Eel River and in lower reaches of tributaries. Pikeminnow compete with and prey upon juvenile salmonids, and are adapted to withstand warmer water temperatures than native salmonids.

What are the current salmonid habitat conditions in the Western Subbasin? How do these conditions compare to desired conditions?

Findings and Conclusions:

Flow and Water Quality:

- Instream flow has been reduced through unpermitted diversion for residential and marijuana cultivation uses, particularly in areas where land use is primarily residential (e.g. Redwood Creek near Redway). Reduced flow (compared to historical averages) has been documented in Western Subbasin streams during the late summer and early fall;
- Low summer flows result in dry or intermittent reaches on streams, which may be stressful to salmonids and lead to juvenile mortality;
- The recent increase in industrial marijuana cultivation coupled with several drought years has led to the increased development or reliance on groundwater wells, which will only further exacerbate low flow conditions in the summer and early fall;
- Water diversion by industrial timber companies for road dust/sediment control has been estimated at 2,000-4,000 gallons/mile/day between May 15th and October 15th. The amount of water used may be substantial at a time when stream flow is already low, particularly in areas with multiple users with high water demand;
- Water quality is reduced by input of fine sediments from roads throughout the subbasin; primarily seasonal roads that were originally used to access or haul timber, many of which are now also used to access residential areas in newly developed locations or where subdivision of larger parcels has occurred;
- Water quality is reduced by marijuana cultivation operations. Water quality is compromised in these areas by the input of fertilizers, pesticides, rodenticides, diesel fuel from generators, and sediment from improperly constructed roads, and clearing and construction activities at grow sites;
- Increased turbidity is stressful to salmonids, especially during the rainy winter months. High levels of turbidity occur during salmon and steelhead spawning season.

Erosion/Sediment:

- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing and feeding habitat for salmonids. High sediment input from natural and anthropogenic sources have resulted in low suitability pool habitat and reduced water quality in streams throughout the subbasin;
- Road density is high (4.8 miles/square mile) in the Western Subbasin, which is the highest density of all three SF Eel River subbasins, reflecting the dominant land use of industrial timber harvest. Legacy logging roads and use of substandard logging roads for hauling and residential access are sources of sediment input into streams throughout the Western Subbasin;
- Soils in the Western Subbasin are prone to erosion, and slides and streambank failures contribute fines to the streams;
- During the historic flood events of 1955 and 1964, very large quantities of sediment entered Western Subbasin streams, and legacy effects of the sediment input are still influencing Western Subbasin streams;
- Increased fine sediment in stream gravel has been linked to decreased fry emergence, decreased juvenile densities, reduced diversity and abundance of invertebrates, loss of winter carrying capacity, and increased predation (Gucinski et al. 2001).

Riparian Condition/Water Temperature:

- Canopy density met or exceeded target values in the early 2000s in nearly all surveyed streams in the Western Subbasin. Canopy density values increased over time (using habitat typing data collected during two time periods: 1990-1999, and 2000-2010); the largest increase was seen in Low Gap

Creek, where mean canopy density increased by 60.2% between surveys conducted in 1990 and in 2007;
- In the 1990s, 25% of the stream length surveyed had canopy densities below 50% and only 43% met target values of 80% or greater. Coniferous canopy cover was relatively low (< 50%) in most streams, and was less than 10% in Bond Creek, Hollow Tree Creek, Michaels Creek, and an unnamed tributary to Durphy Creek;
- In the early 2000s, there was no stream length with less than 50% canopy density, and 85% of surveyed stream length met target values of 80% or greater;
- Canopy density suitability improved over time, and most Western Subbasin streams were in the highest category in in the early 2000s. Suitability scores were in the lowest category on the lower reaches of Redwood Creek (Redway), and in the second lowest suitability category on lower Sproul Creek;
- The average percent of coniferous vegetation increased and percent open canopy decreased considerably in most Western Subbasin streams over time;
- Water temperature data collected by HCRCD (between 1996-2003), and ERRP (in 2012) indicated poor (≥66ºF) instream temperatures at 5 tributary sites and 9 mainstem SF Eel River sites; fair (63-65˚F) instream temperatures at 8 tributary and 1 mainstem sites; and good instream temperatures (50-62˚F) recorded at 40 tributary and 1 mainstem locations in Western Subbasin streams. There were two sites where lethal (≥75ºF) conditions were recorded, both in the mainstem SF Eel River near Piercy (RM 54) and Sylvandale (RM 25);
- Bouma-Gregson recorded average daily temperatures above lethal levels (≥75˚F) on 15 days between July and August 2013 in the mainstem SF Eel River at Richardson Grove (RM 49), and on 9 days in July 2013 at Standish-Hickey State Recreation Area (RM 66).

Instream Habitat:

- Only one surveyed stream met the >40% target value for pool depth: Redwood Creek (tributary to Hollow Tree Creek) had 42% of surveyed habitat length classified as primary pool habitat in 2003. The remaining 43 streams surveyed did not meet target values for primary pool habitat, and values ranged from a high of 34% in Indian Creek in 2008 to a low of 0% in two streams: an unnamed tributary to Durphy Creek in 1993 and Lynch Creek in 1991;
- Quality pool structure is lacking in Western Subbasin streams. The average mean pool shelter rating was 43.5 in the 1990s and 36.4 using habitat data collected between 2000 and 2010; these values are well below the target pool shelter value of 100 for salmonids. Pool shelter was the only habitat component analyzed that decreased in both rating and suitability between the 1990s and early 2000s;
- Boulders were the dominant pool shelter type during both sampling periods. Using habitat data collected in the 1990s, other shelter types were SWD, LWD, undercut banks, and terrestrial vegetation. Using data from the early 2000s, other shelter types were LWD, SWD, undercut banks, terrestrial vegetation, root masses, and whitewater;
- Although pool depths were generally shallow, pool riffle ratios were above optimal ratios (1:1) in Western Subbasin streams, and the percentage of pool habitat relative to riffle habitat increased slightly in recent years (2000-2010) compared to percentages recorded on surveys in the 1990s. In the 2000s, the pool riffle ratio was 60:40, which is generally considered to provide suitable holding area and habitat diversity for both juvenile salmonids and benthic invertebrates.

Gravel/Substrate:

- Cobble embeddedness conditions improved in most Western Subbasin streams over time, with average category 1 embeddedness values of 12.7% for data collected in the 1990s and 34.4% for data collected between 2000 and 2010. Although embeddedness values increased, they were still below target values (>50% category 1) during both time periods;
- The percent of pool tails surveyed in cobble embeddedness category 1 nearly tripled between the 1990s and early 2000s. The percent of pool tails in category 2 stayed nearly the same, and the

percent of pool tails in embeddedness category 3 was reduced by nearly 50% between the two time periods. Only categories 1 and 2 are suitable for salmonid spawning;
- Low substrate embeddedness suitability for salmonids in Western Subbasin streams in the 1990s was due to extensive sediment input from highly erosive soils, active landslides, roads, and historical flood events. Suitability scores increased as a result of sediment from historic floods moving through the system, and restoration projects including road decommissioning and bank stabilization.

Refugia Areas:

- Salmonid habitat conditions were generally rated as high potential refugia (38 of 57 rated stream areas), meaning that these streams have diminished but good quality habitat with salmonids present. Most are currently managed to protect natural resources, with the possibility to become high quality refugia;
- Five Western Subbasin streams were rated as high quality refugia habitat: Indian, Moody, Anderson, Low Gap, and Upper Hollow Tree creeks. These are creeks have relatively undisturbed habitat, with conditions necessary to support species diversity and natural production;
- Only two tributaries were rated low quality (Connick and Little Charlie creeks). These watersheds have few salmonids and highly impaired riparian and instream habitat, mainly because of water diversions for residential and agricultural uses. Current conditions and management practices have modified the natural environment extensively, and major changes are required to improve habitat conditions in these areas;
- The remainder of the tributaries rated (12 of 57) were rated as medium potential refugia, meaning that instream and riparian habitat is fragmented, and salmonids are present but in reduced densities and age class representation. Western Subbasin streams in this category were most of the Redwood Creek (Redway) watershed, lower Hollow Tree, lower Connick, Sawmill, Durphy, and Hartsook creeks.

Barriers and other concerns:
- Both natural barriers (landslides, gradient, and LDA) and anthropogenic barriers (culverts and dams) were mapped using information from stream inventories, field reconnaissance, and the CalFish Passage Assessment Database;
- Most culvert barriers, both total and partial, were located at road crossings along the mainstem SF Eel River, where Highway 101 and smaller roads leading into individual basins cross tributary streams. Two partial culvert barriers are located in the Hollow Tree Creek drainage on land owned by MRC;
- There are two culvert barriers located on Dinner Creek, both of which are total barriers to fish passage. The first culvert is located 8.3 miles up Briceland Thorn Road from Redway (RM 0.85 from China Creek confluence) and the second culvert is located 8.8 miles up Briceland Thorn Road (RM 1.39 from China Creek confluence). Ross Taylor and Associates (2005) recommended replacing both existing culverts with properly sized new culverts that provide unimpeded passage;
- Benbow Dam is located on the mainstem SF Eel River at RM 40. This is not currently a barrier to fish passage, but it has been in the past and is being considered for removal;
- One dam was identified on Jack of Hearts Creek. This was an earthen dam that was built in the summer, but is no longer installed and is not currently considered a barrier to fish passage;
- Forty gradient barriers, mostly waterfalls, were identified in Western Subbasin streams if they occurred in areas other than natural ends of anadromy in headwater areas. These barriers may be partial (a barrier to certain species or life stages), total, or temporal (only a barrier at certain times of the year).

What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions?

Findings and Conclusions:
- Natural erosion rates in the Western Subbasin are high due to the following conditions:

    - All rock types in the SF Eel River Basin are considered lithologically soft, prone to erosion, and sensitive to land use. The major rock type underlying the Western Subbasin is the sandstone/argillite/conglomerate of the Coastal Terrane, which tends to form sharp-crested ridges with well-incised sidehill drainage and is susceptible to debris sliding especially upon steep stream banks and inner gorge areas;
    - The Western Subbasin is located in one of the most seismically active regions in North America, and fault movement can result in uplift or subsidence of the local landscape, increasing the potential for erosion or deposition;
- Floods periodically occur due to high winter precipitation levels and high runoff rates;
- During the rainy season, heavily silted water flows from steep upstream terrain, downstream to lower reaches, increasing turbidity and sediment levels in many subbasin streams;
- The predominant vegetation type is mixed conifer and hardwood forest, covering 73% of the Western Subbasin area. The average percent deciduous canopy was greater than coniferous canopy in surveyed streams, but the percent coniferous canopy increased between the late 1990s (17%) and early 2000s (22%).

How has land use affected these natural processes?

Findings and Conclusions:

Changes in basin due to land use:

- The majority (75%) of the land in the Western Subbasin is used for industrial timber harvest, and is owned by Mendocino Redwood Company and Hawthorne Timber Company. There is less harvest activity now than in the past, and newer forest practices and management actions (including road decommissioning) have prioritized habitat preservation and fisheries habitat management;
- Road density is higher in this subbasin (4.8 miles/square mile) than in either the Northern (3.7 miles/square mile) or Eastern (2.9 miles/square mile) subbasins. Most roads were originally built to access and haul timber, but many are now also used to access marijuana cultivation sites and residences, especially in areas where large parcels have been subdivided into smaller lots;
- Sediment input from land use activities, primarily roads and timber harvest, is particularly problematic in this subbasin due to highly erodible soils and active landslides;
- In the Redwood Creek (Redway) drainage, the primary land use is residential, and there has been a substantial increase in the number of marijuana cultivation operations in this watershed. In 2012, there were 549 grows (226 outdoor and 323 indoor) identified in this drainage alone, with an estimated 16.5 million gallons of water per growing season required to support these operations (Easthouse 2013). Water sources include direct diversion from streams, groundwater wells, and storage tanks, but little is known regarding how much water is supplied by each source.

Possible effects seen in stream conditions:

<u>Instream habitat conditions for salmonids are poor in some streams:</u>

- Low summer flows are exacerbated by diversions, which result in dry or intermittent reaches on streams (especially those that are affected by diversion), which are stressful to salmonids;
- In addition to low flows, water quality (temperature, pollution, turbidity) decreases in areas with high levels of instream diversion and input of fertilizers, chemicals, sediment, and waste from grow operations, resulting in decreased habitat suitability for salmonids;
- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing, and feeding habitat for salmonids. Sediment input from both natural (landslides and streambank erosion) and anthropogenic (timber harvest and road failures and/or degradation) sources are high, with correspondingly high turbidity levels which are stressful for salmonids. Substrate embeddedness values were high in most surveyed reaches, but have shown significant improvement over time;

- Average pool depth and pool shelter values did not meet target values in surveyed Western Subbasin streams (n = 44);
- Boulders were the dominant shelter type in pools, followed by LWD and SWD. Average percent shelter from LWD was less than 5% for data collected during both sampling periods.

<u>Erosion related to timber harvest and roads on unstable soils is a concern:</u>

- Industrial timber harvest occurred in most areas in the subbasin prior to the 1960s, and continues to be the primary land use in more than 75% of the subbasin. Historically, and to a lesser extent currently, sediment enters the streams from timber harvest activities and road related input, including both chronic erosion of fine sediments and catastrophic failure of roads prisms during winter storms;
- Timber harvest, while less of an issue than in the past, still occurred in the headwaters of nearly all Western Subbasin streams between 1991 and 2013. Erosion related to timber harvest is a concern throughout the subbasin due to highly erosive soils, active tectonics contributing to unstable slopes, and heavy rains received during winter months. Logging roads, which are often also used for residential purposes, are significant sources of fine sediment input to streams;
- Timber harvest impacts were magnified by the 1955 and 1964 floods, and sediment pulses from historic land use practices and floods are still moving through Western Subbasin streams.

Based upon these conditions trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead production?

Findings and Conclusions:

Based on available information for this subbasin, it appears that salmonid populations are limited by:

- Low summer flows;
- High summer water temperatures in the middle mainstem and downstream, and in larger tributaries;
- High levels of fine sediments in streams, mainly from roads and timber harvest activities;
- Loss of habitat area and complexity, particularly primary pool habitat and pool shelter;
- Competition with Sacramento pikeminnow.

What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

- Most habitat recommendations from surveys conducted in Western Subbasin streams targeted instream habitat, including pool and cover categories. Most other recommendations targeted erosion/sediment (related to streambanks and roads) and riparian habitat/water temperatures (canopy and temperature);
- Road decommissioning projects are particularly important in this subbasin due to the very high road density and intensive historic and current timber harvest activities;
- Mendocino Redwood Company, Trout Unlimited, CDFW, and USFWS collaborated on a comprehensive restoration program in the Hollow Tree Creek watershed. This program involves upgrading all roads within the watershed, decommissioning roads that are no longer needed, and installing instream habitat enhancement structures. Three phases of restoration were originally planned, beginning in 2003 and extending through 2008, but additional projects and improvements are currently being completed. Monitoring to determine if these activities result in reduced sediment input to streams is ongoing, and additional problem roads may be identified and projects completed in the future;
- Support ongoing efforts by timber harvest review agencies to quantify water usage by industrial timber companies for road dust abatement/sediment control, and support actions designed to encourage efficient use of water;
- Ensure that water diversions used for domestic or irrigation purposes bypass sufficient flows to maintain all fishery resource needs;

- Support and expand projects designed to address solutions to low flow during the late summer months by reducing the number and magnitude of diversions (e.g. SRF's water conservation project in Redwood Creek). Public outreach is needed to increase awareness of land use practices and their impacts on the basin's natural resources;
- Restoration activities that will create additional pool habitat and scour existing shallow pools, while reducing sediment input from roads, are highly recommended throughout this subbasin;
- Identify areas where marijuana cultivation is occurring and quantify environmental effects at sites, including illegal diversions (especially during low flow times), input of pesticides and other pollutants, and sediment loading from these practices. Enforce existing regulations and develop new environmental regulations to target these activities;
- Replace two culverts in Dinner Creek that are total barriers to fish passage. The County of Humboldt recently submitted a proposal for FRGP funding to replace both culverts, in addition to a smaller culvert approximately 700 feet upstream from the second culvert;
- Conduct an upslope erosion inventory in order to identify and map stream bank and road-related sediment sources. Sites should be prioritized and improved;
- Wood recruitment is low in most Western Subbasin streams, and projects that add LWD to streams are recommended. These projects could be combined with pool habitat creation/enhancement projects, since both primary pool habitat and pool shelter are limiting factors for salmonids in this subbasin;
- Consider replanting of native species, like willow, alder, redwood and Douglas fir in areas with little or no native vegetation, or in areas with non-native vegetation;
- Consider thinning hardwoods to increase growth of conifers where riparian forest is strongly dominated by hardwoods and shade canopy will not be adversely affected;
- Monitor streams near land development activities and existing rural residential areas for turbidity, pollution, and drainage issues;
- Continue to conduct biological sampling through the CMP to determine salmonid population abundance and diversity, including but not limited to current CDFW redd counts, adult spawner surveys, and carcass counts, with funding requested to establish and operate of a life cycle monitoring station in Sproul Creek in 2015;
- Consistently collect water quality data, including temperature, dissolved oxygen, and water chemistry throughout the year for several years in order to accurately characterize conditions. Support programs and organizations such as SRF and ERRP that develop studies to monitor the flow, temperature, diversion, and water quality of streams throughout the subbasin, particularly in developed areas.

Subbasin Conclusions

The Western Subbasin covers an area of 219 square miles, or approximately one third of the total SF Eel River Basin area. This subbasin includes the SF Eel River mainstem and the drainage area on the west side of the mainstem between the confluence of Ohman Creek (RM 23) to the headwaters southwest of Laytonville (RM 105). Streams in this subbasin contain runs of Chinook and coho salmon, and steelhead trout. Current salmonid populations are considerably smaller and less well distributed compared to their historic range, but populations appear to be more abundant and widespread in Western Subbasin streams than in other SF Eel River subbasin tributaries. Maintaining or increasing these remaining populations is critical to the recovery of salmon and steelhead along the entire North Coast.

The fishery resources in the Western Subbasin have been adversely impacted by land use and resource development. Historically, these streams provided important spawning and juvenile rearing grounds that enabled salmon and steelhead populations to thrive. Currently, 75% of the land is used for industrial timber harvest. Barnum Timber Company, Hawthorne Timber Company, and Mendocino Redwood Company own most of the land in this subbasin, including nearly all of the land in the Hollow Tree, Indian, and Sproul Creek basins. Hollow Tree Creek and Sproul Creek basins contain some of the most important coho salmon production areas in the entire SF Eel River Basin. The next most significant land use category in the subbasin is residential areas, which compose 11% of the land use and occur mainly in the Redwood Creek drainage (near Redway) and in areas of Sproul Creek.

Road density in the Western Subbasin is very high (4.76 miles/square mile), and more than 80% of all roads in the subbasin are seasonal roads that were originally built to access and haul timber. Many roads are still utilized for these purposes, but some are also used to access residential areas, especially where large parcels have been subdivided. Road surface erosion, road crossing failures and gullies, skid trails, and landslides from roads are the primary anthropogenic sources of sediment input in Western Subbasin streams. Roads that are no longer used or those that were improperly constructed should be targeted for decommissioning and/or upgrading in order to reduce fine sediment input and associated turbidity, thereby improving salmonid habitat in tributaries throughout the subbasin. CDFW, USFWS, MRC, and Trout Unlimited cooperatively developed a restoration program in the Hollow Tree Creek basin that includes the upgrading and decommissioning roads, installing instream structures, and post-project monitoring.

Reduced streamflow, particularly during the dry summer months, due to an increase in the number and volume of diversions (for residential and agricultural uses, and for dust abatement/sediment control on industrial timber company lands), combined with longer dry periods (less precipitation) in the winter and early spring, have dramatically affected salmonids in the basin at all life stages. Low flows are particularly apparent in northern areas of the subbasin, especially in Redwood Creek near Redway, where most land use is residential and extensive industrial marijuana cultivation operations have been documented. These operations have increased dramatically in both number and magnitude in recent years. In 2012, CDFW Environmental Scientist Scott Bauer identified 549 grows (226 outdoor and 323 indoor/greenhouse) with a total of 18,500 plants (8,100 in greenhouses and 10,400 outdoors) estimated to be associated with these operations in Redwood Creek alone. These grow operations consumed more than 16.5 million gallons of water in one growing season (Easthouse 2013), much of which was diverted from nearby tributaries. Moreover, industrial marijuana cultivation expansion coupled with several drought years has led to the increased development or reliance on groundwater wells, which will only further exacerbate low flow conditions in the summer and early fall. Many cultivation operations also significantly reduce water quality by discharging pollutants including pesticides, herbicides, rodenticides, and diesel fuel into streams. Fine sediment input has also increased due to illegal or improperly constructed access roads and/or clearing crop locations, and some unpermitted timber harvest has occurred where land has been cleared at grow sites. These impacts have been increasing while enforcement has been challenging due to safety concerns, limited funding, and a lack of laws and regulations related to these activities. Future actions and regulations must address the detrimental environmental impacts of large-scale, illegal marijuana cultivation operations throughout the subbasin.

Sedimentation and in-filling from large historic flood events, natural landsliding, unstable geology, timber harvest, land subdivision activities, and road erosion and failures have resulted in increased fine sediment and an overall reduction in channel area in Western Subbasin streams. Large amounts of sediment fills in pool habitat, reduces the depth of existing pools, and increases embeddedness of substrate, resulting in a corresponding decrease in available salmonid spawning and rearing habitat. Although streams are designed to move sediment through the system naturally, Western Subbasin streams often do not have sufficient flow to flush out the quantities of sediment. Large volumes of sediment are continually entering streams from both natural and anthropogenic sources, and the basin is still inhibited by legacy effects of the 1955 and 1964 floods.

CDFW crews collected habitat typing data in 44 Western Subbasin streams during two time periods (1990-1999 and 2000-2010), and CWPAP staff analyzed data to determine changes in habitat suitability for salmonids over time. Although values for select factors (canopy density, embeddedness, and percent primary pool habitat) appear to be improving with time, overall suitability scores were still low (negative values) for most factors during both time periods. Average pool shelter complexity values decreased over time, remaining in the lowest suitability category during both sampling periods. Canopy density was in the highest suitability category during the early 2000s, most likely because of management practices promoting growth and recovery of riparian areas since historic damage from floods and intensive timber harvest.

CDFW currently conducts spawning ground surveys annually as part of the CMP on a select percentage of habitat in Western Subbasin streams; surveys include live fish or redd counts and carcass counts. A life cycle monitoring station will be established in the subbasin in the future to record counts of adults and outmigrating smolts. These counts will be used to calibrate spawning ground escapement estimates and freshwater and ocean survival. CDFW submitted a funding request in 2014 to establish a life cycle monitoring station in Sproul Creek in 2015, and information collected at this station will be used to assess the status of CC Chinook and SONCC coho salmon in the ESU.

Spawner survey information was also collected as part of CDFW's index reach sampling efforts in six Western Subbasin tributaries between 2002 and 2012. Surveys were completed between the beginning of November and the beginning of March each year in upper, lower, and WF Sproul (2002-2012) and in Redwood (Redway), Upper Redwood (Pollock), and China creeks (2002-2010). There were more coho salmon and Chinook salmon documented in WF Sproul Creek than in any of the other sampled creeks, with a maximum count of 81 live coho observed in WF Sproul Creek during the 2011-12 sampling season.

Diminishing runs of salmon and to a lesser extent steelhead in SF Eel River Basin streams are susceptible to being reduced to remnant populations. Regulations addressing environmental impacts and their effect on salmonids in the basin have primarily addressed timber harvest practices (and associated impacts from legacy and new roads) and ranching activities, and these rules and guidelines have resulted in decreased riparian impacts, decreased sedimentation from roads, and improved instream conditions in many areas of the basin. However, many regulations that are designed to help protect the basin's salmonid stocks, water resources, and associated stream habitats have not provided sufficient protection since the recent rapid expansion of marijuana cultivation throughout the basin, particularly in areas dominated by residential land use. While new regulations and management activities helped improve habitat in some areas within the subbasin, they have not been on large enough spatial or temporal scales to provide significant improvements to the overall habitat condition and ecosystem function necessary to restore salmonid populations to desirable numbers or ranges.

This subbasin contains critical habitat and runs of salmonids to help in the statewide recovery of salmonids. Both SF Eel River coho salmon and steelhead were recently selected as "salmon strongholds", which represent the healthiest wild Pacific salmon populations remaining, and recognize the high value of the habitats these populations occupy (Wild Salmon Center 2012). Identification of these strong populations is part of a larger conservation effort to complement recovery efforts for salmonids throughout the state. Larger Western Subbasin watersheds such as Hollow Tree and Sproul Creek are particularly important for coho salmon, Chinook salmon, and steelhead due to high quality habitat and relatively healthy, well-established populations.

A cooperative approach with concerted effort is necessary to address diversion, stream temperature, and water quality (fine sediment and pollution) issues in order to improve and expand spawning and rearing habitat for salmonids, and to increase overall ecosystem health in streams throughout the Western Subbasin. Additional monitoring efforts, including the establishment and operation of a life cycle monitoring station in this subbasin will be an important step in understanding population trends of SF Eel River salmonids.

Juvenile coho salmon (photo courtesy of Teri Moore, CDFW).