SF Eel River Northern Subbasin

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Northern Subbasin

Introduction

The Northern Subbasin of the South Fork (SF) Eel River Basin is the smallest of the three subbasins, covering an area of 149 square miles, or 22% of the total basin area (*Table 1*). This subbasin includes the drainage area south of the South Fork Eel River from its confluence with the Eel River (RM 0) to the confluence with Ohman Creek (RM 22.9) and is located entirely in Humboldt County. The subbasin includes 23 miles of the SF Eel River mainstem and 190 miles of tributary stream (116 miles of perennial or blue line stream, and 74 miles of intermittent stream). The largest towns in the subbasin, located along the mainstem SF Eel River, are Weott, Myer's Flat, Miranda, and Phillipsville.

Most of the land in the northern part of the subbasin is owned by the CA State Parks, and in the southern and eastern parts of the subbasin, the primary land uses are residential and timber production. The dominant vegetation type is mixed conifer and hardwood forest (*Figure 1*).

This Subbasin is characterized by a forested landscape of rugged, steep, sharp-crested ridges and narrow stream valleys. Stream elevations range from approximately 85 feet at the confluence to approximately 3,200 feet in the headwaters of the tributaries. The climate is dominated by the coastal marine layer, giving this area mild, foggy summers and wet winters.

Large tributaries with documented salmonid distribution in this subbasin include the Bull Creek drainage in the north and the Salmon Creek drainage in the south. Coho and Chinook salmon, and steelhead trout have been documented in Northern Subbasin streams.

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

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

Area (square miles)	149
Privately Owned (square miles)	71
Publicly Owned (square miles)	78
Principal Land Use	Open space/parks
Primary Vegetation Type	Mixed conifer and hardwood forest
Mainstem Miles	22.9 (RM 0-22.9)
Tributary Miles	190
Total Stream Miles	213
Low Elevation (feet)	85
High Elevation (feet)	3,200

Figure 1. Canoe Creek, flowing through mixed conifer and hardwood forest in Humboldt Redwoods State Park, located in the SF Eel River Northern Subbasin.

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

Hydrology

The Northern Subbasin is made up of eight CalWater Units: North Fork Bull Creek, Upper Bull Creek, Decker Creek, Canoe Creek, Elk Creek, Headwaters Salmon Creek, South Fork Salmon Creek, and Ohman Creek (*Figure 3*). There are 46 named and 62 unnamed tributaries with more than 130 perennial and 75 intermittent stream miles in this subbasin (*Figure 4*). The mainstem SF Eel River is a fifth order stream using the Strahler (1964) classification, and the tributaries are first through fourth order streams. Stream drainage areas in this subbasin range from less than one square mile to 42 square miles (*Table 2*). Bull Creek is the largest tributary to the SF Eel River in the Northern Subbasin with a drainage area of approximately 42 square miles and a stream length of 15 miles. Salmon Creek, in the southern part of the subbasin, is the second largest tributary, with a drainage area of 37 square miles and a stream length of almost 13 miles.

The Northern Subbasin has the highest amount of average annual precipitation in the South Fork Eel River basin, ranging from 60 inches near Miranda and Phillipsville to 115 inches in the headwaters of the Bull Creek drainage. Approximately 70 percent of this precipitation occurs from November to March and generates significant runoff during this five month period.

Other hydrologic attributes of the Northern Subbasin include:

- A drainage area of 149 square miles.
- More than 110 mapped streams.
- 213 miles of stream (133 perennial and 75 intermittent);
- The highest peak flow of 199,000 cubic feet per second (cfs) was recorded at the USGS gage in Miranda during the flood of 1964;
- The lowest peak flow recorded at the same station was in 1977 at 2,260 cfs;
- The highest average annual flow of 7,300 cfs was recorded in 1981;
- The lowest average annual flow was in 1977 at 563 cfs.

Two USGS stream gages currently capture information in the Northern Subbasin. The gauge at Miranda is located in the mainstem SF Eel River at RM 17, and 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). The gauge in the Bull Creek drainage, located approximately 5 miles upstream from the confluence of the SF Eel River, is fed by a much smaller drainage area (28.1 square miles), so discharge is much lower (*Figure 5*). Data were available at the Miranda gauge from 1940-2010, and were available in Bull Creek from 1961-2010. Although average annual discharge was considerably higher for the Miranda gauge due to the much larger drainage area, discharge patterns were similar at the two locations, with extremely low flows in 1977 (10 cfs at Bull Creek and 156 cfs at Miranda), and peak flows in 1983 (287 cfs at Bull Creek and 4393 cfs at Miranda) and in 1974 (249 cfs at Bull Creek and 3,929 cfs at Miranda). Peak flows at these locations occurred during the 1964 flood, with recordings of nearly 200,000 cfs at Miranda and 6,520 cfs at the Bull Creek gauge.

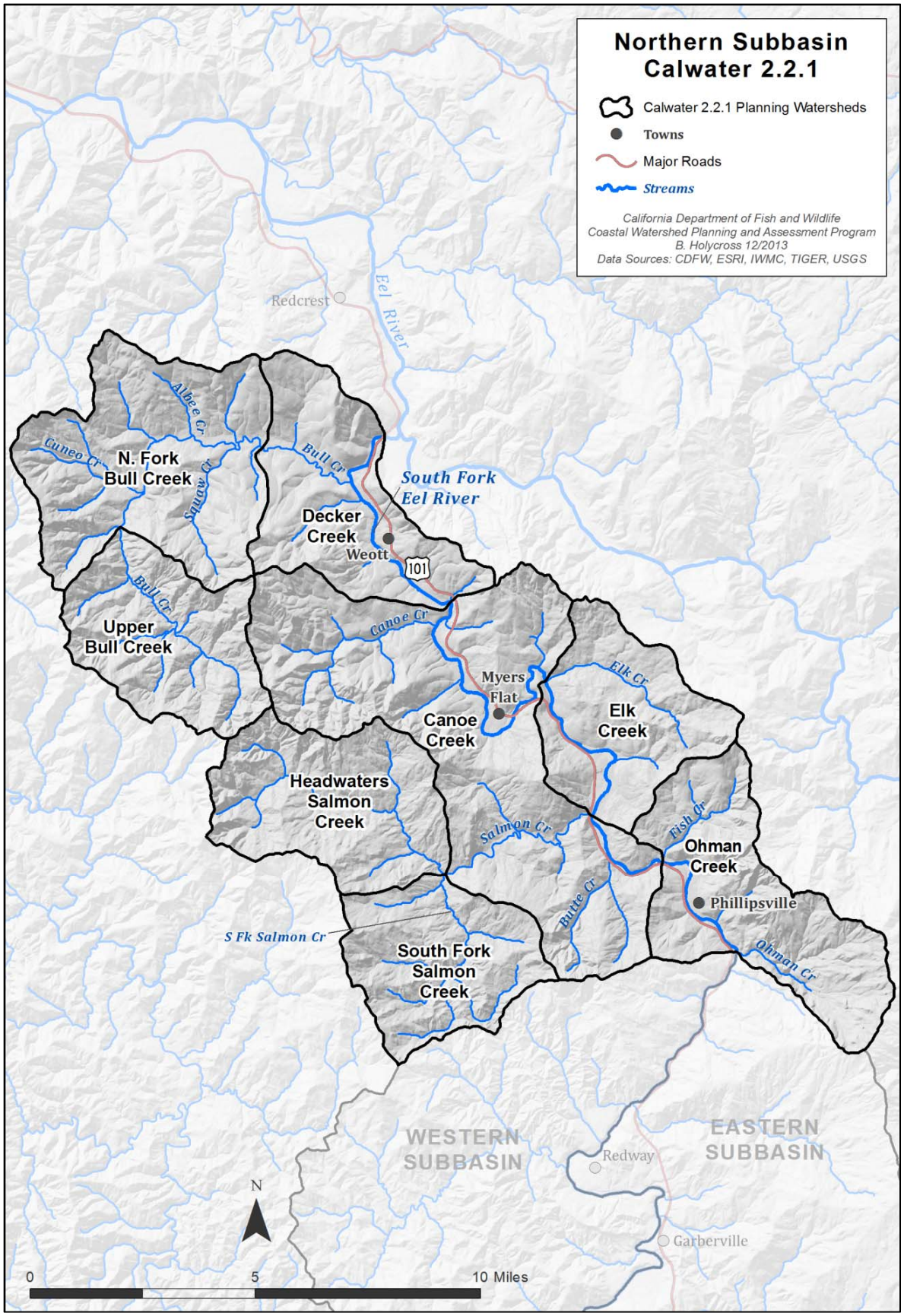


Figure 3. Calwater planning watersheds in the SF Eel River Northern Subbasin.

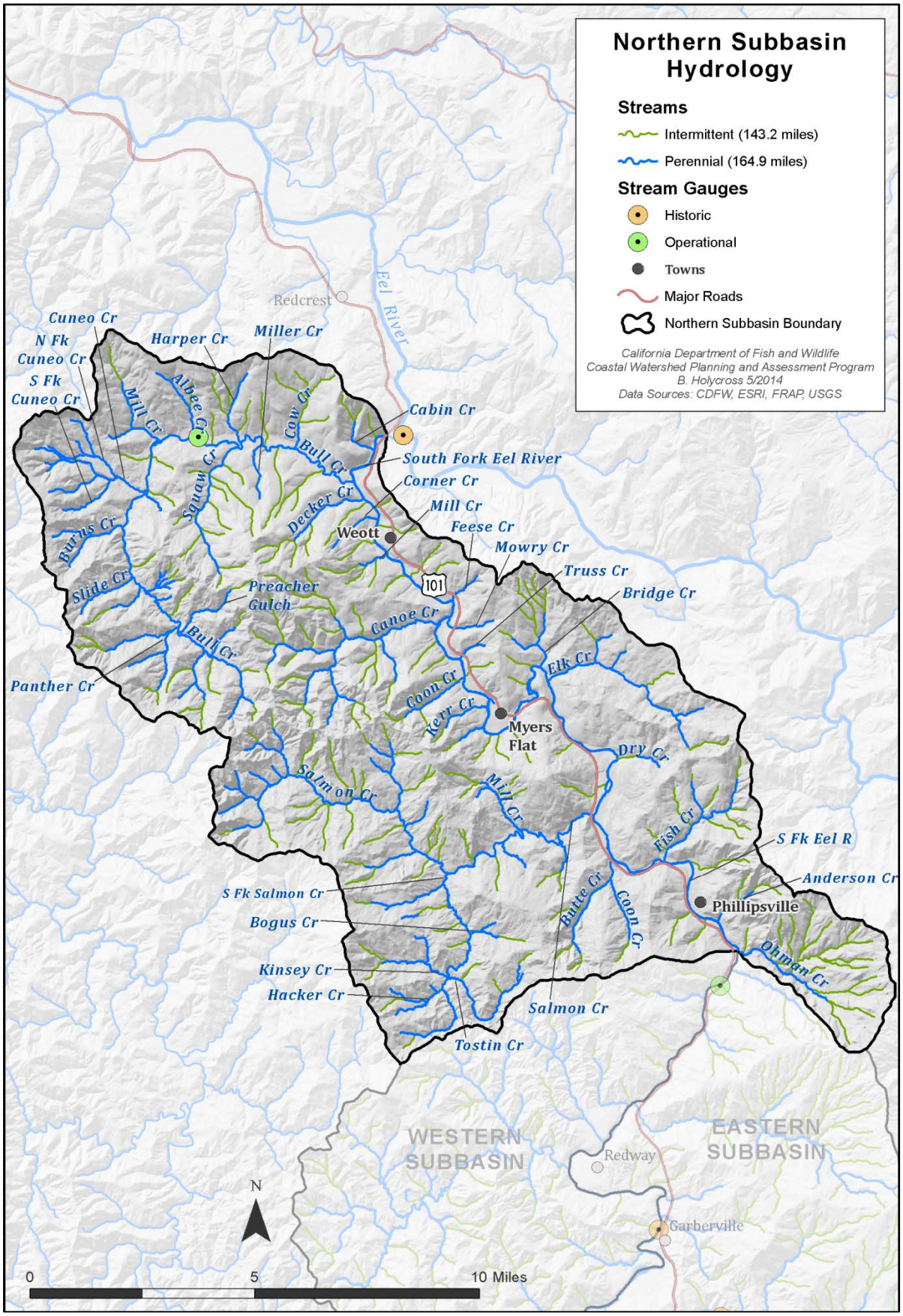


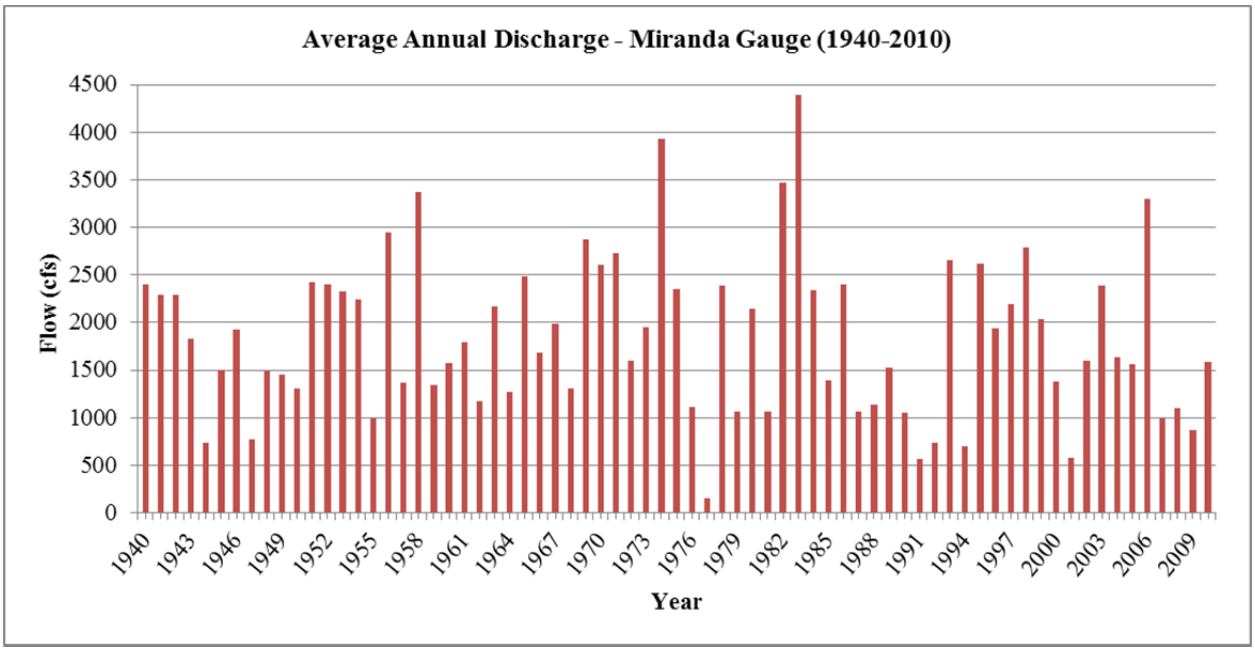
Figure 4. SF Eel River Northern Subbasin streams.

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

Stream	Tributary to:	Length (miles)	Perennial miles	Intermittent miles	Drainage Area miles^2	Stream order
S.F. Eel River	Eel River	22.9	22.9	0.0	149.0	5
LB trib	S.F. Eel River	0.7	0.0	0.7	0.4	int.
LB trib	S.F. Eel River	0.6	0.0	0.6	0.5	int.
Cabin Creek	S.F. Eel River	1.7	1.0	0.7	0.7	1
Bull Creek	S.F. Eel River	15.2	14.7	0.4	41.5	4
Tepee Creek	Bull Creek	1.6	0.0	1.6	0.8	int.
Cow Creek	Bull Creek	2.1	0.7	1.4	2.3	1
Connick Creek	Bull Creek	2.0	0.0	2.0	2.6	int.
Calf Creek	Bull Creek	1.3	0.0	1.3	0.5	int.
Miller Creek	Bull Creek	1.4	1.4	0.0	0.6	1
Harper Creek	Bull Creek	1.8	1.8	0.0	1.6	1
Squaw Creek	Bull Creek	3.9	3.5	0.4	4.7	1
Golpher Creek	Bull Creek	0.8	0.0	0.8	0.2	int.
Albee Creek	Bull Creek	1.8	1.8	0.0	1.3	1
Mill Creek	Bull Creek	2.7	0.9	1.8	3.0	2
RB trib	Bull Creek	0.8	0.0	0.8	0.3	int.
Cuneo Creek	Bull Creek	3.0	3.0	0.0	4.4	3
North Fork Cuneo Creek	Cuneo Creek	1.9	1.9	0.0	1.7	2
South Fork Cuneo Creek	Cuneo Creek	1.4	1.4	0.0	0.7	1
RB trib	Bull Creek	0.6	0.6	0.0	0.4	1
Burns Creek	Bull Creek	1.7	1.7	0.0	1.8	2
RB trib	Bull Creek	0.7	0.0	0.7	0.1	int.
Slide Creek	Bull Creek	1.6	1.6	0.0	1.2	1
LB trib	Bull Creek	1.7	1.0	0.8	0.7	1
RB trib	Bull Creek	0.9	0.8	0.1	0.5	3
RB trib	Bull Creek	0.4	0.4	0.0	0.1	1
RB trib	Bull Creek	1.0	0.0	1.0	0.3	int.
Panther Creek	Bull Creek	1.5	1.5	0.0	3.2	2
LB trib	Panther Creek	2.5	1.7	0.8	1.6	1
RB trib	Panther Creek	1.3	1.0	0.3	1.1	1
Preacher Gulch	Bull Creek	2.3	1.8	0.6	0.9	1
LB trib	Bull Creek	1.4	1.4	0.0	0.3	1
RB trib	Bull Creek	1.5	1.0	0.5	0.6	1
LB trib	Bull Creek	1.0	0.0	1.0	0.3	int.
RB trib	Bull Creek	0.5	0.0	0.5	0.2	int.
LB trib	Bull Creek	0.6	0.6	0.0	0.5	1
Decker Creek	S.F. Eel River	3.1	2.0	1.1	7.0	1
LB trib	S.F. Eel River	1.4	0.0	1.4	0.2	int.
RB trib	S.F. Eel River	0.5	0.0	0.5	0.0	int.
Corner Creek	S.F. Eel River	1.3	1.3	0.0	0.3	1
LB trib	S.F. Eel River	1.0	0.0	1.0	0.3	int.
Mill Creek	S.F. Eel River	1.8	0.8	1.0	2.4	1
LB trib	S.F. Eel River	0.7	0.0	0.7	0.3	int.
Robinson Creek	S.F. Eel River	1.1	0.0	1.1	0.5	int.
RB trib	S.F. Eel River	1.1	0.0	1.1	2.4	int.
Feese Creek	S.F. Eel River	0.9	0.9	0.0	0.8	1
Mowry Creek	S.F. Eel River	1.3	1.3	0.0	0.8	1
Canoe Creek	S.F. Eel River	5.1	4.5	0.6	10.6	2
North Fork Canoe Creek	Canoe Creek	2.7	2.1	0.6	1.9	1
RB trib	S.F. Eel River	0.9	0.0	0.9	0.2	int.
RB trib	S.F. Eel River	0.7	0.0	0.7	0.2	int.
LB trib	S.F. Eel River	0.7	0.0	0.7	0.1	int.
Truss Creek	S.F. Eel River	0.8	0.0	0.8	0.4	int.

Stream	Tributary to:	Length (miles)	Perennial miles	Intermittent miles	Drainage Area miles^2	Stream order
RB trib	S.F. Eel River	0.8	0.0	0.8	0.2	int.
Coon Creek	S.F. Eel River	2.2	0.0	2.2	1.7	1
Kerr Creek	S.F. Eel River	1.7	0.0	1.7	0.5	1
LB trib	S.F. Eel River	1.1	0.5	0.7	0.5	int.
LB trib	S.F. Eel River	0.8	0.0	0.8	0.5	int.
LB trib	S.F. Eel River	0.7	0.0	0.7	0.2	int.
LB trib	S.F. Eel River	1.0	0.0	1.0	0.5	int.
RB trib	S.F. Eel River	0.5	0.0	0.5	0.2	int.
RB trib	S.F. Eel River	0.7	0.0	0.7	0.2	int.
Bridge Creek	S.F. Eel River	2.5	1.7	0.7	2.7	1
Elk Creek	S.F. Eel River	5.6	4.6	0.9	6.7	2
RB trib	S.F. Eel River	0.5	0.0	0.5	0.2	int.
Dry Creek	S.F. Eel River	1.1	0.0	1.1	1.3	int.
LB trib	S.F. Eel River	1.3	0.0	1.3	0.3	int.
Salmon Creek	S.F. Eel River	12.8	12.1	0.8	36.9	4
RB trib	Salmon Creek	1.4	0.8	0.7	1.4	1
Mill Creek	Salmon Creek	2.5	0.9	1.6	2.0	2
RB trib	Salmon Creek	0.9	0.9	0.0	1.9	1
RB trib	Salmon Creek	0.6	0.0	0.6	0.4	int.
LB trib	Salmon Creek	0.9	0.0	0.9	0.4	int.
South Fork Salmon Creek	Salmon Creek	6.1	5.6	0.5	12.5	3
LB trib	S.F. Salmon Creek	0.7	0.0	0.7	1.5	int.
Bogus Creek	S.F. Salmon Creek	1.3	0.6	0.7	1.5	1
LB trib	S.F. Salmon Creek	0.5	0.0	0.5	0.1	int.
Kinsey Creek	S.F. Salmon Creek	2.4	1.7	0.8	2.5	2
Tostin Creek	S.F. Salmon Creek	3.7	3.2	0.4	2.3	2
Hacker Creek	S.F. Salmon Creek	1.4	1.4	0.0	1.3	2
RB trib	S.F. Salmon Creek	0.4	0.0	0.4	0.3	int.
LB trib	Salmon Creek	0.6	0.0	0.6	0.1	int.
RB trib	Salmon Creek	0.7	0.0	0.7	0.2	int.
LB trib	Salmon Creek	1.1	0.0	1.1	0.3	int.
RB trib	Salmon Creek	1.8	1.3	0.5	1.4	1
LB trib	Salmon Creek	0.9	0.9	0.0	0.3	1
RB trib	Salmon Creek	1.1	0.0	1.1	0.3	int.
LB trib	Salmon Creek	2.2	1.7	0.5	2.4	2
LB trib	Salmon Creek	0.7	0.0	0.7	0.2	int.
LB trib	Salmon Creek	1.6	0.0	1.6	0.8	int.
RB trib	Salmon Creek	1.2	0.0	1.2	0.4	int.
RB trib	Salmon Creek	1.1	0.0	1.1	0.9	int.
RB trib	Salmon Creek	1.1	0.0	1.1	0.3	int.
RB trib	Salmon Creek	0.7	0.0	0.7	0.2	int.
LB trib	Salmon Creek	0.6	0.0	0.6	0.2	int.
LB trib	Salmon Creek	1.2	0.0	1.2	0.4	int.
LB trib	Salmon Creek	1.6	1.2	0.4	1.4	2
LB trib	Salmon Creek	0.4	0.4	0.0	0.2	1
LB trib	Salmon Creek	0.6	0.6	0.0	0.3	1
LB trib	Salmon Creek	1.0	1.0	0.0	0.9	2
RB trib	Salmon Creek	0.8	0.0	0.8	0.3	int.
Butte Creek	S.F. Eel River	3.2	2.7	0.5	4.6	2
Coon Creek	Butte Creek	2.1	0.0	2.1	1.9	1
Fish Creek	S.F. Eel River	3.4	2.9	0.5	4.5	2
RB trib	S.F. Eel River	1.6	0.0	1.6	0.9	int.
LB trib	S.F. Eel River	1.0	0.0	1.0	0.8	int.
LB trib	S.F. Eel River	0.8	0.0	0.8	0.5	int.

Stream	Tributary to:	Length (miles)	Perennial miles	Intermittent miles	Drainage Area miles^2	Stream order
Anderson Creek	S.F. Eel River	1.9	1.9	0.0	4.3	1
Ohman Creek	S.F. Eel River	3.8	2.7	1.1	7.2	1



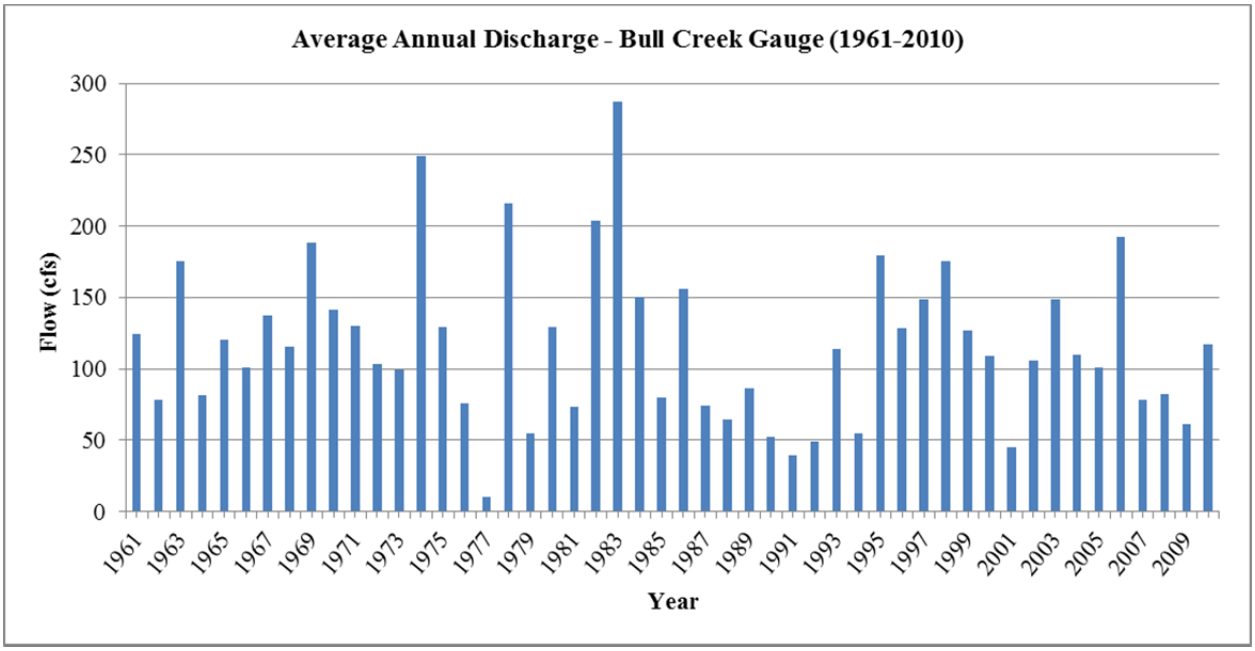


Figure 5. Average annual discharge at the Miranda (top) and Bull Creek (bottom) gauges, located in the SF Eel River Northern Subbasin.

Floods

Large floods occur nearly every decade and typify the storm flows of the South Fork Eel River Basin (*Table 3*). The most infamous floods in recent memory occurred in 1955 and 1964. The effect of these floods on the watershed was exacerbated by extensive logging due to the advent of post-WWII tractor technology, historical changes in local vegetation, 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 a large accumulation of snow in the higher elevations that was melted by a warm storm with sustained, heavy rains. Landslides and resulting sedimentation of the streams were unprecedented - these floods washed away whole towns, reset river patterns, and changed stream morphology for decades. In some cases the lingering effects are still apparent upon the landscape. In the Northern Subbasin the towns of Dyerville, Bull Creek, Weott, Myers Flat, and Phillipsville were severely damaged or completely destroyed. The 1955 flood had a peak flow (at Miranda) of 173 thousand cubic feet per second, and 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 thousand cubic feet per second, exceeded 100 million dollars in damages, and killed at least 19 people in the Mad and Eel River watersheds (Dyett and Bhatia 2002).

Table 3. Flood dates and discharges at USGS Miranda gauge.

Humboldt County Floods – Miranda Gage ***(italicized discharge is approximated by extrapolation from the Scotia gage)***	
Year	**Discharge, cfs**
Jan 22, 1914	*97,300*
Feb 2, 1915	*112,300*
Feb 25, 1917	*90,500*
Dec 11, 1937	*117,300*
Feb 28, 1940	*91,500*
Dec. 22, 1955	173,000
Feb 8, 1960	117,000
Dec. 23, 1964	199,000
Jan 4, 1966	107,000
Jan 16, 1974	122,000
Dec 19, 1981	123,000
Feb 17, 1986	123,000
Source: USGS Gage 11476500	

The Northern Subbasin's stream canyon topography is typified by narrow flood zones that cause rapid inundation of streamside towns and features such as Weott, Myers Flat, Miranda, Phillipsville, and the Avenue of the Giants (Humboldt Co. 2012). During events that cause large amounts of sediment to enter creeks, or in tributaries that are heavily diverted, streams that have historically been perennial may become intermittent.

Dams, Diversions, and Hydrologic Disturbances

There are presently no functioning, legal, man-made dams on the streams of the Northern Subbasin. There are some legal water right diversions within this subbasin and as with most watersheds in Humboldt County there are a significant number of illegal water diversions associated with residences, ranches, and industrial marijuana agricultural practices that remove water from the streams, especially during the dry times of the year.

The towns of Weott, Myer's Flat, Miranda, and Phillipsville have all been developed along the SF Eel River and use water extracted from the river, its tributaries, or shallow groundwater wells that draw from "surface water underflow" (water that has permeated through the soil layer into the weathered bedrock layer on top of the coherent bedrock). This water provides dry season base flow to the streams.

Reaches flowing through towns have often been modified to accommodate development. Modifications include bank armoring, construction of stream crossings such as culverts and bridges, and channelization. These modifications often decrease or eliminate natural stream floodplains. This can increase the volume and velocity of flows during the rainy season. Increases in impervious cover (parking lots, roads, and buildings) associated with development can increase runoff to streams and aggravate flooding problems (http://www.coastal.ca.gov/nps/watercyclefacts.pdf).

There are small remote residences, ranches, and agricultural areas scattered throughout the Northern Subbasin, in areas that are not owned by large timber companies or the CA State Parks. These residences and agricultural operations depend on water extracted from private wells or diverted directly from springs or creeks, which affects the overall subbasin hydrology.

No drainage issues were noted in any of the towns within the Northern Subbasin in the 2012 Humboldt

County General Plan and no specific drainage plans were made. However, the following applicable policies were developed:

- Natural drainage courses, including ephemeral streams, shall be retained and protected from development impacts which would alter the natural drainage courses, increase erosion or sedimentation, or have a significant adverse effect on flow rates or water quality. Natural vegetation within riparian and wetland protection zones shall be maintained to preserve natural drainage characteristics consistent with the Biological Resource policies. Storm water discharges from outfalls, culverts, gutters, and other drainage control facilities that discharge into natural drainage courses shall be dissipated so that they make no significant contribution to additional erosion and, where feasible, are filtered and cleaned of pollutants;
- Peak downstream storm-water discharge shall not exceed the capacity limits of off-site drainage systems or cause downstream erosion, flooding, habitat destruction, or impacts to wetlands and riparian areas. New development shall demonstrate that post-development peak flow discharges will mimic natural flows to watercourses and avoid impacts to Beneficial Uses of Water;
- Drainage design standards for new development shall be adopted by ordinance. The design standards shall ensure that storms of specified intensity, frequency, and duration can be accommodated by engineered drainage systems and natural drainage courses;
- Create storm drainage development guidelines with incentives to encourage low-impact development standards to reduce the quantity and increase the quality of storm-water runoff from new developments. Formulate and require the use of Low-Impact Development (LID) standards to reduce the quantity and increase the quality of storm-water runoff from new developments in watersheds with known significant cumulative impacts from storm-water runoff. For all other watersheds, design storm drainage development guidelines with incentives to encourage Low-Impact Development (LID) standards to reduce the quantity and increase the quality of storm-water runoff from new developments;
- Minimize chemical pollutants in storm-water runoff such as pesticides, fertilizers, household hazardous wastes, and road oil by supporting education programs, household hazardous waste and used oil collection, street and parking lot cleaning and maintenance, use of bio-swales and other urban storm-water best management practices described in the California Storm-water Best Management Practices Handbooks or their equivalent;
- Work with federal and state agencies and local watershed restoration groups to retrofit existing drainage and flood control structures and design new structures to facilitate fish and other wildlife passage in partnership with these agencies;
- Ministerial and discretionary development in Critical Water Supply or Watershed Areas where maintenance of groundwater recharge is determined to be necessary to maintain sustainable groundwater demands or surface water flows shall maintain or increase the site's pre-development absorption to recharge groundwater or be conditioned to reduce effects to water supplies to below levels of significance;
- The design, construction, and maintenance of County roads, bridges, drainages, and other facilities shall minimize stormwater runoff erosion and discharge of sediments and other pollution by following best management practices in accordance with the Five County Water Quality and Stream Habitat Protection Manual for County Road Maintenance in Northwestern California Watersheds (5Cs Manual 2002) or its equivalent;
- Development within stream channels may be approved where consistent with Policy BR-P4, and is limited to the following projects:
    A. Fishery, wildlife, and aquaculture enhancement and restoration projects;
    B. Road crossings consistent with Standard BR-S9 - Erosion Control;
    C. Flood control and drainage channels, levees, dikes, and floodgates;
    D. Mineral extraction consistent with other County regulations;
    E. Small-scale hydroelectric power plants in compliance with applicable

County regulations and those of other agencies;

F. Wells and spring boxes, and agricultural diversions;
G. New fencing, provided it does not impede the natural drainage or wildlife movement and does not adversely affect the stream environment or wildlife movement;
H. Bank protection, provided it is the least environmentally damaging alternative; and
I. Other essential projects, including municipal groundwater pumping stations, provided they are the least environmentally damaging alternative, or necessary for the protection of the public's health and safety.

Geology

Bedrock

The Northern Subbasin is composed of metamorphic, marine sedimentary and igneous rock types of the Franciscan Complex and their associated overlap assemblage of sediments and sedimentary rock types. The Northern Subbasin is made up of predominantly the Yager Terrane of the Coastal Belt, but also consists of some areas of the juxtaposed Central Belt. Descriptions of bedrock, including composition, depositional history, landscape morphology, strength, and erosional characteristics of each rock type represented on the geology map (*Figure 6*) will be briefly discussed below in order of their abundance within the subbasin. *Table 4* contains a brief summary of Northern Subbasin geology types and their attributes.

The Yager Terrane

Folded and faulted interbedded layers of well consolidated sandstone, argillite, and in some places pebble conglomerate of the Yager Terrane of the Coastal Belt dominate the geologic landscape of this subbasin.

This terrane, named by Burdette Ogle in the early 1950s because of its excellent exposure along Yager Creek in the Van Duzen River drainage, makes up 68% of this subbasin. It is considered a tectonostratigraphic terrane because it has been faulted into its current location by tectonic processes as part of the accretionary wedge and contains a stratigraphic history of deposition, age, and metamorphic grade that set it apart from neighboring terranes.

Sediments of the Yager Terrane were originally deposited between 65 and 34 million years ago and transported by rivers from as far away as Idaho (Underwood and Bachman 1986) and accumulated along the continental shelf to the deep ocean floor. The accumulation of sediment that makes up the Yager Terrane is more than 10,000 feet thick in places (Ogle 1953). The sequence of interbedded argillite and sandstone represents marine deposition of sediments during calm periods, punctuated by large underwater landslide events. These subaqueous landslides were likely triggered by large seismic events, tsunamis, storm wave loading, and sediment loading (Goldfinger et al. 2003) attesting to the abundant seismic activity in this region.

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 results in the development of soils that typically support lush forest growth.

The Yager Terrane is relatively stable; however, it has many areas where it is faulted and/or sheared, 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 water and air, and undercutting of the stream bank along bedrock reaches and movement along bedding planes may result in translational landslides. Excessive crumbling of argillite can also be a source of fine sediment input into 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).

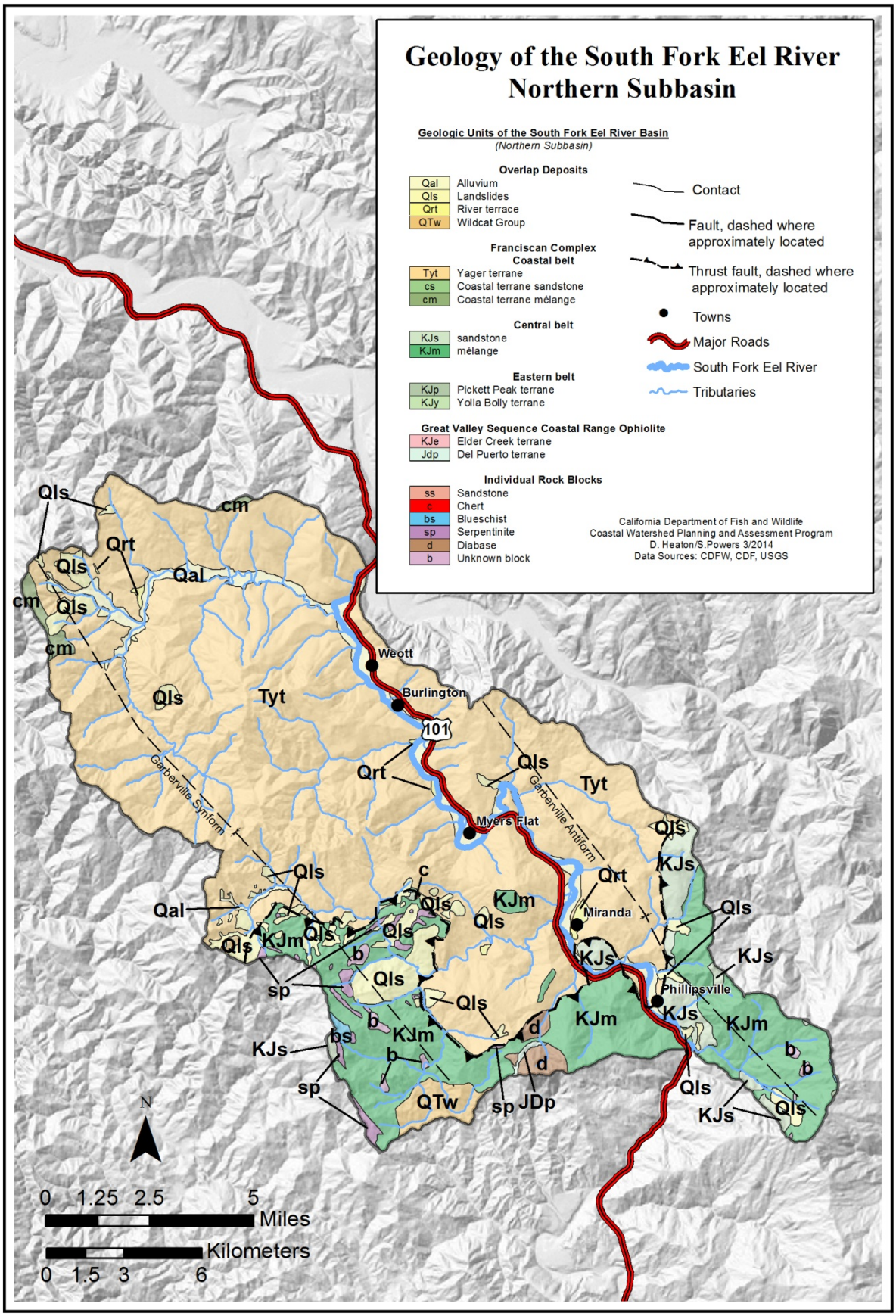


Figure 6. Geologic map of the Northern Subbasin.

Table 4. Geologic formations and unit descriptions in the SF Eel River Northern Subbasin (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 floodplains. Raveling of steep slopes. Sediment trnasport by fluvial and aeolian processes.	0-0.01	4.2
	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	5.2
	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	0.3
	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	1.2
		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, and mélange with limestone lenses, and exotic blocks of rock.	Tends to form forested, sharp-crested ridges with well-incised sidehill drainage; susceptible to debris sliding especially upon steep stream banks. Mélange of the Coastal Terrane tends to form oak and grassland, rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows and secondary debris flows.	1.8-99.6	0.5
		Yager Terrane	Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate.	Steep, straight, forested slopes, sharp ridge crests, V-shaped canyons. 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	67.6
	Central Belt	Sandstone	Large blocks of metasandstone and	Forms forested, moderate to steep, straight to convex slopes, sharp ridge crests, and V-	65.5-161.2	2.7

			metagraywake, interbedded with meta-argillite.	shaped canyons. Generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages.		
		Mélange	Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, metachert.	Oak and grassland, 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	16.3
	Eastern Belt	Yolla Bolly Terrane	Metagraywacke, argillite, and conglomerate with minor metachert and metavolcanic rocks.	Develops sharp-crested, forested ridges generally with V-shaped canyons. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation.	99.6-199.6	0.01
			Mélange – sheared matrix of argillite, sandstone, and conglomerate with blocks of greenstone, metachert, and metagreywacke.	Rolling, hummocky terrain. Boulders protrude from surrounding mélange forming knockers. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation.		
Great Valley Sequence	Coast Range Ophiolite	Del Puerto Terrane	Highly sheared mudstone.	Present locally in the southwestern part of the subbasin.	161.2-145.5	0.1
			Dismembered Ophiolite: chert, basalt, diabase, serpentinite mélange, gabbro, and peridotite.	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, McLauglin, 2000, Kelsey and Allwardt 1975, Kilbourne 1985.						

Central Belt Mélange

Mélange (French for "mixture") of the Central Belt of the Franciscan Complex is the second most abundant rock type within this subbasin, making up approximately 16% of its aerial extent. Mélange can be described as a completely sheared matrix of argillite and sandstone containing very small (gravel sized) to very large (city block sized) mappable, relatively resistant blocks of sandstone, limestone, blueschist, greenstone, serpentinite, and chert.

The mélange of the Central Belt 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 of the continent (Aalto 1981). This mélange was then accreted to the western edge of the continent beginning around 88 million years ago (McLaughlin 2000).

Mélange has undergone such a degree of internal shearing that it has lost much of its internal strength and tends to behave like an extremely viscous liquid, slowly "flowing" over time, mostly in the form of large earthflows. Mélange typically creates a hummocky, rolling landscape with prairies and grasslands occupying the areas of least competence. 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 as well as subsequent debris flows.

Central Belt Sandstone

Sandstone of the Central Belt makes up roughly three percent of the surface of this subbasin. The Central Belt sandstone exists as very large blocks of slightly metamorphosed greywacke ("dirty" sandstone), and argillite (McLaughlin 2000). These blocks most likely formed from 65.5 through 161.2 million years ago as sediment eroded from the continent as far away as Idaho (Underwood and Bachman 1986), washed off the continent, and blanketed the subduction trench between the Farallon and North American plates. Although they

have been metamorphosed, folded, and sheared to some extent, they are more coherent than the mélange. The Central Belt sandstone is generally stable, forming forested, sharp-crested ridges and V-cut valleys. It is prone to debris sliding along steep stream banks and in steep headwater drainages (Kelsey and Allwardt 1975).

Wildcat Group

Relatively young, soft, shallow marine mudstone, siltstone, and sandstone grading upwards through nonmarine sandstone and conglomerate, compose the bedrock of the Wildcat Group which overlaps the Franciscan Complex and makes up around 1% 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 seas, to estuaries and river systems. The Wildcat Group was originally divided into five formations by Burdette Ogle in the early 1950s (downstream of the confluence of the SF Eel River). These were the Pullen Formation, Eel River Formation, Rio Dell Formation, Scotia Bluffs sandstone, and Carlotta Formation. These divisions of the Wildcat Group did not, however, carry over into the SF Eel River Basin and are mapped as either "Wildcat undifferentiated" or as "Tertiary marine deposits".

The Wildcat 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. While the sediments that make up the Wildcat are considered bedrock, they are quite loosely cemented and friable, meaning that the sediment crumbles under light pressure. Landsliding is most common in zones between mudstone and sandstone beds with inward dip, especially during episodes of saturation caused by heavy rain.

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

Quaternary Landslides

Although not technically bedrock, large landslide features (tens to hundreds of acres) influence landscape and erosion, and may indicate how bedrock and overlying soils may behave over time.

Quaternary landslides occupy at least 5% of the subbasin (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.

Landslide deposits produce rumpled, jumbled hillslopes and may develop subsequent debris slides and rotational slumps on steep slopes or eroding toes. Surface erosion and gullying is usually prevalent where vegetation has been stripped (McLaughlin 2000).

Landslide deposits are sensitive to land uses such as timber harvest, development, and road construction 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 of these large landslides erode far enough, become saturated by heavy seasonal rain, or if there is a large, local seismic event, they may reactivate.

Earthflows typically form in mélange due to its very low shear strength, and are capable of contributing immense amounts of sediment to the streams. 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 approximately 70 percent of the landscape in areas of mélange or extensively sheared zones has likely moved (Ellen et al. 2007).

Alluvium

Like landslides, alluvium is also not technically bedrock. Alluvium includes any active stream channel sediments as well as unconsolidated bank deposits and floodplain deposits. This deposit type covers just over 4% of this subbasin.

River Terrace Deposits

River terrace deposits blanket less than 1% of the Northern 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.

River terrace deposits make up extensive flat areas bordering the stream. Most of the towns (Weott, Myer's Flat, Miranda, and Phillipsville) within this subbasin are built on these terraces due to their gentle topography and proximity to the river.

Del Puerto Terrane

The Del Puerto Terrane occupies less than 1% of this subbasin. This terrane is associated with an ophiolite complex and its overlying sedimentary rocks about 190 miles away in the Del Puerto Canyon near San Jose, California (McLaughlin et al., 2000).

In the Northern Subbasin the Del Puerto Terrane occurs as blocks of fine through coarse-grained diabase and some gabbro within the Central Belt mélange. This block forms Bear Buttes northwest of Garberville.

Diabase is an intermediate rock between volcanic basalt and plutonic gabbro, which differ in the pressure and time period under which they cooled and solidified from their magmatic state. Gabbro cooled over a long period of time under immense pressure, producing rocks exhibiting large crystals. Diabase cooled over more moderate time scales and pressures nearer the surface, not allowing crystals to grow as much. Basalt cooled very quickly at the surface, allowing only extremely small crystal growth.

Coastal Terrane

The Coastal Terrane is a division of the Coastal Belt of the Franciscan Complex and consists mainly of slightly metamorphosed, interbedded arkosic sandstone and argillite with minor pebble conglomerate. The Coastal Terrane has been folded, faulted, sheared, and shattered, sometimes to such an extent that it is considered mélange: a highly sheared matrix of the former rock types containing limestone lenses and exotic blocks of rock (McLaughlin et al 2000).

The sedimentary sequences (sandstone, argillite, and conglomerate) are interpreted to be turbidites (sedimentary deposits left from sub-aqueous landslides) and other mass-flow type deposits 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.

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 on 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.

Faults, Folds, and Shear Zones

The Northern Subbasin is located to the east of the north-northwest trending boundary between the Pacific Plate and North American Plate. At present, most movement between the plates consists of 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 and the formation of mountain ranges. The plate boundary is not a single or narrow seam, but is better characterized as a region of crustal deformation that is approximately 65 miles wide. The Northern Subbasin lies within this region of deformation and is sandwiched 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 that lies several miles to the southeast. Both of these faults are right-lateral strike slip faults and are considered active by the State of California which means 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 250–100 years. The Northern Subbasin is underlain by major, mapped, active faults, the Garberville Fault being the most prominent, which makes ground displacement probable within the basin. Strong seismic shaking should be anticipated to occur if the San Andreas, Garberville, or Maacama faults rupture.

A brief description of faults within the Northern subbasin follows, with summary information included in *Table 5*.

Table 5. Northern Subbasin fault descriptions (M = magnitude; R. Int. = recurrence interval).

	Active Faults:	Fault Type	M	R. Int.	Description
Mendocino Triple Junction	Cascadia Megathrust	Thrust	8.3-9.2	500-600	The Cascadia Megathrust allows subductive movement of the Gorda Plate beneath the North American Plate. This fault is capable of generating very large earthquakes (~M9) and usually produces uplift or subsidence of the coastal area adjacent to the Van Duzen River Basin. Several prehistoric seismic events that produced significant tsunamis and sudden uplift or subsidence along this area of the coast have been documented. In 1992 an earthquake of magnitude 7.1 (Richter) occurred that uplifted the coast at Cape Mendocino by about five feet.
	Eastern Mendocino Fracture	Dextral	6.5	17	This high-angle, east-west trending fault represents the plate boundary between the Gorda and Pacific plates. It generates predominantly right-lateral strike-slip earthquakes.
	San Andreas Fault (Northern Segment)	Dextral	7.3-8.3	200-300	The San Andreas fault (Northern segment) is an 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 their 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.
	Gorda Plate	Deep-seismic	7.3	50	This relatively small plate remnant is breaking up as it approaches thesubduction zone. Frequent earthquakes are generated along left-lateral strike-slip faults within the plate itself. The plate is subducting in a northeastward direction.
	Garberville Fault	Dextral	6.9		Consists of several widely spaced, steeply dipping reverse faults with components of dextral slip.
	Briceland Fault	Dextral	6.9	220	Is associated with the Garberville Fault and consists of several widely spaced, steeply dipping reverse faults with components of dextral slip.
	Inactive Faults:	**Fault Type**	**M**	**R. Int.**	**Description**
	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				Mapped fault segment near Piercy.
Sources: USGS 2011, McLaughlin et al. 2000					

The Mendocino Triple Junction

The structure of the Northern Subbasin is induced by tectonic forces generated by the Mendocino Triple Junction, which consists of the interaction of the North American, Pacific, and Gorda plates. The movement of these plates has set up three major fault systems that influence the structure and landscape of this subbasin: the San Andreas Fault Zone between the Pacific and North American plates, the Cascadia subduction zone between the North American and the Gorda plates, and the Mendocino Fracture Zone between the Pacific and the Gorda plates. Of these, the convergent plate boundary of the Cascadia Megathrust and the translational plate boundary of the San Andreas Fault Zone are most influential on the tectonic regime within this subbasin.

The Franciscan Complex was accreted to the western edge of the continent by processes related to the subduction of the Farallon Plate in this region during the geologic past. As northward movement of the Pacific Plate brought the San Andreas fault system northward, this region went from being controlled by compression set up by convergence and subduction of the Farallon under the North American plate to

transpression and translation between the Pacific and North American plates. Under compression, a series of north-west trending folds and thrust faults were set up, and these features controlled the landscape such as the Coastal Belt Thrust and the Garberville synform and antiform. As the San Andreas system became dominant and stress on this area became transpressive, faults acting on this landscape became right-lateral strike-slip (dextral) such as the Garberville/Briceland fault.

In addition to the landscape of this subbasin being controlled by the tectonic regime, folds, faults, and shear zones have affected the area in many ways. Folding of rock layers can create unstable zones of inward dipping increasing the likelihood of landsliding. Seismic activity can destabilize hillslopes, causing widespread landsliding; fault movement can change stream morphology, and faults and shear zones can locally weaken rock strength, enhancing erosion.

Coastal Belt Thrust

The Coastal Belt Thrust fault cuts through this Subbasin, juxtaposing the Coastal Belt and the Central Belt of the Franciscan Complex. The Coastal Belt thrust is likely the zone which accommodated movement between the subducting Farallon plate and the North American plate before accretion of the Coastal Belt when active subduction moved west to its present location along the Cascadia Megathrust.

Garberville Fault Zone

The Garberville fault zone consists of several widely spaced, steeply dipping reverse faults with components of dextral slip that bound elongate 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 2000).

Garberville Synform

The Garberville synform is a prominent downward-arching fold within the rock strata running north by northwest along the west side of the Northern Subbasin.

Garberville Antiform

The Garberville antiform is a prominent upward-arching fold within the rock strata running north by northwest along the east side of the Northern Subbasin.

Uplift

The coastal area to the west of this subbasin is undergoing high rates of uplift (1 to 5 millimeters per year) which translates into uplift in all three SF Eel River subbasins. Studies of river terraces along the mainstem Eel River indicate that at least 1 millimeter per year of uplift reaches past Garberville (Bickner 1985, Merritts and Bull 1989, Merritts and Vincent 1989, Merritts and others 1994). Northeast-southwest compression seems to be generating this region of uplift within the subbasin and has been termed the Mendocino Uplift (McLaughlin and others 1992).

Uplift in this area has increased the potential energy of the streams, allowing them to incise and erode the landscape at high rates leaving steep canyon walls above the streams. As tectonic forces push the land up, gravity tries to pull it down, and the result is usually landslides and rock falls. Landsliding is further exacerbated by heavy seasonal rainstorms that saturate the hillslopes, making them unstable and even more prone to landsliding.

Earthquakes

The Northern Subbasin is within one of the most seismically active regions in the world. Its juxtaposition to the Mendocino Triple Junction to the northwest, the San Andreas fault zone to the west, and the Maacama fault zone to the southwest places this subbasin in a very precarious seismic regime which is susceptible to periodic strong seismic shaking (*Table 6*).

This shaking can trigger rockfalls, landslides, and earth/debris flows as well as increasing erosional processes in the area of surface rupture or liquefaction. Fault movement can result in uplift of the local landscape, increasing the potential for erosion, or may cause the local landscape to subside, increasing the potential for deposition. Faults may deform, break, or weaken rock, leaving the immediate area unstable and more prone to erosion.

Table 6. Significant earthquakes near the SF Eel River.

Large historic earthquakes in proximity to the South Fork Eel River Basin		
Date	**Magnitude**	**Location**
1899 April	7.0	West of Eureka
1906 April	8.25	Great 1906 earthquake
1922 January	7.3	West of Eureka
1923 January	7.2	Cape Mendocino
1980 November	7.2	West of Eureka
1991 August	7.1	West of Crescent City
1992 April	7.2	Cape Mendocino
Source: USGS 2011		

Landslides and Erosion

The Northern Subbasin is underlain by weak and erodible rock types of the Coastal and Central belts of the Franciscan Complex. The Yager Terrane composes the majority of the subbasin and while it is relatively hard and more resistant to erosion than many of the other rock types in the subbasin, it still erodes and contributes sediment at high rates. The majority of natural sediment entering the streams is produced by landslides. The term "landslide" is used in a general sense to refer to the various processes of mass wasting of soil, unconsolidated sediment, or bedrock within this subbasin.

There are both benefits and disadvantages of natural landslides on salmonid populations. Landslides typically contribute large woody debris, large boulders, and spawning gravels from the hillsides and create stream channel diversity like plunge-pools, riffles, meanders, and side channels. However, landslides can also contribute an abundance of fine sediments, strip riparian vegetation, and fill channels and pools. Fish have evolved over time to thrive in the delicately balanced, highly unstable, natural landscape of this area, but anthropogenic activities that result in additional fine sediment input may disrupt this balance.

The likelihood of landslides occurring in an area is related to numerous variables. Major factors that tend to increase the likelihood of landsliding are: 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. In the Northern Subbasin, weak rocks in conjunction with high amounts of rainfall and the dynamic tectonics of the northwestern California create a landscape prone to landsliding.

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

Central Belt mélange, while less abundant than Yager Terrane, is more susceptible to erosion. The high degree of internal shearing within mélange has turned it into an incoherent matrix of its parent rock type (completely smashed and 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 deep-seated earthflows. Mackey and Roering (2011) 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. 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 erode, providing a constant source of fine sediments to 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 forming rills and gullies, as well as secondary slumps and small debris flows which wash additional sediments into streams.

Five 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 most notable, historical slide in the Northern Subbasin is located in Salmon Creek (*Figure 7* and *Figure 8*). This slide occurs in Central Belt mélange

and is the largest mapped Quaternary landslide. Salmon Creek follows the Coastal Belt Thrust (fault) separating Yager Terrane to the east and the Central Belt mélange to the west. This large earthflow has conveyed many large Franciscan boulders to the stream, creating boulder-run/cascade/pool reaches in many areas. It has been estimated that the entire landscape in this area is eroded at a rate of about one millimeter every two-and-a-half years (Gendaszek et al. 2006).

Figure 7. Pseudo-aerial-oblique of Salmon Creek Earthflow 2011.

Figure 8. Salmon Creek Earthflow 2011. View is from the earthflow looking west, across the stream to the Yager Terrane.

Fluvial Geomorphology

The overall fluvial geomorphology of the Northern Subbasin may be described by moderately steep tributaries with steeply incised valleys draining into a low gradient (<1%) mainstem. The 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.

Two basic types of geology control the landscape: relatively resistant sandstone units (including shale and conglomerate) and mechanically weak mélange units (sandstone, shale, and conglomerate sheared and fractured to the point where it loses coherency). Coastal Belt sandstone geology of the Yager Terrane dominates this subbasin and typically produces a rugged landscape with steep sharp ridges and valleys whose trend is predominantly controlled by regional folding and faulting induced by Mendocino Triple Junction and San Andreas tectonics.

Mélange geology exists in the southern portion of this subbasin and typically produces a hummocky topography with a landscape of rolling hills and grassland. Ridge-valley sets of mélange units are strikingly less steep and sharp compared to sandstone units. Exotic rock blocks within mélange protrude, forming knockers jutting out from the terrain. Mélange, lacking coherency, tends to move downhill, over time, in large earthflows. Where active earthflows terminate at streams they usually deliver large amounts of fine sediment and deposit sizeable boulders of exotic rock types. This creates chronic turbidity in streams as well as boulder-runs and cascade reaches, both of which are possible barriers to fish passage.

Sediment Transport

Processes of stream sedimentation are controlled by stream power, which is a combination of discharge and the slope over which a stream 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 as well as steepened knick-zones, transported along moderately steep reaches, and deposited within gentle gradient reaches. Although streams are broadly divided into these three regions, forms of erosion, transport, and deposition occur on all reaches of a stream at any given time, and seasonal variations in stream flow modify where and when such processes occur.

Large storm events trigger more erosion and recruit more sediment to the streams than smaller events. Sediment pulses from large storms migrate slowly downstream and tend to affect the stream for tens of years. Anthropogenic land use can greatly increase the rate of erosion and sediment input to streams, and

it may take upwards of a century for the stream to naturally flush out the sediment pulse.

Terrace deposits are present at several places along the mainstem of the SF Eel River and in some of its tributaries. Stream terraces can be formed in a variety of ways. In a period of tectonic quiescence, stream valleys widen and sediment is deposited within the flood plain; if regional uplift occurs the stream will respond by incising and eventually the flood plain will be left perched above the active stream channel.

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 and 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 are 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 banks of the stream.

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.

Large river floodplain/terrace deposits bordering the mainstem of the SF Eel River 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. Weott, Myer's Flat, Miranda, and Phillipsville are all built on terrace deposits.

The tributaries of the SF Eel River are mostly bedrock controlled: streams create their fluvial-geomorphology from the gradual wearing away of the containing bedrock. Local geology will dictate channel slope, bedforms, pool-riffle-run morphology, bars, flood-planes, and terraces. Regional uplift, folding and faulting, and the mechanical strength and behavior of bedrock control the overall morphology of the streams in the Northern Subbasin.

Although controlled by bedrock, Northern Subbasin streams are still subject to influence from available sediment input. The input of sediment is typically from various hillslope processes such as landsliding and erosion that are often enhanced 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-in of the channels with sediment effectively forced the water up and out of the channel, causing excessive streambank erosion channel widening to accommodate flow.

Bull Creek

The Bull Creek drainage is a good example of the effect of sediment input on the fluvial geomorphology in Northern Subbasin streams. Prior to the 1955 flood the lower reaches of Bull Creek consisted of a deep, meandering channel that was roughly 50 feet wide. After the 1964 flood segments of this channel had widened to approximately 400 feet (Jager and LaVen 1981). Flood-flows, aggradation, and subsequent lateral erosion removed riparian vegetation, hundreds of old-growth redwoods, roads, and bridges, as well as complete stream-side towns.

These two flood events deposited vast amounts of sediment into the channel of Bull Creek and its tributaries. The lower reaches of Bull Creek aggraded by about 15 to 20 feet.

Sediment was deposited to a depth of approximately 40 feet in the lower reaches of Cuneo Creek (a tributary to Bull Creek). The 1955 flood completely buried a bridge across Cuneo Creek with sediment, after which a new bridge had to be built. The 1964 flood completely buried the new bridge with sediment, after which a third bridge was constructed. Presently the channel in the vicinity of the bridges has degraded back to a point where the second bridge has become exposed.

Knickzones

Knickzones are the actively propagating areas of base-level fall throughout the basin. Knickpoints are more numerous on first order streams where stream power is weaker and the knickpoints effectively become trapped. Subsequent base-level fall within the basin will induce a new series of knickpoints which will typically migrate upstream over time and "bunch-up" against the previous knickpoints in areas where the stream power becomes too weak to propagate them further. Knickzones record various bouts of regional

uplift or base-level lowering within the basin, and may create gradients steep enough to become obstacles or barriers to fish passage.

Of the 20 named SF Eel tributaries in the Northern Subbasin, 12 were surveyed for salmonid habitat, and the probable end of anadromy was identified in the field. The end of anadromy of eight of these streams (67%) was associated with a knickzone and usually located towards its downstream end.

Channel Type

The fluvial geomorphology of individual streams within a system can be used to help understand current as well as past fluvial regime changes. Some basic morphologic stream patterns were defined by D.L. Rosgen, and were based on entrenchment, sinuosity, and slope of streams (*Figure 9*). In the most recent (1987 to 2010) Northern Subbasin stream surveys (n = 29), crews documented A, B, C, D, E, F, and G Rosgen channel types (*Table 7*). Type B streams were the most common (39% of Northern Subbasin stream length surveyed), followed by type F (27%), type C (15%) and type A (13%).

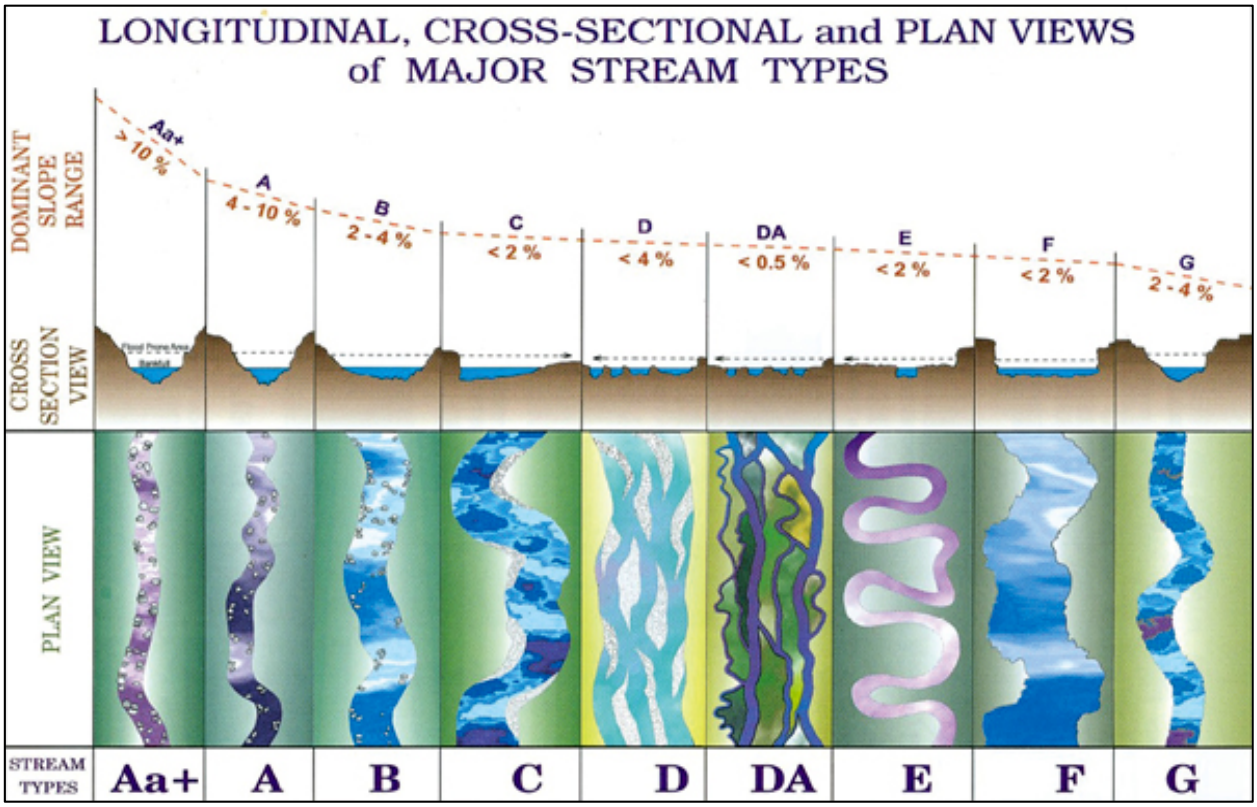


Figure 9. Illustration of channel types A-G (Rosgen 1996, courtesy of Wildland Hydrology).

Table 7. Surveyed channel types by percent of subbasin

Northern Subbasin General Channel Types		
Type	**%**	**Description**
A	13%	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	39%	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	15%	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.
D	1%	Type D streams are wide, have Multiple channels with longitudinal and transverse bars, eroding banks, and have gravel substrates. They are not entrenched and have less than a 2% gradient.

E	1%	Type E channels are low gradient (<2%), meandering, riffle/pool streams with a gravel, sand, or silt substrate.
F	27%	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	4%	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. 2010).

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 most common Northern Subbasin stream types using the level II classification system were F4 and B2 channel types (47,785 and 43,233 ft respectively) (*Table 8*).

Table 8. Surveyed Channel types of the Northern Subbasin by stream reach.

Stream	Length (feet)	Channel Type
Bull Creek	12885	B2
	13301	B3
	12261	B4
	12359	C4
	2218	D4
Cow Creek	1263	A3
	1137	B3
	3038	F3
Connick Creek	11866	C1
Harper Creek	3186	A2
	1494	G3
Squaw Creek	5638	A2
	6327	B2
	2516	F3
Albee Creek	1938	A3
	988	B3
Mill Creek	676	A3
	2006	B2
	1190	E3
	2553	F4
Cuneo Creek	1742	A3
	1108	B3
	4590	C2
N.F. Cuneo Creek	428	A2
	3721	B2
Burns Creek	3674	A2
Brain's Creek	3352	A3
Slide Creek	3349	A3
Panther Creek	2980	A2
	696	B4
Preacher Creek	2700	B1
Decker Creek	1831	A3
Mill Creek	1765	A3

Stream	Length (feet)	Channel Type
Mowry Creek	243	A3
	2281	C3
Canoe Creek	3444	B2
	2347	F2
	4553	F4
Coon Creek	3006	A3
Bridge Creek	2816	B2
	2356	B4
Elk Creek	4396	B2
	1082	B3
	2126	B4
	7722	F4
	6536	G3
Salmon Creek	7638	B2
	8114	B4
	7361	C4
	15488	F4
Mill Creek	2735	B4
S.F. Salmon Creek	17226	F3
	3547	F4
Butte Creek	6567	B3
	738	B4
Coon Creek	2731	F4
Fish Creek	3651	B3
	2047	B4
Anderson Creek	978	E4
	11191	F4
Ohman Creek	1929	C4

Stream Channel Geometry

Longitudinal Stream Profiles

A stream in a topographically steady state of slope (at equilibrium) tends to form a convex slope that exponentially gets steeper towards its headwaters. A stream that is out of equilibrium tends to deviate from this basic pattern along various portions of its length. In Northern Subbasin streams, reasons for deviance from profile equilibrium are typically caused by changes in underlying geology, regional uplift, movement along fault lines, large landslides, and large amounts of sedimentation (aggradation of the stream channel). These processes generally cause the longitudinal profile of a particular stream to become progressively convex (*Figure 10*). 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 Northern Subbasin streams, only two out of 12 (17%) of the surveyed tributaries of the SF Eel River with identified probable 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 of tributaries are out of equilibrium. These areas may be considered sensitive to disturbance and 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.

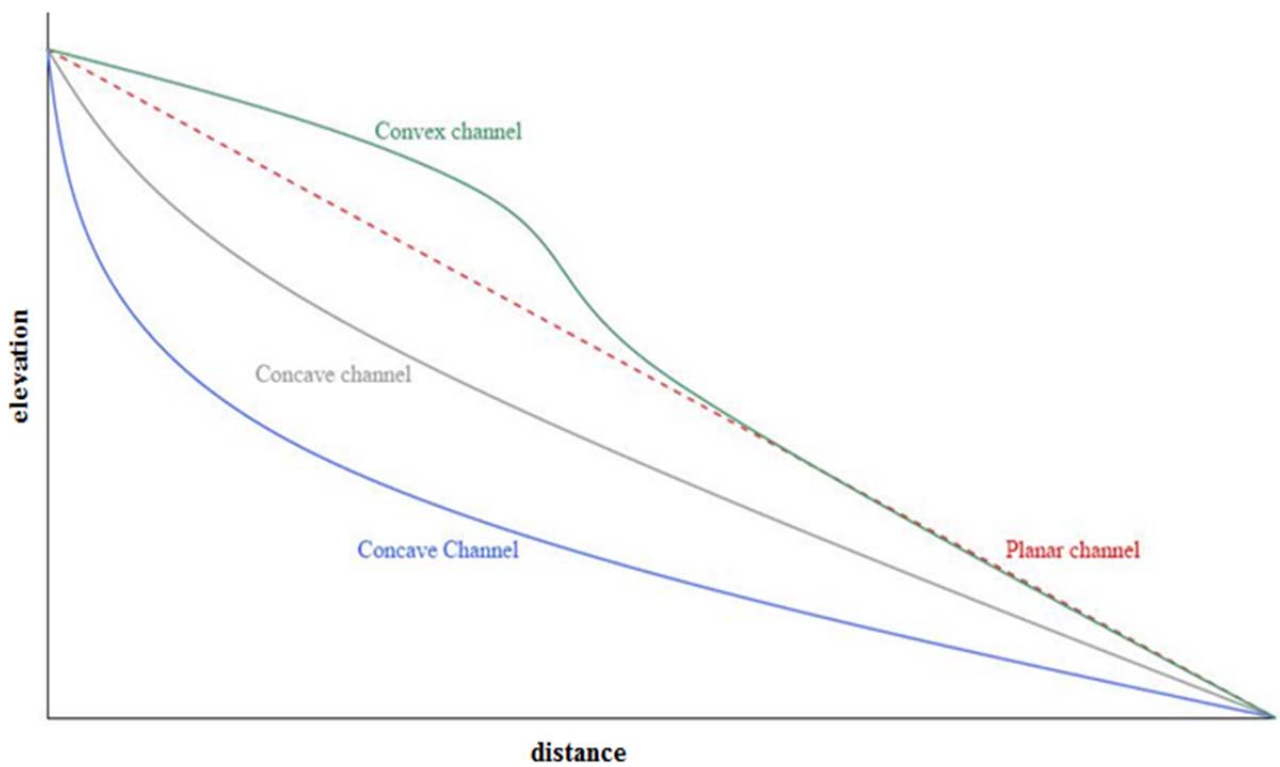


Figure 10. Basic channel profile shapes.

Profiles of Northern Subbasin Streams

Stream profiles were completed for 20 Northern Subbasin streams (*Figure 11*). Knickzones and ends of anadromy (EOA) were included on profiles where applicable; 12 of the 20 streams had EOAs identified in habitat typing reports. Of these 12, 67% had EOAs associated with knickzones (7 were located at the downstream end of a knickzone, and 1 was located in the middle of a knickzone). Thirty three percent (4 of 12) of EOAs were not associated with a knickzone.

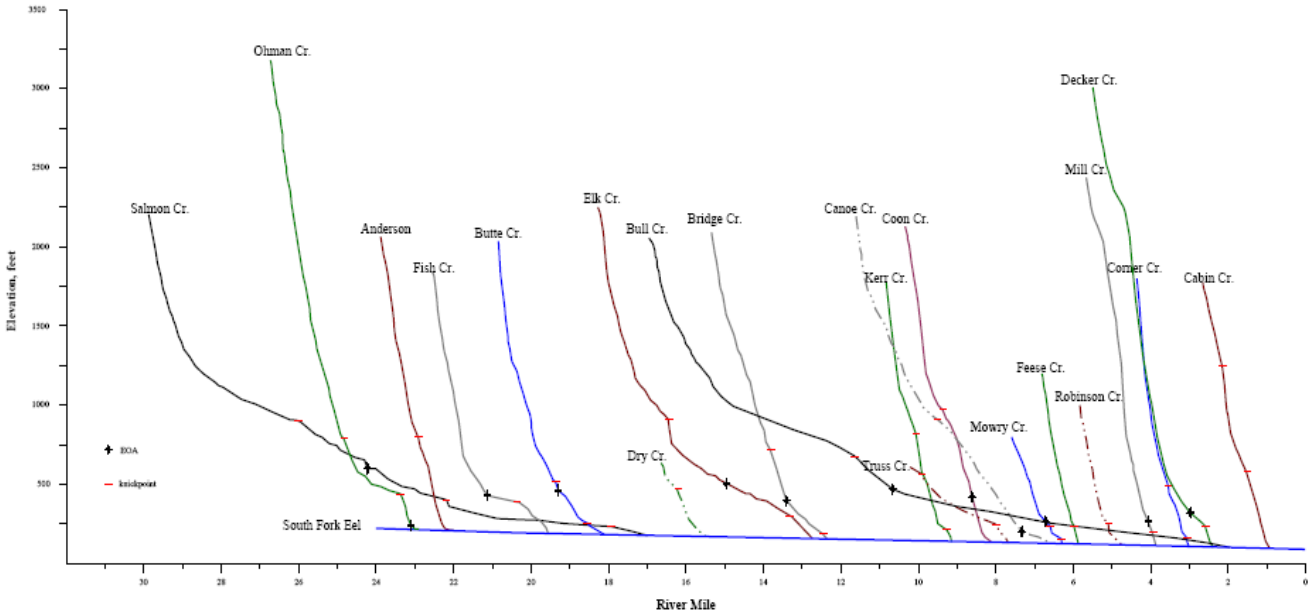


Figure 11. Longitudinal stream profiles of SF Eel River Northern Subbasin streams.

Soils

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

The majority of bedrock throughout the subbasin is composed of sedimentary rock types of the Coastal Belt, producing associated soil types ranging from silt loam to very gravely loam that are prone to mass wasting, hillslope erosion, and transport by fluvial processes. The dominant soil series in the Northern Subbasin is Vandamme-Tramway-Irmulco-Hotel-Dehaven soil series, covering approximately 67% of its area (*Figure 12*). The Vandamme-Tramway-Irmulco-Hotel-Dehaven soil series is associated with and mantles steep, rugged ridges and valleys of Yager Terrane bedrock (sandstone, shale, and conglomerate) of the Coastal Belt (*Table 9*).

The Northern Subbasin receives high levels of rainfall between October and May (up to 115 inches in the Bull Creek headwaters). Rainfall initiated soil movement varies with storm intensity, most noticeably during short-duration, high-intensity storms but still significant during long-lasting, less intense storms. As soil becomes saturated, pore-pressure between grains increases, which lowers its ability to resist downslope movement. A healthy cover of vegetation helps stabilize the underlying soil through root-strength, which increases soil cohesion and evapotranspiration; this can prevent or at least delay soil saturation. Tree cover on hillslopes can increase the soil shear-strength by more than 60%. The soils in this subbasin support a lush growth of redwood and Douglas-fir.

Forest cover in this subbasin reinforces hillslope soils, with roots mechanically reinforcing soils by transferring shear stress in the soil to tensile resistance in the roots (Menashe 2001). Humboldt Redwoods State Park occupies approximately 52% of the subbasin, mainly within the Bull Creek watershed and Grasshopper Mountain, and maintains its forest and vegetation cover in a close-to-natural or recovering state (from wide-spread, intensive logging before the late '60s) with the exception of

access roads, trails and campgrounds. Detrimental effects on soils of compaction and lack of vegetation are not considered widespread within this subbasin.

The Northern Subbasin has periodically experienced fires throughout history. One of the most notable and recent fires was the Canoe Fire of 2003, located in the Canoe Creek drainage within Humboldt Redwoods State Park. Wildfires can weaken soil slope-strength and increase erosion by: decreasing or removing the root mass tensile strength; removing vegetation and duff; decreasing inception and evapotranspiration rates; creating hydrophobic soils which reduce infiltration, absorption, and subsurface hydraulic flow; and increase surface runoff. The negative effects of burned soils can last from years to decades.

Gradual downslope movement of soil caused by gravity, weathering, saturation and rain-splash, and biogenic activity (soil creep) is also present within the soils of this subbasin and delivers sediment to the streams (Stillwater Sciences 1999).

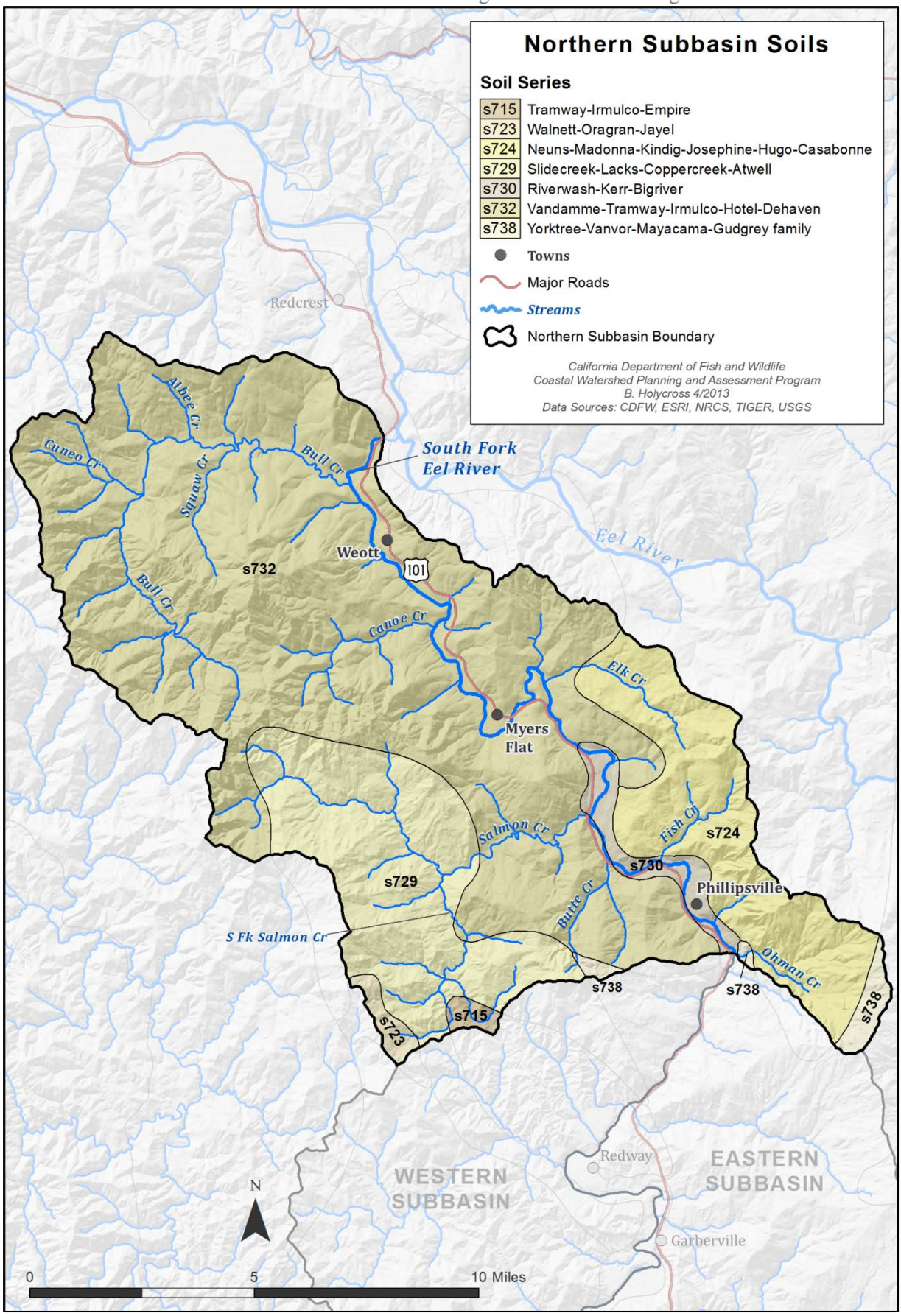


Figure 12. Soils map of the Northern Subbasin.

Table 9. Northern Subbasin soil descriptions.

Soil series	Texture	Description	Parent Bedrock	Slope %
Vandamme-Tramway-Irmulco-Hotel-Dehaven (67%)				
VANDAMME SERIES	loam	Deep, well drained soils formed in material weathered from sandstone or mudstone.	Coastal Belt Yager Terrane.	2 - 75
TRAMWAY SERIES	loam	Moderately deep, well drained soils formed in material weathered from sandstone.		9 - 75
IRMULCO SERIES	loam	Deep or very deep well drained soils formed in material weathered from sandstone.		9 - 75
HOTEL SERIES	very gravelly loam	Moderately deep, well drained soils that formed in material weathered from sandstone.		30 - 100
DEHAVEN SERIES	gravelly loam	Deep, well drained soils formed in material weathered from sandstone.		30 - 99
Slidecreek-Lacks-Coppercreek-Atwell (16%)				
SLIDECREEK SERIES	gravelly loam	Very deep, well drained soils that formed in colluvium and residuum weathered from sandstone and mudstone.	Central Belt Mélange.	9 - 75
COPPERCREEK SERIES	loam	Very deep, well drained soils that formed in colluvium and residuum from schist, sandstone, and mudstone.		9 - 75
ATWELL SERIES	silt loam	Very deep, moderately well drained soils formed in material from sheared sedimentary rocks		15 - 50
Neuns-Madonna-Kindig-Josephine-Hugo-Casabonne (13%)				
NEUNS SERIES	gravelly loam	Moderately deep, well drained soils that formed in slope alluvium and colluvium from metamorphosed igneous and sedimentary rocks.	Central Belt Sandstone and Mélange.	15 - 80
MADONNA SERIES	loam	Moderately deep, well drained soils that formed in material weathered in residuum from sandstone and shale.		15 - 75
KINDIG SERIES	gravelly loam	Deep, well drained soils that formed in residuum and colluvium from metamorphosed igneous and sedimentary rocks. Kindig soils are on mountains.		15 - 80
JOSEPHINE SERIES	gravelly loam	Deep, well drained soils that formed in colluvium and residuum weathered from altered sedimentary and extrusive igneous rocks.		2 - 75
HUGO SERIES	gravelly sandy clay loam	Deep, well drained soils that formed in material weathered from sandstone, shale, schist, and conglomerate.		9 - 75
CASABONNE SERIES	Gravelly loam.	Very deep, well drained soils formed in colluvium and residuum weathered from sandstone or shale.		9 - 75
Riverwash-Kerr-Bigriver (2%)				
KERR SERIES	loam	Dark olive gray recent moderately well drained alluvial soils without profile development that are formed in material derived mainly from micaceous schists.	Alluvium and river terrace deposits.	0 - 5
BIGRIVER SERIES	loamy sand	Very deep, well drained soils formed from alluvium derived from mixed sources.		0 - 5
Yorktree-Vanvor-Mayacama-Gudgrey family (1%)				
YORKTREE SERIES	loam	Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone.	Central Belt Sandstone.	15 - 75
VANVOR SERIES	very gravelly sandy clay loam	Moderately deep, well drained soils on mountains. These soils formed in colluvium from metavolcanic rock.		30 - 75

Soil series	Texture	Description	Bedrock	Slope %
MAYACAMA SERIES	very gravelly sandy loam	Moderately deep, somewhat excessively drained soils formed in material derived from sedimentary and metasedimentary rocks.		9 - 75
GUDGREY SERIES	gravelly sandy clay loam	Deep, well drained soils formed in material weathered from sandstone, schist or shale.		8 - 75
Walnett-Oragran-Jayel (1%)				
WALNETT SERIES	stony loam	Very deep, well drained soils formed in material weathered from serpentinized peridotite.	Central Belt Mélange – peridotite block.	5 - 75
ORAGRAN SERIES	very stony loam	Shallow, well drained soils formed in material weathered from peridotite or serpentinite.		5 - 75
JAYEL SERIES	stony clay loam	Moderately deep, well drained soils formed in material weathered from serpentinized peridotite.		5 - 75
Tramway-Irmulco-Empire (<1%)				
TRAMWAY SERIES	loam	Moderately deep, well drained soils formed in material weathered from sandstone.	Wildcat Group.	9 - 75
IRMULCO SERIES	loam	Deep or very deep well drained soils formed in material weathered from sandstone.		9 - 75
EMPIRE SERIES	loam	Deep, well to moderately drained soils formed in material derived from soft sedimentary rocks.		10 - 40

Vegetation

Two main factors in the decline of salmonids within the SF Eel River Basin over the past century are an overabundance of fine sediments and increasing temperatures in the streams. Vegetation on the landscape has a direct influence on both of these conditions. Hillslope vegetation intercepts and slows the velocity of rainwater and also 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 and 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 and corresponding stream temperatures. Stream bank roots and low hanging branches provide cover for fish. Large woody debris generated by riparian vegetation and recruited by the stream provides habitat and stream channel diversity. Stream bank root systems increase the tensile slope strength of unstable soils, reducing bank failure and subsequent sedimentation.

The predominant vegetation cover type as described by the USFS CALVEG data is mixed conifer and hardwood forest, which covers approximately 55 percent of the Northern Subbasin (*Figure 13*). This vegetation type includes forests and woodlands where conifer is the primary vegetation type and hardwoods are present secondarily. Pacific Douglas-Fir is the primary vegetation type (61%) in this classification, followed by mixed Redwood – Douglas-Fir (36%) and Redwood (3%) (*Table 10*). Conifers are prevalent throughout this subbasin and occupy nearly all areas except river floodplains, 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 type in this subbasin, covering approximately 28% of the subbasin area (*Figure 13*). Conifer forests and mixed conifer forests, when combined, are the major vegetation in the Northern Subbasin, making up nearly 85% of the total vegetation.

Grassland/prairie (herbaceous) vegetation, primarily composed of annual grasses, is the next most abundant vegetative cover, making up 9% of the total subbasin area. This vegetation is found in small, interspersed hillside prairies in the southern part of the subbasin, overlying earthflows 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 1800s ranchers began seeding European short-rooted annual grasses for grazing and these soon replaced the bunch grasses. Replacement of the deeper rooted grasses with shallower rooted annual grasses is believed to have increased surface erosion and hillslope soil stability (Kelsey 1980).

Hardwood forest is the fourth most abundant vegetation category, covering about 6% of the Northern Subbasin area.

GIS data indicate that less than one percent (0.01%) of the subbasin area is covered by agriculture, however this may be an under-representation because pastures used for grazing of livestock may not be included in this vegetation designation since land use is often difficult to ascertain remotely. For this reason, it can be assumed that areas mapped as annual grasslands may also be agricultural in nature and the overall percentage of agricultural lands is likely to be greater than depicted.

Many agricultural practices in this region are covert and undocumented; both legal and illegal marijuana cultivation are becoming large-scale problems when considering water diversion and contamination of streams within the basin. Illegal grow sites are periodically established in remote areas of State Park lands, which make up more than half of the Northern Subbasin area, and on privately owned timberland which includes nearly a quarter of the subbasin area.

To supply a constant, reliable source of water to their plants, growers will typically divert water through plastic pipes from nearby streams or springs to their cultivation sites. The warm, dry portion of the season is when plants require the most water, including plants in the surrounding forest as well as those that are cultivated. Consequently, this is the time period when stream base flows are at their lowest. When low base-flow conditions exist, the

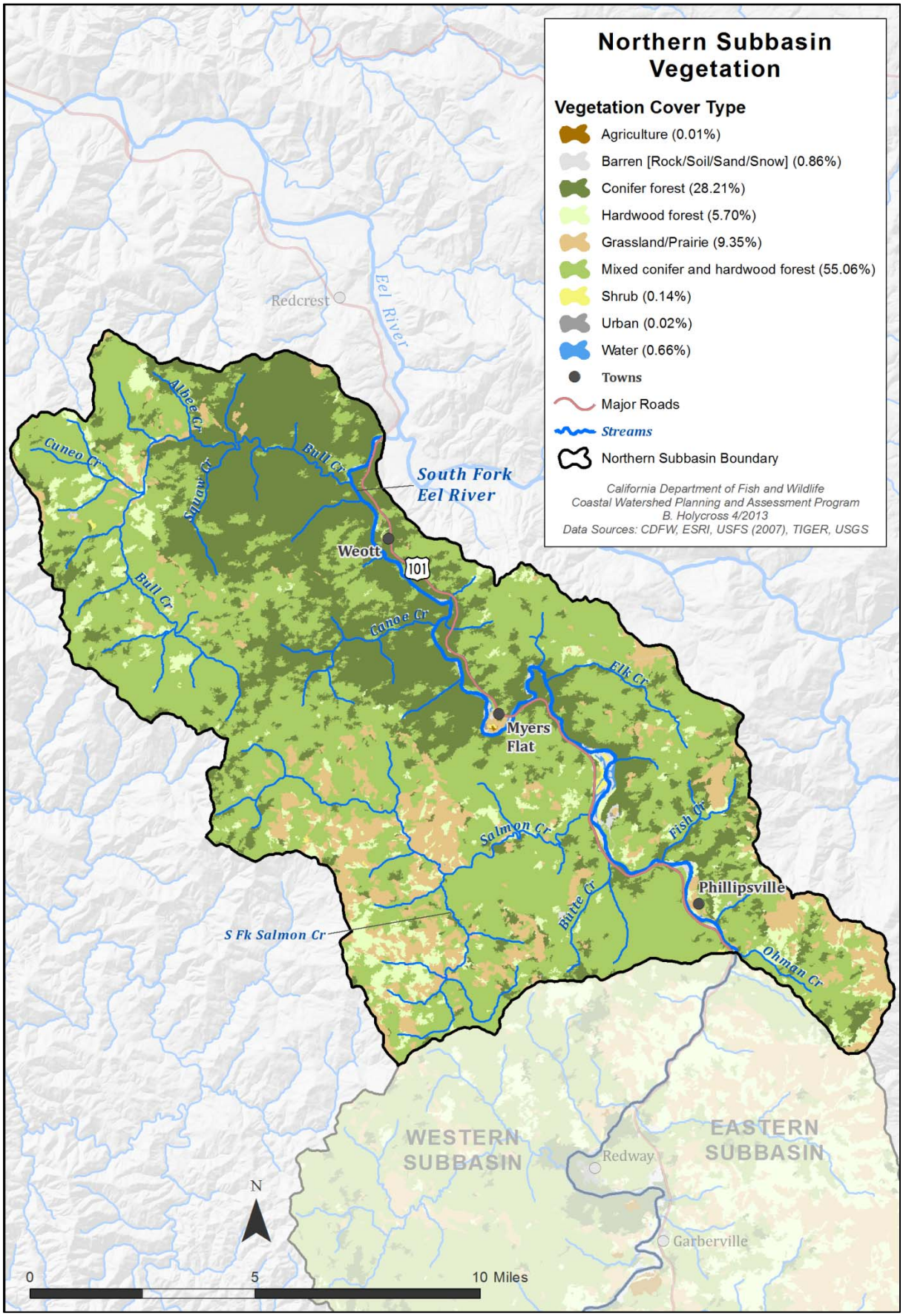


Figure 13. Vegetation map of the Northern Subbasin

Table 10. Vegetation of the Northern Subbasin (USFS CALVEG).

Vegetation Cover Type	% of Subasin	Primary Vegetation Type	% of Type
Mixed conifer and hardwood forest/woodland	55.06%	Pacific Douglas-Fir	61.1%
		Redwood - Douglas-Fir	36.0%
		Redwood	2.5%
		Jeffrey Pine	0.3%
		Incense Cedar	0.1%
Conifer forest/woodland	28%	Redwood - Douglas-Fir	45.1%
		Redwood	39.1%
		Pacific Douglas-Fir	15.3%
		Jeffrey Pine	0.2%
		Non-Native/Ornamental Conifer	0.2%
		Incense Cedar	0.2%
Grassland/Prairie	9.35%	Annual Grasses and Forbs	99.5%
		Pastures and Crop Agriculture	0.3%
		Non-Native/Ornamental Grass	0.1%
		Perennial Grasses and Forbs	0.1%
Hardwood forest/woodland	5.70%	Tanoak (Madrone)	53.0%
		Oregon White Oak	14.3%
		Montane Mixed Hardwood	13.5%
		Canyon Live Oak	5.7%
		Black Oak	5.0%
		California Bay	3.1%
		Riparian Mixed Hardwood	1.9%
		Red Alder	1.4%
		Interior Mixed Hardwood	1.2%
		Willow	0.6%
		Black Cottonwood	0.2%
		Coast Live Oak	0.2%
Barren	0.86%	Barren	62.4%
		Urban-related Bare Soil	37.6%
Shrub	0.14%	Willow (Shrub)	69.8%
		Lower Montane Mixed Chaparral	8.7%
		Wedgeleaf Ceanothus	8.6%
		Scrub Oak	6.8%
		Blueblossom Ceanothus	5.0%
		North Coast Mixed Shrub	1.3%
Urban	0.02%	Urban/Developed (General)	100.0%
Agriculture	0.01%	Agriculture (General)	100.0%
Statistics exclude classification of water			

streams become shallow and warm, and stressors on 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 covert, especially for grows on public parkland or privately owned timber land, they cannot be managed and the cumulative impacts are unknown other than observations of significantly lower streamflows and some streams going dry during relatively wet years. Sedimentation and pollution associated with grow operations are also increasing and becoming a greater concern.

Additional vegetation types are barren, shrub, and urban (all covering <1% of the total subbasin area).

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. The extent, effects, and severity of subsequent fires may be limited by these prescribed burns (Collins et al. 2008).

Fire is one of the primary natural disturbance factors influencing vegetation structure in the Northern 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 (BLM et al. 1996).

Twenty four percent (35 mi^2) of the Northern Subbasin has burned, with 19 fires on record since the early 1900s (*Figure 14*). This percentage is the largest of the three subbasins, with 20% of the Eastern and 21% of the Western subbasin burned since the early 1900s. However, fires have been more prevalent in the Eastern Subbasin, where the number of fires was greatest (35 fires), and lowest in the Western Subbasin (16 fires).

The largest areas in the Northern Subbasin burned between 1990 and 2012 (17 mi^2), and between 1950 and 1969 (15 mi^2). The most recent large fire was the Canoe Fire, started by lightning in 2003, which was not a drought year on the north coast. Coastal redwood forest is usually considered fire resistant, and large fires are rare since large-scale acquisition and fire suppression efforts began 1930s (Scanlon 2007). However, the Canoe Fire burned more than 16 mi^2 (more than 10% of the total subbasin area) in an old growth redwood stand, and was the most significant fire to have burned in coast redwood during the last half century due to the extent and diversity of vegetation types that were burned. Scanlon (2007) stated that historic fire suppression and exclusion practices in this area resulted in higher burn intensity and duration, which may have contributed to greater mortality of old growth stands (*Figure 15 A, B*).

Fire behavior is strongly influenced by vegetation type and fuel moisture content. More than 80% of the Northern Subbasin area vegetation is made up of conifer forest (28%) and mixed conifer and hardwood forest (55%). Large fires in the subbasin (other than the Canoe Fire) burned in the Bull and Salmon Creek drainages, and in areas east of Phillipsville (*Figure 14*) where vegetation types are a mix of conifer/hardwood forest, hardwood forest, shrub, and grassland/prairie.

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.

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 (Humboldt County 2008). These high risk areas have been identified throughout the county, and in 2005 the CalFire-Del Norte Unit Fire Management Plan added the area between Pepperwood and

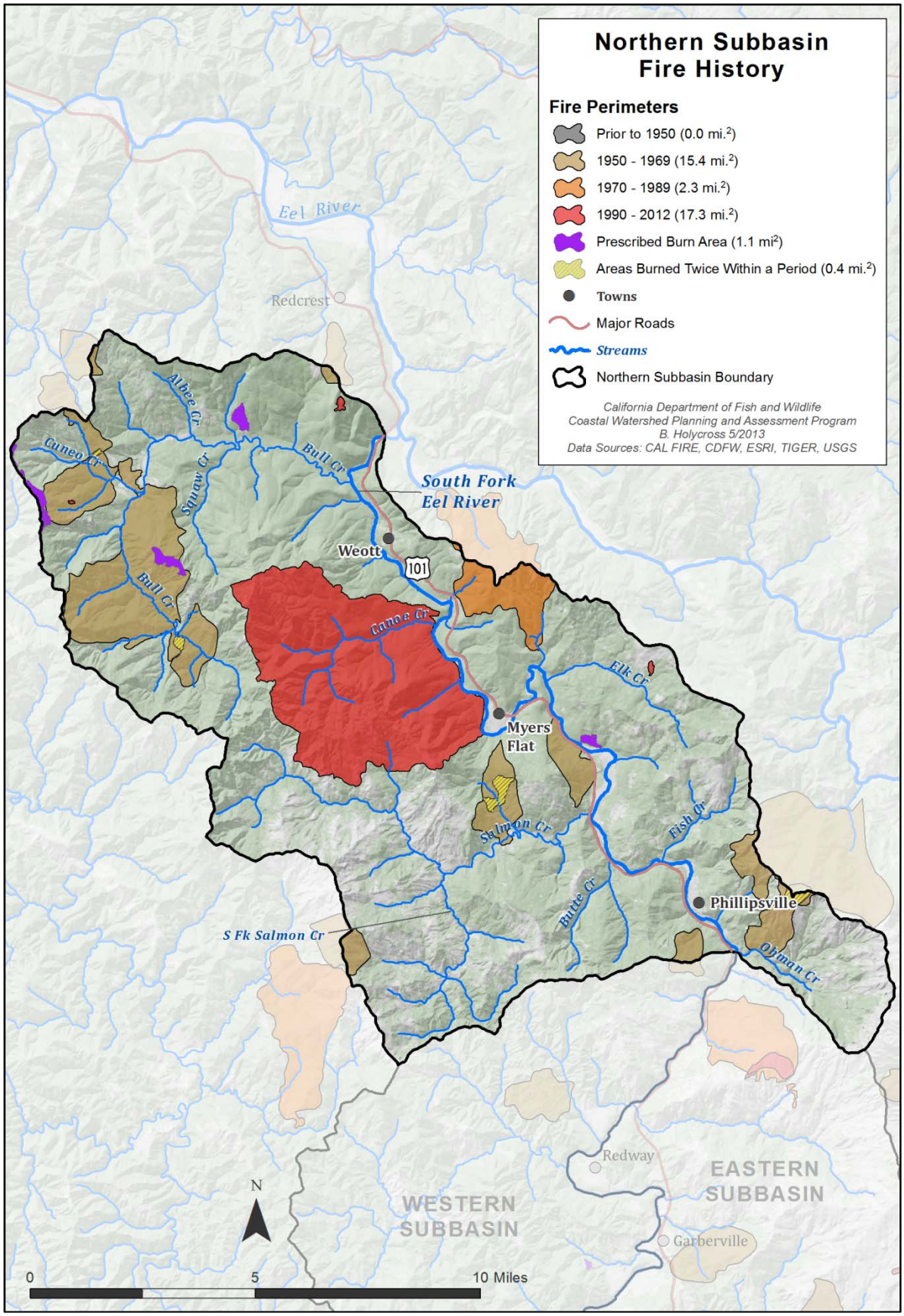


Figure 14. SF Eel River Northern Subbasin fire history, with total square mileage burned within each time period.

Figure 15 A, B. Children's Forest bridge in old growth area of Humboldt Redwoods State Park before (left (A)) and after (right (B)) the Canoe Fire in 2003 (photos courtesy of Dave Stockton, CA State Parks).

Phillipsville (Cathey road/Avenue of the Giants) as an increased fire risk area due to hazardous fuel buildup, wildland-urban interface proximity, high value assets, and fire history. Most of this added land is within the Northern Subbasin boundary, and land use is a mix of Humboldt Redwoods State Park and private property.

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).

Land use practices influence the likelihood of and severity of fires throughout the subbasin. Most of the land in the Northern Subbasin is open space/parkland (52%). There is an active prescribed burning program in place on park property that is maintained cooperatively with efforts of Humboldt Redwoods State Park and the Humboldt-Del Norte Management Unit (CalFire 2012). Benefits of prescribed or controlled burns include the following:

- Hazard reduction - fire decreases fuel loads that may destroy young stands in the event of a wildfire;
- Control of understory vegetation;
- Site preparation – to facilitate natural regeneration or prepare sites for tree planting;
- Enhanced wildlife habitat;
- Improved access; and
- Increase quality and quantity of habitat for fire-dependent native species (USDA-NRCS 1999).

Only 1.1 square miles of the basin area was managed using prescribed burns on Humboldt Redwoods State Park land (*Figure 14*), however, regular use of prescribed fire could reduce fuels so that catastrophic fires are less likely to occur.

Reduced rainfall and drier conditions resulting from climate change may 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. In the future, fire behavior will be less predictable due to changes in temperatures, precipitation, fire frequency and fire severity (Tetra Tech 2013). 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 (CDF 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 2008). Increased erosion and sediment production following fires are of particular concern in the Northern Subbasin due to very high natural and anthropogenic sediment inputs that already exist.

Depleted vegetation in riparian areas 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 Northern 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 Federal land managers (Dwire et al. 2011).

The most recent large fires in the Northern Subbasin occurred in areas of moderate to very high fire threat (*Figure 16*). Thirty eight percent of the land in the subbasin is classified as very high fire threat, and the majority of land (48%) is classified as 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). Thirteen percent of the basin 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). 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.

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, 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). Resource management strategies such as the modification of vegetation structure and fuels can help mitigate the effects of climate change throughout the subbasin.

Sudden oak death (SOD) has spread throughout southern Humboldt and is found in the SF Eel River Basin. In one SOD hot spot between Garberville and Miranda, the rate of expansion of diseased areas was approximately1,500 acres per year from 2004 through 2010 (Valachovic 2011) The OakMapper website (http://www.oakmapper.org/oaks/index/4132) shows two clusters within the SF Eel River hot spot area (*Figure 17*). The northern cluster and the four locations to the south are within the boundary of the Northern Subbasin. Affected stands have the potential to seriously impact 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

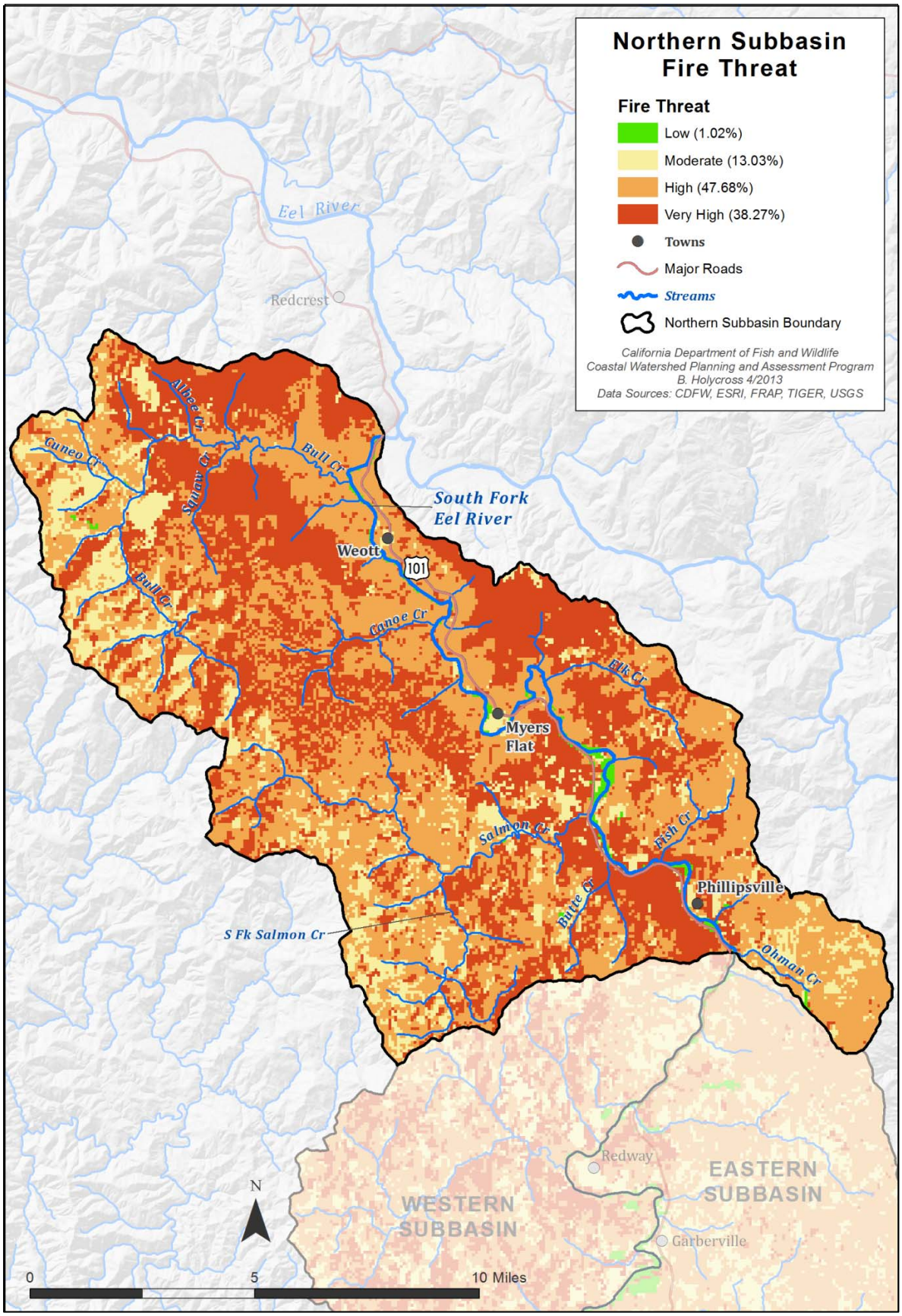


Figure 16. SF Eel River Northern Subbasin fire threat, with percentage of total basin area in each threat category.

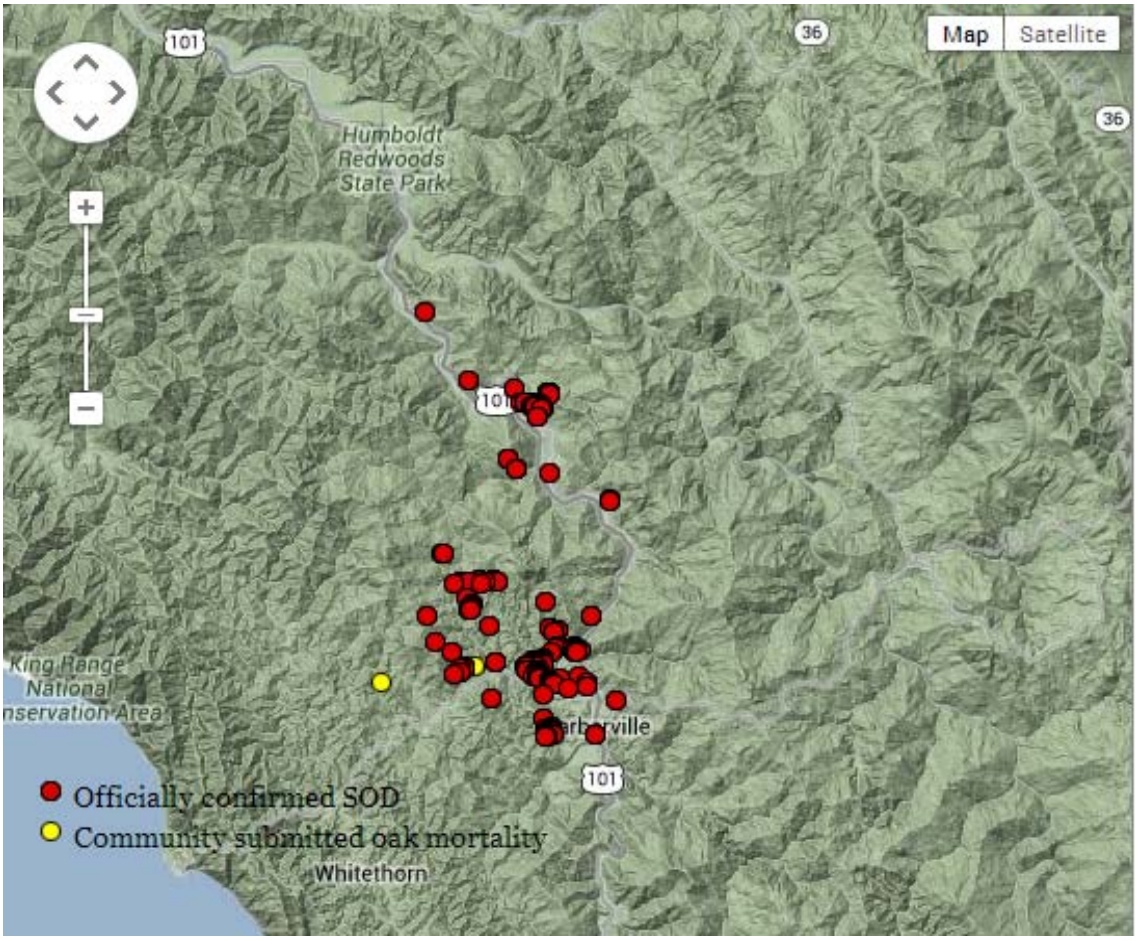


Figure 17. Confirmed (red) and reported (yellow) cases of Sudden Oak Death (SOD) in the SF Eel River Basin, from Oak Mapper website (accessed 2/27/2014). Confirmed locations in the northern cluster of dots are located within Northern Subbasin boundaries.

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 Northern 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 natural sedimentation input from landslides and unstable geology are a concern.

Land and Resource Use

Historic Land Use

The Sinkyone, a subgroup of the Coastal Southern Athabaskans, were the first inhabitants occupying the Northern Subbasin of the SF Eel River Basin (BLM et al. 1996). They subsisted primarily on anadromous fish, with secondary resources including upland game and acorns, and their cumulative impact on the environment and natural resources of the Northern 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 (JMWM 2000). These settlers were primarily trappers who were encouraged by the Homestead Act of 1862 which allowed them to purchase affordable land (160 acre homesteads for $1.25/acre), and also by the disappearance of the Native Americans due to violence, disease, and relocation (JMWM 2000). These homesteaders trapped, farmed, harvested timber, and grazed livestock throughout the Northern Subbasin.

Dyerville, located at the confluence of Bull Creek and the SF Eel River, was the only community of size in the Northern Subbasin in the 1850s and 1860s, although there were small settlements located along the SF Eel in Phillipsville, Myers Flat, and Weott. Dyerville was located where three major wagon roads met: those running along the mainstem Eel, Bull Creek, and the SF Eel (JMWM 2000). In 1912, the Northwestern Pacific Railroad crossed the mainstem Eel at Dyerville and although the rail line did not go up into the SF Eel Basin, the town of South Fork grew up around the depot at Dyerville and became a shipping hub for ranch products, tanbark, and redwood, and also a primary access point for the SF Eel River Basin. In 1923, the Redwood Highway was completed, bringing more people, commerce, and activity to the community of South Fork, and consequently, to the SF Eel River Northern Subbasin.

The tanbark industry was the first large-scale forest management practice in the Northern Subbasin, beginning in the early 1900s and ending in the 1950s with the development of synthetic tannins (JMWM 2000). Peak production of natural tannin occurred between 1900 and 1920. Tanoak bark was peeled from trees (*Figure 18*) and transported out of the area, or sent to a plant in Briceland where the bark was converted to tannin extract. Stripped tanoak trees were left on the ground, and nearly all of the tanoak trees in the Northern Subbasin were harvested during this time (HCRCD 2002).

Figure 18. Early tanbark harvest (photo courtesy of Humboldt State University).

Early logging activity resulted in the removal of all accessible old growth redwood along the creek mouths throughout the Northern Subbasin. In the early 1800s, logs were floated down the SF Eel River to mills as far away as Fortuna, but the river was deemed too long and meandering so logs were cut into more manageable rectangular chunks, known as cants, before floating them downstream (O'Hara and Stockton 2012). Due to the long distance between the harvest areas and larger mills near Fortuna and Humboldt Bay, many trees were used for split products such as railroad ties, shingles, and grape stakes (to support the expanding grape industry in Sonoma and Napa counties). These split products were produced at sites where trees were felled, then transported out of the basin more easily than whole logs (O'Hara and Stockton 2012).

Prior to WW II, Douglas-fir was considered unmerchantable timber, but after the war, nearly all Douglas-fir in the watershed was harvested in an effort to keep up with the post-war building boom BLM et al. 1996). New technologies and additional transportation options allowed harvesters to access remote areas with steep terrain, which resulted in an increase in logging operations throughout the basin, particularly in the densely forested Northern Subbasin. In the 1950s, there were at least seven mills in the Salmon Creek drainage alone; some

were "brush mills", small temporary mills set up close to stands of fir so that trees could be cut and skidded to the mills easily. The mills were dismantled and moved to new locations when the stands were depleted (JMWM 2000). In the Bull Creek drainage in the 1950s, there were four mills, one of which was the Bee Creek mill (*Figure 19*). This mill alone produced 50 million board feet of timber in 1956 (O'Hara and Stockton 2012), and was dismantled in the early 1960s.

Figure 19. Bee Creek Mill in Bull Creek drainage (photo courtesy of Humboldt Redwoods State Park).

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).

Improvements in timber harvest techniques and equipment led to increased harvest efficiency, and there was an increase in timber harvest activity in 1956, when the Humboldt County Supervisors levied a tax on standing timber. As a result, most landowners were forced to harvest timber rather than leave it standing for financial reasons (O'Hara and Stockton 2012). The peak timber production year was 1959 in Humboldt County, and although timber harvest levels have declined recently, the timber industry is still an important component of the economy (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 the natural armoring of stream banks which allowed high flows to scour banks, causing more bank failures and slides (JMWM 2000). In the Northern Subbasin, following the 1964 flood, clearcutting on upper slopes in the Bull Creek drainage was cited as the primary cause for increased sedimentation and subsequent severe damage to the river environment that extended downstream past the confluence of Bull Creek and the SF Eel River (CA State Parks 2012). These damage assessments prompted the State Park to purchase all of the private land in the Bull Creek drainage, and by the 1970s, the State Park owned more than 25,000 acres, including the damaged watershed.

Almost all merchantable timber had been removed from the Northern 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 "new settlers", also known as "back-to-the-landers". Significant changes to the watershed from these activities included the development of 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 beginning in the 1970s has provided an economic boost throughout the subbasin (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, 2013 in the Northern Subbasin of the SF Eel River are: open space/parks, commercial timber production, residential, and grazing/timber (*Table 11*).

Table 11 Four principal land uses in the Northern Subbasin.

Northern Subbasin Land Use	Square Miles	Acres	% of Total Subbasin Area
Open space/parks	77	49,280	52
Timber production	36	23,040	24
Residential	21	13,440	14
Grazing/timber	13	8,320	9

Open Space/Parks

Humboldt Redwoods State Park encompasses more than 53,000 acres, including greater than 17,000 acres of old growth coast redwoods. The park was created in 1921 and with the help of the Save the Redwoods League (SRL), has grown to become the third largest in the California State Park system (Humboldt Redwoods State Park 2012). Shortly after the park's creation, new land acquisitions slowed during the Great Depression, but park staff and SRL representatives continued to plan for park expansion. The end of World War II marked the beginning of a logging boom due to the demand for timber (both redwood and Douglas-fir) to support the postwar building boom. During this time, SRL and CA State Parks rushed to acquire tracts of land before the timber companies could purchase them, especially those in the Bull Creek drainage, in order to protect the Rockefeller Forest (known as the Bull Creek-Dyerville Forest until 1951).

The catastrophic floods of 1955 and 1964 temporarily halted logging operations in the Bull Creek drainage, and many landowners who had previously held out selling their land to the State Parks did so after the damage incurred from the 1964 flood (Humboldt Redwoods State Park 2012). Humboldt Redwoods State Park currently includes the entire Bull Creek watershed (*Figure 20*) and the Rockefeller Forest, the largest remaining old-growth redwood forest in the world. The park and SRL are currently working together on an active reforestation program, replanting thousands of trees in previously logged areas.

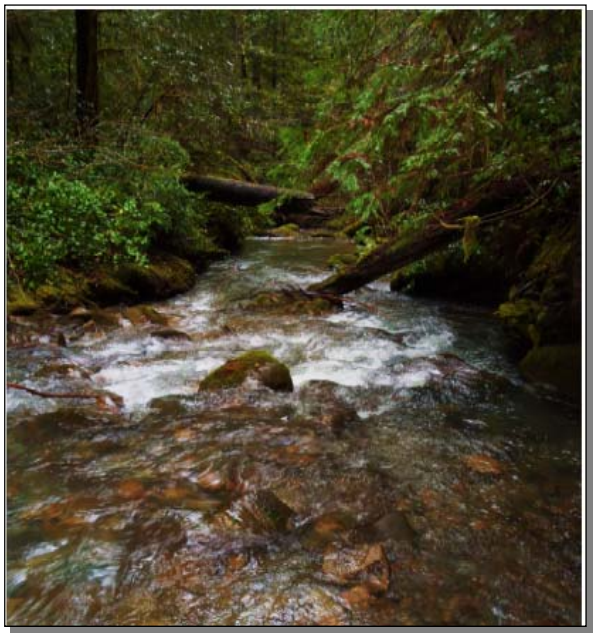


Figure 20. Squaw Creek, a tributary to Bull Creek, located in Humboldt Redwoods State Park.

Tourism, camping, fishing, and river-related recreational activities are increasingly popular throughout the SF Eel River Basin, particularly in the Northern Subbasin where most of the land is owned by the CA State Parks. These public areas are easily accessible to recreationists and tourists, and some landowners sell hunting and fishing rights to organizations or individuals, increasing recreational activities on private lands throughout the subbasin (Downie 1995).

Timber Production

Due to the large amount of land owned by State Parks, large timber companies own a relatively small portion (24%) of the land in the Northern Subbasin (*Table 11*) compared to other subbasins in the SF Eel River Basin. Timber harvest, while less of an issue because of the reduced potential harvest area, still occurs in the headwaters of all of the creeks in this subbasin except those owned by the State Parks (*Figure 21*). Water drafting, which is used by industrial timber companies as a dust abatement measure, will be discussed further in the Water Use: Diversions, Dams, and Hydrologic Disturbances section of this report.

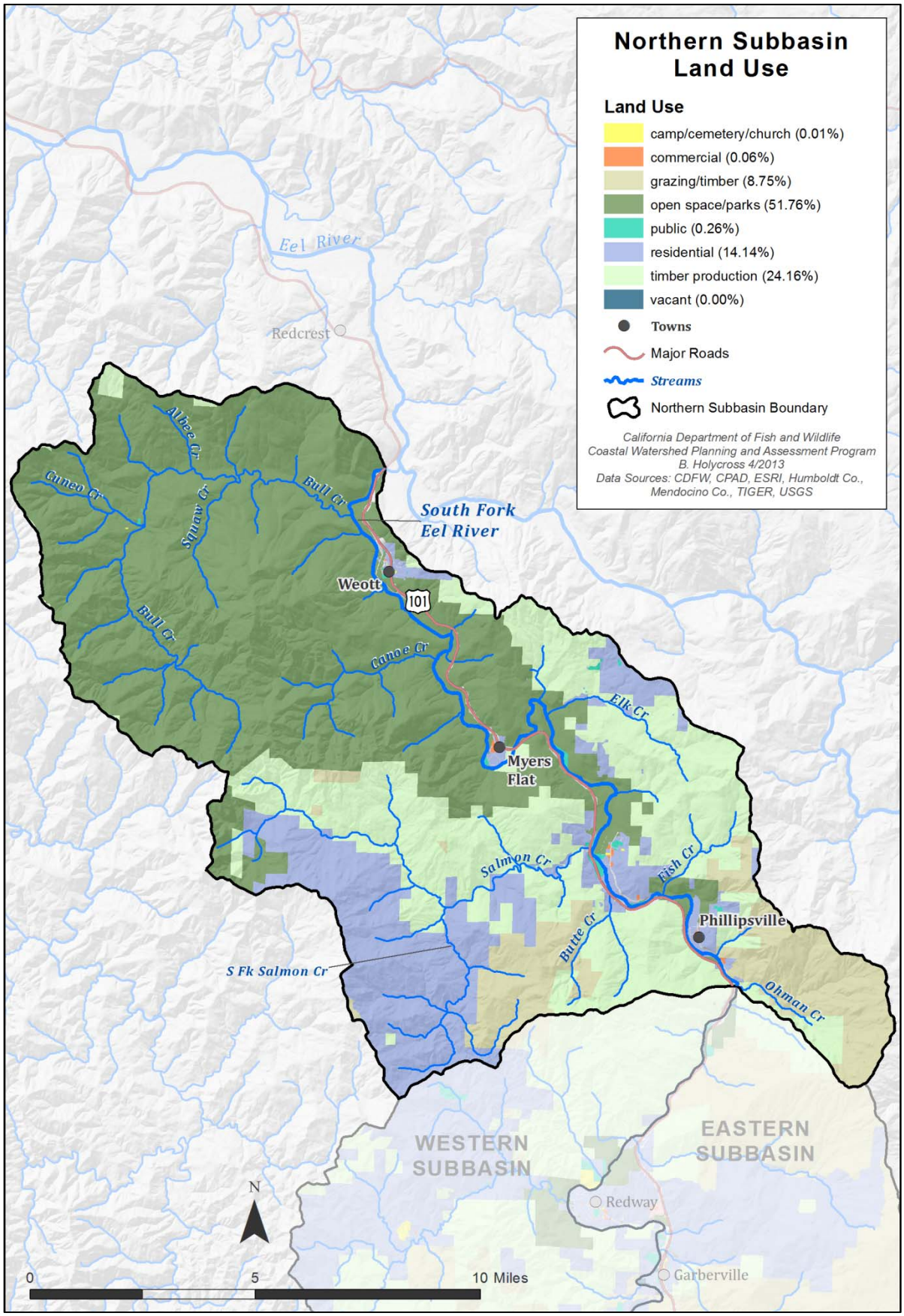


Figure 21. Land use in the Northern Subbasin of the SF Eel River Basin

The most recent timber harvest activity has occurred in the southern and eastern portions of the Northern Subbasin. Since 1995, there have been numerous harvests in the Salmon, Fish, Elk, and Butte creek drainages. All timber harvest activities require the development of plans detailing the amount and method of proposed harvest, and 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) allow non-commercial landowners with less than 2,500 acres of timberland to develop harvest plans that are 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 harvests were commercial (THPs), as opposed to non-commercial (NTOs), and occurred primarily in the southeastern part of the Northern Subbasin (*Figure 22*). The total area of timber harvested in the subasin between 1995 and 2012 was 11,074 acres (*Table 12*). THP harvest area totaled 7,208 acres and individual operations ranged in size from 982 acres to less than one acre. NTO harvest area in the basin totaled 3,866 acres and ranged in size from 1,240 acres to less than one acre. Only one of the NTO harvest amounts (n=52) was greater than 400 acres.

Table 12. Timber harvest by plan type (THP or NTO) for South Fork Eel Northern Subbasin (data from CalFire 2012).

Northern Subbasin	Plan Type	Acres	County
	THP	7208	Humboldt
	NTO	3866	Humboldt
	Subbasin Total	**11074**	

The main silviculture methods used in the subbasin from 1991-2011 were selection (32% of harvested area; 2768 acres), transition (16% of harvested area; 1360 acres), and clearcut (12% of harvested area; 1062 acres) (*Figure 23*). Selection is defined as a method used to regenerate a forest stand, maintaining an uneven-aged structure, by removing trees in all size classes singly, in small groups, or in steps (Adams et al 1994). The transition method is defined as the removal of trees, either individually or in groups, from irregular or even-aged stands to create a balanced uneven-aged stand structure. 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). Slash and ground vegetation left behind following a clearcut is frequently burned to prepare the site for artificial regeneration.

Of the three primary silvicultural methods used in the Northern Subbasin, clearcutting is the most damaging to the environment, resulting in the highest level of disturbance to both terrestrial systems (through soil exposure and instability due to tree removal) and aquatic ecosystems (through removal of shade and reduced large woody debris contribution) (USFS 1985, EPA 2005). All three methods result in increased fine sediment input compared to non-logged areas due to road construction and hauling practices.

There are varying levels of soil disturbance related to yarding techniques. Megahan (1980, in EPA 2005) summarized the results of soil disturbance from logging using different yarding methods in the Pacific Northwest:

- Tractor and skidder yarding had the highest disturbance level, and this method is generally limited to gentle slopes to reduce the potential damage of machine tracks on the soil. A tractor or skidder's weight plus the weight of logs will cause soil compaction, resulting in increased runoff; equipment treads will cause soil disturbance, introducing sediment into the runoff.
- Cable yarding, where logs are pulled uphill by a cable to a road or landing, resulted in the second highest level of soil disturbance. This technique is commonly used in areas where slopes are too steep for tractors or skidders.
- Skyline cable logging had the third highest percent soil disturbance.
- Aerial harvest methods such as helicopter and balloon yarding have the lowest impact on forest soils.

Yarding techniques vary by harvest, and each THP or NTMP includes a section on harvesting practices and the erosion hazard rating (from low to extreme) associated with the planned harvest. For the largest

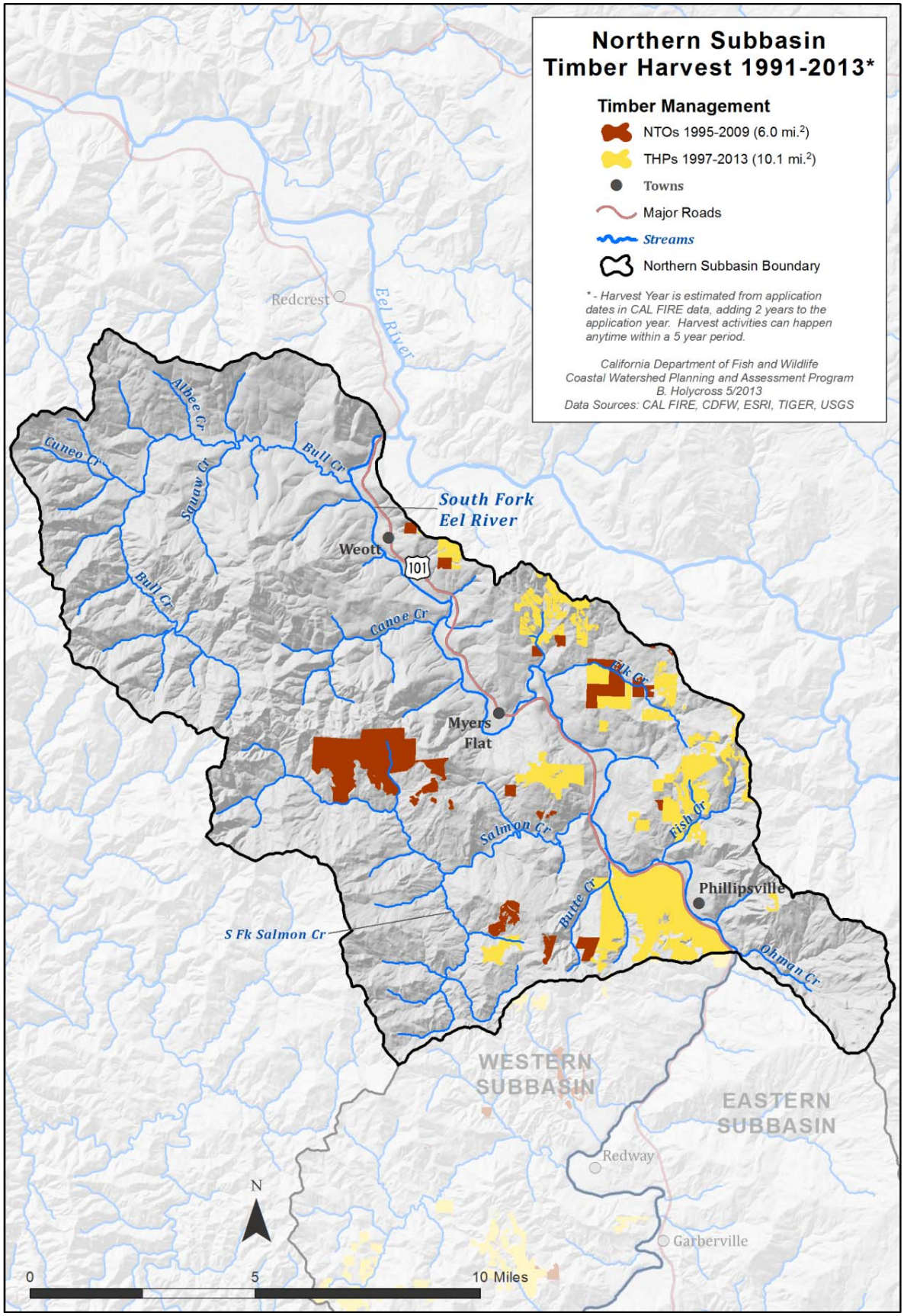


Figure 22. Timber Harvest (NTOs and THPs) between 1995 and 2012 in the SF Eel River Western Subbasin.

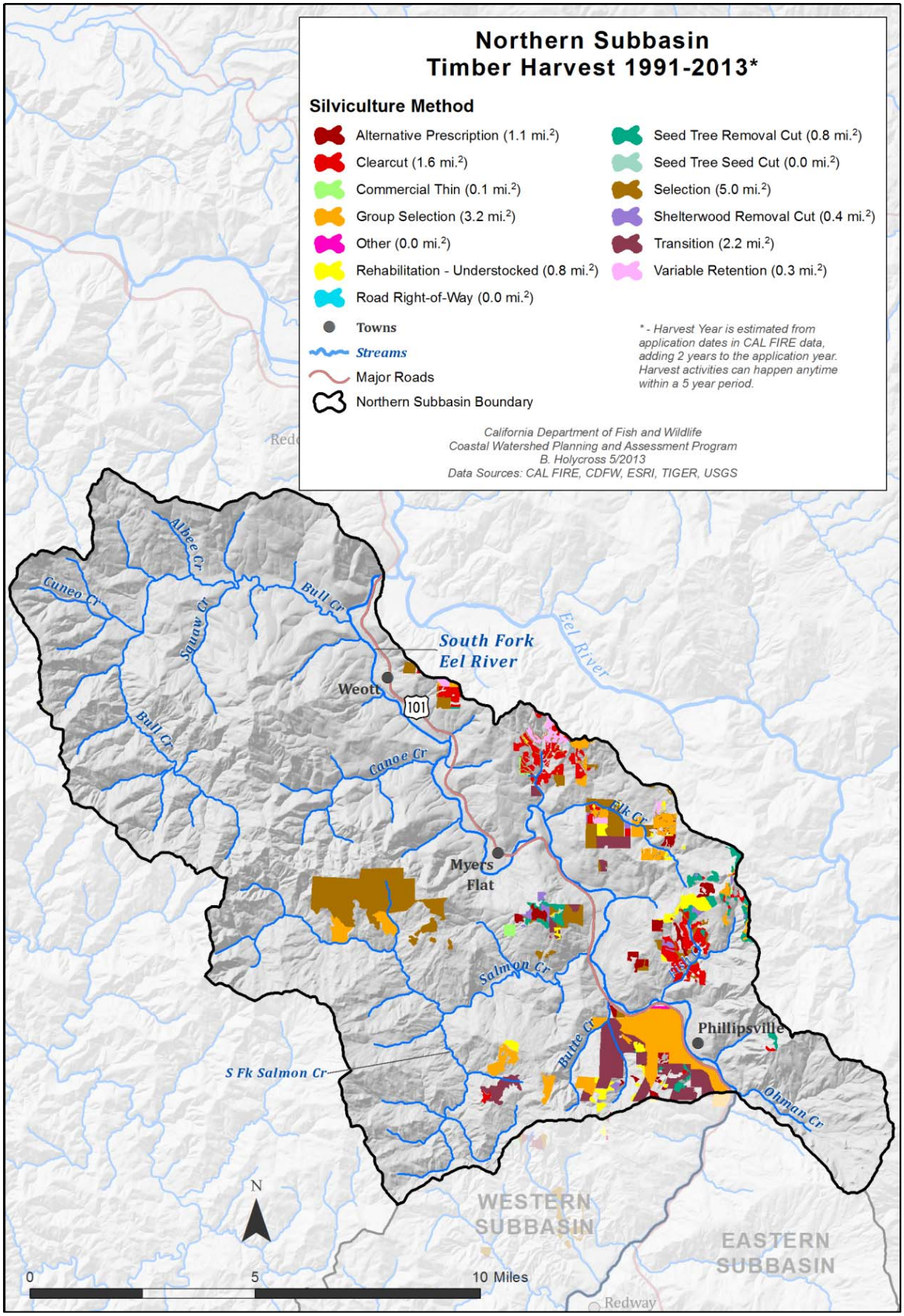


Figure 23. Timber harvest activity by silvicultural method in the SF Eel River Northern Subbasin.

THP (approximately 1,500 acres) in the Northern Subbasin (THP No. 1-09-050HUM; available at: ftp://thp.fire.ca.gov/THPLibrary/North_Coast_Region/), tractor cable/skyline harvesting was used, and the associated erosion hazard rating was low. A combination of techniques is often used, for example, NTMP No. 1-05NTMP-020HUM (361 acres) lists three techniques: ground skidder and tractor (ground based) and tractor cable/skyline. Collectively, these techniques had a moderate erosion hazard rating.

Residential

Approximately 22% of the population of the entire SF Eel River Basin lives in the Northern Subbasin. The population estimate is 1,936 people total (US Census 2010), with a density of 13.17 people/square mile. This population estimate was obtained by adding the population in all the census blocks that were completely within the Northern Subbasin boundary, then identifying blocks partially within these 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.

The total population and the population density in the Northern Subbasin are lower than in the Eastern Subbasin (population 5,846; density 18.27 people/square mile), and higher than in the Western Subbasin (population 1,175; density 5.37 people/square mile). The population density is relatively low because the majority of land in the Northern Subbasin is owned by the State Park. Miranda is the largest town in the Northern Subbasin, with a 2010 US Census population estimate of 520. Other small towns include Weott (population 288) and Myers Flat (population 146); most towns are located along the SF Eel River. Small towns and dispersed rural residential areas comprise 14% of the Northern Subbasin area (*Table 11*), and are located outside State Park boundaries throughout the southern and western areas of the subbasin (*Figure 21*). Of the 23% of the subbasin area that is privately owned, 17% (15,965 acres) are parcels >40 acres, and 6% (5,983 acres) are ≤40 acres in size.

Improved access and relatively easy water development in the recent past has led to increased settlement of many remote areas in the Northern Subbasin. With this increase in the number of developed parcels, there has been a corresponding increase in the number of roads to access parcels, with additional traffic due to multiple vehicles per family and frequent trips to and from residences, all of which contribute to a larger impact on natural resources throughout the subbasin (JMWM 2000). Residential development and associated activities also increase the possibility of pollution from wastewater, industrial chemicals, fossil fuel spills, fertilizers, and poisons used to control rodents and other pests, and it increases the potential for illegal water diversion for households and unregulated agricultural practices. This is a particular concern in the Northern Subbasin due to an increase in legal and illegal marijuana cultivation since the 1970s (Evers 2010). This will be discussed further in the Industrial Marijuana Agriculture section of this report.

Residential development requires the development of water and wastewater systems. The Humboldt County General Plan Draft EIR (2012) lists two groundwater basins in the SF Eel River planning watershed. In the Northern Subbasin, the Avenue of the Giants Community Planning Area (including Stafford, Redcrest, Weott, Myers Flat, Miranda, and Phillipsville) is associated with the Eel River groundwater basin, with the prime source being at the Eel-Van Duzen delta. Approximately 10,000 acre-feet of the estimated annual yield of 40,000 to 60,000 acre-feet are currently being pumped for agriculture throughout the planning area. Groundwater in rural Humboldt County is generally directed to individual domestic needs and irrigation for farmed areas.

Small Community Service Districts provide water (and some wastewater) services to communities in the Northern Subbasin (*Table 13*). The Humboldt Lafco (2009) and Humboldt County General Plan Update EIR (2012) reviewed existing system services and proposed modifications:

- **Miranda Community Services District** provides water and wastewater services.
  - The water system currently has 143 connections, with a capacity of 220. Water is pumped from two wells (110 and 115 gallons per minute (gpm)) which access SF Eel River subsurface flows and feed a 200,000 gallon storage tank. Average daily use is 55-60,000 gpd and maximum daily use is 200,000 gpd in August and September. The CSD currently operates at 85% capacity and has no

plans to upgrade the water system or modify their sphere of influence boundaries.

- The wastewater treatment system transfers effluent from 143 residences to community septic tanks, where it is chlorinated and stored in a settling pond near the SF Eel River. Treated effluent leaches into gravel layers underlying the river and discharge monitoring reports are submitted to the CRWQCB to insure that water quality of effluent meets acceptable standards. There are no plans to modify the system at this time.

- **Myers Flat Municipal Water Association** provides water to 103 connections; all wastewater is treated in individual septic systems in the service area.
- **Phillipsville Community Services District** provides water service only; all residences in the service area are currently served by individual septic systems. The water system currently serves 65 connections, and the system was recently upgraded to address inadequate storage capacity, limited source capacity, inadequate distribution system materials, and lack of treatment. Construction was completed in 2011 and the system can now serve all existing connections and planned development connections.
- **Weott Community Services District** provides water and wastewater services.
  - The water system currently supplies 140 connections, with no additional connections available. There are two surface water sources, both with separate treatment and distribution systems. Peak daily demands are currently 128% of source capacity, and 210% of existing treatment capacity, and demands are higher during summer months. The district plans to install meters and has completed some system upgrades (including addressing major leaks), but no new treatment equipment has been installed.
  - The wastewater system has 134 connections and is operating at 47% capacity. The system is functioning well and no improvements are planned; planned development connections will be served by the existing facilities.

Since the 1970s, groundwater has been used by residences, and is used increasingly for large- and small-scale marijuana cultivation operations throughout the basin. The water supply has not been adequate to keep up with the demand. As a result, residences and growers supplement the groundwater/well water with direct surface diversion, often pumping water into storage tanks for later use, which is particularly problematic for juvenile salmonids during hot, dry summer months (June through October) when flow is at a minimum (Weiser 2012). Diversions will be discussed further in the Water Use section of this report.

Table 13. Water and wastewater service providers in the SF Eel River Northern Subbasin (from Humboldt County General Plan Update Draft EIR 2012).

Water Provider	Connections		Capacity			Usage	
	Existing	Available	Supply (mgd)	Treatment (mgd)	Storage (mg)	Peak Day (mgd)	Connection (gpd)
Miranda Community Services District	143	77	0.338	Not required	0.200	0.220	1,538
Myers Flat Municipal Water Association	103	0	Unknown, but limiting	0	0.300	0.138	1,340
Phillipsville Community Services District	65	0	Unknown, but not limiting	0	0.075	0.085	1,308
Weott Community Services District	140	0	0.202	0.113	0.169	0.258	1,843
Wastewater Service Provider	**Subbasin Served**	**Connections**		**Permitted Capacity (mgd)**		**Flows (mgd)**	
		Existing	**Available**	**Dry Weather**	**Wet Weather**	**Existing Dry Weather**	**Peak Wet Weather**
Miranda Community Services District	Northern	110	59	0.046	N/A	0.030	0.10
Weott Community Services District	Northern	134	151	0.030	N/A	0.014	0.03

Grazing/Timber

Approximately 9% of the land in the Northern Subbasin is utilized for livestock grazing and small timber operations. These differ from commercial timber production operations because they are small, usually family-owned ranches that manage their lands using a variety of techniques and grazing schedules. Streams in the Northern Subbasin are affected by these land use practices because all parcels with active management (e.g. logging) require access roads, which are often built using improper construction techniques and in poorly chosen locations. These roads have become a significant source for water quality degradation in rural watersheds (Kocher et al. 2007). In areas where livestock are allowed unrestricted access to creeks, levels of these constituents may exceed water quality standards in areas with extensive livestock use (Knox et al. 2007). This poses a threat to chemical water quality, increases the amount of sediment introduced into the watershed through bank erosion, and may result in the reduction or elimination of riparian vegetation (Hubbard et al 2004).

Grazing was the primary land use in the Upper Bull Creek drainage until the early 1940s, with ranchers harvesting timber to increase pastureland acreage for grazing, and periodically burning grasslands to maintain open areas for grazing cattle and sheep (Stillwater Sciences 1999, JWMW 2000). During this time, most native bunch grasses were replaced by European grasses and invasive weeds (JMWM 2000). Beginning in 1946, ranchers were required to harvest timber on their land in order to avoid taxation, and grazing, burning, and timber harvest practices all resulted in increased sediment delivery to streams. Following the 1955 and 1964 floods, all of the privately owned ranch land in the Upper Bull Creek drainage was sold to the State Parks, and all grazing activity ceased. Current grazing/timber harvest occurs primarily in the southern part of the Northern Subbasin, east of Phillipsville and west in the Butte Creek and South Fork Salmon Creek drainages (*Figure 21*).

Roads

As the Northern Subbasin was settled in the late 1800s, transportation routes grew and expanded. Wagon trails became roads and roads were upgraded into highways to facilitate transportation of people and resources. In forested upland areas, many logging roads were built to facilitate access to and transport of timber. Most of these logging roads are not paved and many are not mapped.

Cal Fire (CDF) 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. There are approximately 500 miles of roads in the Northern Subbasin (road density = 3.33 miles/square mile). Fifty seven percent (285 miles) are existing seasonal roads used for timber harvest and both public and private property access (*Figure 24*). Most of these seasonal roads are located in the Salmon, Elk, Bridge, and Fish Creek drainages for access to timber harvest sites and for residential access to privately owned parcels in the middle and southern areas of the subbasin.

Historically, there was a significant amount of sediment deposited in Northern Subbasin streams due to past land use practices, especially roads associated with timber harvest and residential development (Stillwater Sciences 1999). Although these activities were reduced in the northern part of the subbasin when the State Park purchased much of the land in the Bull Creek drainage, legacy effects of these practices are still concerns throughout most of the subbasin. Twenty four percent of the land in this subbasin is currently used for timber production, with a higher percentage of use historically. Both new and abandoned seasonal roads contribute to the destabilization of hillslopes and increased sediment delivery to streams. Seasonal roads are designed for long-term periodic (dry weather) use, built to lower engineering standards than permanent roads, and have minimal material surfacing (Kocher et al. 2007). As a result, seasonal roads provide more fine sediment input to streams than any other type of road. McCashion and Rice (1983) determined that logging road erosion increases with the slope traversed by the road and with the amount of traffic, and they found that nearly 25% of erosion measured on logging roads in northwestern California could have been prevented with conventional engineering methods. Restoration projects have focused on rehabilitation of seasonal roads throughout the Northern Subbasin.

In the Salmon Creek watershed, timber harvest and residential development, often with more than one

residence per parcel and extensive marijuana cultivation operations, have resulted in additional road construction and traffic. Road density in this watershed is greater than 7 miles/square mile, which is more than twice the average density for the subbasin. In 2000, JMWM completed a watershed assessment, with the primary goal of inventorying road, hillslope, and streambank sediment delivered to the creek and its tributaries. They found that the potential sediment delivery from roads in this watershed was lower than that found in comparable watersheds, most likely because many of the high-priority sediment producing sites had been identified and treated (JMWM 2000, HCRCD 2002).

Stillwater Sciences (1999) reported that the highest sediment loading in the SF Eel River Basin occurred in the Bull Creek drainage. This was due in part to high precipitation and uplift rates, but also due to increased sediment from natural process such as earthflow toes and associated gullies, shallow landslides, and soil creep; and from road-related sources including road crossing and gully erosion, road prism sheetwash, and skid trail erosion (Stillwater Sciences 1999). The highest rate of sediment production was due to landslides, and road related sediment input was generally lower in this basin due to park restoration efforts.

Permanent roads make up 23% (117 miles) of the roads in the Northern Subbasin, and the majority of these permanent roads are found in Humboldt Redwoods State Park in the northern part of the subbasin (*Figure 24*). This drainage has few seasonal roads compared to watersheds in the southern and eastern parts of the subbasin, due to reduced commercial timber harvest and residential development.

When developing restoration initiatives the NMFS (1996) classified basins considering the following road densities categories: <2 miles/square mile with no valley bottom roads as "properly functioning"; those with densities of 2-3 miles/square mile with some valley bottom roads as "at risk"; and those with densities of >3 miles/square mile with many valley bottom roads as "not properly functioning". According to this classification system, the Northern Subbasin, with an overall road density of 3.33 miles/square mile, is "not properly functioning", and road rehabilitation projects should be a high priority for watershed managers.

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). Road rehabilitation projects that reduce fine sediment input are a priority throughout the subbasin, particularly in Humboldt Redwoods State Park, where the focus of many restoration projects has been on cleaning up and minimizing the effects of legacy logging roads. For a partial list of projects, go to: ftp://ftpdpla.water.ca.gov/users/prop50/09595_Humboldt/TechnicalDoc_Vol4of8/38_Head_Hunter_Smoke_House_Sediment_Tech_docs/Multi-Year%20Project%20Cost%20Summary.pdf. A more detailed review and discussion of ongoing road rehabilitation projects throughout the Northern Subbasin can be found in the Restoration Projects section of this assessment report.

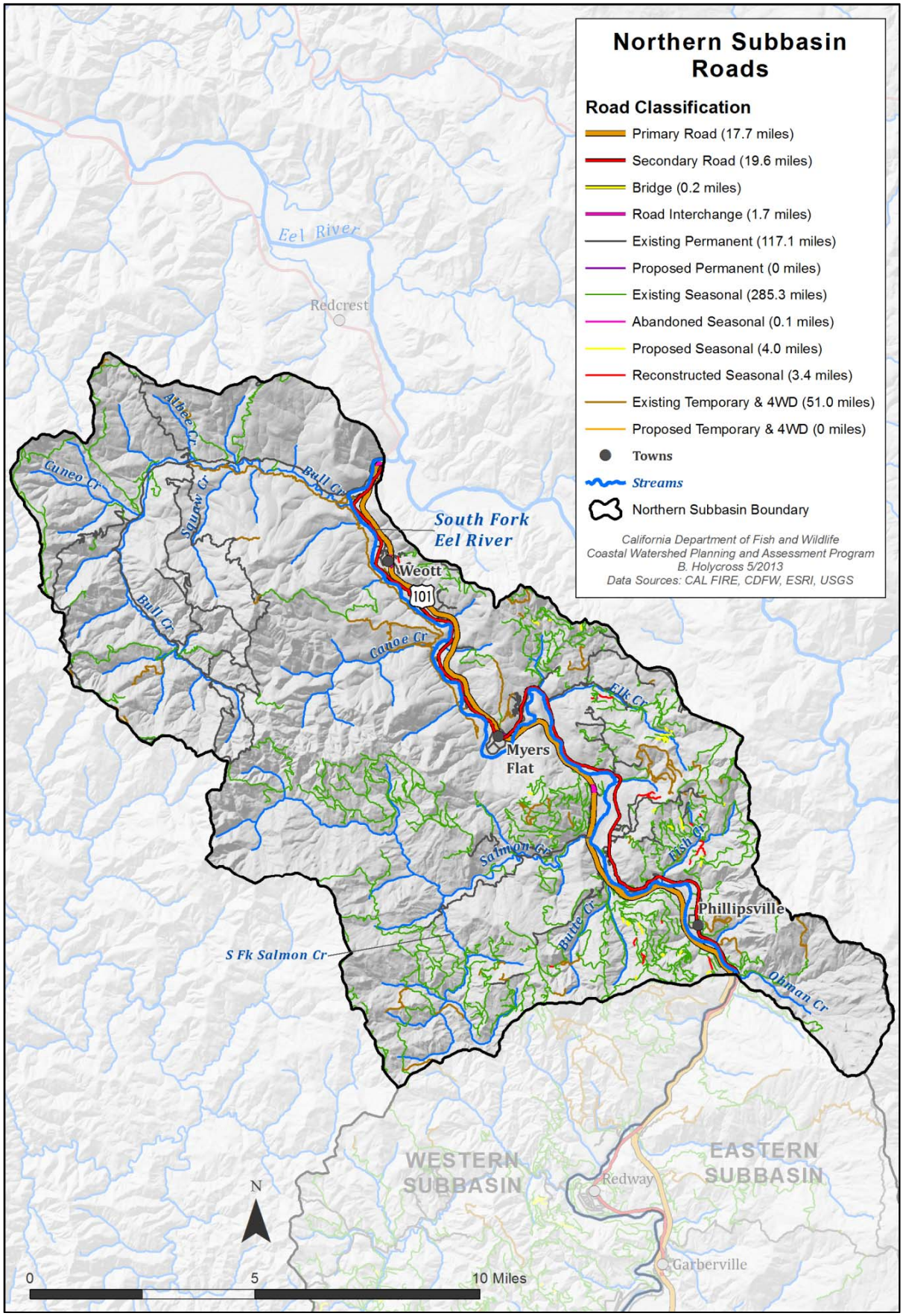


Figure 24. Roads in the SF Eel River Northern Subbasin.

Gravel Mining

Gravel mining activities occur in most north coast rivers, and the primary purpose of these activities is to efficiently supply local markets with construction aggregate while minimizing damaging effects on riverine habitats (CHERT 2011). Aggradation is defined as the increase in land elevation due to deposition of sediment in a streambed. The Eel River Basin has one of the highest natural sediment yields in the world for any river of its size, and channel aggradation from past floods and poor land practices would seem to be more of a concern than downcutting due to over extraction of gravel. Historically, gravel mining activities throughout the Eel River Basin created migration barriers for adult fish, sometimes leading to stranding in shallows and eventual mortality. Problems of over extraction and threats to the fisheries led to a system of monitoring and adaptive management.

Gravel mining occurs in two relatively isolated locations in the SF Eel River Basin between Cooks Valley and Redway (Stillwater Sciences 2008). None of these mining operations are located in the Northern Subbasin. For a complete discussion of gravel mining and its effects on fish and habitat, see the SF Eel River Basin overview, and the Western and Eastern Subbasin sections of this assessment report.

Water Use: Diversions, Dams, and Hydrologic Disturbances

Diversions

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 different 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 approval. 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 SF Eel River Basin remains unknown. For additional information on water rights and diversion, go to: http://www.calsalmon.org/srf-projects/water-rights-education.

In the Northern Subbasin, there are ten appropriative water rights permits for direct diversion currently on file with the State Water Resources Control Board, with total a total maximum diversion amount of approximately 1,204 acre feet per year (*Table 14*). Only one of these includes diversion storage for domestic use and fire protection, with a total storage amount of 2,420 gpd.

Table 14 does not include diversions that are not registered with the State Division of Water Rights, including illegal diversions for residential and/or industrial marijuana growing operations. Water diversion during dry weather, low-flow times (June through October) and pollution are some of the most devastating results of the rapidly expanding marijuana industry, and are associated with large, irresponsible cultivation operations, often located on public land (Evers 2010). This will be discussed further in the Industrial Marijuana Agriculture section of this assessment.

Dams

There are no dams located in the SF Eel River Northern Subbasin.

Table 14. Water rights in the Northern Subbasin of the SF Eel River Basin (WRIMS 2012).

Creek	Application Number	Direct Diversion	Maximum Application Direct Diversion	Diversion Storage	Purpose
UNSP, SF Eel River	A009788	970 gpd	1.1 afy		Recreation
UNSP, Mill Creek	A014029	0.09 cfs	38.4 afy		Irrigation
UNST, Mill Creek	A014076	0.03 cfs	12.8 afy		Irrigation
Pete Creek	A014080	0.4 cfs	289.6 afy		Municipal
UNSP, Bridge Creek	A017465		2.7 afy	2420 gpd	Domestic and fire protection
Feese Creek	A019312	9000 gpd	4.8 afy		Domestic
SF Eel River Underflow	A019923	0.89 cfs	644.3 afy		Temporary municipal (use by 12/1998)
SF Eel River	A022018	0.046 cfs	21.7 afy		Domestic and irrigation
UNST, South Fork Salmon River	A025456	4,800 gpd	2.8 afy		Irrigation and domestic
UNST, Mill Creek	A025677	0.39 cfs	186 afy		Municipal (use by 12/2005)
TOTAL (n=10)			**1204.2 afy**		

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 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 throughout the SF Eel River Basin. During the late 1960s and early '70s, 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 (www.arcataeye.com). In the Salmon Creek and Redwood Creek watersheds, two coho salmon strongholds in the SF Eel River Basin, CDFW Biologist 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 (located in the Northern Subbasin) and 549 grows (226 outdoor and 323 indoor) in the Redwood Creek watershed (*Figure 25, Figure 26*). 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 Redwood Creek is not located within the boundaries of the Northern Subbasin, information on grows 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 Salmon Creek in August and September, 2013. These conditions resulted from limited rainfall in the winter of 2012-2013 and an increase in the number of diversions due to extensive marijuana cultivation operations (*Figure 25*). Flows decreased dramatically during the study, due primarily to active diversions supplying water to grow operations throughout the watershed.

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).

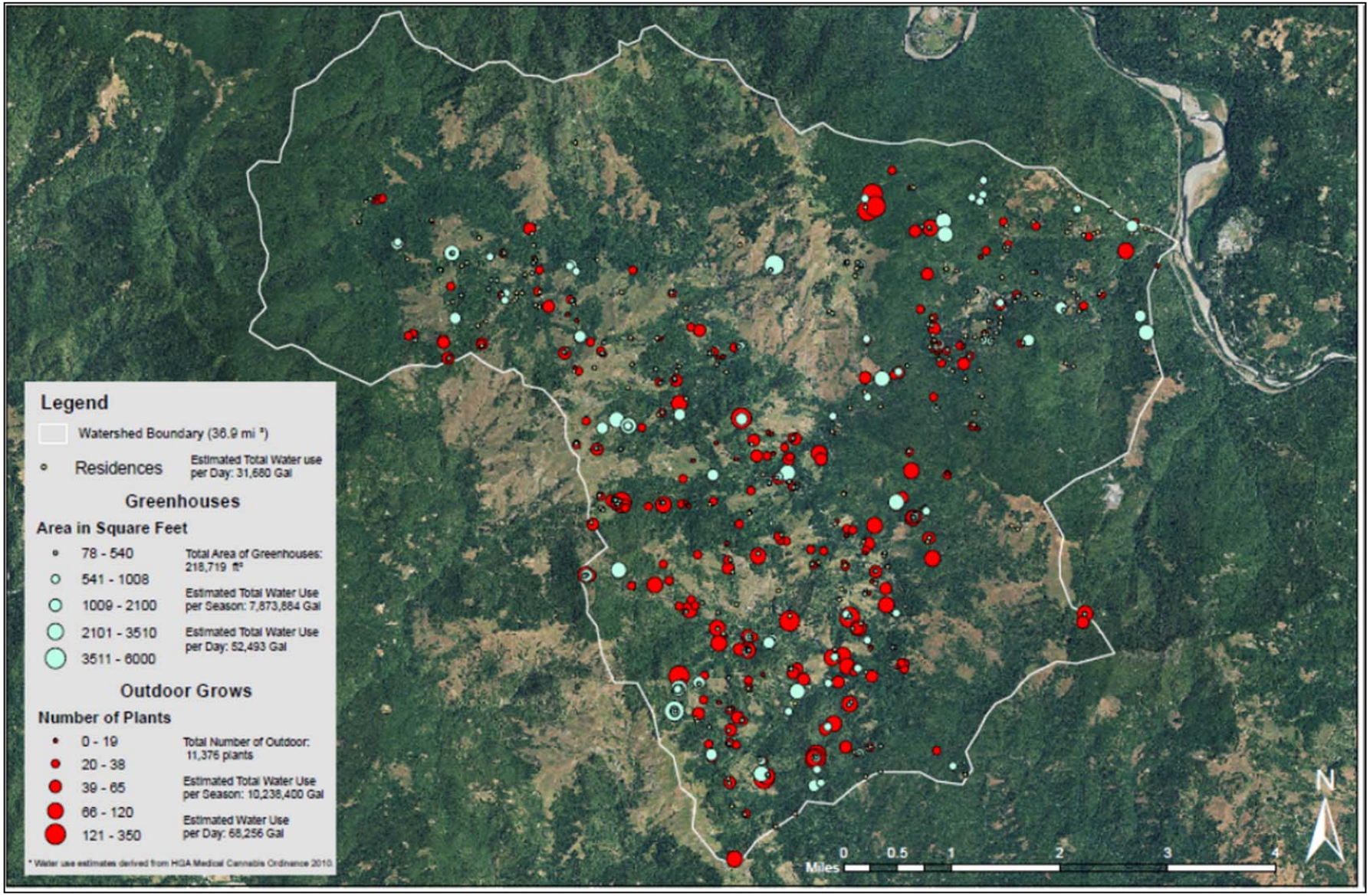


Figure 25. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Salmon Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW 2013).

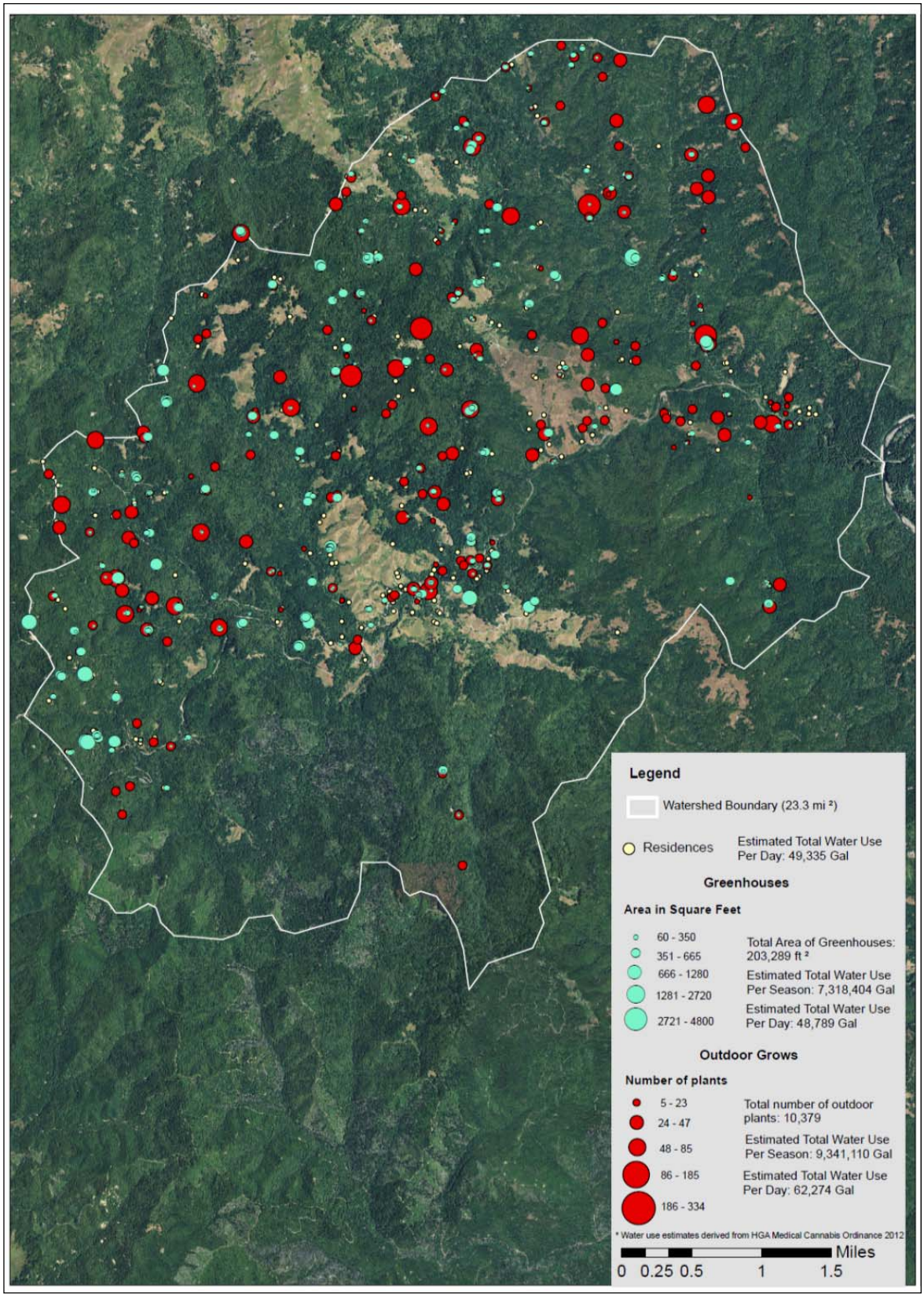


Figure 26. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Redwood Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW 2013).

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 27, Figure 28, and Figure 29* illustrate this potential trend using flow data from the USGS SF Eel River gauging stations near Miranda (RM 17), Leggett (RM 66), and Bull Creek (4 miles upstream from the confluence of the mainstem SF Eel River). Daily mean discharge (in cfs) for the 2011 2012, and 2013 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 dry years, with less than normal rainfall received. *Figure 27* 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 28 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 29* 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 increasing water temperatures, reducing flow at critical times for fish rearing and migration, and altering water chemistry in the entire basin.

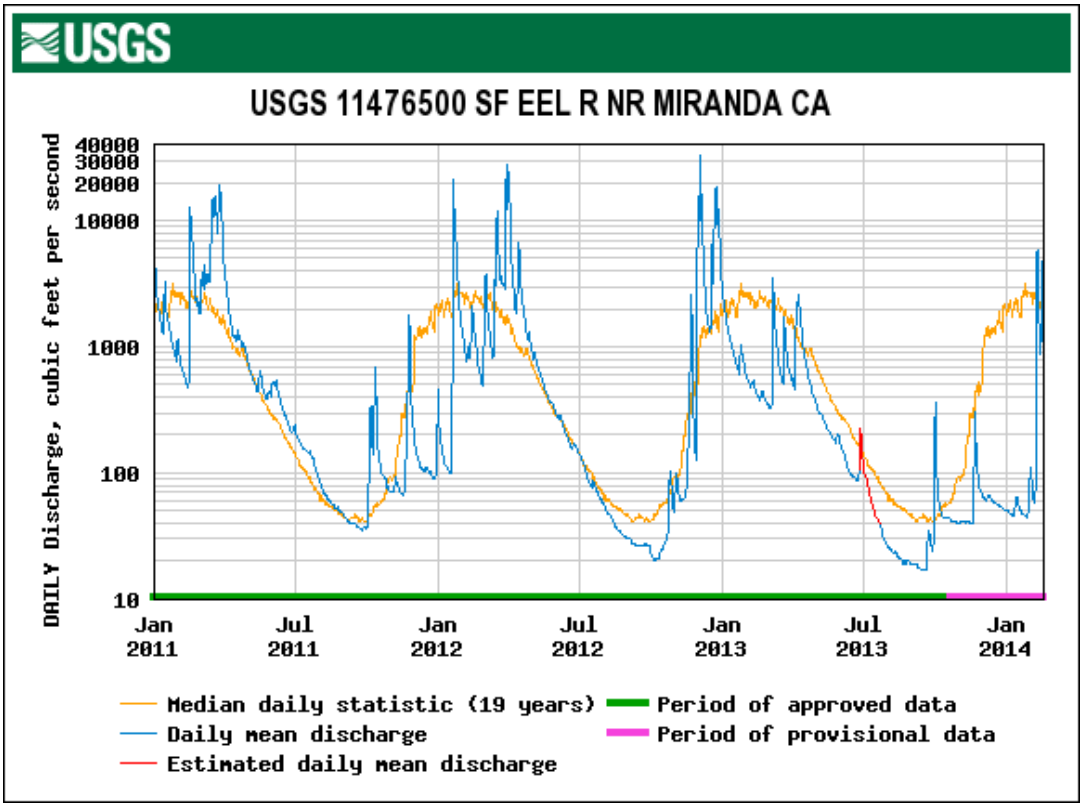


Figure 27. USGS gauging station near Miranda showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (73-year average in cfs).

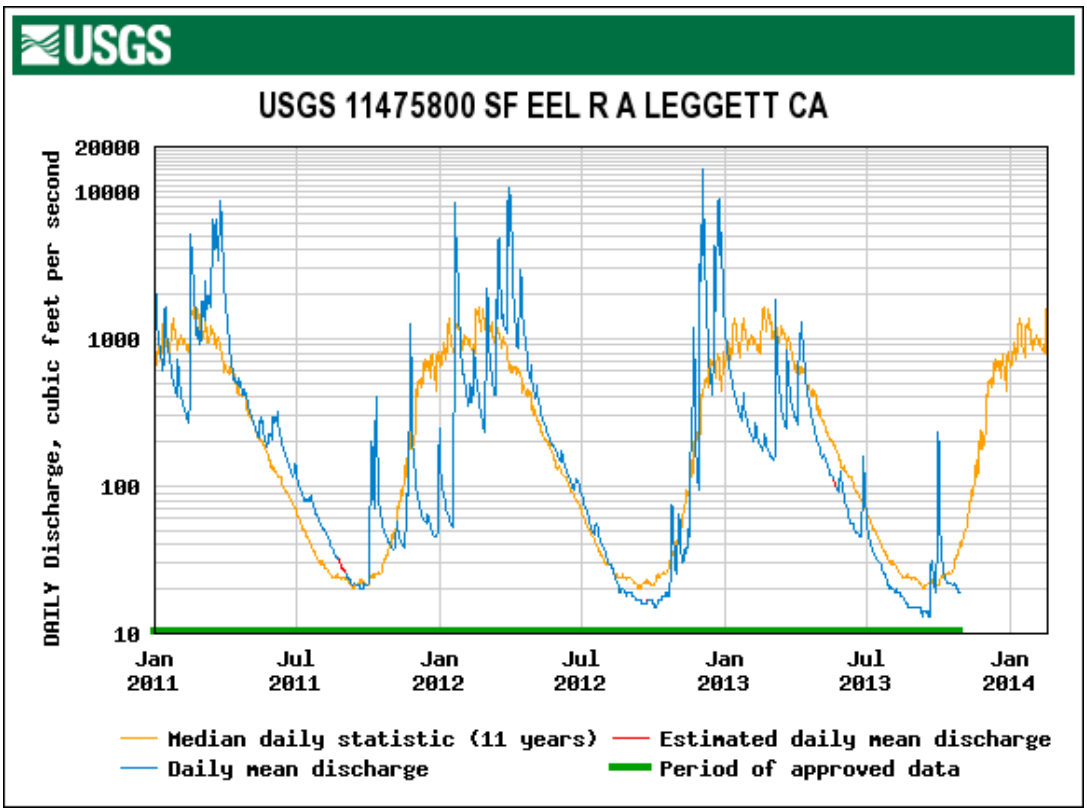


Figure 28. USGS gauging station near Legett showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (40-year average in cfs).

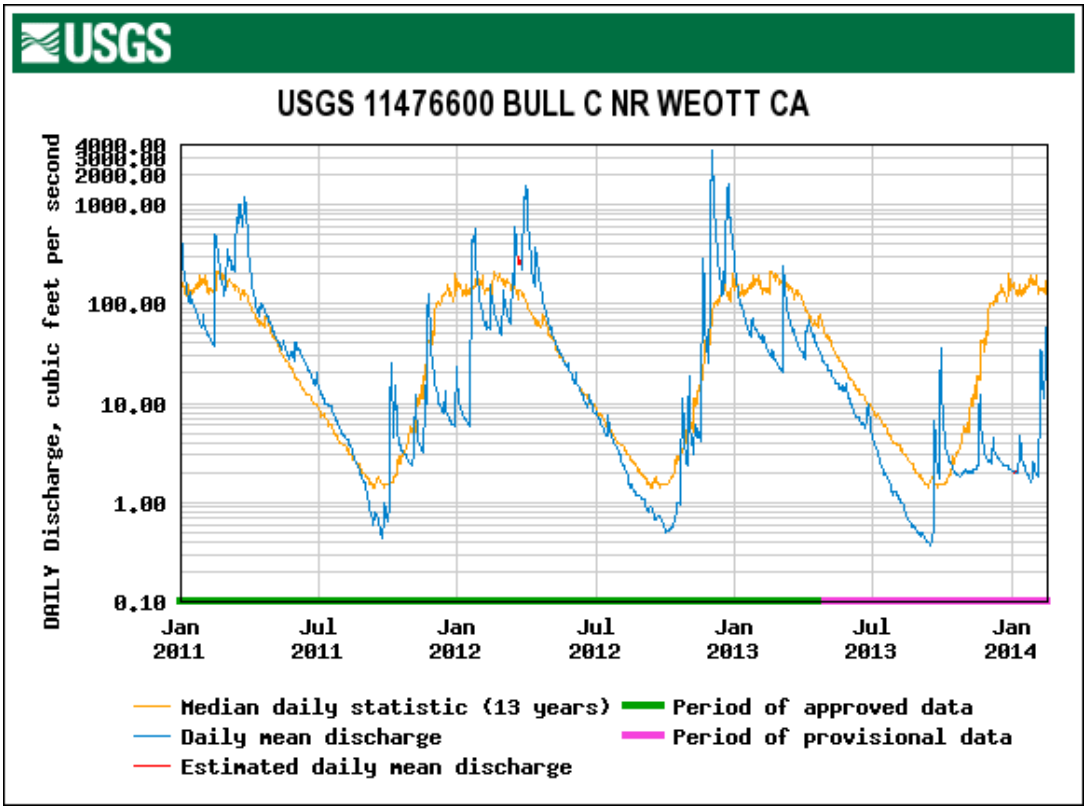


Figure 29. USGS gauging station at Bull Creek showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (52-year average in cfs).

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. Therefore, a wide range of effects to watercourses and their aquatic resources are 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 15*), 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 habitats 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.

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 been shown to:

- 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 15. 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 Northern Subbasin streams by anecdotal accounts and observations made during surveys since 1938. Stream survey efforts were neither specific nor standardized until 1991 when the first edition of the *California Salmonid Stream Habitat Restoration Manual (*Flosi et al. 2010) was published. As a result, many early stream survey observations are not quantitative and have limited use.

Historical salmonid presence documentation is available for 33 Northern Subbasin streams. Information sources include CDFW carcass surveys, stream survey and inventory reports, electrofishing and general field notes, downstream migrant trapping data, and spawning stock and escapement reports (*Table 16*). Coho salmon were found in 12 Northern Subbasin streams. Large tributaries to the mainstem SF Eel River with documented historical coho salmon presence included Bull Creek and Salmon Creek. Chinook salmon were documented in 12 Northern Subbasin streams, and steelhead were found in 20 of the 33 tributaries. Eleven creeks had no record of Chinook, coho salmon, or steelhead presence, but unidentified salmonids were observed in ten of these streams (*Table 16*).

Table 16. Documented fish presence in surveys from 1938 to 2001 in the Northern Subbasin.

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Anderson Creek	3/22/1977	Stream Survey (CDFG 1977)				
	12/22/1988, 1/19/1989	Carcass Survey Summary (CDFG 1989)	X	X		X
Butte Creek (Bear Butte Creek)	6/19/1960	Stream Survey (CDFG 1960)			X	
	5/9/1962	Stream Survey (CDFG 1962)				X
	4/12, 4/23/1968	Electrofishing Field Note (CDFG 1968)		X	X	
	4/30/1969	Field Note (CDFG 1969)		X	X	
	3/15/1974	Memorandum (CDFG 1974)			X	
	7/6/1977	Stream Survey (BLM 1977)			X	
	4/3/1980	Stream Survey (CDFG 1980)				X
Butte Creek and Coon Creek	9/19, 9/25/1984	Stream Survey (CDFG 1984)				X
Bridge Creek	8/3/1938	Stream Survey (CDFG 1938)			X	
	7/6/1961	Stream Survey (CDFG 1961)				X
	7/27/1967	Fish Passage Survey (CDFG 1967)				X

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Bridge Creek (con.)	6/20/1977	Field Note (CDFG 1977)				
	6/29/1993	Stream Inventory Report (CDFG 1993)			X	
	10/6/1993	Stream Inventory Report (CDFG 1993)			X	
Bull Creek	8/3/1938	Stream Survey (CDFG 1938)		X	X	
	Circa 1938	Stream Survey (CDFG no date)			X	X
	11/25/1964	Field Note (CDFG 1964)	X			X
	7/16/1968	Field Note (CDFG 1968)				X
	9/7/1973	Field Note (CDFG 1973)			X	
	8/26/1974	Field Note (CDFG 1974)			X	
	9/16/1982	Population Estimate (CDFG 1982)			X	
	11/27/1982	Spawning Stock Survey (CDFG 1982)				
	1/13/1984	Spawner Survey Summary (CDFG 1984)				
	12/23, 1/22/1988	CWT Recovery Field Note (CDFG 1988)	X	X		
	1/9/1990	Carcass Survey Field Note (CDFG 1990)		X	X	X
	3/22 - 6/1/1988	Downstream Migrant Trapping (PCFFA 1998)	X	X	X	
	7/24, 7/25/1991	Stream Inventory Report (CDFG 1991)			X	
Bull Creek from headwaters forks to Panther Creek	2/20/1987	Field Note (CDFG 1987)			X	
Bull Creek from Cuneo Creek downstream	1988	Downstream Migrant Trapping (CDFG 1998)	X	X	X	
Bull Creek from Mill Creek downstream	12/6/1988	CWT Recovery Field Note (CDFG 1988)	X			
Burns Creek	10/27, 11/3/1998	Stream Inventory Report (CDFG 1998)				X
Cabin Creek	7/4/1962	Field Note (CDFG 1962)				X
	4/8/1980	Stream Survey (CDFG 1980)				X

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Calf Creek	1988	Personal Communication (CDFG email 2003)		X		
Canoe Creek	8/4/1938	Stream Survey (CDFG 1938)			X	
	7/4/1962	Stream Survey (CDFG 1962)				X
	7/1/1977	Stream Survey (CDFG 1977)			X	
	1/4/1980	Stream Survey (CDFG 1980)	X			X
	3/13/1985	Field Note (CDFG 1985)			X	
	1/25/1988	Spawning Stock Survey (CDFG 1988)	X			X
	9/4/1996	Electrofishing Field Note (CDFG 1996)		X	X	
Connick Creek	6/12,6/13/1961	Stream Survey (CDFG 1961)				X
	12/8/1981	Spawning Stock Survey (CDFG 1982)				
	7/12/1993	Stream Inventory Report (CDFG 1993)		X	X	
Coon Creek (tributary to Butte Creek)	5/10/1962	Stream Survey (CDFG 1962)				
	4/3/1980	Stream Survey (CDFG 1980)				X
Corner Creek	5/1/1980	Stream Survey (CDFG 1980)				X
Cow Creek	8/9/1961	Stream Survey (CDFG 1961)				X
	7/29/1963	Stream Survey (CDFG 1963)				X
	7/24/1974	Stream Survey (CDFG 1974)				X
	3/28/1980	Stream Survey (CDFG 1980)			X	
	12/22/1987	Carcass Survey Field Note (CDFG 1987)	X			
	1/22/1988	Field Note (CDFG 1988)	X			
	12/6/1988	Field Note (CDFG 1988)				
	1/18/1989	Field Note (CDFG 1989)				
	1/2/1991	Stream Inventory Report (CDFG 1991)			X	
	1/5/1994	Field Note (CDFG 1994)				
	11/29, 12/29/1994	Spawner Survey Summary (CDFG 1994)				

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Cow Creek (con.)	1/2, 2/16/1996	Field Notes (CDFG 1996)			X	
	7/11/1996	Electrofishing Field Form (CDFG 1996)			X	
	12/8/1996	Field Note (CDFG 1996)				
Cuneo Creek	8/3/1938	Stream Survey (CDFG 1938)			X	
	7/29/1974	Stream Survey (CDFG 1974)			X	
	10/28/1983	Stream Survey (CDFG 1983)				X
	11/11/1983	Field Note (CDFG 1983)			X	
Cuneo Creek (South Fork)	7/26/1991	Stream Inventory Report (CDFG 1991)				
Cuneo Creek (North Fork)	7/25/1991	Stream Inventory Report (CDFG 1991)			X	
Decker Creek	7/4/1962	Stream Survey (CDFG 1962)				X
	1/22/1988	Spawning Stock Survey (CDFG 1988)	X		X	
	12/6/1988	Field Note (CDFG 1988)				
	1/9/1990	Field Note (CDFG 1990)	X			
	6/29/1992	Stream Inventory Report (CDFG 1992)			X	
Dry Creek	6/29/1977	Stream Survey (CDFG 1977)				X
	4/8/1980	Stream Survey (CDFG 1980)				X
	1/17/1985	Stream Survey (CDFG 1985)				X
Elk Creek (tributary to SFER)	8/3/1938	Stream Survey (CDFG 1938)			X	
	6/27, 6/28/1962	Stream Survey (CDFG 1962)			X	
	6/29/1977	Stream Survey (CDFG 1977)			X	
	1/23/1990	Field Note (CDFG 1990)	X			
	8/27/1992	Stream Inventory Report (CDFG 1992)			X	
	1/6/1994	Field Note (CDFG 1994)				
	1995	Personal Communication (CDFG email 2002)		X		

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Feese Creek	7/17/1961	Field Note (CDFG 1961)				X
Fish Creek (tributary to SFER near Miranda)	4/12/1968	Field Note (CDFG 1968)		X	X	
	4/30/1969	Field Note (CDFG 1969)		X	X	
	6/29/1977	Stream Survey (CDFG 1977)				X
	6/28/1993	Stream Inventory Report (CDFG 1999)	X	X	X	
	1/6/1994	Field Note (CDFG 1994)				
Harper Creek	7/29/1963	Stream Survey (CDFG 1963)				X
Mill Creek (tributary to Salmon Creek)	1/19/1989	Stream Survey (CDFG 1989)			X	
	6/12/1990	Electrofishing Field Note (CDFG 1990)				
Mill Creek (tributary to Bull Creek)	7/30/1974	Stream Survey (CDFG 1974)				X
	6/28/1983	Spawning Stock Survey (CDFG 1983)				
	2/13/1986	Activity Report (CDFG 1986)			X	
	12/22/1987, 1/14/88	Carcass Survey Field Note (CDFG 1988)	X			
	1/18/1989	Field Note (CDFG 1989)				
	1/19/1990	Field Note (CDFG 1990)				X
Mowry Creek	7/17/1961	Stream Survey (CDFG 1961)				
	4/17/1980	Field Note (CDFG 1980)				X
Ohman Creek	8/2/1938	Stream Survey (CDFG 1938)			X	
	6/21/1962	Stream Survey (CDFG 1962)				X
Panther Creek	4/15/1980	Stream Survey (CDFG 1980)				X
Panther Creek (West Fork)	3/30/1987	Stream Enhancement Proposal (CCC 1987)			X	
	7/9/1992	Stream Inventory Report (CDFG 1992)			X	
Salmon Creek	6/1/1938	Stream Survey (CDFG 1938)	X		X	
	11/29, 12/18/1966	Field Note (CDFG 1966)	X			

Stream	Date surveyed	Source	Species Present			
			Chinook	Coho	Steelhead	Unidentified Salmonids
Salmon Creek (con.)	7/16/1968	Field Note (CDFG 1968)				X
	6/11/1969	Electrofishing Field Note (CDFG 1969)			X	
	7/29/1971	Field Note (CDFG 1971)			X	
	9/6/1977	Stream Survey (BLM 1977)				
	1986-1990	Downstream Migrant Trapping Summary (PCFFA 1990)	X		X	
	12/30/1987, 1/21/1988	Field Note (CDFG 1988)	X			
	1/18/1990	Field Note (CDFG 1990)	X			
	April, May 1991	Downstream Migrant Trapping Data (PCFFA 1991)	X		X	
	9/21, 9/25/1992	Stream Inventory Report (CDFG 1992)			X	
	1998	Downstream Migrant Trapping Notes (PCFFA 1988)	X	X		
Slide Creek	7/7, 7/8/1992	Stream Inventory Report (CDFG 1992)			X	
Squaw Creek	6/20/1938	Stream Survey (CDFG 1938)	X	X	X	
	Circa 1962	Stream Survey (CDFG no date)			X	
	8/8/1974	Stream Survey (CDFG 1974)				X
	4/29, 5/1/1980	Stream Survey (CDFG 1980)				X
	10/26/1981	Stream Survey (CDFG 1981)				X
	12/22/1987, 1/20/1988	Field Note (CDFG 1988)	X	X	X	
	10/21-10/23/1991	Stream Inventory Report (CDFG 1991)			X	
	1994-2000	Spawning Survey Summary (CDFG 1994-2000)	X		X	X
	12/18/1996	Field Note (CDFG 1996)	X			

There is one long-term salmon and steelhead data set for the SF Eel River Basin, with data collected at the CDFW fish ladder at Benbow Dam, located at approximately RM 40 on the mainstem SF Eel River near Garberville. Although this location is not within the boundaries of the Northern Subbasin (the dam is located approximately 20 RM south of the Northern Subbasin's southernmost boundary), these data most likely reflect salmonid abundance and population trends throughout the SF Eel River Basin. Fish counts were conducted between 1938 and 1976, 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 30*). Linear regression lines for all three species at Benbow Dam show significant declines in abundance, and it is likely that salmonid populations throughout the SF Eel River Basin declined similarly over this time period.

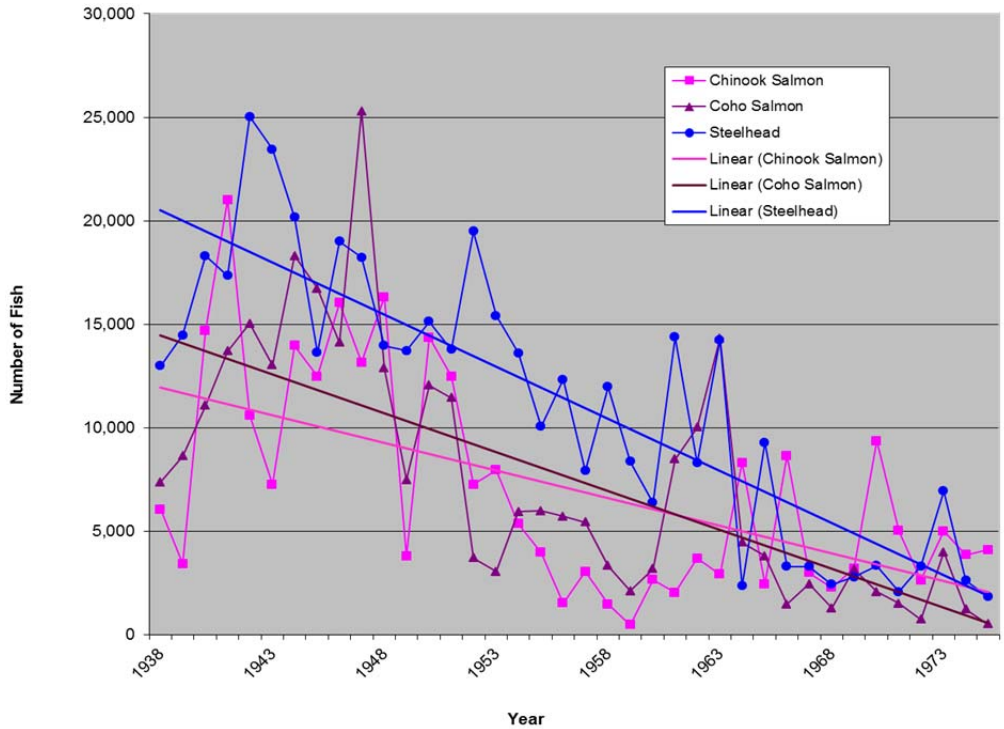


Figure 30. Counts of migrating Chinook salmon, coho salmon, and steelhead at the Benbow Dam fish ladder between 1938 and 1976. Regression lines for all three species show declines over time.

In addition to salmonid species, other native freshwater fish that have been observed in the Northern Subbasin include rainbow trout, pacific lamprey, three-spined stickleback, prickly sculpin, and coastrange sculpin (Brown and Moyle 1997, Stillwater Sciences 2010). Invasive species present in the subbasin include Sacramento pikeminnow, 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 subbasin in recent years.

Current Distribution

Current estimated Chinook salmon, coho salmon, and steelhead distributions in Northern Subbasin streams 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 or imperfect sampling techniques.

Proportionally, in terms of total number of streams and stream miles, the Northern Subbasin contains fewer tributaries and stream miles occupied by salmonids than Eastern and Western subbasin streams (*Table 17*). Although there are fewer salmonid occupied streams in this subbasin, air temperatures are cool and riparian cover is generally good. The climate is strongly influenced by the coastal marine layer and is defined by morning fog and overcast conditions, in contrast to the inland Eastern Subbasin which becomes very hot and dry. Ongoing habitat restoration efforts designed to benefit salmonids have been a high priority in many parts of the subbasin, especially in areas owned by the CA State Parks. Unfortunately, there are also many areas with ongoing issues that have resulted in deteriorating habitat for salmonids, such as high sediment input from active landslides in the Upper Bull Creek drainage and substantial diversion from tributaries for marijuana cultivation operations in the Salmon Creek watershed.

Steelhead, like other anadromous salmonids, use the upstream system in their juvenile and adult migrations, but generally prefer habitats that are located farther inland and in smaller streams than Chinook and coho salmon (Moyle et al. 2008). As stream temperature increases in tributaries, steelhead juveniles will move to faster moving water in riffles to feed, and will seek out cold water refugia at tributary confluences and seeps. As a result of these behavioral traits, and due to their superior jumping abilities, steelhead are the most widely distributed of the three species in all SF Eel River Basin streams (*Table 17*). Coho salmon generally have the most limited distribution of the three species, followed by Chinook and steelhead.

Table 17. 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.								

Coho salmon are present in only 8 Northern Subbasin streams, including the mainstem SF Eel River. Most distribution is limited to areas less than a mile from the confluences of larger creeks (*Figure 31*). Exceptions to this distribution pattern include:

- Bull Creek, with coho salmon presence documented approximately 4 miles upstream from the confluence of the mainstem SF Eel River, and
- Salmon Creek, with coho salmon documented 1-2 miles upstream and into lower Mill Creek.

Current Chinook salmon distribution includes 14 streams, and steelhead trout are found in 23 of the 109 streams in the Northern Subbasin (*Figure 31*). Steelhead are present in more streams currently than in the past, but this may be due to an increase in documentation and sampling effort rather than an increase in actual distribution in Northern Subbasin tributaries.

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, four of which were located in the Northern Subbasin (the remaining six were located in the Western Subbasin and are discussed in the Fishery Resources section in that part of the assessment report). Fifty six surveys were conducted in three Northern Subbasin streams (*Table 18*). Bull Creek sampling reaches were divided into upper and lower sections in 2007. 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 Northern Subbasin streams. Data collected between 2002 and 2012 show relatively large numbers of Chinook (up to 129 live fish and 6 carcasses per season) spawning in Bull Creek compared to other streams surveyed. There were no live coho salmon or carcasses recorded on any survey in any of the four reaches. The total number of redds (not identified to individual species) observed was greatest in Squaw Creek, with as many as 46 redds counted annually.

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.

Table 18. Index reach sampling streams and survey information for Northern Subbasin streams sampled between 2002 and 2012.

Stream	Years Surveyed	# of Surveys
Bull Creek	2002-2007 (no sampling in 2003-2004 season)	12
Upper Bull Creek	2007-2010	4
Lower Bull Creek	2007-2010	4
Squaw Creek	2002-2010	18
Cow Creek	2002-2009	18

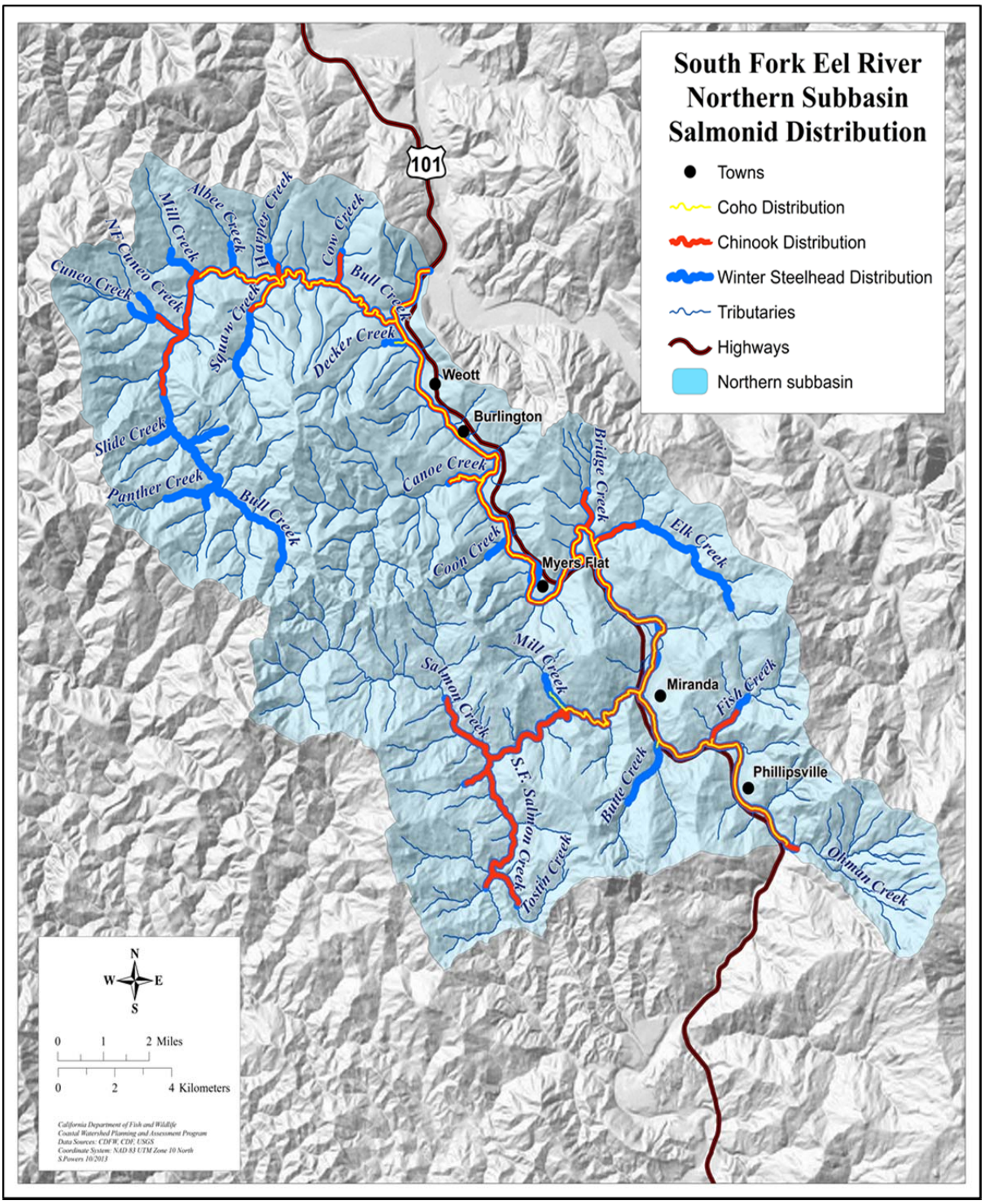


Figure 31. Distribution of Chinook salmon, coho salmon, and steelhead trout in SF Eel River Northern Subbasin streams.

California Coastal Salmonid Monitoring Program (CMP)

Chinook salmon, coho salmon, and steelhead trout spawning ground surveys have been have been completed each year 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 32*). 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. 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 19*). 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 19. 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).

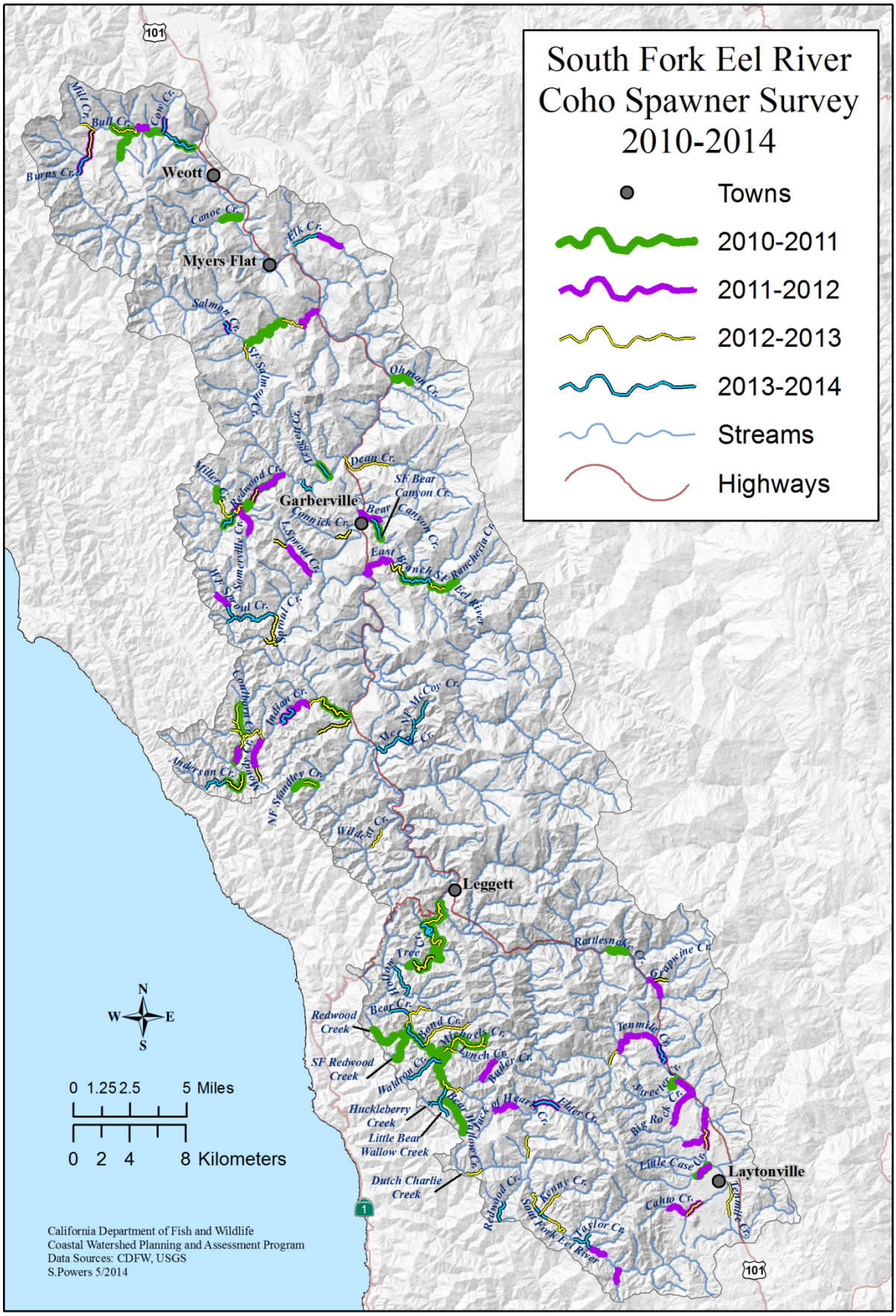


Figure 32. Location of 2010-2014 CMP spawning reaches in the SF Eel River Basin.

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.

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/.

Habitat Overview

Historic Conditions

Habitat data have been collected in Northern Subbasin streams since the 1930s. Observations were originally collected and recorded in memorandum format, with no established methodology. 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. (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 its original publication, and the current (4th) edition is available at: http://www.dfg.ca.gov/fish/resources/habitatmanual.asp.

Historic flood events and 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.

There have been 2 major flood events in the SF Eel River Basin, in 1955 and 1964, both occurring during the month of December. The flood crest in 1955 was 43 feet (at Weott) and in 1964, it was 46 feet (at Miranda) (CA State Parks 2012). During the 1964 flood, channel width increased in the Bull Creek drainage in the Northern Subbasin by up to 400 feet (Jager and LaVen 1981, cited in USEPA 1999), and sedimentation in tributary streams throughout the subbasin reached notable levels. Sediment in Cuneo Creek, a tributary to Bull Creek, buried two bridges with more than 10 meters of sediment since the flood (Dyett and Bhatia 2002). Cuneo Creek has one of the highest sediment yields of any tributary to Bull Creek, due to its location in a zone of high tectonic uplift and shearing, extensive sediment storage, and frequency of landslides associate with natural process and roads (Short 1993, Stillwater Sciences 1999).

Riparian canopy was negatively affected in the past by extensive industrial timber harvesting and flooding. Air photo analysis of canopy openings in Class I and Class II watercourses in the Salmon Creek drainage showed a ten-fold increase between 1947 and 1965, but 1996 air photos show canopy recovery approaching 95% of 1947 photo percentages in upper forested areas (JMWM 2000). Current canopy structure in this drainage has a much higher composition of alder relative to conifers and hardwoods. This new canopy provides shade to stream habitat, but no long term LWD source or multilayered canopy.

Stream surveys were completed by CDFW on 29 Northern Subbasin tributaries, with 106 site visits documented between 1938 and 1990. However, stream survey efforts were neither specific nor standardized until 1990. Most observations in the 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 at the time of survey (*Table 20*). Streams with relatively consistent good habitat ratings were Albee, Connick, North and Middle Forks of Cuneo, Mowry, and Panther creeks.

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 entering Northern Subbasin streams, particularly after the major flood events of 1955 and 1964. These land use practices and related input of sediment and woody debris were reduced when Humboldt Redwoods State Park purchased much of the land in the subbasin, however, there were still many log jams inventoried as partial barriers and recommended for removal. 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 further diminish spawning habitat quality and quantity of downstream gravels.

Table 20. Habitat observations made in the SF Eel River Northern Subbasin from 1938-1990 (ND = site visit but no data recorded).

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Albee Creek	7/31/1974	Stream Survey (CDFG 1974)	Spawning habitat good in lower half mile; upper available for residents. Rearing: lower half mile pool riffle ratio 1:1. Cover from partial log jams and small cascades.	Log jam barrier 1/2 mile upstream from mouth. 5 large log jams above first barrier.
Albee Creek (mouth to 1.2 mi upstream)	4/8/1980	Stream Survey (CDFG 1980)	Lower: Rearing habitat plentiful; spawning habitat good. Upper: Spawning habitat fair to poor; rearing habitat good. Pool riffle ratio 2:3 mouth to culvert; 1:1 culvert to end of survey. Shade 30 - 90% (mouth to culvert) and 60% above. Overall: minimal rehabilitation priority because spawning and rearing habitat area is small; gradient increases just upstream from mouth.	If unnatural obstructions were removed, natural barriers would still inhibit upstream migration.
Anderson Creek	7/6/1961	Stream Survey (CDFG 1961)	Disregard as anadromous fish stream.	10-12" metal pipe above Hwy 101 - no fish passage.
	3/22/1979	Stream Survey (CDFG 1979)	Limited spawning area; small but numerous pools; limited shelter, almost total lack of riparian vegetation.	6' X 8' box culvert at Hwy 101. Built in 1918; too steep for fish passage.
Butte Creek (aka Bear Butte Creek)	6/19/1960	Stream Survey (CDFG 1960)	Good spawning substrate and lots of shade from maples and 2nd growth firs.	Small log jam 500 yds below Coon Creek branch could become impassable.
	5/9/1962	Stream Report (CDFG 1962)	Fair spawning gravel; shelter adequate, primarily log scour pools.	5 log jams.
	4/12 - 4/23/68	Field Note: e-fishing (CDFG 1968)	Habitat good - relatively equal pool and riffle habitat.	No passage issues.
	4/30/1969	Field Note: e-fishing (CDFG 1969)		No passage issues.
	3/16/1977	Field Note (CDFG 1977)	Field visit to determine effect of logging on salmonids; steep gradient (20%) with shallow (<1') pools and narrow riffles; unlikely salmonid habitat.	
	7/6/1977	Stream Report (BLM 1977)	70% canopy shade from madrone, oak and laurel; invertebrates present but not abundant.	Many log jams stopping migration.
	4/3/1980	Stream Survey (CDFG 1980)	Shade canopy 50%; pool riffle ratio 2:3 (pools 3' deep); spawning and rearing habitat plentiful and excellent quality.	Possible new log jams forming in Bear Butte Creek as debris moves downstream from Coon Creek. Stream clearance crew working on stream.
	9/19/1984	Stream Survey (CDFG 1984)	Basin logged in last three years; upper sections of Coon and Butte have slides and other erosion problems; lower areas badly aggraded; pools and rearing habitat filling with fine sediments and gravel; section above Coon Creek managed for resident trout - not anadromous fish.	
Bridge Creek	8/3/1938	Field Note (CDFG 1938)	Excellent spawning areas; good shelter; many steelhead.	
	6/12/1952	Velocity Data Form (CDFG 1952)	ND	

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Bridge Creek (con.)	7/6/1961	Stream Survey (CDFG 1961)	Good spawning gravel and nursery habitat; shelter and cover abundant.	23 separate log jams documented (none total barriers)
	6/20/1977	Field Note (CDFG 1977)	Lack of spawning gravel throughout surveyed area; unstable stream banks; creek appears unsuitable for salmonids.	
	3/19/1980	Stream Survey (CDFG 1980)	Limited spawning and rearing habitat; very short section usable for salmonids; lower section: 85% cover; upper: 10%; pool riffle ratio 1:10 in lower areas.	
	3/16/1983	Stream Survey (CDFG 1983)	Banks steep and unstable; shade canopy averaged 85% (redwoods and alder).	6 obstructions (none total barriers) noted but only 2 recommended for removal because of limited spawning habitat.
	10/16 - 10/17/85	Stream Survey for Enhancement Projects (CDFG 1985)	Spawning habitat fair; good rearing habitat but lack of deep pools; average canopy 60%; bank stabilization and pool forming structures recommended.	
Bull Creek	8/3/1938	Stream Survey (CDFG 1938)	Good spawning areas, pools, and shelter.	
	9/13/1962	Velocity Data Form (CDFG 1962)	Water temp 68 degrees F.	
	7/16/1968	Velocity Data Form (CDFG 1968)	ND	
	4/10/1980	Stream Survey (CDFG 1980)	Relatively low spawning and rearing habitat due to cascading flow, steep gradient, and natural barriers. Numerous slides.	Barrier removal would increase instability and silt load.
	4/15/1980	Stream Survey (CDFG 1980)	Poor shade canopy (30-40%); bottom composition poor; no pools or spawning areas available. Not useful for anadromous fish above Preacher Gulch Rd.	
	9/16/1982	Population Estimate (CDFG 1982)	All salmonids collected were steelhead. Population estimate = 7710 (95% confidence interval).	
	9/9 - 9/11/1985	Stream Survey (CDFG 1985)	Little canopy; instream cover and habitat diversity needed. Wild pigs are the problem - they damage canopy trees. Critical water temps may be limiting factor for rearing in summer due to lack of canopy shade. Cuneo to Slide Creeks - limiting spawning habitat due to boulder dominated substrate, but improved above Slide Creek. Rearing habitat good.	
	2/20/1987	Field Note - spawner survey, habitat assessment (CDFG 1987)	Slides abundant; spawning habitat severely limited by amount of fines.	
	12/23/1987; 1/22/1988	Field Note - CWT recovery (CDFG 1988)	ND	
	12/6/1988	Field Note – CWT recovery (CDFG 1988)	ND	

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Burns Creek	4/10/1980	Stream Survey (CDFG 1980)	Unstable banks and numerous active slides. Shade canopy 10%. Limited spawning areas. Stream had continuous riffle habitat.	
	9/5/1985	Stream Enhancement Work Plan (CDFG 1985)	Good spawning and rearing habitat. Lower section 1:1 pool riffle ratio.	
Cabin Creek	4/4/1962	Stream Survey (CDFG 1962)	Few suitable spawning areas due to substrate (mainly boulders and rubble). Pools are fair nursery areas; extremely abundant caddisflies.	
	4/8/1980	Stream Survey (CDFG 1980)	85% canopy; pool riffle ratio 2:3; aquatic insects plentiful.	Man-made boulder levee at mouth.
	11/15/1984	Stream Survey (CDFG 1984)	85% canopy. Only the first 500' is accessible to anadromous fish due to steep gradient in rest of stream.	Low water barrier at mouth - man-made boulder embankment drops 8-10' into SFER. Inadequate sized culvert under Bull Creek Road.
	9/3/1985	CCC restoration work plan (CDFG 1985)	Canopy averaged 90% - little sunlight may be limiting primary production.	Culvert at mouth is probable barrier.
Calf Creek	4/1/1980	Stream Survey (CDFG 1980)	No value to anadromous fish - no mouth, and seeps into ground 2000' above confluence with Bull Creek.	
	9/4/1985	Stream Survey (CDFG 1985)	Stream not flowing during summer and probably only small flows in winter. Limited value for anadromous fish.	
Canoe Creek	8/4/1938	Stream Survey (CDFG 1938)	Good spawning areas, excellent pools and shelter.	
	7/4/1962	Stream Survey (CDFG 1962)	Abundant pools provide excellent cover. Good spawning gravel limited to lower reaches.	Cascading falls at end of survey were barriers to anadromous fish.
	7/1/1977	Stream Survey (CDFG 1977)	Excellent shelter - pools, undercut banks, shaded riffles, etc. Overall canopy of 60-70%.	Potential barrier 15 yards upstream from mouth; small fallen trees and debris. Should be removed.
	1/4/1980	Stream Survey (CDFG 1980)	Shade canopy 60%; abundant suitable spawning habitat; aquatic insects plentiful; average gradient 2% except at obstruction #18 (5%); pool riffle ratio 1:2.	Low water barrier creating 200' long roughs - end of survey (2.6 mi upstream).
	3/13/1985	Field Note (CDFG 1985)	Deposition from slide filled in pools - gravels and fine sediment averaged 1' deep; large amounts of gravel on margins of stream and fresh sediment from slide deposited on flood terraces.	Massive slide on LB approximately 1.5 miles upstream from mouth.
	10/7/1986	Stream Enhancement Proposal (CDFG 1986)		LDA but no total barriers.
	1/25/1988	Field Note - CWT recovery (CDFG 1988)	Poor water clarity due to unstable banks and mass wasting.	
Connick Creek	6/12 - 6/13/1961	Stream Survey (CDFG 1961)	Nursery potential seems good; shelter adequate; salmonids present.	Thirteen separate log jams (33,600 cu ft) recorded but no total barriers.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Connick Creek (con.)	3/7/1980	Stream Survey (CDFG 1980)	Good spawning substrate composition; rearing habitat and food supply is excellent.	Remove debris above obstruction in channel; not a total barrier.
	4/1/1980	Field Note (CDFG 1980)	Annual stream flow insufficient to support anadromous fish.	
	4/9/1981	Stream Survey (CDFG 1981)	Shade canopy 60%; bank stability fair; pool riffle average 1:7; aquatic invertebrates 10/sq ft; abundant, loose spawning gravel. Good spawning and rearing habitat.	
	12/12/1983	Field Note (CDFG 1983)		One probable barrier at upstream end of survey
	9/3/1985	CCC Salmonid Restoration Work Plan (CDFG 1985)	Excellent spawning areas in lower 300'; debris accumulations and less suitable habitat after 500'.	
Coon Creek	5/10/1962	Stream Survey (CDFG 1962)	Nursery potential fair; shelter adequate.	7 separate major log jams but no complete barriers.
	4/3/1980	Stream Survey (CDFG 1980)	Gradient averaged 10%; canopy averaged 60% (willows, redwood, and hardwoods); spawning and rearing habitat plentiful and excellent quality; invertebrates and salmonids observed in stream.	
Corner Creek	5/1/1980	Stream Survey (CDFG 1980)	Spawning and rearing habitat plentiful; fry observed (below obstruction #3); substrate 40% rubble, 45% gravel; 15% silt/sand.	4 possible barriers noted; mouth choked with roots and debris.
	2/21/1985	Stream Survey (CDFG 1985)	Limited spawning habitat observed; rearing habitat fair; 90% canopy from old growth; 25% gravel & 75% silt/sand.	Two log jams-first on mouth of creek and 270' feet above mouth; recommend not removing log jam, could lose spawning habitat.
Cow Creek	8/9/1961	Stream Survey (CDFG 1961)	Salmonids observed throughout the area; area has never been logged; gravel, sand, slit present; rubble and small quantities of boulders found in upper portion of survey.	18 log jams recorded for a total accumulation of 35,800 cubic feet of material; none appear to be a barrier to fish; seven ft. culvert passes under Honeydew road.
	7/29/1963	Stream Survey (CDFG 1963)	Survey length 830 yards; salmonid fingerlings observed to end of survey; enough gravel to provide adequate spawning area.	Culvert noted 7 feet high, 24 feet long, 200 feet from the mouth; 8100 cubic feet of logs and debris recorded.
	7/24/1974	Stream Survey (CDFG 1974)	Streambed composed of boulders up to 3 feet, gravel and some silt; stream jammed with logs and active slides; flow 0.5 cfs; active spawning is taking place in the lower 1/4 mile of the stream.	1/4 mile up choked with log jams; upper reaches jammed with active slides; culvert noted.
	3/28/1980	Stream Survey (CDFG 1980)	Survey mouth to headwaters (1.5 mile); substrate suitable for spawning throughout entire drainage; good quality DO; insects, canopy and flow throughout stream.	Listed 28 potential barriers and obstructions. Generally logs, chunk and debris with gravel build up. Several slides noted
	5/3/1982	Stream Survey (CDFG)	Spawning habitat poor throughout due to poor quality gravel beds; fair to good rearing habitat; substrate 10% boulders, 40% rubble, 30% gravel, 20% sand/silt.	Recommend clearing obstructions 1-9; remove chunks and debris.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Cow Creek (con.)	3/14/1983	Stream Survey (CDFG 1983)		7 obstructions; 400' above mouth Bull Creek Road Culvert - not a barrier; obstructions generally downed trees and chunks and debris; some with silt and gravel build up; recommend clearing or modifying 2a-7 obstructions.
Cuneo Creek	8/3/1938	Stream Survey (CDFG 1938)	Good spawning, pools, and shelter; steelhead present; heavy fishing.	
	7/29/1974	Stream Survey (CDFG 1974)	Cuneo Creek drains 281.6 acres of thick steep coastal mountians; the south fork is a wide, boulder-littered sterile stream; the middle and north forks are recovering from flood damage; fish were present in only the middle and north forks.	No jams were observed to present barriers to fish migration; continuous cascades and extreme temperature are natural barriers.
Cuneo Creek (Middle Fork)	3/28/1980	Stream Survey (CDFG 1980)	Spawning and rearing habitat plentiful; salmonid fry observed.	9 identified barriers and obstructions; logs, root wads, chunks and debris; gravel behind some logs.
Cuneo Creek (North Fork)	3/27/1980	Stream Survey (CDFG 1980)	Spawning and rearing habitat plentiful; salmonid fry observed.	14 identified barriers and obstructions noted; logs, chunks, and debris; rootwads, boulders creating cascades.
Cuneo Creek (South Fork)	4/1/1980	Stream Survey (CDFG 1980)	Stream banks steep and unstable; gradient variable (10%-20%; at times 42%, end of survey 80%); rearing habiatat available, but spawning habitat scarce; extensive logging above obstruction #22.	Twenty-four barriers and obstructions.
Dry Creek	6/29/1977	Stream Survey (CDFG 1977)	Good to adequate spawning areas; pool riffle ratio 1:1; good shelter in pools; 60-75% canopy; abundant aquatic insects.	Possible barrier at footbridge.
	4/8/1980	Stream Survey (CDFG 1980)	Spawning and rearing habitat plentiful; pool riffle ratio 1:4 (2' deep); 3% gradient.	
	1/7/1985	Stream Survey (CDFG 1985)	Lower area: no good resting pools (pool riffle ratio 1:15); lots of silt in gravels. Middle area: pool riffle ratio 1:4 (depth 1' with good cover); average rearing habitat. Upper area: poor spawning habitat.	Low water barrier at mouth.
Elk Creek	8/3/1938	Stream Survey (CDFG 1938)	Good pools, shelter, spawning habitat, and abundant aquatic insects.	
	6/12/1952	Velocity Measurement (CDFG 1952)	4.12 cfs.	
	6/27 - 6/28/1962	Field Note (CDFG 1962)	Excellent spawning areas; adequate nursery habitat; pool riffle ratio 1:4.	Log jams (some total barriers), and mill pond water gate (debris jam).
	1962	Stream Survey (CDFG 1977)	Good to excellent spawning areas; pool riffle ratio 1:2; good to excellent shelter; abundant fish food; creek dry at mouth at time of survey, intermittent along lower mile, and 0.25 cfs in upper areas.	Numerous log jam barriers; the first total barrier is located 0.25 miles upstream from old Hwy 101 bridge.
	3/11/1980	Stream Survey (CDFG 1980)	Excellent rearing and spawning areas; canopy 10% in lower, 50-60% in middle and upper sections; pool riffle ratios 1:10 in upper and lower, 1:3 in middle section; aquatic insects plentiful.	63 barriers surveyed; first possible total barrier approximately 2000' from mouth.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Elk Creek (con.)	12/28/1982 and 2/4/1983	Stream Survey (CDFG 1983)	Suitable spawning gravel but high amount of siltation; pool riffle ratio 1:10; gradient 2-5%; canopy 20-40%.	21 barriers; no total barriers.
Feese Creek	7/17/1961	Field Note (CDFG 1961)	Small, unimportant tributary to SF Eel River; pool riffle ratio 40:60; adequate spawning areas, nursery habitat, and shelter; 3/5 cfs flow.	
	4/8/1980	Field Note (CDFG 1980)	Stream flow is insufficient to support anadromous fish.	
Fish Creek	6/29/1977	Stream Survey (CDFG 1977)	Good to excellent spawning areas between log jams; pool riffle ratio 1:4; pools shallow with little cover; water temperature 72 degrees F; flow 0.25 cfs.	4 log jams, all barriers.
	2/28/1980	Stream Survey (CDFG 1980)	Banks very unstable; shade canopy 60-70%; pool riffle ratio 1:10.	450' above mouth is old Hwy 101 box culvert - total barrier.
Harper Creek	7/29/1963	Field Note (CDFG 1963)	Abundant spawning gravel but somewhat silted; excellent shelter; 5% gradient; food plentiful.	9 log jams; one complete barrier.
	3/21/1980	Stream Survey (CDFG 1980)	Lower section: very few pools and little canopy at mouth, increasing to 80% upstream; 6% gradient. Upper section: limited spawning habitat; pool riffle ratio 1:10 (2.5' deep); 60-90% canopy; aquatic insects common; rearing habitat plentiful.	22 barriers observed on mainstem and West Fork; three total barriers, one possible low water barrier.
	4/4/1982	Stream Survey (CDFG 1982)	Mainstem and West Fork surveyed. Mainstem: relatively poor spawning habitat; poor quality spawning gravels; significant increase in gradient 3500' above mouth; rearing habitat fair to good until upper section of creek (no good rearing habitat).	6 barriers on mainstem (2 total); 5 barriers on West Fork (4 total).
	5/4/1982	Stream Survey (CDFG 1982)	Poor quality spawning gravels; significant increase in gradient 3500' above mouth; rearing habitat fair to good until upper section of creek (no good rearing habitat).	Boulders creating a series of cascades 20' x 100' with 18% gradient - possible low flow barrier.
	12/14/1984	Stream Survey (CDFG 1984)	Very limited spawning habitat; in lower areas, rearing habitat nearly nonexistent, then adequate in upper areas; canopy 80-90%; pool riffle ratio 1:10; unstable banks and landslides have introduced large amounts of fine sediment.	Probable low water barrier at mouth.
Kerr Creek	7/14/1980	Field Note (CDFG 1980)	Stream dry to 1000' above confluence with SF Eel River; 1000' above where stream started flowing, natural barrier of boulder cascades with 20% gradient; no anadromous fish or habitat.	
Mill Creek (tributary to Bull Creek)	7/30/1974	Field Note (CDFG 1974)	Lower half mile: good spawning habitat; upper reaches: available to resident trout only; summer flow 0.29 cfs with average depth 2.82 inches.	Lower half mile: numerous small jams; upper reaches: numerous large jams and dams.
	3/26/1980	Stream Survey (CDFG 1980)	Lower section of stream good for anadromous salmonids; spawning habitat limited; no shade canopy at mouth but increased to 55% 500' upstream, then increased to 70% in upper reaches; pool riffle ratio 1:2 with average depth 4' in lower section and 1:4 in upper area; rearing habitat plentiful; debris in stream from logging operations.	
	8/22/1985	Stream Enhancement Work Plan (CDFG 1985)	Mouth had subterranean flows to 90' upstream; no canopy at mouth but increased to 70% upstream; 35% fines in substrate, increasing to 40% in some areas due to sediment input from unstable banks.	Boulder cascades above 3700' makes habitat unusable for salmonids.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Mill Creek (tributary to Salmon Creek)	10/22/1988	Stream Survey (CDFG 1989)	No anadromous fishery value due to migration barriers in lower areas; stream inaccessible for adult steelhead in the winter and for juveniles trying to escape warm flows during the summer.	Many debris jams in first mile; 8' falls at 7500' was total barrier to anadromous fish.
Mill Creek (tributary to SF Eel River near Weott)	5/1/1980	Field Note (CDFG 1980)	Stream gradient 14% at mouth, increasing to 45% 100' upstream; very little if any spawning area.	10' falls 250' upstream is complete barrier.
Miller Creek (tributary to Bull Creek)	4/1/1980	Field Note (CDFG 1980)	Annual stream flow insufficient to support anadromous fish.	
	9/4/1985	Survey Discussion (CDFG 1985)	Canopy 80-90%; gradient 1-3%. No standing or running water in 1300' of stream surveyed; due to lack of consistent flows, no restoration actions recommended.	3' high gravel bar at mouth not a barrier at high flows.
Mowry Creek	7/17/1961	Field Note (CDFG 1961)	Stream was dry for 175 yards above mouth; 400 lineal yards of riffle available to anadromous fish; adequate nursery habitat in upper areas; lower portion open and dry at time of survey; pool riffle ratio 70:30; flow 1-3 cfs from 200 yards above mouth.	
	4/17/1980	Field Note (CDFG 1980)	Excellent habitat in Humboldt Redwoods State Park; excellent spawning substrate; creek is active salmonid producer and should be left untouched.	
Ohman Creek	8/2/1938	Stream Survey (CDFG 1938)	Excellent spawning areas; good pools and shelter; abundant food; water temperature 63 degrees F; abundant YOY steelhead.	Impassable 0.2 miles above station (100 yards above Hwy 101 bridge).
	6/12/1952	Velocity Measurement (CDFG 1952)	3.44 cfs.	
	6/21/1962	Field Note (CDFG 1962)	Only 0.25 mile of available habitat; spawning areas reduced by siltation in slow water areas below barrier; favorable pool shelter from boulders; adequate nursery habitat evidenced by the presence of many small salmonid fry.	450 yards above mouth, very steep, huge bouldered, impassable roughs.
	1/31/1980	Stream Survey (CDFG 1980)	Limited spawning area due to all habitat below barrier being riffle; aquatic insects plentiful; shade canopy averaged 70%.	200' above mouth, bedrock and boulder cascades; falls average 6' to 20'.
Panther Creek	4/15/1980	Stream Survey (CDFG 1980)	Spawning and rearing habitat plentiful; gradient averaged 9% in lower section but increased to 30% upstream; pool riffle ratio 1:1; average pool depth 2'; shade canopy 5%; water temperature at time of survey was 50 degrees F but warm water temperatures due to lack of canopy could create a problem for rearing salmonids; plentiful salmonid fry to 3" in length.	
Slide Creek	4/10/1980	Stream Survey (CDFG 1980)	Stream gradient 10% in lower reaches, increasing to 30% at end of survey; shade canopy 10%; pool riffle ratio 1:1; rearing habitat plentiful; spawning habitat available in lower reaches; possible warm water issues from lack of canopy.	10 barriers described; three possible low water barriers; no total barriers.
	9/6/1985	Field Note (CDFG 1985)	First 2000' has limited spawning habitat; siltation and erosion is a problem throughout survey; good rearing habitat.	Boulder roughs and 50% gradient increase is end of anadromy at 4270'.
Squaw Creek	8/8/1974	Stream Survey (CDFG 1974)	Entire area surveyed (mouth to Grasshopper Creek Rd.) accessible to salmonids; pool riffle ratio 1:1; pool depth 2-4'; good cover and insect food.	Barrier 150 yards long in upper survey area; 7 minor barriers.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Squaw Creek (con.)	4/29 and 5/1/1980	Stream Survey (CDFG 1980)	Canopy averaged 90%; gradient 3-4%; pool riffle ratio 3:2; banks generally stable. High priority for restoration (clear obstructions) to release spawning gravel. Excellent salmonid stream.	37 barriers/obstructions described.
	5/12/1982	Stream Survey (CDFG 1982)	Bank stability good first mile, then fair to poor; pool riffle ratio 1:3 for lower and 1:2 for upper sections; average canopy 70%.	17 barriers described (9 possible or total).
	12/11/1984	Stream Survey (CDFG 1984)	Spawning habitat is limiting factor due to high sediment load degrading gravels; rearing habitat plentiful; canopy good (70-90%).	12' falls at site #2 is complete barrier.
	8/28 and 9/12/1985	Field Note (CDFG 1985)	Spawning habitat limited; improvement projects would increase rearing habitat; unstable banks; recommend bank stabilization projects.	
	4/18/1986	Addendum to Project Improvements (CDFG 1986)	Streambank stabilization project to reduce input of fine sediments.	

Current Conditions

Habitat inventories were recently conducted by CDFW on 17 of the tributaries in the Northern Subbasin (*Table 21*). Survey lengths ranged from 13.43 miles (Bull Creek 1991) to 0.12 miles (Bridge Creek unnamed tributary 2007). Survey data were divided into two sampling periods 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 17 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.

Thirteen of the 17 tributaries were surveyed during both the 1990-1999 and 2000-2010 time periods, but surveys were often completed at different times of the year (e.g. Fish Creek was surveyed in June in 1999 but in August in 2007). 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 Northern 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 gauges at Miranda (RM 17) and Bull Creek (four miles upstream from confluence with SF Eel River), average annual flow was very high in 1938 and 1974, and very low in 1977 (*Figure 5*).

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 21* 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 Salmon 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 21*. Average canopy density, embeddedness, length of primary pools, and pool shelter in Northern Subbasin streams did not meet target values during either sampling period. Primary pools were most limiting for salmonids in this subbasin, with percent lengths well below target values in all streams. 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 21. Summary of CDFW habitat inventory data used in analysis for streams in the SF Eel River Northern 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**
Bridge Creek	1993	0.98	60.3	4.8	1.6	48.7
	2007	0.98	89.3	6.4	3.2	28.6
Bridge Creek (unnamed tributary)	2007	0.12	90.2	20.0	0.0	46.0
Bull Creek	1991	13.43	33.1	1.4	0.8	36.4
	2007	9.66	64.0	22.9	6.3	38.4
Butte Creek	1993	1.66	68.0	0	4.0	38.5
	2009	1.38	80.7	40.0	7.8	23.9
Canoe Creek	1992	3.31	76.7	40.2	8.7	87.1
	2007	1.86	81.0	3.6	17.1	75.8
Coon Creek (SFE)	1993	0.65	59.1	38.0	0.8	45.6
	2007	1.09	89.0	33.1	0.2	48.8
Cow Creek	1991	0.63	67.2	2.7	0.8	53.7
	2007	1.03	88.0	15.2	7.3	25.0
Decker Creek	1992	0.79	81.0	2.2	10.4	80.6
	2010	0.60	93.6	46.3	5.8	22.5
Elk Creek	1992	3.53	84.4	6.0	2.3	82.5
	2007	4.14	90.2	39.2	6.6	68.8
Elk Creek (unnamed tributary #7)	2007	0.21	97.6	75.0	0.0	38.8
Fish Creek	1999	2.36	90.0	14.0	2.9	11.4
	2007	1.04	96.1	15.3	2.0	23.4
Harper Creek	1991	0.91	68.0	19.8	0.7	ND
	2007	0.89	90.0	19.7	0.7	32.8

Stream	Survey Year	Survey length (miles)	Mean Canopy Density (%)	Category 1 Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Pool Shelter Rating
Mill Creek (Bull Creek)	1991	0.76	61.3	9.0	0.7	38.7
	2007	1.18	86.3	17.2	3.9	71.4
Mill Creek (Salmon Creek)	2009	0.52	90.8	8.0	0.3	20.6
Ohman Creek	1992	0.28	24.2	0	5.6	20.0
	2007	0.33	61.5	67.0	0.5	26.7
Salmon Creek	1992	5.24	19.9	1.0	17.7	15.0
	2007	7.28	59.7	65.7	11.9	70.4
Squaw Creek	2010	2.74	94.6	22.9	10.0	35.9
AVERAGE	1990-1999		50.5	7.8	5.4	43.0
	2000-2010		75.9	33.4	7.0	49.4

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 between 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 Northern Subbasin streams in each time period, and change in suitability values between time periods were 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 Northern Subbasin streams between the 1990s and early 2000s, but scores were still in low suitability categories (negative values) during both sampling periods (*Table 22*). Overall suitability increased due to increasing embeddedness scores, but also due to a small increase in pool shelter scores between the two sampling periods.

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 Northern 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 12 times using data collected during the 1990s and only 4 times when using data collected between 2000 and 2010.

Table 22. Overall suitability scores and suitability scores by factor in SF Eel River Northern Subbasin streams during two sampling periods: 1990-1999 and 2000-2010.

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	34.52	-0.74	-0.34	-0.96	-0.52	-0.63	-0.58
2000-2010	35.05	-0.24	0.33	-0.99	-0.42	-0.76	0.20

Changes in factor scores over time in specific streams and reaches throughout the subbasin will be discussed further in the individual factor sections of this report.

The overall suitability of habitat for salmonids increased in many Northern Subbasin streams, and in specific reaches in these streams, over time (*Figure 33*). For example, in some larger tributaries, including Bull Creek and Salmon Creek, and in smaller creeks (Mill, Elk, and Butte), suitability in sampled reaches increased over time. Although suitability increased, the majority of reaches were still in the lowest two suitability categories in this subbasin. Two exceptions to this pattern were reaches in lower Salmon and Elk creeks, were in the moderately suitable category in the 2000s.

Although unstable geology in the Northern 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 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 as the CA State Parks purchased additional property, land use patterns changed and environmental disturbance was reduced. Instream habitat and upslope restoration projects are also ongoing, especially in Humboldt Redwoods State Park. 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.

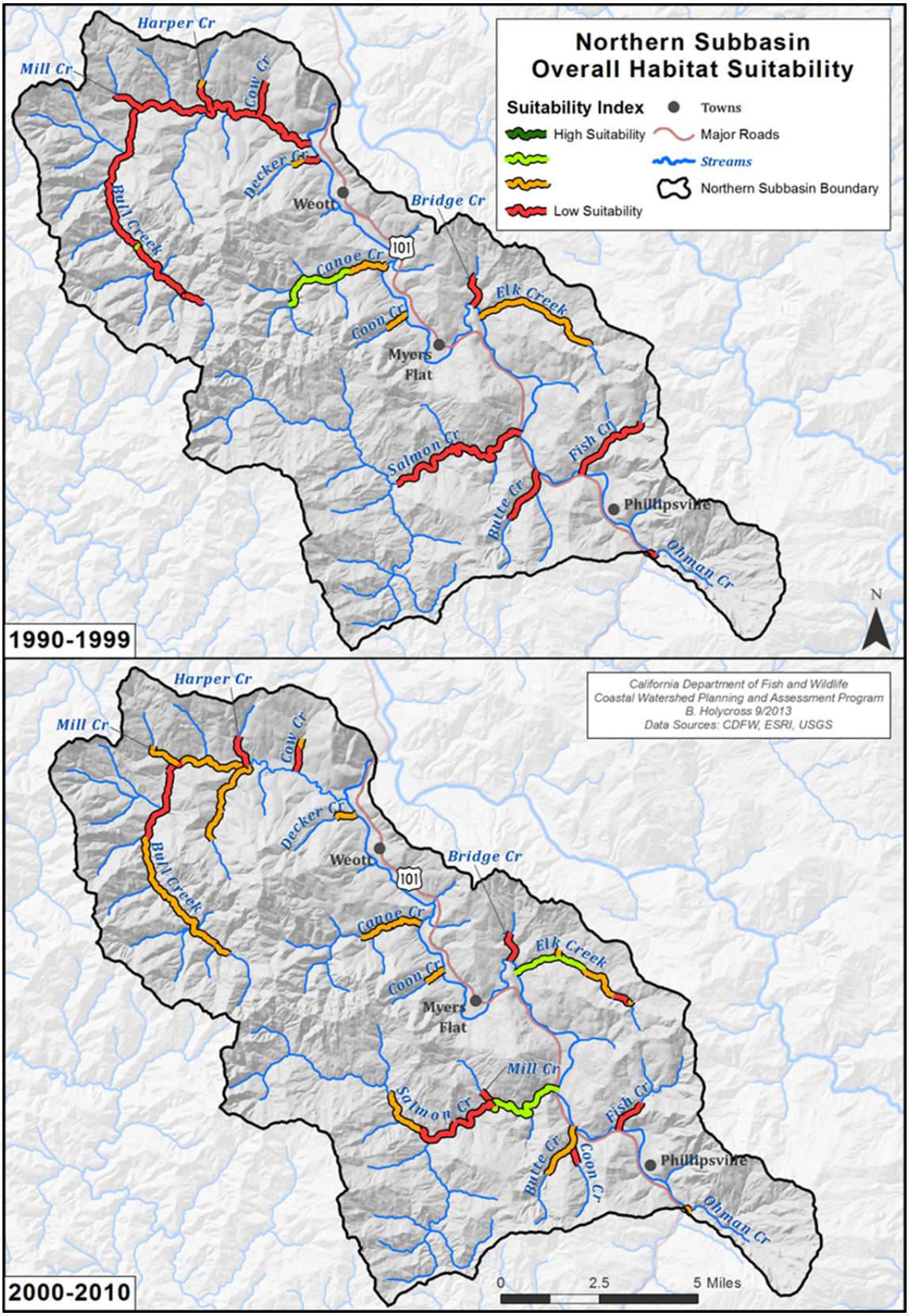
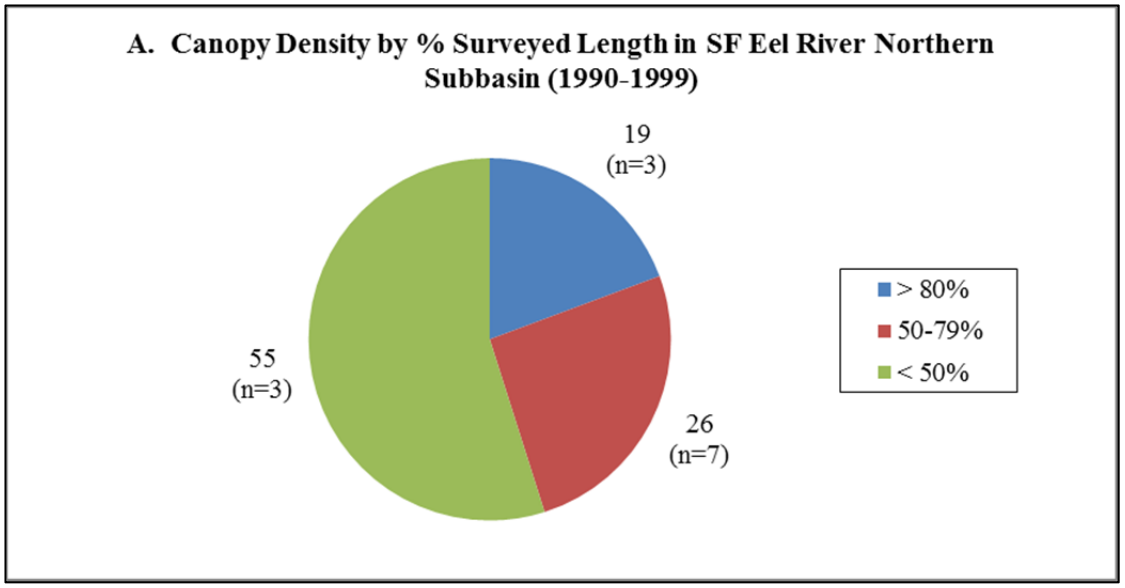


Figure 33. Overall habitat suitability in SF Eel River Northern Subbasin streams, as determined by the EMDS-based analysis using data from two sampling periods: 1990-1999 and 2000-2010.

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 *California Salmonid Stream Habitat Restoration Manual* establishes a target value 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 improved over time in Northern Subbasin streams (*Figure 34 A, B*). In the 1990s, 55% of the stream length surveyed had canopy densities below 50% and only 19% met target values of 80% or greater. In the early 2000s, there was no stream length with below 50% canopy density, and 51% of surveyed stream length met target values.



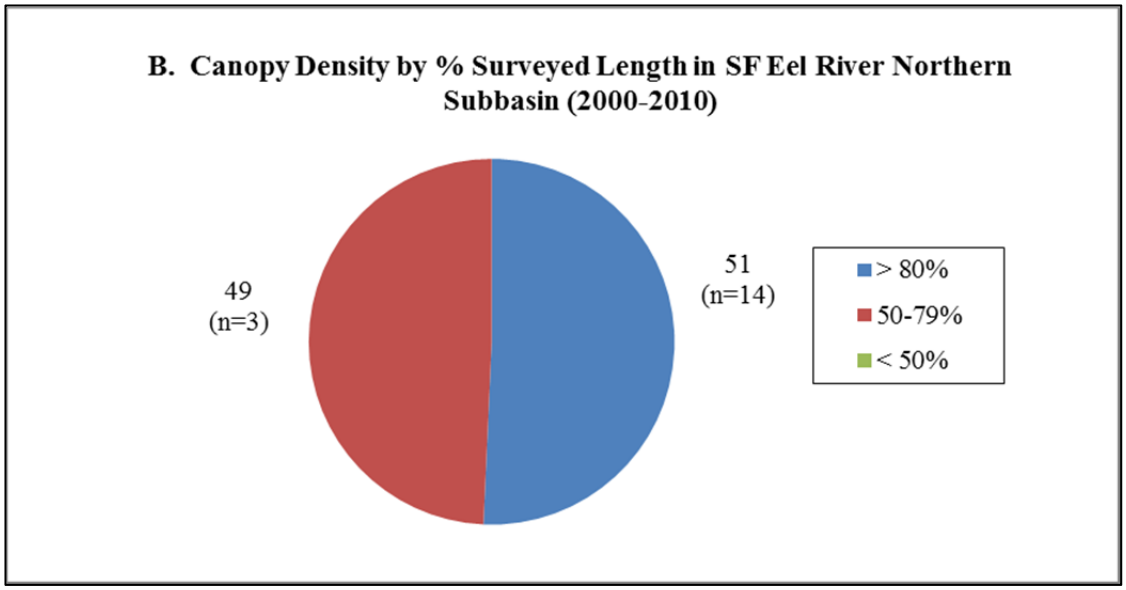


Figure 34A, B. Canopy Density in the Northern Subbasin using data collected from 1990-1999 (A) and 2000-2010 (B); n = number of streams surveyed.

Canopy density suitability scores increased in most Northern Subbasin streams between the two sampling periods (*Figure 35*). From surveys completed between 1990 and 1999, the average canopy score for all Northern Subbasin streams was -0.34 (*Table 22*). During this sampling period, two streams had canopy density suitability in the lowest category: the majority of Bull Creek, and the entire surveyed length of Salmon Creek. These are relatively large streams, and we expect canopy density to decrease as channel width increases. However, even in the upper reaches of these creeks, canopy density was poor in the 1990s, most likely due to past land use activities, damage from historic floods, and unstable geology limiting the establishment of riparian habitat.

During the 2000-2010 sampling period, the average canopy density score for all Northern Subbasin streams was 0.33 (*Table 22*). This increase is most likely due to a combination of changes in land use including a reduction in industrial timber harvest (and the associated reduction in detrimental environmental effects), road improvement and rehabilitation efforts, and ongoing restoration projects such as riparian and instream habitat improvement, and upslope watershed enhancement. Canopy density was in the high suitability category in the uppermost reach of Bull Creek, moderately high in the reach above Harper Creek, moderately low near Panther Creek, and low in the reach near Slide and Cuneo creeks. Low canopy suitability is due to highly unstable and erodible banks in this middle stretch of Bull Creek. The entire Bull Creek drainage was heavily logged in the past, and when the State Park purchased nearly all of the land in the watershed, restoration activities became a priority and concentrated on riparian habitat improvement, upslope watershed restoration, and bank stabilization. The middle reaches of both Bull Creek and Salmon Creek remained in the lowest suitability category for canopy density; however, these are both 4th order streams, with lower canopy densities expected. Restoration projects designed to increase canopy in those areas with reduced channel width are recommended but overall canopy density may remain low in these reaches due to channel morphology. In the middle reaches of Bull Creek, near the confluence of Cuneo Creek, riparian habitat restoration projects have been completed but canopy densities remain low. Future surveys may show improvement in suitability as a result of these projects.

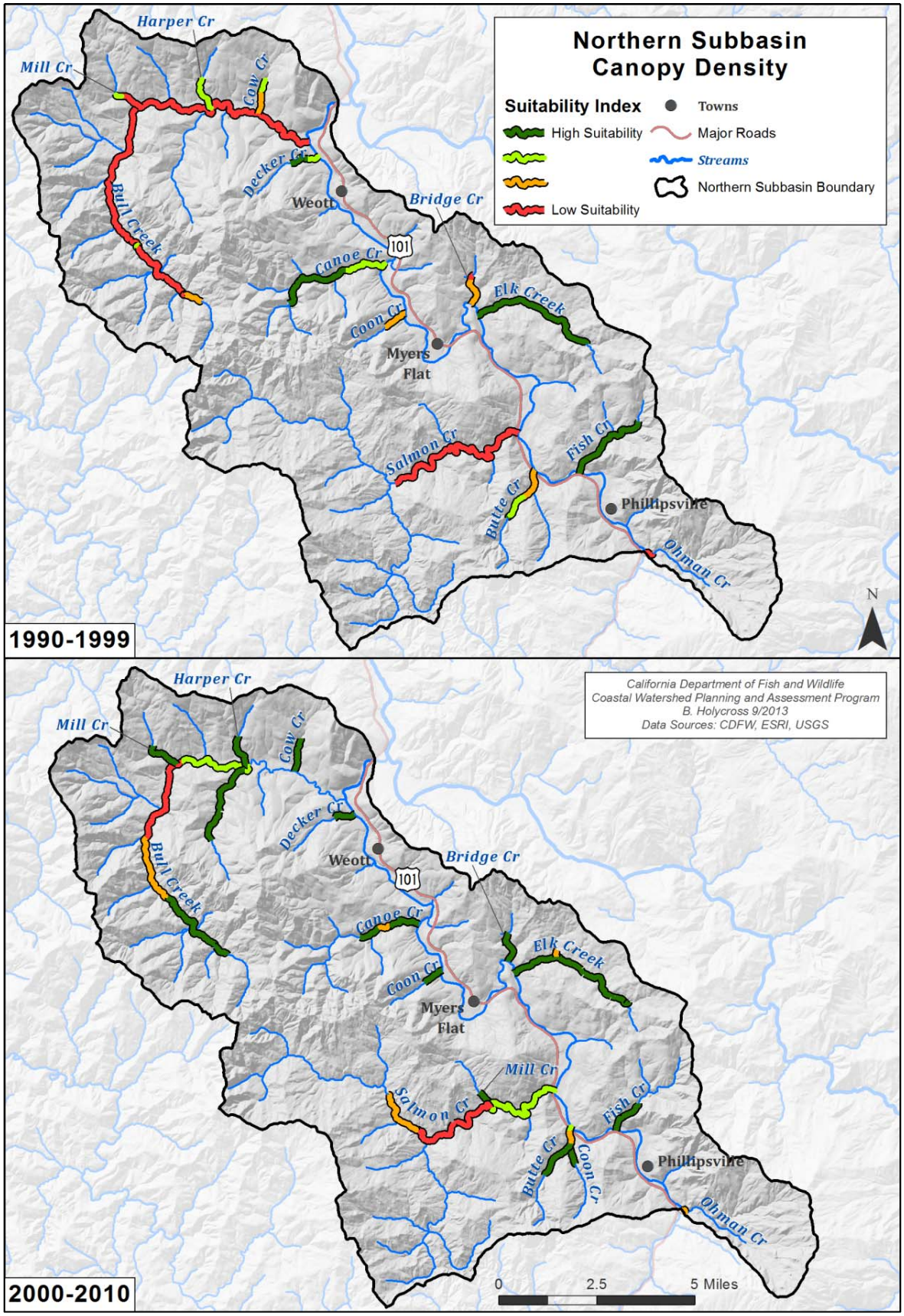


Figure 35. Canopy density suitability for Northern Subbasin streams, as determined by the EMDS-based analysis using data from two sampling decades: 1990-1999 and 2000-2010.

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). Even in streams with very low coniferous canopy percentages, suitability may be high due to high percentages of deciduous canopy (e.g. Elk Creek); restoration efforts in these areas should concentrate on reestablishing coniferous canopy. CDFW field crews visually estimated the percent contribution of canopy from coniferous and deciduous trees during habitat typing surveys.

Coniferous canopy cover was relatively low (< 50%) in most streams, particularly in creeks that are located outside the boundaries of Humboldt Redwoods State Park. The largest streams in the subbasin, Bull Creek and Salmon Creek, had the lowest coniferous canopy percentages (less than 10%) when sampled in the 1990s.

For streams with survey data available from both time periods, the average percent of coniferous vegetation increased and percent open canopy decreased in most streams over time (*Table 23*). An exception to this pattern was Elk Creek and its unnamed tributary, which showed significant decreases in coniferous canopy coverage and increases in deciduous cover due to significant timber harvest activity in recent years.

Table 23. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Northern Subbasin.

STREAM	AVG% CONIFEROUS	AVG% DECIDUOUS	AVG% OPEN
Bridge Creek 93	37.5	22.7	39.8
Bridge Creek 07	44.0	45.3	10.7
Bridge Creek UT 07	46.2	44.0	9.8
Bull Creek 91	4.0	29.1	66.9
Bull Creek 07	16.4	47.6	36.0
Butte Creek 93	21.6	46.4	32.0
Butte Creek 09	21.9	58.9	19.3
Canoe Creek 92	52.4	24.3	23.3
Canoe Creek 07	72.0	9.0	19.0
Coon Creek 93	35.6	23.5	40.9
Coon Creek 07	48.9	37.2	13.9
Cow Creek 91	29.9	37.3	32.8
Cow Creek 07	43.5	44.5	12.0
Decker Creek 92	56.3	24.7	19.0
Decker Creek 10	63.8	29.8	6.4
Elk Creek 92	35.4	49.0	15.6
Elk Creek 07	27.9	62.4	9.8
Elk Creek UT 1 07	27.3	60.1	12.6
Elk Creek UT 7 07	2.7	94.9	2.4
Fish Creek 99	19.6	70.4	10.0
Fish Creek 07	48.6	47.5	3.9
Harper Creek 91	35.6	32.4	32.0
Harper Creek 07	60.4	29.6	10.0
Mill Creek (Bull) 91	13.8	47.5	38.7
Mill Creek (Bull) 07	28.1	58.2	13.7
Mill Creek (Salmon) 09	35.6	55.2	9.2
Ohman Creek 92	17.1	7.1	75.8
Ohman Creek 07	34.8	26.8	38.5
Salmon Creek 92	2.0	17.9	80.1
Salmon Creek 07	21.4	38.3	40.3
Squaw Creek 10	35.9	58.7	5.4

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 21 lists the percent length of primary pool habitat by stream. Percentages ranged from zero (in unnamed tributaries to Bridge and Elk creeks) to 17% (in Salmon Creek in 1992 and Canoe Creek in 2007). Overall percent primary pool habitat (weighted by surveyed length) was 5.4% for habitat surveys completed in the 1990s, and increased slightly to 7.0% for surveys in the early 2000s. These numbers are well below target values.

The percent of primary pool habitat in first through fourth order streams was very low (10% or less) in both the 1990s and the early 2000s (*Figure 36*). In streams with reaches located in both third and fourth order areas, the larger stream order category was used (e.g. middle reaches in Bull Creek). Although the percent of primary pool habitat is low, it increased slightly over time in all order categories.

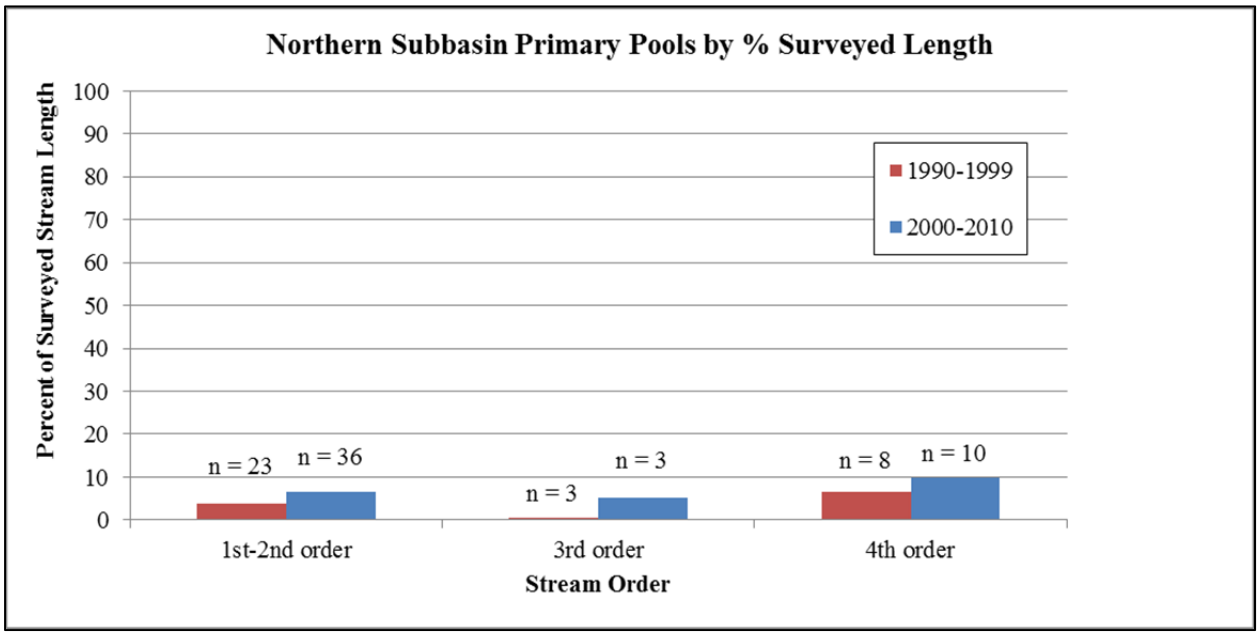


Figure 36. Percent of surveyed habitat in primary pools in the Northern Subbasin, using data collected from 1990-1999 and 2000-2010 (n = number of stream reaches).

Pool depth suitability in Northern Subbasin streams was in the lowest category for most streams during both sampling periods (*Figure 37*). Small sections of Squaw, Canoe, and Butte creeks showed improvement between the 1990s and early 2000s, but pool habitat in Salmon Creek deteriorated over time. Northern Subbasin streams receive a tremendous amount of sediment from both anthropogenic and natural sources. Heavy sedimentation rates, especially during large flood events such as the 1955 and 1964

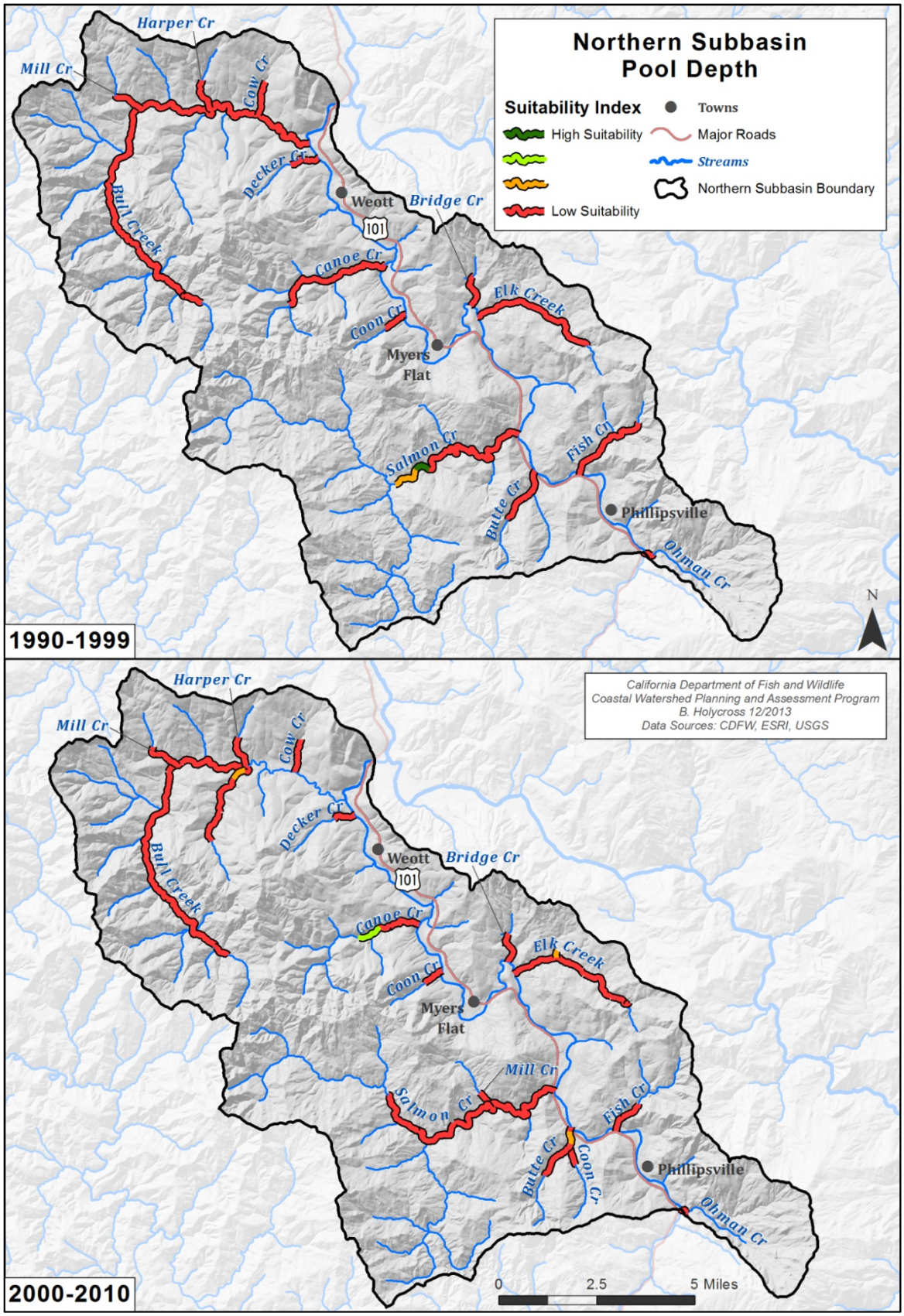


Figure 37. Pool depth suitability in SF Eel River Northern Subbasin streams, as determined by the EMDS-based analysis using data collected between 1990 and 1999, and 2000 and 2010.

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. The highest rate of sediment production in this subbasin is from landslides (Stillwater Sciences 1999), but road density is also very high (3.3 miles/square mile), particularly in areas of the subbasin that are outside State Park boundaries. Sediment input sources from legacy and recently constructed roads include road crossing and gully erosion, road prism sheetwash, and skid trail erosion. Restoration activities that will 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 all life stages of 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 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 shelter/cover enhancement should be considered.

The average mean pool shelter rating for Northern Subbasin streams was 43.0 in the 1990s and 49.4 using habitat data collected between 2000 and 2010 (*Table 21*). Although these values increased slightly over time, they are still well below the target pool shelter value of 100 for salmonids.

Pool shelter values and corresponding scores for most of the reaches in Salmon Creek increased dramatically between the two sampling periods. In 1992, average pool shelter (weighted by reach length) was 15.0; by 2007, this number increased to 70.4 (*Table 21*). Pool shelter suitability increased in the lower and upper reaches of Salmon Creek, and the uppermost reach, located upstream from the confluence with the South Fork Salmon, was in the highest suitability category in the early 2000s (*Figure 38*). Increased suitability is most likely due to strong community involvement in watershed management and active restoration efforts throughout this watershed (JMWM 2000).

Northern Subbasin streams with slight increases in pool shelter suitability values over time were the middle reaches of Bull Creek, and a few reaches in Butte, Bridge, Coon, Cow, and Mill creeks (*Figure 38*). Pool shelter suitability decreased over time in Decker, Canoe, and Elk creeks, most likely due to land use practices (e.g. recent timber harvests in Elk Creek) and lack of bank stability and LWD recruitment in these streams.

Restoration projects targeting streams with particularly low pool shelter values and potential salmonid presence should be a high priority throughout the Northern Subbasin. 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.

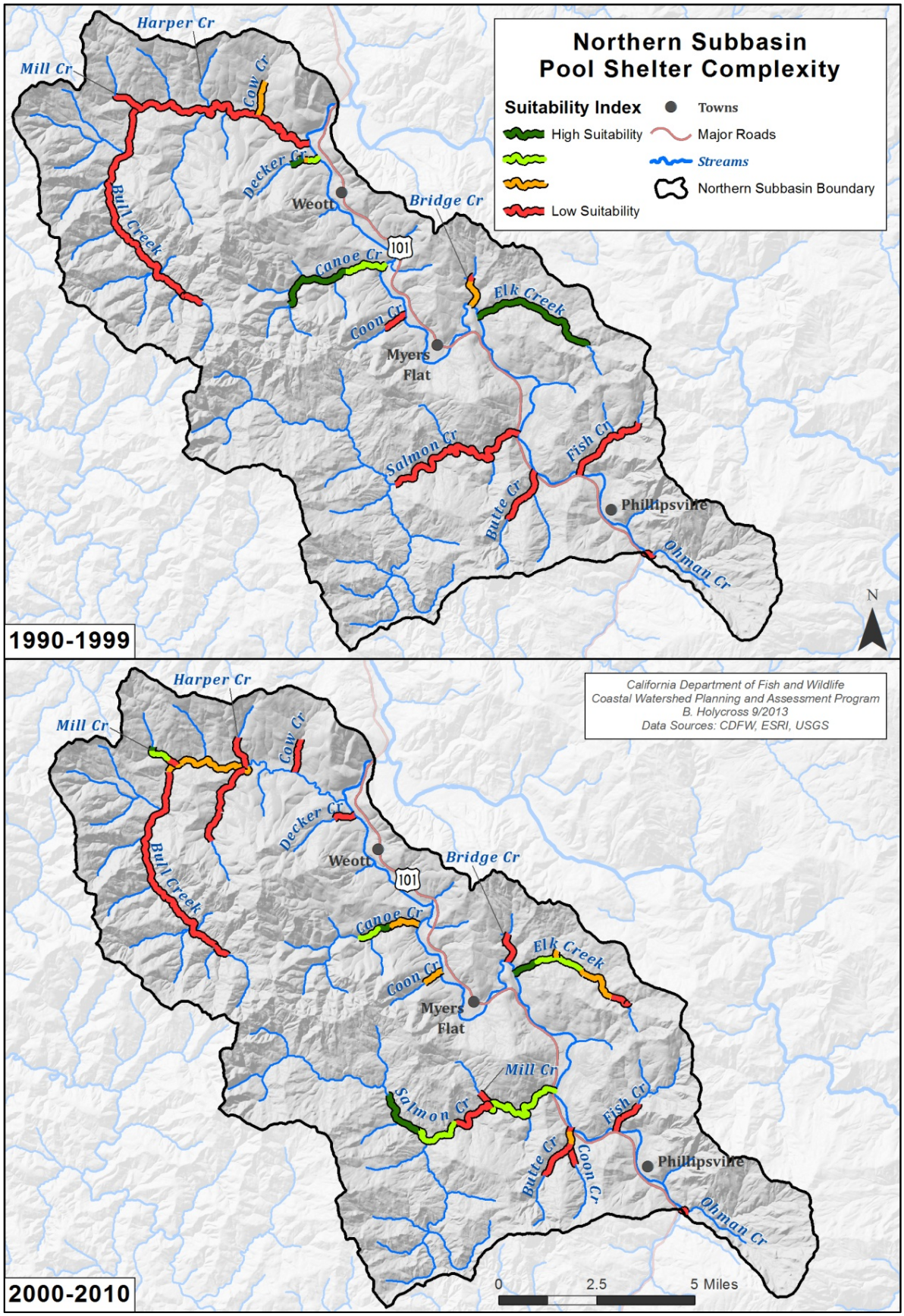


Figure 38. Pool shelter suitability for Northern Subbasin streams, as determined by the EMDS-based analysis using data collected between 1990 and 1999, and 2000 and 2010.

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 39* 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 Northern Subbasin streams over time, with average percent category 1 embeddedness values of 7.8% for data collected in the 1990s and 33.4% for data collected between 2000 and 2010 (*Table 21*).

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 39*). Although nearly 30% 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 percent of pool tails in category 2 stayed nearly the same (35-38%); the percent of pool tails in embeddedness category 3 was approximately 50% less; and the percent of pool tails in category 4 were reduced by about 75% when comparing the two time periods. The percent of pool tails in category 5 increased over time, especially in the Bull Creek drainage where sediment input from slopes and active landslides is widespread.

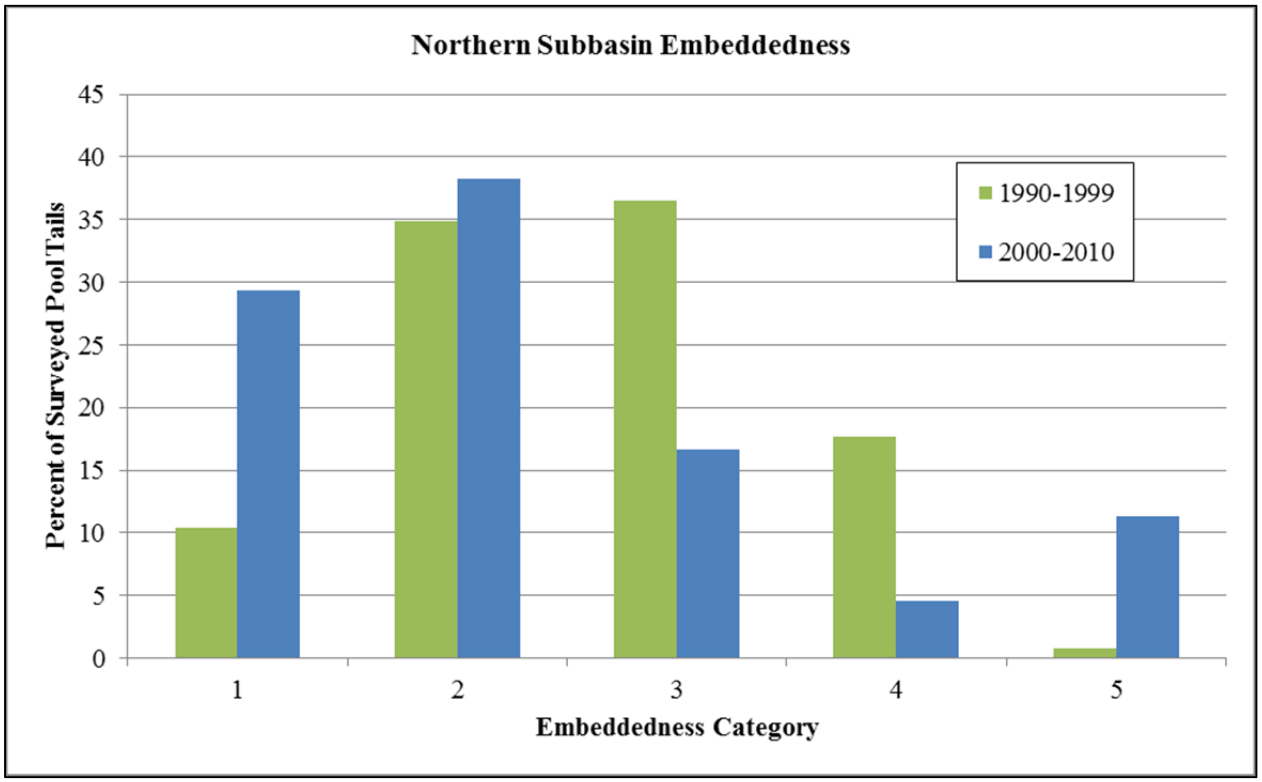


Figure 39. Cobble Embeddedness in the Northern Subbasin, using data collected from 1990-1999 and 2000-2010.

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 Northern Subbasin between the 1990s and early 2000s (*Figure 40*). The most dramatic increases were recorded in Salmon Creek, which had overall embeddedness suitability values in the lowest category in the 1990s, increasing to the highest suitability in the 2000s. Other streams with improved embeddedness suitability in some or all surveyed reaches were Bull, Decker, Elk, Ohman, and Butte creeks. These improvements are most likely due to sediment from historical floods moving through the system, and to bank stabilization and upslope watershed restoration projects that have been completed or are in progress throughout the subbasin.

Embeddedness scores decreased in the upper reaches of Canoe Creek between the two time periods. This was due to habitat degradation (in both old and young growth stands) and associated increases in sediment input resulting from the Canoe Creek fire in 2003.

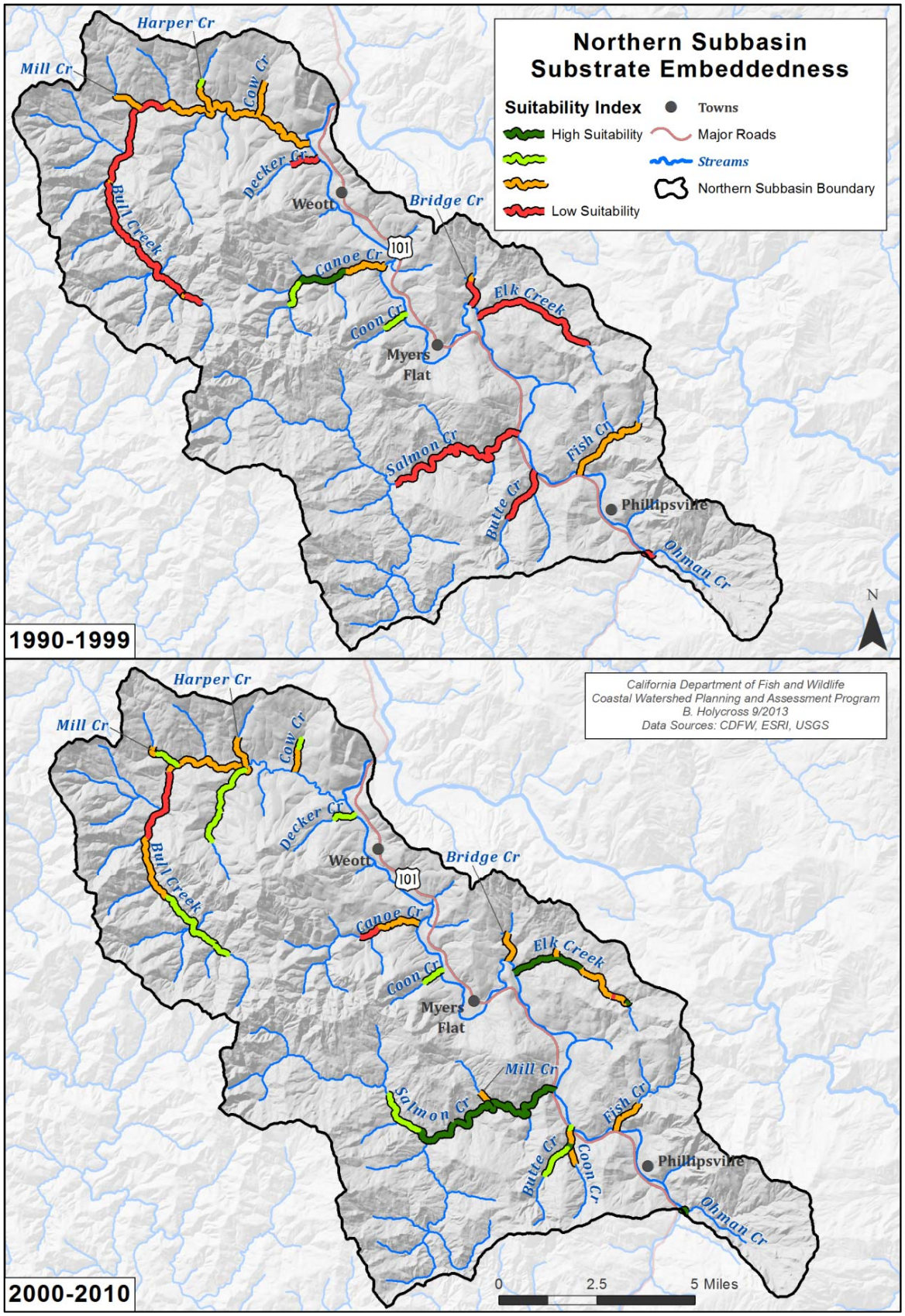


Figure 40. Embeddedness suitability in Northern Subbasin streams, as determined by the EMDS-based analysis using data collected during between 1990 and 1999, and 2000 and 2010.

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 Northern 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 Northern Subbasin streams in all subbasin reaches during both time periods (*Table 24*). LWD was the second most dominant shelter type in Northern Subbasin streams during both sampling periods. Large woody debris increased as the dominant shelter, from only 2 reaches in the 1990s to 9 reaches in the early 2000s. This was expected due to the predominance of coniferous and hardwood forest vegetation types, which supply LWD to streams, and due to restoration efforts and management strategies designed to encourage natural LWD recruitment and placement in Northern Subbasin streams.

Table 24. Dominant pool shelter type by number of reaches surveyed in Northern Subbasin streams.

Dominant Shelter Type	1990-1999	2000-2010
Boulders	30	31
Root masses	0	3
Terrestrial vegetation	0	2
LWD	2	9
SWD	1	1
Aquatic vegetation	0	0
Undercut banks	0	1
Whitewater	0	0
Total number of reaches surveyed	**33**	**47**

The average percent shelter from LWD in pools in Northern Subbasin streams was relatively low during both sampling periods, but increased slightly over time (*Table 25*). These low values may be due in part to past management practices. In the 1960s and 1970s, large wood was aggressively removed from channels, but recent restoration activities have emphasized adding large wood back into streams, 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 low (<5%), indicating the need for additional large wood as vital rearing and holding habitat components in all Northern Subbasin streams.

Table 25. Total length of pool habitat and average percent shelter from LWD in Northern Subbasin streams using data collected during two time periods: 1990-1999 and 2000-2010.

Northern Subbasin	Total length of pool habitat (mi)	Avg % shelter from LWD
1990-1999	6.86	2.09
2000-2010	8.57	3.31

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).

The percentages of pool habitat in Northern Subbasin streams were below optimal levels during both sampling periods (*Table 26*). Aggradation from numerous active landslides and unstable geology may have contributed to a decrease in channel complexity and less than optimal pool-riffle ratios in this subbasin, particularly in the Bull Creek drainage near Cuneo, Burns, and Slide creeks.

Table 26. Percent pool and riffle habitat, and pool riffle ratios for Northern 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	20	40	33 : 66
2000-2010	24	41	37 : 63

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 31 sampling locations (30 in tributaries and one in the mainstem SF Eel River) in the Northern Subbasin (*Figure 41*). Data loggers were generally deployed from June through October, and

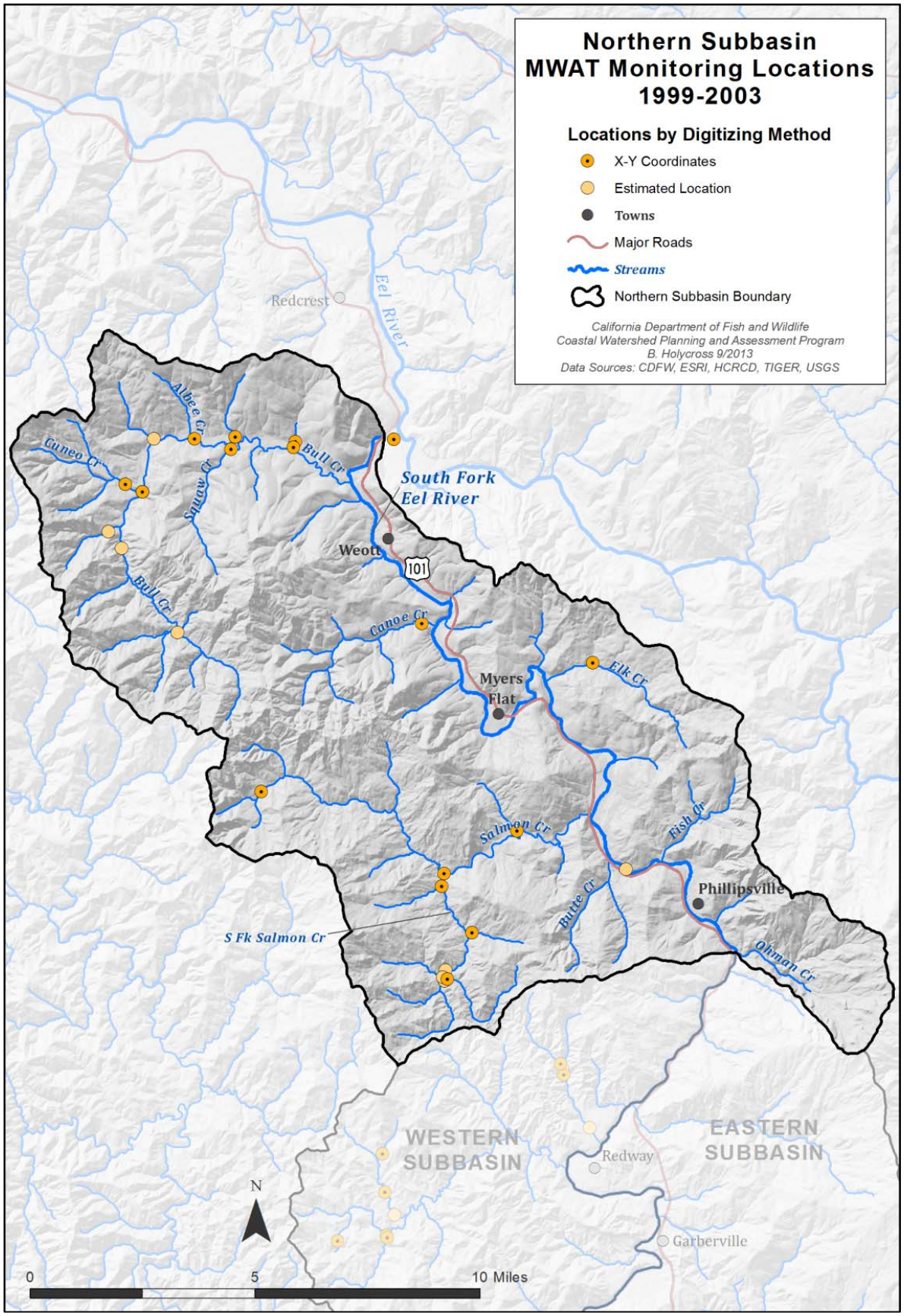


Figure 41. Locations of temperature monitoring sites in the SF Eel River Northern Subbasin (Friedrichsen 2003).

not all sites were sampled every year. Some large streams (e.g. Bull Creek) 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, 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 temperatures based on MWATs, considering the effect of temperature on salmonid viability, growth, and habitat fitness (*Table 27*). 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 27. 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 suitability ranges, only 8 sites (on 6 creeks) in the Northern Subbasin had good stream temperatures (*Table 28*). Seven sites (on 6 creeks) had fair stream temperatures, and more than half of the sampled sites (16 locations on 11 creeks) had poor stream temperatures (*Figure 42*). Many of the sampling sites in areas with poor temperatures were located in the two largest streams in the subbasin, Bull and Salmon creeks, and at one site in the mainstem SF Eel River. The mainstem Bull Creek above Rockefeller Forest has very little canopy cover and large amounts of sediment entering from upstream sites near Cuneo Creek, resulting in increased temperatures from shallow pools filled in with sediment, and increased direct solar radiation from reduced riparian cover and wide channels. Warm water temperatures in mainstem Salmon Creek are due to reduced riparian canopy and increased water diversion for residential use and industrial marijuana cultivation operations. Researchers obtained a maximum daily average reading at the Miranda Bridge site in the mainstem SF Eel River of 76˚F, which exceeded the lethal temperature for salmonids if cooler refuge areas 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.

Table 28. Maximum weekly average temperatures (MWATs) and ranges collected in SF Eel River Northern 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)				
Cow Creek	1532	60	60	5
Cow Creek	9623	60	60	4
Canoe Creek	1303	62	62	1
Cow Creek	1305	61	61	1
Cuneo Creek	1444	62	62	1
Decker Creek	8065	61	61	1
Harper Creek	1467	61	61	1
Squaw Creek	1302	61-62	61	5
Fair Stream Temperature (63-65°F)				
Bull Creek	1668	57-66	63	3
Canoe Creek	9622	63	63	3
Preacher Gulch	8031	63	63	2
Cuneo Creek	8048	62-66	64	2
Elk Creek	8004	62-68	64	4
Mill Creek	8033	64	64	3
Bull Creek	1512	59-69	65	5
Poor Stream Temperature (≥66°F)				
Bull Creek above Kemp	8064	67	67	1
Burns Creek	1424	67	67	2

Creek	Site	MWAT Range (°F)	Average MWAT (°F)	Years of Data
Panther Creek/Bull Creek	8066	66	66	1
Salmon Creek (Moeschke's)	8023	62-73	67	3
Tostin Creek	8039	66-68	66	3
Bogus Creek	8037	63-73	68	2
Bull Creek	1417	68	68	1
Bull Creek	8047	69	69	1
Cuneo Creek	1670	68	68	2
Kinsey Creek	8036	66-69	68	2
Salmon Creek	1629	73-75	74	2
Salmon Creek, South Fork	8024	71	71	1
Salmon Creek, lower	8056	73	73	1
Salmon Creek, South Fork	8055	70-71	71	2
Salmon Creek, South Fork Estes	8042	69	69	1
South Fork Eel River (Miranda)	1415	76	76	1

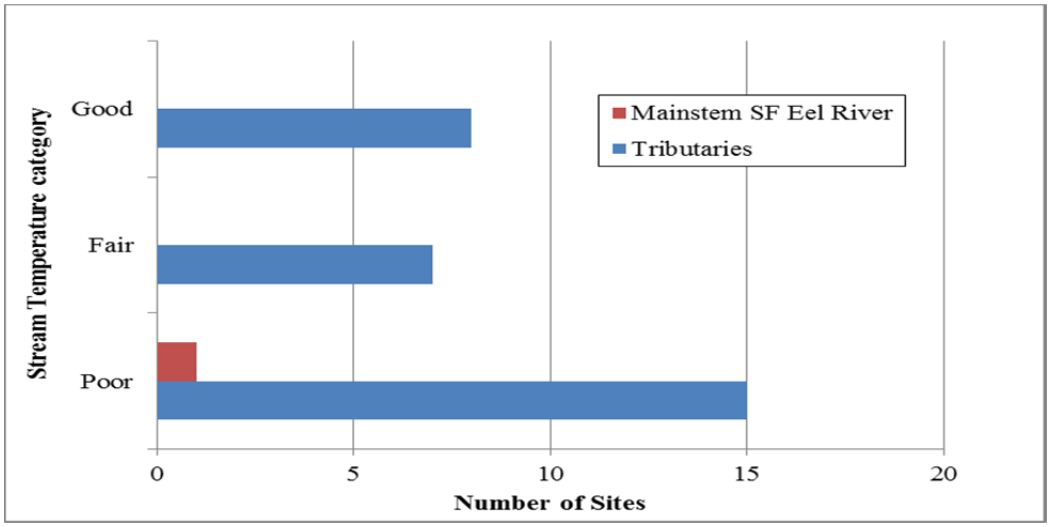


Figure 42. Number of sites in each suitability rating category for MWATs collected from 1999-2003 (n=31; 30 tributary and 1 mianstem sites) in SF Eel River Northern Subbasin streams (data from Friedrichsen 2003).

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 the Eel River Basin. Higgins compared 2012 stream temperatures with data collected at similar locations by HCRCD between 1995 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. Mainstem temperatures near Piercy were above optimal for salmonids, and near Phillipsville and Miranda, recorded temperatures were highly stressful 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, Higgins 2012). 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 Northern 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).

Northern Subbasin streams had more poor temperature conditions compared to Eastern and Western subbasin streams because of the relatively large number of sampling locations (27 of 31) in the Bull and Salmon creek drainages. The mainstem of Bull Creek has very little canopy cover and large amounts of sediment entering from upstream sites near Cuneo Creek, resulting in increased temperatures from shallow pools filled in with sediment and increased direct solar radiation from reduced riparian cover and wide channels. Warm water temperatures in mainstem Salmon Creek are a result of reduced riparian canopy and decreased flow from water diversions.

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 7 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 43*). Of the SF Eel River sites, daily average temperatures 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. At the Phillipsville site, located within the Northern 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 Northern Subbasin streams, particularly in tributaries to larger creeks and in locations further upstream in tributaries sampled by Friedrichsen et al. and ERRP. 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.

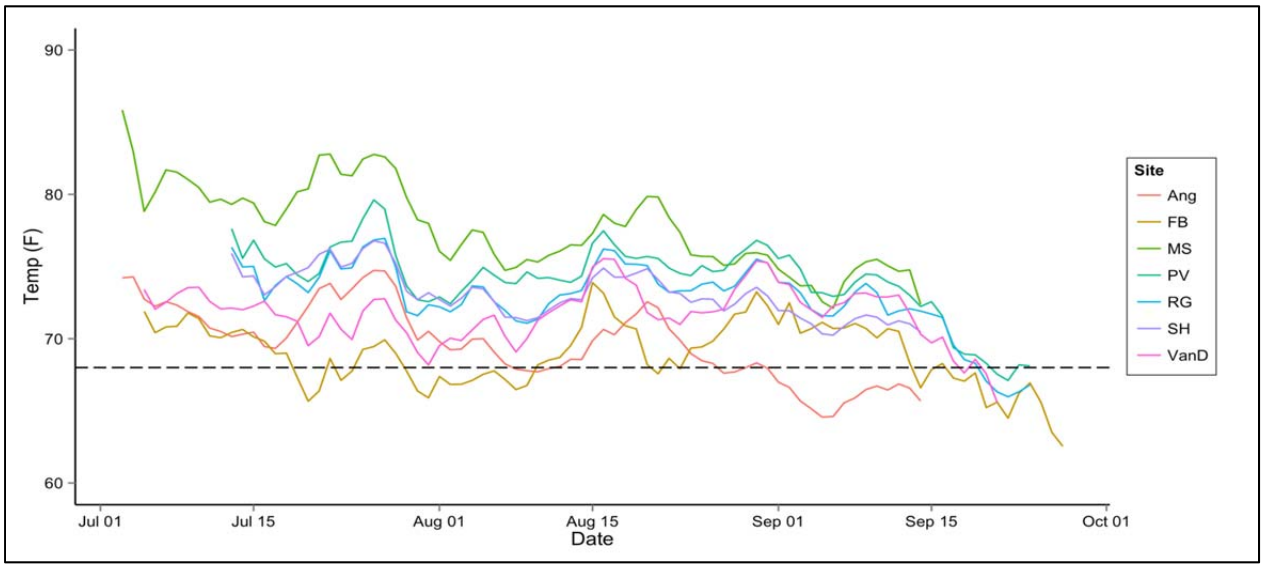


Figure 43. Daily average temperatures (degrees F) from July 3 through September 24, 2013, recorded at 7 sampling locations in the Eel River Basin. Data and graph provided by Keith Bouma-Gregson (UC Berkeley, 2014). Ang = Angelo Reserve; FB = Fernbridge; MS = Mainstem Outlet Creek; PV = Phillipsville; 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 Northern 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 two locations in the Northern Subbasin: the mainstem SF Eel River near Miranda (RM 17), and Bull Creek (RM 2). The Bull Creek gauge is located approximately 4 miles upstream from the confluence of the SF Eel River, near the confluence of Albee Creek. Records from these gauges 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 44, Figure 45*). These low flows may be caused by an increase in both the number of diversions and the quantity of water diverted from subbasin streams and tributaries for agricultural and domestic uses.

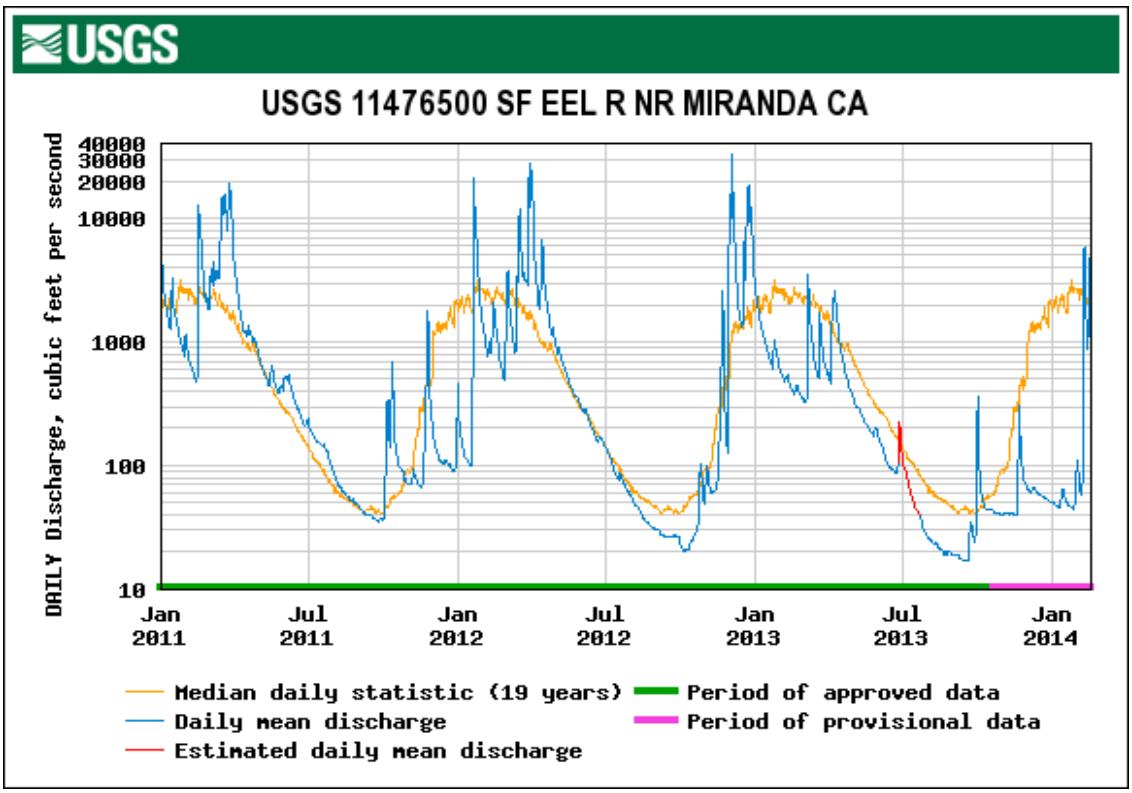


Figure 44. Daily mean discharge (in cfs) and mean daily discharge (73-year average in cfs) for USGS gauging station at SF Eel River near Miranda, showing 2011-2014 data.

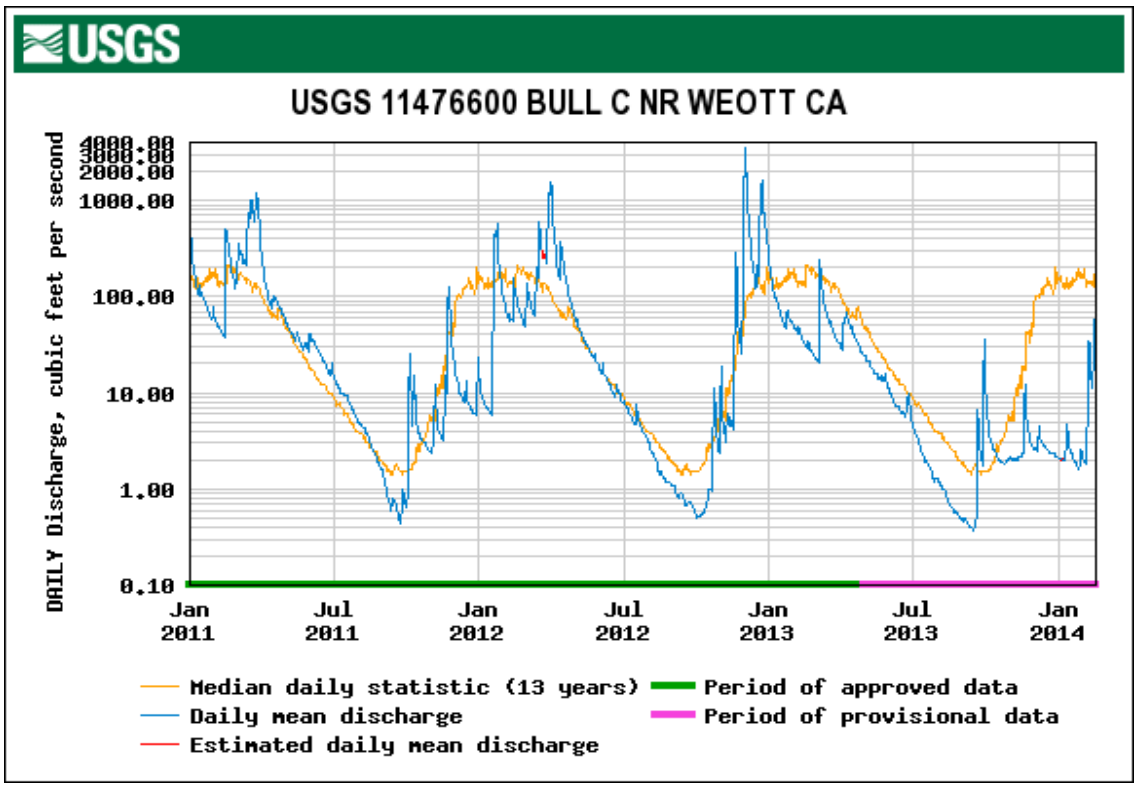


Figure 45. Daily mean discharge (in cfs) and mean daily discharge (52 year average in cfs) for USGS gauging station at Bull Creek, showing 2011-2014 data.

In August and September 2013, CWPAP staff conducted a brief low flow study in the SF Eel River Basin, collecting information at 6 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 (due to limited rainfall in the winter of 2012-2013, and to an increase in the number of diversions for residential use and marijuana cultivation) throughout the basin, and to compare conditions in streams that are heavily diverted with those that are not heavily diverted. In streams that were not impacted by diversion (n = 15) and in streams that were not heavily impacted by diversion (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. In Salmon Creek, CWPAP staff noted significant decreases in flow and reduced salmonid habitat between field visits conducted on 8/27/2013 and 9/19/2013 (*Figure 46 A, B*).

Figure 46 A, B. View of Salmon Creek from Maple Hills Road bridge (RM 0.15) on 8/27/2013 (left (A)) and on 9/19/2013 (right (B)). While flow was diminished, the stream channel was connected in August; however, when field crews returned three weeks later only one isolated pool was present below the bridge.

The Salmonid Restoration Federation (SRF) initiated a low flow study in Redwood Creek near Redway, located just south of the Northern Subbasin boundary. SRF began collecting baseline streamflow data in the summer of 2013. Data were collected at eleven sites in the Redwood Creek watershed, from upstream areas including Pollock and China Creeks, to downstream sites near the confluence of Redwood Creek and the SF Eel River. 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;
- 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.

Although the Redwood Creek watershed is not within the boundaries of the Northern Subbasin, SRF's findings most likely apply to other areas throughout the SF Eel River Basin, particularly in areas with similar land use patterns such as Salmon Creek in the Northern Subbasin. For a full description of the SRF low flow project and results, see the Flow section in the Western Subbasin part of this assessment.

Water Diversion and Voluntary Conservation

The effects of low flow, diversions, and warm water temperatures on salmonids are major concerns in streams throughout the Northern Subbasin. There are currently no projects in development to address these issues in Northern Subbasin streams, but there are ongoing efforts in Redwood Creek (near Redway), which is located just south of the subbasin boundary. The Redwood Creek watershed has similar land use patterns and low flow concerns as Salmon Creek. A brief overview of the study is presented here, but for a more detailed description of the project and results, see the Western Subbasin section of this report. For additional information and project updates, go to the SRF website: http://www.calsalmon.org/

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, thereby reducing diversions and increasing 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.

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.

Preliminary results from the Redwood Creek study indicated the following:

- Flow was intermittent in most streams from August through September;
- All sites had less than 1 gpm flow in mid-September;
- Bedrock substrate was the main factor in maintaining pools; and
- Groundwater recharge was highly variable.

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.

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 Northern Subbasin watersheds.

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, 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 29*).

Table 29. 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
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 t/km^2/year of natural sediment, there was one t/km^2/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/km^2/year or 1.9 tons/km^2/day on a 15 year running average (*Table 30*). 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 30. USEPA basinwide estimates of sediment sources for the SF Eel River Watershed from 1981-1996 (USEPA 1999).

Sediment Source	Total sediment input (t/year)	Unit area sediment input (t/km2/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 t/km^2/year, and the TMDL for the basin would be 473 t/km^2/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 Northern 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 Northwestern California between 1998 and 2003 (PWA 2005). The study area included 12.23 miles of decommissioned roads in the Bull Creek drainage in the SF Eel River Northern Subbasin, with 94 treated sites (81 stream crossings, 3 landslides, and 10 "other" sites). PWA 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 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. Other sediment reduction projects completed in the basin (see Fish Restoration Programs section) will 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 7 Eel River Basin sites (one of which is located in the Northern Subbasin at Phillipsville) while collecting cyanotoxin and temperature data in the summer of 2013. He 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, 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 Northern 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 Northern Subbasin (Salmon Creek and Elk 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, Salmon Creek invertebrate populations were among the healthiest in the SF Eel River Basin. Conditions have changed in the Salmon Creek watershed since Friedrichsen's study was completed; streams are heavily diverted, and much of the diverted water is used 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 needed 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.

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 47*), 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 47. 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 Northern Subbasin drainages where nutrients, sediment, and/or pollutants are entering streams from large marijuana cultivation operations (e.g. Salmon 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 lower mainstem areas of SF Eel River in the Northern 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 Northern Subbasin, cyanobacteria blooms have been reported only in the mainstem SF Eel River. However, additional studies targeting Northern 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 (natural or anthropogenic), lifespan (temporary or permanent), and effectiveness (partial or total). Natural barriers include gradient, landslide, flow/habitat, 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 Northern Subbasin. Most of the barriers are gradient barriers, followed by total and partial culvert barriers (*Figure 48*). In the Northern Subbasin, there were four landslide barriers located in the upper Bull Creek drainage, and three LDA barriers in lower Bull Creek (*Figure 49*). 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 48. Example of total culvert barrier in Feese Creek.

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 its entire 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. Most culvert barriers are located in Northern Subbasin streams near the mainstem SF Eel River, where Highway 101 and its frontage road cross tributaries. Two partial culvert barriers are located in the Bull Creek drainage, where the Mattole Road crosses Cow and Harper creeks.

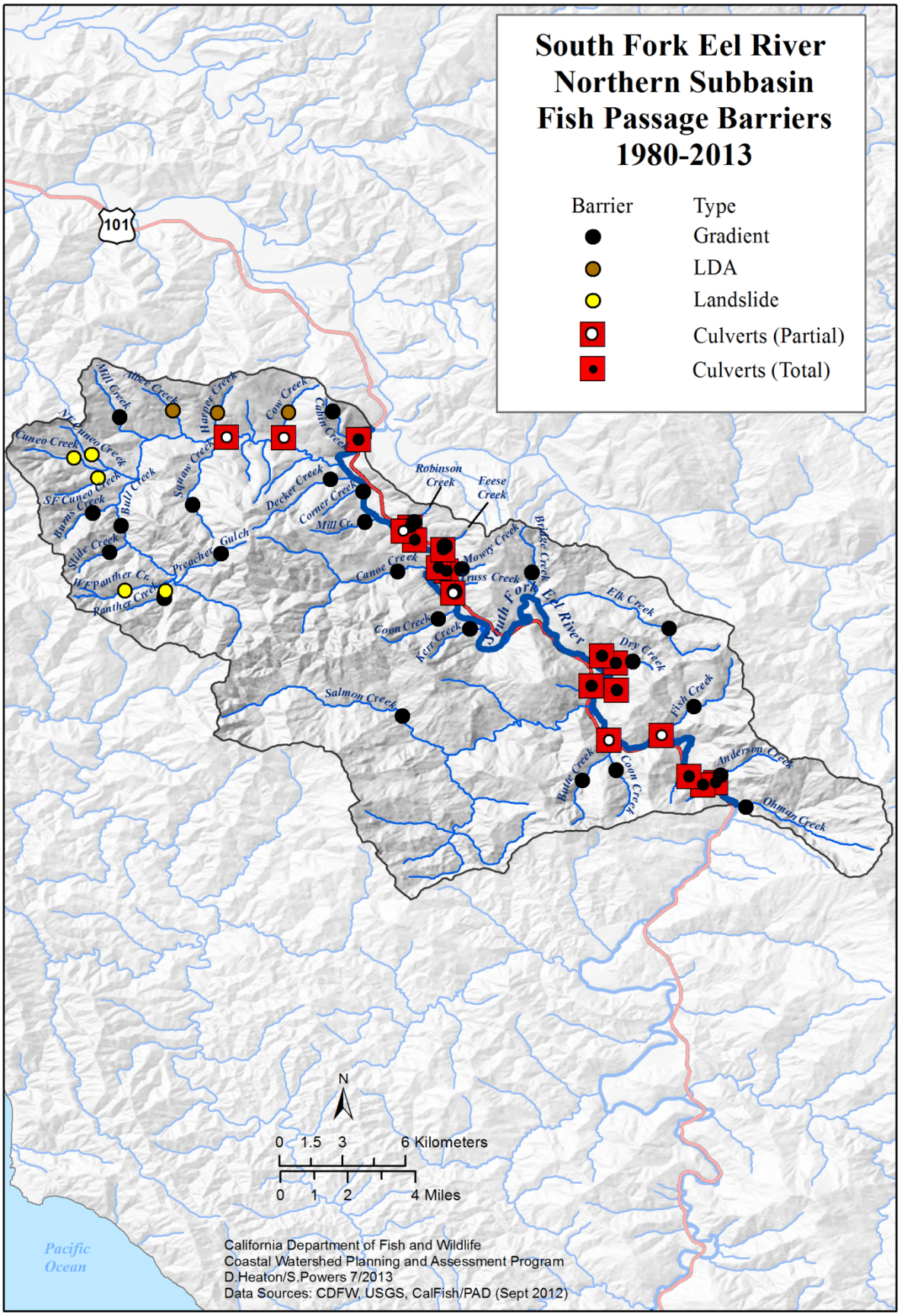


Figure 49. Fish passage barriers in the SF Eel River Northern Subbasin.

Gradient barriers caused by boulders or bedrock are found throughout Northern Subbasin streams (*Figure 50*). Most of the gradient barriers mapped in the Northern Subbasin were waterfalls, which are considered extreme examples of gradient barriers. The largest waterfall barrier (30' high) in the Northern Subbasin can be found on Salmon Creek (RM 7.3), 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 persist for decades as total barriers. Stream inventories in the Northern Subbasin found LDA barriers in Cow, Harper, and Albee creeks. Historically, large flood events resulted in increased sediment and woody debris (large and small) input to streams. Many large debris jams were documented in stream surveys following the floods, and restoration activities at that time 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.

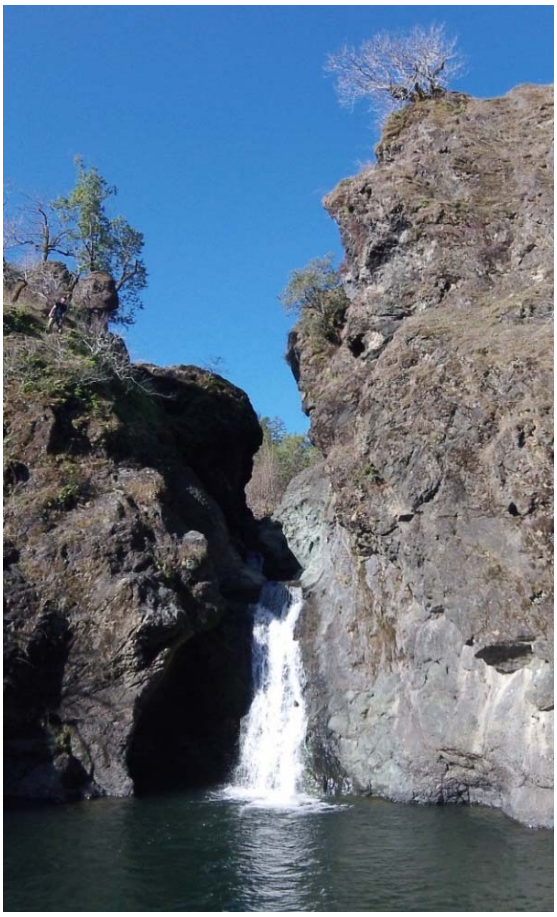


Figure 50 A, B. Thirty foot bedrock waterfall barrier on upper Salmon Creek (left (A)) and house sized boulder creating a 20' waterfall barrier (right (B)) to fish passage on Ohman Creek, 450 meters upstream of the confluence with the South Fork Eel River.

Habitat Conclusions

Overall Suitability

CWPAP staff assessed changes in Northern 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, spawning habitat was generally good in Northern Subbasin streams, but siltation and habitat destruction from past land use practices and flooding was noted following the large flood events in 1955 and 1964. Barriers documented on historical surveys were primarily log jams and landslide debris, with the same large gradient barriers (waterfalls) as those identified in recent habitat typing surveys.

Where habitat data were available from both the late 1990s and early 2000s, average embeddedness and canopy density scores in Northern Subbasin streams increased considerably, and most primary pool length and pool shelter scores increased slightly over time (

Table 31). Although some increases in these factor values were seen, average values were below target values for all streams and these habitat factors are likely limiting to salmonid populations.

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 in most Northern Subbasin streams over time.

Pool depth and pool shelter were well below target values, and suitability in most Northern Subbasin streams was in the lowest suitability category for both of these factors. Pool shelter suitability increased slightly in Bull and Salmon creeks, but primary pool habitat was lacking. Both pool depth and pool shelter are likely limiting factors in Northern Subbasin streams.

Cobble embeddedness suitability increased on nearly all Northern Subbasin streams when comparing habitat data collected in the 1990s and early 2000s. Embeddedness scores increased significantly on Ohman and Salmon creeks, where suitability in the 1990s were in the lowest category, and by the early 2000s were in the highest suitability category. Improvements in spawning habitat conditions are due to sediment from large historic flood events moving through the system, and to restoration activities designed to reduce erosion in streams throughout the subbasin.

Summer water temperature measurements showed that water temperatures were good for salmonids in headwaters areas near Branscomb, but were stressful for salmonids at downstream sites near the confluence with the Eel River. Many of the sampling sites in poor habitats were located in the two largest streams in the subbasin, Bull and Salmon creeks, and lethal temperatures were recorded in the mainstem SF Eel River. Mainstem Bull Creek has very little canopy cover and large amounts of sediment entering from upstream sites near Cuneo Creek, resulting in increased stream temperatures from shallow pools filled in with sediment, and increased direct solar radiation from reduced riparian cover and wide channels. Warm water temperatures in mainstem Salmon Creek are due to reduced riparian canopy and increased water diversion for 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 Northern 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 temporary road construction. 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.

Table 31. EMDS-based Anadromous Reach Condition Model suitability results for factors in Northern Subbasin streams (ND = no data available).

Stream	Survey Year	Mean Canopy Density (%)	Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Pool Shelter Rating
Bridge Creek	1993	-	--	--	-
	2007	++	-	--	--
Bridge Creek (unnamed tributary)	2007	++	--	--	--
Bull Creek	1991	--	--	--	--
	2007	-	-	--	--
Butte Creek	1993	+	--	--	--
	2009	++	+	--	--
Canoe Creek	1992	++	+	--	++
	2007	++	-	--	+
Coon Creek (SF Eel River)	1993	-	+	--	--
	2007	++	+	--	-
Cow Creek	1991	-	-	--	-
	2007	++	-	--	--
Decker Creek	1992	++	--	--	+
	2010	++	+	--	--
Elk Creek	1992	++	--	--	++
	2007	++	+	--	+
Elk Creek (unnamed tributary #7)	2007	++	++	--	--
Fish Creek	1999	++	-	--	--
	2007	++	-	--	--
Harper Creek	1991	+	-	--	ND
	2007	++	-	--	--
Mill Creek (Bull Creek)	1991	-	-	--	--
	2007	++	+	--	+
Mill Creek (Salmon Creek)	2009	++	-	--	--
Ohman Creek	1992	--	--	--	--
	2007	-	++	--	--
Salmon Creek	1992	--	--	--	--
	2007	-	++	--	+
Squaw Creek	2010	++	+	--	--
Key: ++ = Highest Suitability			**-- = Lowest Suitability**		

Restoration Projects

Cataloging restoration projects has been facilitated by increased funding and the associated tracking requirements. 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 Northern Subbasin.

There have been 68 restoration projects, totaling more than 7 million dollars in funding, completed in the Northern Subbasin from 1982 to the present (*Table 32*). The most common type of project has been upslope watershed restoration, followed by: bank stabilization; watershed evaluation, assessment and planning; and instream habitat improvement. The highest levels of funding have been allocated to upslope watershed restoration (more than half of the overall funding) and bank stabilization projects. Primary historical land uses in this subbasin were commercial timber harvest, residential development, and grazing/non-industrial timber harvest, but much of the land is currently within the boundaries of Humboldt Redwoods State Park, and restoration has been a focus of the CA State Park system.

Upslope watershed restoration projects have been completed in select tributaries of Bull Creek and throughout the Salmon Creek watershed (*Figure 51*). Bank stabilization projects have been done primarily in the Salmon Creek watershed and in some areas of upper Bull Creek. Riparian habitat improvement projects have been completed in middle Bull Creek near Cuneo Creek, Salmon Creek, and in the mainstem SF Eel River. Instream habitat improvement projects have been completed in the mainstem Bull Creek, Tostin Creek, and Elk Creek.

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

Table 32. Northern Subbasin restoration project type and funding (1982 to 2013).

Project Type	# of Projects	Total Project Funding
Bank Stabilization	10	$1,107,529
Cooperative Rearing	3	$72,548
Fish Passage Improvements	1	$319,848
Instream Habitat Improvement	8	$513,810
Land Acquisition	0	$0
Monitoring	3	$122,412
Other *	8	$168,556
Riparian Habitat Improvement	1	$35,743
Upslope Watershed Restoration	24	$4,389,170
Watershed Evaluation, Assessment & Planning	10	$568,939
Total	**68**	**$7,298,556**
* "Other" includes education/outreach, training, capacity building and public involvement.		

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. In the northern part of the subbasin, which is nearly entirely owned by the CA State Park system, restoration has been a high priority. Following the 1955 and 1964 floods, the Park purchased the last acreage in the Bull Creek drainage and industrial timber harvest ended in more than half of the subbasin. Current management actions are needed to address diversion, flow, and pollution in residential areas, particularly in the larger watersheds such as Salmon Creek in the southern part of the subbasin.

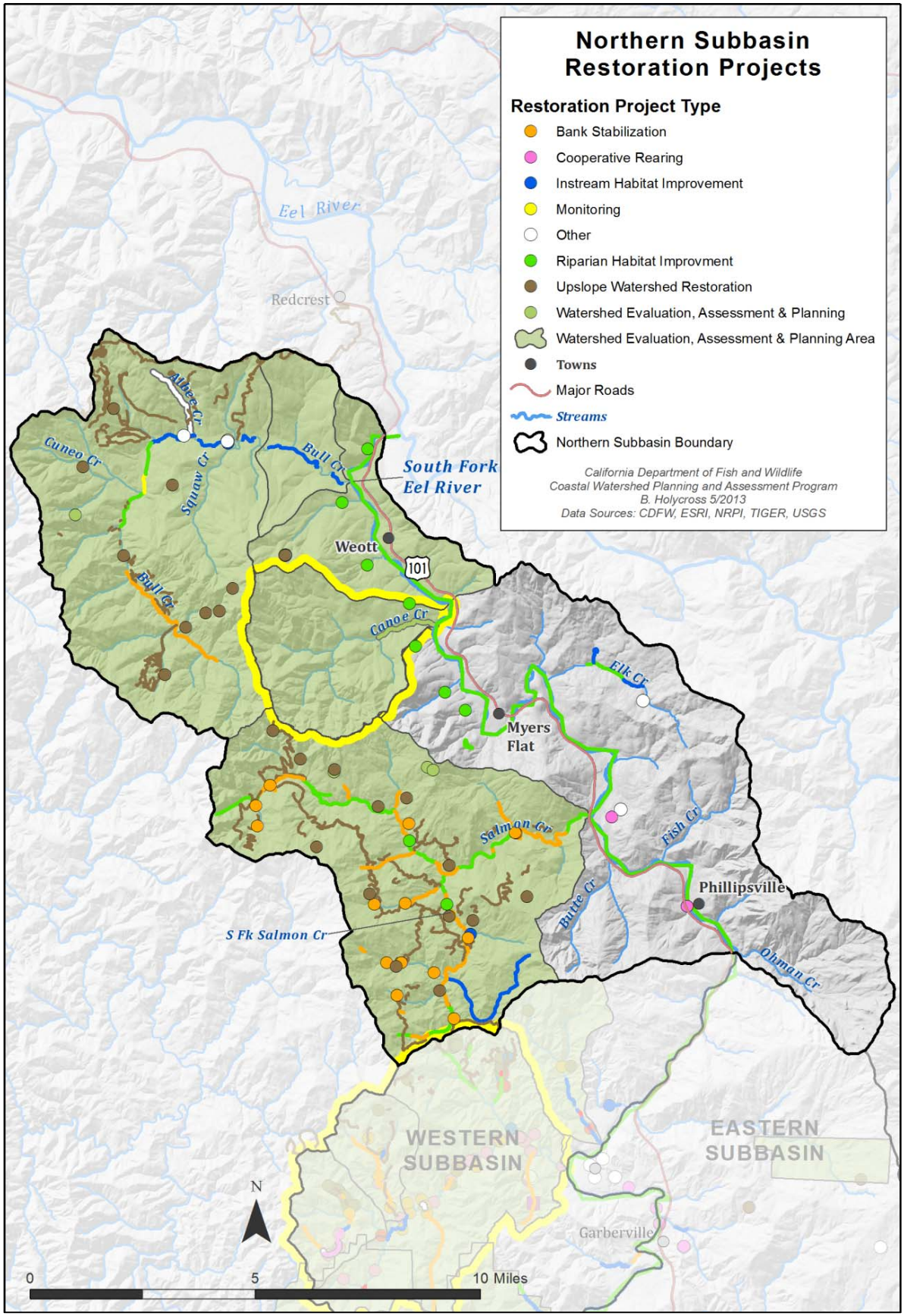


Figure 51. Restoration projects completed between 1982 and 2013 in the Northern Subbasin.

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 Northern Subbasin, 34 streams were inventoried (58 surveys; 108 miles total), and recommendations for each were selected and ranked by a CDFW biologist (*Table 33*). 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 SF Eel River Basin Profile.

In order to compare tributary recommendations within the subbasin, the recommendations of each stream were collapsed into five target issue categories (*Table 34*). The top three recommendations of each stream are considered to be 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 Northern Subbasin is instream habitat: recommendations for pool/cover categories occur more than twice as frequently as both erosion/sediment and riparian/water temperature categories (*Table 34*).

However, comparing recommendation categories in the subbasin by number of tributaries can be confounded by differences in the length surveyed in each tributary. Therefore, the number of stream miles within the subbasin assigned to various recommendation categories was calculated (*Figure 52*). By examining recommendation categories by number of stream miles, the most important target issue remains instream habitat (>150 miles of streams surveyed had this as the primary recommendation). Riparian/water temperature and erosion/sediment recommendations were the second and third most important target issues in Northern Subbasin streams. Because of the high number of recommendations dealing with these target issues, high priority should be given to restoration projects that emphasize riparian improvement or other projects resulting in decreased instream temperatures, and sediment reduction projects addressing input from both natural and anthropogenic sources throughout the subbasin.

Table 33. Occurrence of stream habitat inventory recommendations for streams of the Northern Subbasin.

Stream	Survey Length (miles)	Bank	Roads	Canopy	Temp (A=study required)	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Albee Creek (1991)	0.6	4				1	2		3		5
Brian's Creek (1992)	0.6					1	2				3
Bridge Creek (1992)	1	3	4			1	2	5			
Bridge Creek (1993)	1	3	4			1	2				
Bridge Creek (1999)	0.9	4	5	6	A1	2	3				
Bridge Creek (2007)	1	3	4		A5	1	2				
Bull Creek, Lower (1991)	8.6	4	5	6	A1	2	3				
Bull Creek, Middle (1991)	1.1	4	5			1	2		3		6
Bull Creek, Upper (1991)	3.7	4	5	7		1	2		3		6
Bull Creek, Lower (1998)	9	4	5	6	A1	2	3				
Bull Creek, Upper (1998)	3.2	1	2	3	A8	5	6	4	7	9	10
Bull Creek (2001)	0.4	4	5	6	A1	2	3	7	8	9	10
Bull Creek (2007)	9.7	3	4	5	A6	1	2				
Bull Creek Unnamed Trib (1992)	1.4	2		1		3			4		
Burns Creek (1991)	0.6	3				1	2				4
Burns Creek (1998)	0.7	2		1							
Butte Creek (1993)	1.7	1	2	5		3	4		6		
Butte Creek (2009)	1.4	3		4	A1		2				
Canoe Creek (1992)	3.4	5		3	A1	2	4				
Canoe Creek (2007)	1.9				A2		1				
Coon Creek (SFE) (1993)	0.7	6		3		4	2		5		1
Coon Creek (SFE) (2007)	0.6				A2		1				
Coon Creek (Butte) (2007)	0.5	3			A4	2	1				
Cow Creek (1991)	0.6	3				1	2				4

Stream	Survey Length (miles)	Bank	Roads	Canopy	Temp (A=study required)	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Cow Creek (2007)	1				A2		1				
Cuneo Creek (1991)	1.4	2	3	1		4	5				
Cuneo Creek, NF (1991)	0.8	4		1		2	3				
Cuneo Creek, SF (1991)	0.2					1	2				
Decker Creek (1992)	0.8										1
Decker Creek (2010)	0.6				A1		2				
Elk Creek (1992)	3.5	2	4		A1	3	6	5			
Elk Creek (2007)	4.1	2			A3	1					
Elk Creek, Unnamed Trib #1 (2007)	0.25				A1						
Elk Creek, Unnamed Trib #7 (2007)	0.21				A1						
Fish Creek (Miranda) (1993)	2.5	4		5	A1	2	3				
Fish Creek (Miranda) (1999)	2.4	5			A1	3	4				2
Fish Creek (Miranda) (2007)	1				A4	3	2				1
Harper Creek (1991)	0.9	4				1	2		3		5
Harper Creek (2007)	0.9				A3		2				1
Mill Creek (Bull) (1991)	0.8	3	4			1	2				
Mill Creek (Bull) (2007)	1.2	4			A1	2	3				5
Mill Creek (Salmon) (2009)	0.5	4			A1	2	3	5			
Mowry Creek (1993)	0.5					1	2				3
Ohman Creek (1992)	0.3			1		3	2				4
Ohman Creek (2007)	0.3			4	A1	2	3				
Panther Creek, Main (1991)	1.5	1	5	6	A4	2	3				7

Stream	Survey Length (miles)	Bank	Roads	Canopy	Temp (A=study required)	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Panther Creek, Main (1998)	0.7	3		2	A1	4	5				
Panther Creek, SF (1991)	1.4	3				1	2				4
Panther Creek, WF (1991)	1.4	1		2		3	4				5
Panther Creek, Unnamed Trib (1991)	1.3	1		4	A5	2	3				6
Panther Creek,Unnamed Trib (1998)	0.9	3	4	2	A1	5	6	7			
Preacher Gulch (1992)	0.6	1				2	3				
Salmon Creek (1992)	5.2	3	4	2	A1		5				
Salmon Creek (2007)	7.3	2		3	A4		1				
Salmon Creek, SF (1996)	3.9			1	A2	3	4				
Slide Creek (1992)	0.6	1				2					
Squaw Creek (1991)	2.5	3				1	2				
Squaw Creek (2010)	2.7				A1		2				

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 34. Top five ranking recommendation categories by number of tributaries in the Northern Subbasin.

Northern Subbasin Target Issue	Related Table Categories	Count
Erosion / Sediment	Bank / Roads	30
Riparian / Water Temp	Canopy / Temp	39
Instream Habitat	Pool / Cover	80
Gravel / Substrate	Spawning Gravel / LDA	4
Other	Livestock / Fish Passage	7

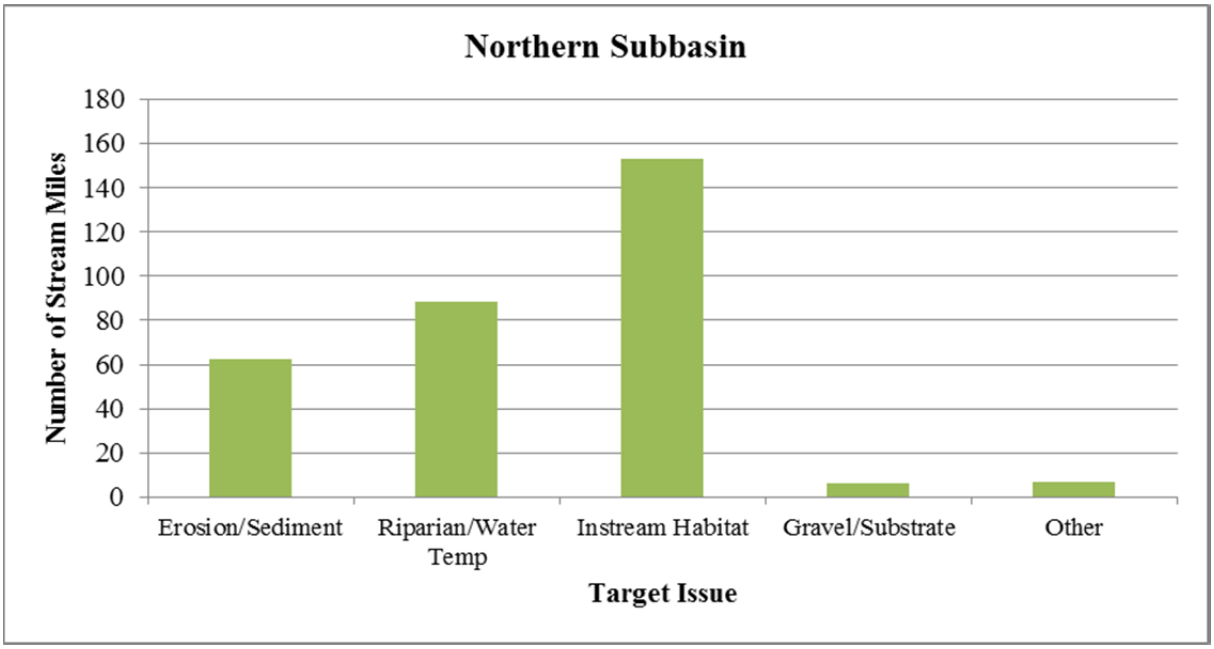


Figure 52. Recommendation target issues by stream miles for the Northern Subbasin.

Refugia Areas

The interdisciplinary team identified and characterized refugia habitat in the Northern 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.

Eighteen Northern Subbasin streams were rated as salmonid refugia areas. 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.

Salmonid habitat conditions in the Northern Subbasin on streams surveyed by CDFW are generally rated as medium potential refugia, with 11 of 18 streams surveyed in that category (*Figure 53*). Squaw and Bull creeks provide the best salmonid habitat in this subbasin, with Squaw Creek being rated high quality habitat and Bull Creek as high potential habitat.

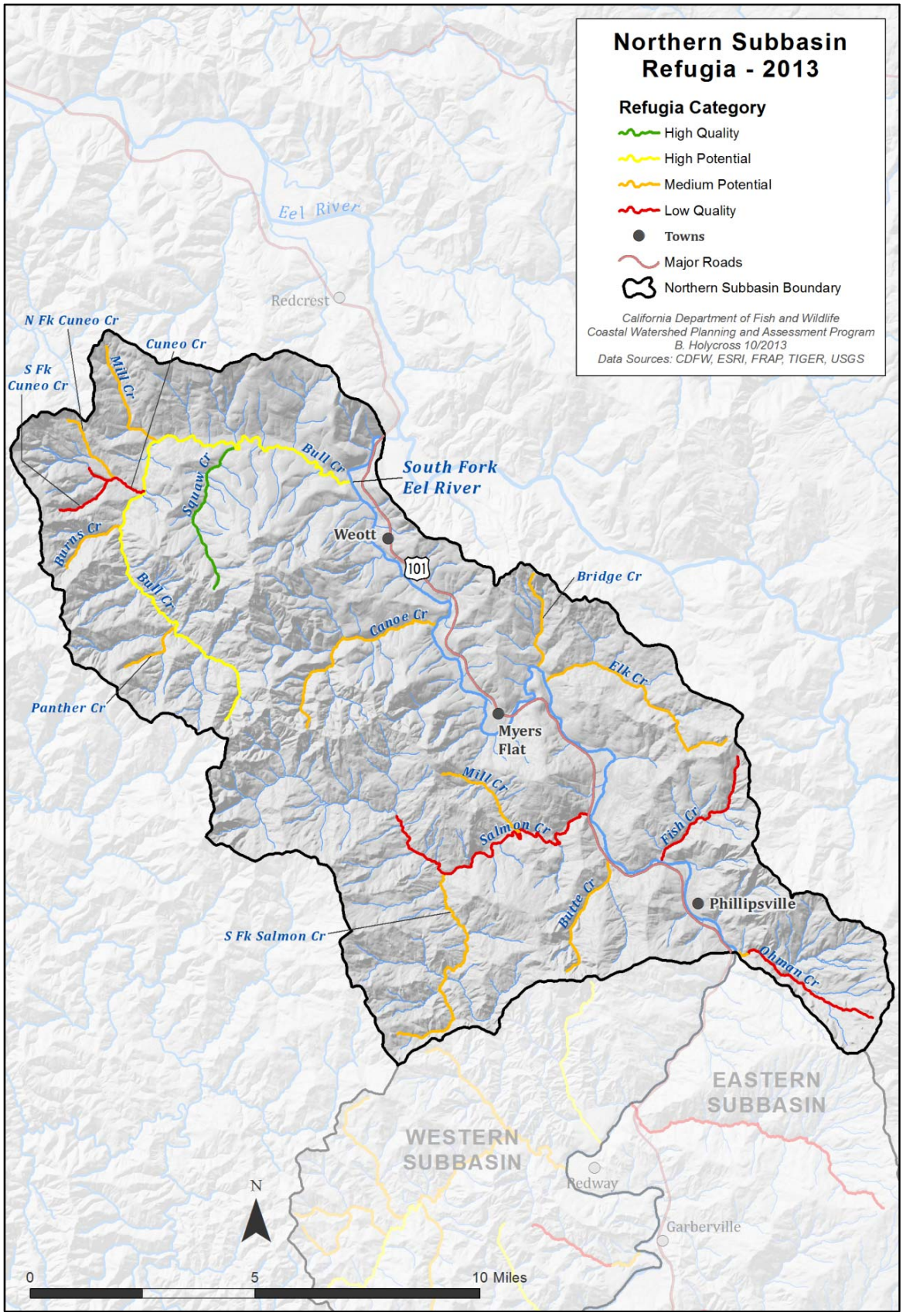


Figure 53. Refugia categories in SF Eel River Northern Subbasin streams.

These streams are both within the boundaries of Humboldt Redwoods State Park, and management priorities include tree planting in areas with intensive historic timber harvest, instream restoration projects (installing and improving instream structures), and road decommissioning projects. Squaw Creek is a high quality salmonid stream flowing through areas of old growth coast redwood forest, with excellent riparian condition and low management impacts (disturbed terrain, displaced vegetation, and diversion). Bull Creek was rated as a high potential refugia stream because although the vegetation and riparian conditions in some areas are relatively high quality, overall pool quality and shelter are low due to extensive fine sediment input in upstream areas, unstable geology, and historic practices such as logging and instream wood removal.

Five streams were rated as low quality refugia: Cuneo, South Fork Cuneo, Salmon, Fish, and Ohman creeks for the following reasons:

- Cuneo and South Fork Cuneo Creek receive a great deal of fine sediment input from active landslides and unstable geology on surrounding slopes. Canopy density, pool depth and shelter, and embeddedness values are all low in the upper Bull Creek watershed;
- Salmon Creek is heavily diverted for residential use and marijuana cultivation, and pool quality is low throughout the drainage;
- A culvert on lower Fish Creek has a steep (7.6%) slope and is a partial barrier to adult salmonids and likely a complete barrier to juveniles. This culvert needs to be replaced and modified, and although the project has been proposed in the past, funding has not yet been secured.
- Ohman Creek has a very limited anadromous reach due to a 15' waterfall approximately 1500' upstream from the confluence with the SF Eel River. The team split this creek into two sections (at 1800' upstream from the confluence of the mainstem SF Eel River) because of significant differences in conditions and salmonid use between lower and upper areas. The upper section was rated as low quality refugia habitat and the lower section as medium potential habitat.

Key Subbasin Issues

- Altered flow regimes from diversion, particularly during low flow periods in late summer;
- Addition of fertilizers, pollutants, and sediment to streams from marijuana cultivation operations;
- Erosion from landslides, roads, construction waste, and ground disturbance;
- Erosion related to timber harvest activities on unstable soils;
- Poor quality pool habitat (depth, shelter, and quality) in most Northern Subbasin streams;
- Low quality refugia in Salmon Creek, 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 Northern 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 Northern Subbasin?

Findings and Conclusions:

- The Northern Subbasin supports populations of Chinook salmon, coho salmon, and steelhead trout;
- Using data from two long term data sets for salmonid populations in the SF Eel River Basin (Benbow dam counts occurring from 1938-1976, and Van Arsdale counts from 1933 to the present), 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 in Northern 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 33 Northern Subbasin streams dating back to the late 1930s indicate the presence of presence of Chinook salmon in 12 tributaries (36% of streams sampled), coho salmon in 12 tributaries (36% of streams sampled), and steelhead trout in 20 tributaries (61% of streams sampled) in the Northern Subbasin;
    - Current salmonid distribution, based on data collected in 109 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 14 tributaries (13% of sampled streams), coho salmon in 8 tributaries (7% of sampled streams), and steelhead trout in 23 tributaries (21% of sampled streams) in the Northern Subasin;
- 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), and due to 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 Northern 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. Reduced flow (compared to historical averages) has been documented in Northern Subbasin streams during the late summer and early fall;
- Low summer flows result in dry or intermittent reaches on streams, which may be detrimental or stressful to salmonids;
- Water quality is reduced by marijuana cultivation operations, particularly in areas where land use is primarily residential (e.g. Salmon Creek). 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;
- 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;
- 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, and are particularly apparent in the Bull Creek drainage, but are thought to occur throughout the subbasin;
- Road density is high (3.3 miles/square mile) in the Northern Subbasin, and is more than twice as high (7 miles/square mile) in the Salmon Creek drainage. Legacy logging roads and new residential road construction are sources of sediment input into streams throughout the subbasin;

- Soils in the Northern 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 Northern Subbasin streams, and this sediment is still moving through the system;
- 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 most surveyed streams in the Northern Subbasin, and values increased over time (using habitat typing data collected during two time periods: 1990-1999, and 2000-2010);
- In the 1990s, 55% of the stream length surveyed had canopy densities below 50% and only 19% met target values of 80% or greater. Coniferous canopy cover was relatively low (< 50%) in most streams, especially those creeks that are located outside the boundaries of Humboldt Redwoods State Park. The largest streams in the subbasin, Bull Creek and Salmon Creek, had the lowest coniferous canopy percentages (less than 10%);
- In the early 2000s, there was no stream length with less than 50% canopy density, and 51% of surveyed stream length met target values of 80% or greater;
- Canopy density suitability was in the highest category in most Northern Subbasin streams in the early 2000s. Suitability was in the lowest category on select reaches of Bull and Salmon creeks, and the second lowest suitability category in very limited areas of Butte, Elk, and Canoe creeks;
- The average percent of coniferous vegetation increased and percent open canopy decreased in most streams over time. An exception to this pattern was Elk Creek and its unnamed tributary, which showed significant decreases in coniferous canopy coverage and increases in deciduous cover due to significant timber harvest activity in recent years;
- Water temperature data collected by HCRCD (between 1996-2003), and ERRP (in 2012) indicated poor (≥66ºF) conditions at 16 sites, fair (63-65˚F) conditions at 7 sites, and good conditions (50-62˚F) at 7 locations in Northern Subbasin streams. There was one site where lethal (≥75ºF) conditions were recorded, in the mainstem SF Eel River near Miranda;
- Bouma-Gregson recorded average daily temperatures above lethal levels (≥75˚F) on 27 days between July and August 2013 in the mainstem SF Eel River at Phillipsville.

Instream Habitat:

- None of the surveyed streams met target values for pool depth, and the percent of stream length surveyed that was primary pool habitat was less than 10% in all stream order categories during both habitat sampling periods;
- Quality pool structure is lacking in Northern Subbasin streams; the average mean pool shelter rating was 43.0 in the 1990s and 49.4 using habitat data collected between 2000 and 2010. These values are well below the target pool shelter value of 100 for salmonids, although they increased slightly over time;
- Boulders were the dominant shelter type, followed by LWD, in Northern Subbasin streams in all subbasin reaches during both time periods;
- Pool riffle ratios were below optimal ratios (1:1) in any Northern Subbasin streams, but 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.

Gravel/Substrate:

- Cobble embeddedness conditions improved in most Northern Subbasin streams over time, with average embeddedness values of 7.8% for data collected in the 1990s and 33.4% 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 more than 50% between the two time periods. Only categories 1 and 2 are suitable for salmonid spawning;
- Low substrate embeddedness suitability for salmonids in Northern Subbasin streams is due to extensive sediment input from highly erosive soils, active landslides, roads, and historical flood events.

Refugia Areas:

- Salmonid habitat conditions were generally rated as medium potential refugia, meaning that habitat is degraded or fragmented and salmonids are present but reduced in density and age class representation. Habitat may improve with modified management practices and restoration efforts;
- Only Squaw Creek was rated as high quality salmonid habitat in this subbasin. It is the only creek with relatively undisturbed habitat, with conditions necessary to support species diversity and natural production;
- Bull Creek was rated as high potential refugia habitat. This watershed currently has diminished but good quality habitat, and may become high quality refugia habitat with current natural resource management practices;
- Cuneo, South Fork Cuneo, Salmon, Fish, and Ohman Creeks were all rated low quality. These watersheds have few salmonids and highly impaired riparian and instream habitat. Current conditions and management practices have modified the natural environment extensively, and major changes are required to improve habitat conditions.

Barriers and other concerns:

- Both natural (landslides, gradient, and LDA) and anthropogenic (partial and total culvert) barriers 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 were located in the Bull Creek drainage, where the Mattole Road crosses Cow and Harper Creeks;
- Five landslide barriers were identified in upper Bull Creek: one each in Cuneo, NF Cuneo, and SF Cuneo Creeks, and two in the Panther Creek drainage. Habitat restoration and evaluation, assessment, and planning projects have been completed at many of these sites to reduce sediment input and stabilize stream banks;
- Three LDA barriers were identified in the Bull Creek drainage, in Albee, Harper, and Cow Creeks;
- Gradient barriers, mostly waterfalls, were identified in Northern 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), and some form of gradient barrier was identified in most streams in the subbasin.

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 Northern Subbasin are high due to:
  - 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 Northern Subbasin is sandstone of the Yager Terrane, which is made up of moderately erodible fine-grained marine sediments;

  - The relatively unstable geology of the subbasin results in many shallow landslides or debris flows, and streams are affected by sediment deposits from steep slopes in tributaries, mainly in upstream areas such as Cuneo Creek in the Bull Creek drainage;
  - The Northern 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 throughout Subbasin streams;
- The predominant vegetation type is mixed conifer and hardwood forest, covering 55% of the 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 (18%) and early 2000s (30%).

How has land use affected these natural processes?

Findings and Conclusions:

Changes in basin due to land use:

- Most (52%) of the land in the Northern Subbasin is owned by the CA State Parks; acquisition occurred between 1920s and 1970s, and the Humboldt Redwoods State Park now includes all of the land in the Bull and Canoe Creek drainages. Historically, timber harvest was the primary land use in these watersheds. Since the Park acquired the property, management actions have prioritized forest habitat preservation and fisheries habitat management;
- In the Salmon Creek 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 567 grows (281 outdoor and 286 indoor) identified in this drainage alone, with an estimated 18 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;
- 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.

Possible effects seen in stream conditions:

<u>Instream habitat conditions for salmonids are thought to be poor:</u>

- Low summer flows are exacerbated by diversions, which result in dry or intermittent reaches on streams, which are stressful to salmonids;
- In addition to low flows, water quality (temperature, pollution, turbidity) decreases in areas with high 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 and anthropogenic 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;
- None of the surveyed streams met target values for pool depth or pool shelter;
- Boulders were the dominant shelter type in pools, followed by LWD. Average percent shelter from LWD was less than 5% for both sampling periods;
- Pool:riffle ratios were well below optimal (1:1) ratios

Erosion related to timber harvest on unstable soils is a concern:

- Industrial timber harvest occurred in most areas in the subbasin prior to the 1960s, when the CA State Park system purchased the last of the land in the northern part of the subbasin (including almost all of the Bull Creek drainage). Landslides are abundant in upper Bull Creek, and large amounts of sediment are constantly entering streams from natural sources. Historically, additional sediment entered the streams from timber harvest and related activities such as road building;
- Timber harvest, while less of an issue than in the past, still occurred in the headwaters of all of the creeks (located outside the State Park boundary) in this subbasin from 1991 to 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;
- 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 Northern Subbasin streams;

Based upon these conditions trends, and relationships, are there elements that could be considered to be limiting factors for salmonid 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;
- High levels of fine sediments in streams;
- Loss of habitat area and complexity, particularly primary pool habitat and pool shelter;
- Competition with and predation pressure from Sacramento pikeminnow.

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

- Restoration activities that will create additional pool habitat and scour existing shallow pools, while reducing input from surrounding hillsides, are highly recommended throughout this subbasin;
- More than half of all habitat recommendations targeted instream habitat, including pool and cover categories. Most other recommendations targeted riparian habitat/water temperatures (canopy and temperature) and erosion/sediment (related to streambanks and roads);
- Ensure that water diversions used for domestic or irrigation purposes bypass sufficient flows to maintain all needs of fishery resources;
- 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 and developing environmental regulations;
- Support ongoing efforts by timber harvest review agencies to quantify water usage by industrial timber companies for road dust abatement, and support actions designed to encourage efficient use of water;
- Carefully modify log debris accumulations in tributaries over time, with attention paid to resultant downstream sediment loading;
- Conduct an upslope erosion inventory in order to identify and map stream bank and road-related sediment sources. Sites should be prioritized and improved;
- Stabilize eroding stream banks with appropriately designed structures and vegetation;
- Increase depth, area or shelter complexity in pools, by adding LWD or combinations of boulders and LWD. This must be done where banks are stable, or in conjunction with stream bank armor to prevent erosion;

- 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;
- Conduct biological sampling to determine salmonid usage and populations, including but not limited to the continuation of current CDFW redd counts and establishment and operation of a life cycle monitoring station within the SF Eel River Basin;
- Consistently collect water quality data, including temperature, dissolved oxygen, and water chemistry throughout the year for several years in order to accurately characterize conditions;
- Regular use of prescribed fire could reduce fuels so that catastrophic fires are less likely to occur. The CA State Parks system already has a prescribed burning program in place in the northern part of the subbasin;
- 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 Northern Subbasin covers an area of 149 square miles, or 22% of the total SF Eel River Basin area. This subbasin includes the drainage area south of the South Fork Eel River from its confluence with the Eel River (RM 0) to the confluence with Ohman Creek (RM 22.9). Streams in this subbasin contain runs of Chinook and coho salmon, and steelhead trout. Current coho salmon populations are considerably smaller and less well distributed compared to their historic range. 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 Northern 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, 52% of the land is owned by the CA State Parks, and watersheds within the park boundary are relatively undisturbed, with fewer deleterious effects than in areas with other land use practices. Only 24% of the land in this subbasin is used for industrial timber production, which is considerably less than in the Eastern and Western subbasins, and adverse effects to streams and fish that are usually associated with intensive timber harvest are reduced in this subbasin.

Reduced streamflow, particularly during the dry summer months, due to an increase in the number and volume of diversions (for dust abatement on industrial timber company lands, and for residential and agricultural uses), combined with longer dry periods in the winter and early spring, have dramatically affected salmonids in the basin at all life stages. Low flows are particularly apparent in southern areas of the subbasin, especially in Salmon Creek, 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 biologist Scott Bauer identified 567 grows (281 outdoor and 286 indoor/greenhouse) with a total of 20,000 plants (8,700 in greenhouses and 11,300 outdoors) estimated to be associated with these operations in Salmon Creek alone. These grow operations consumed more than 18 million gallons of water in one growing season, much of which was diverted from nearby tributaries. 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 and unstable geology, timber harvesting practices, land subdivision activities, and road construction associated with industrial and residential uses have resulted in increased fine sediment and an overall reduction in channel area in Northern 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. Natural sediment input from active landslides is especially apparent in the upper Bull Creek drainage, where unstable hillslopes have caused large landslides that are total barriers to salmonid passage. Although streams are designed to move sediment through the system naturally, Northern Subbasin streams often do not have sufficient flow to move the quantities of sediment through, especially with the large volumes of sediment that entered streams during the 1955 and 1964 floods.

CDFW crews collected habitat typing data in 17 Northern 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, percent primary pool habitat, and pool shelter complexity) appear to be improving with time, overall suitability scores were still low (negative values) during both time periods in most streams. Individual factor scores and corresponding suitability values were low for all variables except canopy density and embeddedness in the early 2000s, when average values for the entire subbasin were positive but still not in the highest suitability category.

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 use (e.g. Salmon Creek). While land acquisition by the CA State Parks, and restoration efforts by public and private entities have helped improve certain 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. The Northern Subbasin contains critical habitat and runs of salmonids to help in the statewide recovery of salmonids. Concerted efforts are needed 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 Northern Subbasin.

Cuneo Creek, SF Eel River Northern Subbasin.