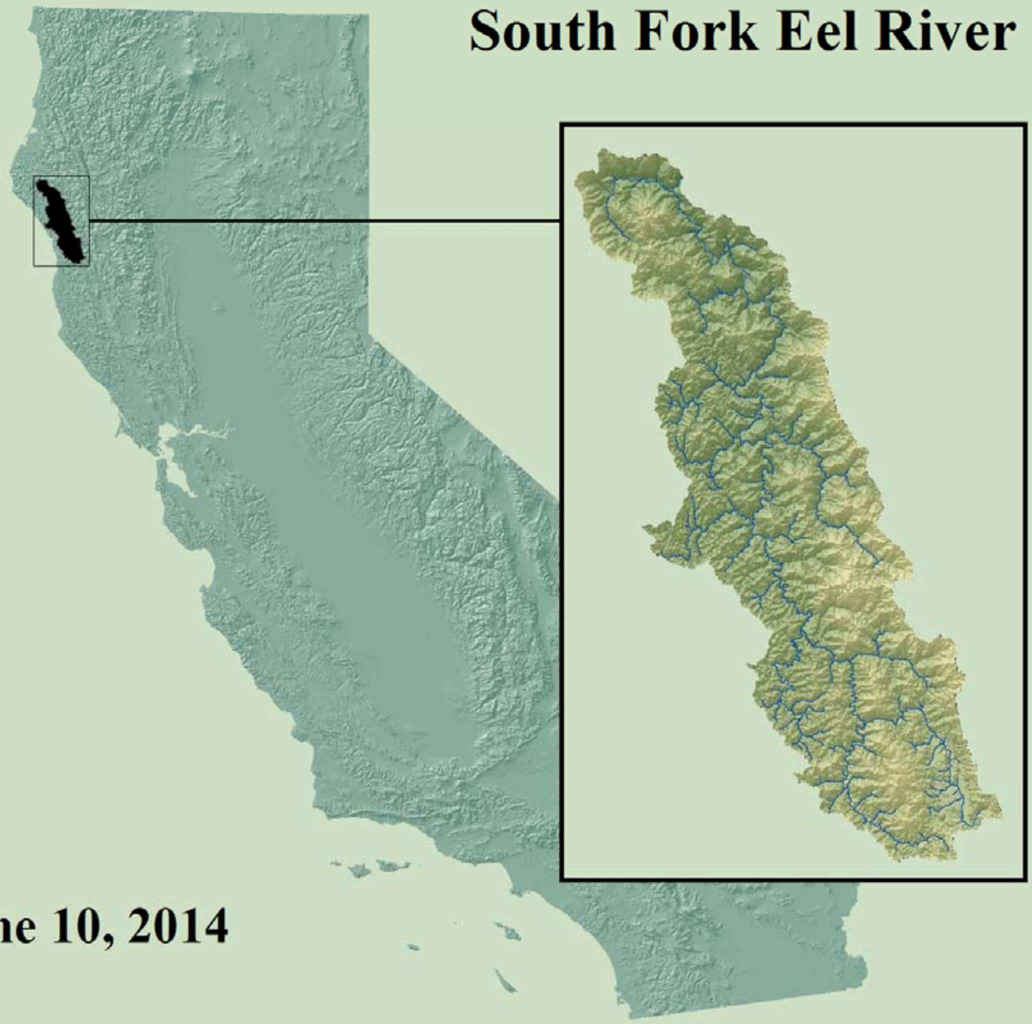
Coastal Watershed
Planning & Assessment
Program

South Fork Eel River



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South Fork Eel River Watershed Assessment

Prepared through a cooperative effort by

California Department of Fish and Wildlife
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Upper mainstem South Fork Eel River near Branscomb, CA

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California Coastal Watershed Planning and Assessment Program Introduction and Overview

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California Coastal Watershed Planning and Assessment Program Introduction and Overview

The Coastal Watershed Planning and Assessment Program (CWPAP) is a program of the California Department of Fish and Wildlife (CDFW) based in Fortuna, CA. CDFW's large scale assessment efforts began in 2001 as a component of the North Coast Watershed Assessment Program (NCWAP), an interagency effort between the following agencies: California Resources Agency, CA Environmental Protection Agency, CDFW, CA Department of Forestry and Fire Protection, CA Geological Survey, CA Department of Water Resources, and North Coast Regional Water Quality Control Board. Due to budget constraints, the NCWAP was discontinued in 2003. At that time, CDFW established the CWPAP to continue large-scale watershed assessments along California's coast to facilitate fishery improvement and recovery efforts. The 690 square mile South Fork (SF) Eel River Basin, which is located in southern Humboldt County and northern Mendocino County, was selected as a CWPAP assessment area because of its high fishery value to anadromous salmonids, including coho salmon that are listed as threatened by both state and federal agencies. This report was guided by following the outlines, methods, and protocols detailed in the NCWAP Methods Manual (Bleier et al. 2003). The program's assessment is intended to provide answers to six guiding assessment questions at the basin, subbasin, and tributary scales.

Program Guiding Questions

- What are the history and trends of the size, distribution, and relative health and diversity of salmonid coastal populations?
- What are the current salmonid habitat conditions, and how do these conditions compare to desired conditions?
- What are the effects of geologic, vegetative, fluvial, and other endemic watershed attributes on natural processes and watershed and stream conditions?
- How has land use affected or disturbed these natural attributes, processes, and/or conditions?
- As a result of those attributes, natural processes, and land use disturbances, are there stream and habitat elements that could be considered to be factors currently limiting salmon and steelhead production?
- If so, what watershed management and habitat improvement activities would most likely lead toward more desirable conditions for salmon and steelhead in a timely, reasonable, and cost effective manner?

These questions systematically focus the assessment procedures and data gathering, and provide direction for syntheses, including the analysis of factors affecting anadromous salmonid production. The questions progress from the relative status of the salmon and steelhead resource, to an assessment of the watershed context by looking at processes and disturbances, and lastly to the resultant conditions encountered directly by the fish: flow, water quality, nutrients, and instream habitat elements, including free passage at all life stages. The watershed products delivered to streams shape the stream and create habitat conditions. Thus, watershed processes and human influences determine salmonid health and production and help identify what improvements could be made in the watershed and its streams.

CWPAP assessments do not address marine influences on the ocean life cycle phase of anadromous salmonid populations. While these important influences are outside of the scope of this program, we recognize their critical role upon sustainable salmonid populations and acknowledge that good quality fresh water habitat alone is not adequate to ensure sustainability. However, freshwater habitat improvements benefit their well-being and survival during their two freshwater life cycle phases and thus can create stronger year classes in the ocean.

Goals

- Organize and provide existing information, and develop limited baseline data to help evaluate the effectiveness of various resource protection programs over time;
- Provide assessment information to help focus watershed improvement programs, and to assist landowners, local watershed groups, and individuals in developing successful projects. This will help guide support programs, such as the CDFW Fishery Restoration Grants Program (FRGP), toward those watersheds and project types that can efficiently and effectively improve freshwater habitat and lead to improved salmonid populations;
- Provide assessment information to help focus cooperative interagency, nonprofit, and private sector approaches to protect watersheds and streams through watershed stewardship, conservation easements, and other incentive programs;
- Provide assessment information to help landowners and agencies better implement laws that require specific assessments such as the State Forest Practice Act, Clean Water Act, and State Lake and Streambed Alteration Agreements.

North Coast Salmon, Stream, and Watershed Issues

Pacific coast anadromous salmonids hatch in freshwater, migrate to the ocean as juveniles where they grow and mature, and then return as adults to freshwater streams to spawn. This general anadromous salmonid life history pattern is dependent upon a high quality freshwater environment at the beginning and end of the cycle (Bjornn and Reiser 1991). Different salmonid species and stocks utilize diverse inter-specific and intra-specific life history strategies to reduce competition between species and increase the odds for survival of species encountering a wide range of environmental conditions in both the freshwater and marine environments (Groot and Margolis 1991). These strategies include the timing and locations for spawning, length of freshwater rearing, juvenile habitat partitioning, a variable estuarine rearing period, and different physiologic tolerances for water temperature and other water quality parameters.

Salmonids thrive or perish during their freshwater phases depending upon the availability of cool, clean water, free access to migrate up and down their natal streams, clean gravel suitable for successful spawning, adequate food supply, and protective cover to escape predators and ambush prey (*Figure 1*). These life requirements must be provided by diverse and

Figure 1. Example of high quality spawning habitat in the SF Eel River Basin.

complex instream habitats as the fish move through their life cycles (JNRC 2002). If any life requirements are missing or in poor condition at the time a fish or stock requires it, fish survival can be affected. These life requirement conditions can be identified and evaluated on a spatial and temporal basis at the stream reach and watershed levels. They comprise the factors that support or limit salmonid stock production.

The specific combination of these factors in each stream sets the carrying capacity for salmonids of that stream. The carrying capacity can thus be changed if one or more of the factors are altered. The importance of individual factors in setting the carrying capacity differs with the life stage of the fish and time of year. All of the important factors for salmonid health must be present in a suitable, though not always optimal, range in streams where fish live and reproduce (Bjornn and Reiser 1991).

Within the range of anadromous salmonid distribution, historic stream conditions varied at the regional, basin and watershed scales. Wild anadromous salmonids evolved with their streams shaped in accordance with the inherent, biophysical characteristics of their parental watersheds, and stochastic pulses of fires, landslides, and climatic events (Waples et al. 2008). In forested streams, large trees grew along the stream banks contributing shade, adding to bank stability, and moderating air and stream temperatures during hot summers and cold winter seasons. The streams contained fallen trees and boulders, which created instream habitat diversity and complexity. The large mass of wood in streams provided important nutrients to fuel the aquatic food web. During winter flows, sediments were scoured, routed, sorted, and stored around solitary pieces and accumulations of large wood, bedrock, and boulders, forming pool, riffle, and flatwater habitats.

Two important watershed goals are the protection and maintenance of high quality fish habitats. Preserving high quality habitat and restoring streams damaged by poor resource management practices of the past are both important for anadromous salmonid populations (Bisson et al. 1997). Science-based management has progressed significantly and “enough now is known about the habitat requirements of salmonids and about good management practices that further habitat degradation can be prevented, and habitat rehabilitation and enhancement programs can go forward successfully” (Meehan 1991).

Through the course of natural climatic events, hydrologic responses and erosion processes interact to shape freshwater salmonid habitats. These processes influence the kind and extent of a watershed’s vegetative cover as well, and act to supply nutrients to the stream system. When there are no large disturbances, these natural processes continuously make small changes in a watershed. Managers must constantly evaluate these small natural changes as well as changes made by human activity. Habitat conditions can be drastically altered when major disruptions of these small interactions occur (Swanston 1991).

Major watershed disruptions can be caused by catastrophic events, or system reset events (Junk et al. 1989), such as the 1955 and 1964 north coast floods. They can also be created over time by multiple small natural or human disturbances. These disruptions can drastically alter instream habitat conditions and the aquatic communities that depend upon them (Lake 2000). Thus, it is important to understand the critical interdependent relationships of salmon and steelhead with their natal streams during their freshwater life phases, their streams’ dependency upon the watersheds within which they are nested, and the energy of the watershed processes that binds them together.

In general, natural disturbance regimes like landslides and wildfires do not impact larger basins like the 690 square mile SF Eel River Basin in their entirety at any given time. Rather, they normally rotate episodically across the entire basin as a mosaic composed of the smaller subbasin, watershed, or sub-watershed units over long periods. This creates a dynamic variety of habitat conditions and quality over the larger basin (Reice 1994).

The rotating nature of these relatively large, isolated events at the regional or basin scale assures that at least some streams in the area will be in suitable condition for salmonid stocks. A dramatic, large-scale example occurred in May 1980 in the Toutle River, Washington, which was inundated with slurry when Mt. St. Helens erupted. The river rapidly became unsuitable for fish. In response, returning salmon runs avoided the river that year and used other nearby suitable streams on an opportunistic basis, but returned to the Toutle two years later as conditions improved. This return occurred much sooner than had been initially expected (Quinn et al. 1991).

Human disturbances, although individually small in comparison to natural disturbance events, are usually widely distributed across basin level watersheds (Reeves et al. 1995). For example, a rural road or building site is an extremely small land disturbance compared to a 640-acre landslide or wildfire covering several square miles. However, when all the roads in a basin the size of the SF Eel River are looked at collectively, their disturbance effects are much more widely distributed than a single large, isolated landslide that has a high, but relatively localized impact to a single sub-watershed.

Human disturbance regimes collectively extend across basins and even regional scales and have cumulative, lingering effects. Examples include water diversions, conversion of near stream areas to urban usage, removal of large mature vegetation, widespread soil disturbance leading to increased erosion rates, construction of levees or armored banks that can disconnect the stream from its floodplain, and the installation of dams and reservoirs that disrupt normal flow regimes and prevent free movement of salmonids and other fish. These disruptions often develop in concert and in an extremely short period of time on the natural, geologic scale. One of the biggest challenges to sustainable resource management is understanding and developing management strategies that minimize the cumulative effects of human disturbances on fish populations and ecological communities (Scrimgeour et al. 2003).

Human disturbances are often temporally concentrated due to newly developed technology or market forces such as the California Gold Rush, the post- WWII logging boom in Northern California, or the new "Green Rush" of industrial marijuana production (Evers 2010, Easthouse 2013). The intense human land use of the last century, combined with the transport energy of two mid-century record floods on the North Coast, created stream habitat impacts at basin and regional scales. The result of these recent combined disruptions has overlain the pre-European disturbance regime process and conditions within the region.

Consequently, stream habitat quality and quantity are generally reduced throughout most of the North Coast region. It is within this heavily impacted environment that both human and natural disturbances continue to occur, but with vastly fewer habitat refugia than were historically available to salmon and steelhead. Thus, a general reduction in salmonid stocks can at least partially be attributed to this impacted freshwater environment.

Factors Affecting Anadromous Salmonid Production

The concept that fish production is limited by a single factor or by interactions between discrete factors is fundamental to stream habitat management (Meehan 1991). A limiting factor can be anything that constrains, impedes, or limits the growth and survival of a population.

Identifying freshwater factors that are currently at a level that limits production of anadromous salmonids in North Coast basins is a key component of CWPAP watershed assessment. This limiting factors analysis (LFA) provides a means to evaluate the status of a suite of key environmental factors that affect anadromous salmonid life history, and is an important tool for developing management actions to conserve and recover salmonid populations (Trask 2003). LFAs are based on comparing measures of habitat components such as water temperature and pool complexity to a range of reference conditions determined from empirical studies and/or peer reviewed literature. If a component's condition does not fit within the range of reference values, it may be viewed as a limiting factor. This information is useful when identifying underlying causes of stream habitat deficiencies, and it helps reveal links between watershed processes and land use activities.

Chinook salmon, coho salmon, and steelhead trout all utilize headwater streams, larger rivers, estuaries, and the ocean during parts of their life history cycles. In the freshwater phase in salmonid life history, adequate flow, free passage, suitable stream conditions, suitable water quality (such as low water temperatures and low turbidity levels), and functioning riparian areas are essential for successful completion of their anadromous lifecycle (Barnhart 1986, Healy 1991, Sandercock 1991).

Water Quantity

Stream flow can be a significant limiting factor for salmonids, affecting fish passage, and quantity and quality of spawning, rearing, and habitat refugia areas. For successful salmonid production, stream flows should follow the natural hydrologic regime of the basin (Poff et al. 1997). A natural regime minimizes the frequency and magnitude of storm flows and promotes better base flows during dry periods of the water year. Salmonids evolved with the natural hydrograph of coastal watersheds, and changes to the timing, magnitude, and duration of low flows and storm flows can disrupt the ability of fish to follow life history cues. Adequate instream flow during low flow periods is essential for fish passage in the summer time, and is necessary to provide juvenile salmonids free forage range, cover from predation, and utilization of localized temperature refugia from seeps, springs, and cool tributaries. Adequate flow is also required for smolts migrating downstream to the estuary while they are still physiologically adapted to make the transition from freshwater to salt water habitats (Berggren and Filardo 1993).

Water Quality

Important aspects of water quality for anadromous salmonids are water temperature, turbidity, water chemistry, and sediment load. In general, suitable water temperatures for salmonids are between 48-56°F for successful spawning and incubation, and between 50-52°F and 60-64°F, depending on species, for growth and rearing (Bell 1986, Armour 1991, Carter 2005). Additionally, cool water holds more oxygen, and salmonids require high levels of dissolved oxygen in all stages of their life cycle.

A second important aspect of water quality is turbidity. Fine suspended sediments (turbidity) affect nutrient levels in streams that in turn affect primary productivity of aquatic vegetation and insect life (Power 2003). This eventually reverberates through the food chain and affects salmonid food availability. Additionally, high levels of turbidity interfere with juvenile salmonids' ability to feed and can lead to reduced growth rates and survival due to an impaired ability to find food and food assemblage changes (Suttle et al. 2004, NOAA Restoration Center 2011).

A third important aspect of water quality is stream sediment load. Salmonids cannot successfully reproduce when forced to spawn in streambeds with excessive silt, clay, and other fine sediments. Eggs and embryos suffocate under excessive fine sediment conditions because oxygenated water is prevented from passing through the egg nest, or redd (Gibbons and Salo 1973). Additionally, high sediment loads can cap the redd and prevent emergent fry from escaping the gravel into the stream at the end of incubation (Chapman 1988). High sediment loads can also cause abrasions on fish gills, which may increase susceptibility to infection. At extreme levels, sediment can clog the gills, causing death (Gibbons and Salo 1973). High sediment loads also fill in pool habitats, resulting in reduced cover and shelter for juveniles and adults, and, materials toxic to salmonids can cling to sediment and be transported to downstream areas.

Fish Passage

Free passage describes the absence of barriers to the instream movement of adult and juvenile salmonids. Free movement in streams allows salmonids to find food, escape from high water temperatures, escape from predation, and migrate to and from their stream of origin as juveniles and adults. Connectivity of habitats is an important consideration in salmonid restoration for all species and life stages (Roni et al. 2002). Temporary or permanent dams, poorly constructed road crossings, landslides, debris jams, or other natural and/or man-caused channel disturbances can disrupt or prevent free passage.

Instream Habitat Conditions

Complex instream habitat is important for all lifecycle stages of salmonids. Habitat diversity for salmonids is created by a combination of deep pools, riffles, and flatwater habitat types. Pools, and to some degree flatwater habitats, provide escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas, particularly for young coho salmon. They are also necessary for providing adult resting areas. A high level of fine sediment can fill pool and flatwater habitats, reducing pool depth and burying complex niches created by large substrate and woody debris. Riffles provide clean spawning gravels and oxygenated water. Steelhead fry use riffles during rearing. Flatwater areas often provide spatially divided pocket water units (Flosi et al. 1998) that separate individual juveniles, which helps promote reduced competition and successful foraging.

The ratio of pool, riffle, and flatwater units is a measure of habitat diversity, and in habitats where complexity has been reduced by natural or anthropogenic degradation, restoration actions can be developed to restore habitat ratios and invertebrate biodiversity (Ebersole et al. 1997)

Riparian Zone

A functional riparian zone helps to control the amount of sunlight reaching the stream, provides vegetative litter, and contributes invertebrates to the local salmonid diet. These contribute to the production of food for the aquatic community, including salmonids. Tree roots and other vegetative cover provide stream bank cohesion and buffer impacts from adjacent uplands. Near-stream vegetation eventually provides large woody debris and complexity to the stream (Flosi et al. 1998).

Riparian zone functions are important to anadromous salmonids for numerous reasons. Riparian vegetation helps keep stream temperatures in the range that is suitable for salmonids by maintaining cool stream temperatures in the summer and insulating streams from heat loss in the winter (Poole et al. 2001, Poole and Berman 2001). Larval and adult macroinvertebrates are important to the salmonid diet and are dependent upon nutrient contributions from the riparian zone (Gregory et al. 1991). Additionally, stream bank cohesion and maintenance of undercut banks provided by riparian zones in good condition maintain diverse salmonid habitat, and help reduce bank failure and fine sediment yield to the stream. Lastly, the large woody debris provided by riparian zones shapes channel morphology, helps retain organic matter and provides essential cover for salmonids (Murphy and Meehan 1991).

Excessive natural or human-caused disturbances to the riparian zone, as well as directly to the stream and/or the basin itself can have serious impacts on the aquatic community, including anadromous salmonids. This habitat loss and damage occurring in most Northern California coastal streams and watersheds is a primary factor in the listing of Chinook salmon, coho salmon, and steelhead trout stocks under the Endangered Species Act (Levin and Schiewe 2001, Nehlsen et al. 2001).

Disturbance and Recovery of Stream and Watershed Condition

Natural and Human Disturbances

The forces shaping streams and watersheds are numerous and complex. Streams and watersheds change through dynamic processes of disturbance and recovery (Madej 1999). In general, disturbance events alter stream equilibrium and average conditions, while recovery occurs as stream conditions return towards equilibrium after disturbance events.

Given the program's focus on anadromous salmonids, an important goal is to determine the degree to which current stream and watershed conditions in the region are providing salmonid habitat capable of supporting sustainable populations of anadromous salmonids. To do this, we must consider the habitat requirements for all species and life stages of salmonids. We must look at the disturbance history and recovery of stream systems, including riparian and upslope areas, which affect the streams through multiple biophysical processes.

Disturbance and recovery processes can be influenced by both natural and human events. A disturbance event such as sediment input from a natural landslide can fill instream pools, destroying salmon habitat just as readily as sediment from a road failure. During recovery, natural processes (such as small streamside landslides) that replace instream large woody debris washed out by a flood flow help to restore salmonid habitat, as does large woody debris placed in a stream by a landowner as a part of a restoration project.

Natural disturbance and recovery processes, at scales from small to very large, have been at work on north coast watersheds since their formation millions of years ago. Recent major natural disturbance events have included large flood events such as those that occurred in 1955, 1964 (Lisle 1981a), as well as ground shaking and related tectonic uplift associated with the 1992 Cape Mendocino earthquake (Carver et al. 1994).

Major anthropogenic disturbances (e.g., post-European development, dam construction, agricultural and residential conversions, and timber harvest methods used before the implementation of the 1973 Z'Berg-Nejedly Forest Practice Act) have occurred over the past 160 years (Cafferata and Spittler 1998, Yoshiyama and Moyle 2010). Salmonid habitat also was degraded during parts of the last century by well-intentioned but misguided restoration actions such as removing large woody debris from streams (Spence et al. 1996, Stillwater Sciences 1997). More recently, efforts at watershed restoration have been made, generally at the local level. For example, in California and the Pacific Northwest, minor dams from some streams have been removed to clear barriers to spawning and juvenile anadromous fish. For a thorough treatment of stream and watershed recovery processes, see the publication by the Federal Interagency Stream Restoration Working Group (FISRWG 1998).

Defining Recovered

There is general agreement that improvements in a condition or set of conditions constitute recovery. In that context, recovery is a process. One can determine a simple rate of recovery by the degree of improvement over some time period, and from only two points in time. One can also discuss recovery and rates of recovery in a general sense. However, a simple rate of recovery is not very useful until put into the context of its position on a scale to the endpoint of recovered.

In general, recovered fish habitat supports diverse and stable fish populations. Recovered not only implies, but necessitates, knowledge of an endpoint. In the case of a recovered watershed, the endpoint is a set of conditions deemed appropriate for a watershed with its processes in balance and able to withstand perturbations without large fluctuations in those processes and conditions. However, the endpoint of recovered for one condition or function may be on a different time and geographic scale than for another condition or function.

Some types and locations of stream recovery for salmonids can occur more readily than others. For example, in headwater areas where steeper source reaches predominate, suspended sediment such as that generated by a streamside landslide or a road fill failure may start clearing immediately, while coarser sediments carried as bedload tend to flush after a few years (Lisle 1981a; Madej and Ozaki 1996) or from large flood events, after many decades.

Broadleaf riparian vegetation can return to create shading, stabilize banks, and improve fish habitat within a decade or so. In contrast, in areas lower in the watershed where lower-gradient response reaches predominate, it can take several decades for deposited sediment to be transported out (Madej 1982), for widened stream channels to narrow, for aggraded streambeds to return to pre-disturbance level, and for streambanks to fully re-vegetate and stabilize (Lisle 1981b). Lower reach streams will require a similar period for the near-stream trees to attain the girth needed for recruitment into the stream as large woody debris to help create adequate habitat complexity and shelter for fish, or for deep pools to be re-scoured in the larger mainstems (Lisle and Napolitano 1998).

Factors and Rates of Recovery

Over the past quarter-century, several changes have allowed the streams and aquatic ecosystems to move generally towards recovery. The general rate of timber harvest on California's north coast has slowed during this period (Morgan et al. 2012). This is due to a declining number of timber harvesting plan (THP) submissions, but larger average harvest sizes per plan. The increased cost of timber sale preparation has led to reduced profitability from small harvests (Thompson and Dicus 2005). Timber harvesting practices have greatly improved over those of the post-war era, due to increased knowledge of forest ecosystem functions, changing public values, advances in road building and yarding techniques, and regulation changes such as mandated streamside buffers that limit equipment operations and removal of timber. Further, most north coast streams have not recently experienced a large event comparable to the 1964 flood. Therefore, we would expect most north coast streams to show signs of recovery (i.e., passive restoration [FISRWG 1998]). However, the rates and degrees of stream and watershed recovery will likely vary across a given watershed and among different north coast drainages.

In addition to the contributions made to recovery through better land management practices and natural recovery processes, increasing levels of stream and watershed restoration efforts are also contributing to recovery. Examples of these efforts include road upgrades and decommissioning, removal of road related fish passage barriers, installation of instream fish habitat structures, etc. While little formal evaluation or quantification of the contributions of these efforts to recovery has been made, there is a general consensus that many of these efforts have made significant contributions (Whiteway et al. 2010, Roni et al. 2010).

Continuing Challenges to Recovery

Given improvements in timber harvesting practices in the last 30 years, the time elapsed since the last major flood event, and the implementation of stream and watershed restoration projects, many north coast streams show indications of trends towards recovery (Madej and Ozaki 1996). Ongoing challenges associated with past activities that are slowing this trend include:

- Chronic sediment delivery from legacy (pre-1975) roads due to inadequate crossing design, construction and maintenance (Stillwater Sciences 1999);
- Skid trails and landings (Cafferata and Spittler 1998);
- A lack of improvements in stream habitat complexity, largely from a dearth of large woody debris for successful fish rearing (Dominguez and Cederholm 2000);
- The continuing aggradation of sediments in low-gradient reaches that were deposited as the result of activities and flooding in past decades (Koehler et al. 2001).

Increasing subdivision in several north coast watersheds raises concerns about new stream and watershed disturbances. Private road systems associated with rural development have historically been built and maintained in a fashion that does little to mitigate risks of chronic and catastrophic sediment inputs to streams. While more north coast counties are adopting grading ordinances that will help with this problem, there is a significant legacy of older residential roads that pose an ongoing risk for sediment inputs to streams. Other issues appropriate to north coast streams include potential failures of roads during catastrophic events, erosion from house pads and impermeable surfaces, removal of water from streams for domestic uses, effluent leakages, and the potential for dumping of toxic chemicals used in illicit drug labs.

Some areas of the north coast have seen rapidly increasing agricultural activity, particularly conversion of grasslands or woodlands to marijuana cultivation. Such agricultural activities have typically been subject to little agency review or regulation and can pose significant risk of chronic sediment, chemical, and nutrient inputs to streams.

Associated with development and increased agriculture, some north coast river systems are seeing an increase in water diversion, from both streams and groundwater sources connected to streams, for human uses. Water withdrawals pose a cumulative chronic disturbance to streams and aquatic habitat (SWRCB 2010). Such withdrawals can result in reduced summer stream flows that impede the movement of salmonids and fewer important habitat elements such as pools. Further, the withdrawals can contribute to elevated stream water temperatures that are harmful to salmonids.

Key questions for landowners, agencies, and other stakeholders revolve around whether the trends toward stream recovery will continue at their current rates, and whether those rates will be adequate to allow salmonid populations to recover in an acceptable time frame. The potential exists for new impacts from both human activities and natural disturbance processes to compromise recovery rates, and complex biological and environmental systems make establishment of an exact timeline for recovery difficult (CDFG 2004). Predicting the direct effects and any cumulative effects of those impacts will require additional site-specific information on sediment generation and delivery rates, and additional risk analyses of other major disturbances. Our discussion here does not address marine influences on anadromous salmonid populations. While these important influences are outside of the scope of this program, we recognize their importance for sustainable salmonid populations and acknowledge that high quality freshwater habitat alone is not adequate to ensure sustainability.

Climate Change

Anthropogenic climate change is altering ecosystems worldwide, with the average global temperature increasing 1.4˚F over the past century (USEPA 2013). Increased global temperatures have been accompanied by warmer ocean temperatures and increased acidification, rising sea levels, and changes in local weather patterns resulting in intense rainfall and flooding, drought, and heat waves. Climate change is modifying the volume, timing, and quality of water resources, which directly affect salmonid populations in freshwater habitats by increasing stream temperatures and altering flow regimes. Mote and Salathè (2010) reviewed 21 global climate change models used by the Intergovernmental Panel on Climate Change (IPCC) in their Fourth Assessment Report and summarized projected changes in the Pacific Northwest, including:

- Average annual air temperature increases of 1.1˚C (2.0˚F) by the 2020s, 1.8˚C (3.2˚F) by the 2040s, and 3.0˚C (5.3˚F) by the 2080s (compared to the average annual temperature from 1970-1999);
- Small (1-2%) changes in annual precipitation, with some models predicting a shift toward wetter fall and winter conditions, with drier summers;
- Nearshore sea surface temperatures substantially exceeding interannual variability;
- Little change in coastal upwelling; and
- Highly variable sea level rise estimates, depending on factors such as polar ice sheet instability and local tectonic activity, ranging from 20 cm (8”) to 1.3 m (50”).

Chinook salmon, coho salmon, and steelhead trout occupy a variety of instream habitats and have variable life history event timing. Therefore, individuals of each species will encounter a different suite of stream flow and temperature changes resulting from climate change at each life stage (Beechie et al. 2012). These changes will have significant impacts on both SF Eel River salmonid populations and the food webs that sustain them, especially if predicted changes in rainfall and temperature are realized.

Wetter fall and winter conditions will result in higher than normal flows and possibly flooding. This could wash away nests, especially those of Chinook and coho salmon that spawn in the beginning of the winter storm season.

In relation to salmonid life cycle requirements, current stream temperatures in the SF Eel River Basin are generally good in Western Subbasin streams, but poor to fair in Eastern and Northern Subbasin streams. Increases in stream temperature resulting from projected increases in air temperature in areas where current stream temperatures are poor or near lethal for salmonids will pose a high threat to salmonids (Beechie et al. 2012), especially in the late summer and early fall months when stream temperatures are highest. In the SF Eel River Basin, areas with high stream temperatures are located in sampled locations in the mainstem downstream from the confluence of Rattlesnake Creek (RM 75), to below Miranda (RM 4) (Friedrichsen 1998 and 2003, Higgins 2012). Salmonids in these habitats may be less affected by increasing stream temperatures due to climate change if they can access cooler habitat in tributaries, or if there are cool water refugia from groundwater seeps nearby, but the location and stability of these seeps are spatially and temporally unpredictable.

Madej (2011) reported that over the last century, summer temperatures have increased and summer low flows have decreased in north coastal California streams. Increasingly drier summer conditions will be especially problematic for SF Eel River Basin salmonids, due to the already low flows and associated warm temperatures resulting from diversion and reduced flow in late summer months. Reduced flows would result in more juvenile stranding and a decrease in the limited amount of rearing habitat currently available throughout the Basin. Purchasing water rights or implementing water conservation measures that leave more water in streams in areas where withdrawals or diversions have already led to reduced flow can ameliorate predicted decreases in low flows due to climate change (Beechie et al. 2012).

Reduced rainfall and drier conditions resulting from climate change may also affect the natural fire regime in many areas (Flannigan et al. 2000, Fry and Stephens 2006). In Humboldt County, fire behavior in the future will be less predictable due to changes in temperatures, precipitation, fire frequency and fire severity (Tetra Tech 2013). Changes in the natural fire regime are a concern in all three subbasins, particularly in the drier Eastern Subbasin. Grassland habitat is more prevalent, air temperatures are higher, and slope gradients are greater in the Eastern Subbasin compared to the Northern and Western subbasins, where fuel potential is high but the climate is damp (Tetra Tech 2013).

Snowpack is a key component of the hydrologic cycle (Hamlet et al. 2005, Mote et al. 2005). The current warming trend is causing an increase in the amount of precipitation falling as rain, or an earlier melting of snow, or a combination of both in snowmelt basins (Barnett et al. 2005). In the Klamath River Basin in Northern California, warmer winter temperatures have caused earlier runoff peaks in both snowmelt and groundwater basins (Mayer and Naman 2011). Although snowmelt provides runoff to some SF Eel River tributaries, it is not the primary flow source for SF Eel River Basin streams.

Moyle et al. (2012) outlined methods to determine the baseline vulnerability of native salmonids and to assess the likely impact of climate change on these species. Based on predicted effects from climate change on freshwater fish in California, they stated that the future distribution of most native fish will become more restricted, and some populations may go extinct. Small populations are less resilient than larger populations, and will be affected more by variations in natural conditions due to climate change, especially if there is an increase in the frequency of stochastic events such as extreme floods or prolonged droughts. Invasive species (e.g. pikeminnow, with a higher tolerance for elevated water temperatures) will not be affected as much as native species, and may become dominant in diminished freshwater ecosystems as conditions change.

Fisheries management practices will need address localized environmental issues resulting from projected climate change. Rieman and Isaak (2010) suggested that fisheries managers will need to prioritize limited resources if enhanced resistance and resilience of existing species or communities is key. Management plans should include:

- Development of a local information base, including climate change projections and current conditions;
- Facilitation of transitions to new conditions;
- Coordination of efforts between resource managers to ameliorate the effects of climate change; and

- Creation of an iterative process to reevaluate and revise plans, including assumptions, as progress is monitored (Tillmann and Siemann 2011).

Recovery actions and restoration projects must also be adapted in the context of natural resource management and conservation to address environmental variations associated with climate change. In order to help ecosystems withstand and adapt to new climate conditions, managers will need to identify conservation targets, consider their vulnerability, evaluate management options, assess the effectiveness of proposed restoration efforts, and develop and implement management and monitoring strategies (Battin et al. 2007, Glick et al. 2009).

Habitat deterioration associated with climate change will make recovery targets much more difficult to attain, and managers and regulators will need to anticipate and track multiple environmental changes and species trajectories (Battin et al. 2007, Barbour and Kueppers 2012). Recovery actions are currently being developed by NOAA Fisheries for SONCC coho salmon, which are listed as threatened in the SF Eel River Basin. The draft recovery plan is available at: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/southern_oregon_northern_california_coast/southern_oregon_northern_california_coast_recovery_plan_documents.html. Recovery actions that are designed to enhance lower elevation habitats (e.g. SF Eel River streams) are more likely to be successful in protecting salmonids than those in higher elevation basins where the snow-rain transition will be greatest (Battin et al. 2007).

Climate change will dramatically alter ocean conditions and productivity, which directly affect salmonid populations (Behrenfeld et al. 2006), but CWPAP assessments do not address marine influences on the ocean life cycle phase of anadromous salmonid populations. We recognize the critical role of ocean conditions upon sustainable salmonid populations and acknowledge that good quality freshwater habitat alone is not adequate to ensure sustainability. However, in this assessment, we will concentrate on how potential changes to freshwater habitats may affect the well-being and survival of salmonids during their two freshwater life cycle phases.

Policies, Acts, and Listings

Several federal and state statutes have significant implications for watersheds, streams, fisheries, and their management. Here, we present only a brief listing and description of some of the laws.

Federal Statutes

One of the most fundamental of federal environmental statutes is the National Environmental Policy Act (NEPA). NEPA is essentially an environmental impact assessment and disclosure law. Projects contemplated, prepared, or funded by federal agencies must have an environmental assessment completed and released for public review and comment, including the consideration of more than one alternative. The law does not require that the alternative with the lowest impact be chosen, only that the impacts are disclosed.

The Federal Clean Water Act has a number of sections relevant for watersheds and water quality. Section 208 deals with non-point source pollutants arising from silvicultural activities, including cumulative impacts. Section 303 deals with water bodies that are impaired to the extent that their water quality is not suitable for the beneficial uses identified for those waters. For water bodies identified as impaired, the US Environmental Protection Agency (EPA) or its state counterpart (locally, the North Coast Regional Water Quality Control Board (NCRWQCB) and the State Water Resources Control Board (SWRCB)) must set targets for Total Maximum Daily Loads (TMDLs) of the pollutants that are causing the impairment. Section 404 addresses the alterations of wetlands and streams through filling or other modifications, and requires the issuance of federal permits for similar activities.

The Federal Endangered Species Act (ESA) addresses the protection of animal species whose populations are dwindling to critical levels. Two levels of species risk are defined. A threatened species is any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. An endangered species is any species that is in danger of extinction throughout all or a significant portion of its range. In general, the law forbids the take of listed species. Taking is defined as harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting a species or attempting to engage in any such conduct. Section 4(d) of the ESA prohibits any take of species listed as endangered, but some take of threatened species that does not interfere with salmon survival and recovery can be allowed. Section 10 of the ESA allows NMFS to issue a permit for take of threatened species for scientific research, habitat conservation plans (HCPs), artificial propagation programs, and harvest management programs. An HCP is a document that describes how an agency or landowner will manage their activities to reduce effects on vulnerable species. An HCP discusses the applicant's proposed activities and describes the steps that will be taken to avoid, minimize, or mitigate the take of species that are covered by the plan.

Many of California's salmonids are listed under the ESA, including three species found in the SF Eel River Basin (*Table 1*). SONCC coho salmon were originally listed by the National Marine Fisheries Service (NMFS) in 1997, CC Chinook salmon in 1999, and NC steelhead Distinct Population Segment (DPS) in 2000. Five-year status reviews were completed by NMFS in 2011 for these listed species, with recommendations that the status remain "threatened" for all three. NMFS determined that the biological status of SONCC coho salmon has worsened due in part to ocean survival conditions, drought effects, and small population size since the previous status review in 2005, and recommended careful monitoring and re-evaluation of the status of this species in 2-3 years (NMFS 2011a).

Table 1. ESA listed salmonids in the SF Eel River Basin.

Common Name	Scientific Name	Status
Coho Salmon (Southern Oregon/Northern California)	*Oncorhynchus kisutch*	Threatened (Federal and State)
Chinook Salmon (California Coastal)	*Oncorhynchus tshawytscha*	Threatened (Federal)
Steelhead Trout (Northern California)	*Oncorhynchus mykiss*	Threatened (Federal)

State Statutes

The state equivalent of NEPA is the California Environmental Quality Act (CEQA). CEQA goes beyond NEPA in that it requires the project or plan proponent to select and implement the proposed alternative with the lowest environmental impact. When the selected alternative would still cause significant adverse environmental impacts, a statement of overriding considerations must be prepared.

The Porter-Cologne Water Quality Control Act establishes state water quality law and defines how the state will implement the federal authorities that have been delegated to it by the EPA under the federal Clean Water Act. For example, the EPA has delegated to the state certain authorities and responsibilities to implement TMDLs for impaired water bodies and NPDES (national pollution discharge elimination system) permits to point-source dischargers to water bodies.

Sections 1600 et seq. of the Fish and Game Code are implemented by the Department of Fish and Wildlife. These agreements are required for any activities that alter the beds or banks of streams or lakes. A 1600 agreement typically would be involved in a road project where a stream crossing was constructed. While treated as ministerial in the past, the courts have more recently indicated that these agreements constitute discretionary permits and thus must be accompanied by an environmental impact review per CEQA.

The California Endangered Species Act (CESA) (Fish and Game Code §§ 2050, et seq.) generally parallels the main provisions of the Federal Endangered Species Act and is administered by the CDFW. SONCC Coho salmon in the SF Eel River Basin are listed as threatened under CESA.

From a recovery and management perspective, the State of CA emphasizes natural, as opposed to hatchery, spawning and rearing in natural habitats. Hatchery production may be appropriate to protect and expand populations in specific situations (e.g. rescue rearing efforts in the Mattole River Basin), but natural production should take preference when both alternatives are feasible. Recovery and protection of native salmonids should be accomplished primarily through stream habitat improvement efforts (CDFG 2002).

The Z'Berg-Nejedly Forest Practice Act (FPA) and associated Forest Practice Rules (CalFire 2012) establish extensive permitting, review, and management practice requirements for commercial timber harvesting. Evolving in part as a response to water quality protection requirements established by the 1972 amendments to the federal Clean Water Act, the FPA and Rules provide for significant measures to protect watersheds, watershed function, water quality, and fishery habitat.

Assessment Strategy and General Methods

The NCWAP developed a Methods Manual (Bleier et al. 2003) that identified a general approach to conducting a watershed assessment, described or referenced methods for collecting and developing new watershed data, and provided a preliminary explanation of analytical methods for integrating interdisciplinary data to assess watershed conditions. This chapter provides brief descriptions of data collection and analysis methods used in the SF Eel River Assessment. See the Methods Manual and Analysis Appendix for a more detailed description of the assessment methods, data, and analysis.

Watershed Assessment Approach in the SF Eel River Basin

The steps in a large-scale assessment include:

- Conduct external scoping and outreach. Receive public input from agencies, private entities, and individuals. Compile, analyze, and report input to identify issues and promote cooperation;
- Determine logical assessment scales. The SF Eel River Basin assessment delineated the basin into three subbasins (Northern, Eastern, and Western) for assessment and analyses purposes;
- Discover and organize existing data and information;
- Identify data gaps needed to develop the assessment;
- Collect field data. CDFW habitat typing crews surveyed more than 300 miles of habitat in 118 streams in the SF Eel River Basin between 1990 and 2010. These data, along with information from CDFW spawner surveys, and historical field notes and stream survey documents were compiled for this assessment. Additional data were provided by private and agency cooperators;
- Conduct limiting factors analysis (LFA). An analysis based on the Ecological Management Decision Support system (EMDS) was used to evaluate factors at the tributary scale. These factors were rated to be either beneficial or restrictive to the well-being of fisheries;
- Conduct refugia rating analysis. Watershed, stream, habitat, and fishery information were combined and evaluated in terms of their importance to salmon and steelhead;
- Develop conclusions and recommendations;
- Facilitate monitoring of conditions.

CWPAP Products and Utility

CWPAP assessment reports and their appendices are intended to be useful to landowners, watershed groups, agencies, and individuals to help guide restoration, land use, watershed, and salmonid management decisions. The assessments operate on multiple scales ranging from the detailed and specific stream reach level to the very general basin level. Therefore, findings and recommendations also vary in specificity from being particular at the finer scales, and more general at the basin scale.

Assessment products include:

- A basin level report that includes:
  - A collection of the SF Eel River Basin's historical information;
  - A description of historic and current hydrology, geology, land use, water quality, salmonid distribution, and instream habitat conditions;
  - An evaluation of watershed processes and conditions affecting salmonid habitat;
  - A list of issues developed by landowners, agency staff, and the public;
  - An analysis of the suitability of stream reaches and the watershed for salmonid production and refugia areas;
  - Tributary and watershed recommendations for management, refugia protection, and restoration activities to address limiting factors and improve conditions for salmonid health and productivity;
  - Monitoring recommendations to improve the adaptive management efforts;
- Ecological Management Decision Support system (EMDS) based models to help analyze instream conditions;
- Databases of information used and collected;
- A data catalog and bibliography;
- Web based access to the Program's products:
  - http://www.coastalwatersheds.ca.gov/,
  - http://www.calfish.org, http://bios.dfg.ca.gov,
  - http://www.dfg.ca.gov/biogeodata/gis/imaps.asp

Assessment Report Conventions CalWater 2.2.1 Planning Watersheds and CWPAP Subbasins

The California Watershed Map (CalWater Version 2.2.1) is used to delineate planning watershed units (*Figure 2*). This hierarchy of watershed designations consists of six levels of increasing specificity: Hydrologic Region, Hydrologic Unit, Hydrologic Area, Hydrologic Sub-Area, Super Planning Watershed, and Planning Watershed (PW). PWs are used by CWPAP to delineate basins, subbasins, and drainages.

CalWater 2.2.1 PWs may not represent true watersheds. Because PWs were created using elevation data rather than flow models, PWs may cut across streams and ridgelines, especially in less mountainous areas. Streams, such as the mainstem SF Eel River, can flow through multiple PWs. In addition, a stream, or administrative boundary, such as the California state border, may serve as a division between two PWs. For these and other reasons, PWs may not depict the true catchment of a stream or stream system. Despite these potential drawbacks, the use of a common watershed map has proven helpful in the delineation of basins and subbasins.

The assessment team subdivided the SF Eel River Basin into three subbasins for assessment and analyses purposes (*Figure 3*). These are the Northern, Eastern, and Western subbasins. In general, these subbasins have distinguishing attributes common to the CalWater 2.2.1 Planning Watersheds (PWs) contained within them.

Variation among subbasins is a product of natural and human disturbances. Characteristics that can distinguish subbasins within larger basins include differences in elevation, geology, soil types, aspect, climate, vegetation, fauna, human population, land use and other social-economic considerations.

Demarcation in this logical manner provides a uniform methodology for conducting large scale assessment. It provides a framework for the reporting of specific findings as well as assisting in developing recommendations for watershed improvement activities that are generally applicable across the relatively homogeneous subbasin area.

CalWater was created by the California Interagency Watershed Mapping Committee (IWMC), a collaboration of nine state and federal agencies. Since 2000, the IWMC has supported the development of a new dataset known as the Watershed Boundary Dataset (WBD). This new dataset is nationally consistent, and is delineated and geo-referenced to the USGS 1:24,000 scale. The WBD is now part of the USGS National Hydrography Dataset (NHD), and will eventually replace CalWater (T. Christy, CDFW, personal communication). Future CWPAP watershed assessments may use WBD to delineate planning watershed units. For additional information on WBD and the transition from CalWater, see: http://nhd.usgs.gov/wbd.html.

Hydrologic Hierarchy

Watershed terminology often becomes confusing when discussing different scales of watersheds involved in planning and assessment activities. The conventions used in the SF Eel River Basin assessment follow guidelines established by the Pacific Rivers Council. The descending order of scale is from basin level (e.g., SF Eel River Basin) to subbasin level (e.g., Northern Subbasin) to watershed level (e.g., Bull Creek) to sub-watershed level (e.g., Upper Bull Creek) (*Figure 4*).

The subbasin is the assessment and planning scale used in this report as a summary framework. In the watershed hierarchy, findings and recommendations are broader at the basin level and more specific at the sub-watershed level. Subbasin findings and recommendations are based on more specific watershed and sub-watershed level findings; therefore, there may be exceptions or modifications to recommendations when applied at different levels within the hydrologic hierarchy.

Terminology

The term “watershed” is used in both the generic sense, to describe watershed conditions at any scale and as a particular term to describe the watershed hierarchy introduced above. It is important to consider

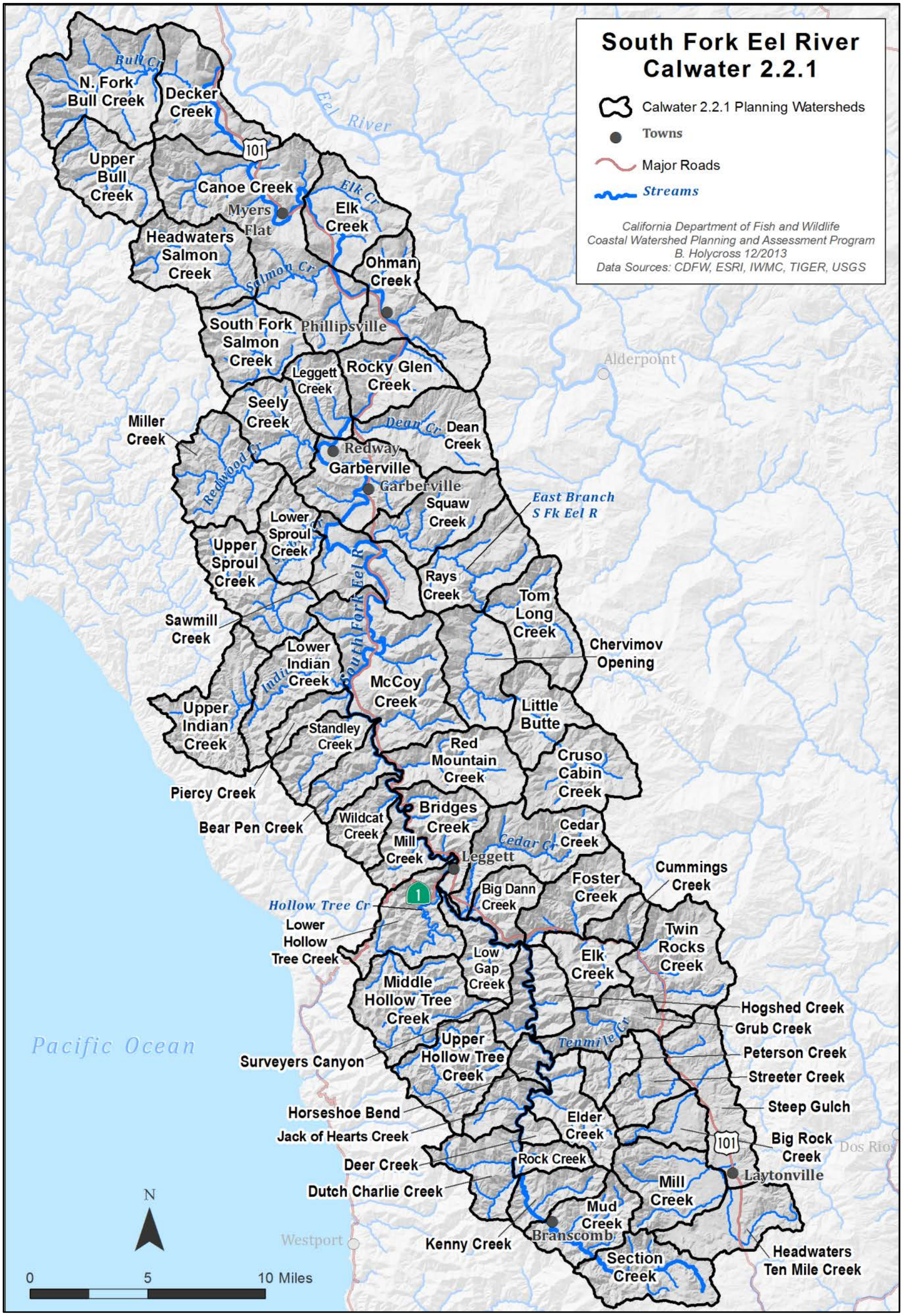

Figure 2. SF Eel River Basin - CalWater 2.2.1 planning watersheds

Figure 3. SF Eel River Basin and Northern, Eastern, and Western Subbasin boundaries.

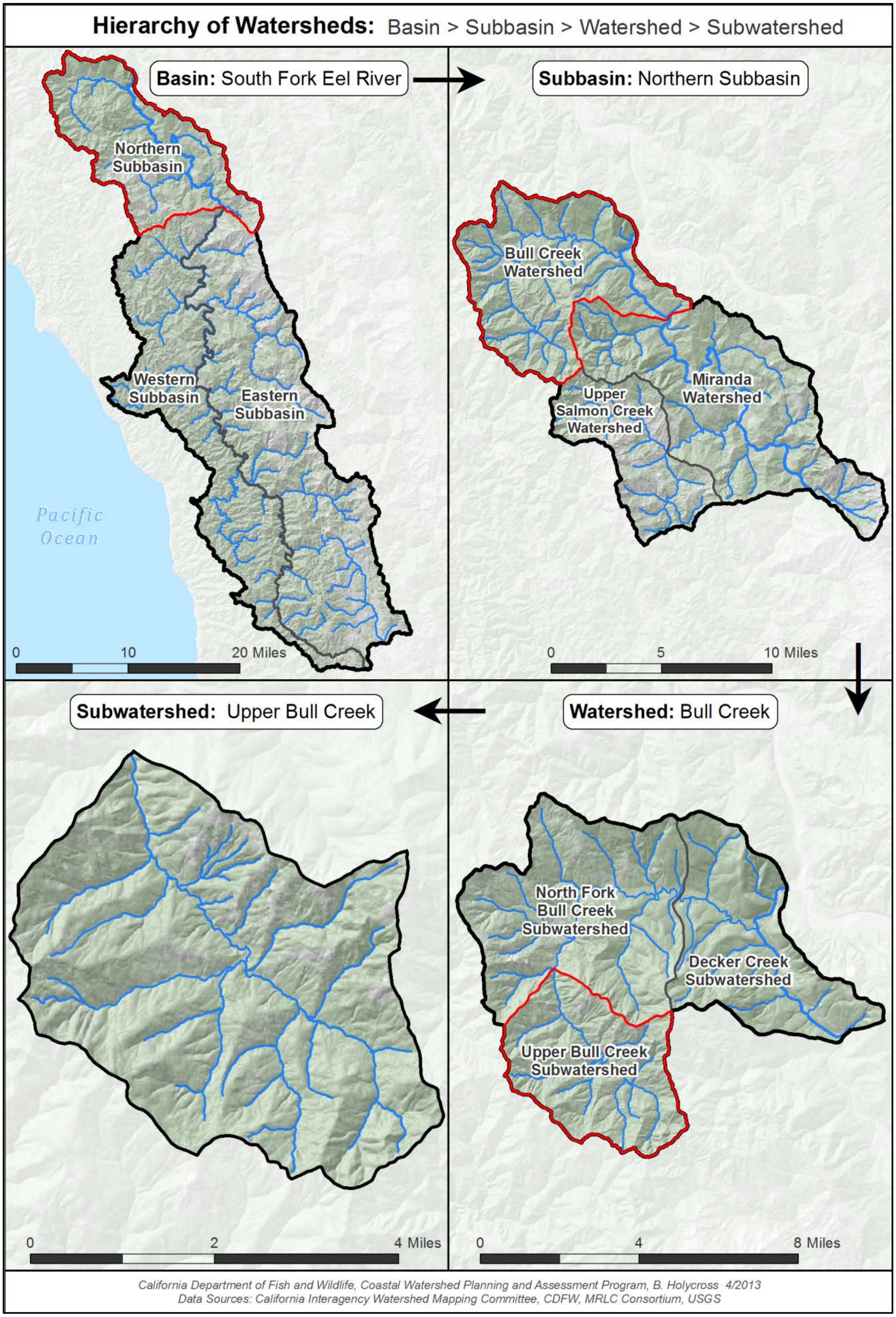

Figure 4. Hydrography Hierarchy in Bull Creek watershed, SF Eel River Basin.

the context of the term when used to reduce confusion. A watershed area is often approximately 20–40 square miles; sub-watersheds can be much smaller, but for assessment purposes must contain at least one perennial, un-branched stream.

Another important term is "river mile," indicated as RM. RM is used to assign a specific, measured distance upstream from the mouth of a river or stream to a point or feature upstream. In this report, RM is used to locate points along the SF Eel River and/or its tributaries (e.g. Benbow Dam is at RM 40).

Electronic Data Conventions

Members of the CWPAP collected or created hundreds of data records for synthesis and analysis purposes and most of these data were either created in a spatial context or converted to a spatial format. Effective use of these data between the partner departments required establishing standards for data format, storage, management, and dissemination. Early in the assessment process, the CWPAP held a series of meetings designed to gain consensus on a common format for the often widely disparate data systems within each department. The objective of these meetings was to establish standards which could be used easily by each department, were most useful and powerful for selected analysis, and would be most compatible with standards used by potential private and public sector stakeholders. Participants agreed on the following standardized format for spatial data used in the program and base information disseminated to the public through the program (see the data catalog at the end of this report for a complete description of data sources and scale):

Data form: standard database format usually associated with a Geographic Information System (GIS) shapefile or personal geodatabase (Environmental System Research Institute, Inc. © [ESRI]). Data were organized by watershed. Electronic images were retained in their current format.

Spatial Data Projection: spatial data were projected from their native format to Teale Albers, North American Datum (NAD) 1983.

Scale: most data were created and analyzed at 1:24,000 scale to (1) match the minimum analysis scale for planning watersheds, and (2) coincide with base information (e.g., stream networks) on USGS quadrangle maps (used as Digital Raster Graphics [DRG]).

Data Sources: data were obtained from a variety of sources including spatial data libraries with partner departments or were created by manually digitizing from 1:24,000 DRG.

The metadata available for each spatial data set contain a complete description of how data were collected and attributed for use in the program. Spatial data sets that formed the foundation of most analysis included the 1:24,000 hydrography and the 10-meter scale Digital Elevation Models (DEM). Hydrography data were created by manually digitizing from a series of 1:24,000 DRG then attributing with direction, routing, and distance information using a dynamic segmentation process (for more information, see Cadkin 2002). The resulting routed hydrography allowed for precise alignment and display of stream habitat data and other information along the stream network. The DEM was created by USGS from base contour data for the entire study region.

Source spatial data were often clipped to watershed, planning watershed, and subbasin units prior to use in analysis. Analysis often included creation of summary tables, tabulating areas, intersecting data based on selected attributes, or creation of derivative data based on analytical criteria. For more information regarding the approach to analysis and basis for selected analytical methods, see Chapter 2, Assessment Strategy and General Methods, and Chapter 4, Interdisciplinary Synthesis and Findings.

Assessment Methods

Hydrology

There are three United States Geological Survey (USGS) river gages located within the basin: at Bull Creek (USGS ID 1147660), Miranda (USGS ID 11476500), and Leggett (USGS ID 11475800). There are also historic records from five additional, discontinued USGS river gages: at Branscomb (USGS ID 1145500), Laytonville (USGS ID 1145700), Garberville (USGS ID 1146000, 11475940), and Dyerville (USGS ID 1146620) (*Table 2*).

Table 2. USGS gages within the SF Eel River Basin.

Continuous:	Catchment miles^2	Years of record
11476500 SF Eel River near Miranda	537	1940 - 2012
11476600 Bull Creek	28.1	1960 - 2012
11475800 SF Eel River at Leggett	248	1964 - 2012
Discontinued:		
11475500 SF Eel River near Branscomb	43.9	1947-70
11475700 Tenmile Creek near Laytonville	50.3	1958-74
11475940 East Branch SF Eel River near Garberville	74.3	1966-72
11476000 SF Eel River at Garberville	468	1912-13, 1940
Partial records:		
11476620 SF Eel River at Dyerville	689	1963 - 1964

An approximation of likely historic flows occurring at the mouth of the SF Eel River (Dyerville Gage) was generated using nearby, existing gage records, basin area, and available precipitation data.

Geology and Fluvial Geomorphology

A generalized geologic map was compiled for use in this report using published USGS maps and limited, geologic field and aerial photo reconnaissance mapping. This map was then simplified by combining rock types of similar age, composition, and geologic history. Landslides depicted on the map are derived from McLaughlin et al (2000) and represent only large Quaternary landslide features as of 2000. Calculations of area occupied by each rock type were based on GIS interpretation. Limited field reconnaissance as well as a review of aerial photos (Humboldt County) from years 1941, 1963, 1967 and 1996 and recent images from Google-Earth was conducted to gather specific geologic information relevant to the report. A review of the available literature, published and unpublished, pertinent to the geology of the local area was used to gather information presented in this report.

Stream profiles were constructed primarily from USGS topographic 7.5 minute quadrangle coverage of the basin. Profile topography was combined with geologic information and maps from McLaughlin et al (2000), Kilbourne (1983 and 1984) and Spittler (1983 and 1984), and available GIS maps and data. Subsurface geology was extended from the surface vertically and does not reflect the actual inclination of subsurface geologic units, contacts, or faults.

Vegetation and Land Use

The USDA Forest Service (USFS) CALVEG vegetation data were used to describe basin-wide vegetation. This classification breaks down vegetation into major "vegetation cover types". These are further broken down into a number of "vegetation types".

A literature search was conducted to obtain all available historic land use data. More recent land use data was obtained from the Humboldt County Planning Department. Additionally, more detailed records of logging activity (THPs and NTOs) from 1991 to present were obtained from California Department of Forestry (CDF) in digital format.

Year 2010 census data were analyzed to provide population estimates for each SF Eel subbasin. The 2010 data were available from the CDF's Fire and Resource Assessment Program (FRAP). The Census Bureau statistics are organized at several levels including: State, County, Census County Division (CCD), Census Tract, Block Group, and Block. The SF Eel River basin contains sections of census tracts, which are made up of individual blocks. Block population totals were compiled to determine the estimated population of each SF Eel River subbasin. Blocks that crossed the basin or subbasin boundaries were examined more closely and population values were weighted based on the percentage of block area within the basin or subbasin boundary.

Fish Habitat and Populations Data Compilation and Collection

CDFW compiled existing available data and gathered anecdotal information pertaining to salmonids and the instream habitat on the SF Eel River and its tributaries. Anecdotal and historic information was cross-referenced with other existing data whenever possible. Where data gaps were identified, access was sought from landowners to conduct habitat inventory and fisheries surveys. Habitat inventories and biological data were collected following the protocol presented in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998).

Fish Passage Barriers

A total of 133 structures considered potential barriers to fish passage were evaluated between 1980 and 2012 in the SF Eel River Basin. Barriers were identified using a variety of sources, including DFW habitat and spawner survey reports, the CalFish Passage Assessment Database, profile analysis, NMFS' SONCC coho intrinsic potential map, field validation, and expert professional judgment. There are many types of barriers in the SF Eel River watershed including but not limited to: steep gradients, cascades, woody debris jams, landslides, and culverts. These barriers can be classified as temporary, partial, and total, and each type has different impacts on salmonid species and life stages (*Table 3*).

The most frequently encountered man-made barrier is culverts. Culverts often create temporary, partial, or complete barriers for adult and/or juvenile salmonids during their freshwater migration activities, and the cumulative effect of blocked habitat in Northern California streams is likely significant (Bates 1999, Taylor and Associates 2005).

Table 3. Definitions of barrier types and their potential impacts to salmonids (Taylor 2000).

Barrier Category	Definition	Potential Impact
Temporary	Impassable to all fish some of the time.	Delay in movement beyond the barrier for some period of time.
Partial	Impassable to some fish at all times.	Exclusion of certain species and life stages from portions of a watershed.
Total	Impassable to all fish at all times.	Exclusion of all species from portions of a watershed.

Target Values from Habitat Inventory Surveys

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. In the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 2010) target values were given for canopy density, primary pool frequency, and pool shelter/cover (*Table 4*). Target values for embeddedness were established by the NCWAP team, using a modification of Flosi et al.'s (2010) consideration of category 1 cobble embeddedness as the highest quality spawning habitat. Because of the incompetent Franciscan geology found throughout the SF Eel River Basin, many streams contain large amounts of fine sediment in streams. The NCWAP team determined that streams with a preponderance of habitat with categories 1 and 2 embeddedness would be suitable for spawning salmonids, and set a value of >50% category 1 and 2 embeddedness as the target for this factor. When habitat conditions fall below the target values, restoration projects may be proposed in an attempt to meet critical habitat needs for salmonids.

Table 4. Habitat inventory target values.

Habitat Element	Canopy Density	Embeddedness	Primary Pool* Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-100%	0-300 Rating
Target Values	>80%	>50% of the pool tails surveyed with category 1 & 2 embeddedness values	>40% of stream length	>100

*Primary pools are pools >2 feet deep in 1st and 2nd order streams, >3 feet deep in 3rd order streams, or >4 feet deep in 4th order streams

Canopy Density - Eighty Percent or More of the Stream Should be Covered by Canopy

Near-stream forest density and composition contribute to microclimate conditions. These conditions help regulate air temperature and humidity, which are important factors in determining stream water temperature. Along with the insulating capacity of the stream and riparian areas during winter and summer, canopy density levels provide an indication of the potential present and future recruitment of large woody debris to the stream channel. Re-vegetation projects should be considered when canopy density is less than the target value of 80%.

Good Spawning Substrate - Fifty Percent or More of the Pool Tails Sampled Should be Fifty Percent or Less Embedded

Cobble embeddedness is the percentage of an average sized cobble piece, embedded in fine substrate at the pool tail. The best coho salmon and steelhead trout spawning substrate is classified as Category 1 cobble embeddedness or 0-25% embedded. Category 2 is defined by the substrate being 26-50% embedded.

Cobble embedded deeper than 51% is not within the range for successful spawning. The target value is for 50% or more of the pool tails sampled to be 50% or less embedded (categories 1 and 2). Streams with less than 50% of their length greater than 51% embedded do not meet the target value and do not provide adequate spawning substrate conditions.

Pool Depth/Frequency - Forty Percent or More of the Stream Should Provide Pool Habitat

During their life history, salmonids require access to pools, flatwater, and riffles. Pool enhancement projects are considered when pools comprise less than 40% of the length of total stream habitat. The target values for pool depth are related to the stream order. First and second order streams are required to have 40% or more of the pools 2 feet or deeper to meet the target values. Third and fourth order streams are required to have 40% or more of the pools 3 feet or deeper or 4 feet or deeper, respectively, to meet the target values. A frequency of less than 40% or inadequate depth related to stream order indicates that the stream provides insufficient pool habitat.

Shelter/Cover - Scores of One Hundred or More Means That the Stream Provides Sufficient Shelter/Cover

Pool shelter/cover provides protection from predation and rest areas from high velocity flows for salmonids. Shelter/cover elements include undercut banks, small woody debris, large woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains (whitewater), boulders, and bedrock ledges. All elements present are measured and scored. Shelter/cover values of 100 or less indicate that shelter/cover enhancement should be considered.

Water Quality

The maximum weekly average temperature (MWAT) is the maximum value of the seven day moving average temperatures. The CWPAP staff created suitability ranges for habitat based on MWATs, considering the effect of temperature on salmonid viability, growth, and habitat fitness (*Table 5*). 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 lethality is ≥75°F.

Table 5. CWPAP-defined salmonid habitat quality ratings for MWATs.

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

Ecological Management Decision Support System

The Ecological Management Decision Support (EMDS) system software was developed at the USDA Forest Service, Pacific Northwest Research Station (Reynolds 1999). It employs a linked set of software that includes MS Excel, NetWeaver, EMDS and ArcGIS™. The NetWeaver software, developed at Pennsylvania State University, helps scientists model linked frameworks of various environmental factors called knowledge base networks (Reynolds et al. 1996).

These networks specify how various environmental factors will be incorporated into an overall stream or watershed assessment. The networks resemble branching tree-like flow charts, graphically showing the assessment's logic and assumptions, and are used in conjunction with spatial data stored in a Geographic Information System (GIS) to perform assessments and render the results into maps.

EMDS was used as an analysis tool in previous NCWAP and CWPAP watershed assessments. However, due to changes in EMDS 4.2 software and compatibility issues with ArcMap 10.0, CWPAP staff created a program in Visual Basic to synthesize information on stream reach condition using instream habitat data for 4 factors: canopy density, pool depth, pool shelter, and cobble embeddedness. Our analysis used similar logic, factors, and assumptions, but a more simplified model framework compared to the EMDS analysis used in previous CWPAP watershed assessments. Habitat suitability maps were designed by importing model output data into ArcMap 10, and the analysis was referred to throughout the assessment report as an "EMDS based analysis". A brief introduction to EMDS is presented below in order to describe the logic and assumptions used in the SF Eel River Basin analysis; for a more detailed explanation, see Appendix A.

Development of the North Coast California EMDS Model

NCWPAP staff began development of EMDS knowledge base models with a three-day workshop in June of 2001 organized by the University of California, Berkeley. In addition to the assessment program staff, model developer Dr. Keith Reynolds and several outside scientists also participated. As a starting point, analysts used an EMDS knowledge base model developed by the Northwest Forest Plan for use in coastal Oregon. Based upon the workshop, subsequent discussions among staff and other scientists, examination of the literature, and consideration of localized California conditions, the assessment team scientists then developed preliminary versions of the EMDS models.

The Knowledge Base Network

For California's north coast watersheds, the assessment team constructed a knowledge base network, the Stream Reach Condition Model. The model was reviewed in April 2002 by an independent nine-member science panel, which provided suggestions for model improvements. According to their suggestions, the team revised the original model. The Stream Reach Condition model addresses conditions for salmonids on individual stream reaches and is largely based on data collected using CDFW stream survey protocols found in the *California Salmonid Stream Habitat Restoration Manual*, (Flosi et al. 2010).

In creating these models, the team used what is termed a tiered, top-down approach. For example, the Stream Reach Condition model tested the truth of the proposition: The overall condition of the stream reach is suitable for maintaining healthy populations of native Chinook, coho, and steelhead trout. A knowledge base network was then designed to evaluate the truth of that proposition, based upon existing data from each stream reach. The model design and contents reflected the specific data and information analysts believed were necessary, and the manner in which they should be combined, to test the proposition.

In evaluating stream reach conditions for salmonids, the model uses data from several environmental factors. The first branching tier of the knowledge base network shows the data based summary nodes on: 1) in-channel condition; 2) stream flow; 3) riparian vegetation and: 4) water temperature (*Figure 5*). These nodes are combined into a single value to test the validity of the stream reach condition suitability proposition. In turn, each of the four summary branch node values is formed from the combination of its more basic data components. The process is repeated until the knowledge base network incorporates all information believed to be important to the evaluation (*Figure 6*).

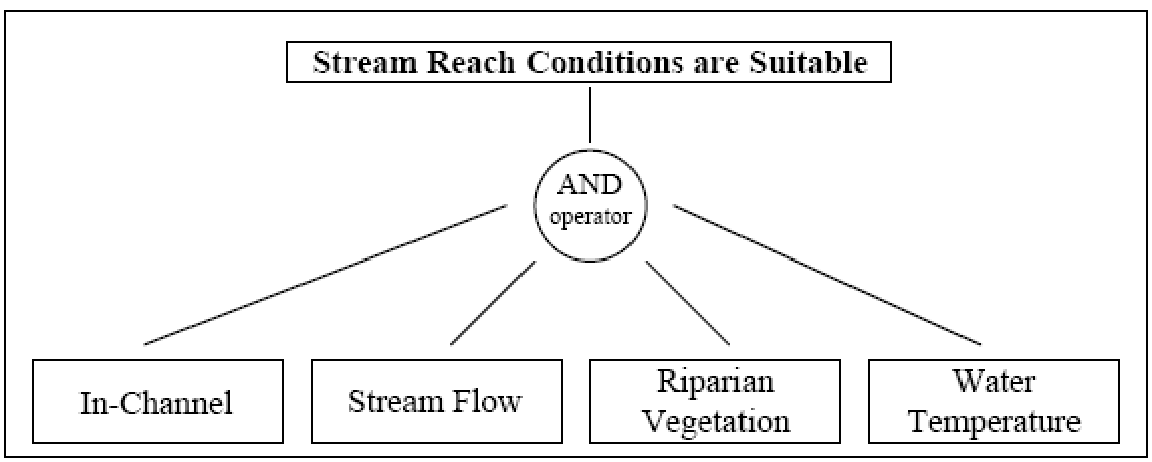

Figure 5. Tier one of the stream reach knowledge base network.

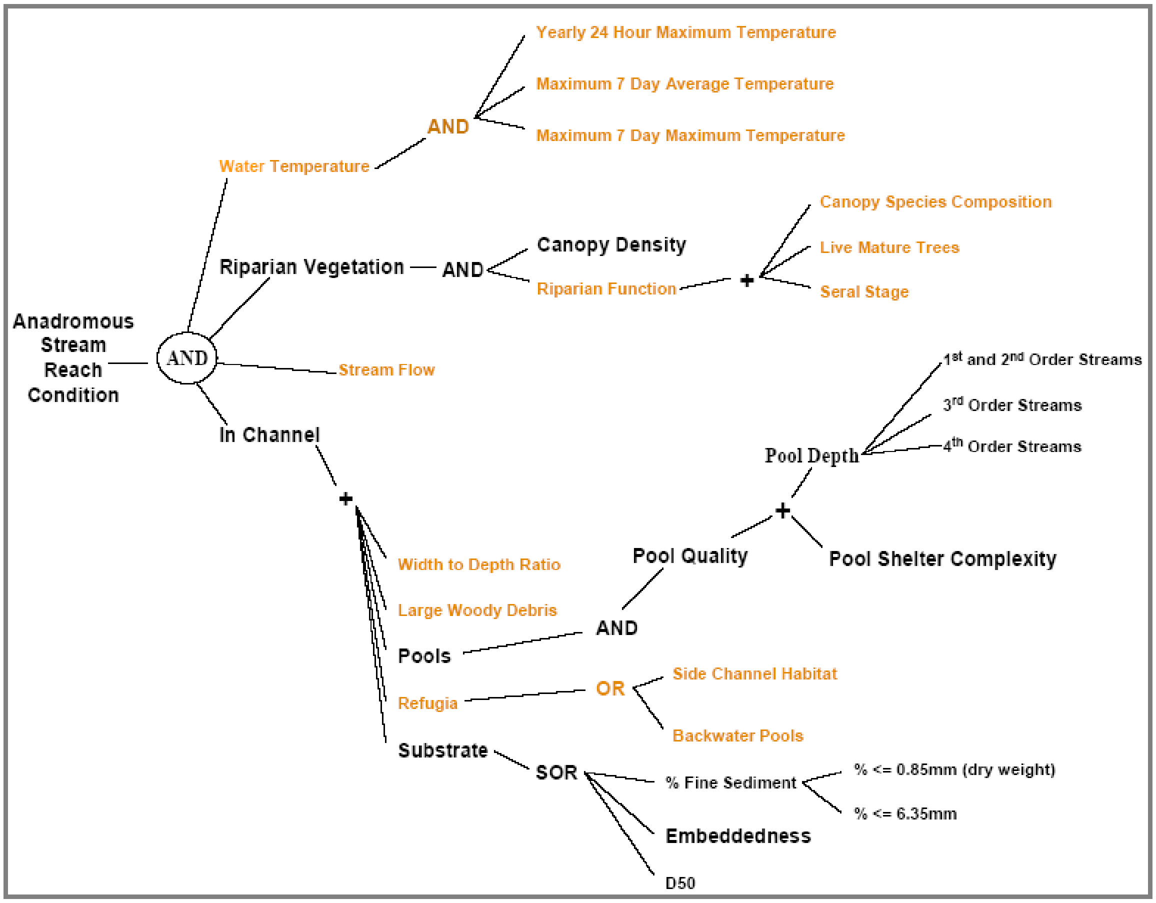

Figure 6. Graphic representation of the stream reach condition model.

Habitat factors populated with data in the SF Eel River Basin assessment model are shown in black. Other habitat factors considered important for stream habitat condition evaluation, but data limited in the SF Eel River assessment, are shown in orange.

In *Figure 5*, the *AND operator* indicates a decision node that means that the lowest, most limiting value of the four general factors determined by the model will be passed on to indicate the potential of the stream reach to sustain salmonid populations. In that sense, the model mimics nature. For example, if summertime low flow is reduced to a level deleterious to fish survival or well-being, regardless of a favorable temperature regime, instream habitat, and/or riparian conditions, the overall stream condition is not suitable to support salmonids.

Although model construction is typically done top-down, models are run in an EMDS type analysis from the bottom up. That is, stream reach data are usually entered at the lowest and most detailed level of the several branches of the network tree (the leaves). The data from the leaves are combined progressively with other related attribute information as the analysis proceeds up the network. Decision nodes are intersections in the model networks where two or more factors are combined before the resultant information moves up the network (*Figure 6*).

The model assesses the degree of truth (or falsehood) of each proposition. Each proposition is evaluated in reference to simple graphs called reference curves that determine the degree of truth/falsehood, according to implications of the data for salmon. *Figure 7* shows an example reference curve for the proposition that stream temperature is suitable for salmon. The horizontal axis shows temperature ranging from 30-80° F, while the vertical axis is labeled Truth Value and ranges from values of +1 to -1. The upper horizontal line arrays the fully suitable temperatures from 50-60°F (+1). The fully unsuitable temperatures are arrayed at the bottom (-1). Those in between range from fully suitable to fully unsuitable and are rated accordingly. A similar numeric relation is determined for all attributes evaluated with reference curves in the models.

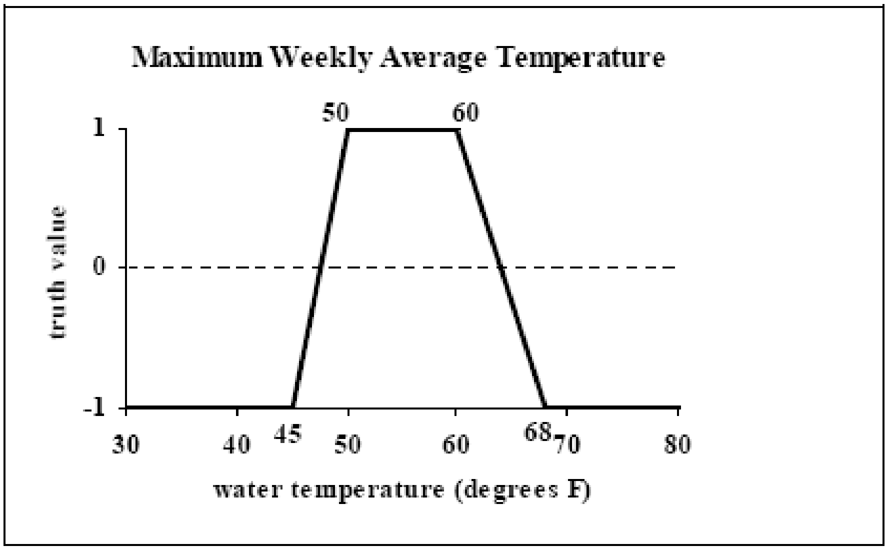

Figure 7. Reference curve for stream temperature.

This type of reference curve is used in conjunction with data specific to a stream reach. This example reference curve evaluates the proposition that instream water temperature is suitable for salmonids. Break points on the curve can be set for individual species, life stages, or seasons of the year. Curves are dependent on the availability of data to be included in an analysis.

For each evaluated proposition in the model network, the result is a number between –1 and +1. The number relates to the degree to which the data support or refute the proposition. In all cases a value of +1 means that the proposition is completely true, and –1 implies that it is completely false, while in-between values indicate degrees of truth (i.e. values approaching +1 are closer to true and those approaching –1 are closer to completely untrue). A zero value means that the proposition cannot be evaluated based upon the data available. Breakpoints occur where the slope of the reference curve changes. For example, in *Figure 7*, breakpoints occur at 45, 50, 60, and 68°F.

CWPAP staff used a four-class system for depicting truth-values. Values ranged between +1 (highest suitability) and –1 (lowest suitability). Between 0 and 1 are two classes which, although unlabeled in the legend, indicate intermediate values of better suitability (0 to 0.5, and 0.5 to 1). Symmetrically, between 0 and –1 are two similar classes which are intermediate values of worse suitability (< 0 to –0.5, and –0.5 to –1). These ranking values are assigned based upon condition findings in relation to the criteria in the reference curves. *Table 6* summarizes Stream Reach Condition model information and parameters.

Table 6. Reference curve metrics for the stream reach condition model.

Stream Reach Condition Factor	Definition and Reference Curve Metrics
Aquatic / Riparian Conditions	
Summer MWAT	• Maximum 7-day average summer water temperature • < 45°F fully unsuitable, 50-60°F fully suitable, > 68°F fully unsuitable. • Water temperature was not included in current evaluation.
Riparian Function	
Canopy Density	• Average percent of the thalweg within a stream reach influenced by tree canopy. • < 50% fully unsuitable, ≥ 85% fully suitable.
Seral Stage	Seral stage composition of near stream forest. Under development.
Vegetation Type	Forest composition Under development.
Stream Flow	Model parameters are in development; currently, stream flow is considered separately from EMDS based analysis in the assessment process.

Stream Reach Condition Factor	Definition and Reference Curve Metrics
In-Channel Conditions	
Pool Depth	• Percent of stream reach with pools of a maximum depth of 2.5, 3, and 4 feet deep for first and second, third, and fourth order streams respectively. • ≤ 15% fully unsuitable, 33 – 55% fully suitable, ≥ 85% fully unsuitable.
Pool Shelter Complexity	• Relative measure of quantity and composition of large woody debris, root wads, boulders, undercut banks, bubble curtain, overhanging and instream vegetation. • ≤ 30 fully unsuitable, ≥ 100 - 300 fully suitable.
Pool Frequency	Percent of pools by length in a stream reach. Under development.
Substrate Embeddedness	• Pool tail embeddedness is a measure of the percent of small cobbles (2.5" to 5" in diameter) buried in fine sediments. • The model calculates categorical embeddedness data to produce evaluation scores between –1 and +1. The proposition is fully true if evaluation scores are 0.8 or greater and -0.8 evaluate to fully false.
Percent Fines in Substrate <0.85mm (dry weight)	• Percent of fine sized particles <0.85 mm collected from McNeil type samples. • < 10% fully suitable, > 15% fully unsuitable. • There was not enough of percent fines data to use percent fines in evaluations
Percent Fines in Substrate <6.4 mm	• Percent of fine sized particles < 6.4 mm collected from McNeil type samples. • <15% fully suitable, >30% fully unsuitable. • There was not enough of percent fines data to use percent fines in evaluations.
Large Woody Debris (LWD)	• The reference values for frequency and volume are derived from Bilby and Ward (1989) and are dependent on channel size. • See Analysis Appendix for details. • Most watersheds do not have sufficient LWD survey data for use in the analysis.
Winter Refugia Habitat	• Winter refugia habitat is composed of backwater pools, side channel habitats, and deep pools (> 4 feet deep). • Not implemented at this time.
Pool to Riffle Ratio	Ratio of pools to riffle habitat units. Under development.
Width to Depth Ratio	Ratio of bankfull width to maximum depth at velocity crossovers. Under development.

Advantages Offered by EMDS Based Analysis

The EMDS based analysis offers a number of advantages for use in watershed assessments. Instead of being a hidden black box, each model has an open and intuitively understandable structure. The explicit nature of the model networks facilitates open communication among agency personnel and with the general public through simple graphics and easily understood flow diagrams. The models can be easily modified to incorporate alternative assumptions about the conditions of specific environmental factors (e.g., stream water temperature) required for suitable salmonid habitat.

Using model outputs, CWPAP staff used Geographic Information System (GIS) software, to map the factors affecting fish habitat and show how they vary across a basin. The models also provide a consistent and repeatable approach to evaluating watershed conditions for fish. In addition, the maps from supporting levels of the model show the specific factors that, taken together, determine overall watershed conditions. This latter feature can help identify what is most limiting to salmonids, and thus assist in prioritizing restoration projects or modifying land use practices.

Limitations of the EMDS Based Model and Data Input

While EMDS based syntheses are important tools for watershed assessment, they do not by themselves yield a course of action for restoration and land management. Analysis results require interpretation, and how they are employed depends upon other important issues, such as social and economic concerns. In addition to the accuracy of the model constructed, the dates and completeness of the data available for a stream or watershed will strongly influence the degree of confidence in the results. External validation of the model using fish population data and other information should be done.

One disadvantage of linguistically based models is that they do not provide results with readily quantifiable levels of error. Therefore, the EMDS model should only be used to indicate the quality of watershed or instream conditions based on available data and the model structure. It is not intended to provide highly definitive answers, such as those obtained from a statistically based process model. The model does provide a reasonable first approximation of conditions through a robust information synthesis approach; however, its outputs need to be considered and interpreted using other information sources and with an understanding of the inherent limitations of the model and its data inputs. It also should be clearly noted that this model does not assess the marine phase of the salmonid life cycle, nor does it consider fishing pressures.

Program staff identified some model or data elements needing attention and improvement in future iterations. These currently include:

- Completion of quality control evaluation procedures;
- Adjust the model to better reflect differences between mainstem and tributary habitat, for example, the modification of canopy density standards for wide streams;
- Develop a suite of Stream Reach Model reference curves to better reflect the variation in expected conditions for different geographic watershed locations, depending on geology, vegetation, precipitation, and runoff patterns.

At this time, all of the recommendations made by peer reviewers have not been implemented into the models. Additionally, results should be used as valuable but not necessarily definitive products, and their validation with other observations is necessary. The *Analysis Appendix* provides additional detail concerning the system structure and operations.

Adaptive Application for EMDS Based Model and CDFW Stream Habitat Evaluations

CDFW has developed habitat evaluation standards, or target values, to help assess the condition of anadromous salmonid habitat in California streams (Flosi et al. 2010). These standards are based upon data analyses of over 1,500 tributary surveys, and considerable review of pertinent literature. The model reference curves have similar standards, adapted from CDFW, but following peer review and professional discussion, they have been modified slightly. As a result, slight differences occur between values found in Flosi et al. (2010) and those used in the model. Reference curves developed for the analysis are provided in the *Analysis Appendix* of this report.

Both habitat evaluation systems have similar but slightly different functions. Stream habitat standards developed by CDFW are used to identify habitat conditions and to establish priorities among streams considered for improvement projects based upon standard CDFW tributary reports. The EMDS based model compares select components of the stream habitat survey data to reference curve values and expresses degrees of habitat suitability for fish on a sliding scale. In addition, the model produces a combined estimate of overall stream condition by combining the results from several stream habitat components. In the fish habitat relationship section of this report, we utilize target values found in Flosi et al. (2010), field observations, and results from reference curve evaluations to help describe and evaluate stream habitat conditions.

Due to the wide range of geology, topography and diverse stream channel characteristics which occur within the North Coast region, there are streams that require more detailed interpretation and explanation of results than can be simply generated by suitability criteria or tributary survey target values. For example, pools are an important habitat component and a useful stream attribute to measure. However, some small fish-bearing stream channels may not have the stream power to scour pools of the depth and frequency considered to be high value "primary" pools by CDFW target values, or to be fully suitable according to the model. Often, these shallow pool conditions are found in low gradient stream reaches in small watersheds that lack sufficient discharge to deeply scour the channel. They also can exist in moderate to steep gradient reaches with bedrock/boulder dominated substrate highly resistant to scour, which also can result in few deep pools. Therefore, some streams may not have the inherent ability to attain conditions that meet the suitability criteria or target values for pool depth. These scenarios result in pool habitat conditions that are not considered highly suitable by either assessment standard. However, these streams may still be very important because of other desirable features that support valuable fishery resources. As such, they receive additional evaluation with our refugia rating system and expert professional judgment. Field validation of any modeling system results is a necessary component of watershed assessment and reporting.

Limiting Factors Analysis

A main objective of CDFW watershed assessment is to identify factors that limit production of anadromous salmonid populations in North Coast watersheds.

This process is known as a limiting factors analysis (LFA). The limiting factors concept is based upon the assumption that eventually every population must be limited by the availability of necessary support resources (Hilborn and Walters 1992) or that a population's potential may be constrained by an overabundance, deficiency, or absence of a watershed ecosystem component. Identifying stream habitat factors that limit or constrain anadromous salmonids is an important step towards setting priorities for habitat improvement projects and management strategies aimed at the recovery of declining fish stocks and protection of viable fish populations.

Although several factors have contributed to the decline of anadromous salmonid populations in the Northwest, habitat loss and modification are major determinants of their current status (FEMAT 1993, Yoshiyama and Moyle 2010). Our approach to a LFA integrates two habitat based methods to evaluate the status of key aspects of stream habitat that affect anadromous salmonid production - species life history diversity and the ability of a stream to support viable populations.

The first method uses priority ranking of habitat categories based on a CDFW team assessment of data collected during stream habitat inventories. The second method uses the EMDS based model to evaluate the suitability of key stream habitat components to support anadromous fish populations. These habitat-based methods assume that stream habitat quality and quantity play important roles in the ability of a watershed to produce viable salmonid populations.

The LFA assumes that poor habitat quality and a reduction in favorable habitat impairs fish production. LFA focuses primarily on those physical habitat factors in freshwater and estuarine ecosystems that affect spawning and subsequent juvenile life history requirements during low flow seasons. Two general categories of factors or mechanisms limit salmonid populations:

- Density independent mechanisms, which generally operate without regard to population density. These include factors related to habitat quality such as stream flow and water temperature or chemistry. In general, fish will die regardless of the population density if flow is inadequate, or if water temperatures or chemistry reach lethal levels; and
- Density dependent mechanisms, which generally operate according to population density and habitat carrying capacity. Competition for food, space, and shelter are examples of density dependent factors that affect growth and survival when populations reach or exceed the habitat carrying capacity.

The CWPAP approach considers these two types of habitat factors before prioritizing recommendations for habitat management strategies. Priority steps are given to preserve and increase the amount of high quality (density independent) habitat in a cost effective manner.

Restoration Needs/Tributary Recommendations Analysis

CDFW crews inventoried 118 tributaries to the SF Eel River between 1990 and 2010, using protocols in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 2010). The stream inventories are a combination of several stream reach surveys: habitat typing, channel typing, biological assessments, and in some reaches LWD and riparian zone recruitment assessments. An experienced Biologist and/or Habitat Specialist conducted quality assurance/quality control (QA/QC) on field crews and collected data, performed data analysis, and determined general areas of habitat deficiency based upon the analysis and synthesis of information.

CDFW biologists selected and ranked recommendations for each of the inventoried streams, based upon the results of these standard CDFW habitat inventories, and updated the recommendations with the results of the stream reach condition EMDS based synthesis and the refugia analysis (*Table 7*). These selections are made from stream reach conditions that were observed at the times of the surveys and do not include upslope watershed observations other than those that could be made from the streambed. They reflect a single point in time and do not anticipate future conditions. However, these general recommendation categories have proven to be useful as the basis for specific project development, and they provide focus for on-the-ground project design and implementation.

It is important to remember that stream and watershed conditions change over time and periodic survey updates and field verification are necessary if watershed improvement projects are being considered. In general, recommendations designed to reduce erosion and sediment input by treating roads and failing stream banks, and those that improve riparian and near stream vegetation, precede instream recommendations in reaches within watersheds with high levels of disturbance. Instream improvement recommendations are usually a high priority in streams that reflect watersheds in recovery or those in good health. Various project treatment recommendations can be made concurrently if watershed and stream conditions warrant.

Table 7. List of tributary recommendations in stream tributary reports.

Recommendation	Explanation
Water Surface Flows	Dry stream reaches were measured and analyzed to be a high percent of overall stream length surveyed and impacting the aquatic community.
Water Temperature	Summer water temperatures were measured to be above optimum for salmon and steelhead in survey reaches
Pool	Pools are below CDFW target values in quantity and/or quality
Cover	Escape cover is below CDFW 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
Canopy	Shade canopy is below CDFW target values
Spawning Gravel	Spawning gravel is deficient in quantity and/or quality
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

Fish passage problems, especially in situations where favorable stream habitat reaches are being separated by a man-caused feature (e.g., culvert), are usually a treatment priority. Good examples of these are the recent and dramatically successful Humboldt County/CDFW culvert replacement projects in tributaries to Humboldt Bay. In these regards, the program's more general watershed scale upslope assessments can go a long way in helping determine the suitability of conducting instream improvements based upon watershed health. As such, there is an important relationship between the instream and upslope assessments.

Additional considerations must enter into the decision-making process before these general recommendations are further developed into improvement activities. In addition to watershed condition considerations as a context for these recommendations, there are certain logistic considerations involved in ranking recommendations for project development. These can include work party access limitations based upon lack of private party trespass permission and/or physically difficult or impossible locations of selected work sites. Biological considerations are made based upon the propensity for potential projects to benefit multiple or single fishery stocks or species. Cost benefit and project feasibility are also important factors in project design, development, and selection.

Potential Salmonid Refugia

Establishment and maintenance of salmonid refugia areas containing high quality habitat and sustaining fish populations are activities vital to the conservation of our anadromous salmonid resources (FEMAT 1993; Reeves et al. 1995). Protecting these areas will prevent the loss of remaining high quality salmon habitat and salmonid populations. Therefore, a refugia investigation project should focus on identifying areas found to have high salmonid productivity and diversity.

Identified areas should then be carefully managed for the following benefits:

- Protection of refugia areas to avoid loss of the last best salmon habitat and populations. The focus should be on protection for areas with high productivity and diversity;
- Refugia area populations which may provide a source for re-colonization of salmonids in nearby watersheds that have experienced local extinctions, or are at risk of local extinction due to small population size and stochastic effects;
- Refugia areas provide a hedge against the difficulty in restoring extensive, degraded habitat and recovering imperiled populations in a timely manner.

The concept of refugia is based on the premise that patches of aquatic habitat provide habitat that retains the natural capacity and ecologic functions to support wild anadromous salmonid spawning and rearing. Anadromous salmonids exhibit typical features of patchy populations; they exist in dynamic environments and have developed various dispersal strategies including juvenile movements, adult straying, and relatively high fecundity for an animal that exhibits some degree of parental care through nest building (Reeves et al. 1995).

Conservation of patchy populations requires conservation of multiple suitable habitat patches and maintenance of passage corridors between them. Potential refugia may exist in areas where the surrounding landscape is marginally suitable for salmonid production or altered to a point that stocks have shown dramatic population declines in traditional salmonid streams (Bartholow 2005, Sutton and Soto 2012). If altered streams or watersheds recover their historic natural productivity through either restoration efforts or natural processes, the abundant source populations from nearby refugia can potentially re-colonize these areas or help sustain existing salmonid populations in marginal habitat (May and Peterson 2003). Protection of refugia areas is noted as an essential component of conservation efforts to ensure long-term survival of viable stocks, and a critical element towards recovery of depressed populations (Sedell et al. 1990; FEMAT 1993; Frissell 1993, Frissell et al. 2000).

Refugia habitat elements include the following:

- Areas that provide shelter or protection during times of danger or distress;
- Locations and areas of high quality habitat that support populations limited to fragments of their former geographic range, and;
- A center from which dispersion may take place to re-colonize areas after a watershed and/or subwatershed level disturbance event and readjustment.

Spatial and Temporal Scales of Refugia

These refugia concepts become more complex in the context of the wide range of spatial and temporal habitat required for viable salmonid populations. Habitat can provide refuge at many scales from a single fish to groups of them, and finally to breeding populations. For example, refugia habitat may range from a piece of wood that provides instream shelter for a single fish, or individual pools that provide cool water for several rearing juveniles during hot summer months, to watersheds where conditions support sustaining populations of salmonid species. Refugia also include areas where critical life stage functions such as migrations and spawning occur, at both the stream reach and watershed scale (Feist et al. 2003). Although fragmented areas of suitable habitat are important, their connectivity is necessary to sustain the fisheries (May and Peterson 2003).

Today, watershed scale refugia are needed to recover and sustain aquatic species (Moyle and Sato 1991). For the purpose of this discussion, refugia are considered at the fish bearing tributary and subbasin scales. These scales of refugia are generally more resilient to the deleterious effects of landscape and riverine disturbances such as large floods, persistent droughts, and human activities than the smaller, habitat unit level scale (Sedell et al. 1990).

Standards for refugia conditions are based on reference curves from the literature and CDFW data collection at the regional scale. CWPAP staff used these values in EMDS models to formulate recommendations. Li et al. (1995) suggested three prioritized steps to use the refugia concept to conserve salmonid resources:

- Identify salmonid refugia and ensure that they are protected;
- Identify potential habitats that can be rehabilitated quickly;
- Determine how to connect dispersal corridors to patches of adequate habitat.

Refugia and Metapopulation Concept

The concept of anadromous salmonid metapopulations is important when discussing refugia. The classic metapopulation model proposed by Levins (1969) assumes that the environment is divided into discrete patches of suitable habitat. These patches include streams or stream reaches that are inhabited by different breeding populations or sub-populations (Barnhart 1994; McElhany et al. 2000). A metapopulation consists of a group of sub-populations which are geographically located such that over time, there is likely genetic exchange between the subpopulations (Barnhart 1994). Metapopulations are characterized by:

1) Relatively isolated, segregated breeding populations in a patchy environment that are connected to some degree by migration between them, and

2) A dynamic relationship between extinction and re-colonization of habitat patches.

Anadromous salmonids fit well into the subpopulation and metapopulation concept because they exhibit a strong homing behavior to natal streams forming sub-populations, and they have a tendency to stray into new areas. The straying or movement into nearby areas results in genetic exchange between subpopulations or seeding of other areas where populations are at low levels. This seeding comes from abundant or source populations supported by high quality habitat patches which may be considered refugia (May and Peterson 2003).

Habitat patches differ in suitability and population strength. In addition to the classic metapopulation model, other theoretical types of spatially structured populations have been proposed (Li et al. 1995; McElhany et al. 2000). For example, the core and satellite (Li et al. 1995) or island-mainland population (McElhany et al. 2000) model depicts a core or mainland population from which dispersal to satellites or islands results in smaller surrounding populations. Most straying occurs from the core or mainland to the satellites or islands. Satellite or island populations are more prone to extinction than the core or mainland populations (Li et al. 1995; McElhany et al. 2000).

Another model termed source-sink populations is similar to the core-satellite or mainland-island models, but straying is one way, only from the highly productive source towards the sink subpopulations. Sink populations are not self-sustaining and are highly dependent on migrants from the source population to survive (May and Peterson 2003). Sink populations may inhabit typically marginal or unsuitable habitat, but when environmental conditions strongly favor salmonid production, sink population areas may serve as important sites to buffer populations from disturbance events (Li et al. 1995) and increase basin population strength. In addition to testing new areas for potential suitable habitat, the source-sink strategy adds to the diversity of behavior patterns salmonids have adapted to maintain or expand into a dynamic aquatic environment.

The metapopulation and other spatially structured population models are important to consider when identifying refugia because in dynamic habitats, the location of suitable habitat changes (McElhany et al. 2000) over the long term from natural disturbance regimes (Reeves et al. 1995) and over the short term by human activities. Satellite, island/patch, and sink populations need to be considered in the refugia selection process because they are an integral component of the metapopulation concept. They also may become the source population or refugia areas of the future.

Methods to Identify Refugia

Currently there is no established methodology to designate refugia habitat for California's anadromous salmonids. This is mainly due to a lack of sufficient data describing fish populations, metapopulations, habitat conditions, and productivity across large areas. This lack of information is consistent across all study basins especially in terms of metapopulation dynamics. Studies are needed to determine population growth rates and straying rates of salmonid populations and sub-populations to better utilize spatial population structure to identify refugia habitat.

Classification systems, sets of criteria, and rating systems have been proposed to help identify refugia type habitat in north coast streams, particularly in Oregon and Washington (Moyle and Yoshiyama 1992; FEMAT 1993; Li et al. 1995; Frissell et al. 2000). Upon review of these works, several common themes emerge. A main theme is that refugia are not limited to areas of pristine habitat. While ecologically intact areas serve as dispersal centers for stock maintenance and potential recovery of depressed sub-populations, lower quality habitat areas also play important roles in long-term salmonid metapopulation maintenance. These areas may be considered the islands, satellites, or sinks in the metapopulation concept. Implementing ecosystem management strategies that are aimed at maintaining or restoring natural processes may result in improved habitat quality, increases in fish numbers, and stronger metapopulations.

A second common theme is that over time within the landscape mosaic of habitat patches, high quality habitat areas will suffer impacts and become less productive, while areas of low quality habitat will recover and become more productive. These processes can occur through either human caused or natural disturbances or through succession to new ecological states. Regardless, it is important that a balance be maintained in this alternating, patchwork dynamic to ensure that adequate high quality habitat is available to support viable anadromous salmonid populations (Reeves et al. 1995).

Approach to Identifying Refugia

The CWPAP interdisciplinary refugia identification team identified and characterized refugia habitat using expert professional judgment and criteria developed for North Coast watersheds. The criteria considered different values of watershed and stream ecosystem processes, the presence and status of fishery resources, water quality, and other factors that may affect refugia productivity. The expert refugia team encouraged other specialists with local knowledge to participate in the refugia identification and categorization process.

The team also used results from information processed by the EMDS at the stream reach and planning watershed/subbasin scales. Stream reach and watershed parameter evaluation scores were used to rank stream and watershed conditions based on field data. Stream reach scale parameters included pool shelter rating, pool depth, embeddedness, and canopy cover. Water temperature data were also used when available. The individual parameter scores identified which habitat factors currently support or limit fish production (see EMDS and limiting factors sections).

Professional judgment, field note analysis, local expert opinion, habitat inventory survey results, water quality data results, and EMDS scores determined potential locations of refugia. If a habitat component received a suitable ranking from the EMDS model, it was cross-referenced with survey results from that particular stream and with field notes from that survey. The components identified as potential refugia were then ranked according to their suitability to encourage and support salmonid health.

When identifying anadromous salmonid refugia, the program team considered several non-substitutable habitat needs for salmonids at various stages of their life cycle. According to NMFS (2001), these needs include:

- Adult migration pathways;
- Spawning and incubation habitat;
- Stream rearing habitat;
- Forage and migration pathways;
- Estuarine habitat.

The highest quality refugia areas are large, meet all of these life history needs, and therefore provide complete functionality to salmonid populations. These large, intact systems are scarce today and smaller refugia areas that provide only some of the requirements have become very important areas, but they cannot sustain large numbers of fish. These must operate in concert with other fragmented habitat areas for life history support, and refugia connectivity becomes very important for success (May and Peterson 2003). The refugia team considered relatively small areas in tributaries because they provide partial refuge values while contributing to the overall refugia rating of larger scale areas. Therefore, the team's analyses used the tributary scale as the fundamental refugia unit. CDFW created a tributary scale refugia-rating worksheet with 21 condition factors that were rated on a sliding scale from high quality to low quality.

The 21 condition factors were grouped into five categories:

- Stream condition;
- Riparian condition;
- Native salmonid status;
- Present salmonid abundance;
- Management impacts (disturbance impacts to terrain, vegetation, and the biological community).

Additionally, NCRWQCB created a worksheet specifically for rating water quality refugia. The worksheet has 13 condition factors that were rated on a sliding scale from high quality to low quality.

These 13 condition factors were grouped into three categories:

- In-stream sediment related;
- Stream temperature related;
- Water chemistry related.

Tributary ratings were determined by combining the results of NCRQCB water quality results, EMDS results, and data in CDFW tributary reports by a multidisciplinary, expert team of analysts. The various factors' ratings were combined to determine an overall tributary rating on a scale from high to low quality refugia. Tributary ratings were subsequently aggregated at the subbasin scale and expressed a general estimate of subbasin refugia conditions. Factors with limited or missing data were noted. In most cases there were data limitations on 1–3 factors. These were identified for further investigation and inclusion in future analyses.

The program has created a hierarchy of refugia categories that contain several general habitat conditions. This descriptive system is used to rank areas by applying results of the analyses of stream and watershed conditions described above, and are used to determine the ecological integrity of the study area. A basic definition of ecological integrity is "the ability [of an ecosystem] to support and maintain a balanced, integrated, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley 1981).

Salmonid Refugia Categories and Criteria

High Quality Habitat, High Quality Refugia:

- Maintains a high level of watershed ecological integrity;
- Contains the range and variability of environmental conditions necessary to maintain community and species diversity and supports natural salmonid production;
- Contains relatively undisturbed and intact riparian corridor;
- All age classes of historically native salmonids present in good numbers, and a viable population of an ESA listed salmonid species is supported;
- Provides population seed sources for dispersion, gene flow and re-colonization of nearby habitats from straying local salmonids;
- Contains a high degree of protection from degradation of its native components.

High Potential Refugia

- Watershed ecological integrity is diminished but remains good;
- Instream habitat quality remains suitable for salmonid production and is in the early stages of recovery from past disturbance;
- Riparian corridor is disturbed, but remains in fair to good condition;
- All age classes of historically native salmonids are present including ESA listed species, although in diminished numbers;
- Salmonid populations are reduced from historic levels, but still are likely to provide straying individuals to neighboring streams;
- Currently is managed to protect natural resources and is resilient to degradation, which demonstrates a strong potential to become high quality refugia.

Medium Potential Refugia

- Watershed ecological integrity is degraded or fragmented;
- Components of instream habitat are degraded, but support some salmonid production;
- Riparian corridor components are somewhat disturbed and in degraded condition;
- Native anadromous salmonids are present, but in low densities; some life stages or year classes are missing or only occasionally represented;
- Relatively low numbers of salmonids make significant straying unlikely;
- Current management or recent natural events have caused impacts, but if positive change in either or both occurs, responsive habitat improvements should occur.

Low Quality Habitat, Low Potential Refugia

- Watershed ecological integrity is impaired;
- Most components of instream habitat are highly impaired;
- Riparian corridor components are degraded;
- Salmonids are poorly represented at all life stages and year classes, especially older year classes;
- Low numbers of salmonids make significant straying very unlikely;
- Current management and/or natural events have significantly altered the naturally functioning ecosystem and major changes in either of both are needed to improve conditions.

SF Eel River Basin Overview

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South Fork Eel River Basin

The South Fork (SF) Eel River Basin comprises 688 square miles, and is the second largest subbasin in the Eel River Basin, located in Northern California. The Eel River reaches the Pacific Ocean approximately 200 miles north of San Francisco, near the city of Eureka, Humboldt County, at latitude 40° 38' 32" N, longitude 124° 18' 43" W (*Figure 1*). The SF Eel River confluence with Eel River is located upstream at river mile forty (RM 40). The 100 mile long mainstem SF Eel River is split by Humboldt and Mendocino counties. The SF Eel River has 683 miles of perennial blue line streams according to the USGS 7.5" maps.

Figure 1. Location of the South Fork Eel River Basin within the Eel River Basin.

The Eel River Overview and Context

The Eel River is the third largest river in California with a drainage basin of 3,684 square miles (CDFW 1997). The mainstem Eel River is approximately 197 miles in length with 832 tributaries – totaling 3,526 miles of blue line stream according to the USGS 7.5" maps. Elevations on the mainstem range from sea level at the mouth to over 6,700 feet at the headwaters. The four principle tributaries are the Van Duzen River, South Fork Eel River, North Fork Eel River, and Middle Fork Eel River.

Because the Eel River catchment is large and complex, CWPAP divided the watershed into several basins, five of which were selected for assessment (*Figure 2*). This report assesses salmonid populations and conditions in the South Fork (SF) Eel River Basin. The Lower Eel River assessment (including the Salt River) was completed in 2010, and the Van Duzen River assessment is currently available in draft form at the CWPAP website (http://coastalwatersheds.ca.gov/). The SF Eel River Basin assessment area makes up approximately 19% of the entire Eel River catchment (690 square miles) and is defined as the watershed area from the river's mouth, upstream approximately 105 miles. The mainstem SF Eel River receives flow from 450 tributaries, adding up to 885 miles of contributing tributaries. The South Fork Eel River runs in a northwestern direction from its headwaters near the town of Branscomb, to its mouth near the town of Weott (*Figure 1*). The SF Eel River catchment lies within Humboldt and Mendocino Counties.

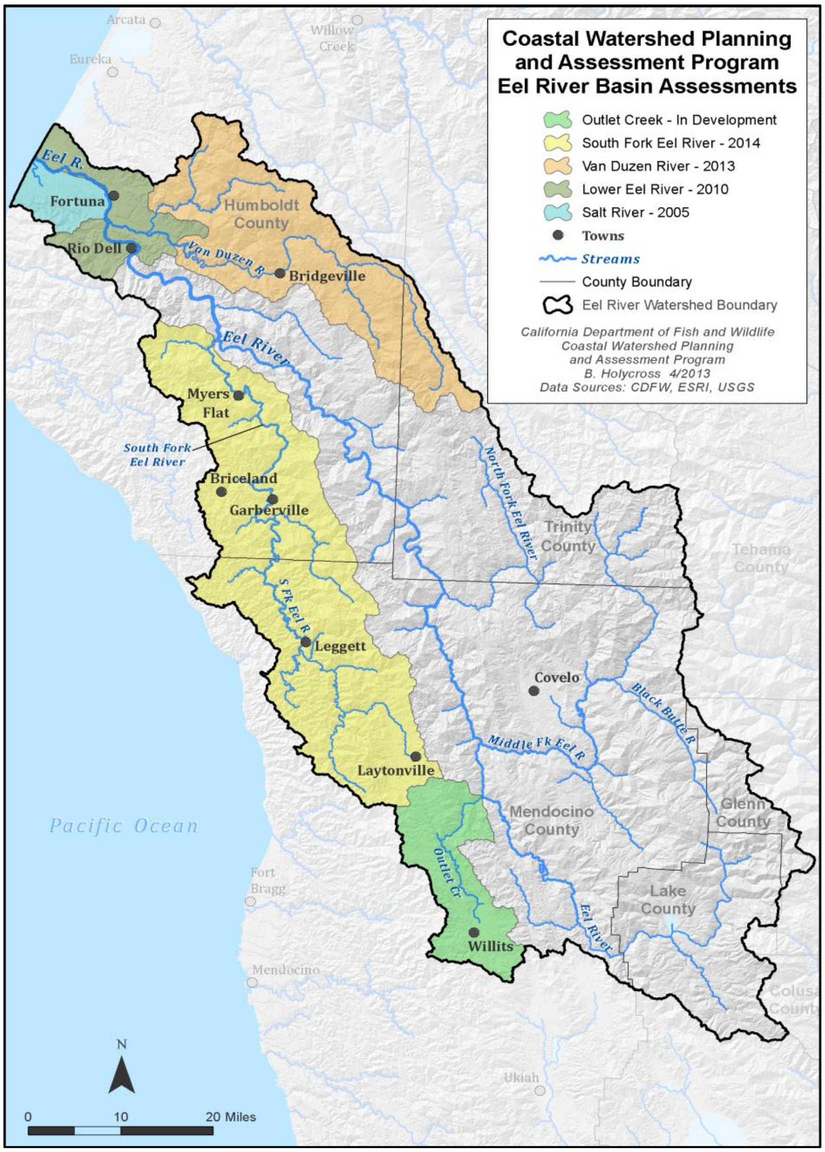


Figure 2. CWPAP assessment areas within the Eel River catchment.

The name of the Eel River reflects the large number of so-called eels, which are actually Pacific Lamprey (*Lampetra tridentata*) that Euro-American settlers observed being collected by the native peoples in the area of the lower Eel River. The river's Native American name, "Wiot," meaning "plenty," was based upon the wealth of natural resources including enormous runs of salmon, steelhead, lamprey and other fishes. These fish were harvested every fall (Humboldt Times September 23, 1854, in: Trinity Associates 1996).

Large salmon runs of the Eel River Basin allowed Euro-American settlers to establish a lucrative commercial fishery that supplied a number of canneries in the lower river. By 1858, these canneries were supplying canned and salted salmon to markets from California to the east coast, as well as outside the country (McEvoy 1986). Historical records show that the Eel River was one of the largest producers of salmon and steelhead in California. This young fishery was described as equal to the Sacramento River fishery, though surpassing it in terms of price (Humboldt Times April 10, September 11, 1858, in: Trinity Associates 1996). Even though the Eel River remains the third largest producer of salmon and second largest of steelhead in the state, overall salmon runs in the Eel have dramatically declined (CDFW 1997). Defining and quantifying the causes of this decline can be difficult, though most surely they have been exacerbated by the cumulative effects of human disturbance impacts upon a dynamic system (Yoshiyama and Moyle, 2010). Anadromous salmonids currently present within the South Fork Eel River Basin include coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead trout (*Oncorhynchus mykiss*).

The National Marine Fisheries Service (NMFS) has listed northern California runs of coho (1997), Chinook (1999), and steelhead (2000) as threatened under the federal Endangered Species Act. The California Fish and Game Commission also listed coho as threatened in 2005.The mainstem SF Eel River downstream of the Mendocino/Humboldt county line at RM 40 provides depositional reaches for sediment transported from the upper reaches of the basin, and as such respond to the systems natural delivery processes. As part of this highly dynamic environment, the SF Eel experiences very high levels of sedimentation due to natural hillslope processes occurring on fragile, erodible soils, unstable, soft bedrock, and driven by high levels of precipitation (Reynolds et al. 1981). Additionally, the area is situated in a very tectonically active area, thus, landslides and earth flows introduce large quantities of sediment to streams. The Eel River system has the highest recorded average suspended sediment yield of any US river its size (Brown and Ritter 1971) (*Figure 3*), and in 1998, the US Environmental Protection Agency (USEPA) listed the SF Eel River as an impaired water body due to excessive sediment and high summer water temperature.

Figure 3. Sediment entering the ocean from the Eel River Basin after December 2012 storms (photo from Lost Coast Outpost (Kemp 2012) and taken by NASA; available at: http://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2012-12-15).

SF Eel River Subbasin Scale

For purpose of this assessment and analysis, the SF Eel River Basin was divided into three subbasins (Northern, Eastern, and Western) and is comprised of a total of 61 CalWater 2.2.1 Planning Watersheds (*Figure 4* subbasins, *Figure 5* Calwater, *Table 1* General Attributes).

Subbasins were designated based on several attributes, including geography, geology, climate patterns, vegetation, and land use. The original Calwater planning watershed boundaries were edited to more accurately reflect the drainage patterns and watershed processes within the SF Eel when delineating subbasins. Chinook salmon, coho salmon, and steelhead have been documented in fish surveys in all three subbasins.

The Northern Subbasin is the northern most portion of the SF Eel River Basin, including all drainages from its mouth to RM 23, at Ohman Creek; the total area is 149 square miles. There are 213 miles of streams within the subbasin; 139 miles of these are perennial and 74 are intermittent. The mainstem SF Eel River in this subbasin receives sediment transported from the Eastern and Western subbasins as well as from Northern Subbasin tributaries.

Table 1. General attributes of the South Fork Eel River Basin.

General attributes of the South Fork Eel River Basin				
Attribute	**Northern Subbasin**	**Eastern Subbasin**	**Western Subbasin**	**Total SF Eel**
Square Miles	149	320	219	688
% of basin	22	46	32	100
Mainstem miles	23	82	82	105
Tributary miles	190	359	312	966
Principal Communities	Weott, Myer's Flat, Miranda, and Phillipsville	Redway, Garberville, Benbow, Piercy, Leggett, Laytonville, and Branscomb	Briceland, Hales Grove	Laytonville, Redway, and Garberville
Dominant Geology	Yager Terrane	Central Belt Mélange	Coastal Terrane	Central Belt Mélange, Coastal Terrane
Dominant Vegetation	Mixed conifer and hardwood forest	Mixed conifer and hardwood forest	Mixed conifer and hardwood forest	Mixed conifer and hardwood forest
Dominant Land Use	State Parks, Forestry	Forestry, ranching/timber, residential	Agriculture, forestry	Forestry, State Parks
Salmon Species	Coho, Chinook, Steelhead	Coho, Chinook, Steelhead	Coho, Chinook, Steelhead	Coho, Chinook, Steelhead

The Eastern Subbasin is the largest of the three and includes all of the SF Eel drainage east of the mainstem and to the south of the Northern Subbasin. This includes all of the eastern drainages from RM 23 to the headwaters at RM 105. The Eastern Subbasin has a catchment area of 320 square miles. This subbasin contains 441 miles of stream, 302 of which are perennial and 139 are intermittent.

The Western Subbasin is the second largest subbasin in the assessment area, with a catchment area of 219 square miles. This subbasin includes 82 miles of the mainstem SF Eel River from Ohman Creek to the headwaters and includes the western tributaries. There are approximately 394 miles of stream in this subbasin, 254 of which are perennial and 140 are intermittent.

Figure 4. South Fork Eel River Basin and Northern, Eastern, and Western subbasins.

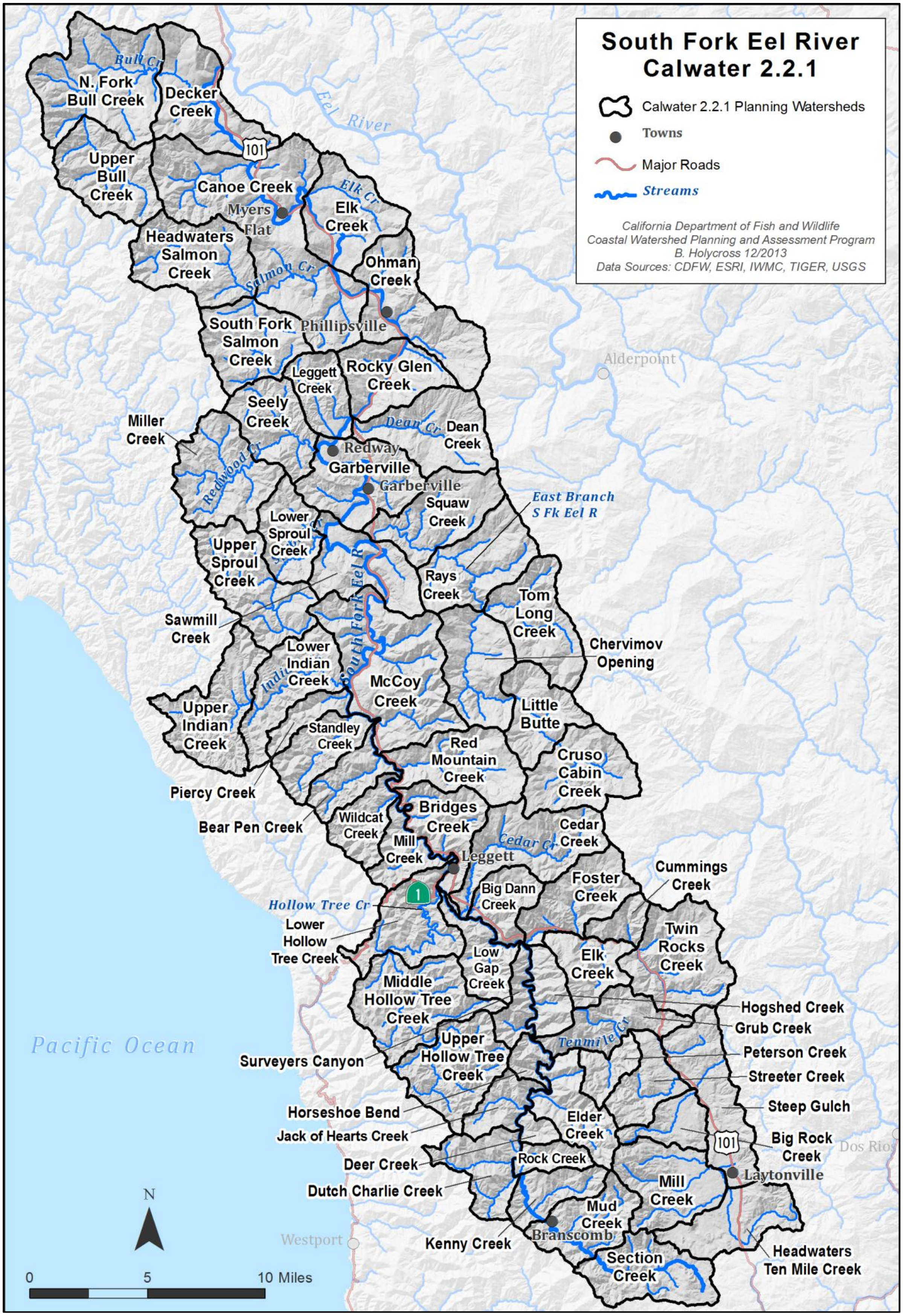


Figure 5. South Fork Eel River Basin delineated using CalWater2.2.1.

Climate

A long rainy season and foggy to dry summer season are characteristic of the climate in the SF Eel River. The rainy season, which generally begins in October and lasts through April, accounts for 90% of the Eel River Basin's mean annual runoff (Monroe et al. 1974). California Department of Water Resources (CDWR) collects precipitation data at Miranda, Garberville, Standish Hickey State Park, Richardson Grove State Park, Cummings, and Branscomb, located within the basin. These data record information from water years 1917 to the present. Garberville, located in the northern half of the basin, receives a mean annual precipitation of 57 inches and Branscomb, at the southern end of the basin, receives 79 inches.

Climate data were analyzed using the PRISM model, which incorporates measurements of precipitation, temperature, elevation, and other climatic factors to produce estimates of monthly, yearly, and event-based precipitation (http://www.prism.oregonstate.edu/). An isohyetal contour map of the SF Eel River Basin shows that mean annual precipitation is lowest in the Western Subbasin (69 inches per year) and highest in the upper elevations of the Northern Subbasin at Panther Gap in Bull Creek (84 inches per year). Data collection stations were located throughout the SF Eel River Basin, primarily along the mainstem (*Figure 6*). Throughout the year, the SF Eel River Basin receives highly variable amounts of precipitation. While average monthly precipitation ranges from less than 1 inch to greater than 10 inches over the period of record (*Figure 7*), monthly maximum precipitation reached over 48 inches at Branscomb in December 1964.

The dry season is generally May through September. The Northern and Western subbasins are strongly influenced by the coastal marine layer and defined by morning fog and overcast conditions, whereas the inland Eastern Subbasin becomes very hot and dry.

Climate Change

Globally, widespread observations of temperature increases and changes in other climate variables provide indisputable evidence that the Earth's climate is warming. Similar to global temperature increases, statewide annual average air temperatures have increased by 1.5 degrees Fahrenheit per century (CEPA 2013). While the North Coast region of California shows a smaller trend in increased temperatures over the last 30 years (CEPA 2013), the SF Eel River Basin is nonetheless affected by climate change. These impacts are discussed in greater detail in the Program Introduction & Overview (Climate Change section).

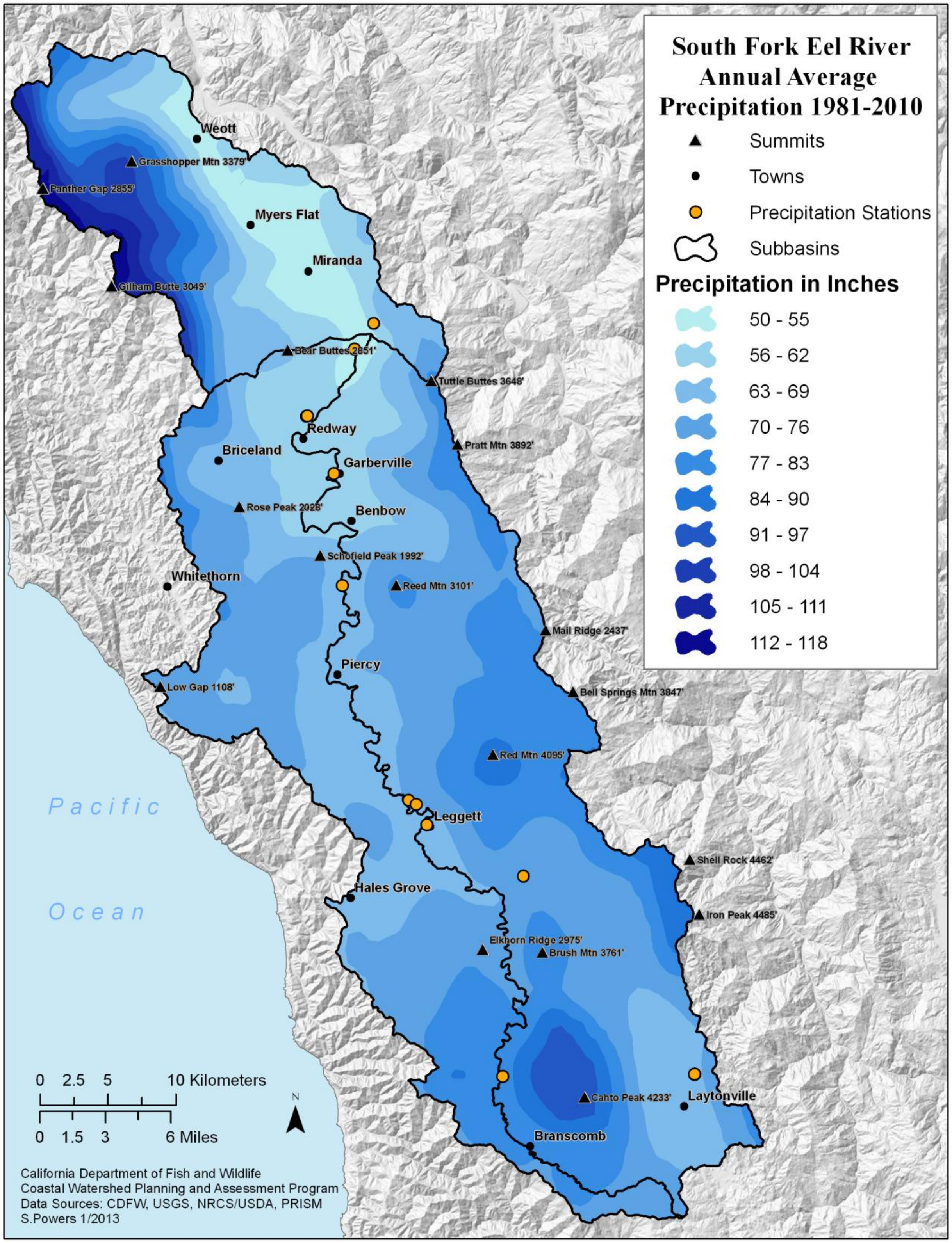


Figure 6. Average annual precipitation and data collection stations in the SF Eel River Basin.

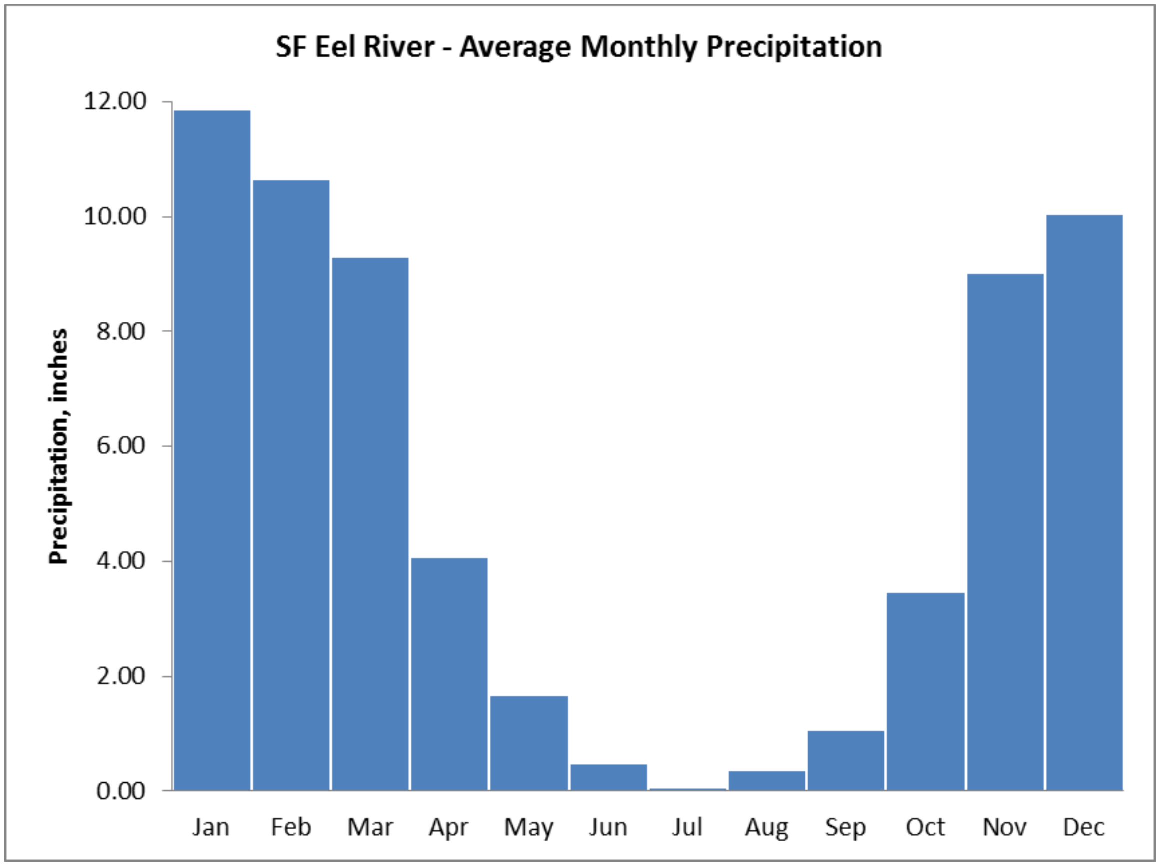


Figure 7. SF Eel River Basin - Average annual precipitation (Based on available records from Garberville and Richardson's Grove)

Hydrology

Figure 8. SF Eel River streams.

There are approximately 1040 miles of stream within the SF Eel River Basin (*Figure 8*). Lengths of individual streams and river mile locations are described in detail in the subbasin sections.

In order to help evaluate and categorize streams and rivers, streams are assigned a stream order classification based on the branching pattern of river systems (Strahler 1957). A first order stream is defined as the smallest perennial (i.e. those with sufficient flow to develop biota), un-branched tributary to appear on a 7.5-minute USGS quadrangle (1:24,000 scale) (Leopold et al. 1964). When two first order streams join, they form a second order stream. When two second order streams join, they result in a third order stream; and as streams of equal order meet they result in a stream of the next higher order (Flosi et al. 1998). Accordingly, the majority of the mainstem SF Eel River is a fifth order stream. Most tributaries in this basin are intermittent or first or second order (*Figure 9*). Water Year (WY) differs from our normal calendar year, and defines a 12-month period starting October 1 and ending in September 30 of the following year. The date of the WY refers to the year with the maximum number of months of data collected during the 12- month period (e.g. October 1964 through September 1965 would be WY1965 and contains the December 1964 flood).

Records from six out of eight USGS river gauges located within the basin were used to determine hydrologic trends (*Table 2*). Only three of these have kept continual records and are currently operating:

- USGS 11476500 SF Eel River at RM 17 near Miranda (1940 to the present)
- USGS 11476600 Bull Creek, located approximately 4 miles upstream from the confluence of the SF Eel River at RM 2(1960 to the present)
- USGS 11475800 SF Eel River at RM 66 near Leggett (1964 to the present)
- USGS 11476620 SF Eel River at Dyerville (water quality only 1963-1964)
- USGS 11475500 SF Eel River near Branscomb (1947 - 1970)
- 11475700 Tenmile Creek near Laytonville (1958 – 1974)
- 11475940 East Branch SF Eel River near Garberville (1966 – 1972)
- 11476000 SF Eel River at Garberville (1912 – 1913 and 1940)

Table 2. Summary of USGS SF Eel River gauge statistics.

Continuous:	Catchment miles^2 above gauge	Gauge location (stream and RM)	Years of record
11476500 SF Eel River near Miranda	537	SF Eel River RM 17	1940 - 2012
11476600 Bull Creek	28.1	Bull Creek RM 4	1960 - 2012
11475800 SF Eel River at Leggett	248	SF Eel River RM 66	1964 - 2012
Discontinued:			
11475500 SF Eel River near Branscomb	43.9	SF Eel River RM 88	1947-70
11475700 Tenmile Creek north of Laytonville	50.3	Tenmile Creek RM 8	1958-74
11475940 East Branch SF Eel River near Garberville	74.3	East Branch SF Eel River RM 2	1966-72
11476000 SF Eel River at Garberville	468	SF Eel River RM 34	1912-13, 1940
Partial records:			
11476620 SF Eel River at Dyerville	688	SF Eel River RM 0	1963 - 1964

There are two additional USGS gauges currently operating in the SF Eel River Basin: one on Cahto Creek and one on Elder Creek. Data from these gauges were not used to determine hydrologic trends because discharge was very low (<10 cfs) in Elder Creek (due to the small catchment size) and very low or dry in Cahto Creek (due to small catchment size and diversion pressure). The Miranda gauge (WYs 1940 to present) measures gauge height and water flow in cubic feet per second (cfs). Annual

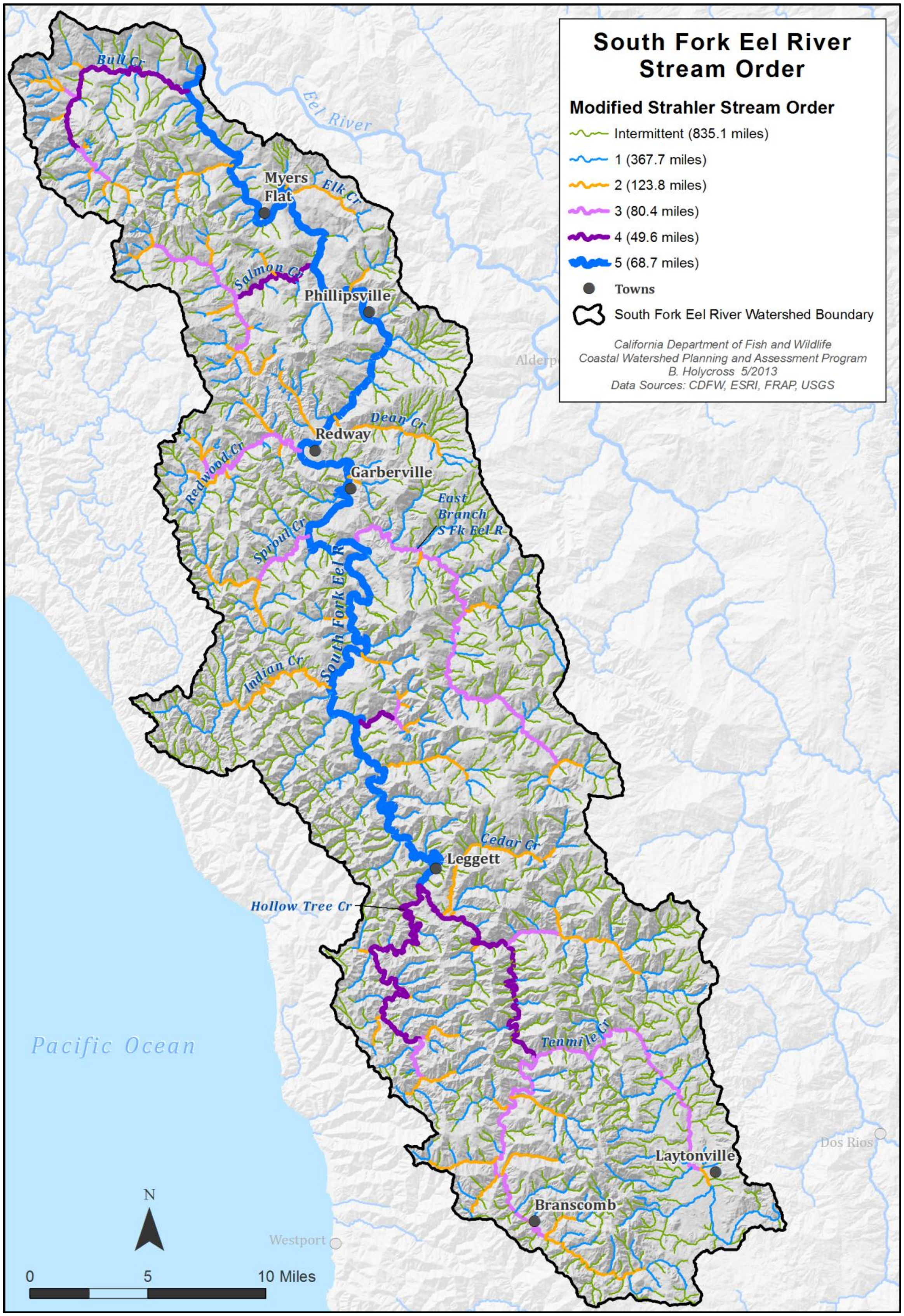


Figure 9. Stream order in the South Fork Eel River Basin.

mean discharge at the Miranda gauge over the period of record was 1,842 cfs. Minimum monthly mean discharge ranged from approximately 14 to 704 cfs, while maximum mean monthly discharge ranged from approximately 131 to 17,530 cfs (*Table 3*). Maximum mean daily discharges are far greater, ranging from 11 to 161,000 cfs. As a point of reference, in 2012 the SF Eel River channel at the Miranda site had a capacity of approximately 88,000 cfs.

Because the Eel River Basin receives highly varied precipitation and has altered runoff rates, discharge is typified by low flows in the summer and extreme peaks in the winter. For example, a minimum mean daily flow of 10 cfs was once recorded in the late summer of 1964 at Miranda, while over the period of record, 12 years have recorded at least 1 day with a mean daily discharge greater than 88,000 cfs (*Table 4*). Moreover, there have been several substantial floods in the latter half of the 20th century. The most destructive floods in the period of record occurred in WYs 1956 and 1965. During the December 1964 flood, the maximum mean daily flow at Miranda was 161,000 cfs and the maximum peak flow was 199,000 cfs. On December 22, 1964, the river gauge at Miranda was 13 feet above flood stage and had a discharge of 199,000 cfs, which was over twice the normal channel capacity. The current channel capacity at this gauge site is approximately 88,000 cfs, which correlates with a gauge height of 33 feet and is considered flood stage (USGS data).

Table 3 Statistics of mean monthly discharge for South Fork Eel River near Miranda over the period of record, WY 1940 to 2011.

USGS 11476500 SF Eel near Miranda (1940 to 2011)					
Month	**Mean Discharge (cfs)**	**Maximum Mean Discharge (cfs)**	**Water Year**	**Minimum Mean Discharge (cfs)**	**Water Year**
October	240	2,886	1951	17	2002
November	1,310	10,130	1974	50	1959
December	4,100	17,260	1965	75	1976
January	5,210	17,530	1970	207	1977
February	4,680	16,640	1986	284	1977
March	3,560	13,000	1983	704	1977
April	1,850	8,425	1982	176	1977
May	729	2,580	2005	122	1977
June	312	1,754	1993	53	1977
July	113	361	2005	20	1977
August	59	131	1983	18	1977
September	56	221	1986	14	2008
Data from USGS (2012).					

Table 4. Water years with mean daily discharge at Miranda greater than the channel's capacity of 88,000 cfs (data from USGS 2012).

WY	**Days of discharge >88,000 cfs**	**Max mean daily (cfs)**
1956	1	100,000
1965	2	161,000
1974	1	110,000
1986	1	94,000
The period of record is Water Year 1940 to 2012		

Currently, stream gauges capture flow information for approximately three-fourths of the basin at the Miranda gauge (*Figure 10*) and the upper third of the basin at the Legget gauge. In addition, most of the Bull Creek drainage is captured at the gauge in Humboldt Redwoods State Park. Due to the lack of stream gauges capturing information from the whole basin a hypothetical flow was modeled to determine the total flow statistics from the whole basin as well as its contribution to the Lower Eel River System.

There is currently no stream gauge located at the mouth of the SF Eel River; however one was in existence from 1963 until 1964 and was used for water quality sampling but not for flow data. A gauge at this location would be useful in determining total flows from this system.

Figure 10. Site photo taken at location of USGS stream gauge (11475800) on the mainstem SF Eel River near Leggett (photo courtesy of USGS National Water Information System).

Hypothetical flows may be surmised, however, by using data from a few nearby gauges (SF Eel at Miranda, Lower Eel River at Scotia, and Eel River at Fort Seward), along with drainage area calculations and precipitation records. The following graphs (*Figure 11*) representing data from a hypothetical gauge at the mouth of the SF Eel River were constructed using this process. Historical changes in the watershed, including change or removal of vegetation, road drainage, and increased impervious surfaces have altered the basin's response to heavy precipitation. Heavy sedimentation rates, especially during large flood events such as the 1955 and 1964 floods, have modified South Fork Eel River channels from relatively stable and deep to relatively unstable and shallow channels. These factors combined with the rugged terrain, elevations within the SF Eel catchment reach up to 4,200 feet, and loss of riparian vegetation in upstream tributaries cause water to runoff very rapidly downstream. During periods of extensive and/or intensive rain, river levels rise rapidly and flooding may occur in the mainstem, the propensity of which increases towards its confluence with the Eel River. Periods of intensive and/or extensive rainfall often occur during winter months and flooding becomes an issue throughout the basin.

The 2012 Humboldt County General Plan update reviewed policies related to drainage patterns, hydrology, and water quality. These policies will be discussed in detail in the Northern Subbasin hydrology section, because this subbasin is located entirely within the boundaries of Humboldt County.

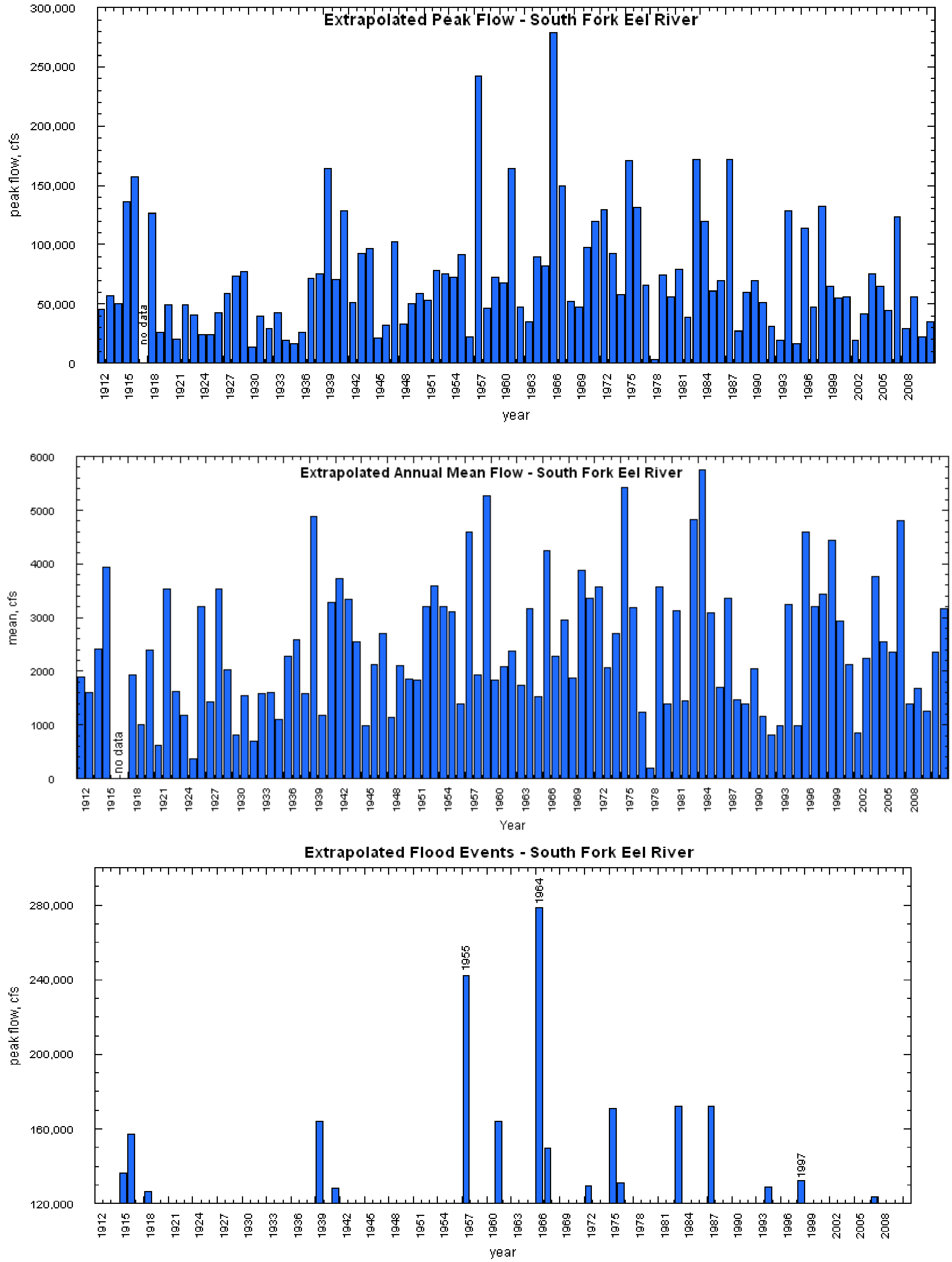


Figure 11. Extrapolated peak flow, annual mean flow, and flood events on SF Eel River, 1912-2011.

Geology

Geologic Overview

The South Fork Eel River Basin is located in geology of the Franciscan Complex of the Northern California Coast Ranges Geomorphic Province. Sedimentary and metamorphic rock types compose rugged, northwest trending mountain ranges bounded by faults related to nearby triple-junction tectonics. The topography of the basin varies from relatively flat, uplifted river terraces along the mainstem; to hummocky, meadowland shaped by large earthflows; to steep mountainous regions composed of relatively resistant rock types.

West vs. East

A striking feature of the landscape of the SF Eel River Basin is that the west side differs drastically from the east side in landscape morphology, vegetation, and fish presence and distribution.

Landscape

The west side landscape exhibits steep hillslopes, sharp ridge-crests, and relatively deep canyons. A strong marine layer influence produces redwood-Douglas Fir forest that typically provides a robust streamside canopy. The streams on the western side are generally cooler than on the eastern side and support a larger population of salmonids. The east side is farther inland than its counterpart, resulting in hotter and dryer conditions with less shade canopy. Oak woodlands interspersed among prairie grasslands and hummocky hills with large, protruding blocks of rocks dominate the landscape of the eastern side of the basin.

Geologic reasons for these differences are numerous but the major factors include bedrock composition, rock-strength, and hill-slope stability, and the predominant style of mass wasting.

The western and the eastern side of the basin sit upon two different accreted belts of the Franciscan Complex. The western side is situated on the Coastal Belt and the eastern side on the Central Belt. These belts differ in age, depositional history, accretionary emplacement, metamorphic grade, and to some extent composition. In general, the Coastal Belt is more coherent than the Central Belt.

Definitions of Key Geologic Terms

Accretion *– Tectonic addition of continental material to the edge of a preexisting continent.*

Terrane *– a geologic body of accreted material that retains a distinct stratigraphic history structurally fault-bounded from surrounding bodies.*

Mélange *– a completely sheared matrix of shale, sandstone, or serpentinite containing pebble sized to very large mappable blocks of exotic rock.*

Composition

The western side of the basin is composed predominantly of argillite (shale) and sandstone of the Coastal Terrane and the Yager Terrane of the Coastal Belt of the Franciscan Complex (*Figure 12*). These rock types are made out of fine-grained, marine sediments that while being moderately erodible are less prone to erosion than the rock types present within the eastern side of the basin.

The eastern side of the basin is largely composed of mélange and sandstone of the Central Belt of the Franciscan Complex and is also composed of fine-grained marine sediments. Central Belt Mélange was derived from argillite and sandstone but has subsequently been tectonically sheared to such a degree that it has lost much of its coherency and is very easily eroded.

Rock-Strength

Although the Coastal Belt has been sheared in places and contains mélange units, the geology of the western side of the basin generally has higher rock-strength than the mélange of the east side of the basin. The greater rock-strength of Coastal Belt geology allows for steep ridge/canyon sets to form, providing shade for the streams.

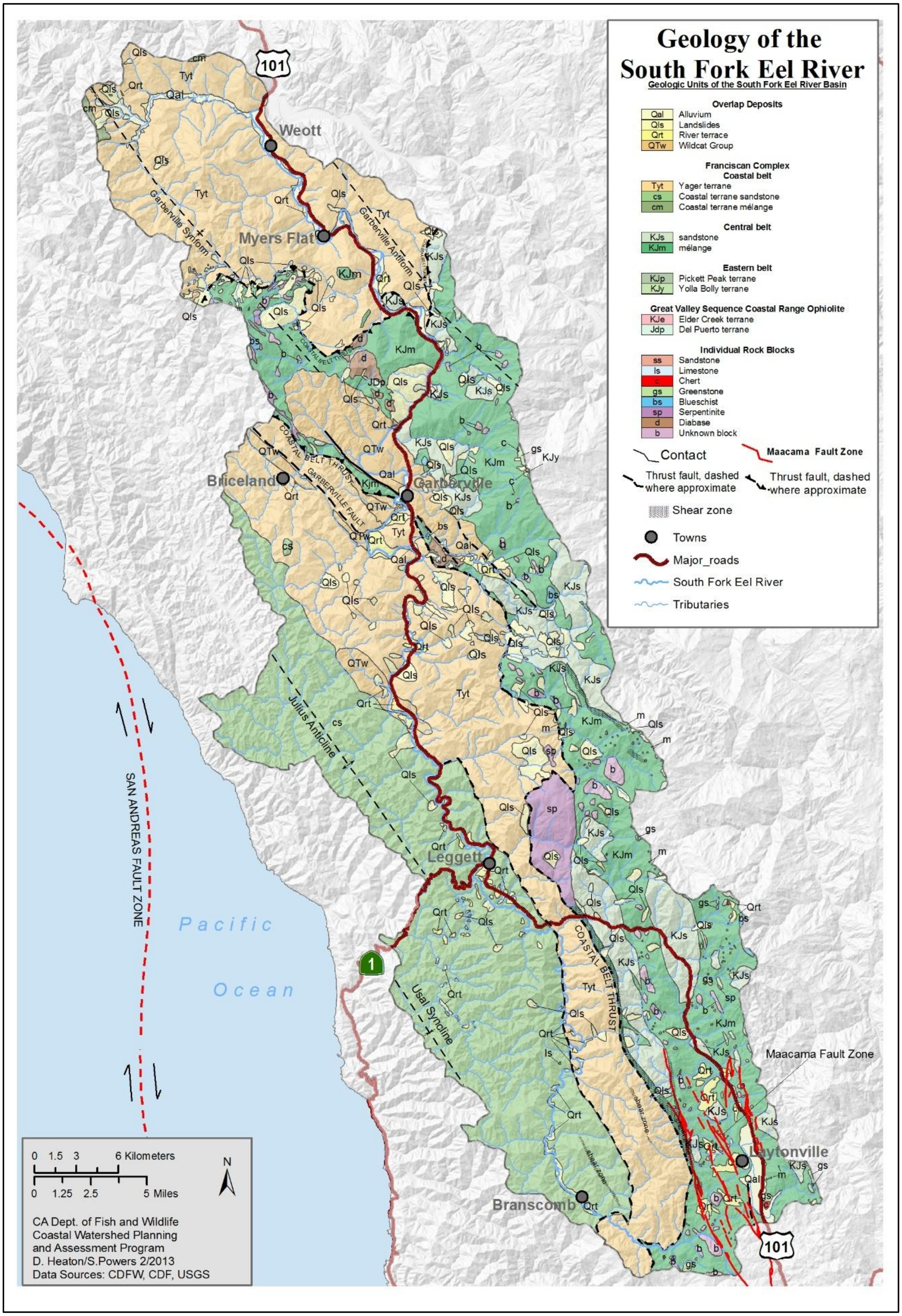


Figure 12. Generalized geologic map of the SF Eel River Basin.

On the eastern side of the basin, mélange does not have the internal strength to form steep, sharp ridges; rather it tends to behave like a very viscous liquid and flows downhill over time, creating a landscape of rounded hummocky hills that tend to produce less shade for the streams.

Hillslope

Greater rock-strength of the Coastal Belt geology of the western side of the basin leads to greater hillslope stability which, with shade, aspect, and influence of the marine layer, allows a healthy growth of mixed conifer and redwood forest to dominate the vegetation providing more highly functioning riparian areas including more shade for the streams. Greater hillslope stability on the western side somewhat limits the prevalence and severity of landslides which, in turn, delivers less sediment into the streams.

Central Belt Mélange on the eastern side lacks internal shear strength and frequently moves in large earthflows, delivering vast amounts of sediment to the streams and producing a hummocky landscape of low relief hills with only more resistant rock-blocks sticking conspicuously out, referred to as "Franciscan Knockers".

Movement of hillslope material, especially in earthflows, hampers the establishment of trees and typically gives rise to crumpled looking prairies surrounded by oak woodlands which cling to relatively more stable land. Stream bank landsliding is quite prevalent within mélange material which tends to limit the formation of healthy riparian zones. The rounded ridges of mélange material do not typically cast as much shade into their valleys as do the west side ridges. In general, the lack of shade from landscape morphology and vegetation and shallower stream channels from the greater input of sediments tends to produce higher temperatures within the streams on the eastern side of the basin.

Geologic Composition of the SF Eel River Basin

The rock types of the SF Eel River Basin consist mainly of accreted, sedimentary rock types originally deposited in a marine environment that existed off the coast of the North American continent from 250 million until about 800 thousand years ago. In conjunction with these are igneous rocks derived from the oceanic crust and the underlying asthenosphere/mantle. Lying atop these are terrestrial deposits of alluvium, alluvial fans, river terraces, landslides, and soil.

This basin is dominated by the Coastal Belt and the Central Belt of the Franciscan Complex and is divided nearly equally between the two. The Yager Terrane and the Coastal Terrane of the Coastal Belt consist mainly of marine sandstone, argillite, and minor conglomerate, lenses of carbonate, and mélange and its associated, interspersed rock-blocks. Mélange and sandstone units likewise compose the Central Belt. Overlying these two belts are deposits of much younger marine sedimentary rocks as well as river terraces, alluvium, alluvial fans, landslide deposits, and an overlying mantle of soil (McLaughlin et al 2000) (*Table 5).*

All of the rock types in the SF Eel River Basin are considered lithologically soft, prone to erosion and sensitive to land use. A more detailed description of the rock types present in each individual subbasin is included in the corresponding subbasin geology section of this report.

Table 5. Geologic relations and descriptions of units within the SF Eel River Basin (ma = millions of years before the present).

Unit	Belt/Rock Type	Formation / Terrane	Composition	Age	Years (ma)	% Basin Area
Overlap Deposits	Alluvium		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay.	Holocene	0-0.01	1.6
	Landslide		Large, disrupted, clay to boulder debris and broken rock masses.	Holocene-Quaternary	0.01-2	4.6
	River Terrace		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel.	Holocene-Quaternary	0.01-2	5.4
		Rohnerville formation	Unconsolidated, gently folded, older Eel/Van Duzen River gravel, sand, silt and clay	Upper Pleistocene	0.01-0.13	
		Hookton formation	Poorly consolidated-unconsolidated marine-nonmarine sand, gravel, and silt.	Mid-upper Pleistocene	0.13-0.78	
	Wildcat Group Undifferentiated	Carlotta Formation	Partially indurated, nonmarine conglomerate, sandstone, and clay. Minor lenses of marine siltstone and clay.	Early Pleistocene	0.78-1.8	<1
		Scotia Bluffs Sandstone	Shallow marine sandstone and conglomerate	Late Pliocene	1.8-3.6	
		Rio dell Formation	Marine mudstone, siltstone, and sandstone	Late Pliocene	1.8-3.6	
		Eel River Formation	Marine mudstone, siltstone, and sandstone	Early Pliocene	3.6-5.3	
		Pullen Formation	Marine mudstone, siltstone, and sandstone	Upper Miocene - Lower Pliocene	5.3-11.6	
Franciscan Complex	Coastal Belt	Coastal Terrane	Slightly metamorphosed, interbedded arkosic sandstone and argillite with minor pebble conglomerate, limestone lenses, and exotic blocks of rock.	Pliocene-late Cretaceous	1.8-99.6	22.3
		Yager Terrane	Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate.	Eocene-Paleocene	33.9-65.5	34.5
	Central Belt	Sandstone	Large blocks of metasandstone and metagraywake, interbedded with meta-argillite.	Late Cretaceous-late Jurassic	65.5-161.2	7.2
		Mélange	Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, metachert.	Early tertiary-late Cretaceous	1.8-65.5	20.5
	Eastern Belt	Yolla Bolly Terrane	Semi-schistose metagraywacke with minor metachert and metavolcanic rocks.	Early Cretaceous-Mid Jurassic	99.6-199.6	<1
			Mélange (sheared matrix of meta-argillite, metasandstone, and metaconglomerate) containing brocks of greenstone and metachert (Chicago rock).			

Unit	Belt/Rock Type	Formation / Terrane	Composition	Age	Years (ma)	% Basin Area
Franciscan Complex (con.)			Metagreywacke (Hammerhorn Ridge)	Late – Mid Jurassic	145.5-175.6	
			Argillite, metagreywacke, conglomerate (Broken formation, Devil's Hole Ridge)	Early Cretaceous – Mid Jurassic	99.6-175.6	
	Eastern Belt	Yolla Bolly Terrane	Argillite (Little Indian Valley)	Early Cretaceous – Late Jurassic	99.6-145.5	<1
Great Valley Sequence	Coast Range Ophiolite	Del Puerto Terrane	Mudstone	Early Cretaceous	99.6-145.5	<1
			Dismembered Ophiolite: chert, basalt, diabase, serpentinite mélange, and serpentinized peridotite.	Mid – Late Jurassic	145.5-175.6	
Sources: Kilbourne, 1985, Ogle, 1953, McLauglin, 2000.						

Accretionary History

The geology of the SF Eel River Basin records a history of accretion that stretches from the beginning of the Mesozoic, 250 million years ago, until well into the Cenozoic, about 1.8 million years ago. Accretion over this time is responsible for building the land that underlies the SF Eel River Basin as well as much of California.

At the westernmost leading edge of California a slab of subducting oceanic crust (Gorda plate) formed a megathrust fault to accommodate its movement relative to the overriding North American plate. Movement of these plates created deformation and a subduction trench (Cascadia Megathrust) which subsequently fills with sediment from river systems empting into the ocean. Tectonic forces and the resulting movement within the subduction zone create a complex region where sediments and crustal fragments are fractured, churned, metamorphosed, and then added to the continent to later be exhumed by uplift and erosion. After a time the active subduction zone steps westward to accommodate the newly accreted material and continues the process. Each time the subduction zone steps west, the new chunk of accreted material is left behind and thus accretion builds the western edge of California under the Eel River Basin (*Figure 13*).

This accreted geology underlying the Eel River Basin has been termed the "Franciscan Complex" and has been subdivided into "belts" - Coastal Belt, Central Belt, and Eastern Belt (*Figure 12*). These belts have further been subdivided into "terranes" (*Table 5*).

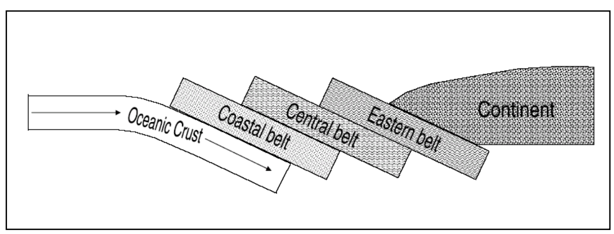


Figure 13. Simplified diagram showing accretion of the Franciscan Complex.

Tectonic Setting of the Eel River Basin

Tectonic movements of the earth's crust coupled with the climatic environment of this area over the last several million years have created a unique watershed history to which salmonids have diversified and adapted. The complex tectonic regime of the West Coast of North America has been a controlling factor in the development of the landscape of the SF Eel River Basin. It dictates the aspect and trend of valleys and ridgelines as well as their drainages.

The tectonics of the Eel River Basin are controlled by the interaction of the North American, Pacific and Gorda plates. The area of interaction between the three plates is known as the Mendocino Triple Junction. Transpression (translation and compression) generated by tectonic activity at the Triple Junction has caused intense deformation of this region evidenced by a myriad of folds, thrust faults, fracturing and uplift of the landscape highly affecting the SF Eel River Basin (*Figure 14*).

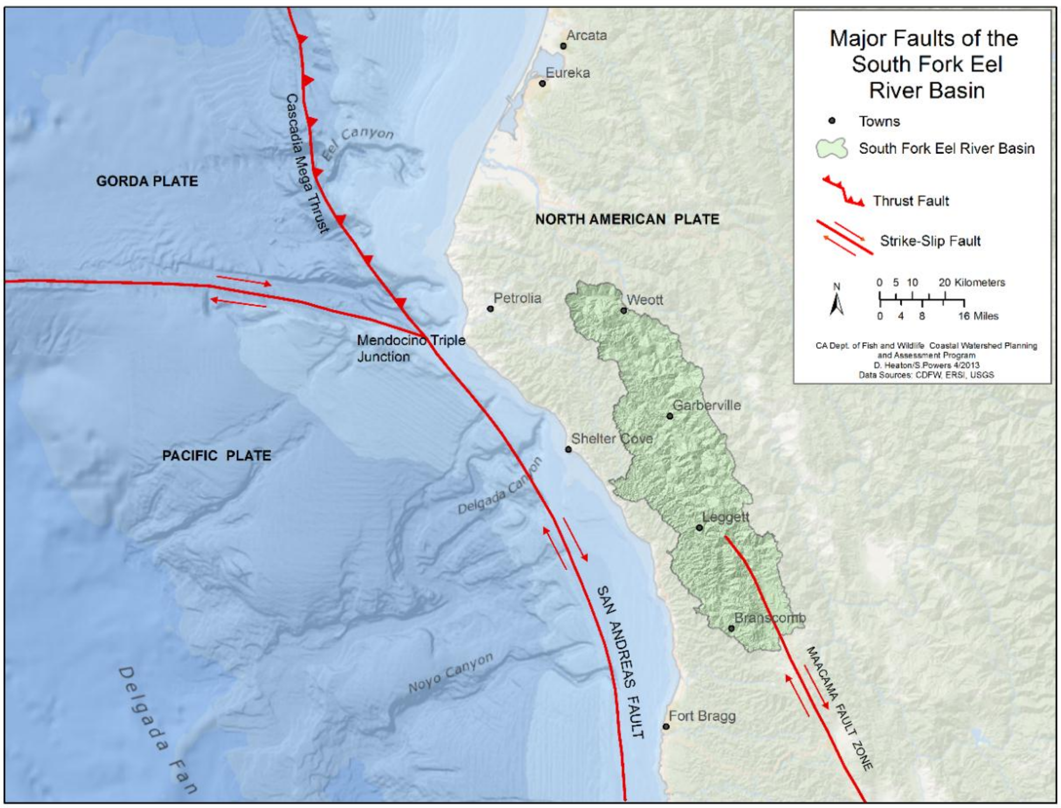


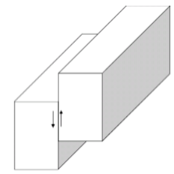
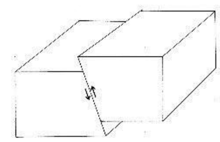
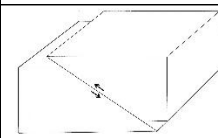
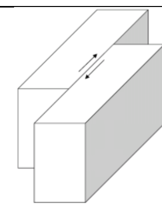
Figure 14. Plate interaction of the Northwest coast of California.

Plate movement generates several influential faults that affect the basin. The most notable faults are the San Andreas to the west of the basin and the Maacama extending into the basin and to the south.

The San Andreas Fault System

The southern two thirds of the SF Eel River Basin is situated within an active, 70 kilometer wide, right lateral deformation zone created by the transpressional plate boundary between the Pacific and North American Plate known as the San Andreas Fault zone (Kelsey and Carver, 1988). The San Andreas Fault zone dominates the tectonic regime in this area and gives rise to a myriad of right lateral, strike-slip faults and shear zones (including the Maacama Fault) actively deforming, disrupting and dislocating geologic units of the basin (*Table 6*). Fault strands associated with this plate boundary exist within this basin and influence the landscape, drainage, and geologic aspect of the region. Forces generated by this transform plate boundary have folded, sheared and faulted the bedrock making it extremely weak and prone to enhanced erosion, adding to the sedimentation of the streams.

Table 6. Fault type descriptions and diagrams.

Fault Type	Description	Diagram
Vertical	A fault in which relative movement between the hanging wall and the foot wall occurs along a vertical plain.	
Reverse	A fault in which the hanging wall moves upward relative to the footwall along a plain who’s dip is between 46° - 89°	
Thrust	A fault in which the hanging wall moves upward relative to the foot wall along a plain that has a dip of 45° or less.	
Dextral	A fault where relative movement viewed across the fault is to the right. Also known as a right-lateral fault.	

Regional Uplift

Much of this region has been uplifted over the past 20 million years, with rates increasing during the last 5 million years. Uplift is currently occurring at a relatively high rate of one to five millimeters per year.

Uplift of 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, increasing the potential for landsliding. As tectonic forces push the land up, gravity tries to pull it down through erosion and mass wasting. Uplift also creates locally steepened stream reaches that pose barriers to anadromy.

The geologic setting of the SF Eel River Basin contributes to high sediment yields within the streams. The geology of this basin is susceptible to shallow landslides, especially within inner gorge areas and to deep-seated landslides and earthflows. High rates of tectonic uplift and compression have further faulted, folded, and weakened this bedrock. Uplift has also effectively raised the potential energy of the streams allowing them to erode the landscape and incise at higher rates.

Mass wasting and erosion affect fluvial geomorphic conditions, as well as stream habitat conditions. The distribution of landslides, channel types, and sediment yield is controlled by physical properties of the various geologic formations that form the foundation of the watershed as well as stress fields and fault lines resulting from the tectonic setting of this region.

Uplift and corresponding incision of the landscape has left large areas of poorly consolidated through unconsolidated marine/river terrace deposits steeply perched above active stream channels. Locally, bedrock is overlaid by marine and river terrace deposits, estuarine deposits, and alluvium. These perched sediments tend to slump, slide and ravel into watercourses contributing fine sediments.

Earthquakes

The SF Eel River Basin is located in one of the most seismically active regions in North America (*Figure 15*). The geology is typified by an abundance of folds, faults, shear zones, disrupted and internally sheared strata, as well as high rates of uplift driven by tectonic interaction.

Tectonic stresses inherent to the Mendocino Triple Junction and the San Andreas system drive frequent, periodic movement on faults (earthquakes) within and in close proximity to the basin.

Earthquakes can trigger mass wasting as well as increasing erosional processes in the area of surface rupture or liquefaction of sediments. Fault movement can result in uplift or subsidence of the local landscape, increasing the potential for erosion or deposition, respectively. Faults may deform, break, or weaken rock, leaving the immediate area unstable and more prone to erosion.

Major historical earthquake events that have affected this basin are included in *Table 7*.

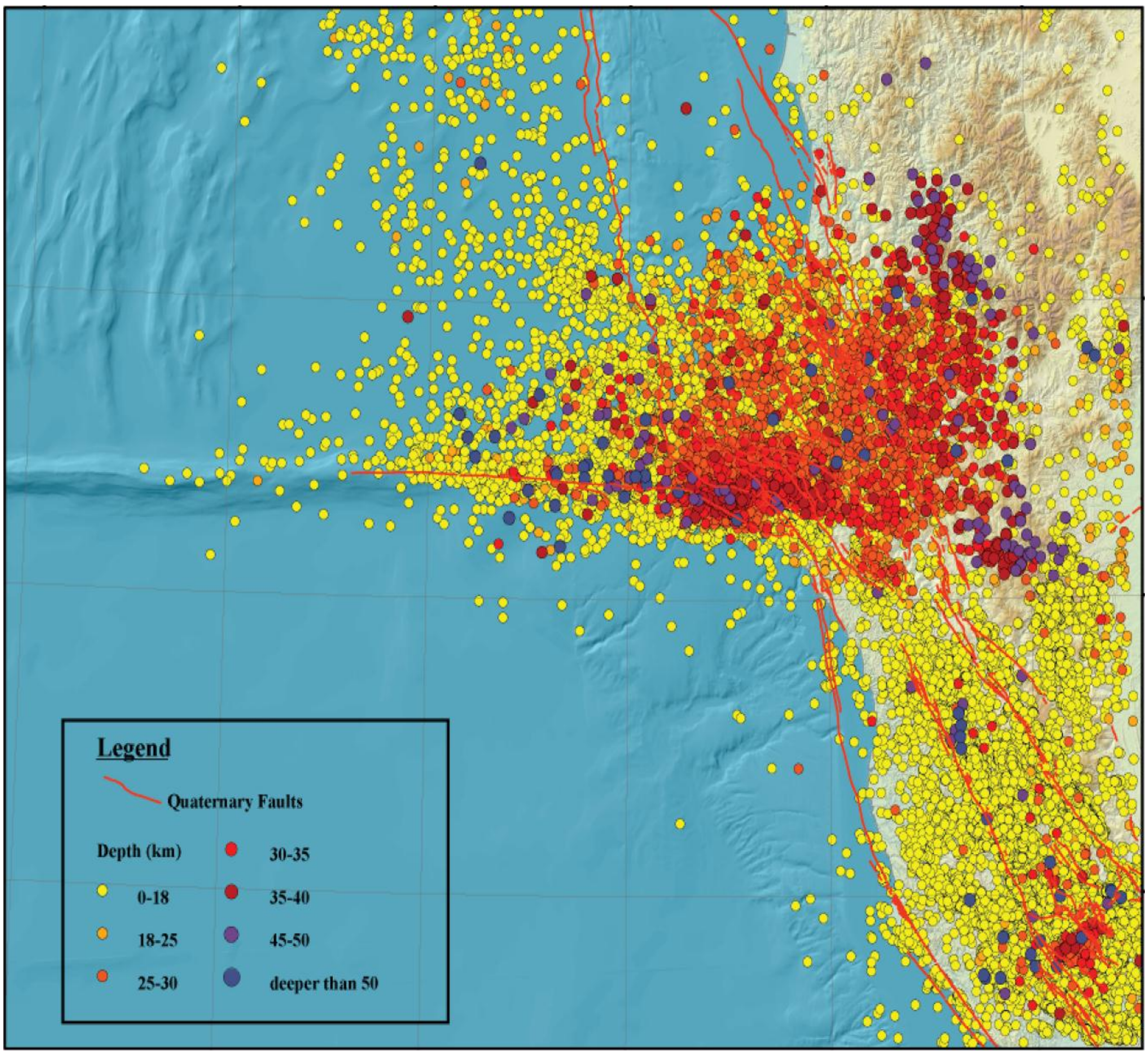


Figure 15. Map of regional seismisity from 1975 - 2006 (reproduced from Pryor and McPhearson 2006).

Table 7. Major recorded earthquakes affecting the SF Eel River Basin.

LARGE HISTORIC EARTHQUAKES IN PROXIMITY TO THE SF EEL RIVER BASIN		
Date	**Magnitude**	**Location**
1700 January	9.0	Cascadia Megathrust
1899 April	7.0	West of Eureka
1906 April	8.3	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

Landslides and geomorphic features related to landsliding were mapped throughout Humboldt and Mendocino County from aerial photographs by the California Geological Survey (CGS) during the 1990's at a scale of 1:24,000. As identified and characterized by CGS in those efforts, several different types of landslides and related geomorphic features exist within the basin and are listed in *Table 8*.

Erosion is dependent upon geology, topography, rainfall, soil structure, vegetative cover, and land use. The climate of this region, wet winters with periods of heavy, sustained rain coupled with easily erodible geology combine to form one of the most susceptible landscapes to erosion in the United States (Brown and Ritter 1971). With a natural environment where the landscape is easily eroded, sensitivity to land use is enhanced.

The strata of the SF Eel River Basin are composed of three separate terrane types: the Coastal Terrane and Yager Terrane of the Coastal Belt, and Mélange of the Central Belt of the Franciscan Complex. The Coastal Terrane and Yager Terrane tend to fail via shallow debris flows and translational/rock slides. Mélange slopes tend to fail via deep-seated massive earthflows, and contribute larger amounts of sediment to the streams relative to the other terrane types.

Earthflows tend to develop secondary surface erosion features such as rills and ruts, which compound the rate of erosion/sedimentation. Roads were the largest contributor of anthropogenic sediments to the SF Eel River (

Table ***9***). Estimates of road related erosion within the SF Eel River Basin were in excess of 300 metric tons per square kilometer of land per year and total erosion (inclusive of natural and anthropogenic) were about 700 metric tons per square kilometer of land per year (USEPA 1999).

A more detailed discussion of landsliding and erosion, specific to each subbasin is included in the basin Land Use and subbasin Geology sections of this report.

Table 8. General landslide types within the SF Eel River Basin (from CGS 2011).

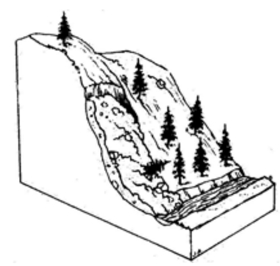
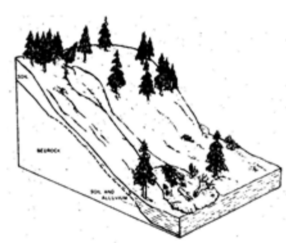
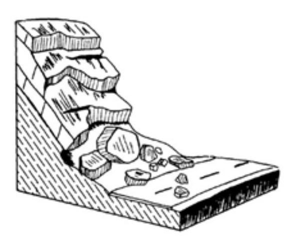
General Landslide Types Within The SF Eel River Basin	
TRANSLATIONAL/ROTATIONAL SLIDE: A landslide in which the bedrock that moves remains mainly intact. Rock slides can range in size from small and thin to very large and thick. The sliding occurs at the base of the rock mass along zones of weakness. The sliding surface may be curved or planar in shape. Rock slides with curved sliding surfaces are commonly called "slumps" or "rotational slides," while those with planar failure surfaces are commonly called "translational slides," "block slides," or "block glides." Rock slides commonly occur on relatively steep slopes in competent rocks. Slope gradients are commonly from 35% to as steep as 70 %.	
EARTH FLOW: A Soil Flow landslide where the majority of the soil materials are fine-grained (silt and clay) and cohesive. The material strength is and movement occurs on many discontinuous shear surfaces throughout the landslide mass. This movement along numerous internal slide planes disrupts the landslide mass leading to cumulative movement that resembles the flow of a viscous liquid characterized by a lumpy, or "hummocky" slope morphology. Earth flows commonly occur on moderately steep slopes from 10% to as steep as 30%. Earth flows typically are initiated by periods of prolonged rainfall and sometimes don't initiate until well after a storm or the rainy season has passed.	
DEBRIS SLIDE: A slide of coarse-grained soil. Its overall strength is generally higher than earth flows, but there may be a very low strength zone at its base. Debris slides typically move initially as shallow intact slabs of soil and vegetation, but break up after a short distance. The debris is deposited at the base as a loose hummocky mass, and may be rapidly removed by erosion. Debris slides commonly occur on very steep slopes, as steep as 60% to 70%, usually in an area where the base of a slope is undercut by erosion. Debris slides form steep, un-vegetated scars which are likely to remain un-vegetated for years. A single heavy rainstorm or series of storms may deliver enough rain to trigger debris slides. Debris slide scars are extremely steep and therefore are very sensitive to renewed disturbance. Erosion at the base of debris slide scars may trigger additional slides. Cutting into the base of a debris slide scar may also trigger renewed slides. Even without additional disturbance, debris slide scars tend to ravel and erode, leading to small rock falls and debris slides.	
DEBRIS FLOW: A non-cohesive, coarse-grained (fine sand to boulder size particles) Soil Flow. Debris flows are most often triggered by intense rainfall following a period of less intense precipitation, or by rapid snowmelt. High pore water pressures cause the soil and weathered rock to rapidly lose strength and flow downslope. Debris flows can move very rapidly, at rates ranging from meters per hour to meters per second and travel relatively long distances. Individual debris flows typically are small in areal extent and their deposits are relatively thin.	
ROCK FALL: A landslide where a mass of rock detaches from a steep slope by sliding, spreading or toppling and descends mainly through the air by falling, bouncing or rolling. Intense rain, earthquakes or freeze-thaw wedging may trigger this type of movement. Rockfalls occur on steep slopes of hard, fractured rock. Rockfall deposits are loose piles of rubble that may be easily removed by erosion.	

Table 9. SF Eel River Basin sedimentation estimates (from USEPA 1999).

SF Eel River – Basinwide Sedimentation Estimates			
Sediment Source	**Total sediment input, t/yr**	**Unit area sediment input (t/km2/yr)**	**Percent of total**
Natural Sediment Sources (54% of total sedimentation)			
Earthflow toes and associated	478,800	269	38%
Shallow landslides	132,500	74	11%
Soil creep	62,980	35	5%
Subtotal	674,280	378	54%
Anthropogenic Sources (46% of total sedimentation)			
Shallow landslides, anthropogenic (roads &harvest)	216,200	121	17%
Skid trail erosion	21,534	12	2%
Road surface erosion	67,512	38	5%
Road crossing failures and	276,500	155	22%
Subtotal	581,746	326	46%
Total	1,256,026	704	100%

Soils

The term “soil” in this report reflects a geomorphologic definition. The soil referred to in this text is considered to be any loosely consolidated material overlying bedrock slopes mixed upward by biogenic and mechanical processes. Given this definition, the South Fork Eel River Basin is mantled with unstable soils.

During periods of extensive rain, as well as episodes of intensive rain stream water becomes heavily saturated with suspended sediment. The amount, duration and intensity of precipitation have a direct effect on soil stability and erodibility (Bryan 2000). The Eel River has the highest recorded average annual suspended sediment load per square mile of any river in the United States (Brown and Ritter 1971). Sedimentation has had a substantial effect on the hydrology and vegetation of the basin and thus has impacted habitat use by salmonids (Monroe et. al 1974, Williams 1988).

Weathering processes within the SF Eel River Basin create from the bedrock up, a series of geomorphic layers: bedrock, weathered/disrupted bedrock, and soil with a venire of decomposing vegetation (duff) at the surface. In a naturally functioning system precipitation (rain, snow, and fog) is intercepted by vegetation and routed to the duff layer where it then infiltrates into the soil (Fallon and Tate 2002). If rainfall exceeds the infiltration capacity of the soil water will usually temporarily pond at the surface in small depressions or in severe cases flow downhill over the surface. As water infiltrates into the soil through capillary action in pore-spaces and gravity it flows generally down-slope following the soil layer to the nearest stream. During heavy rain soil may take only hours to transport water to the channel as storm flow. Some of the water, absorbed by the soil, sinks to the fractured or disrupted weathered bedrock zone, and flows downslope to the stream channel, but flow rates are much slower. This weathered bedrock zone retains water over the course of the year, facilitates dry-season tree growth, and provides summer-fall base flow to the streams. Compaction of the soil may occur as part of several modes of land use. Compaction lowers the infiltration rate of the soil causing a greater amount of precipitation to convert to overland flow increasing surface erosion rates and delivering increased amounts of fine sediment to the streams.

The underlying bedrock is generally responsible for the soil’s texture and erosion characteristics. The stability of the soils and the sediment contribution from soils found in the Lower Eel River Basin depends largely on:

- Soil sediment grain size, consolidation, cohesion and compaction - soils with high sand and silt content are typically more susceptible to erosion than soils with high clay content which exhibit a greater degree of cohesion;
- Soils move more easily on steep slopes;
- Soils saturated by sustained, heavy rain are more prone to sliding and surface erosion;

- Type and amount of vegetation cover;
- Land use practices – grazing, timber harvest, roads, etc. increase erosion;
- Compaction reduces infiltration of water into soil and increases overland flow and surface erosion.

The majority of bedrock in the subbasin is composed of various sedimentary rock types considered to be soft to very soft. This bedrock produces associated soil types ranging from silt-loam to cobbly-loam (the majority being loam and gravelly loam) that range from 1 to 7 feet in depth and are prone to erosion and transport by mass wasting, fluvial processes, and wind. Soil mantled slopes in the basin are considered to be moderate to highly unstable and prone to mass wasting. The terrain in upstream tributaries is generally dominated by steep slopes that are composed of relatively sensitive soils. Therefore, landslides are common upstream, and are usually activated during the rainy season (Syvitski and Morehead 1999).

The ability of soils to resist erosion is based on physical characteristics. The size and interaction of particles (i.e. the ratio between clay, silt, sand, and gravel) gives rise to the classification of soil texture and may be further categorized by the content of larger grains such as cobbles and boulders (Brown 2003). Loam has roughly equal amounts of sand, silt, and clay. The pattern in which particles are arranged within a soil creates its fabric/structure. Both of these attributes dictate how a soil will move and/or erode over time when acted upon by water, gravity, and temperature. Soils with high sand and silt content are typically more susceptible to erosion than soils with high clay content which exhibit a greater degree of cohesion. Generally, soils with high infiltration rates, organic matter, and good soil structure have greater resistance to surface erosion.

Vegetation cover tends to stabilize soil. A mesh of intertwining roots increases the tensile strength, shear strength, and cohesion of the soil (Ghestem et al. 2011). Roots also draw water out of the soil decreasing the likelihood of pore pressure related slope failure. When vegetation (especially trees) is removed from a slope, the roots tend to decay and lose their stabilizing influence before new vegetation can restabilize the soil. This window of enhanced instability usually occurs within 5 to 8 years.

On bare soil where vegetation and the duff layer have been removed the impact of raindrops can disperse grains and lead to surface erosion (Furbish et al. 2009). Fine sediments such as sand, silt, clay and organic matter can be easily removed by the raindrop splash and subsequent runoff. Rainfall initiated soil movement varies with storm intensity, most noticeable during short-duration, high-intensity storms but still significant during long-lasting, less-intense storms.

Landscape morphology can be used as an indicator of relative slope/soil stability (Allan 2004). Many kinds of trees have a difficult time taking hold on slopes that experience yearly to decadal movement. Meadows and grasslands in the SF Eel River Basin are often located in these zones of unstable ground. They are susceptible to surface erosion, headward erosion, and gullying.

The dominant soil series in the SF Eel River Basin is Wohly-Holohan-Casabonne covering approximately 43% of the basin area. The Wohly-Holohan-Casabonne soil series is associated with bedrock of the Central Belt Mélange and Sandstone and Coastal Belt Coastal and Yager Terrane (*Figure 16* and *Table 10*).

Figure 16. SF Eel River Basin soils.

Table 10. Soil series in the SF Eel River Basin.

SF Eel River Basin Soils				
Soil series	**Texture**	**Description**	**Parent Rock**	**Slope %**
Wohly-Holohan-Casabonne (43%)				
WOHLY SERIES	loam	Very deep, well-drained soil formed in residuum weathered from sandstone and shale.	Central Belt Mélange and Sandstone. Coastal Belt Coastal and Yager Terrane.	9 -75
HOLOHAN SERIES	extremely gravelly sandy loam	Very deep, well drained soils formed in colluvium weathered from sandstone.		9 - 75
CASABONNE SERIES	gravelly loam	Very deep, well drained soils formed in colluvium and residuum weathered from sandstone or shale.		9 - 75
Vandamme-Tramway-Irmulco-Hotel-Dehaven (15%)				
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
Zeni-Yellowhound-Ornbaun-Kibesillah (14%)				
ZENI SERIES	loam	Moderately deep, well drained soils formed in material weathered from sandstone or mudstone.	Coastal Belt Coastal Terrane	9 - 75
YELLOWHOUND SERIES	gravelly loam	Deep, well drained soils formed in material weathered from sandstone or conglomerate.		9 - 99
ORNBAUN SERIES	loam	Deep, well drained soils formed in material weathered from sandstone and mudstone.		9 - 75
KIBESILLAH SERIES	very gravelly loam	Moderately deep, well drained soils formed in material weathered from sandstone.		9 - 99
Yorktree-Vanvor-Mayacama-Gudgrey family (8%)				
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
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

Soil series	Texture	Description	Parent Rock	Slope %
Slidecreek-Lacks-Coppercreek-Atwell (5%)				
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	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
Yorkville-Yorktree-Witherell-Squawrock-Shortyork (4%)				
YORKVILLE SERIES	loam	Very deep, well drained soils that formed in material weathered from chloritic schist and other sedimentary and metamorphic rocks.	Central Belt Sandstone and Mélange.	5 - 75
YORKTREE SERIES	loam	Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone.		15 - 75
WITHERELL SERIES	loam	Very deep, somewhat excessively drained soils formed in material weathered from sandstone.		5 - 75
SQUAWROCK SERIES	cobbly loam	Moderately deep, well drained soils formed in material weathered from sandstone or graywacke.		15 - 75
SHORTYORK SERIES	gravelly loam	Very deep, well drained soils formed in material weathered from sandstone, schist, shale and graywacke.		8 - 75
Neuns-Madonna-Kindig-Josephine-Hugo-Casabonne (4%)				
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.		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
Yokayo-Xerocrepts-Pinole-Arbuckle (2%)				
YOKAYO SERIES	sandy loam	Deep, well drained soils formed in material weathered from old alluvium from sedimentary rock.	Alluvium and river terrace deposits.	0 - 30
XEROCREPTS	Gravelly loam	Moderately deep, well drained soils formed in material derived from colluvium from metasedimentary rocks.		5 - 75
PINOLE SERIES	gravelly loam	Very deep, well drained soils formed in alluvium weathered from sedimentary and other rock sources.		0 - 30
ARBUCKLE SERIES	sandy loam	Very deep, well drained soils that formed in alluvial materials from mainly conglomerate and metasedimentary rocks.		0 - 75
Tramway-Irmulco-Empire (2%)				
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

Soil series	Texture	Description	Parent Rock	Slope %
EMPIRE SERIES	loam	Moderately deep, well to moderately drained soils formed in material derived from soft sedimentary rocks (terraces).		10 - 40
Dingman-Beaughton (2%)				
DINGMAN SERIES	cobbly clay loam	Moderately deep, well drained soils formed in material weathered from serpentine and peridotite.	Central Belt Mélange – peridotite block	5 - 50
BEAUGHTON SERIES	gravelly loam	Shallow, well drained soils that formed in material weathered from serpentinized peridotite rocks.		5 - 60
Riverwash-Kerr-Bigriver (1%)				
RIVERWASH	N/A	Barren alluvial areas of unstablilized sand silt, clay or gravel reworked by frequently by stream activity.	Alluvium and river terrace deposits.	0 - 5
KERR SERIES	loam	Dark olive gray recent moderately well drained alluvial soils without profile development that are formed in material derived mainly from micaceous schists.		0 - 5
BIGRIVER SERIES	loamy sand	Very deep, well drained soils formed from alluvium derived from mixed sources.		0 - 5
Speaker-Sanhedrin-Kekawaka-Hopland (1%)				
SPEAKER SERIES	gravelly loam	Moderately deep, well drained soils that formed in colluvium weathered from sedimentary and metamorphic rocks.	Central Belt Mélange.	2 - 75
SANHEDRIN SERIES	gravelly loam	Very deep, well drained soils formed in colluvium and residuum weathered from sandstone, shale and siltstone.		2 - 75
KEKAWAKA SERIES	loam	Very deep, well drained soils formed in material weathered from sedimentary rocks.		2 - 75
HOPLAND SERIES	loam	Very deep, well drained soils formed in colluvium and residuum weathered from sandstone or shale.		9 - 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
Cole (<1%)				
COLE SERIES	clay loam	Very deep, somewhat poorly drained soils that formed in alluvium from mixed sources.	Alluvium	0 - 5

Fluvial Geomorphology

The overall fluvial geomorphology of the SF Eel River Basin may be described by wide, shallow, gentle to moderately graded, entrenched streams with steep reaches containing large boulder runs and cascades (generally at the toes of earthflows). Stream elevation changes significantly where tributaries cross large resistant rock blocks, draining into a low gradient mainstem.

The orientation of major drainage patterns follows the trend of tectonic structures (folds and faults) within the basin. The trend of these features (~N25°W) is mainly controlled by regional folding and faulting induced by Mendocino triple Junction and San Andreas tectonics.

Relatively resistant sandstone units of the Coastal Terrane and Yager Terrane control the topography and influence vegetation in the western side of the basin. These rock types typically produce forested, rugged landscapes with steep sharp ridges and narrow valleys. Western streams are bedrock-controlled and tend to form waterfalls or high gradient cascade reaches where there is a change from softer to harder bedrock, where knickzones and/or landslides are present, or where there is local offset from faulting.

Mélange geology influences topography and vegetation in the Eastern side of the basin, which is characterized by a landscape of hummocky hills and ridges with oak woodlands and grasslands. Mélange moves via large earthflows. Where active earthflows terminate at streams, toe erosion recruits large amounts of fine sediment and large boulders into streams. Excessive recruitment of sediment and/or boulders increases turbidity and influences the morphology of the stream channel, resulting in boulder runs and cascades that may act as barriers to fish passage.

Sediment Transport

Stream power, a combination of the stream's discharge and the slope over which it runs (velocity), and the sediment available to the stream system (Lord et al. 2009) predominantly control processes of stream sedimentation. In general, sediment is eroded from steep reaches, transported along moderate reaches, and deposited within gentle reaches. Streams are typically divided into a source reach (channel gradient of >20%), transport reach (channel gradient 4-20%), and depositional reach (channel gradient <4%) in terms of sedimentation based on stream-channel slope (*Figure 17*). Erosion, transport, and deposition occur on all reaches of a given stream at any given time and at differing scales. Seasonal variations in stream flow and local stream morphology alter where and when such processes occur.

The recruitment and transport of the majority of sediment through the system occurs during large storm events that typically occur in the SF Eel River Basin between October and April. Heavy, long duration rainstorms can completely saturate hillslope soil and trigger various types of landsliding and surface erosion. The sediment-pulses from these storms migrate slowly downstream and tend to affect the stream for tens of years (JMWM 2000). Land use can significantly increase the natural rate of erosion and sediment input to the streams. Very large storm/flood events (e.g. 1955 and 1964 floods) can mobilize enough sediment to require a century or more for the stream to naturally flush it out (Kelsey 1977).

Stream terrace deposits are present at several places along the mainstem of the SF Eel River and some of its tributaries. Terraces typically form in a number of ways (Pazzaglia 2013);

1) Terraces can occur in a period of tectonic quiescence when stream valleys are widened by erosion 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.

2) Large flood events can trigger widespread bank erosion and landsliding, recruiting excess sediment into the stream and redepositing it, greatly aggrading the stream valley. In decades following the flood event, the channel typically incises through the deposit to its former level, leaving terrace deposits perched along its banks.

3) Large landslides may block the stream from time to time causing a landslide dam. Water backing up behind the dam usually triggers many smaller streamside landslides which contribute large amounts of sediment that become impounded behind the dam. Eventually the dam is breached and worn away and the stream responds by incising into the impounded deposit, leaving terraces perched along the banks of the stream.

4) During high stands of sea level (maximum extent of sea level rise), streams deposit sediment and their slopes decrease. Eventually as the seas recede, the streams readjust and incise, leaving behind terrace deposits.

Large river floodplain/terrace deposits bordering the mainstem of the SF Eel River have been developed since prehistoric time due to their proximity to water, flat morphology that is easy to build on, and sediment that supports good crop growth and vegetation/forest cover. The majority of towns within the SF Eel River Basin have been developed on these terrace deposits.

The tributaries of the SF Eel River are predominantly bedrock controlled, with fluvial-geomorphologic features created from the interaction between flowing water and containing bedrock as opposed to a strict interaction between sediment supply and transport power of stream-flow. Regional uplift, folding and faulting, and the mechanical strength and behavior of bedrock strongly influence the morphology of the streams in the basin.

Stream morphology within the basin is also influenced by sediment input from various hillslope processes, including landsliding and surface erosion,

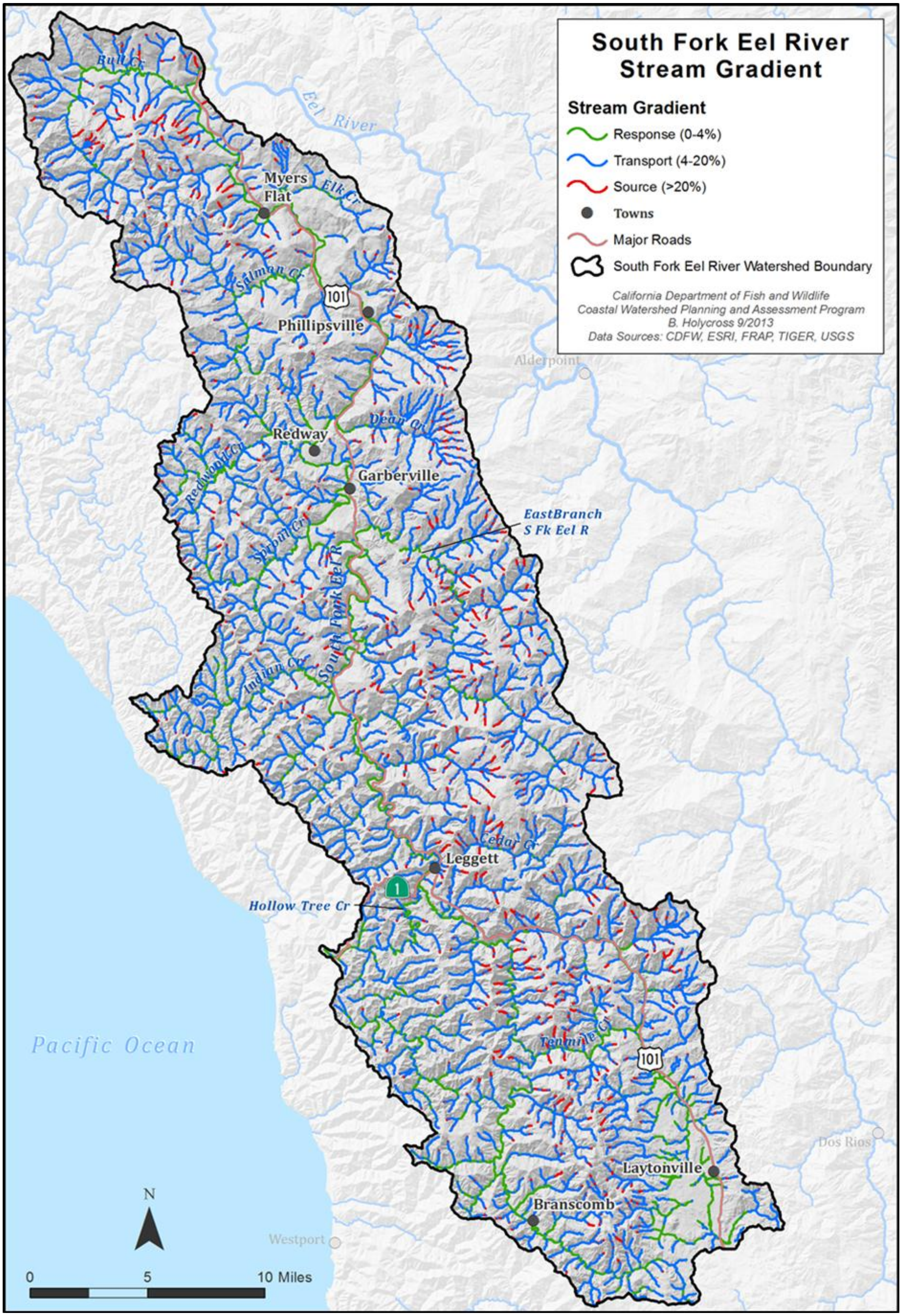


Figure 17. SF Eel River Basin stream gradient classification.

that are often affected by land use and management activities. The 1955 and 1964 floods recruited massive amounts of sediment into the streams over the entire basin, aggrading the lower reaches of the channels and completely burying bedrock. Filling-in of the channels with sediment displaces water up and out of the channel, causing bank erosion and channel widening to accommodate flow volume. Aggradation of the streams subsequently increases flooding by reducing in-channel flow space (Kelsey 1977). For a more detailed discussion of historic floods and their effects on SF Eel River streams, see the Hydrology section.

Spawning Gravel

Bank erosion and streamside landsliding recruit cobble and gravel sized sediment needed by salmonids for redd construction, egg emplacement, and rearing. This sediment is locally sorted through flow dynamics in and around relatively large semi-permanent features such as boulders, large woody debris, and resistant bedrock exposures.

Knickzones

Knickzones are areas of locally steepened stream channel formed from upstream propagating base-level fall and or regional uplift of the surrounding landscape.

Knickzones develop in response to a relative basal lowering of the controlling stream, migrate upstream over long periods of time, and tend to coalesce on streams lacking the stream power to propagate them further (*Figure 18*). Subsequent base-level fall will induce a new series of knickzones (*Figure 19*) which, over time, will "bunch-up" against the previous knickzones where limited by stream power (Anderson 2008, Foster 2010). 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.

A prominent knickzone has developed on the mainstem of the SF Eel River between Rattlesnake Creek (RM 74, elevation 820') and Tenmile Creek (RM 82, elevation 1200'). This eight mile long, 380 foot tall knickzone may be the result of cumulative past base-level lowering events stalling due to significantly reduced stream power near Rattlesnake Creek, which comprises about 22% of the upstream drainage. Furthermore, studies of stream channel steepness values indicate local uplift (Foster 2010). Estimated regional rates of uplift suggest that sea level reduction during the last 125 thousand years may have controlled the base-level of this knickzone. During its propagation, as the knickzone passed upstream, it would cause subsequent formation and upstream propagation of major knickzones along tributaries with enough stream power to allow sufficient incision. It is common for these reaches to develop waterfalls or cascade/boulder reaches. Tributary knickzones tend to stall out where stream power decreases. Most major knickzones in the SF Eel River Basin are thought to be the response to regional uplift balanced by stream incision lowering the base-level of the river (Foster 2010). Minor knickzones seem to reflect local changes in bedrock, landslides, or faulting.

Of the 205 named SF Eel River tributaries, 113 were surveyed for salmonid habitat, with probable end of anadromy identified in the field. The end of anadromy in 15 (75%) of these streams was easily associated with a knickzone.

Bedrock waterfalls or cascade/boulder reaches marked the end of anadromy for 11 mainstem tributaries. Nine (60%) of these waterfall/cascade reaches were easily associated with local stream knickzones.

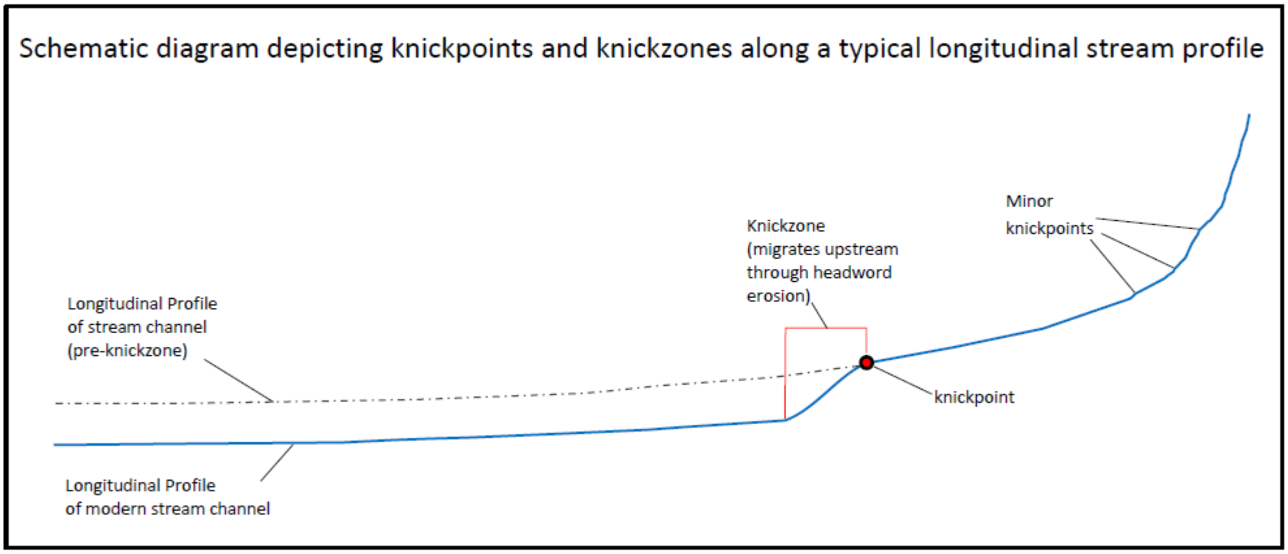


Figure 18. Typical stream profile showing knickpoint morphology.

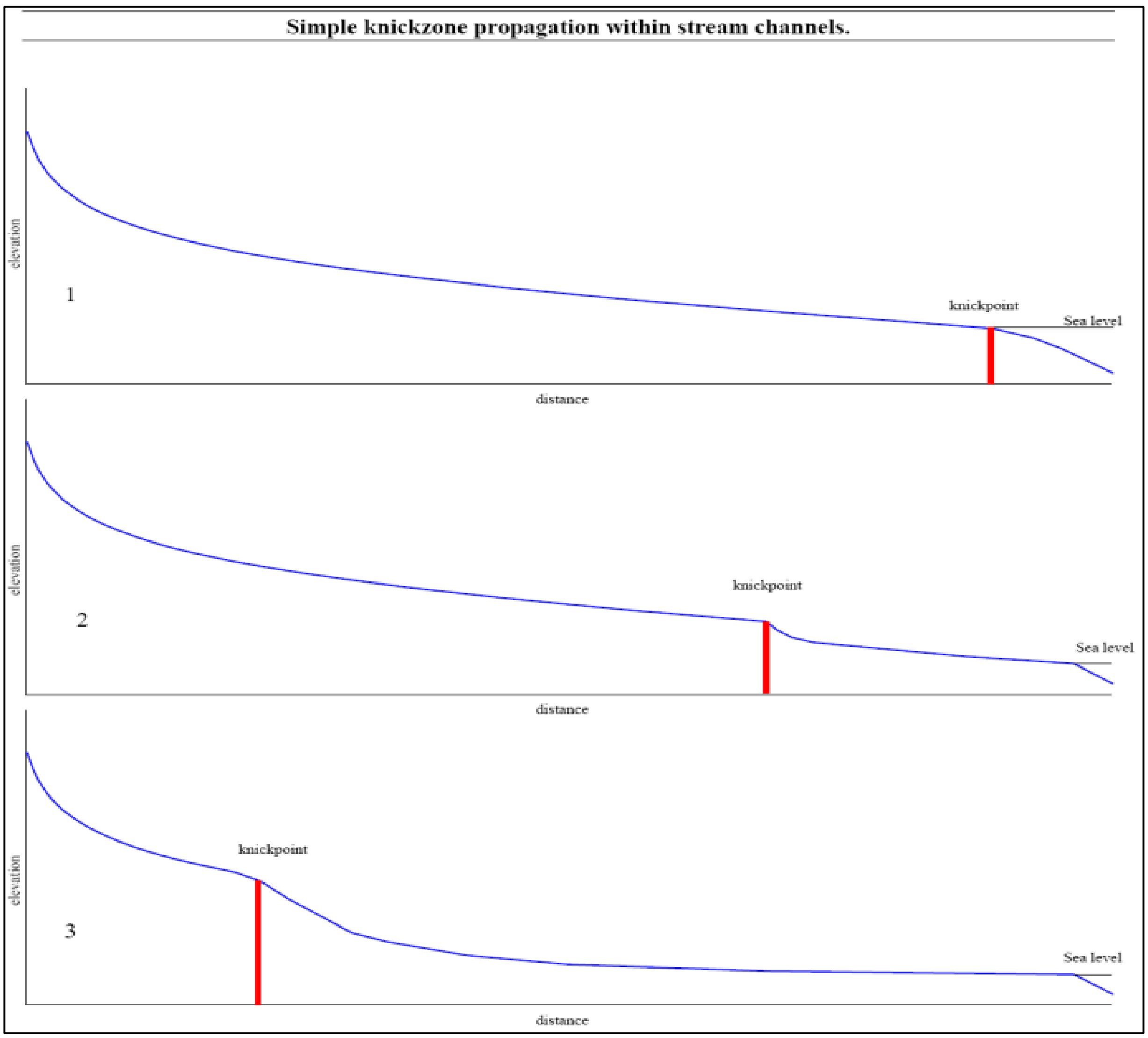


Figure 19. Knickzone Propagation: Sea level sets base level of stream (1); lowering of base level propagates upstream migration of knickpoint (2); knickpoint stalls out where stream flow becomes insufficient (3).

Stream Channel Geometry

Longitudinal Stream Profiles

Over time, in ideal conditions a stream will carve into the landscape and form a channel slope in relative balance to its erosive stream power, sediment availability, and strength of bedrock, eventually reaching a relatively steady state. A stream in a topographically steady state of slope (at equilibrium) tends to form a topographically smooth, concave slope that gets exponentially steeper towards its headwaters (*Figure 20*). A stream that is out of equilibrium tends to deviate from this basic pattern along various portions of its length. Typical divergence from this pattern is caused by changes in underlying geology, regional uplift, movement along stream-crossing faults, large landslides, and large amounts of sediment (aggradation) within the stream channel.

These processes tend to express themselves by causing the longitudinal profile to become progressively convex or form prominent knickzones that migrate upstream over time by headwater erosion. Changes in the natural resistance of the bedrock to erosion may also cause deviance in the longitudinal profile. Sections of the stream channel that are significantly out of equilibrium may become locally too steep (>10% channel slope) to allow passage of fish and may shorten the length of anadromy.

Longitudinal profiles were generated for the main tributaries of the SF Eel River and plotted graphically by subbasin; these are included in the respective subbasin sections of this report. Only 22 out of the 83 mainstem tributaries (27%) of the SF Eel River have profiles that similar to those in a state of equilibrium. Uplift or basal lowering has created multiple knickzones that are apparent on longitudinal stream profiles that have a pattern that is out of equilibrium. Knickzones may be considered sensitive to disturbance and may create limits to 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 the stream in these areas.

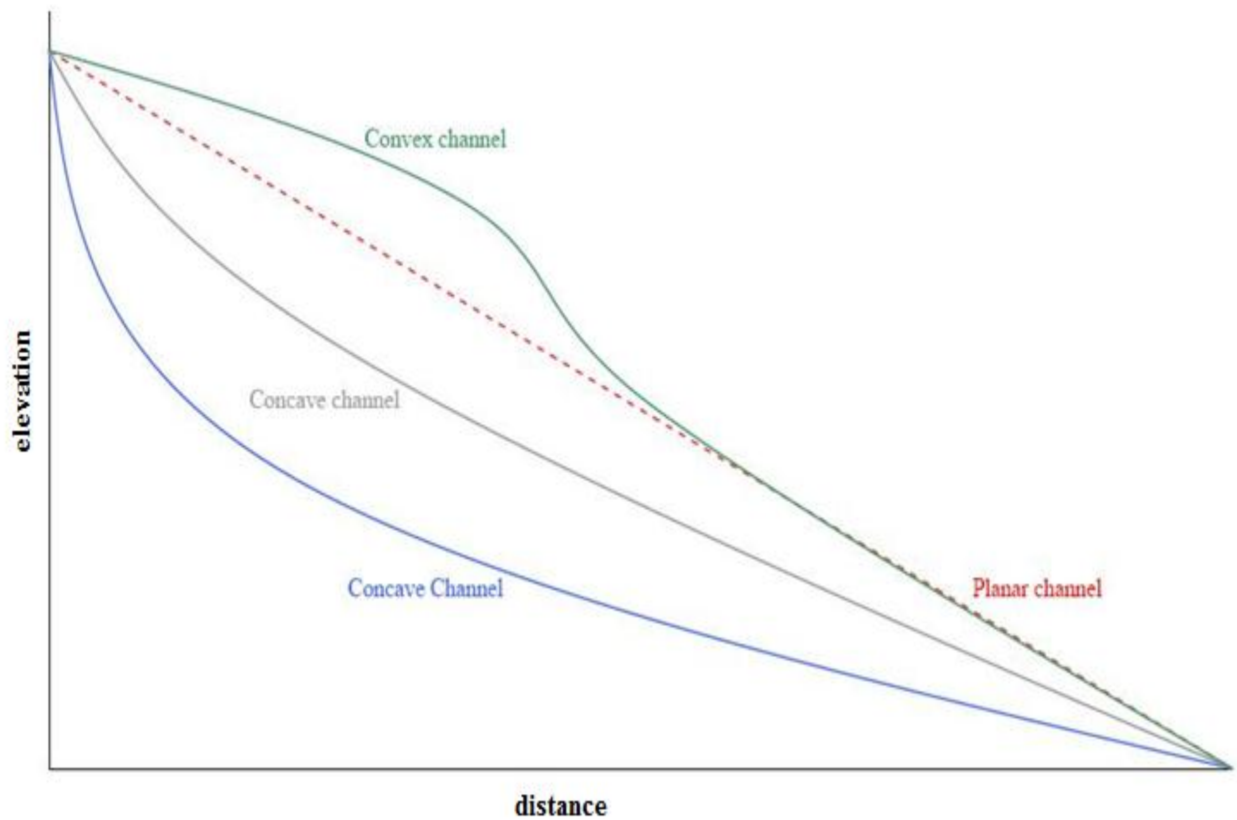


Figure 20. Graphic representation of general stream profile form.

Channel Types

The fluvial geomorphology of individual streams within a system can be used to better understand current as well as past fluvial regime changes. Some basic morphologic stream patterns have been defined by D.L. Rosgen (1996; *Figure 21*). The most recent (1983 to 2010) stream surveys of 113 tributaries of the SF Eel River found all Rosegen channel types (A through G) represented (*Table 11*).

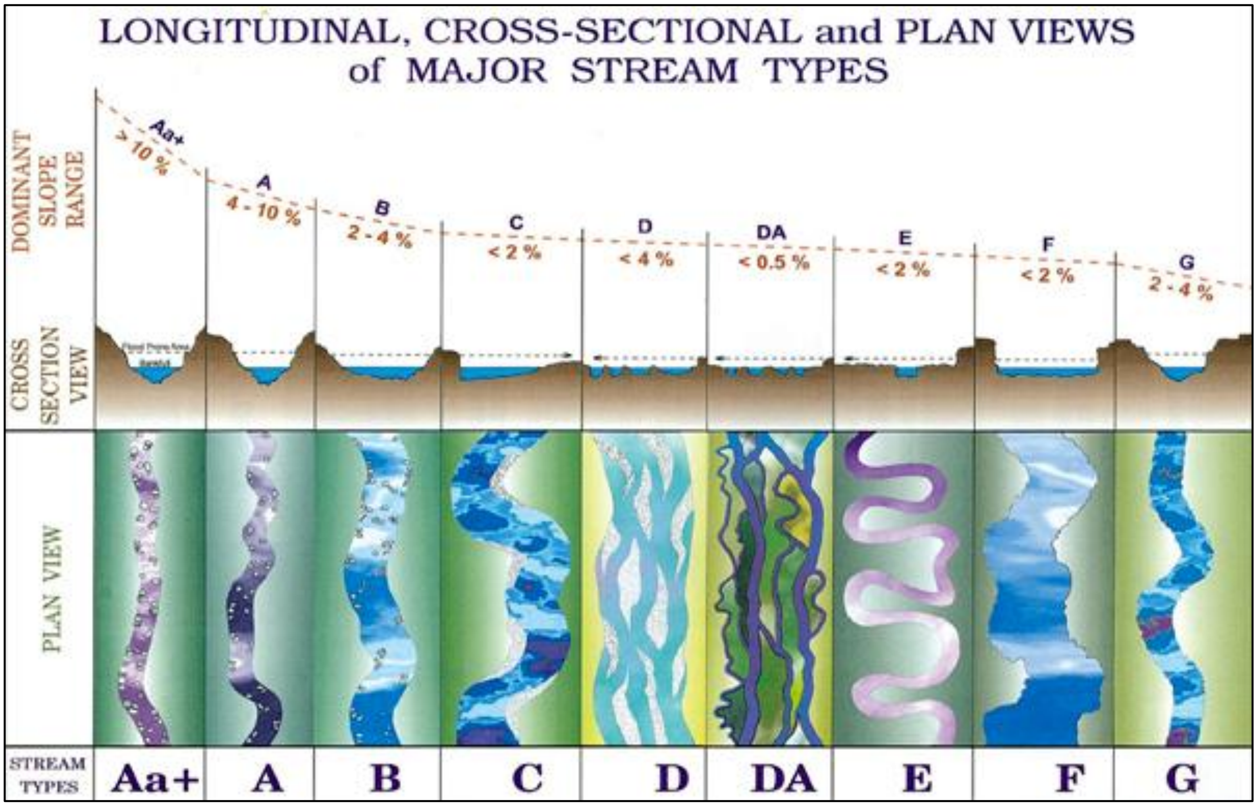


Figure 21. Illustration of how channel types A-G are delineated based on entrenchment, sinuosity, and slope (Rosgen 1996, courtesy of Wildland Hydrology).

The majority, approximately 75%, of the channels surveyed within the SF Eel River Basin were composed of Type F (38.7%) and Type B channels (36.6%) (*Table 11*). Type F channels are wide, shallow, single thread channels that are deeply entrenched, low gradient (<2%) reaches that often have high rates of bank erosion. Type F channel reaches flow through low-relief valleys and gorges, have frequent meanders, and are typically working to create new floodplains. Type B channels are also wide, shallow, single thread channels. These channels, however, are moderately entrenched, moderate gradient (2-4%) reaches, which are riffle-dominated with step/pool sequences. Type B reaches flow through broad valleys, have few meanders, and do not have well-developed floodplains.

Table 11. SF Eel River Basin channel type and description.

Type	%	Description
A	5.7%	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	36.6%	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	14.5%	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.

Type	%	Description
D	1%	Type D channels are wide, shallow, alluvial channels typically exhibiting meandering, braiding and/or multi-channeled morphology.
E	.2%	Type E stream reaches are meandering, single thread, riffle/pool channels with a low width to depth ratio. They are slightly entrenched, low gradient (<2%) reaches. Type F reaches flow through low-relief valleys and gorges, are typically working to create new floodplains.
F	38.7%	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	3.2%	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).

Vegetation

One of the most visually striking features of the SF Eel River Basin is the contrast in vegetation between the east and west sides *(Figure 22).* The west side is thickly forested with lush conifers while the east is dominated by interspersed scrubby oak woodlands and hillside prairies. This division of vegetation is brought about by climate differences as well as the underlying geology and topography.

The USDA Forest Service (USFS) CALVEG vegetation data were used to describe basin-wide vegetation. This classification system breaks down vegetation into major "vegetative cover types." These are further broken down into a number of "vegetation types." The predominant vegetative cover type in the SF Eel River Basin is mixed conifer and hardwood forest at approximately 53% (*Figure 22*). Of this cover type, 69% is described as Pacific Douglas-Fir and 29% as redwood – Douglas-fir (*Table 12*).

Redwood occurs primarily in the northern part of the basin, and the predominance of this vegetation type in this area is due in part to Humboldt Redwoods State Park ownership and preservation efforts. Redwood also occurs on river terrace deposits bordering the mainstem of the SF Eel. The Avenue of the Giants was constructed along many of these terrace deposits. Coast redwood stands generally grow within a narrow strip along the Northern California coast, and are closely associated with fog and sediments deposited from continual river flooding (Jebens 1999). Vegetation that commonly occurs in stands of redwood and Douglas-fir includes: redwood sorrel, western sword fern, Sitka spruce, and madrone, among others. Most coniferous forest in the SF Eel River Basin is considered productive timberland by the USFS.

Hardwood forest/woodlands occupy approximately 17% of the basin and are dominant on the east side of the basin. These woodlands primarily contain oak trees (94%) and are associated with the unstable geology of the Central Belt Mélange.

Conifer forest makes up about 17% of the basin and is dominated by Douglas-fir and redwood. Albin and Law (2006) found that coho presence was strongly related to the percentage of coniferous vegetation in areas adjacent to Mendocino coastal streams, but noted that topographic features such as low gradient terrain may favor both coniferous forest habitat and coho presence.

Agricultural land makes up less than one percent of the SF Eel River Basin but because a good deal of the agriculture is covert in nature (marijuana production) and many interspersed grassland/prairies have been converted to grazing land, it is hard to estimate the actual extent of this vegetation cover type. Agriculture occurs predominantly on low-lying river terraces and floodplains bordering the mainstem SF Eel River.

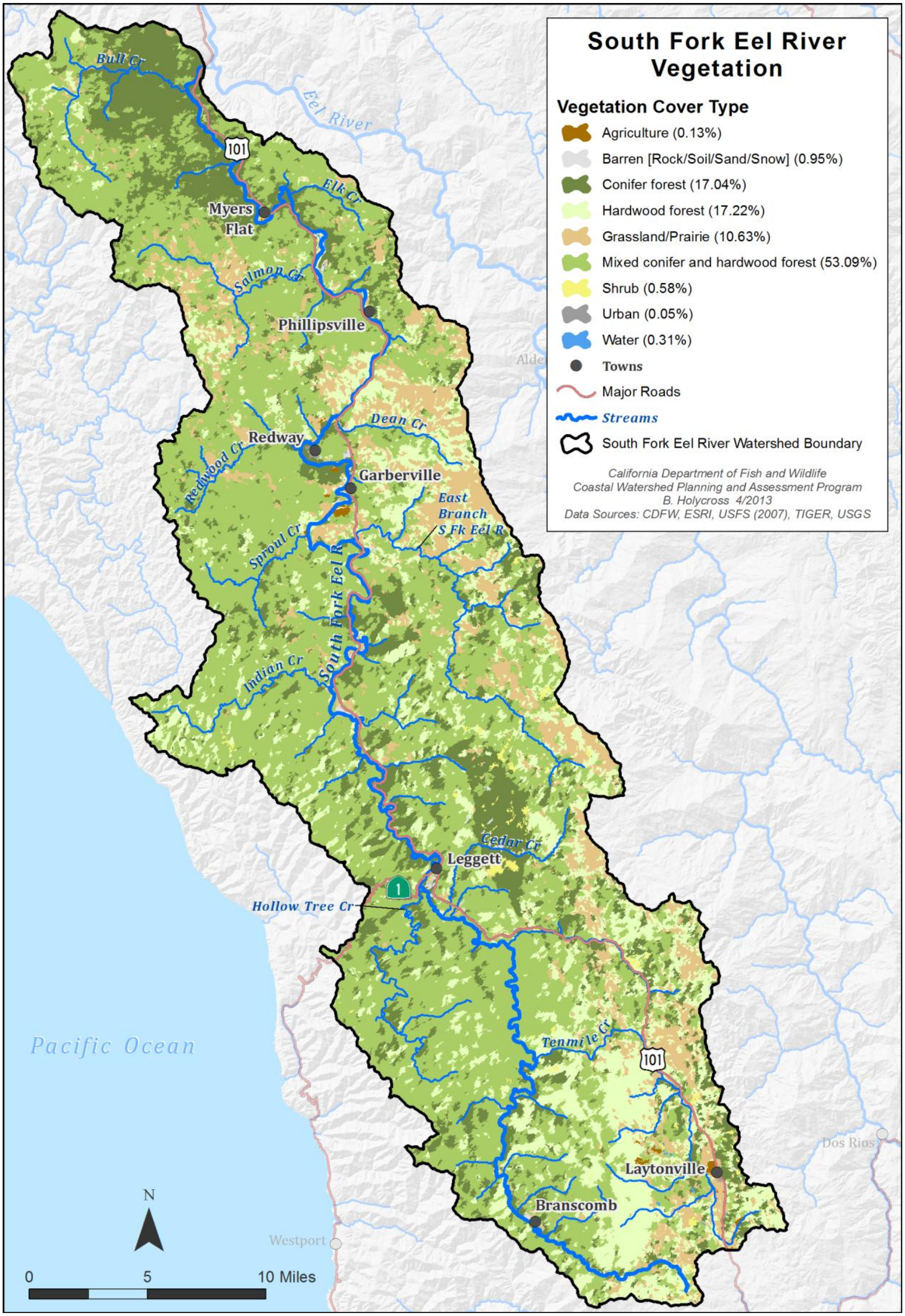


Figure 22. Vegetation of the SF Eel River Basin.

Grassland/prairie (herbaceous vegetation) that is not mapped as agricultural is the fourth most abundant category in the SF Eel River Basin, covering approximately 11% of the total area.

Ninety-nine percent of the herbaceous vegetation in the SF Eel River Basin is considered annual grasses and forbs, which as described above, likely is or has been used for agricultural purposes. This vegetation may be made up of either native or nonnative species.

Nearly one percent of this basin has been mapped as barren and mostly reflects large blocks of exotic rock cropping out from the Central Belt Mélange, mostly in the eastern portion of the basin. This designation also reflects active stream channel deposits found primarily along the mainstem SF Eel River, as well as recent landslide scars throughout the basin.

Close to one percent of the vegetation in this basin has been delineated as shrub, more than half of which is chaparral and scrub oak.

The remaining (<1%) of vegetation in the SF Eel River Basin has been classified as urban lands. Like the previous vegetation types, abundance varies by subbasin.

This USFS classification describes current vegetation as of 2007. However, vegetation in the SF Eel River Basin may have changed considerably over time due to climate and land use. For example, native bunch grasses have been replaced over time by European annual grasses in areas where grazing of livestock has occurred. The use of fire as a management tool virtually stopped since the late 1800s causing vegetation changes throughout the SF Eel River Basin. Additional changes have come from timber harvesting practices that have depleted forest stands and riparian vegetation. Some of the earliest timber harvesting began as a result of agriculture, when ranchers hired loggers with the singular purpose of clearing lands for grazing (Tetra Tech 2002).

Table 12. SF Eel River Basin vegetation cover type and primary vegetation type (USFS CALVEG).

Vegetation Cover Type	% of Basin	Primary Vegetation Type	% of Type
Mixed conifer and hardwood forest/woodland	53.26%	Pacific Douglas-Fir	69.16%
		Redwood - Douglas-Fir	28.86%
		Douglas-Fir Ponderosa Pine	0.65%
		Ponderosa Pine	0.64%
		Redwood	0.60%
		Jeffrey Pine	0.07%
		Incense Cedar	0.03%
Hardwood forest/woodland	17.27%	Tanoak (Madrone)	50.10%
		Oregon White Oak	31.15%
		Canyon Live Oak	10.95%
		Black Oak	3.87%
		California Bay	1.66%
		Montane Mixed Hardwood	1.11%
		Valley Oak	0.40%
		Riparian Mixed Hardwood	0.18%
		Interior Mixed Hardwood	0.16%
		Interior Live Oak	0.16%
		Red Alder	0.10%
		Madrone	0.08%
		Willow	0.05%
		Black Cottonwood	0.02%
		Coast Live Oak	0.01%

Vegetation Cover Type	% of Basin	Primary Vegetation Type	% of Type
Conifer forest/woodland	17.09%	Pacific Douglas-Fir	43.06%
		Redwood - Douglas-Fir	30.99%
		Redwood	16.20%
		Ultramafic Mixed Conifer	5.19%
		Ponderosa Pine	1.93%
		Sargent Cypress	0.98%
		Jeffrey Pine	0.71%
		Douglas-Fir Ponderosa Pine	0.67%
		Mixed Conifer - Pine	0.15%
		Non-Native/Ornamental Conifer	0.06%
		Incense Cedar	0.05%
Grassland/Prairie	10.67%	Annual Grasses and Forbs	99.17%
		Pastures and Crop Agriculture	0.64%
		Non-Native/Ornamental Grass	0.12%
		Perennial Grasses and Forbs	0.06%
Barren	0.95%	Barren	60.47%
		Urban-related Bare Soil	39.46%
		Dune	0.08%
Shrub	0.58%	Lower Montane Mixed Chaparral	25.24%
		Scrub Oak	24.76%
		Manzanita Chaparral	13.52%
		Blueblossom Ceanothus	13.24%
		Ultramafic Mixed Shrub	9.26%
		Chamise	9.02%
		Willow (Shrub)	3.90%
		Wedgeleaf Ceanothus	0.45%
		Coyote Brush	0.35%
		Upper Montane Mixed Chaparral	0.19%
		North Coast Mixed Shrub	0.07%
Agriculture	0.13%	Agriculture (General)	100.00%
Urban	0.05%	Urban/Developed (General)	100.00%
Statistics exclude classification of water			

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). Pre-European settlement fire patterns 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.

Fire frequency, size, and severity are influenced by habitat structure and composition, climate, weather, prior fire history, land management activities, and physical properties such as elevation and aspect (Flannigan et al. 2000, Pilliod et al. 2003). Contemporary land uses such as agriculture and urbanization have reduced the amount of flammable vegetation, and most fires are now effectively suppressed using advanced technology and increased early efforts to protect resources, commodities, and people. To reduce the potential for severe, widespread fires, state and federal policies and programs such as the California Fire Plan and the US Department of Agriculture/US Department of the Interior National Fire Plan began emphasizing fuel treatments as the only practical means of altering potential wildfire behavior (CalFire 2003). In some areas where cutting and removal of fuel is controversial, infeasible, or prohibitively expensive, fire has been used as a tool to reduce fuel loads. These prescribed burns may limit the extent, effects, and severity of subsequent fires (Collins et al. 2008).

In the SF Eel River Basin, fire is one of the primary natural disturbance factors influencing vegetation structure. Post-fire stands are usually a mosaic of burn severities, from unburned to stand-replacing, all in the same watershed. Native Americans and European settlers used fire to manage grasslands and prairies, and to maintain a low ratio of conifers to oaks in existing tanoak stands (USBLM et al. 1996). Historic ranching, open range grazing, farming, timber/fuelwood harvesting, and residential and commercial land development all placed increased demands on land and resources, leading to significant changes in ignition patterns and to the vegetation landscape (i.e., fuels) with which fire interacts.

Modern land use practices have continued to influence the likelihood and effects of wildfire throughout the SF Eel River Basin. Logging on highly erodible hillslopes has altered the natural hydrology of the Basin, 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. Natural resource lands surround many unincorporated areas in Humboldt County. Areas where communities border parklands or industrial timberlands are known as the wildland-urban interface (*Figure 23*).

Figure 23. Backfire set in the path of the 2003 Canoe Creek Fire, located in the wildland-urban interface near Myers Flat (photo courtesy of Dave Stockton, CA State Parks).

In this interface, a combination of fuel, weather, and topographical conditions may create an environment of increased wildland fire risk (Tetra Tech 2008). These high risk areas have been identified throughout the county, and CalFire has developed a Fire Management Plan (2003) that considers fire risk in developed areas based on hazardous fuel buildup, wildland-urban interface proximity, high value assets, and fire history. Goals include protecting both people and natural resources from damaging wildfires that result from unnaturally high levels of fuels.

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

- 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).

The two largest fires that occurred recently in the SF Eel River Basin were the Canoe Fire (2003), located just south of Weott in the Northern Subbasin, and the Red Mountain Lightning Fire (2008) in the Cedar Creek drainage in the Eastern Subbasin (*Figure 24*). More than 21% (147 square miles) of the total basin area burned between the early 1900s

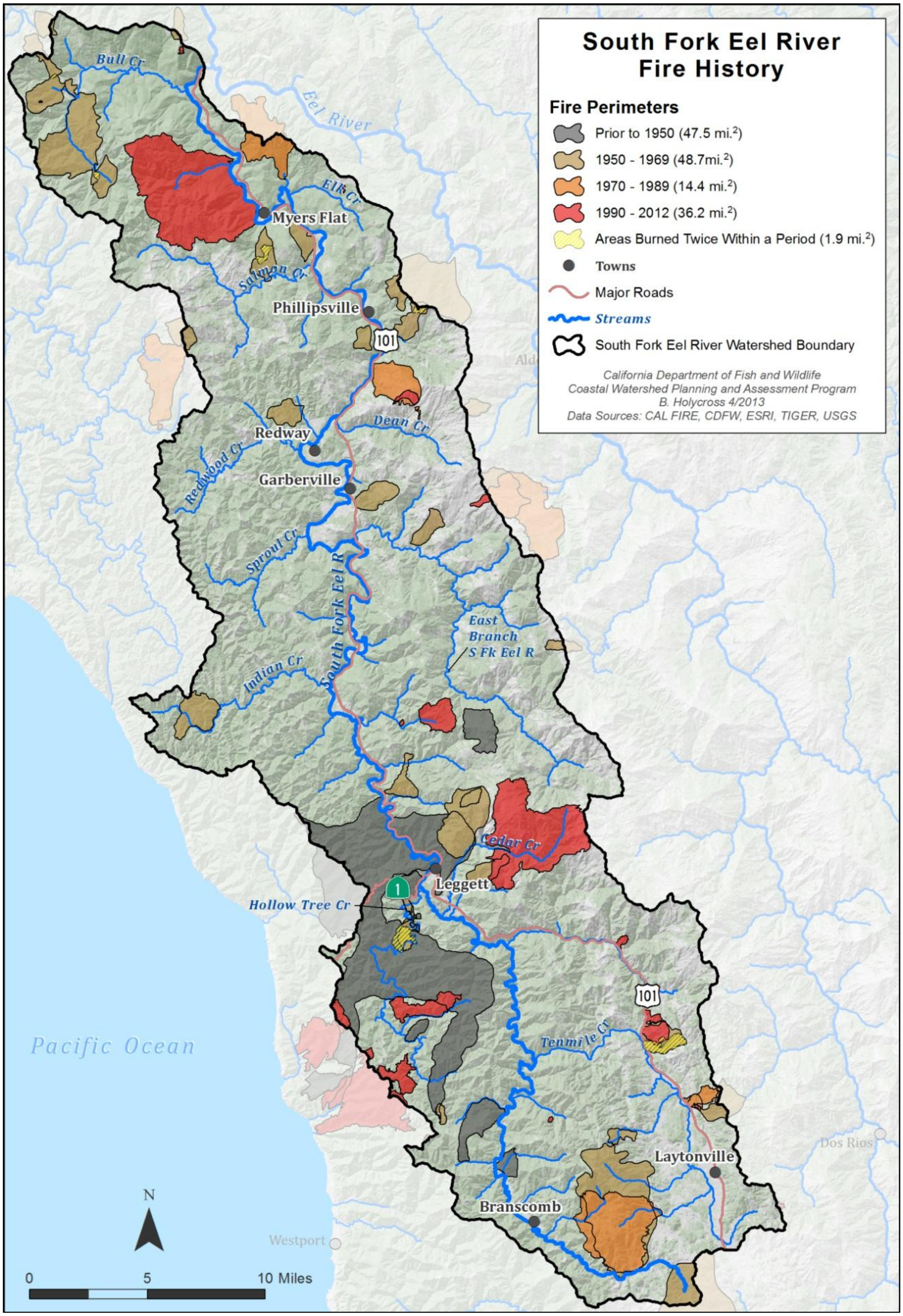


Figure 24. SF Eel River fire history, including areas prior to 1950 through 2012, with square miles burned in each time period.

and 2012, with the greatest area (48 square miles, or 7% of the total basin area) burned between 1950 and 1969 (*Figure 24*). Prior to 1950, the largest fire was the Will Creek Fire near Leggett, which burned more than 40 square miles in 1945. The Eastern Subbasin has the largest burned area of the three subbasins, followed by the Western and Northern subbasins (*Table 13*).

The larger number of fires and corresponding burned acreage in the Eastern Subbasin is due to hotter, drier summer conditions, a higher prevalence of grassland and shrub vegetation types, steeper ravines, and more difficult access (fewer roads) compared to the other subbasins. Another example of this can be seen in the Western Subbasin, southwest of Garberville. There have been no fires recorded in the entire Sproul Creek watershed and in large parts of the Redwood Creek and Indian Creek watersheds since the early 1900s. Some areas in the basin have burned more than once, as indicated on the map; square mileage of these areas was included twice in the calculations of overall area burned for each year class.

Table 13. Area burned by subbasin in SF Eel River Basin (data from early 1900s through 2012).

Subbasin	# Fires	Area Burned (mi^2)	Subbasin Area (mi^2)	Percent Subbasin Area Burned
Northern	19	35	149	21
Eastern	35	64	320	20
Western	16	48	220	22

The Canoe Fire in the Northern Subbasin was the largest recent fire, burning more than 10,000 acres in 2003. This fire was relatively unusual because it was the largest fire to occur primarily in old-growth coast Redwood forest since the beginning of the fire suppression era (*Figure 25*). Old growth redwood forest is usually considered fire resistant. Historic fire suppression and exclusion practices in the area of the Canoe Fire resulted in higher burn intensity and duration, which may have contributed to greater mortality of old growth stands (Scanlon 2007).

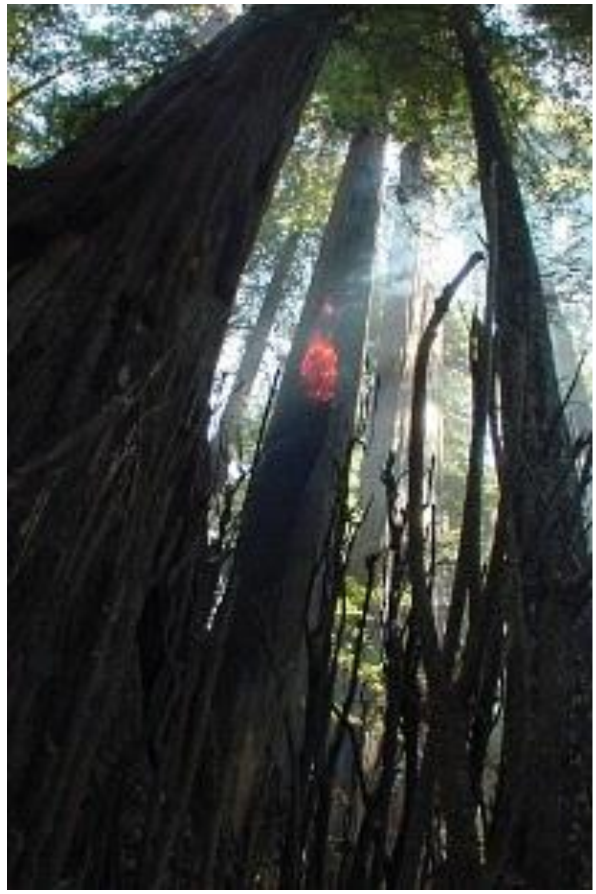


Figure 25. Fire in the Children's Forest, an old-growth area within the boundaries of the 2003 Canoe Fire (photo courtesy of Dave Stockton, CA State Parks).

Fires on private lands in the basin are generally small due to rapid and extensive initial response (close proximity of crew bases), good access to start locations, good detection coverage, and local rancher and volunteer contributions to firefighting efforts (CalFire 2012). The suppression of wildfire over time has resulted in a buildup of fuels and has increased the potential for large fires, which burn with greater intensity than under natural conditions. Fire suppression and the corresponding buildup of fuels have led to the development of prescribed burning on public lands, primarily in the Northern Subbasin where the majority of the land is owned by Humboldt Redwoods State Park. The prescribed burning program is maintained cooperatively through efforts of the State Park and the Humboldt-Del Norte Management Unit (CalFire 2012), and is designed to restore the natural burning cycle, decrease fuel loads, improve habitat for native species that evolved with periodic fires, and control exotic plant species.

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 SF Eel River Basin 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 throughout the SF Eel River Basin. 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 SF Eel River Basin occurred in areas of high and very high fire threat (*Figure 24* and *Figure 26*). Most of the land within the basin boundaries (69% of total basin area; 475 square miles) is classified as high or very high fire threat. The National Wildfire Coordinating Group (2002) developed terms and ratings for fire danger levels, which are summarized below:

- Very high – Fires start easily from all causes; after ignition, fires spread rapidly and increase in intensity; fires burning light fuels quickly develop high intensity characteristics when burning into heavier fuels; spot fires are a danger;
- High - 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; fires may become serious and their control difficult unless they are attacked successfully while small;
- Moderate – Fires start from most accidental causes, and the number of starts is generally low (except with lighting fires); fires in open grasslands spread rapidly on windy days; timber fires spread slowly to moderately fast; average fires are moderate in intensity; fires are not likely to become serious and control is relatively easy;
- Low – Fires do not ignite readily; fires in grasslands will burn a few hours after rain; timber fires spread slowly by creeping or smoldering; there is little danger of spotting.

Thirty percent (207 square miles) of the basin area is classified as moderate fire threat. Only one percent (7 square miles) is designated as low threat and these areas are considered 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.

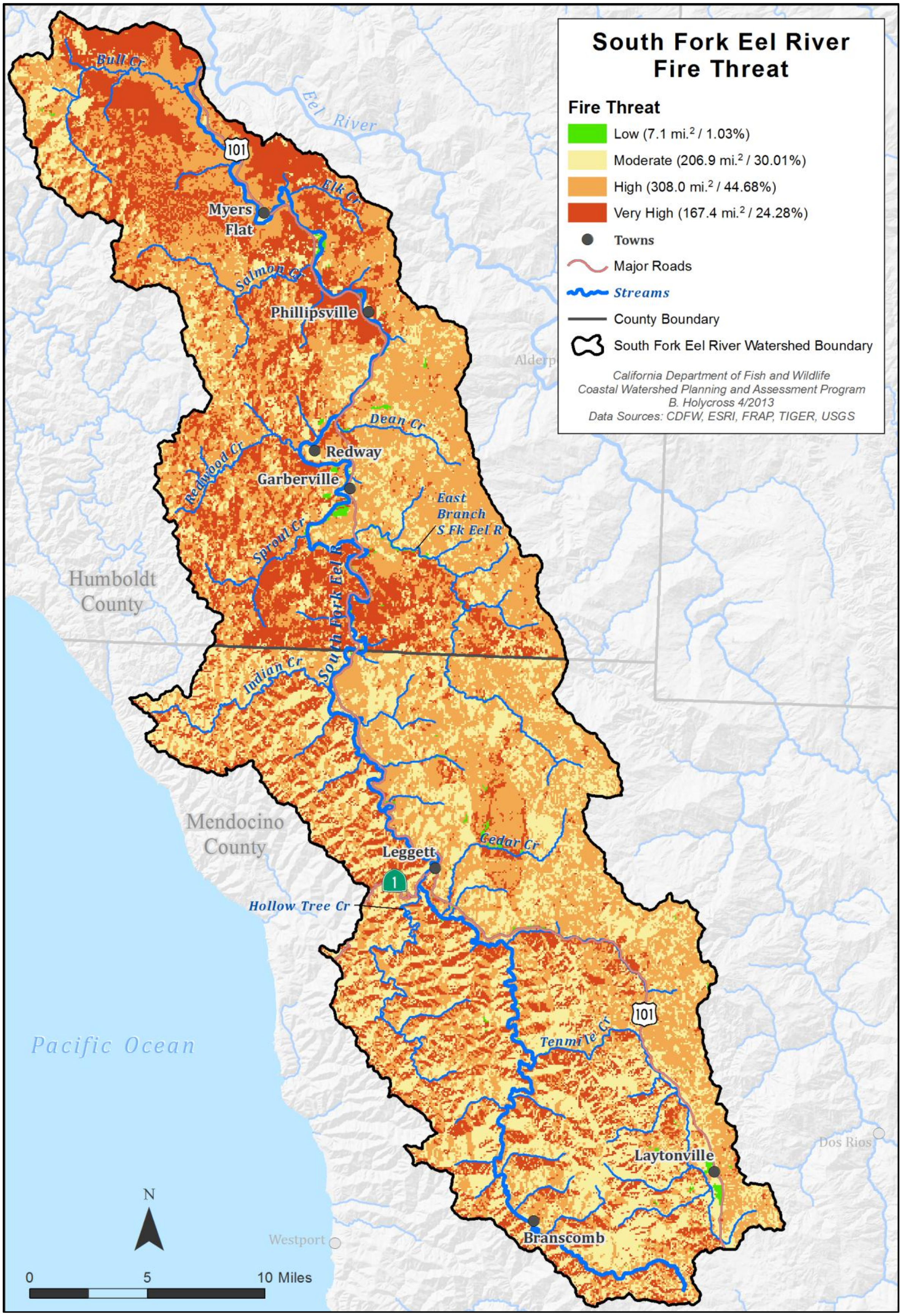


Figure 26. SF Eel River Basin fire threat, with percent of total basin area in each threat category.

Fire threats were calculated using slightly different techniques in Humboldt and Mendocino Counties, resulting in higher percentages of very high fire threat in Humboldt County (*Figure 26*). CalFire is currently working on new fuel and hazard ratings to standardize techniques across counties.

Despite the generally damp climate prevailing in Humboldt County forests, CDF (2005) suggested a fire return interval of 50 to 100 years in the northern part of the county and 12 to 50 years in the southern part, which includes the SF Eel River Basin. The potential fire hazard in drier inland areas of the basin (e.g. the Eastern Subbasin) is exacerbated by hot, dry summers and frequently occurring drought conditions (Mendocino County 2009). Fire season in Humboldt County generally begins in June, peaks in August, and ends in October.

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 basin.

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 approximately1500 acres per year from 2004 through 2010 (Valachovic 2011). 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 increased rates of fire spreading, flame length, and fireline intensity, which reduces the effectiveness of firefighting strategies and techniques (Valachovic et al. 2011).

There is currently no cure known for SOD once trees are infected, so management actvitites are designed to prevent the spread of the disease to succeptible trees. Best management practices vary by user groups and local activites, and recommendation lists can be found at:
http://www.suddenoakdeath.org/diagnosis-and-management/best-management-practices/

Related fungal pathogens are spread by soil, water, and infected plant material, so transporting freshly cut wood or soil from infected areas is not recommended. Contaminated equipment (e.g. saws and vehicles), surface water, and ground water may also lead to the spread of pathogens. For additional information on SOD and management, go to: http://nature.berkeley.edu/garbelotto/english/factsheet.php

In summary, fire is a natural and important part of the disturbance regime of the SF Eel River Basin. 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.

Land and Resource Use

Native American tribes inhabited the Eel River watershed beginning 5,000 to 10,000 years ago (USBLM et al. 1996). Pomo Indians and Athabascan people, including aboriginal groups of Sinkyone and Cahto tribes occupied the SF Eel River Basin. They lived in small semi-sedentary villages, moving throughout the basin to take advantage of seasonally available resources. Natural resources, such as large and small game, plants, and fish (salmon, steelhead, sturgeon, and lamprey) were plentiful throughout the basin, and the population density within the SF Eel River Basin equaled or exceeded the density seen in other North American agricultural societies (USBLM et al. 1996). Even with this comparatively high density of people, their cumulative impact on the resources and the environment was relatively small (Yoshiyama and Moyle 2010).

In the 1850s and 1860s, the first Euro-Americans came to the SF Eel River Basin. Trappers were the first inhabitants, followed by homesteaders and ranchers after the passage of the Homestead Act in 1862 (HCRCD 2002). Conflict between Native Americans and settlers between 1855 and 1865 resulted in the extirpation of nearly all native people living in the basin. The U.S. Army placed the remaining surviving natives on the Round Valley and Hoopa reservations (Downie1995). By 1910, there were only 100 documented Sinkyone people in the area (HCRCD 2002). With the reduced and relocated native population, the number of settlers increased rapidly, and during this period nearly all public lands were conveyed to private ownership. In order to earn enough money to survive, homesteaders worked intensively, peeling tanbark, building roads, and harvesting available redwoods on their lands. Many homesteaders supplemented their existence by hunting and fishing (HCRCD 2002) but still struggled to survive. Beginning in the early 1900s, there was a slow transition from homesteads to ranches, and the primary economic activities at this time were related to ranching. Many ranches were large (thousands of acres) and most ran sheep; wool was the principal commercial product exported at that time (USBLM et al. 1996). Successful families bought up less successful homesteads and formed large ranches, and by 1921, property ownership was similar to today's configuration, even though the population was much smaller (HCRCD 2002).

Historically, the most significant limiting factor to settlement and development in the SF Eel River Basin was transportation. Until the early 1900s, the only transport option was the Humboldt Mendocino wagon road. Constructed in 1876, this road linked Eureka with the San Francisco Bay Area (HCRCD 2002). With the passage of the State Highway Act in 1910 and subsequent construction of the Redwood Highway, settlements along the old wagon road declined while those along the highway grew rapidly (HCRCD 2002). Flats along the river were developed and tourism became a major industry. Construction of the highway also increased opportunities for transporting lumber, thereby increasing logging activities.

The improvement of roads, construction of bridges, and completion of the Northwestern Pacific Railroad in 1914 (linking Eureka with Willits and other southern cities) led to more efficient export of crops, dairy products, cattle, timber products, and salmon from the Humboldt Bay area. There was a significant increase in the population and in development during the 20th century in the SF Eel River watershed compared to the North Fork Eel and Van Duzen River watersheds (USBLM et al. 1996). This was primarily due to economic activities such as the tanbark industry, logging, and tourism in the SF Eel River Basin. Other land use impacts included: fire, timber production, ranching, farming, urban and suburban development, and recreation (DFG 1997).

Population

While many small towns lie within the basin, none of them contain significantly large populations and overall the basin remains predominantly rural. The largest towns are Laytonville and Redway, with 2010 US Census population estimates of 1,227 and 1,225 people, respectively (*Table 14*). The total SF Eel River Basin resident population estimate from the 2010 Census was 8,984 people (*Table 15*). This population estimate was obtained by looking at all of the census blocks within the SF Eel River Basin boundary, adding the population in those blocks that were fully contained within the boundary, then identifying any blocks with areas outside the basin boundaries ("straddling blocks"). The population in these straddling blocks was estimated proportionally based on the amount of each block area that was within the basin boundary, and was added to the total population estimate.

More than half of the population (65%) lives in the Eastern Subbasin, which contains the 3 largest towns of the entire SF Eel River Basin: Laytonville, Redway, and Garberville. Population density is relatively sparse in the Northern and Western subbasins (22% and 13% of the total SF Eel River Basin population, respectively); this reflects land ownership in most of the Northern Subbasin by the CA State Parks, and by the lack of small towns in the Western Subbasin. However, the majority of people in all of the subbasins live in towns along the mainstem SF Eel River, which is the boundary between the Eastern and Western subbasins. Because most towns are located very close to the boundary line, it may be more meaningful to look at population distribution throughout the entire SF Eel River Basin, noting that the population is concentrated along the mainstem SF Eel River.

Table 14. Population data from 2010 US Census for communities in the SF Eel River Basin.

Principal Communities	2010 Census Population	Subbasin
Laytonville	1,227	Eastern
Redway	1,225	Eastern
Garberville	913	Eastern
Miranda	520	Northern
Myers Flat	146	Northern
Weott	288	Northern
Legett	122	Eastern

Table 15. Population and population density of the SF Eel River Basin by subbasin (data from 2010 US Census).

Subbasin	Population (% of total SFER Basin Population)	Area (Square Miles)	Population Density (Population/Square Mile)
Northern	1,963 (22%)	149	13.17
Eastern	5,846 (65%)	320	18.27
Western	1,175 (13%)	219	5.37
Total	8,984 (100%)	688	13.06

Ownership

Seventy eight percent of the land in the SF Eel River Basin is privately owned, with 34% (236 mi^2) held in non-timber company parcels >40 acres in size, 32% (222 mi^2) owned by timber companies, and 12% (79 mi^2) held in non-timber company parcels of ≤ 40 acres (*Figure 27)*. The remaining 22% (150 mi^2) of the land in the basin is public property; with 15% (103 mi^2) owned by Humboldt Redwoods State Park and the Angelo Coast Range Reserve (University of California), and 7% (48 mi^2) owned by the USBLM (*Figure 27*). General land use across the basin fits four main categories: timber harvest (44% of basin area), open space/parks (23% of basin, primarily in the Northern and Eastern subbasins), dispersed rural development (17% of basin), and family-owned grazing/timber operations (15% of basin) (*Figure 28*).

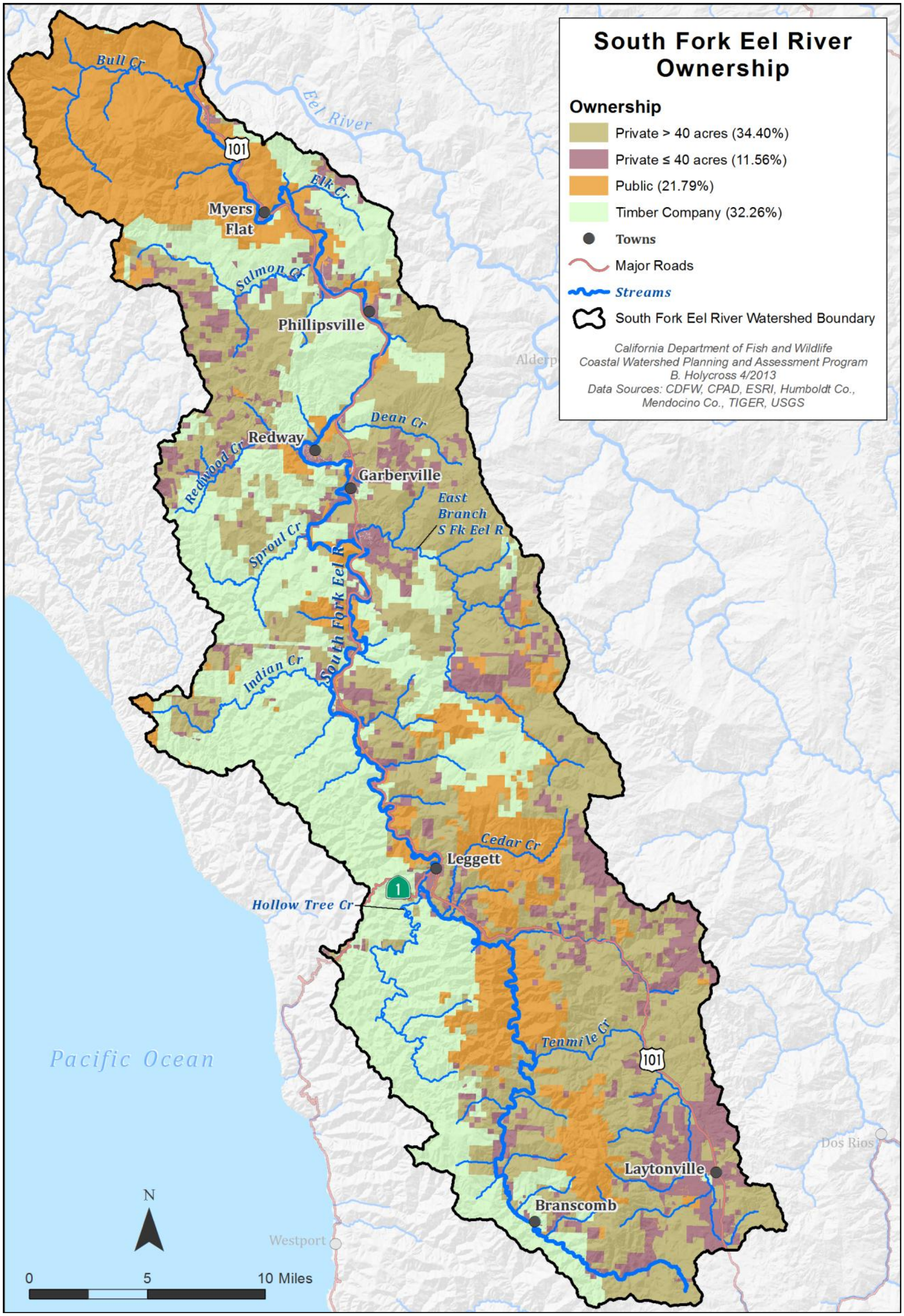


Figure 27. Land ownership in the SF Eel River Basin.

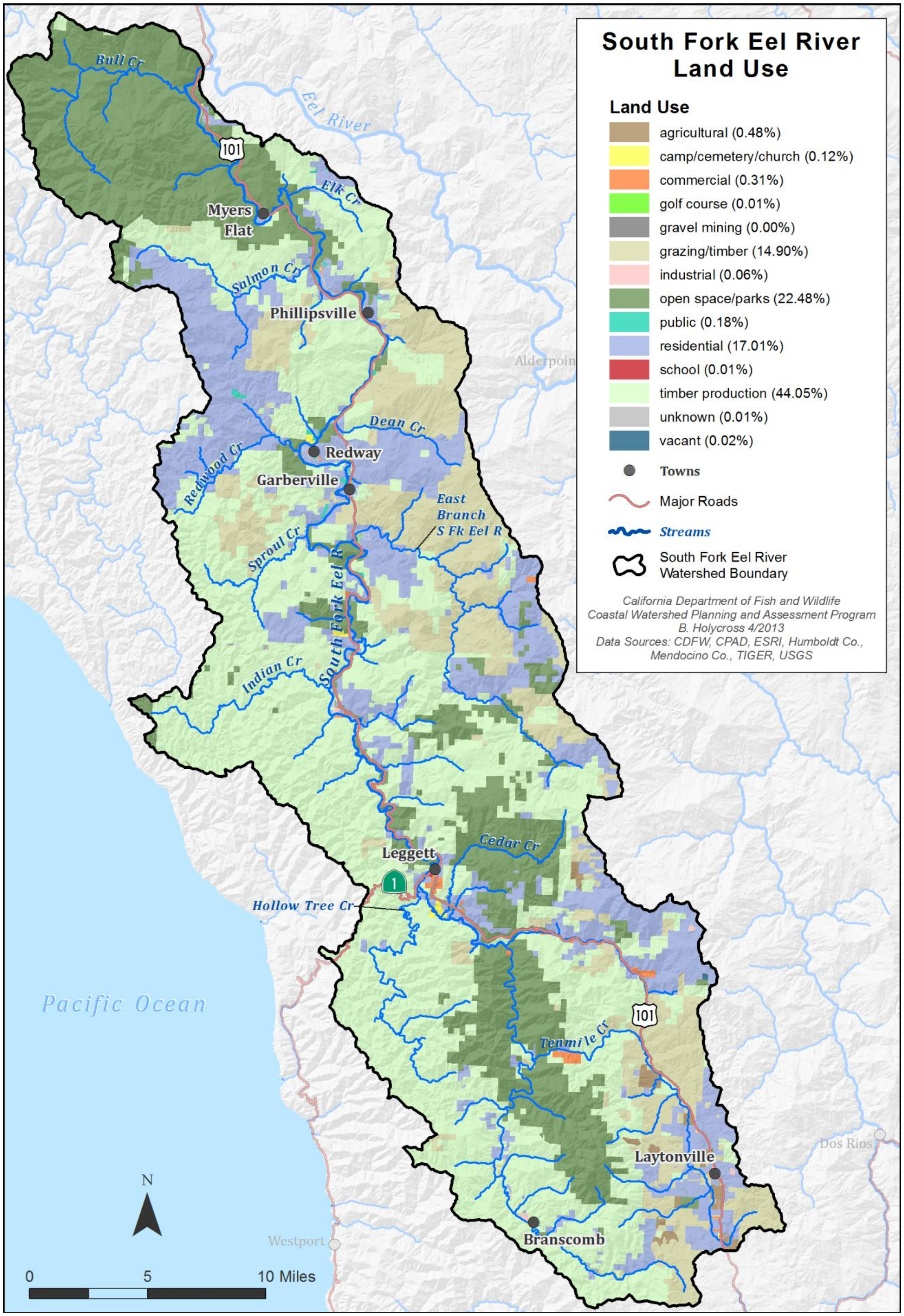


Figure 28. Land use in the SF Eel River Basin.

Forest Management

Historic

The tanbark industry was the first large-scale forest management practice in the SF Eel River Basin, 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 29*) and transported out of the area, or sent to a plant in Briceland where the bark was converted to tannin extract.

Figure 29. Historical harvest of tanoak tree bark for conversion to tannin extract (photo courtesy of Humboldt State University).

Stripped tanoak trees were left on the ground, and although most harvesting took place near Briceland, extending west toward the Mattole River Basin, nearly all of the tanoak trees in the South Fork Eel Basin were harvested during this time (HCRCD 2002).

Prior to 1947, timber harvest was limited to large redwood trees accessible near creek mouths in the lower watershed; Douglas-fir was not considered merchantable timber at that time (JMWM 2000). In the 1880s, logs were floated downstream to mills as far away as Fortuna, but the river was determined to be too long and meandering so logs were cut into cants, or more manageable rectangular chunks, before floating them downstream (O'Hara and Stockton 2012). Due to the long distance between the harvest areas and mills in the Fortuna and Humboldt Bay area, many large trees harvested in the SF Eel River Basin 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 (O'Hara and Stockton 2012).

After WWII, the economy expanded rapidly and new technologies, combined with an increased demand for timber due to the post war building boom, resulted in massive harvesting of both redwoods and Douglas-fir trees throughout the basin. Tractor yarding and truck hauling became the predominant timber harvest and log transport methods, replacing steam donkey cable yarding and railroad hauling throughout the Eel River Basin (HartCrowser 2004). Post-WWII timber harvest allowed for additional harvest at a faster rate but resulted in increased ground disturbance and reduced water and habitat quality. The use of heavy equipment also made timber harvest possible in remote, steep terrain areas that were previously inaccessible (Downie 1995). Those invasive and highly disruptive harvest methods soon resulted in unstable stream banks, loss of aquatic habitat complexity, and log jams acting as fish passage barriers throughout the basin.

In addition to improvements in timber harvest techniques and equipment, there was an increase in timber harvest 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). Many private landowners also sold their timber rights to logging companies, and since these companies did not own the land, logging practices were poor. Road construction and logging methods were designed to reach and harvest as much timber as possible, with little or no consideration given to regeneration, slope stability, and future productivity (HCRCD 2002).

In the 1950s, there were 7 temporary mills in the Salmon Creek watershed alone (JMWM 2000). The peak timber harvest year for Humboldt County was 1959 (Downie 1995), and by the late 1960s, nearly all of the old growth Douglas-fir on private lands in the SF Eel River Basin had been logged and the mills were closed (HCRCD 2002).

Since 1973, with the passage of the Z'Berg-Nejedly Forest Practice Act, environmental regulations have become stricter, resulting in improved timber harvest practices.

Although timber harvest levels have declined recently, the timber industry is still an important component of the economy in both counties (Downie 1995). The reasons for the decline in harvest levels include: consolidation following the postwar construction boom; conversion from virgin-growth to second growth forests (resulting in reduced log supplies); major improvements in technology and productivity; and increased foreign timber imports (Humboldt County 2007). Land conversion to grazing or residential development has also contributed to the overall decrease in production (Downie 1995).

Current

Forty four percent (304 square miles, or 194,337 acres) of the land in the SF Eel River Basin is designated for commercial timber production (*Figure 28*). This is the principal land use for the basin. Timber harvest occurred on approximately 9% (approximately 60 square miles, or 38,280 acres) of the total basin area land between 1995 and 2012, and the dominant silviculture method in the basin was seed tree removal cut, used to harvest 1.8% (8022 acres) of the total basin area. Logging operations have occurred in each of the three subbasins, with the most activity in the Western Subbasin, followed by the Northern and Eastern subbasins.

Timber harvest activities require the development of plans detailing the amount and method of planned 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) were established by the CA Legislature in 1989 to allow non-commercial landowners with less than 2,500 acres of timberland to develop harvest plans that were not as expensive and time-consuming as THPs (CalFire 2003). NTMPs are permanent, and once approved, the actual harvest is reported in a notice of timber operations (NTO). Commercial harvest by timber companies and private landowners with more than 2,500 acres of timberland requires the development of a timber harvest plan (THP). Based on CalFire data collected between 1995 and 2012, most timber harvest occurred in the Western Subbasin, and in the eastern part of the Northern Subbasin (*Figure 30*). The total basin-wide harvested area (including both THPs and NTOs) was 38,280 acres, 16,907 acres in Humboldt County and 21,373 acres in Mendocino County (*Table 16*). THP harvest area totaled 35,715 acres (12,912 in Humboldt County and 22,803 in Mendocino County) and ranged in size from 1,051 acres to less than one acre. NTO harvest area in the basin totaled 5.998 acres (4805 in Humboldt County and 1,193 in Mendocino County) and ranged from 1,240 acres to less than one acre. Only one of the NTO harvest amounts (N=95) was greater than 400 acres.

Records of logging activity from 1991 to present are available in digital format for all subbasins in the SF Eel River (http://egis.fire.ca.gov/watershed_mapper/). Earlier logging information is available in paper records from CDF, but these data remain largely unanalyzed at this time.

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

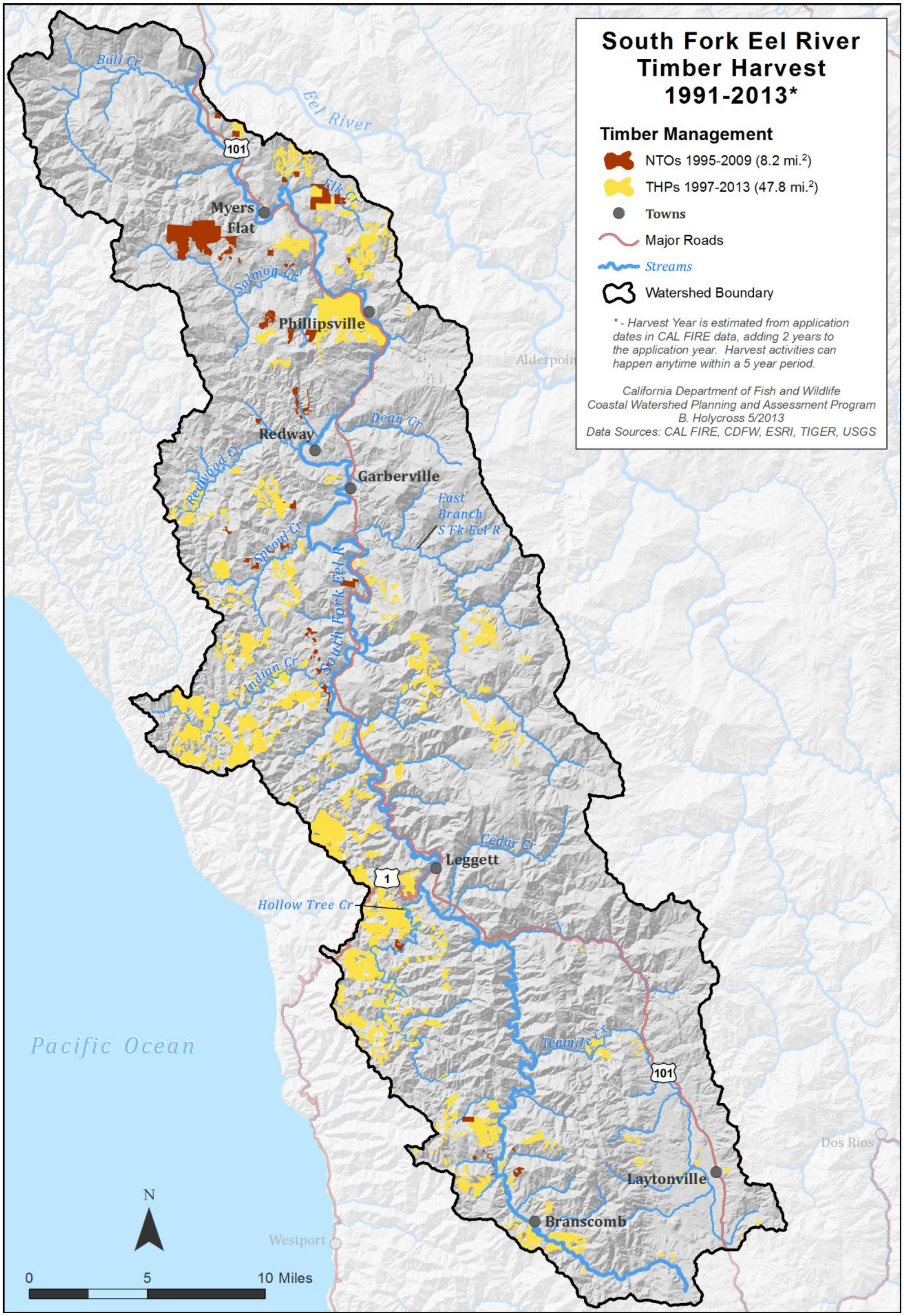


Figure 30. Timber Harvest (NTOs and THPs) between 1995 and 2013 in the SF Eel River Basin.

Table 16. Timber harvest by plan type (THP or NTO) for South Fork Eel River Basin and subbasins (data from CalFire 2012).

		Basin/Subbasin Acreage			
Plan Type	**County**	**Northern**	**Eastern**	**Western**	**SFER Basin**
THP	Humboldt	7208	1489	3544	12241
THP	Mendocino	0	4503	16393	20896
	Total THP Acreage	**7208**	**5992**	**19937**	**33137**
NTO	Humboldt	3866	1	799	4666
NTO	Mendocino	0	102	375	477
	Total NTO Acreage	**3866**	**103**	**1174**	**5143**
	Total Harvest Acreage	**11074**	**6095**	**21111**	**38280**

In the Pacific Northwest, there are two basic timber harvest strategies: even-aged and uneven-aged management (USFS 1985). Even-aged management silvicultural techniques include clearcutting, seed tree removal, and shelterwood removal, with either natural or (more commonly) artificial regeneration. Uneven-aged management involves removing individual or small groups of trees, resulting in structural diversity within each stand, but lacking distinct successional stages seen in even-aged stands (USFS 1985). All NTMPs require sustainable, uneven-aged management (selection harvest).

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

Felling and yarding methods that make the most contact with the forest floor result in the highest level of disturbance. Megahan (1981, in USEPA 2005) summarized the results of soil disturbance from logging using different harvesting 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.

Based on CDF data, the most common types of silviculture methods in the basin since 1991 are group and seed tree removal cut (24% of the harvested area; 8,022 acres) followed by single tree selection (16% of the harvested area; 5,475 acres) and clearcut (12% of the harvested area; 4,128 acres) (*Figure 31*). In the Western and Eastern subbasins, seed tree removal is the primary method of timber harvest (33% (6,448 acres) and 20% (1,057 acres) of the total area harvested in each subbasin, respectively.

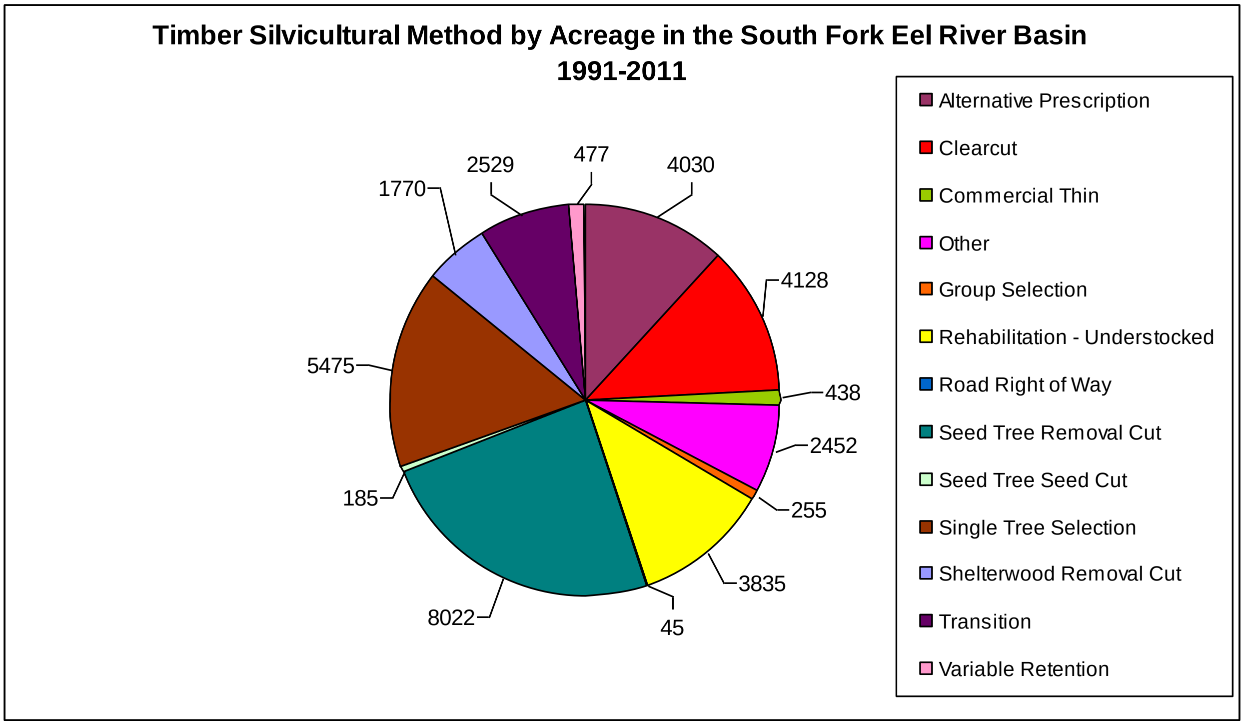


Figure 31. Number of acres in various silviculture methods in the SF Eel River Basin from 1991-2011 (CDF data).

In the Northern Subbasin, selection is the dominant method (32% of the harvested area; 2,768 acres) (*Figure 32*). Seed tree removal cuts are defined as the cutting of widely dispersed seed trees after regeneration is established (Adams et al. 1994). Single tree (as opposed to group) selection is defined as the removal of individual trees of different size classes to promote growth of remaining trees and to provide space for regeneration. 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.

All timber operations must conform to current California Forest Practice Rules. Some companies operating in the basin have created more complex and sophisticated management plans to guide their timber harvest operations and protect wildlife. For example, Humboldt Redwood Company has developed a Habitat Conservation Plan (HCP), which is designed to keep the forest ecosystem healthy and functional while timber is harvested. HCPs vary greatly in size, duration, and species covered. Historically, they were developed for specific projects, but they have evolved into broad-based, landscape level planning tools that are becoming one of the most innovative conservation options under the ESA (USFWS and NMFS 1996).

Of the privately owned parcels greater than 640 acres in the SF Eel River Basin, several timber companies own relatively large percentages of the watershed. Barnum Timber Company is the largest owner, with a total of 12,216 acres (6.1 % of the watershed), followed by Humboldt Redwood Company with 6,419 acres (3.2% of the watershed), and Eel River Sawmills with 5,559 acres (2.8% of the watershed) (Dyett and Bhatia 2002).

In July, 2008 the Pacific Lumber Company (PALCO) was officially transferred over to Mendocino Redwood Company and Marathon Structured Finance Fund LP, a PALCO creditor (The Forestry Source 2008). Mendocino Redwood Company shortly thereafter renamed PALCO as the Humboldt Redwood Company. This transfer of ownership will have a significant effect on the management of the 220,000 acres of land in Humboldt County now managed by Humboldt Redwood Company. Under PALCO management, an average of 150 to 160 million board feet was cut from 2000 to 2005 on their 220,000 acres of land in Humboldt County. That figure dropped to 99 million board feet in 2006, and fell to 77 million board feet last year. Under the new management of the Humboldt Redwood Company, annual harvesting

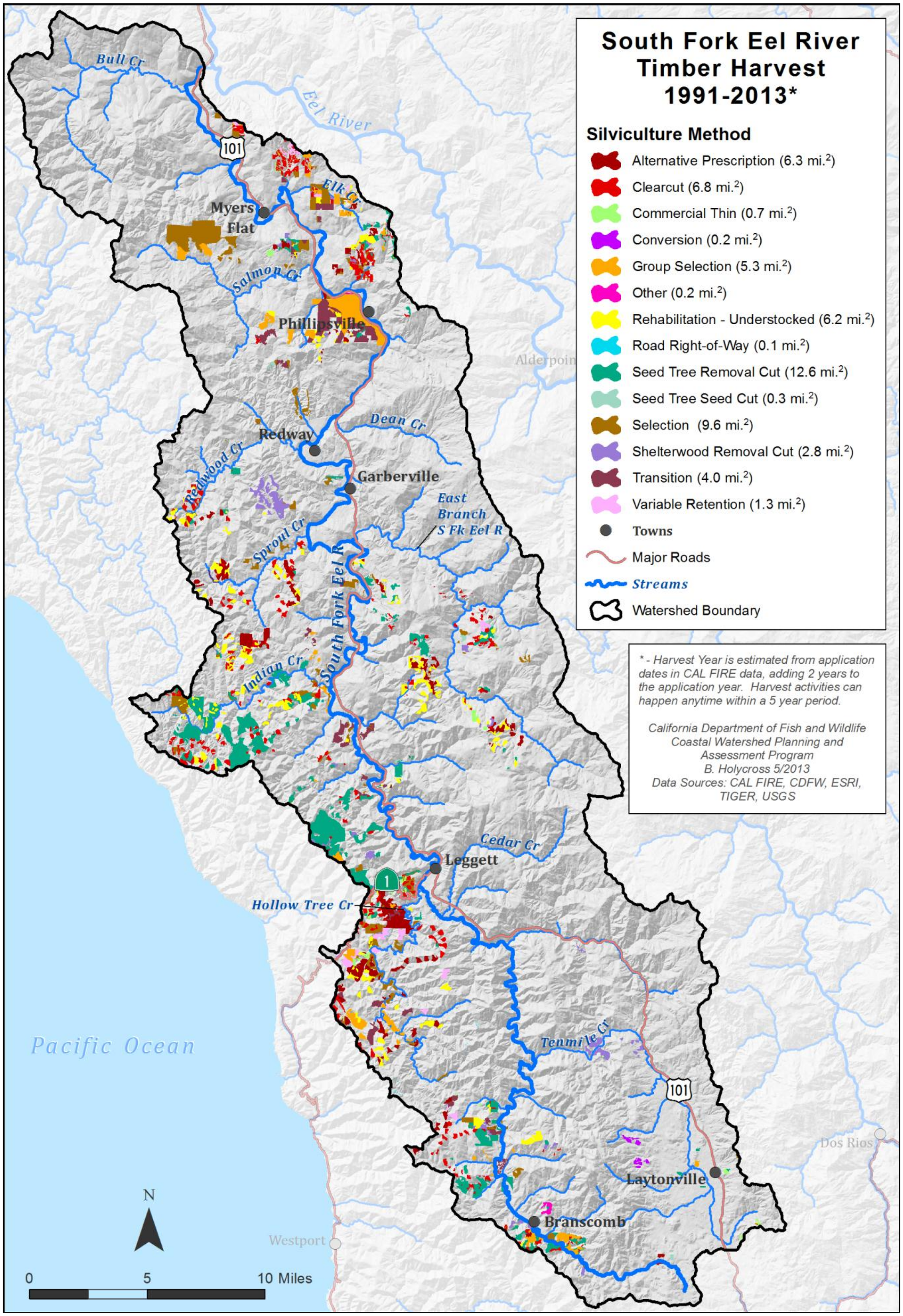


Figure 32. Timber harvest activity by silviculture method for the SF Eel River Basin.

will be limited to 55 million board feet per year for the next decade and a no-cut policy for old growth will be observed (Building Products.com 2008).

Logging has been the principal land use in the SF Eel River Basin, and while the amount of timber harvested has decreased over time, this activity has been one of the most significant anthropogenic causes of freshwater habitat degradation leading to salmonid decline in the Pacific Northwest. Logging activities may result in increased sedimentation in streams, changes in light, temperature, and flow regimes, loss of invertebrate food and organic debris, and changes in channel morphology (Hicks et al. 1991). Small (second- to fourth-order streams) that support spawning and rearing salmonids are most easily altered by forest management activities (Chamberlin et al. 1991). Poor watershed conditions caused by logging and mining throughout the SF Eel River Basin were further exacerbated by the effects of the 1955 and 1964 floods in almost all drainages (Moyle et al. 2008). The State of the Eel (Downie 1995) did not specifically identify timber harvest as a threat to the SF Eel River ecosystem, but it did mention rural road networks as a significant source of erosion. This source will be discussed further in the Roads and Railroads section of this analysis.

Open Space/Parks

More than 22% of the land in the SF Eel River Basin is open space/parkland (*Figure 28*). In the Northern Subbasin, approximately half (51%) of the total subbasin area is owned by Humboldt Redwoods State Park near the community of Myers Flat and the entire Bull Creek drainage (*Figure 27*). Humboldt Redwoods State Park was created in 1921, and is the third largest in the California State Park system; it encompasses more than 53,000 acres, including 17,000 acres of old growth coast redwoods (Humboldt Redwoods State Park 2012). State Park and Save the Redwoods League (SRL) staff have worked together since the park's establishment to acquire land and 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 from the 1964 flood (Humboldt Redwoods State Park 2012). Humboldt Redwoods State Park currently includes the entire Bull Creek watershed and the Rockefeller Forest, the largest remaining old growth redwood forest in the world.

Other large areas of open space/parkland in the SF Eel River Basin are located in the Eastern and Western subbasins (18% and 9% of total basin area, respectively). The US Bureau of Land Management (USBLM) manages the Elkhorn Ridge Wilderness (11,271 acres), located between Leggett and Laytonville in both the Eastern and Western subbasins (the SF Eel River bisects the wilderness area) (*Figure 27*). The USBLM also manages the South Fork Eel Wilderness (12,867 acres total), divided into two management units: the Red Mountain Unit, east of Leggett; and the Cahto Peak Unit, west of Laytonville. Both of these management units are located in the Eastern Subbasin.

The Angelo Coast Range Reserve is a relatively small (± 7500 acres) area of open space/park land located northwest of Laytonville, mainly in the Eastern Subbasin (with a small portion of the reserve in the Western Subbasin). It is part of the University of California Natural Reserve System, which are lands set aside to protect representative natural ecosystems of California for university level research and teaching (http://angelo.berkeley.edu).

Other small areas of open space/parks along the South Fork Eel River, distributed throughout the basin, include: Benbow Lake, Richardson Grove, and Standish Hickey State Parks and Smithe Redwoods State Reserve. There is also a small area of the basin in the headwaters of the Indian Creek drainage that is within the boundaries of Sinkiyone Wilderness State Park.

Residential

Approximately 17% (117 square miles, or 74,880 acres) of the SF Eel River Basin is rural residential property (*Figure 28*). The largest town is Laytonville (population 1,227) in the southern part of the basin, followed by Redway (population 1,225) and Garberville (population 913) in the northern part of the basin.

Residential developments affect the environment by increasing the density of roads (this will be discussed further in the Roads and Railroads section of this assessment), diverting ground and surface water for domestic use, necessitating the need for wastewater management (community sewage and/or individual septic systems), and by increasing the potential for both point and nonpoint source pollution in a watershed. Point source pollution is defined as that which can be traced to a single location or "point" (such as a sewage treatment plant), whereas nonpoint source pollution comes from many diffuse sources, and is principally caused by stormwater, snowmelt, or agricultural runoff moving across the landscape and diffusing into the ground. The runoff picks up natural and human pollutants and deposits them throughout the watershed (Humboldt County 2012).

In May 2002, the Humboldt County Board of Supervisors adopted a grading, excavation, erosion, and sedimentation control ordinance (available at: http://co.humboldt.ca.us/planning/building/ordinances/grading/default.asp) to reduce potential impacts of development on water quality, sensitive habitats, geology, and biological resources. This ordinance contains a comprehensive set of regulations and was developed in conjunction with multiple state and federal regulatory agencies including the CA Coastal Commission, CalFire, SWRCB, USEPA, and US Army Corps of Engineers. In Mendocino County, grading permits may be required for development projects, and Coastal Zone regulations may apply (http://www.co.mendocino.ca.us/planning/pdf/1-Introduction_Binder_Edited.pdf). Although these ordinances are in place and permits required, much of the development in the SF Eel River Basin is unpermitted, similar to the Mattole River watershed where back-to-the-landers have been building unpermitted homes since the 1960s (Scott-Goforth 2013). A general distrust of government and fear of regulatory staff presence on rural properties (often related to illegal marijuana harvesting activities) has led to many landowners bypassing or ignoring the permitting process. As a result, grading, water diversion, and water storage practices on residential parcels are often unregulated.

Compared to other parts of California, major development of water resources has not occurred in the SF Eel River Basin. Groundwater (as opposed to surface water) development in the basin is generally limited due to problems stemming from a lack of alluvial aquifer storage capacity, and many groundwater wells rely on hydrologic connection to the rivers and streams (CDWR 2003a). There are a few municipal water providers located in larger towns along the SF Eel River (*Table 17*), but most residences in the basin obtain water from individual wells or surface water diversion. Water suppliers include the Garberville Sanitation District and Redway Community Services District in the Garberville groundwater basin; Weott Community Services District and Myers Flat Municipal Water System in the Weott groundwater basin, and Laytonville Water District in the Laytonville groundwater basin (Mendocino County 2009, Chapter 3; Humboldt County 2012). No major surface water storage exists in the basin; water projects are surface water diversions, some small dams and reservoirs, and many small stock watering ponds (Mendocino County 2009, Chapter 3). The basin normally receives substantial wintertime precipitation, but relies on groundwater to supply residences outside of the larger communities during the dry summer months.

Some of the community services districts in the subbasin also provide wastewater treatment (*Table 18*). A lack of wastewater infrastructure has limited development in some areas in the basin. The community of Laytonville is currently served by individual septic systems, but these systems do not function well in an area with such high rainfall and an elevated water table. Developers are currently studying the feasibility of installing a wastewater treatment system for the town and surrounding community (Mendocino County 2009, Chapter 3). Individual water and wastewater service providers are discussed in more detail in the individual subbasin sections of this report.

Table 17. Municipal water service providers in the SF Eel River Basin (Humboldt County General Plan Update Draft EIR 2012 (ND – no data available).

Provider	Subbasin	Connections		Capacity			Usage	
		Existing	Available	Supply (mgd)	Treatment (mgd)	Storage (mg)	Peak Day (mgd)	Connection (gpd)
Miranda Community Services District	Northern	143	77	0.338	Not required	0.200	0.220	1,538
Myers Flat Municipal Water Association	Northern	103	0	Unknown, but limiting	0	0.300	0.138	1,340
Phillipsville Community Services District	Northern	65	0	Unknown, but not limiting	0	0.075	0.085	1,308
Weott Community Services District	Northern	140	0	0.202	0.113	0.169	0.258	1,843
Benbow Water Company	Eastern, Western	113	0	0.327	0.200	0.150	0.382	3,381
Garberville Sanitation District	Eastern, Western	396	25	0.461	0.330	0.270	0.310	787
Redway Community Services District	Eastern, Western	600	180	0.838	0.460	0.375	0.475	792
Laytonville County Water District	Eastern	ND*	ND	ND	ND	ND	ND	ND
Briceland Community Services District	Western	26	0	0.010	Unknown, but not limiting	0.042	0.040	1,538

Table 18. Wastewater treatment providers in the SF Eel River Basin (Humboldt County General Plan Update Draft EIR 2012).

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
Garberville Sanitation District	Eastern, Western	420	180	0.162	0.235	0.140	0.55

Redway Community Services District	Eastern	524	175	0.186	0.64	0.140	0.43

Grazing/Timber

Approximately 15% (103 square miles, or 65,920 acres) of the SF Eel River Basin 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 schedules. Streams throughout the basin are affected by these land use patterns because all parcels with active management practices such as logging and grazing 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 nutrients (primarily phosphorous and nitrogen) and/or pathogenic microorganisms from animal waste may exceed water quality standards in areas with extensive livestock use. Watersheds with concentrated livestock populations have been shown to discharge as much as 5 to 10 times more nutrients than watersheds in cropland or forestry (Hubbard et al. 2004). Grazing in and around streams 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).

Most grazing and small timber operations occur in the Eastern Subbasin (25% of total subbasin area; 50,947 acres), followed by the Northern and Western subbasins (9% (8,369 acres) and 5% (6,414 acres) of total area, respectively). The relatively high proportion of land used for grazing/timber in the Eastern Subbasin is related to the predominance of grassland vegetation in the Eastern Subbasin. Vegetation type is influenced by climate, parent material and soils, topographic position, and disturbance (USBLM et al. 1996). The dry climate, soils, and practice of converting hardwood or coniferous forests to pasture land in the Eastern Subbasin have resulted in a large proportion of grassland habitat in the subbasin.

In the Northern Subbasin, grazing was the primary land use in Upper Bull Creek until the early 1940s; ranchers periodically burned grasslands to maintain open areas for grazing cattle and sheep (Stillwater Sciences 1999). 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 Upper Bull Creek Basin was sold to the State Parks, and all grazing and timber harvest activities were discontinued. Current grazing/timber harvest occurs primarily in the southern part of the Northern Subbasin, east of Phillipsville and in the Eastern Subbasin (*Figure 28*) where grassland/prairie is the dominant vegetation type.

Roads and Railroads

Roads

As the SF Eel River Basin was settled in the late 1800s, transportation routes grew and expanded. Wagon trails became roads and roads were upgraded into highways to transport people and goods throughout the basin (*Figure 33*). In forested upland areas, many logging roads and some seasonal railroads were built to facilitate the access and transport of timber; most of these logging roads are not paved and some are not mapped. Many of these roads are now used to access rural subdivisions and agricultural sites in addition to hauling timber.

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 currently more than 2,000 miles of improved and unimproved roads in the SF Eel River Basin, including: 1,522 miles of unimproved roads, 382 miles of improved roads, 78 miles of primary roads, and 59 miles of secondary roads (Dyett and Bhatia 2002).

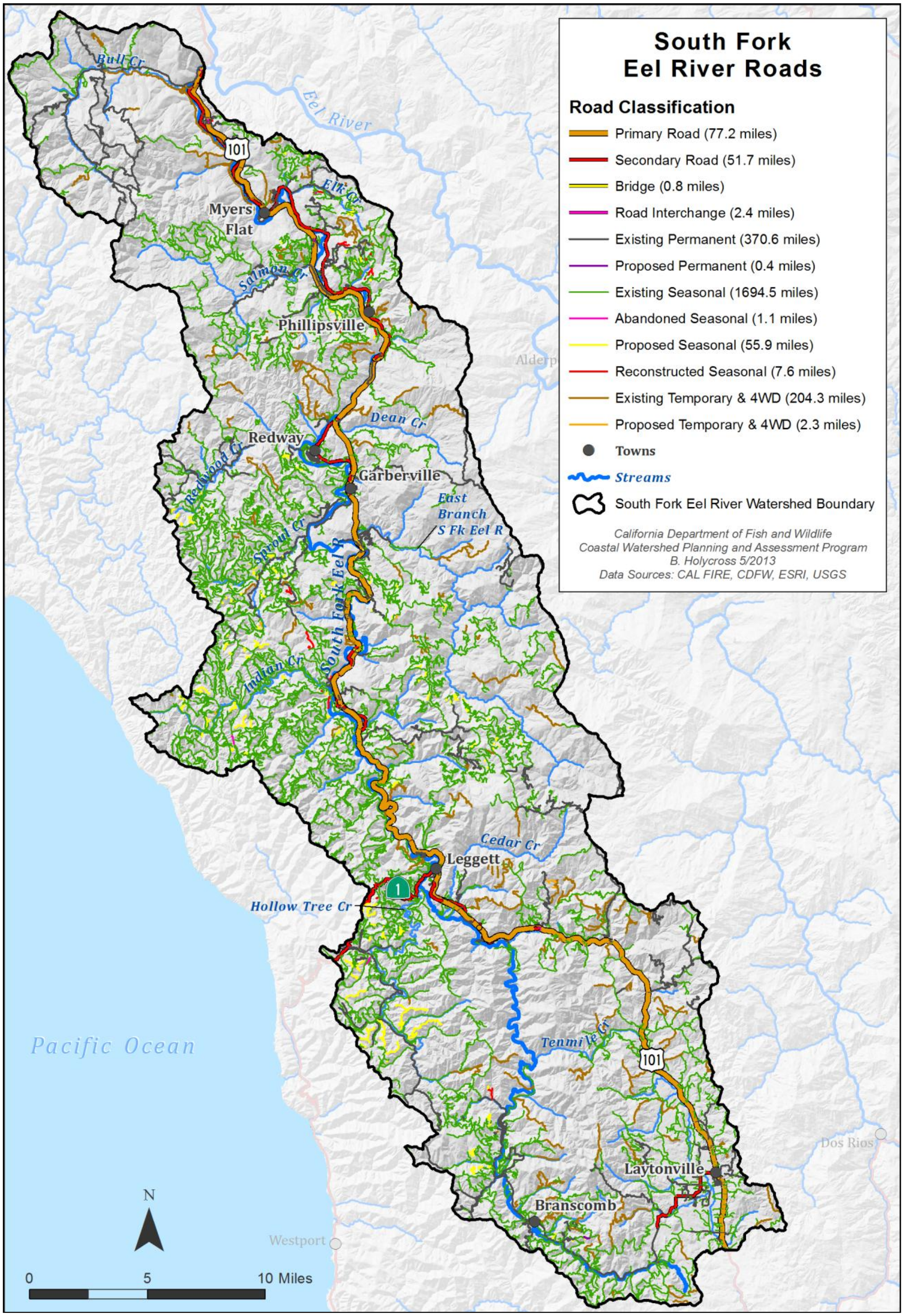


Figure 33. Roads in the SF Eel River Basin.

Road density for the entire basin is 3.58 mi/ mi^2, with the highest density in the Western Subbasin (4.76 mi/mi^2), followed by the Northern (3.33 mi/mi^2) and Eastern (2.88 mi/mi^2) subbasins (*Table 19*). NMFS (1996) classified basins with road densities of <2 mi/mi^2 with no valley bottom roads as "properly functioning", those with densities of 2-3 mi/mi^2 with some valley bottom roads as "at risk", and those with densities of >3 mi/mi^2 with many valley bottom roads as "not properly functioning" when developing restoration initiatives. According to this classification system, the SF Eel River Basin, Western, and Northern subbasins are "not properly functioning", and the Eastern Subbasin is considered "at risk".

Forest roads and land use practices can influence the physical characteristics of streams, modify the quality of habitat for salmonids, and may affect growth and survival of juveniles and adults. Hicks et al. (1991) summarized the potential effects of timber harvest and roads on streams and salmonids (*Table 20*). Most of the roads in the SF Eel River Basin were originally constructed as seasonal roads used for hauling timber, and road density is a reflection of the primary land use and therefore road type in each subbasin (*Table 19*, *Figure 28*). Of the three subbasins, the Western Subbasin has the highest overall road density, the highest percentage of seasonal roads and the highest percentage of land allocated for commercial timber harvest (75% of the subbasin). The Northern Subbasin has the lowest percentage of existing seasonal roads; the primary land use is open space/parkland (51% of the subbasin), with only 24% of the subbasin designated for commercial timber harvest.

Table 19. Road density, road type, and selected land use in SF Eel River Basin and subbasins. Data from CalFire,CDFW, ESRI, and USGS.

		Subbasin		
	Northern	**Eastern**	**Western**	**SF Eel River Basin**
Road density (mi/sq. mi)	3.33	2.88	4.76	3.58
Percentage of existing seasonal roads	57	60	81	69
Percentage of land used for timber production	24	32*	75*	44*
* timber harvest is the primary land use in the basin/subbasin				

Table 20. Influence of hillslope timber harvest and roads on physical characteristics of streams, and potential changes in habitat and salmonid growth and survival (From. Hicks et al. 1991)

Forest Practice	**Potential change in physical stream environment**	**Potential change in quality of salmonid habitat**	**Potential consequences for salmonid growth and survival**
Timber harvest from hillslopes; forest roads	Altered Streamflow regime	Short-term increase in streamflows during summer	Short-term increase in survival
		Increased severity of some peak flow events	Embryo mortality caused by bed-load movement
	Accelerated surface erosion and mass wasting	Increased fine sediment in stream gravels	Reduced spawning success; reduced food abundance; loss of winter hiding space
		Increased supply of coarse sediment	Increased or decreased rearing capacity
		Increased frequency of debris torrents; loss of instream cover in the torrent track; improved cover in some debris jams	Blockage to migrations; reduced survival in the torrent track; improved winter habitat in some torrent deposits
	Increased nutrient runoff	Elevated nutrient levels in streams	Increased food production
	Increased number of road crossings	Physical obstructions in stream chammel; input of fine sediment from road surfaces	Restriction of upstream movement; reduced feeding efficiency

Highway 101, the only primary road in the basin, follows the SF Eel River from north of Weott to south of Leggett, then up the Rattlesnake Creek drainage and south to Laytonville (*Figure 33*). The highway was built from 1909 to 1923 and crosses the South Fork Eel and many of its tributaries throughout all three subbasins.

Many of the roads and railroads built in the basin either cross streams or run alongside them. Both of these types of roads can affect stream condition and site condition by accelerating erosion and sediment loading, altering channel morphology, and changing runoff characteristics throughout the watershed (Furniss et al. 1991). All of these changes affect fish habitat, therefore, road location and road design should be considered when constructing roads to reduce sediment input (Amaranthus et al. 1985, Cafferata and Spittler 1998). Stream crossings may create fish passage barriers or sediment sources (Cafferata et al. 2004), and roads that run along streams can also act as sediment sources and limit the ability of a stream channel to migrate across its floodplain. Additionally, many roads added sediment to streams as they were built.

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

In the sediment source analysis for the SF Eel River Basin (Stillwater Sciences 1999), average sediment delivery in the entire basin was approximately 700 t/km^2/yr, with 46% of the total loading contributed by anthropogenic sources (*Figure 34*). Road-related landslides, road crossings, and gully erosion were the largest anthropogenic sources of sediment, but the effects of specific land management practices were not addressed in the analysis.

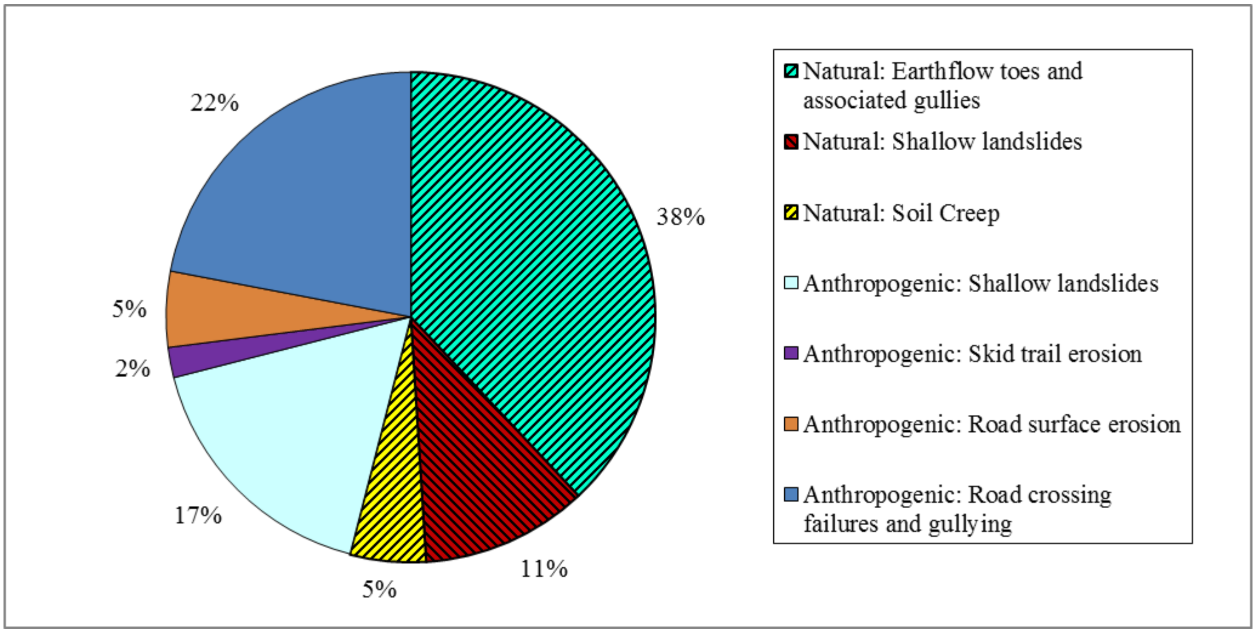


Figure 34. Sediment sources in the SF Eel River Basin (from USEPA 1999; data from Stillwater Sciences 1999). Shaded sections are sediment inputs from natural sources.

Erosion from rural and logging roads includes two major components concerning salmonid rearing and survival: chronic erosion of fine sediments during winter rainstorms that result in reduced survival of eggs; and catastrophic failure of roads prisms during winter storms that result in loss of rearing habitat (Downie 1995). Due to the SF Eel River Basin geologic setting (steep slopes, rapid uplift, and unstable soils), in general, logging creates more erosion from acceptable logging practices and from legacy and new logging roads relative to those in more stable geologic locations (*Figure 35*).

Figure 35. Example of legacy road failure in SF Eel River Basin.

Roads that are improperly located, constructed, or maintained may initiate or accelerate slope failure, resulting in increased sediment input in nearby streams (Yee and Roelofs 1980). The frequency of slope failures due to improper road construction can increase from a few to hundreds of times, depending on soil type and steepness, bedrock structure and composition, and the presence of subsurface water (Furniss et al. 1991). Unless old roads are storm proofed or decommissioned, they will continue to release sediment into water courses.

Where roads cross streams, culverts, bridges, or low water crossings are installed. Road crossings may become barriers to fish passage due to excessive water velocity, outfall barriers, insufficient water depth in culverts, disorienting turbulent flow, or a combination of these conditions (Furniss et al. 1991). Road crossings must be engineered and maintained to allow efficient passage of water, and consequently passage of different life stages and species of fish. Specific road and stream crossing upgrade projects are discussed in the Restoration Projects section of each subbasin report.

Railroads

Railroad construction in the Eel River began in 1884 with the construction of the Eel River and Eureka line, designed to provide shipping from the lower Eel River to Humboldt Bay. In 1885, the railroad laid track from Fortuna to Eureka and in the same year, the Pacific Lumber Company built a section of railroad connecting Scotia to the Eel River and Eureka line, with logging branches of this railroad extended eight miles up the Eel River by 1902.

Various local railroad companies merged to form the Northwestern Pacific Railroad in 1907. The entire line that connected Eureka to Willits and all points south to Marin County was completed in 1914. The North Coast Rail Authority (NCRA), founded in 1989 to ensure continuation of rail service in Northwestern California, purchased the railroad line from Willits north in 1992. This line followed the mainstem Eel River, and it was shut down in 1997 due to damage from major floods and landslides and has not reopened. There is ongoing discussion about reopening the line, but it would require a major overhaul because most of the line is currently derelict. In addition, geologic conditions that have led to the poor condition of the railroad have not changed, thus any railroad would require costly maintenance and repair as well as cause further sediment erosion into the Eel River and its tributaries. The Department of Toxic Substance Control and the North Coast Regional Water Quality Control Board are concerned with landslide and debris cleanup issues involved with reopening the railroad line (NCRWQCB 2005). SF Eel River salmonids would be adversely affected by this additional erosion when traveling up the Eel River as migrating adults or while traveling downstream as juveniles, in the 40 mile stream reach between the ocean and the confluence of the South Fork and mainstem Eel Rivers. Additional sediment input and other effects from reopening the rail line would not be causes for concern in the SF Eel River Basin because the main rail line does not run directly through the SF Eel River drainage.

Historically, there was a small logging railroad line in the SF Eel River Basin between Bear Harbor on the Mendocino coast and the now defunct town of Andersonia, located on the SF Eel River across the river from Piercy. This railroad was originally established in 1896 by the Bear Harbor and Eel River Railroad, a subsidiary to the Bear Harbor Lumber Company. The railroad was constructed east from Bear Harbor through a low gap in the coastal range, where a funicular (or cable) system used rail cars loaded with logs running downhill to pull empty cars back to the top of the steep incline. From there, the railroad ran 10 miles east to Moody, a small logging town in the Indian Creek drainage, with plans to expand the line to Garberville (Hough 2010). In 1903, the Bear Harbor and Eel River Railroad sold out to the Southern Humboldt Lumber Company, and the railroad was completed east to the SF Eel River (following the course of Indian Creek) to Andersonia. Following a series of financial and logistical problems, which culminated with the 1906 earthquake destroying the sawmill in Andersonia and causing major landslides throughout the basin, the rail line was abandoned (Hough 2010). The only remaining evidence of the rail line today is some decomposing track in the upper Indian Creek watershed (*Figure 36*).

Figure 36. Old railroad tracks in Anderson Creek, in the upper Indian Creek watershed.

Mining

There is very little activity related to mining in the SF Eel River Basin. The upper portions of Red and Little Red Mountain, east of Leggett, contain chromite ore deposits. By 1920, there were more than 100 claims for mines around these mountains, but very little chromite was mined, most likely because it was not economically feasible to transport the ore to market (HCRCD 2002).

In 1978, the Hanna Mining Company purchased 5,000 acres east of Leggett and filed claims on an additional 3,400 acres of USBLM land with the intention of mining nickel. No mining ever took place, primarily due to public objection concerning the mining company's practices, but also due to numerous environmental concerns (Ukiah Daily Journal 1978, USBLM et al. 1996).

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 (Klein et al. 2011). Gravel mining was first documented in the Eel River Basin in 1911 and was directly related to road surfacing needs of the time. Instream mining continued throughout the early part of the century and increased in the 1950s and 1960s.

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 in the Eel River Basin created migration barriers for adult fish, sometimes leading to stranding on shallows and mortality. Problems of over extraction and threats to the fisheries led to a system of monitoring and adaptive management.

Currently, mining operators are required to communicate and cooperate with regulatory agencies including NMFS, USFWS, CDFW, and USACOE, and with the County of Humboldt's Extraction Review Team (CHERT) to prevent these types of incidents from reoccurring. CHERT is a non-regulatory scientific advisory committee that was appointed by the Humboldt County Board of Supervisors in 1992 to address the complexities in properly managing instream gravel mining in the Mad River. In 1997, CHERT expanded to review most riverine gravel mining operations in Humboldt County that remove 5,000 cubic yards (cy) or more annually, including those in the Eel River system. For each harvest site, CHERT estimates the mean annual recruitment (MAR) of bedload in relation to the surrounding instream mining operations. Based on the MAR, CHERT sets limits on the maximum volume of aggregate available for harvest each year, recommending that extraction not exceed 75% of MAR in salmonid-bearing rivers and streams; and extraction occurs only after analysis has determined the MAR for a particular mining reach. Without specific reach analysis, 25% of MAR should be the guideline (Laird et al. 2000).

It is important that gravel mining be managed in a way that does not further decrease salmonid habitat and, ideally, works with riverine dynamics to maintain or improve the quality habitat that still exists. In 1993, extraction companies began to consider reducing profitability for habitat improvement. Mining plans included the design of "alcoves", or trenches used by juvenile salmonids to escape high mainstem velocities during winter flows and as thermal refugia in warmer summer months (Klein et al. 2011).

Gravel mining occurs in two relatively isolated locations in the SF Eel River Basin between Redway and Cook's Valley. Three operations are located near Garberville between RM 33.5 to 34.0 (*Figure 37*), and one site is located at Cooks Valley, near Piercy at RM 50 (Stillwater Sciences 2008).

The total extracted volume at all sites between 1997 and 2010 averaged 49,578 cy per year, and ranged from a high of 75,900 cy in 1999 to a low of 24,833 cy in 2008 (Klein et al. 2011). Extracted totals averaged 71% of the annual percent approved, ranging from 110% in 1997 to 38% in (Klein et al. 2011). Gravel mining operations are relatively small, and the average extracted volume for the South Fork Eel is relatively low compared to other north coast streams (*Table 21*). The Lower Eel River had the highest average extracted volume per year (198,923 cy), followed by the Mad River (149,300 cy) and Van Duzen River (107,580 cy).

Figure 37. Gravel mining operation at Tooby Park, west of Garberville, in the Western Subbasin.

Table 21. Historical extraction volume summaries for selected rivers in Humboldt County from 1992 - 2010. Mad River data from 1992-2010; all other river data from 1997-2010 (Klein et al. 2011).

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

The percent extracted versus approved each year ranged from a high of 91% for the Mad River to a low of 64% on the Lower Eel River. The average volume extracted from the Lower Eel River is more than four times the volume extracted from the South Fork, and the amount extracted would have been more than six times greater if the approved volume had been removed from the Lower Eel River sites.

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

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

In turn, these effects on stream channels can impact aquatic life. Gravel mining has been shown in studies and in practice to negatively affect salmonid habitat for both spawning adults and rearing juveniles (Brown et al. 1998, Laird et al. 2000). Direct effects on salmonids can include harming juveniles during mining operations, destruction of spawning and rearing habitat, loss of deep holding pools for adult and juvenile migration, and creating the potential for fish entrapment (Packer et al. 2005). Additional impacts to salmonids can occur due to destruction of riparian zones, decreased food (macroinvertebrates) in stream channels, and toxic chemical spills that could occur during mining activities (Packer et al. 2005). Increased stream temperatures due to gravel mining activities that result in shallowing or reduced pool habitat and decreased riparian cover may also adversely affect adult and juvenile salmonids (Laird et al. 2009).

All salmonids migrating upstream to the SF Eel River and its tributaries travel through the Lower Eel River, which holds the highest commercial instream extraction volume of any north coast river, and one of the two highest cumulative volumes of instream aggregate extracted on the west coast of the United States (the other is the Mad River) (Laird et al. 2000). In light of the high quality of this instream aggregate, there is the potential for this resource area to experience elevated demand pressure, especially if transport becomes more cost effective. If gravel mining activity increases in any or all of the Eel River basins, it most likely will affect SF Eel River juvenile fish in rearing habitats and adult fish along their mainstem migratory route.

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 California, 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 continues to increase.

There are 47 licensed, permitted, or pending water rights within the SF Eel River Basin (*Table 22*). This table does not include riparian users and other diversions that are not registered with the State Division of Water Rights, including illegal diversions for industrial marijuana grow 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 Marijuana Cultivation section of this assessment report.

Water rights permits exist for stream diversions and for groundwater taken in the basin. Table 3 contains data on diversions and diversion amounts for each of the three subbasins, and for diversions located on the SF Eel River on the boundary line between the Eastern and Western subbasins. The Eastern Subbasin contains the most permitted diversions (23), and the largest amount of diverted water (1583.6 afy) of the three subbasins, followed by those located on the Eatern/Western subbasin boundary line (11 diversions totaling 1404.4 afy). This large number of diversions is due to the Eastern Subbasin having the lowest annual precipitation of the three subbasins, and the highest percentage of land use dedicated to grazing/timber (25% compared to 9% in the northern and 5% in the Western Subbasin).

In addition to precipitation, the interaction between surface water and groundwater influences stream flow. Groundwater is not static; it is part of a dynamic flow system that moves into and through aquifers from areas of high water-level elevation to areas of low water-level elevation (CDWR 2003a, available at: http://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/Interaction/).

The interaction of groundwater and surface water is affected by the interchange of local and regional groundwater flow systems with the rivers and by

Table 22. Water rights in the SF Eel River Basin (from SWRCB eWRIMS database, accessed in 2012). UNSP = Unnamed spring; UNST = Unnamed stream.

Creek	Application Number	Direct Diversion	Maximum Application Direct Diversion	Diversion Storage	Purpose
Northern Subbasin					
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**		
Eastern Subbasin					
East Branch SF Eel River	A004413	0.52 cfs	722.7 afy		Irrigation and recreation (Benbow dam)
Mad Creek	A005356	0.05 cfs	36.2 afy		Domestic and irrigation
Big Dann Creek	A006426	10,250 gpd	11.5 afy		Domestic and irrigation
Elder Creek	A007409	11,000 gpd	12.3 afy		Domestic and irrigation
Cedar Creeek	A008060	5000 gpd	5.6 afy		Domestic
Big Dann Creek	A009518	11,500 gpd	12.9 afy		Domestic
UNSP, Mad Creek	A013240	6500 gpd	7.3 afy		Domestic
Mill Creek	A013912	0.09 cfs	30.4 afy		Irrigation
East Branch SF Eel River	A014691	0.5 cfs	183.5 afy		Irrigation
Mill Creek	A016449	2000 gpd	1.3 afy		Domestic
Cahto Creek	A017809	0.25 cfs	76.4 afy		Irrigation
UNST, Mud Springs Creek	A018702	0.5 cfs	182 afy		Irrigation, stock watering, and recreation
Harmony Spring #1, Little Dean Creek	A019533	2500 gpd	2.8 afy		Domestic
Cedar Creek	A019712	1200 gpd	1.3 afy		Domestic
Holland Lake, Cahto Creek	A020971		220 afy	380 afy	Irrigation, recreation, stock watering, and fish culture
UNCR, Lewis Creek	A021811		2 afy	2 afy	Recreation and fire protection
Mill Creek	A021922	900 gpd	1 afy		Domestic
UNST, Mud Springs Creek	A022328		42 afy	42 afy	Irrigation, stock watering, recreation, and fire protection
Cedar Creek	A023021	5000 gpd	3 afy		Domestic
Grapewine (Grapevine) Creek	A025138		11 afy	11 afy	Recreation and fire protection
UNSP, Fish Creek	A025693A	420 gpd	0.1 afy		Domestic
UNST, Rattlesnake Creek	A027792	10,080 gpd	11.3 afy		Domestic

Creek	Application Number	Direct Diversion	Maximum Application Direct Diversion	Diversion Storage	Purpose
UNSP, UNST, Dean Creek	A029049	0.12 cfs (irrigation), 420 gpd (stock watering and domestic)	7 gpd	1 afy	Storage: fire protection, irrigation, recreation, and stock watering. Direct Diversion: irrigation, stock watering, and domestic
TOTAL (n = 23)			**1583.6 afy**		
Western Subbasin					
UNST, Redwood Creek	A010198	12,000 gpd	13.4 afy		Domestic and irrigation
Durphy Creek	A014652	0.046 cfs	33.3 afy		Standby emergency domestic and fire protection
Connick Creek	A025864	1600 gpd	0.1 afy		Domestic
TOTAL (n = 3)			**46.8 afy**		
On boundary line between Eastern and Wstern Subbasins (Mainstem SF Eel)					
SF Eel River	A005317	0.15 cfs	41.4 afy		Domestic and irrigation
SF Eel River	A009686	0.155 cfs	112.2 afy		Municipal
SF Eel River	A011876	0.223 cfs	161.5 afy		Domestic
SF Eel River	A016088	0.14 cfs	34.2 afy		Irrigation (2 sites)
SF Eel River	A023691	0.337 cfs	81 afy		Irrigation, domestic, stock watering
SF Eel River	A023017	1.05 cfs	441 afy		Municipal and domestic (use by 12/1995)
UNSP, SF Eel River	A023018	0.123 cfs	52 afy		Municipal and domestic (use by 12/1989)
UNST (AKA Marshall Creek)	A025436	0.04 cfs	13.5 afy		Domestic
UNSP, Rancheria Creek	A025693B	420 gpd	0.1 afy		Domestic
SF Eel River	A029329		37.5 afy		Industrial and mining (use by 12/1997)
SF Eel River	A029981		430 afy		Municipal (use by 12/1999. 2 sites)
TOTAL (n = 11)			**1404.4 afy**		
TOTAL FOR ALL SUBBASINS (n = 47)			**4239 afy**		

flooding and evapotranspiration (Winter et al. 1998). Groundwater-level fluctuations due to aquifer storage changes involve either the addition or extraction of water from the aquifer, both through natural means and human involvement.

Most rights are for direct diversions, and diverted water is used for municipal and domestic purposes, including irrigation, fire protection, recreation, and stock watering.

There are six water rights for diversion storage, five of which are located in the Eastern Subbasin and one in the Northern Subbasin. These storage diversions are used primarily for fire protection, which is more of a concern in the Eastern Subbasin due to drier conditions and a higher wildfire risk compared to other subbasins.

Benbow Dam

No major dams or power generating facilities are currently located within the SF Eel River Basin. However, historically, the Benbow Dam (operational from 1938 to 2008) was located at RM 40 on the mainstem SF Eel River near the town of Garberville. This dam was a hollow core, ogee (S-curve shaped in cross section) concrete dam measuring approximately 60 feet wide by 300 feet long and 15 feet high built by the Benbow family between 1931 and 1937. The dam was originally constructed to provide hydroelectric power for development in Benbow Valley near Garberville, and was purchased by PG&E in the 1943, then sold back to the Benbow family in the mid-1950s. In 1958, the land and dam was purchased by the State of California (State Parks), and from 1958 – 2008 (with some breaks due to floods, repairs, or other issues), flashboards were inserted into I beam supports along the concrete dam each summer between mid-June and mid-September to form a recreational lake, provided there was adequate water flow in the river. When the flashboards were in place, the dam was a complete barrier to juveniles moving upstream; migrating adult salmonids could pass over the sill or through the fish ladder. When the flashboards were not in place, the dam structure limited the migration of juvenile salmonids and was therefore considered a partial barrier (CA State Parks 2009).

Fish ladders were added to the north and south ends of the existing dam in 1932 and 1938, respectively. In 1977 the center section of the dam was removed to facilitate fish passage when the flashboards were not installed (NMFS 2002). Adult fish counts were conducted at the dam from 1938-1976, and will be discussed further in the Fishery Resources section of this report. Although these counts represent a relatively small proportion of the total Eel River Basin spawning populations, this record provides some of the best long-term monitoring data of adult salmonids in the entire basin (Taylor 1978).

When the flashboards were in place, the dam formed a 1,060 acre foot reservoir (Benbow Lake) with a maximum depth of 20 feet and a surface area of approximately 123 acres that extended approximately 1.3 miles upstream from the dam to near the confluence with Fish Creek (*Figure 38*). Average channel gradient in the Benbow Lake area is 0.29%, a drop of 15 feet per mile (Madej 2001).

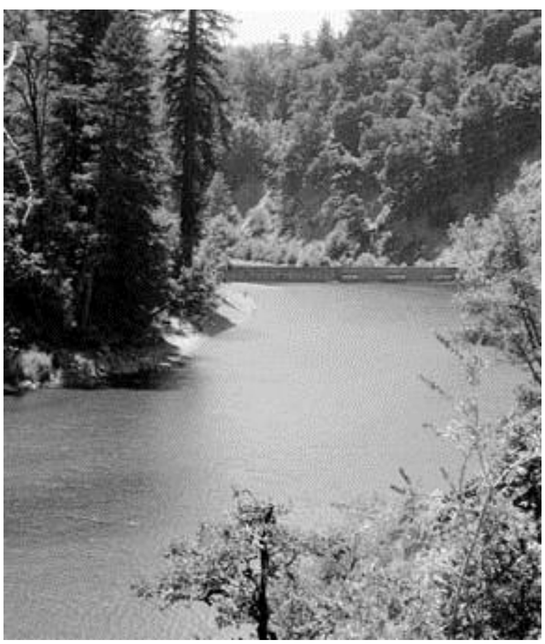


Figure 38. Benbow reservoir, when impounded (Photo by Arno Holschuh, North Coast Journal 2001).

The timing of installation and removal of flashboards was intended to minimize impacts to smolts passing the dam and to minimize smolt mortality downstream (NMFS 2002). This timing was based on recommendations from a three-year study by Roelofs et al. (1994) that examined river conditions and juvenile salmonid migration patterns. Between 1991 and 2008, flashboard installation occurred after June 15th under the following conditions: 1) river flow at Benbow Dam was below 200 cfs, 2) daily maximum water temperature below the dam exceeded 23° C for three consecutive days, and 3) diving observations found fewer than 20 0+ Chinook salmon in the reach between Twin Trees Bridge and just downstream of the Fish Creek confluence. Flashboard removal occurred prior to September 15th or when flow exceeded 150 cfs at the Miranda gauge, whichever came first (NMFS 2002).

In 2008 the Division of Dam Safety required that State Parks complete a structural evaluation of the dam to continue operating. Beginning in 2009, the seasonal dam was not installed to form the lake for summer recreational use, and State Parks is currently proposing to demolish and remove the dam because of high maintenance and rehabilitation costs, and existing environmental impacts produced by the dam. In October 2013, NOAA Fisheries announced that they will provide $205,500 in restoration funding to remove the Benbow Dam (http://www.redwoodtimes.com/ci_24413217/noaa-fisheries-announces-funding-habitat-restoration-benbow-dam).

Summer high water temperatures in the SF Eel River are within the lethal range for salmonids (Kubicek 1977, Friedrichsen 2003), and habitat in the impoundment reach was considered marginal for juvenile steelhead in the summer (Roelofs et al. 1994). Although average and maximum daily temperatures within Benbow Lake were not significantly higher than those in the mainstem SF Eel River, the daily temperature (diel) fluctuation of the water in the river from 1.5 miles upstream to 1.2 miles downstream of the dam was suppressed by the impoundment of water (Roelofs et al. 1994), which occurred until 2008. The greater surface area to volume ratio of water in the lake resulted in the lake water absorbing more solar radiation and radiating heat energy more slowly than water in the summer low flow channel (NMFS 2002). As a result, over-summering juveniles rearing in the vicinity of Benbow Lake remained upstream, moved downstream past the dam, or compensated behaviorally for elevated stream temperatures by utilizing coldwater refugia formed by inlets or upwelling groundwater during the hottest time of the day (Harris 1995). Young of the year (YOY) Chinook salmon are more temperature-sensitive and more vulnerable to predation than YOY coho salmon and steelhead trout, and were given priority when determining dam closing guidelines (Roelofs et al. 1994, NMFS 2002).

Sacramento pikeminnow, *Ptychocheilus grandis* (also known as Sacramento squawfish), have been documented in high densities in the deep pool at the base of the dam (CA State Parks 2009), leading to concern about predation upon juvenile salmonids. Pikeminnow are very effective predators of juvenile salmonids, and are one of the most abundant invasives in the Eel River Basin (Reese and Harvey 2002). Sacramento pikeminnow and California roach thrive in warm, low flow waters; salmonid populations near the dam may decrease, and juveniles may occupy different habitats when these invasive species are present (Reese and Harvey 2002). Invasive species will be discussed in detail in the Fishery Resources section of this report.

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 in the SF Eel River Basin and surrounding areas. During the late 1960s and early 1970s, a large influx of "back to the landers" came to the SF Eel River Basin in search of an independent, peaceful, and rural lifestyle (USBLM et al. 1996). With the decline of the timber and fisheries industries, also in the 1970s, the local economy began to dwindle. With favorable climate conditions and available land, back to the landers, displaced forest workers, and successive generations of homesteaders turned their ingenuity and agricultural talents to cultivating marijuana to accommodate the rising demand both locally and throughout the state. Mendocino and Humboldt Counties are home to some of 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 including the SF Eel River, 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, S. Bauer, CDFW, personal communication 2013). Bauer identified 567 grows (281 outdoor and 286 indoor/greenhouse) in the Salmon Creek drainage, and 549 grows (226 outdoor and 323 indoor) in the Redwood Creek watershed (*Figure 39*, *Figure 40*). 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).

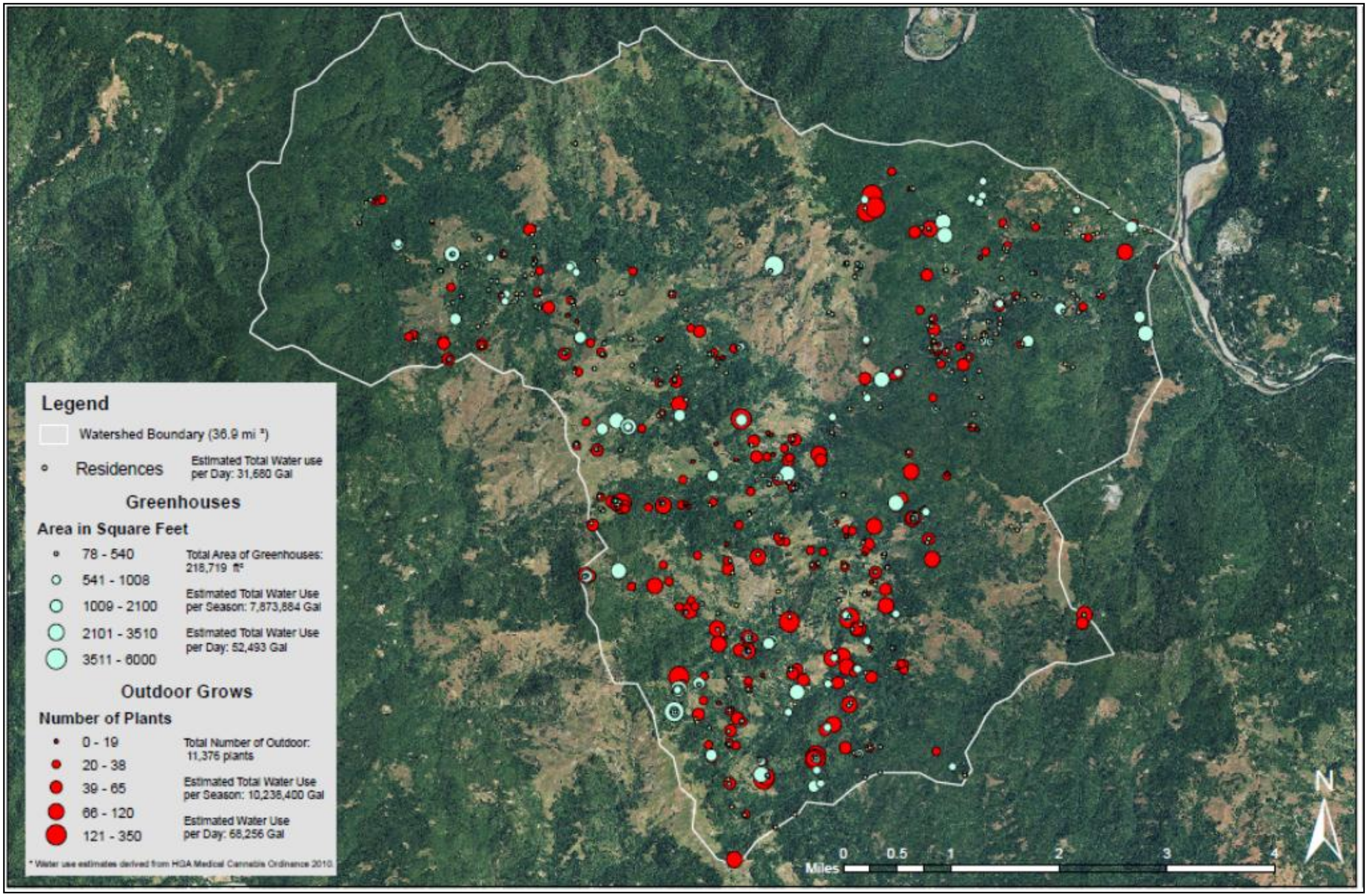


Figure 39. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Salmon Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW 2013).

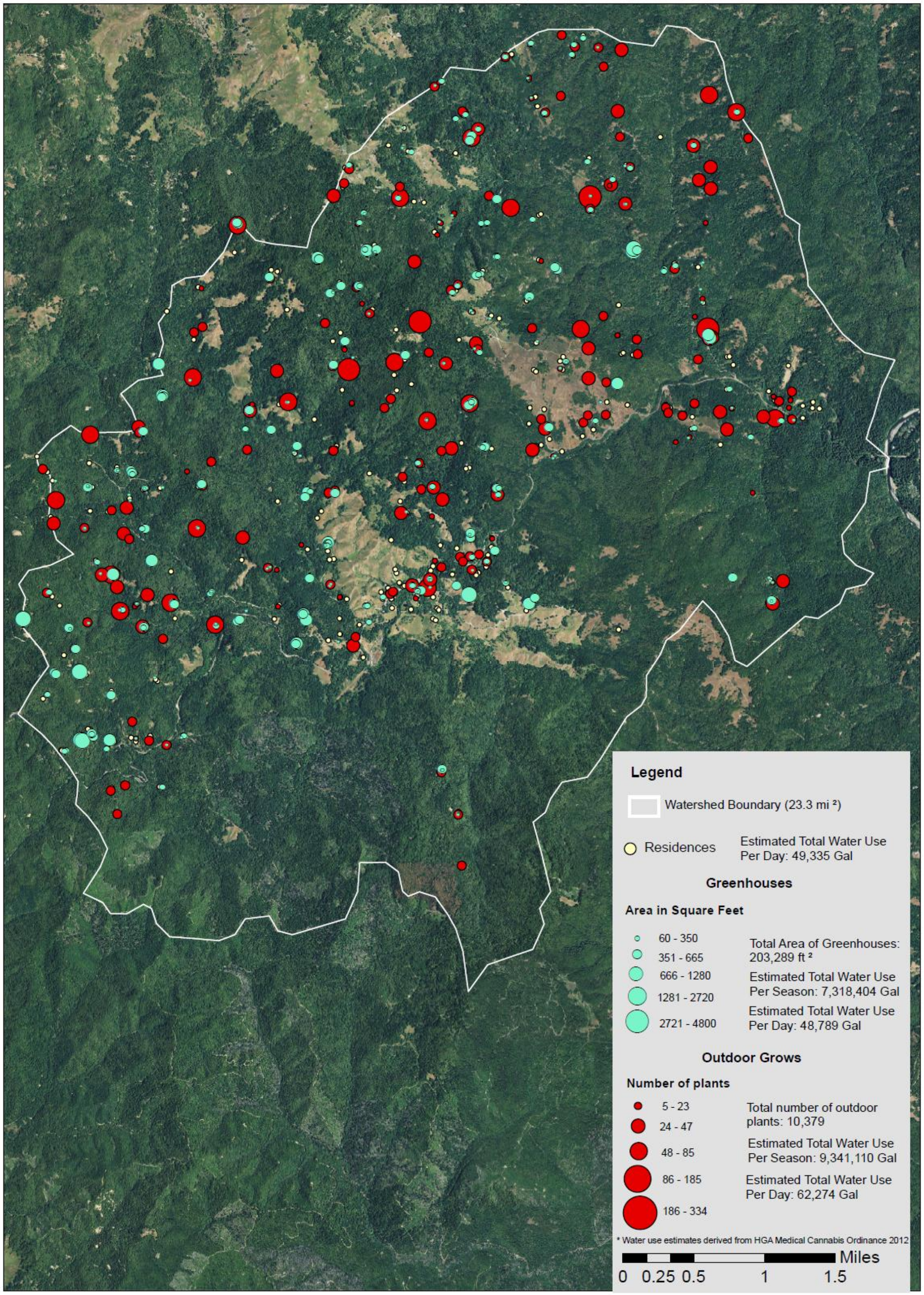


Figure 40. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Redwood Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW 2013).

While numerous factors may be relevant (wet spring vs dry spring, overall summer temperatures, etc.) a 10,000 square foot outdoor marijuana grow operation uses approximately 250,000 gallons of water in a five-month growing season (T. LaBanca, CDFW, personal communication 2012). Considering the number of outdoor and indoor operations within the watershed, this industry is having a significant effect on water flows in the SF Eel River and its tributaries. A recent trend has emerged that shows atypical low flows occurring during the late summer to early fall even during wet weather years (T. LaBanca, personal communication 2012). *Figure 41*, *Figure 42*, and *Figure 43* illustrate this potential trend using flow data from the USGS SF Eel River gauging stations near Miranda, Leggett, and Bull Creek. 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 41* 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 42 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 43* 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, affecting water temperatures, flow at critical times for fish rearing and migration, and water chemistry throughout the basin.

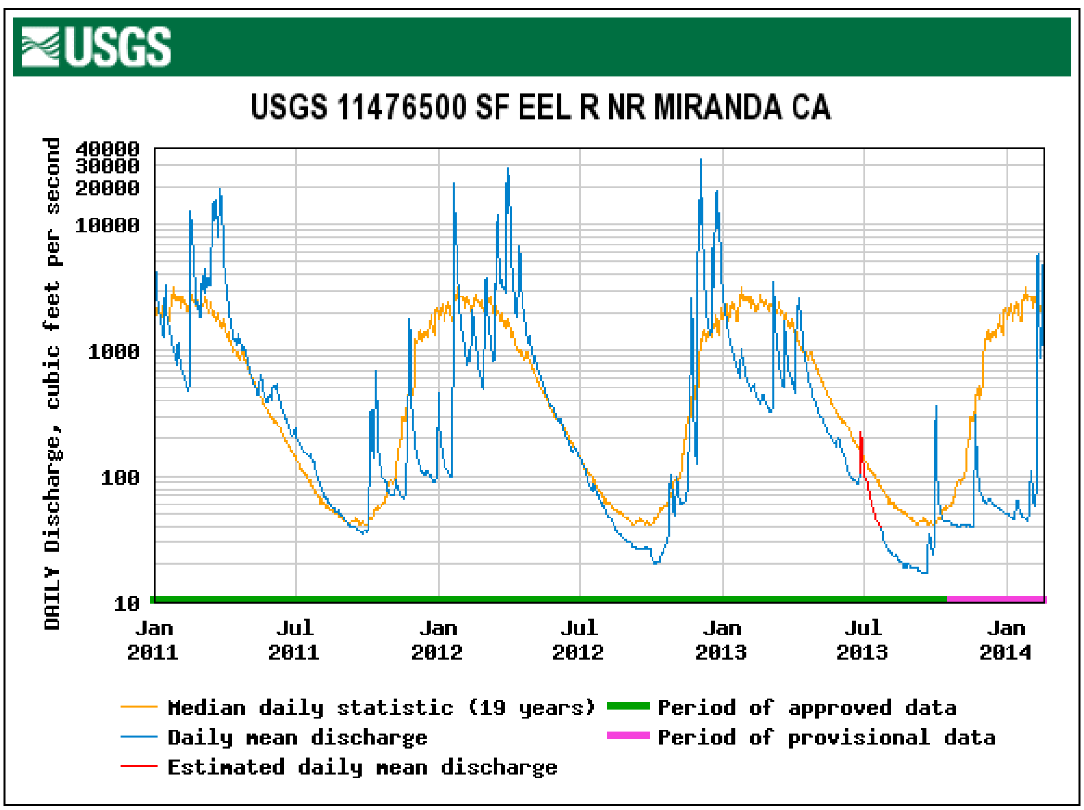


Figure 41. USGS gauging station near Miranda showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (73-year average in cfs).

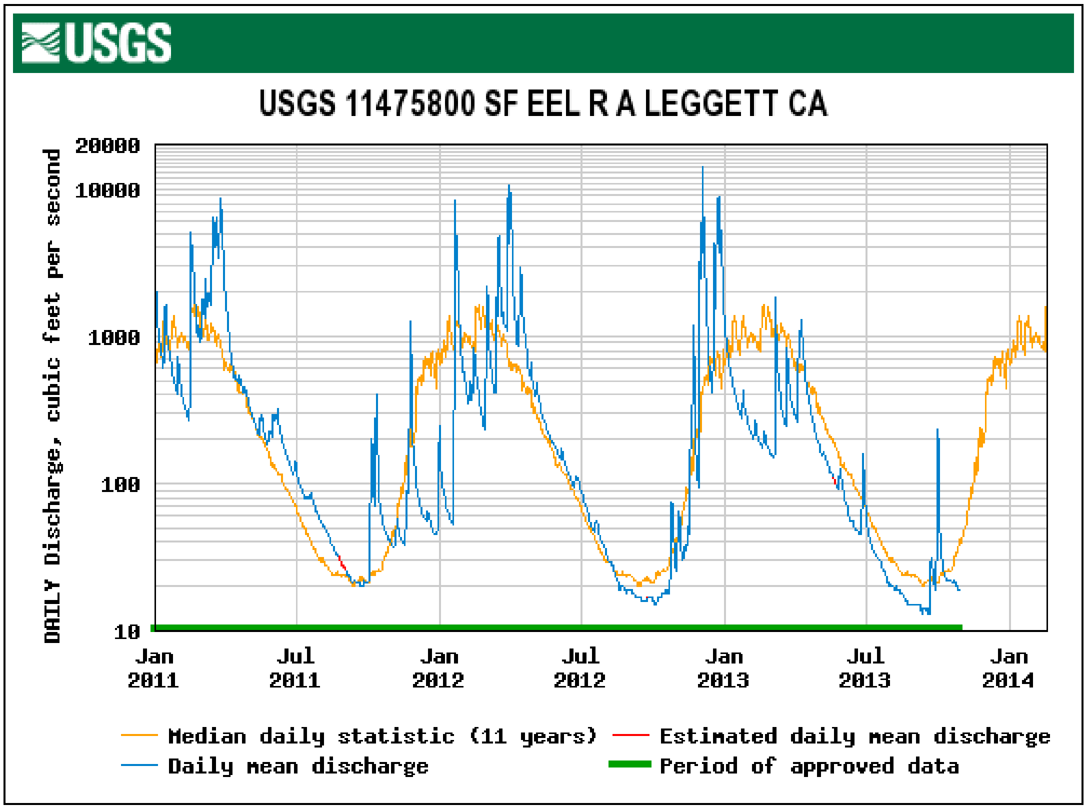


Figure 42. USGS gauging station near Legett showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (40-year average in cfs).

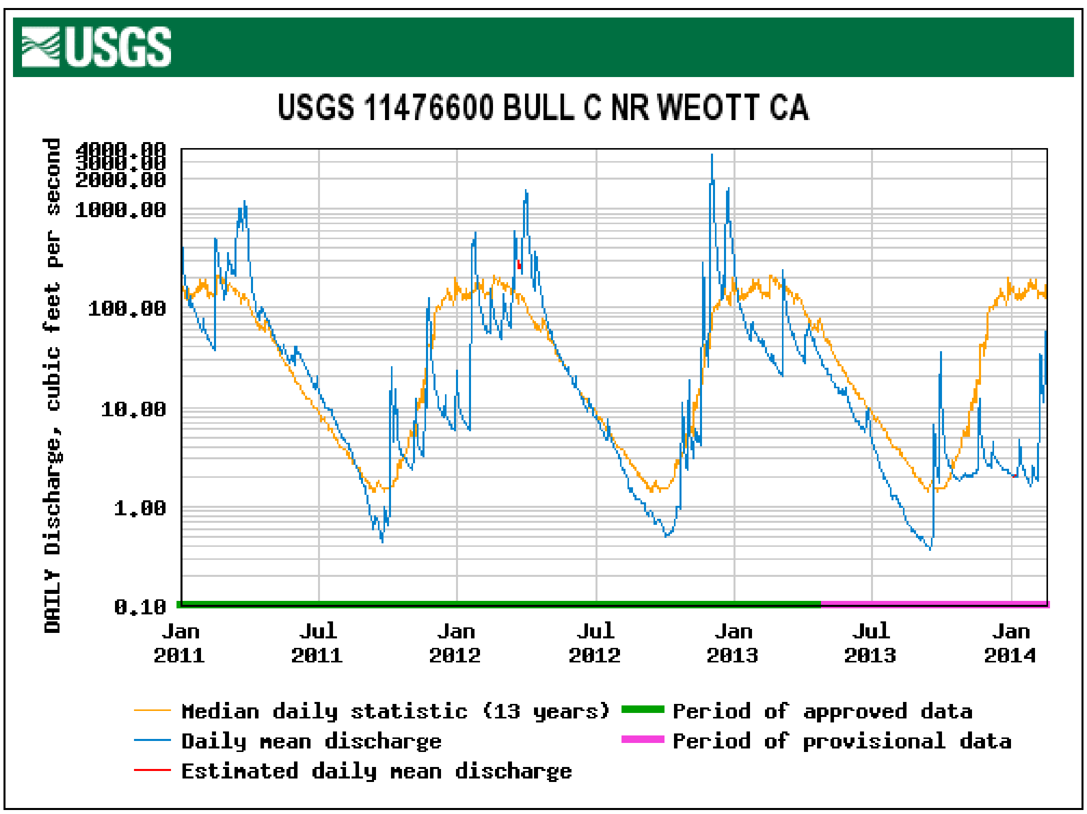


Figure 43. USGS gauging station at Bull Creek showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (52-year average in cfs).

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 23*), 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.

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 23. 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.

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).

Fishing

Historic

Native Americans in the SF Eel River Basin fished for hundreds of years prior to the arrival of Euro-American settlers without seriously depleting fish populations (Downie 1995). Shortly after arriving, the settlers established a commercial salmon fishery in the Eel River estuary, which began in 1853 and continued until the early 1920s. The fishery quickly grew and by the late 1850s the salmon catch from the Eel River was greater than that of the Sacramento River (Lufkin 1996). The expanding commercial fishery brought a significant number of jobs and revenue to Humboldt County. Canneries were built to process and store fish, and in 1883 they were operating at their peak, producing 15,000 cases of canned salmon annually (Downie 1995). This production translates into population estimates averaging 93,000 fish (coho and Chinook salmon, and steelhead and cutthroat trout) per year, approaching 600,000 fish (mostly Chinook salmon), in peak year 1877 (Yoshiyama and Moyle 2010). Because cannery records yield a conservative estimate of Chinook numbers, Yoshiyama and Moyle (2010) estimated that historic Chinook salmon runs numbered between 100,000 and 800,000 fish per year in the late 1800s.

Fishing regulations were introduced in the 1890s in response to concerns about depletion of the fishery, and attempts to regulate the commercial fishery with various rules and laws were implemented by the State Fish and Game Commission, which eventually became the CDFG (now the CDFW). The laws included net restrictions (most salmon fishing involved employing large seine nets in the river), shortened seasons, and closed areas. In 1912, canneries were banned, and the last records documenting commercial harvests from the Eel River estuary are from 1918 (Report of Commissioner of Fish and Fisheries).

Declining local salmonid populations throughout the Eel River Basin made competition with the Sacramento River commercial fishery economically difficult, and in 1922, the commercial fishery was closed by legislation after CDFW managers determined that Eel River salmon populations were at risk from combined in-river and ocean harvests (CDFG 2010).

Historic salmon catches varied from year to year. The reported annual harvest of Chinook salmon in the Eel River Basin ranged from approximately 20,000 in 1857 to 150,000 in 1903. Coho salmon harvests were rarely reported, but in 1895, a meager year for Chinook harvests, approximately 13,600 coho salmon (±160,000 lbs) and 62,500 steelhead (±500,000 lbs) were reported caught (CDFG 2010). Factors influencing the size of the harvests included: river conditions, the size and timing of salmon runs, fishing effort, market demand, and fishing regulations.

The history of the commercial salmon fishery reveals important information about the run size, run timing, and species composition of the Eel River's salmonid stocks. Newspaper articles documented at least two fall runs of Chinook in the Eel River: 1) an early fall run that were often caught in the estuary from as early as August, but mostly October through mid-November, and 2) a second peak in catches that occurred in late fall, from mid-November through December and sometimes in January. These newspaper articles were substantiated by reviews of various reports by the U.S Fish Commission, the State Fish Commission, and the CDFW. Articles also tell of adult steelhead being caught in the estuary year round. The steelhead fishery had peaks in April, May, and June representing a summer run, and a winter run in December through March. The steelhead half pounder run was strongest in August and September.

In addition to commercial fishing, recreational fishing has also played an important role throughout the Eel River Basin. Historically, there was fishing for juvenile trout in the summer and adult trout and salmon in the fall and winter. Past accounts of the recreational fishery in the Eel River estuary describe excellent conditions for salmon and steelhead fishing over the entire delta, with anglers gaining access to the catch "from boat to shore" (Haley 1970). Transportation options were limited but fishing was very popular in the South Fork Eel Basin; fishermen accessed these remote locations on foot, by vehicle, or arriving by train, disembarking at the Dyerville station located at the confluence of the South Fork and mainstem Eel River (*Figure 44*) and traveling upstream (S. Downie, CDFW, personal communication, 2012). The advent of guided drift boats and a three fish daily limit brought on the zero bag limit, or "catch and release" practice in 1991. Since then, the steelhead/rainbow trout population has increased as measured by angler success and carcass surveys (S. Downie, CDFW, personal communication, 2014).

Figure 44. Dyerville station, located at the confluence of the South Fork and Mainstem Eel Rivers (photo from City of Fortuna: http://sunnyfortuna.com/railroad/local_stations_02.htm)

Historically, outmigrant and over-summering juvenile steelhead trout fishing was popular throughout the Eel River Basin, especially in the lower river. Juvenile trout were caught from June to August (Murphy and DeWitt 1951). There was also fishing for coho salmon in the fall, however, the bulk of the coho salmon runs usually occurred as the turbidity of the water increased in November and December, which made fishing more difficult (Murphy and DeWitt 1951).

There was a small marine fishery in the Eel River estuary, with occasional harvests of Pacific herring (*Clupea harengus pallasii*), Pacific sardines (*Sardinops sagax*) and surfsmelt species harvested in the late 1800s and early 1900s; dependable catches of pile surfperch (*Damalichthys vacca*) in the early 1950s (Murphy and DeWitt 1951); and redtail surfperch (*Amphistichus rhodoterus*) in the mid-1970s (Puckett 1975).

Current

The Eel River fishery has diminished from once being considered world class to one that can no longer support a commercial fishery and whose sport fishery's economic contribution to the region is much reduced. Presently, the recreational fishery targets Chinook salmon and steelhead trout; fishing for coho salmon is prohibited.

Between the mouth of the SF Eel River and Rattlesnake Creek, there are two open seasons (from the end of May through the end of September, and from the beginning of October through the end of

March), with all fishing limited to catch and release and using barbless hooks. Throughout the fall and winter season, low flow restrictions are in place on the SF Eel River downstream from Rattlesnake Creek, and fishing is closed when minimum flow is less than 340 cfs at the gauging station at Miranda (Fishing regulations available at: http://www.dfg.ca.gov/regulations/).

Chinook salmon fishing usually begins with the low flow regulations beginning October 1st, when the first rains increase the number of migrating fish. The adult run of S F Eel River Chinook enter the Eel River estuary in September and hold in pools in the lower Eel River while waiting for enough runoff to initiate further movement to upstream spawning areas (Jensen 2000; Halligan 1998). Half-pounder steelhead are also present in the river in August, and the prime fishing period for them is from August to November. In October, larger winter-run steelhead trout enter the catch, and can be caught by Chinook fishermen. Steelhead fishing increases in the winter months and continues until the end of March. The steelhead fishery is catch and release only, unless the fish have an adipose clip indicating they were of hatchery origin. Anglers fishing for steelhead in all anadromous waters within the state must fill out a report card, which serves two purposes: to gather steelhead angling information, which is used to monitor catch trends over time; and to generate revenue dedicated specifically to projects that restore steelhead habitat and populations in California. Both Chinook and steelhead are taken either from the shore or using boats (mainly drift boats, but also power/jet boats), trolling in larger flatwater and pools.

There are a few additional minor fishing resources in the Eel River Basin, but most of these fish are not usually found as far upstream as SF Eel River Basin. Sport fishing for American shad (*Alosa sapidissima*) occurs from April to June, mostly on riffles immediately downstream from the mouth of the Van Duzen River (Puckett 1975). American shad do not usually move upstream into the SF Eel River, but are known to be in the mainstem Eel River upstream to the confluence with the NF Eel River at RM 96.5 (S. Downie, personal communication 2012). Fish caught in the estuary include a variety of surfperch, starry flounder, and surfsmelt species, and Native tribal members actively fish along the banks in the estuary for Pacific lamprey (*Lampetra tridentate*. Dungeness crab (*Metacarcinus magister*) is an additional sport fishery in the estuary each fall.

Fish Habitat Relationship

Fishery Resources

Anadromous fish populations in the Eel River Basin have decreased in both distribution and abundance compared to historic estimates. Yoshiyama and Moyle (2010) estimated that Chinook salmon, coho salmon, and spring/summer steelhead trout populations in the Eel River Basin were on a trajectory towards extinction in the next 50 years; only winter steelhead may persist due to higher abundance and more widespread distribution than other species throughout the watershed.

The SF Eel River is the most productive major tributary for salmon and trout in the system, and it is one of the last remaining wild (non-hatchery) coho salmon streams in California (Save the Redwoods and USBLM 2001). The SF Eel River currently supports populations of Southern Oregon/Northern California Coast (SONCC) ESU coho salmon, fall-run California Coastal (CC) ESU Chinook salmon, and winter-run Northern California (NC) DPS steelhead trout (Bjorkstedt et al. 2005, Yoshiyama and Moyle 2010). The basin also provides important habitat for other native and non-native species of fish, reptiles, and amphibians (*Table 24*).

Table 24 Fishery resources of the SF Eel River Basin.

Common Name	Scientific Name
Anadromous	
Coho Salmon	*Oncorhynchus kisutch*
Chinook Salmon	*Oncorhynchus tshawytscha*
Steelhead Trout	*Oncorhynchus mykiss*
Pacific Lamprey	*Lampetra tridentata*
Three-spined Stickleback	*Gasterosteus aculeatus*
Freshwater	
Coastrange Sculpin	*Cottus aleuticus*
Prickly Sculpin	*Cottus asper*
Sacramento Sucker	*Catostomus occidentalis*
California Roach*	*Hesperoleucas symmetricus*
Brown Bullhead*	*Ameiurus nebulosus*
Sacramento Pikeminnow*	*Ptychochelis grandis*
Largemouth Bass*	*Micropterus salmoides*
Smallmouth Bass*	*Micropterus dolomieu*
Speckled Dace*	*Rhinichthys osculus*
Green Sunfish*	*Lepomis cyanellus*
Bluegill	*Lepomis macrochirus*
Reptiles and Amphibians	
Western Pond Turtle	*Clemmys marmorata*
Pacific Giant Salamander	*Dicamptodon tenebrosus*
Rough-skinned Newt	*Taricha granulosa*
Southern Torrent Salamander	*Rhyacotriton variegatus*
Western Toad	*Bufo boreas*
Tailed Frog	*Ascaphus truei*
Pacific Treefrog	*Pseudacris regilla*
Red-legged Frog	*Rana aurora*
Foothill Yellow-Legged Frog	*Rana boylei*
Bullfrog*	*Rana catesbeiana*

* Indicates non-native species introduced to the basin.
From: Mackey 1981, Mcleod 1982, Downie 1995, USBLM et al. 1996, Brown and Moyle 1997, HCRCD 2002, Flosi 2010 (Hollow Tree Creek restoration project), Garwood 2012, UC Davis 2012.

Chinook and coho salmon, and steelhead trout are all federally listed species (*Table 25*). The National Marine Fisheries Service (NMFS) originally listed CC Chinook, SONCC coho salmon, and NC steelhead as threatened under the federal Endangered Species Act, and the most recent status reviews for all three species in 2011 recommended no change in listing status (NMFS 2011a, 2011b, 2011c). Of the three federally listed species, the state of California currently considers only SONCC coho salmon as threatened.

Table 25. ESA listed salmonids in the SF Eel River Basin, with updated status information and ESU map links.

Common Name	Scientific Name	Status	Date First Listed	Most Recent Status Review	ESU/DPS Map link
Coho Salmon (Southern Oregon/Northern California Coast ESU)	*Oncorhynchus kisutch*	Threatened (Federal and State)	NMFS (1997); CDFW (2005)	NMFS (2005); CDFW (2005)	http://www.westcoast.fisheries.noaa.gov/publications/gis_maps/maps/salmon_steelhead/esa/coho/web_pdfs_sonc_coho.pdf
Chinook Salmon (California Coastal ESU)	*Oncorhynchus tshawytscha*	Threatened (Federal)	1999	2005	http://www.westcoast.fisheries.noaa.gov/publications/gis_maps/maps/salmon_steelhead/esa/chinook/web_pdfs_cc_chinook.pdf
Steelhead Trout (Northern California DPS)	*Oncorhynchus mykiss*	Threatened (Federal)	2000	2006	http://www.westcoast.fisheries.noaa.gov/publications/gis_maps/maps/salmon_steelhead/esa/steelhead/nc_steelhead.pdf

In 2010, the North American Salmon Stronghold Partnership, based in Portland, Oregon, recognized the SF Eel River as one of six salmon stronghold watersheds in California. These six watersheds contain approximately 70% of the state's remaining salmon and steelhead diversity, and must be maintained and enhanced for recovery to be successful (Wild Salmon Center 2012). Within these watersheds, specific populations were identified as strong populations using selection methodology based on McElhaney et al. (2000). Coho salmon and steelhead trout in the SF Eel River were identified as strong populations, characterized by:

- >75% natural origin spawners;
- Individuals that express most of their life history diversity traits; and
- Relatively high wild abundance and productivity relative to the ESU.

The Pacific Salmon Stronghold Conservation Act (first introduced in 2009 and reintroduced in the US House of Representatives in 2011) is designed to increase technical and financial support for conservation efforts in stronghold watersheds, and will complement recovery efforts currently in place for federally listed salmonids (Wild Salmon Center 2012).

The most serious salmon and steelhead declines throughout the Eel River Basin occurred after the 1955 and 1964 floods (CDFG 1977). For example, Chinook populations, which historically ranged between 100,000-800,000 fish per year, declined to approximately 50,000-100,000 fish per year by the mid-1950s, and further declined to fewer than 10,000 fish per year after the floods (Yoshiyama and Moyle 2010). Both floods caused extensive landsliding (with associated increased sediment inputs); stream channel migration, aggradation, and scour; widespread loss of riparian vegetation; and fine sediment deposition on floodplains. These impacts were exacerbated by extensive land disturbance from unregulated tractor logging throughout the Eel River Basin (S. Downie, CDFW, personal communication, 2014).

In addition to natural factors affecting salmonid populations, there are many human-caused factors that have resulted in decreasing fish abundance and distribution throughout their range. According to Becker and Reining (2009) and Yoshiyama and Moyle (2010), the most commonly cited anthropogenic factors in streams of the Eel River watershed are (in unranked order):

- Habitat and stream degradation due to cattle grazing, timber harvest, and water diversion;
- Construction of fish passage barriers including dams, road crossings, weirs, concrete channels, and other structures;
- Increased sedimentation through hydrologic modification and changes in land use; and
- Overfishing.

Climate change is further exacerbating these problems, and the vulnerability of fish populations to environmental changes varies locally. Increasing air temperatures and decreasing precipitation are two effects of climate change that result in a reduction of cold water habitat required by salmonids (Rieman and Isaak 2010). In Northern California streams, Johnstone and Dawson (2010) documented a reduction in the number of foggy summer days and greater evaporative demand, which may also result in reduced flows, warmer stream temperatures, and stressful conditions for fish in the future.

Habitat restoration can help mitigate the negative effects of climate change, particularly in lower elevation basins (Battin et al. 2007). Projects designed to re-aggrade incised channels, and restore floodplain connectivity and stream flow are most likely to increase salmonid habitat diversity and population resilience if stream temperatures increase and flows are reduced (Beechie et al. 2012).

SF Eel River salmonids migrate to and from the ocean through the mainstem Eel River and the Eel River estuary, and residence time in these downstream habitats varies with species and life stage. The estuary is particularly important as a rearing and transition environment for outmigrant juvenile salmonids, and the habitat condition and availability of food may affect survival rates (Tschaplinski 1988, Magnusson and Hilborn 2003). The Eel River estuary has also been documented as an important holding area for adult steelhead during upstream spawning migrations (Murphy and DeWitt 1951). The importance of these migratory corridor habitats and the impact of changes in these habitats on SF Eel River salmonids are discussed in the Lower Eel River Watershed Assessment (CDFG 2010).

Non-native species of freshwater fish, particularly Sacramento pikeminnow and California roach, have affected salmonids throughout the basin. Pikeminnow, first introduced around 1980, are voracious salmonid predators and have become increasingly abundant throughout all tributaries in the Eel River Basin (Yoshiyama and Moyle 2010). Pikeminnow abundance appears to be declining compared to population estimates in the late 1980s and 1990s. Pikeminnow and their interaction with salmonids will be discussed further in the individual species sections of this report.

Historic Distribution and Abundance

There are two long-term salmon and steelhead count data sets for the Eel River Basin: CDFW fish ladder counts at Benbow Dam and fish counting station totals at Van Arsdale Fisheries Station (VAFS), located at Cape Horn Dam (mainstem Eel RM 157). Benbow Dam counts were conducted between 1938 and 1976, and counts at Cape Horn started in the 1920s and continue today. Benbow Dam counts show more than an 80% decline in coho salmon, Chinook salmon, and steelhead trout populations over the periods of record in the SF Eel River Basin (*Figure 45*). Linear regression lines for all three species show significant declines in abundance between 1938 and 1976, and it is likely that salmonid populations throughout the Eel River Basin declined similarly over this time period.

VAFS steelhead counts show decreasing abundance over the period of record, with a high of 9,528 steelhead counted in 1944 and a low of 31 in 1990 (http://www.pottervalleywater.org/van_arsdale_fish_counts.html). There was a capture, spawn, rear, and release program in place at VAFS from 1970 to 1996. Steelhead numbers were strongly influenced by these hatchery operations (*Figure 46*), and mainstem Eel River counts do not necessarily reflect population trends in the SF Eel River.

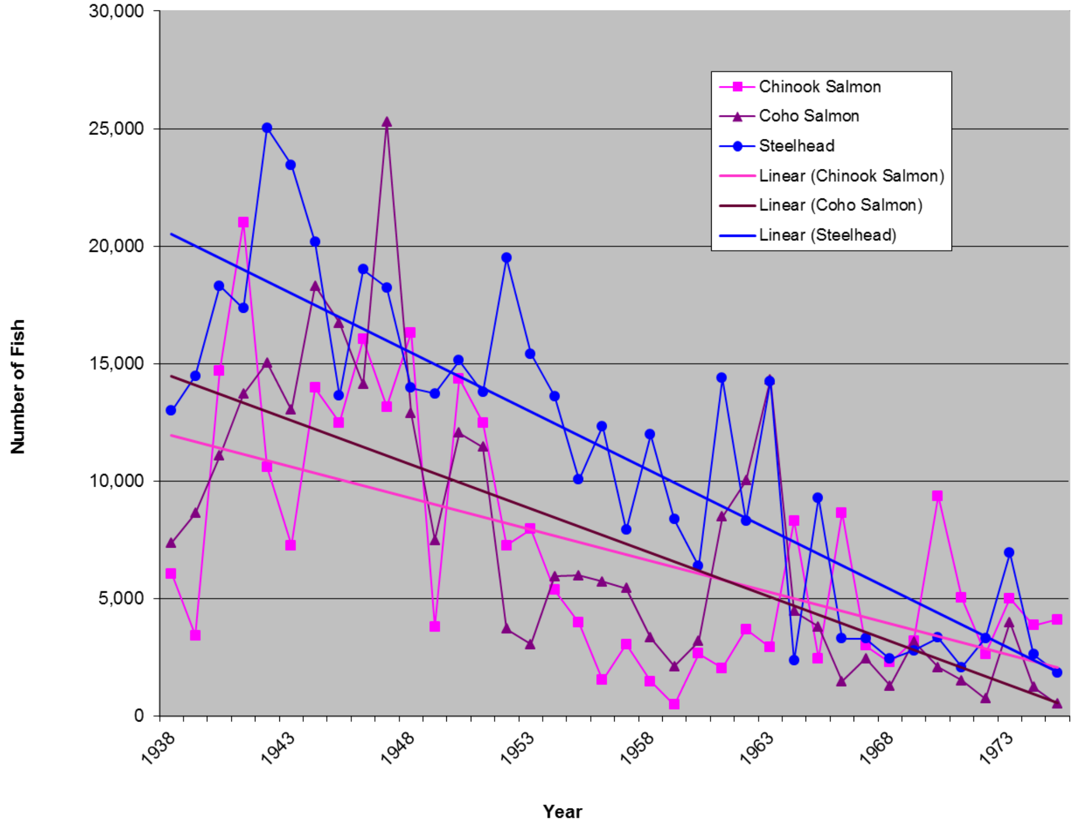


Figure 45. Count of salmonids at Benbow Dam, SF Eel River, 1938-1976. Linear regression lines for all three species show declines over time.

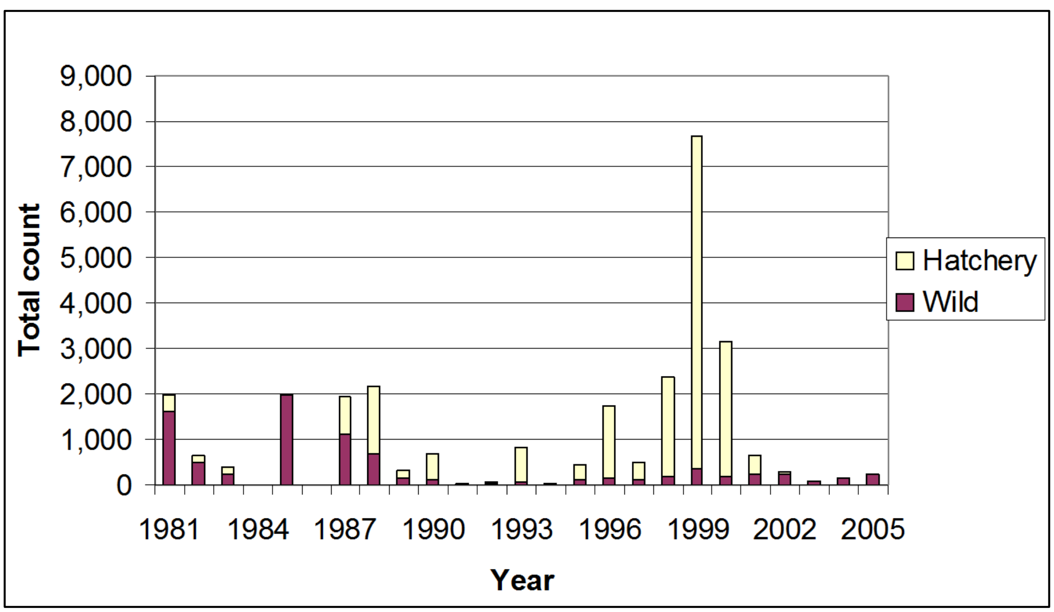


Figure 46. Hatchery and wild steelhead counts at VAFS from 1981-2005 (Perry 2006).

Historic accounts and past stream surveys provide records of fish species observations and distribution within the basin. Chinook and coho salmon, and steelhead trout presence has been documented in approximately 100 miles of the mainstem SF Eel River, from the confluence upstream to the headwaters southeast of Laytonville. Historic survey information is primarily from CDFW files, but also includes some reports from USBLM, Mendocino Redwood Company, and PCFFA. These reports documented a mix of adult and juvenile fish presence in 130 SFER streams (434 surveys total) between 1938 and 2001 (*Table 26*). Information on salmonid presence/absence by species was available for the mainstem SFER (13 surveys), and for 31 streams (132 surveys) in the Northern Subbasin, 49 streams (122 surveys) in the Eastern Subbasin, and 50 streams (180 surveys) in the Western Subbasin. Complete tables of streams sampled, salmonid presence/absence, and survey sources are included in the subbasin sections of this report.

Table 26. Historic salmonid presence/absence recorded on surveys by decade in the SF Eel River Basin.

Years	Northern Subbasin	Eastern Subbasin	Western Subbasin	Mainstem
1930s	Bridge, Bull, Canoe, Cuneo, Elk, Ohman, Salmon, and Squaw creeks.	Cedar, Dean, McCoy, Milk Ranch, Rancheria, Rattlesnake, Ray's, Red Mountain, Tenmile creeks, and East Branch SF Eel River.	Durphy, Indian, Leggett, Low Gap, Piercy, Redwood (Redway), Sawmill, and Sommerville creeks.	SF Eel River
1940s		Cedar and Tenmile creeks.	Hollow Tree and Little Sproul creeks.	
1950s		Cahto and Elk creeks.	Durphy Creek.	SF Eel River
1960s	Butte, Bridge, Bull, Cabin, Calf, Canoe, Connick, Coon, Cow, Cuneo, Elk, Feese, Fish, Harper, Mowry, Ohman, Salmon, and Squaw creeks.	Bear Canyon (Bear Gulch), Bear, Big Dan, Big Rock, Bridges, Cahto, Cedar, Cummings, Dean, Deer, Dora, Elder, Elk, Fish, Foster, Fox, Grapewine (Grapevine), Horse Pasture, Little Dan, Little Rock, McCoy, Milk Ranch, Mill (tributary to Tenmile), Mud, Mud Springs, Rancheria, Rattlesnake, Ray's, Red Mountain, Rock, Streeter, Taylor, Tenmile, Tuttle, Twin Rocks creeks, and East Branch SF Eel River.	Anderson (tribuary to Indian), Bear Pen, Bear Wallow, Bond, China, Dinner, Durphy, Hartsook, Haun, Hollow Tree, Hooker, Huckleberry, Indian, Jack of Hearts, La Doo, Leggett, Little Charlie, Little Waldron, Lost Pipe, Low Gap, Lynch, Michael's, Middleton, Mill (tributary to SFER), Moody, Mule, Parker, Piercy, Redwood (Branscomb), Redwood (Hollow Tree), Redwood (Redway), Sawmill, Section Four, Seely, Sommerville, Sproul, Standley, Warden, and Wildcat creeks.	
1970s	Anderson, Butte, Bridge, Bull, Canoe, Cow, Cuneo, Dry, Elk, Fish, Mill (tributary to Bull), Salmon, and Squaw creeks.	Bear, Big Dan, Cedar, Cummings, Elder, Elk, Elkhorn, Foster, Grapewine (Grapevine), Kenny, Little Rock, McCoy, Mill (tributary to Tenmile), Misery, Mud, Muddy Gulch, Rattlesnake, Rock, Squaw, Taylor, Tom Long, Wilson, Windem creeks, and East Branch SF Eel River.	Anderson (tributary to Indian), Butler, Eagle, Hollow Tree, Indian, Jack of Hearts, Leggett, Little Charlie, Low Gap, Middleton, Moody, Piercy, Redwood (Branscomb), Redwood (Redway), Sebbas, Section Four, Seely, Sproul, Standley, Surveyors Canyon, and Thompson creeks.	
1980s	Anderson, Butte, Bull, Cabin, Canoe, Connick, Coon, Corner, Cow, Cuneo, Decker, Dry, Mill (tributary to Salmon), Mill (tributary to Bull), Mowry, Panther, WF Panther, Salmon, and Squaw creeks.	Cedar, Dean, Foster, Low Gap, McCoy, Milk Ranch, Rattlesnake, Red Mountain, Streeter, Tenmile creeks, and East Branch SF Eel River.	Bond, Butler, China, Dinner, Durphy, Dutch Charlie, Hartsook, Hollow Tree, Huckleberry, Indian, Leggett, Little Sproul, Low Gap, Michael's, Piercy, Pollock, Redwood (Branscomb), Redwood (Hollow Tree), Redwood (Redway), Sawmill, Seely, Sproul, WF Sproul, Standley, Waldron, and Wildcat creeks.	SF Eel River

Years	Northern Subbasin	Eastern Subbasin	Western Subbasin	Mainstem
1990s	Bridge, Bull, Burns, Canoe, Connick, Cow, Cuneo (NF and SF), Decker, Elk, Fish, Mill (tributary to Salmon), Mill (tributary to Bull), WF Panther, Salmon, Slide, and Squaw creeks.	Bear Canyon (Bear Gulch), Bridge, Dean, Little Rock, Rock, Taylor creeks, and East Branch SF Eel River.	Bond, China, Cox, Dinner, Dutch Charlie, Hollow Tree, Huckleberry, Jack of Hearts, La Doo, Leggett, Little Sproul, Low Gap, Pollock, Redwood (Hollow Tree), Redwood (Redway), Sproul, WF Sproul, Waldron, and Warden creeks.	
2000-2001	Canoe, Cow, Salmon, and Squaw creeks.		China, Jack of Hearts, Leggett, Redwood (Redway), Sproul, and WF Sproul creeks.	

In the SF Eel River Basin, there are 10 stream names that are repeated for different streams in multiple subbasins, or in the same subbasin at different locations (*Table 27*). For example, there are three Redwood creeks, all located in the Western Subbasin. To reduce confusion, duplicate named creeks may be referred to with either a location name or "tributary to" designation added to the stream name (e.g. Redwood Creek (Briceland), Redwood Creek (tributary to Hollow Tree Creek), and Redwood Creek (Branscomb)).

Table 27. SF Eel River Basin streams with duplicate names and subbasin location.

Stream Name	Total Number	Subbasin Location (number)
Anderson Creek	2	Northern (1); Western (1)
Bear Creek	2	Eastern (1); Western (1)
Coon Creek	2	Northern (2)
Elk Creek	2	Northern (1); Eastern (1)
Fish Creek	2	Northern (1); Eastern (1)
Low Gap Creek	2	Eastern (1); Western (1)
Mill Creek	5	Northern (3); Eastern (1); Western (1)
Miller Creek	2	Northern (1); Western (1)
Redwood Creek	3	Western (3)
Squaw Creek	2	Northern (1); Eastern (1)

Current Distribution and Abundance

Northern and Western subbasin streams have more documented fish presence due to more favorable instream conditions such as cooler summer water temperatures due in part to increased coniferous and hardwood forest vegetation , afternoon shade from terrain, and the extent of the coastal marine layer. In contrast, the Eastern Subbasin has hotter, drier summer conditions, and a higher prevalence of grassland and shrub vegetation types compared to the other subbasins. Eastern Subbasin streams also generally have higher gradient compared to those in the other subbasins; many areas in upper tributaries have gradient greater than 10%, which limits accessibility to coho and Chinook salmon, and steelhead trout (*Table* 28). Eastern Subbasin streams had more than twice the number of stream miles in the highest gradient category compared to Northern or Western subbasin streams.

Table 28. Number of miles and percent of total stream mileage in three gradient classes in SF Eel River subbasin streams (based on GIS analysis).

Stream Gradient	Northern Subbasin		Eastern Subbasin		Western Subbasin		South Fork Eel River Basin	
	miles	%	miles	%	miles	%	miles	%
0 - 5%	87.133	30%	216.404	31%	260.11	53%	563.647	38%
5 - 10%	43.345	15%	105.841	15%	90.809	19%	239.995	16%
> 10%	163.733	56%	365.721	53%	138.815	28%	668.269	45%

Current estimated Chinook salmon, coho salmon, and steelhead distribution maps (*Figure 47*, *Figure 48*, and *Figure 49*) 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 fisheries 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.

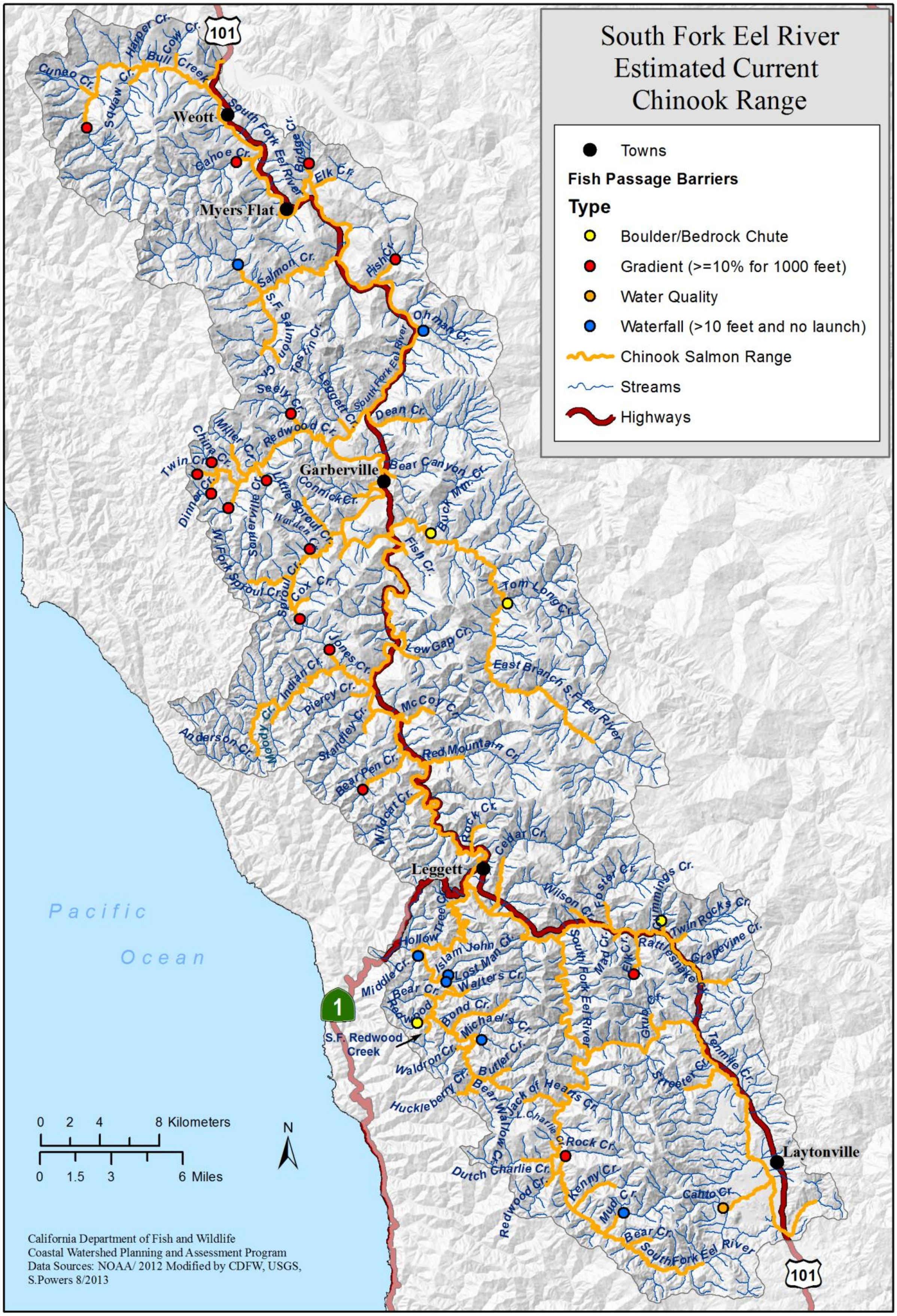


Figure 47. SF Eel River Basin Chinook salmon estimated current range, with documented barriers.

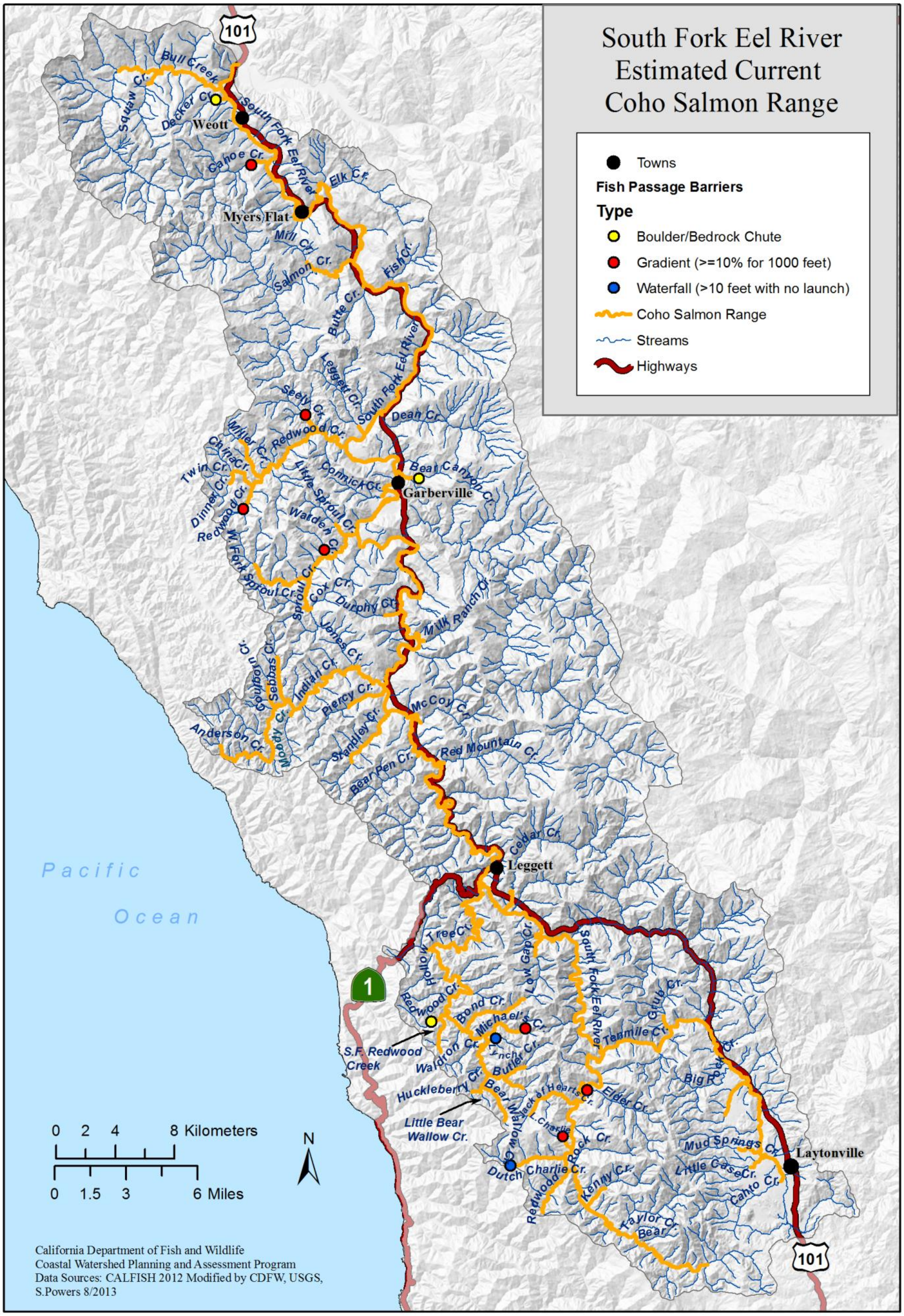


Figure 48. SF Eel River Basin coho salmon estimated current range, with documented barriers.

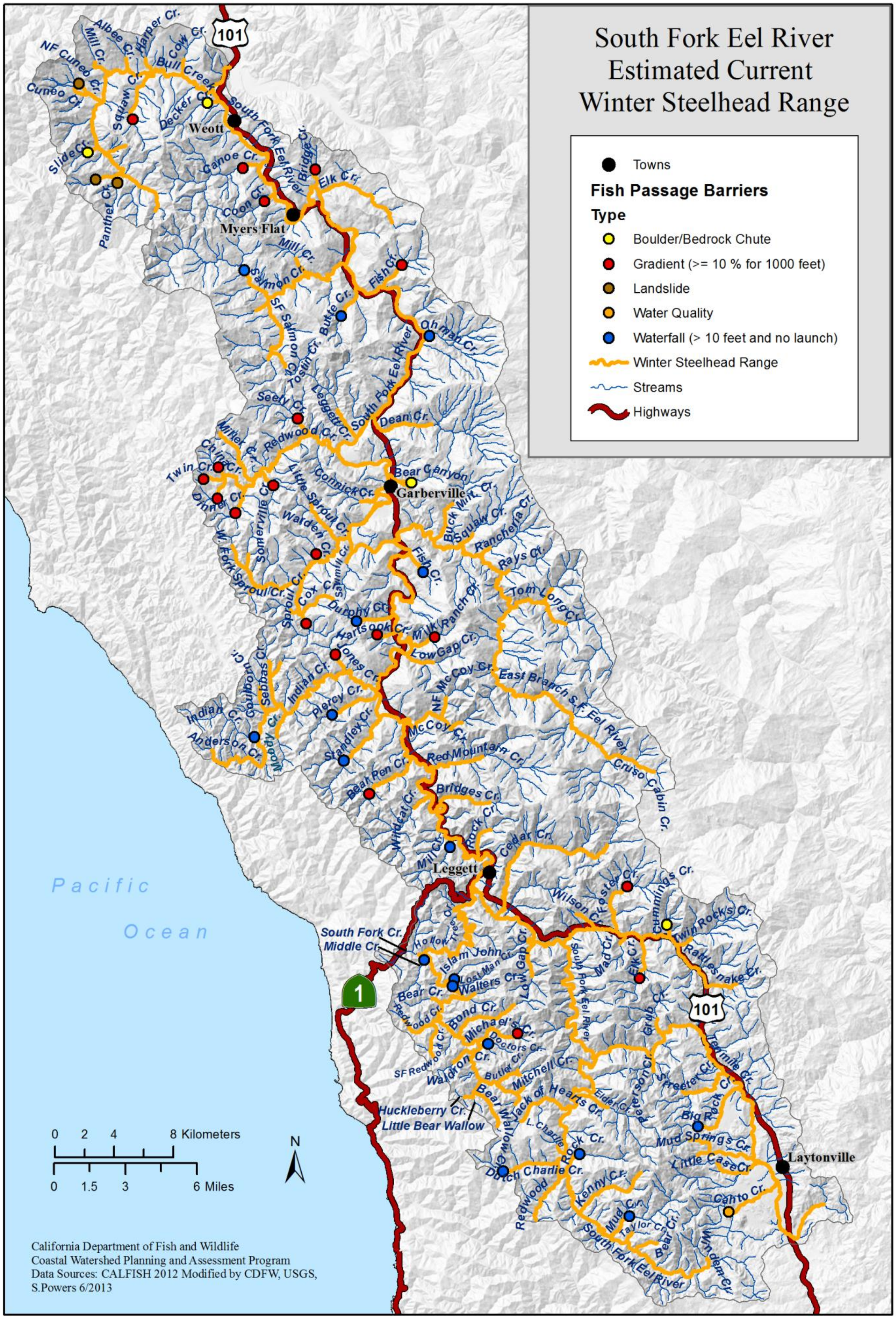


Figure 49. SF Eel River Basin steelhead trout estimated current range, with documented barriers

Steelhead trout are the most widely distributed of the three species, and are generally found further upstream and in more tributaries than either Chinook or coho salmon in each subbasin (*Table 29*). Coho salmon have the most limited distribution of the three salmonid species in all subbasins. Of the three subbasins, the Western has the highest number of tributary streams with salmonids present, followed by the Eastern and Northern subbasins. Steelhead and Chinook have been documented in a similar number of miles of tributary streams in the Eastern and Western subbasins, but they are found in a greater number of tributaries in the Western Subbasin. Stream mileage is based on total mileage available and does not consider barriers present in subbasin streams. Natural and manmade barriers and their effect on salmonid distribution will be discussed in individual species distribution sections.

Table 29. Number of tributary streams and approximate number of stream miles currently occupied by anadromous salmonids in SF Eel River 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.

Preliminary distribution estimates for Chinook, coho and steelhead, respectively, (*Figure 47*, *Figure 48*, and *Figure 49*) do not confirm that salmon and steelhead are present in specific reaches; rather they indicate the possibility that salmonids are present. Additionally, the estimated distribution does not prove that salmonids were not historically present in areas above the estimated gradient barriers. Other factors that influence salmonid distributions include flow limitations, channel shape and size, and barriers (e.g. waterfalls). Known barriers affecting salmonid distribution are included on estimated distribution maps.

Chinook Salmon, *Oncorhynchus tshawytscha*

Figure 50. Freshwater female Chinook salmon, photo courtesy of CDFW.

The Eel River Basin currently supports a fall run of Chinook salmon. Since 2010, there has been an increase in the number of Chinook counted at the Van Arsdale Fisheries Station (VAFS): 2,314 in 2010, 2,430 in 2011, and 3,471 in 2012 (http://eelriver.org/fish-monitor/fish-count/). The previous high Chinook count from station data collected since 1946 was 1,754 in 1986. These are combined adult and jack counts, and the numbers are higher than those seen historically, reflecting good fall flows at VAFS (Parks 2011). Reports of widespread Chinook spawning throughout the Eel River Basin and an apparent increase in the Chinook population since 2010 is most likely due to favorable ocean conditions (Good et al. 2005), however, in historic cycles, abundance is often followed by declines, when ocean productivity and climatic conditions are less favorable. It is too early to tell if the increase seen since 2010 reflects a new trend in abundance following the long decline in Chinook populations throughout the Eel River watershed.

Three to four year-old Chinook salmon generally enter the Eel River estuary between September and February. Two year-old precocious males (jacks) also enter during this time period. Adult Chinook salmon move upstream into the mainstem SF Eel

River after sufficient rains in the fall. CDFW biologists initiate spawner surveys in SF Eel River tributaries when flows of 100 cfs or greater are recorded at the Bull Creek gauge. These flows are sufficient for salmonids to move further up into SF Eel River tributaries. Peak spawning usually occurs in December, but in times of extreme or unusual weather patterns, the timing and location of spawning may change. For example, there was very little rainfall in Humboldt County in November and December 2013 (1.35" received in Eureka, with normal precipitation 13.73") (http://www.nws.noaa.gov/climate/index.php?wfo=eka). During the peak spawning time, there was insufficient flow for fish to move into tributaries, and many spawned in the mainstem SF Eel River (A. Renger, personal communication, 2014).

Spawning occurs in tributary streams on gravel with diameters of 0.5 to 5 inches, with less than 5% fines (CDWR 2003b). Prime spawning water velocities range between 1 to 3.5 feet/second, but are highly variable (Healey 1991). Optimal spawning water temperatures range between 42ºF to 56ºF (Richter and Kolmes 2005). Considerable egg mortality can occur at temperatures greater than 57.5ºF. Eggs that are deposited in redds commonly hatch in 40 to 60 days, provided there is adequate water percolation through spawning gravels (Healey 1991). Chinook eggs located in mainstem redds will most likely develop normally unless large storm events generate high flows that move the substrate and disturb the eggs prior to hatching.

Juvenile Chinook salmon outmigrate from SF Eel River streams at 3 to 6 months old and have been observed in the Eel River estuary in all but the winter months. Puckett (1977) documented juveniles increasing in size with season and proximity to the mouth, noting that the estuary provides an important transition area for juvenile salmon preparing for out-migration. Similarly, Cannata and Hassler (1995) noted that the higher abundance of juvenile Chinook salmon in the estuary in July corresponded to ocean entry, and described the estuary as a nursery area for juvenile salmon. Increased temperatures in tributaries may cause early outmigration of Chinook salmon from the SF Eel River, possibly leading to increased reliance on the estuary (Roberts 1992).

Current Chinook distribution includes 103 miles of mainstem and 195 miles of tributary habitat in the SF Eel River Basin (*Table 29*). Chinook have been observed in 85 SF Eel River Basin tributaries, with extensive distribution in larger tributaries including: Bull, Salmon, Redwood, Sproul, Indian, Red Mountain, Hollow Tree, Rattlesnake, and Tenmile creeks, and the East Branch South Fork Eel River (*Figure 47*). Chinook are more widely distributed in Western Subbasin streams, most likely because of increased gradient and fewer large tributaries in Northern and Eastern Subbasin streams compared to Western Subbasin streams.

Coho salmon, Oncorhynchus kisutch

Figure 51. Mature freshwater female coho salmon (photo courtesy of NOAA Fisheries).

The Eel River Basin has one run of coho salmon (three year-old adults) that generally enters the river between September and February, with arrival in the upper basin peaking in November-December (Baker and Reynolds 1986). Within the Eel River system, coho salmon are most abundant in the South Fork, with spawning in tributary streams peaking in most years in January-February.

Optimal spawning conditions are similar to Chinook salmon, but coho salmon usually spawn in smaller streams than those used by Chinook. Fry generally emerge from redds between 10 and 15 weeks (8 to 12 weeks for egg incubation, 4 to 10 weeks for emergence) depending on water temperatures (Moyle et al. 1995). In 50˚F water, swimups begin after approximately 50 days (S. Downie, CDFW, personal communication, 2014). In the SF Eel River, spring water temperatures are approximately 55˚F, and may be cooled further by low air temperatures in streams such as Hollow Tree Creek.

Juvenile coho salmon remain in fresh water for one year before downstream migration to the estuary and thence to the ocean. Once juveniles descend from their freshwater natal streams, it is likely that they use the estuary in the winter and spring as a transition before ocean entry (Cannata and Hassler 1995). Coho salmon presence in the Eel River estuary has been documented by Murphy and

DeWitt 1951, Puckett 1977, and Cannata and Hassler 1995. After entering the ocean, coho salmon typically spend two years feeding, growing, and maturing before returning to their natal streams to spawn.

Historically, counts of coho salmon at Benbow Dam on the SF Eel River were made between 1938 and 1976. The largest number of fish reported was over 25,000 in 1947, but only 509 were counted during the final year of sampling in 1976 (CDFG 1994). Moyle and Morford (1991) estimate a current run size of approximately 1,000 coho for the entire SF Eel River Basin.

Current coho salmon distribution includes 102 miles of mainstem and 137 miles of tributary habitat in the SF Eel River Basin (*Table 29*). Coho salmon have been observed in 59 SF Eel River tributaries, primarily in lower reaches of larger tributaries. Many of these tributaries also supported coho salmon historically (Brown and Moyle 1991; Hassler et al. 1991), including Bull, Salmon, Redwood, Sproul, Indian, Hollow Tree, and Tenmile creeks (*Figure 48*). Coho salmon have a more limited distribution than Chinook and steelhead primarily because coho salmon tend to be most abundant in lower velocity, lower gradient, and less constrained stream reaches than both Chinook and steelhead (Meehan and Bjornn 1991, Agrawal et al. 2005).

In 1991, Brown and Moyle estimated that the South Fork Eel River supported the largest remaining wild populations of coho salmon in California; they estimated the abundance of coho salmon for the entire SF Eel River was 1,320 adults, but stated that this was probably an overestimation based on their methods. The current distribution map shows most coho salmon in Northern and Western Subbasin streams (*Figure 48*). Presence has not been detected in a majority of Eastern Subbasin streams, presumably due to higher stream gradients in tributaries, reduced riparian cover, lower summer flows, and higher stream temperatures (no marine layer and no shady afternoon aspect of canopy) when compared to Northern and Western Subbasin streams.

The Recovery Strategy for CA Coho Salmon (CDFG 2004) identified the SF Eel River Basin Recovery Unit as one Hydrologic Area (HA), which was further subdivided into three Hydrologic Subareas (HSAs), with problems facing coho salmon identified by subarea:

- Weott HSA – includes the lower SF Eel River and its tributaries (similar to the Northern Subbasin considered in this assessment).
- Benbow HSA – includes the middle reaches of the SF Eel River and its tributaries.
- Laytonville HSA – includes the upper reaches of the SF Eel River and its tributaries.

Problems identified by CDFG (2004) in all three HSAs include: high summer water temperatures, degraded or limited pool quality and quantity, limited escape cover and shade canopy, increased sedimentation from roads and bank failures, limited spawning gravel quality and quantity, grazing in riparian areas, debris accumulations retaining sediment, and fish passage barriers.

CDFG recommended 63 populations of coho salmon within the SF Eel River Basin as key populations to maintain or improve, and 22 areas to establish populations (*Table 30*). Of the 63 populations to maintain or improve, most are located in Western Subbasin streams (38), followed by Eastern (15), Northern (9) Subbasin streams. One population in the SF Eel River headwaters is located on the border between the Eastern and Western subbasins. Of the sites to establish populations, most are located in Eastern Subbasin streams (13), followed by Western (7) and Northern (2) Subbasin streams. Sites chosen to establish populations are those streams with high quality habitat (or the potential for habitat restoration resulting in high quality habitat) with historic records of coho distribution but no currently confirmed presence.

Trout Unlimited developed the Conservation Success Index (CSI; http://www.tu.org/science/conservation-success-index) to quantify and map the conservation status of freshwater fish, and to help guide conservation actions to benefit specific populations of native salmonids, including SONCC coho salmon. They determined that watersheds throughout the Eel River Basin were at the highest risk to increasing summer temperatures related to climate change, and recommended both habitat restoration and population restoration as conservation strategies in the SF Eel River Basin.

Table 30. Coho Recovery Document Recommendations for coho populations in the SF Eel River Basin.

Key Populations to Maintain or Improve (Subbasin) (n=63)	**Sites to Establish Populations (Subbasin) (n=22)**
Anderson Creek (N)	Barnwell Creek (W)
Bear Creek *(*E; *Laytonville HSA*)	Bear Canyon Creek (E)
Bear Pen Creek (W)	Bear Creek*(*W; *Benbow HSA)*
Bear Wallow Creek (W)	Bridges Creek (E)
Big Rock Creek (E)	Connick Creek (W)
Bond Creek (W)	Cox Creek (W)
Bull Creek (N)	Cummings Creek (E)
Butler Creek (W)	Dean Creek (E)
Butte Creek (N)	Deer Creek (E)
Cahto Creek (E)	East Branch SF Eel River (E)
Canoe Creek (N)	Fish Creek *(*E; *Benbow HSA)*
Cedar Creek (E)	Fish Creek *(*N; *Weott HSA)*
China Creek (W)	Foster Creek (E)
Coulborn Creek (W)	Little Low Gap Creek (W)
Dark Canyon Creek (W)	Mill Creek *(*W; *Benbow HSA)*
Decker Creek (N)	Mill Creek *(*E; *Laytonville HSA)*
Dinner Creek (W)	Mill Creek (N; *Weott HSA;* tributary to Bull Creek)
Doctors Creek (W)	Mud Creek (E)
Durphy Creek (W)	Rattlesnake Creek (E)
Dutch Charlie Creek (W)	Squaw Creek *(*E; *Benbow HSA)*
Elder Creek (E)	Streeter Creek (E)
Elk Creek (N)	Warden Creek (W)
Grub Creek (E)	
Haun Creek (W)	
Hollow Tree Creek (W)	
Huckleberry Creek (W)	
Indian Creek (W)	
Jack of Hearts Creek (W)	
Jones Creek (W)	
Kenny Creek (E)	
Leggett Creek (W)	
Little Bear Wallow Creek (W)	
Little Charlie Creek (W)	
Little Sproul Creek (W)	
Low Gap Creek (E)	
McCoy Creek (E)	
Michaels Creek (W)	
Milk Ranch Creek (E)	
Mill Creek (N; *Weott HSA*)	
Miller Creek (W)	
Moody Creek (W)	
Mud Springs Creek (E)	
Mule Creek (W)	
Piercy Creek (W)	
Red Mountain Creek (E)	
Redwood Creek *(*W; *Benbow HSA)*	
Redwood Creek *(*W; *Laytonville HSA)*	
Upper Redwood (Pollock) Creek (W; *Benbow HSA)*	
Rock Creek (E)	
Salmon Creek (N)	
Sebbas Creek (W)	
Seely Creek (W)	

Key Populations to Maintain or Improve (Subbasin) (n=63)	**Sites to Establish Populations (Subbasin) (n=22)**
SF Eel River (E and W)	
South Fork Redwood Creek (W)	
Sproul Creek (W)	
Squaw Creek *(*N; *Weott HSA)*	
Standley Creek (W)	
Taylor Creek (E)	
Ten Mile (Tenmile) Creek (E)	
Waldron Creek (W)	
Walters Creek (W)	
West Fork Sproul Creek (W)	
Wildcat Creek (W)	

Steelhead, Oncorhynchus mykiss

Figure 52. Steelhead trout, photo courtesy of CDFW.

SF Eel River steelhead are the most widely distributed salmonid in the basin, with superior leaping and swimming abilities that allow them to reach upper watershed areas and spawn significantly further upstream than coho salmon (Shapovalov and Taft 1954, Gallagher 2001). There are three runs of steelhead trout in the Eel River: winter run, fall run (also referred to as half-pounders), and spring/summer run. Unlike Pacific salmon, steelhead do not necessarily die after spawning, and can make up to four spawning runs (Barnhart 1986). Hopelain (1998) reported that repeat spawning by steelhead ranged from about 17.6% for small coastal streams to 63.6% for spring run of the Klamath-Trinity River system. In Northern California populations, the frequency of two spawning migrations is higher than that seen in populations north of Oregon, but more than two spawning migrations is still unusual (Busby et al. 1996).

Winter run steelhead adults (4 to 5 years old) enter the Eel River beginning in September to spawn. Upstream migration is usually correlated with storm events and migration is highest when stream levels are rising and falling; upstream movement may cease during peak flows (Shapovalov and Taft 1954). The run continues through May, with a peak in February (CDFG 1997).

Fall run, or "half pounder" steelhead are sexually immature individuals that return to natal streams after 3 to 5 months in the ocean. For the most part, these individuals do not spawn, but return to the ocean until they reach maturity, at which time they will again return to freshwater to spawn.

Spring/summer run steelhead are a smaller presence in Northern California streams. The Middle Fork Eel River supports the largest run of spring/summer run steelhead in California (Moyle et al. 2008). In general, these fish enter the Middle Fork between March and June, migrating to its upper reaches above Black Butte River where they hold in deep pools during the summer months (Puckett 1975). Spawning doesn't occur until late December through April (Moyle et al. 2008). There have been a few anecdotal reports of summer steelhead in the SF Eel River between Wilderness Lodge and Rattlesnake Creek from the 1930s to the 1960s, but the run was relatively small (CDFG 1992; Becker and Reining 2009).

Ideal steelhead spawning conditions include water temperatures between 40ºF and 55ºF (Carter 2005), water velocities of 1.5 feet/second, and gravel diameters between 0.25 and 4 inches, with few sediment fines (Swift 1976). Under these types of conditions, steelhead eggs will generally hatch in approximately 30 days. The young sac fry tend to stay within the gravel for 2 to 4 weeks, using their yolk before emerging. In general, steelhead remain in freshwater for two years, before migrating to the ocean and returning to spawn at 4 to 5 years of age.

Juvenile steelhead have been noted in nearly all fish surveys of the SF Eel River Basin. This species, like other anadromous salmonids, uses the upstream system in their juvenile and adult migrations. Steelhead 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.

Steelhead distribution throughout the SF Eel River Basin has not changed over time as much as abundance; winter steelhead remain in many historically occupied streams (Yoshiyama and Moyle 2010). Steelhead were historically present in 153 streams in the SF Eel River Basin (Becker and Reining 2009), and are currently present in 120 tributaries consisting of 308 streams miles (*Table 29*). They also distribute through 103 miles of the mainstem. Steelhead production has been highest near Branscomb (RM 96), where tributaries are narrower, have more riparian cover, and cooler water temperatures than downstream areas (Becker and Reining 2009). Fish counts conducted at Benbow Dam from 1938-1976 show that population abundance was very low compared to historical levels by the time sampling stopped in 1976 (*Figure 45*). Although early counts of steelhead may have been larger due to stocking from the 1930s through the 1950s, the trend of declining populations continued in the 1960s and 1970s, even after most stocking practices stopped (see the Stocking section of this report). For a detailed description of steelhead resources in individual SF Eel River Basin streams, see Becker and Reining (2009).

All steelhead originating in the SF Eel River migrate to and from the ocean through the mainstem Eel River and the Eel River estuary. Adult and juvenile steelhead hold in pools in the mainstem Eel River, and the estuary has been identified as an important holding area for adult steelhead during upstream spawning migrations (Murphy and DeWitt 1951). Additional information on habitat conditions and steelhead in this migratory corridor outside the boundaries of the SF Eel River Basin can be found in the Lower Eel River Basin Assessment (CDFG 2010).

Sacramento pikeminnow, Ptychocheilus grandis

Figure 53. Sacramento Pikeminnow. Photo courtesy of CDFW.

The Sacramento pikeminnow is a large piscivorous cyprinid (minnow) that was introduced into the Eel River system in Pillsbury Lake 1979, and has since become widespread throughout the Eel River Basin, including the mainstem SF Eel River and its tributaries (Brown and Moyle 1997, Harvey and Nakamoto 1999). Pikeminnow are native to the Sacramento-San Joaquin drainage and several smaller coastal drainages in California. They usually live in clear low to mid-elevation streams and rivers with deep pools and slow runs. High winter discharge appears to limit their upstream extent (Harvey and Nakamoto 1999). Pikeminnow prefer water temperatures ranging from 64.4° to 82.4°F, though they are capable of withstanding extremes up to 100.4°F.

While juvenile pikeminnow feed during the day, adults feed during dawn and dusk in riffles and stay in deeper pools during the day (Harvey and Nakamoto 1999). Undercut banks and aquatic vegetation provide good cover. Pikeminnow are predaceous and move from smaller prey such as aquatic insects to crustaceans and fish as they grow bigger, becoming piscivorous at age 3.

Pikeminnow become sexually mature at age three or four. Spawning mainly occurs in small tributary streams in April through May, when water temperatures reach a range of 59-68°F. Spawning is in gravel substrate in riffles or shallow flowing areas at the base of pools. Females produce an average of 15,000 to 40,000 eggs each and eggs hatch in four to seven days. Young fish disperse in small schools and to deeper water with time, often occupying protected riffles and fast water. Pikeminnow grow slowly but may reach great lengths (a 28” specimen was found in the SF Eel River (S. Downie, CDFW, personal communication, 2014) and ages in excess of 16 years.

Pikeminnow can create problems for native salmonids and other native fish and amphibians. Pikeminnow can prey upon and compete with juvenile salmonids for food (Brown and Moyle 1981). Pikeminnow prefer warmer water temperatures than native salmonids, therefore changes in the Eel River system that promote warmer water temperatures (such as loss of riparian vegetation, reduced pool depths, and reduced river flows) could promote Sacramento pikeminnow over salmonid species (Harvey et al. 2002). Competitive effects of juvenile pikeminnow on juvenile steelhead were shown to be greater in warmer water temperatures (Reese and Harvey 2002). Additionally, reservoirs that decrease winter discharge may extend the pikeminnow's upstream distribution (Harvey and Nakamoto 1999).

Sacramento pikeminnow are present as far downstream as the Eel River estuary (Cannata 1995). Eel River pikeminnow show seasonal migration patterns over long-distances, thus any small-scale local control efforts are likely to be thwarted by individual pikeminnow movements throughout the basin (Harvey and Nakamoto 1999). Pikeminnow populations appear to be decreasing since peaks in the late 1980s and early 1990s. These decreases may be caused by higher spring flows during wet years, and angler efforts to catch and kill as many pikeminnow as possible. Reduced pikeminnow populations may also play a role in the increasing number of Chinook in the Eel River Basin, particularly in the mainstem. Further studies of abundance trends and distribution are necessary to determine the effects of pikeminnow on salmonid populations in the SF Eel River Basin.

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. Thirty eight surveys were conducted on three Northern Subbasin streams and 325 surveys were conducted in three Western Subbasin streams (*Table 31*). Bull Creek was surveyed as one reach from 2002-2007, then split into upper and lower Bull Creek beginning in 2007. Sproul Creek sampling reaches included upper, lower, and West Fork locations. Survey sites were not randomly selected; CDFW biologists selected index reaches based on known salmonid (primarily coho salmon) presence in areas with relatively good quality instream and riparian habitat. Annual surveys also differed in sampling duration and effort, and redds were not assigned to species; however, these data provide a continuous record of spawner survey information in select streams.

Table 31. Index reach sampling streams and survey information for SF Eel River streams sampled between 2002and 2012 (Bull Creek surveys were divided into Upper and Lower reaches in beginning in the 2006-07 season).

Stream	Subbasin	Years Surveyed	# of Surveys
Lower Bull Creek	Northern	2007-2010	4
Upper Bull Creek	Northern	2007 - 2010	4
Bull Creek	Northern	2002 – 2007 (no data collected in 2003-04 season)	12
Squaw Creek	Northern	2002 - 2010	18
Cow Creek	Northern	2002 - 2009	18
Lower Sproul Creek	Western	2002-2012	74
Upper Sproul Creek	Western	2002-2012	74
West Fork Sproul Creek	Western	2002-2012	74
Redwood Creek (Redway)	Western	2002-2010	34
Upper Redwood (Pollock) Creek	Western	2002-2010	35
China Creek	Western	2002-2010	34

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

Coho salmon (live fish and carcasses) were not observed in any Northern Subbasin streams sampled between 2002 and 2010, but were present in all of the reaches sampled in the Western Subbasin. West Fork Sproul Creek contained the most live coho salmon (81), coho salmon carcasses (64), and total salmonid redds (128) observed during the 2011-12 sampling season.

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

Index reach data will be discussed further in the Northern, Western, and Eastern subbasin sections of this report.

California Coastal Salmonid Monitoring Program (CMP)

Chinook salmon, coho salmon, and steelhead trout spawning ground surveys have been have been completed 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 54*). The number of reaches sampled varied slightly by year, and sampling occurred between mid-November and late March.

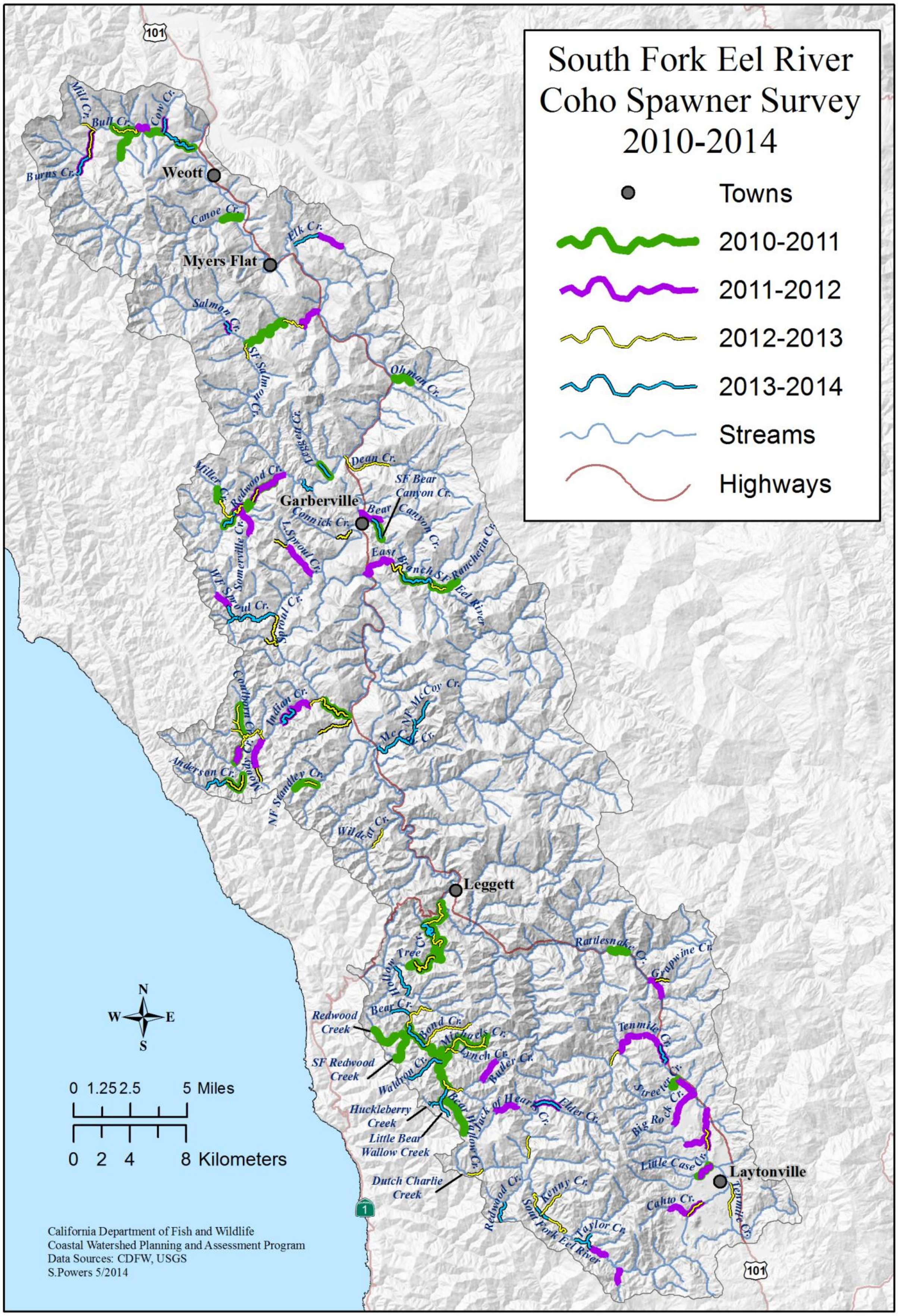


Figure 54. Location of 2010-2014 CMP spawning reaches in the SF Eel River Basin.

Field crews recorded the number of spawning fish, carcasses, and redds observed in each reach, including identifying the salmonid species that constructed each redd where possible (*Table 32*). 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 32. Summary of CMP regional spawning ground surveys and estimates of total salmonid redd construction in the SF Eel River (data from Ricker et al. 2014a – 2014d). UI = unidentified salmonids.

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

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

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

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

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

Stocking

The Eel River Basin contains a long history of stocking salmonids throughout the basin. With the beginning of commercial fishing in the early 1850s in the estuary, fishing pressure increased rapidly on Eel River stocks. Declining fishery harvest production in the late 1800s gave rise to a hatchery program intended to augment salmonid stocks (Brown and Haley 1974). Limited hatchery operations eventually expanded throughout the Eel River drainage, including some locations in the SF Eel River.

While hatchery operations have varied in intensity and location over the years, salmon and steelhead have been planted throughout the Eel River Basin. Hatchery records indicate more than 39 million Chinook salmon and 9 million steelhead have been planted in the Eel River Basin since 1900 (Steiner Environmental Consulting 1998). There is currently no estimate for the number of coho planted in the Basin. The effectiveness of a century of hatchery operations in restoring salmonid populations in the Eel River has been unsubstantiated.

Similar to historic management practices of hatchery programs throughout the state, Eel River salmonid stocks were sometimes supplemented with brood stock raised outside the basin, also with limited success. External sources of eggs, fry, and planted fish include Battle Creek, Mill Creek, and McCloud River in the Sacramento River system, Prairie Creek (Redwood National Park), Klamath River, Mad River, Gibson Creek in the Russian River watershed, and some eggs from the Washougal watershed in Oregon and Washington.

Historically, there were five small hatchery operations in the Eel River Basin (Leitritz 1970, S. Downie, CDFW, personal communication, 2014).

1) Price Creek Hatchery produced Chinook and steelhead, and operated from 1897-1916 on the lower mainstem Eel River (RM 12). The hatchery was unsuccessful in obtaining ripe eggs from Eel River Chinook or steelhead, so the first eggs were shipped from Battle Creek in Shasta County. In 1902, steelhead from this hatchery were the first fish of this species planted in the state. The hatchery was moved upstream to Steelhead Creek near Fort Seward (RM 65) in 1916, mainly due to the inadequate egg source, but also to high sediment loads and warm water temperatures at the Price Creek location.
2) Fort Seward Hatchery produced steelhead, and operated from 1916-1942 on the lower mainstem Eel River at RM 65. This location was selected for its improved water supply and better transportation system with the NW Pacific railroad line. Still, in 1938, it was recommended that the facility be dismantled and a new one built, but the hatchery continued to operate until 1942, when it was determined to be of limited effectiveness and was closed.
3) Cedar Creek Hatchery (known as the Cedar Creek Experimental Station from 1949-1950) produced coho and steelhead from 1949-1964, and was located approximately 1 mile south of Leggett at the confluence of Cedar Creek and the SF Eel River (RM 70). Large floods periodically disrupted operations, with extensive damage sustained in 1955 (*Figure 55*). After the 1955 flood, the hatchery resumed operations and by 1956, there were approximately 500,000 young steelhead in rearing ponds (Leitritz 1970).
4) Van Arsdale Fisheries Station (VAFS) was formerly the Snow Mountain Egg Collecting Station, established in 1907 and located at Cape Horn Dam on the mainstem Eel River (RM 157). Steelhead and Chinook eggs were collected at VAFS for only two periods of hatchery operations: steelhead stock rescue spawning occurred from 1970-1996,

and Chinook yearlings were planted from 1996-2003. This facility is no longer operating as a hatchery, but Chinook and steelhead adults are still counted annually (http://www.pottervalleywater.org/van_arsdale_fish_counts.html). Coho salmon have been recorded infrequently at the facility with 47 trapped in the 1946-47 season, one in the 2000-01 season, and 4 in the 2001-02 season. Steelhead and Chinook numbers were strongly influenced by these hatchery operations, and mainstem Eel River counts from VAFS do not necessarily reflect population trends in the SF Eel River.

5) Yager Creek Hatchery, operated by Pacific Lumber Company (PALCO), was originally established in 1972 and consisted of rearing ponds at Scotia on the mainstem Eel River (RM 21). The facility at Yager Creek, a tributary to the Van Duzen River, was built in 1976, and two satellite facilities were constructed in 1993 on SF Yager Creek and Corner Creek. These facilities produced Chinook and steelhead until 1995.

Figure 55. Damage from 1955 flood at Cedar Creek Hatchery, located at the confluence of Cedar Creek and the SF Eel River (RM 70).

Smaller cooperative fish rearing facilities, which were private or community-operated rearing ponds that produced broodstock from non-hatchery returning adults, were located in a small number SF Eel River tributaries.

The Salmon Restoration Association (Fort Bragg) operated the Hollow Tree Creek Egg Collecting and Rearing Station (also known as Hollow Tree Hatchery), located approximately 9 miles upstream from the confluence of the SF Eel River, from 1979-2002. This operation had an estimated capacity of 150,000 Chinook smolts (Sommarstrom 1984). Coho salmon were also spawned there during three separate years, and the eggs were transported to a tributary to Big River in Mendocino County, Warm Springs Hatchery, and the Leggett Rearing Ponds (CDFG 1994).

The Rotary Club of Garberville operated the Sproul Creek Rearing Ponds, located at RM 66 on the mainstem Eel River, from 1980-1986. This operation had an estimated capacity of 25,000 steelhead smolts (Sommarstrom 1984).

Smaller satellite rearing pond operations were located throughout the basin in Albee Creek, Redwood Creek (Redway), Dinner Creek, SF Salmon Creek, Sproul Creek (mainstem by the mouth and later moved to the mouth of Little Sproul Creek), and upper SF Rattlesnake Creek (H. Vaughn, personal communication, 2014). All of these operations were small and somewhat ineffective at producing salmonids (S. Downie, CDFW, personal communication, 2014). Currently, there are no active fish hatchery or egg collecting operations in the SF Eel River Basin.

Habitat Overview

Freshwater and estuarine habitat degradation and loss have been identified as the leading factors in the decline of anadromous salmonids (Murphy 1995, Gregory and Bisson 1997, CDFG 2002, Yoshiyama and Moyle 2010). Thus, widespread declines in California, including the SF Eel River, of Chinook and coho salmon, and steelhead trout are likely linked to their sensitivity to degradation of specific habitat components necessary to complete the freshwater and/or estuarine phase of their life cycle. Because steelhead tolerate a wider range of habitat conditions than the other anadromous species, they are more widely distributed in the SF Eel River Basin and have persisted in streams where other species have declined or are now rarely observed.

In order to meet the needs of all life stages of anadromous salmonids, the SF Eel River Basin must provide the following conditions: appropriate diverse stream flow regimes; suitable water quality; high quality gravel substrate for spawning and egg incubation; suitable instream and riparian conditions; and adequate food supplies in fish bearing streams throughout the watershed. High quality instream and riparian habitat is especially important for coho salmon and steelhead, because they spend a year or more rearing in streams (*Figure 56*).

Historic land use activities, particularly timber harvest and rural residential development, have resulted in modifications to natural stream channels and conditions. The most notable changes affecting fish have been in elevated stream temperatures, reduced flow regimes, and increased sediment input rates and volumes. These changes from historic stream conditions have resulted in reduced salmonid habitat quality and quantity.

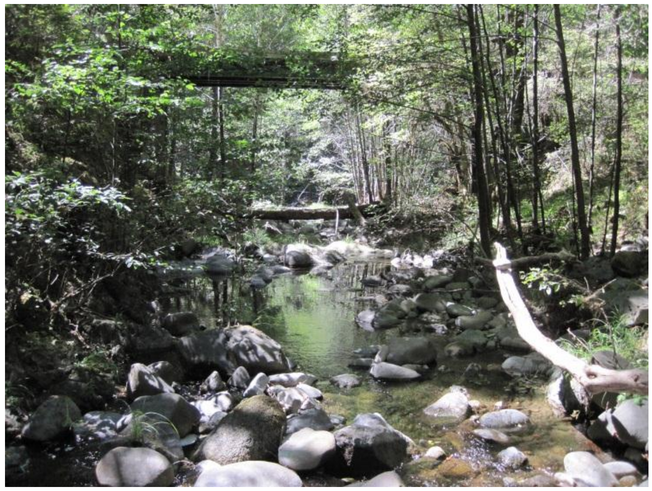


Figure 56. Example of high quality riparian and instream habitat in Elder Creek, located in the SF Eel River headwaters.

Identifying salmonid life history strategies at basin and regional scales provides clues to the range of stream conditions and environmental requirements for fish. Salmonids display a range of behavioral patterns that are a product of their habitat and abundance trends; the more diverse a population is, the more likely the species will survive and reproduce as environmental conditions change (McElhaney et al. 2000). Some species or life history strategies may already be lost or rarely observed in the SF Eel River Basin due to changing stream conditions.

By gaining insight into the relationships between diverse life history strategies, fishery population dynamics and status, and by accurately assessing stream habitat condition, fisheries biologists and managers can design and direct restoration efforts that will lead to the recovery of salmonid populations.

Historic Conditions

Habitat and fish distribution/abundance data have been collected in SF Eel River Basin streams since the 1930s. Observations were originally collected and recorded in memorandum format, with no established methodology. Beginning in the 1950s, CDFG used a standard stream survey form to record data, but it was not until the early 1990s that a standard habitat inventory protocol was developed by Flosi et al. (first edition published in 1991). This protocol, the *California Salmonid Stream Habitat Restoration Manual*, 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.

There are approximately 450 tributaries that feed into the SF Eel River and habitat surveys or other types of surveys where specific habitat information was collected were conducted on 114 of those creeks between 1938 and 1990 (*Table 33*). Some creeks were surveyed in multiple years, or different reaches were studied, for a total of 332 surveys. The results of past stream surveys were not quantitative and cannot be used in comparative analyses with current habitat inventories; however, they do provide a description of habitat conditions at the time of the survey.

Table 33. Historic habitat surveys by decade in the SF Eel River Basin.

Years	Northern Subbasin	Eastern Subbasin	Western Subbasin	Mainstem
1930s	Bridge, Bull, Canoe, Cuneo, Elk, and Ohman creeks.	Big Dan, Cedar, Dean, Elder, Mad, McCoy, Milk Ranch, Rancheria, Rattlesnake, Ray's, Red Mountain, Rock, Rattlesnake, Fox, Squaw, Tenmile creeks, and East Branch SF Eel River.	Durphy, Dutch Charlie, Indian, Leggett, Low Gap, Piercy, Redwood (Branscomb), Redwood (Redway), Sawmill, Sommerville, and Sproul creeks.	SF Eel River
1940s		Cedar, McCoy, and Tenmile creeks.	Hollow Tree, Little Sproul, and Sproul creeks.	SF Eel River
1950s	Bridge, Elk, and Ohman creeks.	Cahto, Cedar, and Mud creeks.	Jack of Hearts Creek	SF Eel River
1960s	Anderson, Butte, Bridge, Bull, Cabin, Connick, Coon, Cow, Elk, Feese, Mowry, and Ohman creeks.	Bear, Big Dan, Cahto, Cedar, Cummings, Dean, Elder, Elk, Fish, Grapewine (Grapevine), Grizzly, Grub, Horse Pasture, Little Cedar, Little Dan, Mad, McCoy, Milk Ranch, Mill (Laytonville), Mud, Rancheria, Rattlesnake, Ray's, Red Mountain, Rock, Rocky Glen, Little Rock, Windem, Squaw, Streeter, Taylor, Tuttle, Twin Rocks, Williams creeks, and East Branch SF Eel River.	Anderson, Bear Pen, Butler, China, Dinner, Durphy, Dutch Charlie, Hartsook, Hollow Tree, Hooker, Indian, Jack of Hearts, La Doo, Leggett, Little Low Gap, Little Sproul, Low Gap, Lynch, Michael's, Piercy, Redwood (Branscomb), Redwood (Hollow Tree), Redwood (Redway), Sawmill, Section Four, seely, Sommerville, Sproul, Standley, Waldron, Warden, Wildcat creeks, and SF Eel River UT (Benbow).	
1970s	Albee, Anderson, Butte, Bridge, Canoe, Cow, Dry, Fish, Mill (tributary to Bull), and Squaw creeks.	Bear, Big Dan, Cedar, Cummings, Elder, Elk, Fish, Grapewine (Grapevine), Grizzly, McCoy, Mill (Laytonville), Misery, Mud, Paralyze Canyon, Rattlesnake, Rock, Taylor, Tenmile, Tom Long creeks, and East Branch SF Eel River.	Anderson, Butler, Dutch Charlie, Jack of Hearts, Leggett, Low Gap, Lynch, Piercy, Redwood (Branscomb), Redwood (Redway), Section Four, Standley, and Surveyors Canyon creeks.	

Years	Northern Subbasin	Eastern Subbasin	Western Subbasin	Mainstem
1980s	Albee, Butte, Bridge, Bull, Burns, Cabin, Calf, Canoe, Connick, Coon, Corner, Cow, Cuneo, Dry, Elk, Feese, Fish, Harper, Kerr, Mill (tribs to Bull, Salmon, and SF Eel), Mowry, Ohman, Panther, Slide, and Squaw creeks.	Bear Canyon, Dean, Low Gap, Milk Ranch, Rocky Glen, Squaw, and Tom Long creeks.	Butler, China, Dinner, Durphy, Hartsook, Hollow Tree, Indian, Leggett, Little Sproul, Low Gap, Michael's, Redwood (Hollow Tree), Redwood (Redway), Sawmill, Sproul, Warden, and WF Sproul creeks.	SF Eel River

Summary tables of historic habitat conditions appear in the subbasin sections of this report. In general, surveys described a range of habitat conditions. Most of the earliest stream surveys were conducted in the late 1930s and generally indicated good spawning and rearing conditions. Unstable geology, intensive timber harvest, and road building associated with multiple land use activities resulted in an increase in fine sediments, reduction in suitable spawning areas, and increased temperatures due to reduced riparian cover and fewer deep pools over time. Many surveys conducted in the 1970s and 1980s included recommendations to remove wood from streams; log jams were often a result of increased logging debris loaded into Eel River streams by the 1955 and 1964 flood events, particularly in Northern and Western Subbasin streams. These jams were perceived to impede fish passage and trap sediment in the channels.

The two major flood events in the SF Eel River Basin occurred in 1955 and 1964, both during the month of December. These events modified instream and riparian habitats significantly, resulting in increased sedimentation (particularly in areas with unstable geology and high road densities), widening of streams, and increases in large and small woody debris input. Many historical habitat surveys noted specific changes to streams and riparian areas following these large flood events. Summaries of habitat conditions from historical surveys are included in subbasin sections of this report.

Current Conditions

CDFW habitat typing crews completed surveys on 118 streams in the SF Eel River Basin between 1990 and 2010, and most streams were surveyed at least twice within that time frame. For example, Butte Creek in the Northern Subbasin was surveyed in 1993 and again in 2007. Habitat survey data were compared to target values defined in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 2010) to determine if habitat conditions within the streams are limiting to salmonid production. Data collected during these habitat inventories describe canopy density, cobble embeddedness of pool tails, length of primary pools, and mean pool shelter coverage along surveyed reaches within the SF Eel Basin (*Table 34*). CWPAP staff evaluated these habitat 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 34* and are 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 survey. Detailed tributary analysis results are presented in the subbasin sections.

Table 34. Summary of CDFW habitat inventories conducted between 1990-1999 and 2000-2010 in SF Eel River streams and subbasins, with associated target values (Flosi et al. 2010).

Subbasin	Survey Length (miles)	Total # Pools	Mean Canopy Density (%)	Length of Primary Pools (%)	Pool Shelter Rating	Category 1 Pool Tail Cobble Embeddedness (%)
TARGET VALUES			>80	>40	>100	>50
1990-1999						
Northern	34.52	822	50.52	5.36	43.02	7.78
Eastern	35.46	759	57.01	42.16	69.08	10.50
Western	85.70	2669	64.69	12.50	43.47	12.67
SF Eel River Basin	155.68	4250	59.80	16.42	49.20	12.40
2000-2010						
Northern	35.05	883	75.89	7.02	49.43	33.39
Eastern	41.85	813	68.70	14.78	27.02	28.49
Western	101.55	3194	88.40	14.53	36.36	34.36
SF Eel River Basin	178.45	4974	81.32	13.22	36.74	32.79

Habitat surveys were divided into two groups: those conducted between 1990 and 1999, and those conducted between 2000 and 2010. Data were analyzed separately and results from these two time periods were used to assess current habitat suitability (using 2000-2010 data) and to gain an understanding of how conditions may be changing over time (by comparing 1990-1999 and 2000-2010 suitability scores).

The number of reaches and the total stream length surveyed varied by stream (*Table 35*). 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.

Surveys in the same creek on more than one year in the same time period (e.g. Hollow Tree and Standley creeks) that were completed in different sections of the stream were treated as individual surveys. If multiple surveys were completed in a creek in the same time period and in the same reaches (e.g. Fish Creek 1993 and 1999), only the most recent survey data were used in the analyses to reflect the most current conditions. Only habitat typing surveys completed on perennial streams were used in the analyses. However, some perennial streams contain dry reaches during certain times of the year (usually in late summer) due to variation in annual precipitation, natural aquifer levels, and magnitude of diversion. These dry reaches were categorized as Type 7 (Flosi et al. 2010) in habitat typing reports.

Streams that were surveyed during both time periods were often completed at different times of the year (e.g. Butte Creek was surveyed in October in 1993 but in June in 2009). 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 SF Eel River Basin (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. Annual peak and average flow in the SF Eel River were very high in 1998 and 2006, and very low in 1991 and 2001 (*Figure 11*).

Surveys completed on the same stream in both time periods may also show changes 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.

The Western Subbasin had the highest number of streams surveyed (n = 43), and the longest total length of stream miles surveyed (187.3 miles) of the three subbasins (*Table 35*). Eighteen streams (69.6 miles) were surveyed in the Northern Subbasin and 10 streams (77.4 miles) were surveyed in the Eastern Subbasin. The mainstem SF Eel River is the dividing line between the Eastern and Western subbasins, and surveys completed in the upper mainstem reaches were analyzed with Western Subbasin streams due to similarities in geography, geology, climate patterns, aspect/exposure, vegetation, and land use.

Table 35. CDFW habitat surveys in the SF Eel River Basin by subbasin and by sampling interval for surveys used in habitat suitability analyses (2000-2010 and 1990-1999). UN = unnamed.

2000-2010 Habitat Surveys (17 streams, total length = 35.1 miles)			
NORTHERN Subbasin Streams	**Date**	**# Reaches**	**Survey Length (mi.)**
Bridge Creek	June 2007	2	0.98
Bridge Creek (UN tributary)	June 2007	1	0.12
Bull Creek	July 2007	6	9.66
Butte Creek	June 2009	4	1.38
Canoe Creek	June 2007	3	1.86
Coon Creek (tributary to SF Eel)	June 2007	1	1.09
Cow Creek	June 2007	3	1.03
Decker Creek	July 2010	2	0.60
Elk Creek	July-August 2007	6	4.14
Elk Creek (UN tributary #7)	August 2007	1	0.21
Fish Creek	August 2007	2	1.04
Harper Creek	June 2007	2	0.89
Mill Creek (tributary to Bull)	June 2007	4	1.18
Mill Creek (tributary to Salmon)	July 2009	1	0.52
Ohman Creek	July 2007	1	0.33
Salmon Creek	October 2007	4	7.28
Squaw Creek	July 2010	3	2.74

1990-1999 Habitat Surveys (13 streams, total length = 34.5 miles)			
NORTHERN Subbasin Streams	**Date**	**# Reaches**	**Survey Length (mi.)**
Bridge Creek	June 1993	2	0.98
Bull Creek	June-July 1991	11	13.43
Butte Creek	October 1993	3	1.66
Canoe Creek	June 1992	3	3.31
Coon Creek (tributary to SF Eel)	July 1993	1	0.65
Cow Creek	July 1991	2	0.63
Decker Creek	June 1992	3	0.79
Elk Creek (tributary to SF Eel)	July-August 1992	1	3.53
Fish Creek	June 1999	1	2.36
Harper Creek	July 1991	2	0.91
Mill Creek (tributary to Bull)	July 1991	2	0.76
Ohman Creek	October 1992	1	0.28
Salmon Creek	July-August 1992	3	5.24

2000-2010 Habitat Surveys (10 streams, total length = 41.9 miles)			
EASTERN Subbasin Streams	**Date**	**# Reaches**	**Survey Length (mi.)**
Bear Canyon Creek	June 2009	3	1.44
Bear Canyon Creek (SF)	June 2009	3	0.81
Big Rock Creek	July 2009	2	3.98

1990-1999 Habitat Surveys (9 streams, total length = 35.5 miles)			
EASTERN Subbasin Streams	**Date**	**# Reaches**	**Survey Length (mi.)**
Bear Canyon Creek	June 1999	2	1.40
Bear Canyon Creek (SF)	June 1999	1	0.30
Big Rock Creek	July-August 1994	2	3.95

EASTERN Subbasin Streams (con.)	Date	# Reaches	Survey Length (mi.)
Cahto Creek	July 2009	2	3.06
Kenny Creek	October 2005	3	2.57
McCoy Creek	October 2007	2	4.60
Milk Ranch Creek	July 2007	2	1.51
Mud Creek (tributary to SF Eel)	August 2007	5	4.25
Streeter Creek	July 2009	1	0.92
Tenmile Creek	June-July 2009	12	18.71

EASTERN Subbasin Streams	Date	# Reaches	Survey Length (mi.)
Cahto Creek	July 1996	1	3.97
Kenny Creek	July 1996	2	3.65
McCoy Creek	July 1995	2	4.19
Milk Ranch Creek	July 1993	2	0.80
Mud Creek (tributary to SF Eel)	August-September 1996	1	1.45
Tenmile Creek	September-October 1996	6	15.76

2000-2010 Habitat Surveys (43 streams, total length = 101.55 miles)			
WESTERN Subbasin Streams	**Date**	**# Reaches**	**Survey Length (mi.)**
Anderson Creek	September-October 2008	2	2.29
Bear Pen Creek	July-August 2007	3	2.82
Bear Wallow Creek	September-October 2002	3	2.14
Bond Creek	June-July 2003	5	2.63
Butler Creek	September 2002	1	1.43
Butler Creek (UN left bank tributary)	September 2002	1	0.29
China Creek	June 2009	1	2.20
Cox Creek	August-September 2004	1	1.29
Doctors Creek	July 2003	1	0.30
Durphy Creek	August-September 2006	2	1.76
Durphy Creek Tributary	September 2006	1	0.49
Dutch Charlie Creek	July-August 2007	3	2.88
Hartsook Creek	June 2009	2	1.32
Hollow Tree Creek	October 2002	2	1.89
	June-July 2003	1	3.44
Huckleberry Creek	September 2002	5	1.48
Indian Creek	September-October 2008	4	9.75
Jack of Hearts Creek	October 2005	1	3.07
Leggett Creek	September 2007	1	3.25
Low Gap Creek	September 2007	1	2.51
Lynch Creek	July 2003	1	0.19

1990-1999 Habitat Surveys (29 streams; total length = 85.7 miles)			
WESTERN Subbasin Streams	**Date**	**# Reaches**	**Survey Length (mi.)**
Bear Pen Creek	July-August 1992	1	3.38
Bear Wallow Creek	June 1990	1	1.41
Bond Creek	July-October 1991	5	1.83
Butler Creek	July 1990	2	1.22
China Creek	June 1998	2	2.87
Cox Creek	June-July 1993	1	1.22
Doctors Creek	July 1991	1	0.16
Durphy Creek Tributary	June 1993	1	0.43
Dutch Charlie Creek	September 1992	3	3.55
Hartsook Creek	June 1999	1	1.25
Hollow Tree Creek	July 1992	1	14.82
Huckleberry Creek	July-August 1990	1	1.18
Indian Creek	June-July 1993	2	11.15
Jack of Hearts Creek	June and October 1992	1	2.88
Leggett Creek	June 1995	1	2.31
Little Sproul Creek	June 1995	1	1.66
Low Gap Creek	July 1990	4	2.71
Lynch Creek	July 1991	1	0.31
Michaels Creek	July 1991	1	1.75
Moody Creek	July 1993	1	1.65
Pollock Creek	June 1998	1	2.04

WESTERN Subbasin Streams (con.)	Date	# Reaches	Survey Length (mi.)
Michaels Creek	June-July 2003	2	2.60
Mill Creek	September 2010	1	0.33
Moody Creek	September-October 2008	1	1.74
Piercy Creek	October 2007	2	2.21
Pollock Creek (Upper Redwood)	June-July 2009	3	2.68
Redwood (Hollow Tree)	June-July 2003	4	1.99
Redwood Creek (Branscomb)	July 2007	2	2.43
Redwood Creek (Redway)	June-July 2009	3	7.43
SF Eel River Headwaters	August 2007	1	5.38
SF Redwood Creek	July 2003	2	1.86
SF Redwood Creek (UN tributary)	July 2003	1	0.19
Sproul Creek	August 2004	4	6.15
Sproul Creek (tributary 5)	August 2004	1	0.48
Standley Creek	October 2007	2	3.04
	September-October 2009	1	1.91
Twin Creek (UN tributary to China)	June 2009	1	0.54
Waldron Creek	August 2002	3	1.44
Warden Creek	July 2004	2	0.38
WF Sproul Creek	July-August 2004	3	5.04
WF Sproul Creek (tributary 8)	August 2004	1	0.55
WF Sproul Creek (tributary 9)	August 2004	1	1.54
Wildcat Creek	July-August 2007	1	2.31
Wood Creek	September 2002	2	0.99

WESTERN Subbasin Streams	Date	# Reaches	Survey Length (mi.)
Redwood Creek (Branscomb)	November 1993	2	2.43
SF Eel River Headwaters	August 1996	1	9.06
SF Redwood Creek	July 1991	1	1.68
Standley Creek	July-August 1992	1	3.10
Waldron Creek	July and October 1991	1	1.38
Warden Creek	October 1992	2	0.38
WF Sproul Creek	October 1992	1	5.52
Wildcat Creek	August-September 1992	2	2.37

Overall Habitat Suitability

Four factors (canopy density, pool depth, pool shelter complexity, and substrate embeddedness) were used in the EMDS-based analysis to determine overall habitat suitability using habitat typing data collected from two separate time periods: 1990 to 1999, and 2000 to 2010. Suitability scores were calculated by assessing how measured values compared to target values for each factor. Overall habitat suitability and suitability of each factor used in the analysis were calculated based on a weighted (by reach or stream length surveyed) average for each subbasin in each time period, and the change in suitability values between time periods was compared for streams and reaches in each of the three subbasins, and in the entire SF Eel River Basin. The Basin Overview section presents habitat suitability information and analysis results on a subbasin scale, and suitability by streams is addressed in individual subbasin sections.

Suitability scores calculated from factor values ranged between +1 and -1, and were divided into four categories:

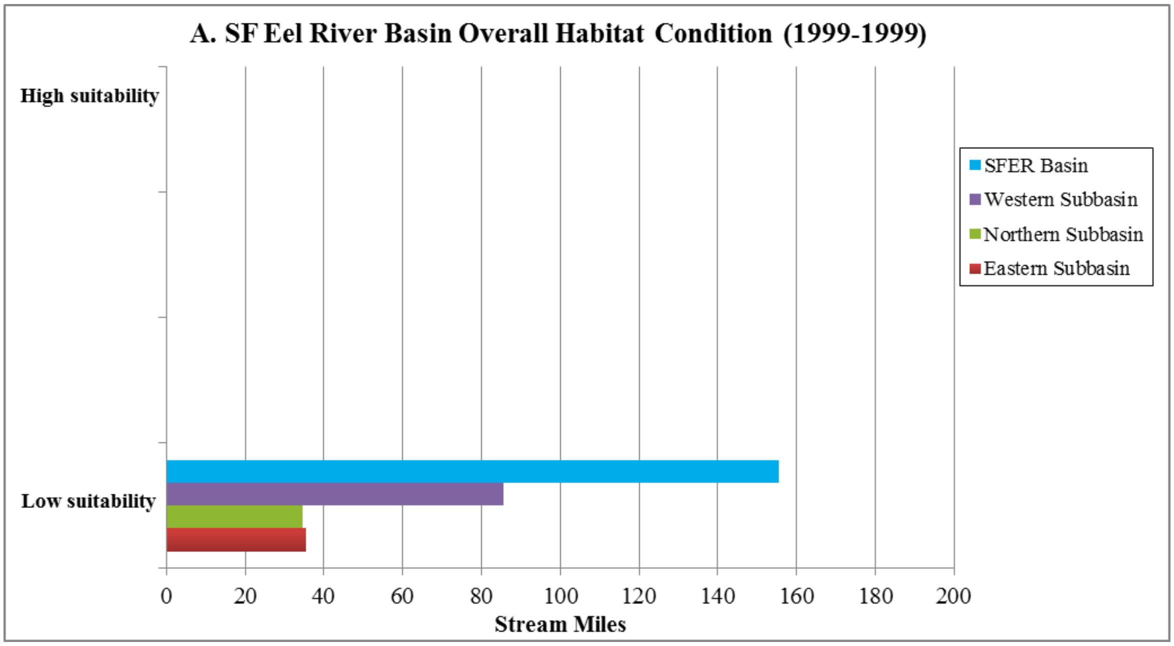
- 1.00 - 0.50 (high suitability);
- 0.49 - 0;
- -0.01 - -0.49; and
- -0.50 - -1.00 (low suitability).

For a detailed discussion of the analysis framework and calculation of suitability scores, see the Analysis Appendix.

Overall suitability improved between the 1990s and early 2000s in the Northern and Western subbasins, and in the entire SF Eel River Basin (*Table 36*). Increases were due primarily to improved embeddedness scores in both subbasins and in the basin over time. Eastern Subbasin overall suitability scores were lower in 2000-2010 than in 1990-1999, and were in the lowest suitability category (-0.5 - -1.0) during both sampling periods (*Figure 57 A*, *B*). Reduced suitability in the Eastern Subbasin is primarily due to a decrease in pool shelter complexity scores between the two sampling periods, which resulted in low pool quality scores; the influence of each factor on overall suitability and changes in specific factor scores will be discussed further in the individual factor sections of this report. Although most factor suitability scores improved over time, overall suitability was low (negative) in all subbasins and in the basin as a whole during both sampling periods.

Table 36. Overall habitat suitability scores, average suitability scores of individual factors included in the analysis, and stream miles surveyed in SF Eel River Basin and subbasins between 1990-1999 and 2000-2010.

1990-1999	**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**
Northern Subbasin	34.52	-0.74	-0.34	-0.96	-0.52	-0.63	-0.58
Eastern Subbasin	35.46	-0.56	-0.05	0.52	0.12	0.16	-0.53
Western Subbasin	85.70	-0.75	0.06	-0.71	-0.60	-0.62	-0.44
Total SFER Basin	155.68	-0.70	-0.06	-0.54	-0.42	-0.48	-0.49
2000-2010							
Northern Subbasin	35.05	-0.24	0.33	-0.99	-0.42	-0.76	0.20
Eastern Subbasin	41.85	-0.71	0.09	-0.58	-0.90	-0.76	0.03
Western Subbasin	101.55	-0.39	0.87	-0.61	-0.69	-0.64	0.15
Total SFER Basin	178.45	-0.38	0.58	-0.68	-0.70	-0.68	0.14



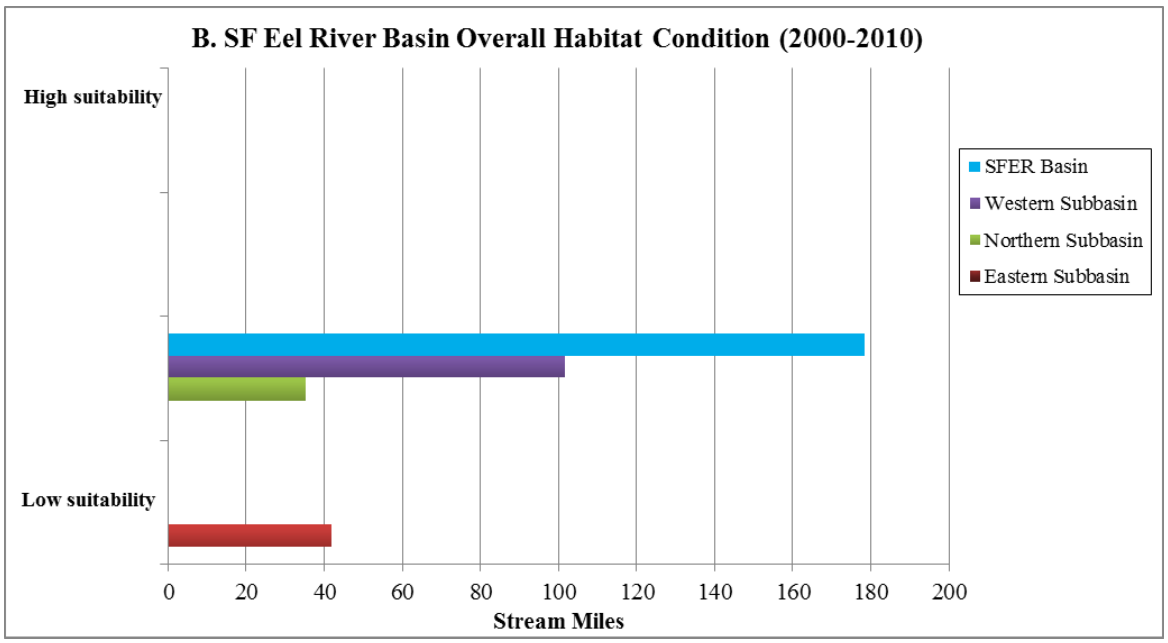


Figure 57 A, B. Overall habitat condition by stream miles surveyed for SF Eel River Basin and subbasin streams using habitat data collected from 1990-1999 (A) and 2000-2010 (B).

Overall suitability and suitability of each of the 4 factors used in the analysis was calculated for each reach sampled on each habitat typing survey, however, crews did not always sample the same reaches on the same creeks in each time period (*Figure 58*, *Figure 59*). In general, overall habitat suitability for salmonids increased in individual streams throughout the basin when comparing 1990-1999 data with 2000-2010 data.

Of the three subbasins surveyed, the Western Subbasin had the most miles of stream surveyed during both time periods, followed by the Eastern and Northern subbasins. The Eastern Subbasin is the largest of the three, but the Western Subbasin had the most documented fish presence and the largest number of tributary miles currently used by salmonids. Therefore, more habitat surveys were completed in Western Subbasin streams and subsequently more restoration projects were completed and more total project funding dedicated to projects in this subbasin compared to the Northern and Eastern subbasins (see the Fish Restoration

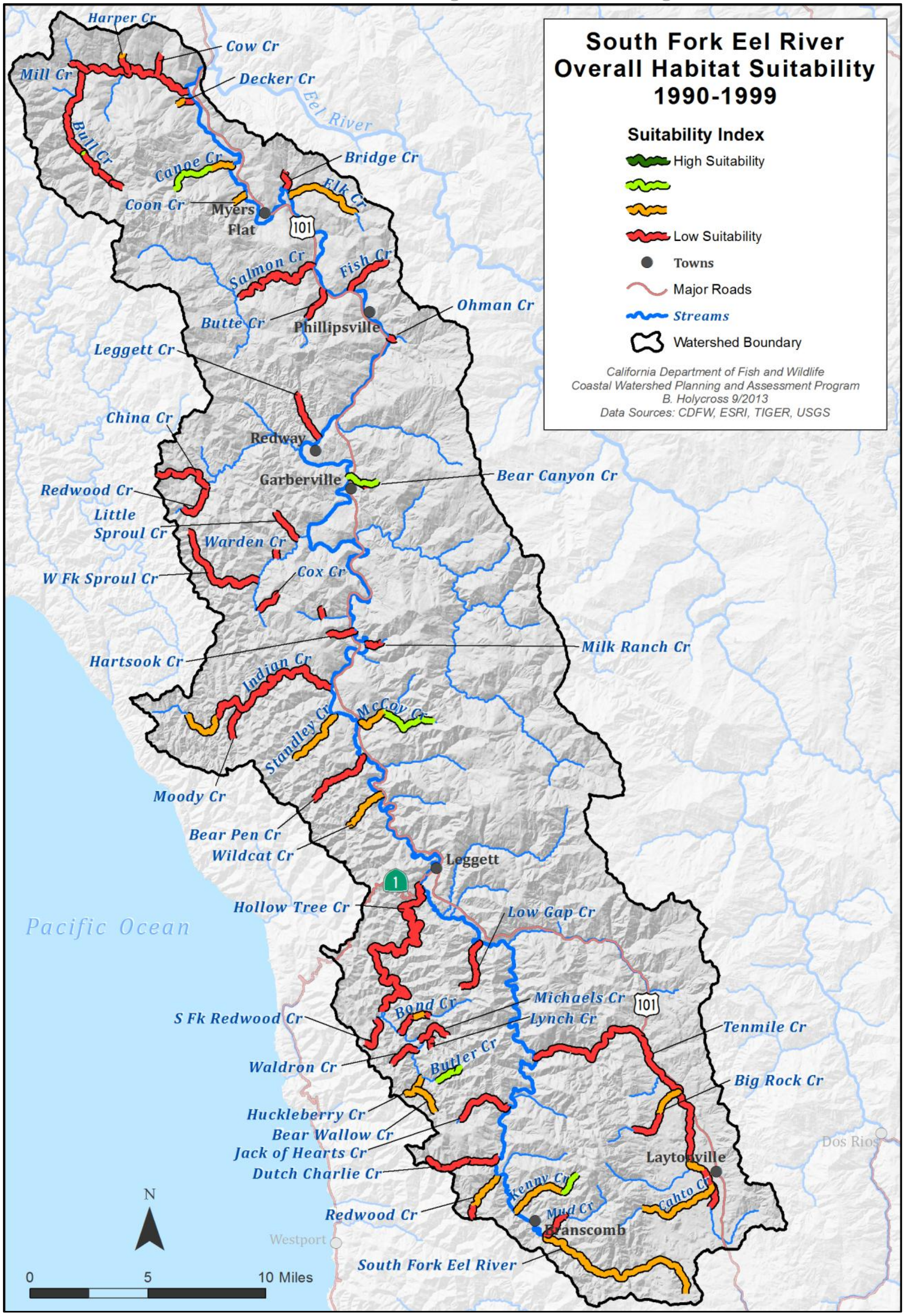


Figure 58. Overall suitability from habitat typing data collected between 1990 and 1999 in streams and reaches of the SF Eel River Basin, as determined by the EMDS-based analysis.

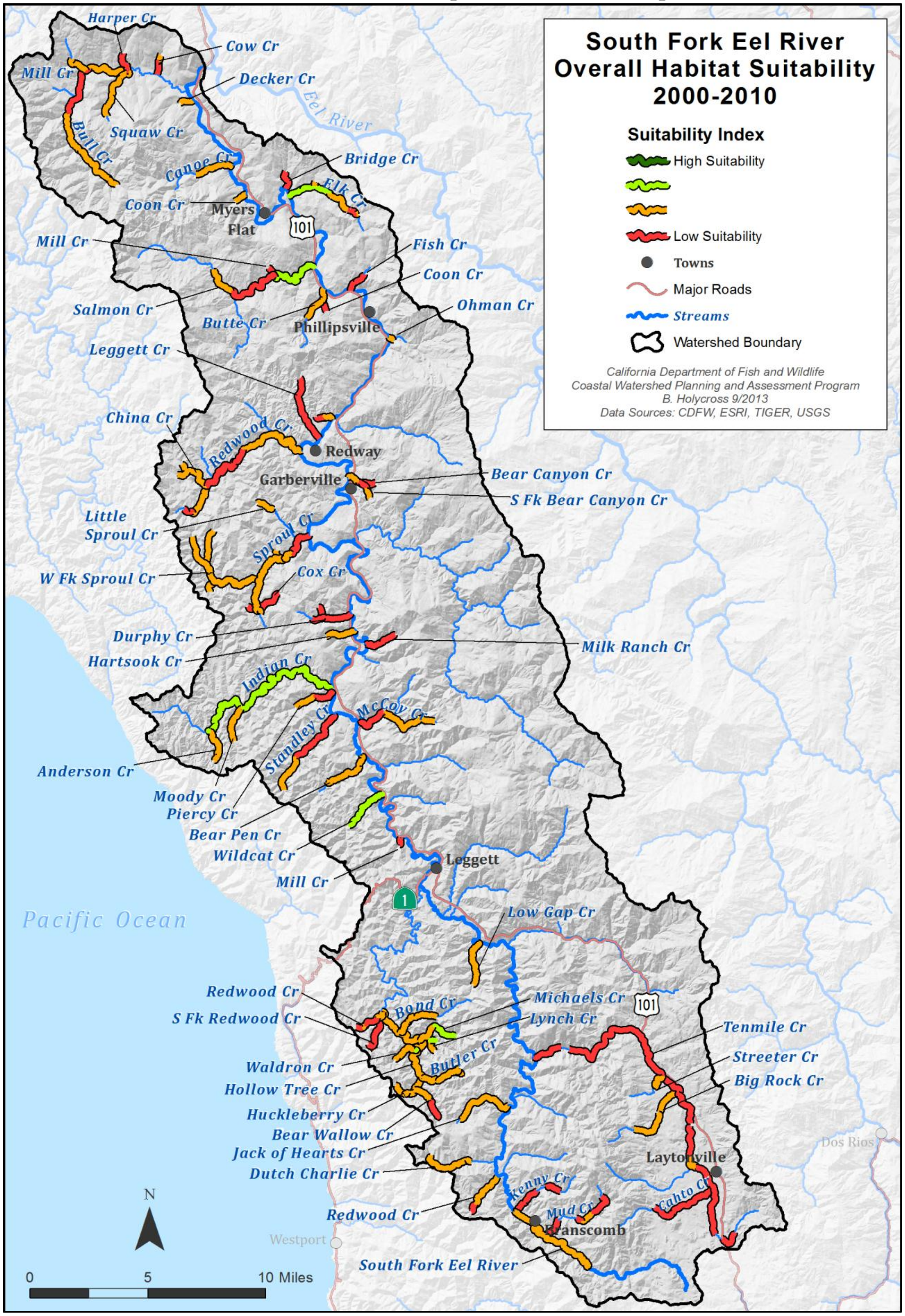


Figure 59. Overall suitability from habitat typing data collected between 2000 and 2010 in streams and reaches of the SF Eel River Basin, as determined by the EMDS-based analysis.

Programs section). Completed restoration projects and changes in some land use practices such as timber harvesting, with the potential to increase riparian canopy, reduce fine sediment delivery, and increase LWD recruitment to streams, may be responsible for an increase in suitability scores over time. However, other land use practices such as the illegal harvesting of marijuana and increased water diversion from streams may be keeping some suitability scores low, and may result in decreases in habitat suitability in the future when considering the same habitat factors.

Canopy

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* (Flosi et al. 2010) establishes a target of 80% for shade canopy along coastal streams. The CDFW recommends areas with less than 80% shade canopy as candidates for riparian improvement efforts.

Basin-wide canopy density improved over time in SF Eel River streams. Habitat surveys conducted between 1990 and 1999 recorded canopy density values below 50% in ten streams, three each in the Northern and Eastern Subbasin, and 4 in the Western Subbasin. Nineteen streams had canopy densities of 50-79%, and only 22 streams met the target value of 80% and were considered suitable (*Figure 60A*). Only one stream (Tenmile Creek, in the Eastern Subbasin) surveyed between 2000 and 2010 had canopy densities of less than 50%, and was evaluated as unsuitable in the analysis. Twelve streams surveyed during this time period had canopy densities of 50-79%, and 60 streams (67% of surveyed streams) met the target value of 80% measured canopy (fully suitable) (*Figure 60B*).

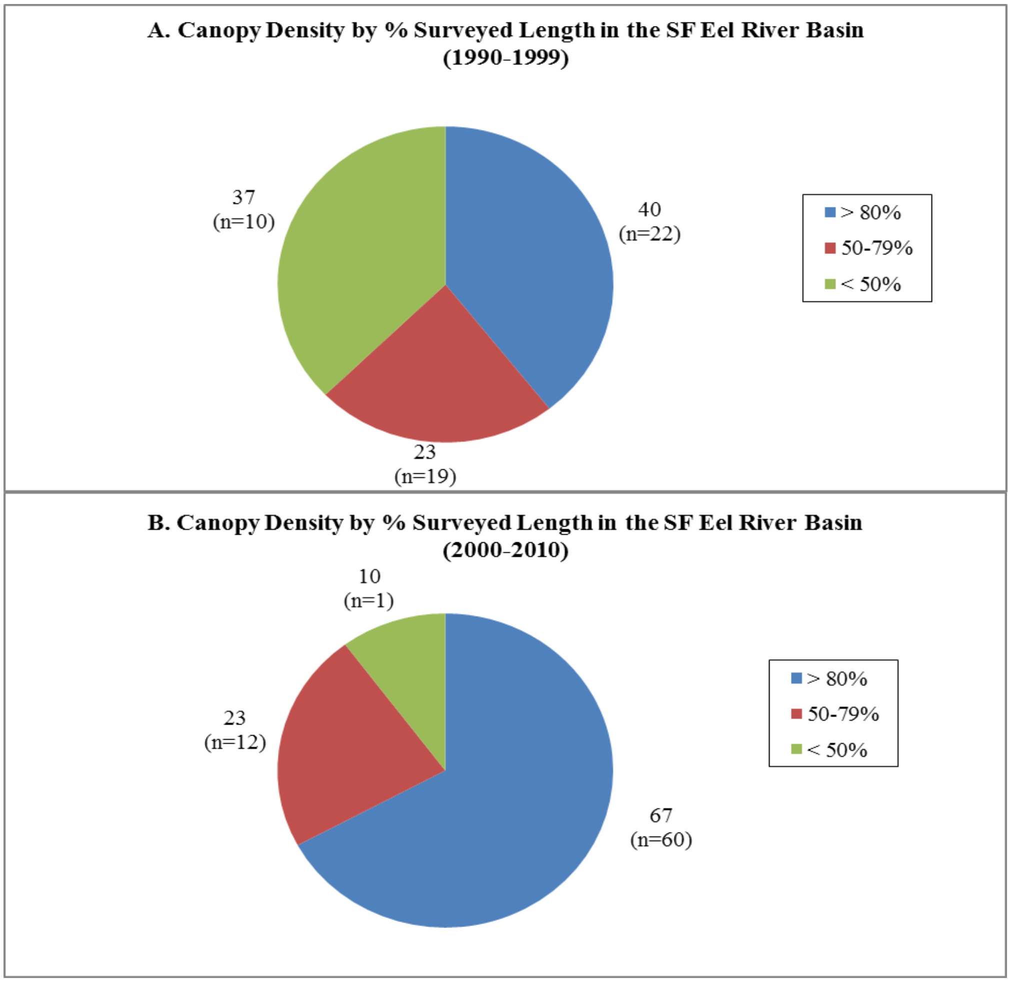


Figure 60A, B. Canopy density in the SF Eel River Basin in streams surveyed from 1990-1999 (A) and 2000-2010 (B); n = number of streams in canopy density range.

Overall canopy density suitability scores (weighted by reach and averaged for all streams in each subbasin) increased between the two time periods (*Figure 61 A, B*). Canopy density scores were higher than any other factor scores used in the analysis. Canopy density (riparian vegetation score) is evaluated with an "in channel score" (a combination of pool depth, pool complexity, and substrate embeddedness factors), at the final decision node where the lower of the two scores is used to indicate the potential of the stream reach to sustain salmonid populations (see Analysis Appendix). In SF Eel River 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.

Canopy density suitability scores were generally lower in all habitat typed reaches in SF Eel River Basin streams during the 1990s (*Figure 62*) than in the early 2000s (*Figure 63*). Many streams in the Northern and Western subbasins showed improved canopy density scores over time, and larger streams such as Bull Creek and Indian Creek showed significant improvement in many habitat typed reaches. Western Subbasin streams had the highest canopy density suitability values during the most recent sampling period.

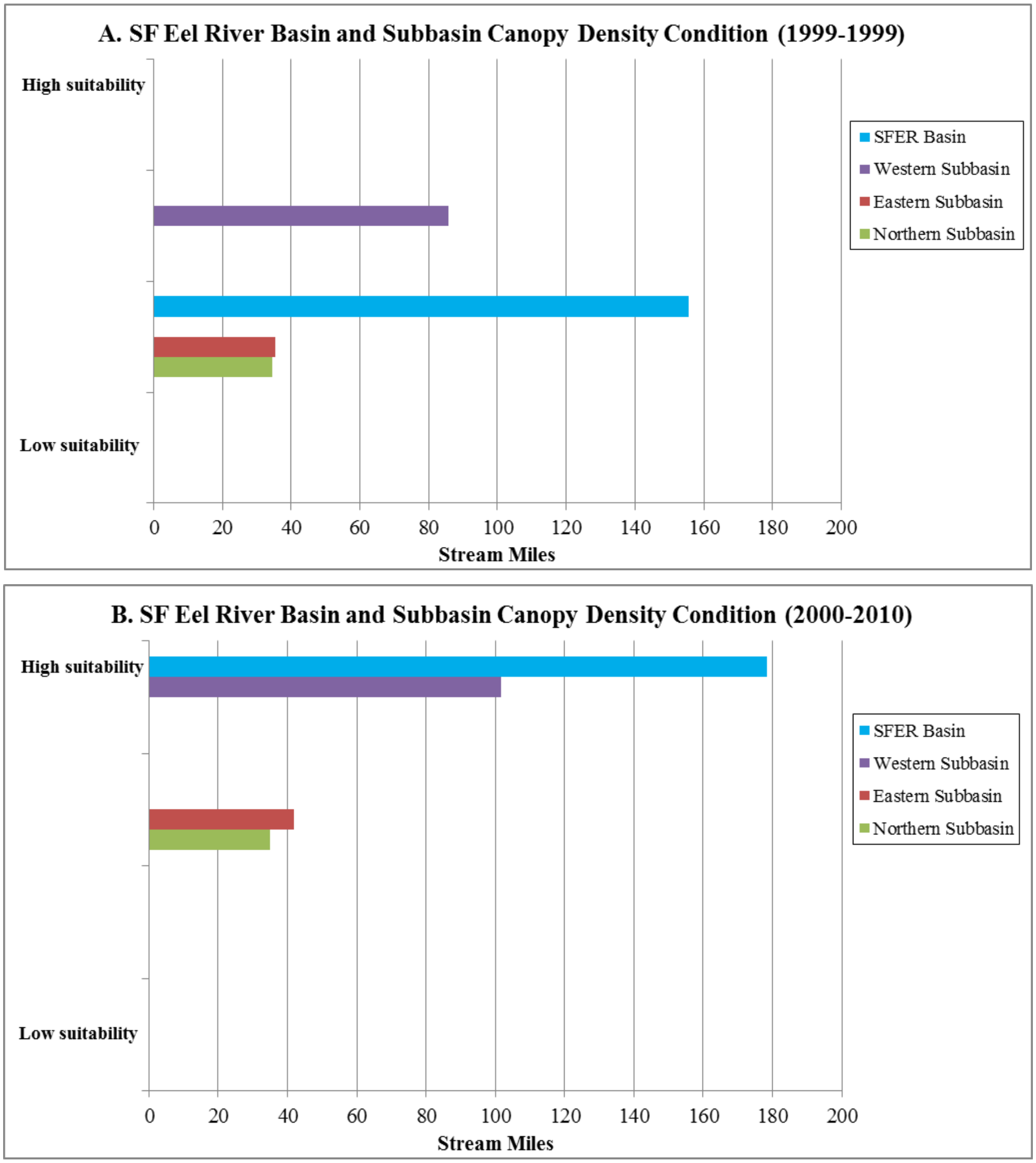


Figure 61 A, B. Canopy density condition by stream miles in the SF Eel River Basin and subbasins from 1990-1999 (A) and 2000-2010 (B).

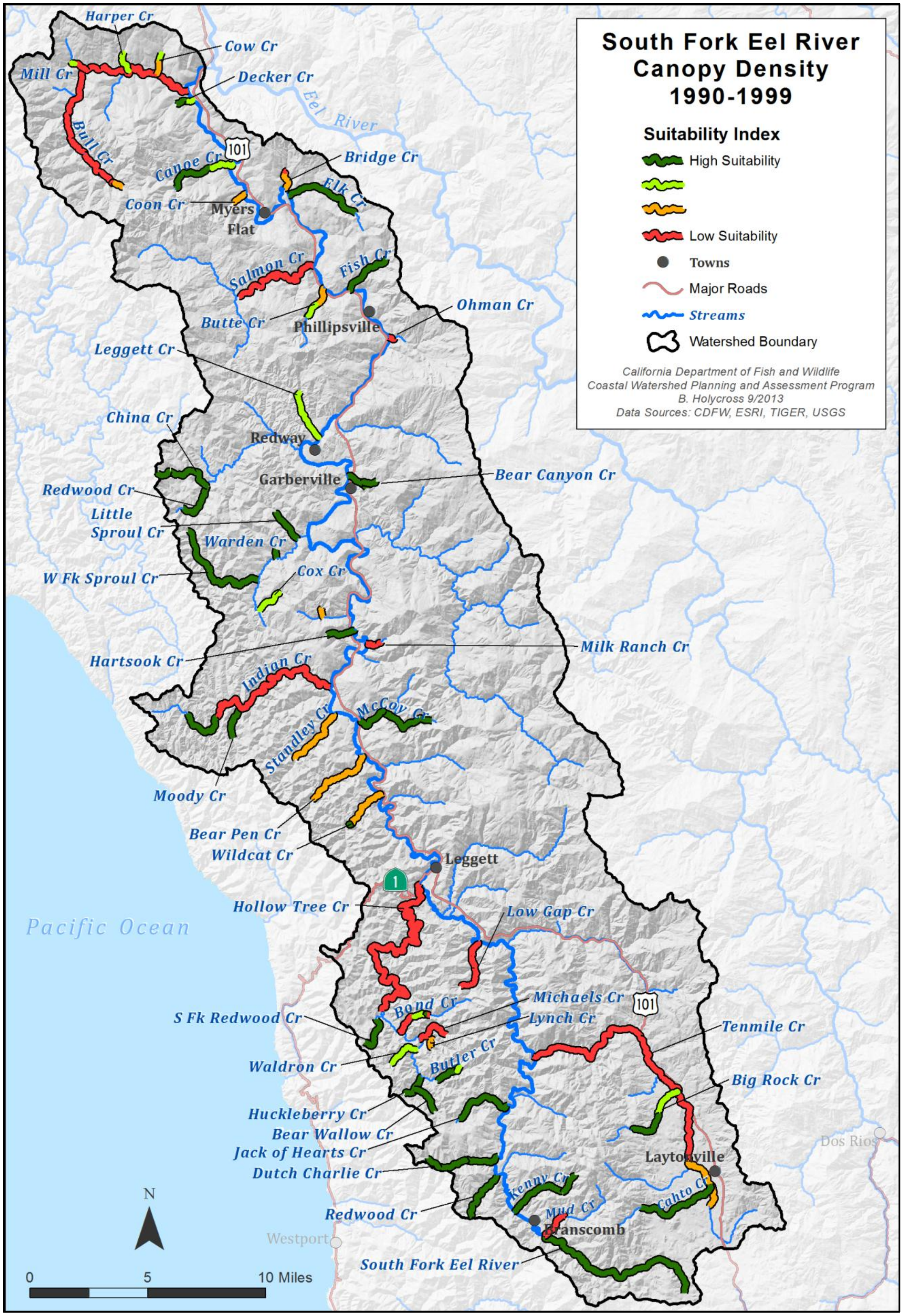


Figure 62. Canopy density suitability in SF Eel River Basin streams from habitat typing data collected between 1990 and 1999, as determined by the EMDS-based analysis.

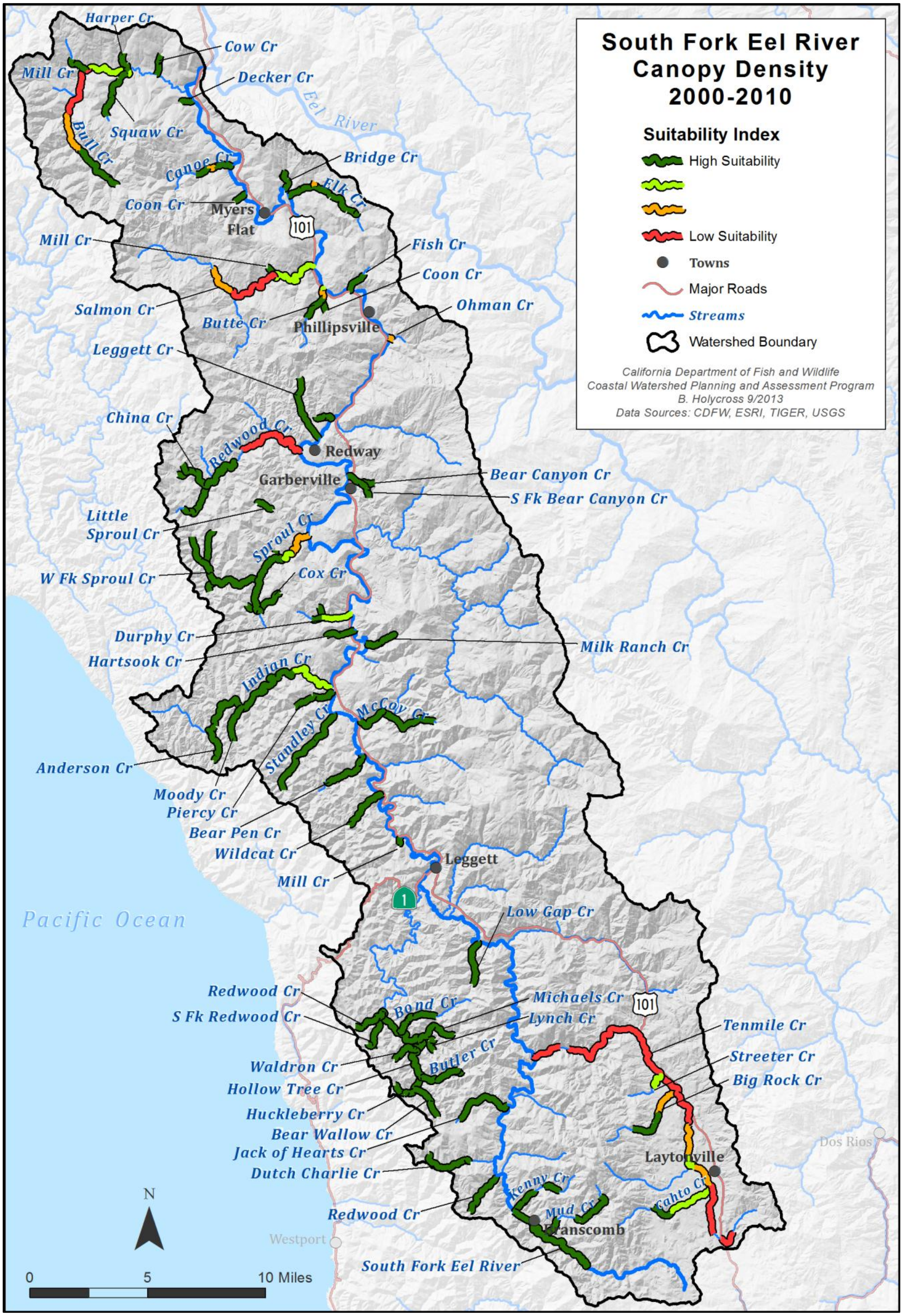


Figure 63. Canopy density suitability in SF Eel River Basin streams from habitat typing data collected between 2000 and 2010, as determined by the EMDS-based analysis.

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, but do not provide the LWD recruitment potential of larger, more persistent coniferous trees (Everest and Reeves 2006). In the SF Eel River Basin, the percent contribution of canopy density from coniferous and deciduous trees was estimated visually during habitat typing surveys.

The percent of both coniferous and deciduous canopy vegetation increased in all subbasins when comparing the two time periods (*Figure 64 A, B*). The ratio of percent coniferous canopy to total canopy also increased in the Eastern and Western subbasins, and in the SF Eel River Basin as a whole when comparing the two time periods. Canopy density of deciduous and coniferous vegetation combined was below 80% in all subbasins during the 1990-1999 time period, but met or exceeded the 80% target value in the Western Subbasin and in the entire SF Eel River Basin using data collected between 2000 and 2010. This increase may be attributed to re-vegetation projects in riparian areas combined with management strategies such as modified timber harvest practices, including the development of riparian exclusion zones, throughout the basin.

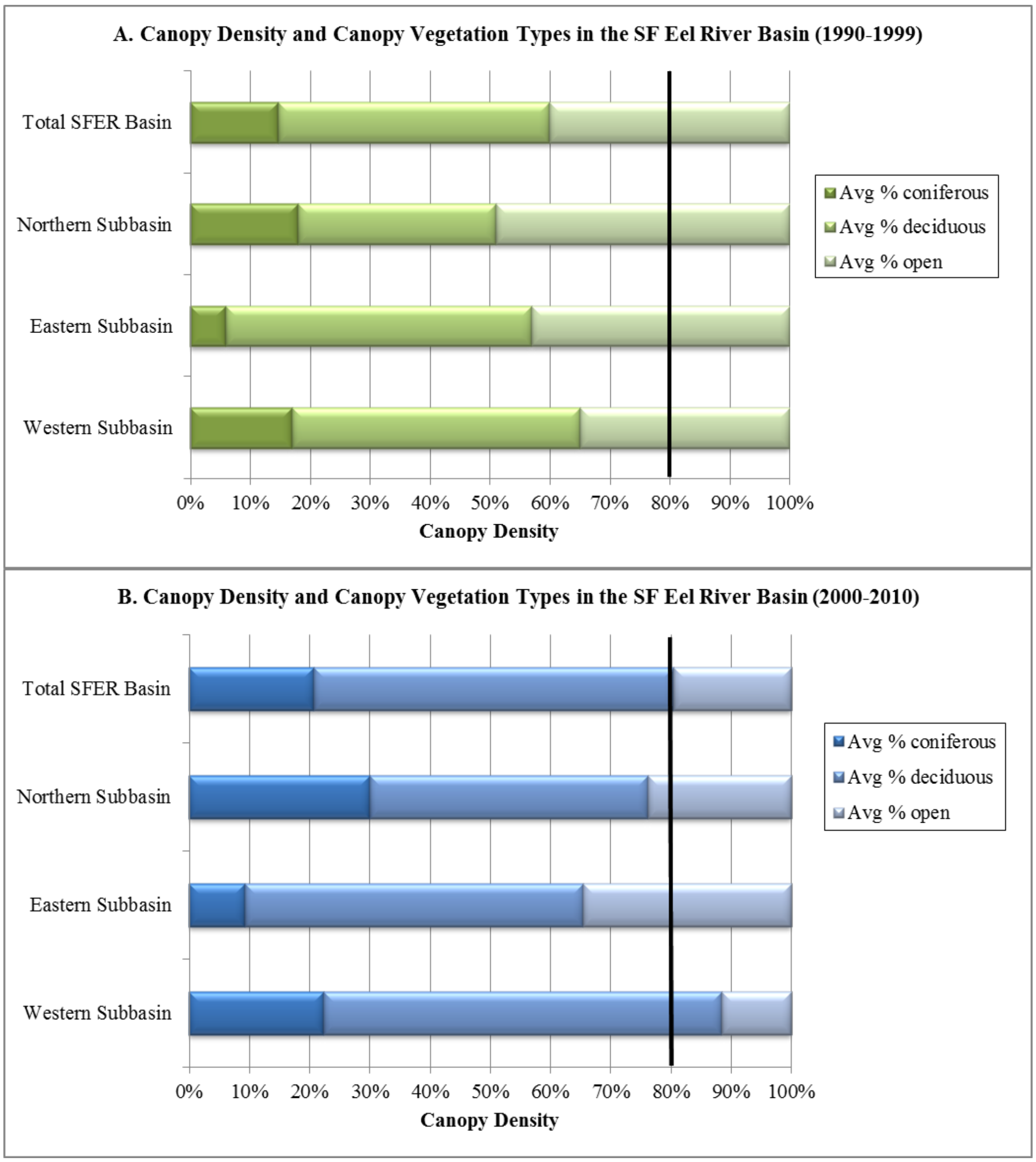


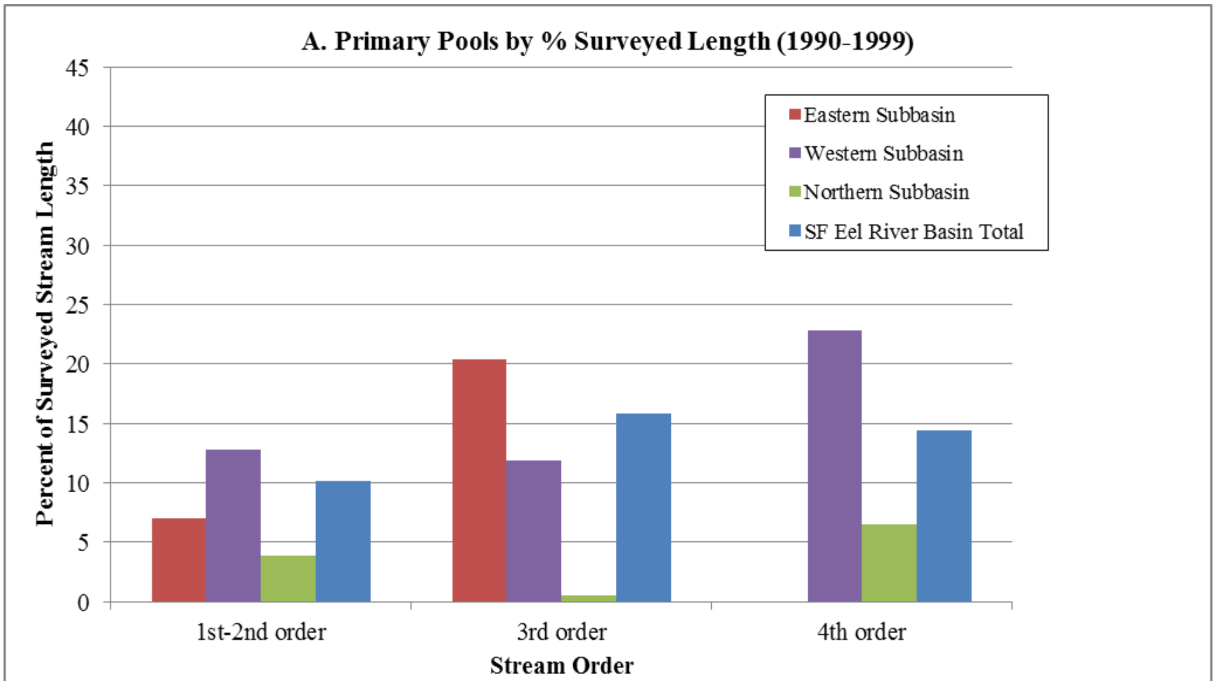
Figure 64 A, B. Relative percentages of coniferous, deciduous, and open canopy cover types in surveyed streams from 1990-1999 (A) and 2000-2010 (B) in the SF Eel River Basin. Line at 80% indicates CDFW target value for shade canopy in coastal streams.

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.

Primary pool habitat by percent surveyed length increased in all subbasins when comparing recent data (collected between 2000 and 2010) with those collected on habitat surveys in the 1990s (*Figure 65 A, B*). Percent primary pool habitat in all stream order categories was well below target values of 30-55% for streams surveyed during the 1990s (*Figure 65 A*), and was generally higher but still mostly below target values for streams surveyed in the 2000s (*Figure 65 B*). For all SF Eel River streams, the adjusted percent primary pool habitat in the 1990s was approximately 10% of the surveyed stream length in first and second order streams (n = 78 reaches), 16% in third order streams (n = 10 reaches), and 14% in fourth order streams (n = 9) (*Figure 65 A*). For data collected between 2000 and 2010, an average of 12% of the surveyed stream length was primary pool habitat in first and second order streams (n = 131 reaches), 27% of habitat was primary pools in third order streams (n = 21) and approximately 10% of surveyed habitat was primary pools in fourth order streams (n = 7). Values were closest to target percentages in third order streams (n = 8) in the Eastern Subbasin in the 2000s, where 38% of surveyed stream length was primary pool habitat (*Figure 65 B*).

Most third order stream data in the Eastern Subbasin were collected from surveys conducted on Tenmile Creek: six out of 6 reaches used in the analysis with data collected from surveys between 1990 and 1999, and 8 out of 9 reaches used in the analysis with data collected on surveys between 2000 and 2010. Future studies using data from other third order streams would be valuable to determine whether all streams in the Eastern Subbasin have similar high percentages of primary pool habitat as those seen in Tenmile Creek.



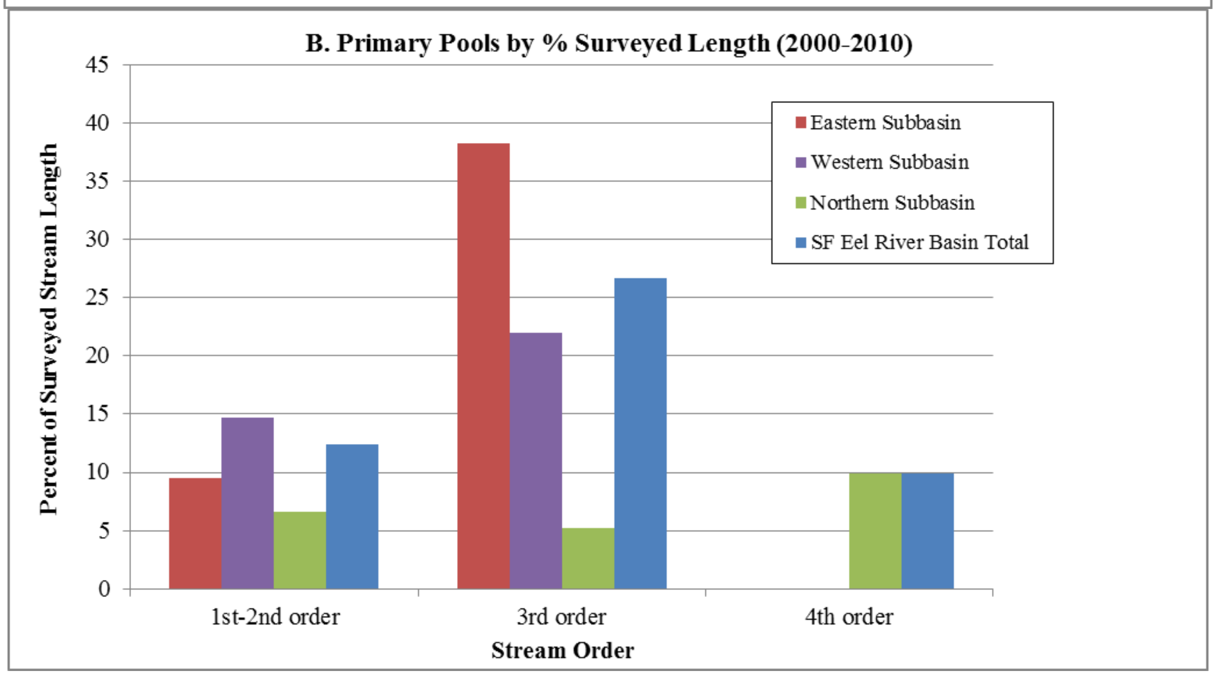


Figure 65 A, B. Percent of surveyed stream length in primary pool habitat in the SF Eel River Basin during two sampling decades: 1990-1999 (A) and 2000-2010 (B).

Pool depth condition as determined by the EMDS-based analysis increased slightly, but was still low for all SF Eel River streams combined when comparing the two sampling decades (*Figure 66* A, B). Western Subbasin stream scores were in the lowest suitability category during both time periods. The Eastern Subbasin had some stream length with suitable scores for pool depth during the 1990-1999 time period, but pool depth suitability decreased over time because three streams (Bear Canyon, Cahto, and McCoy creeks) with high suitability scores (+1) in the 1990s decreased to the lowest suitability levels (-1) in the early 2000s. Pool depth condition in Northern Subbasin streams improved slightly over time, but overall suitability was still low.

Pool frequency and depth may decrease and therefore suitability scores may decrease due to the removal of LWD, lack of LWD recruitment, and increases in sediment delivery to streams (Spence et

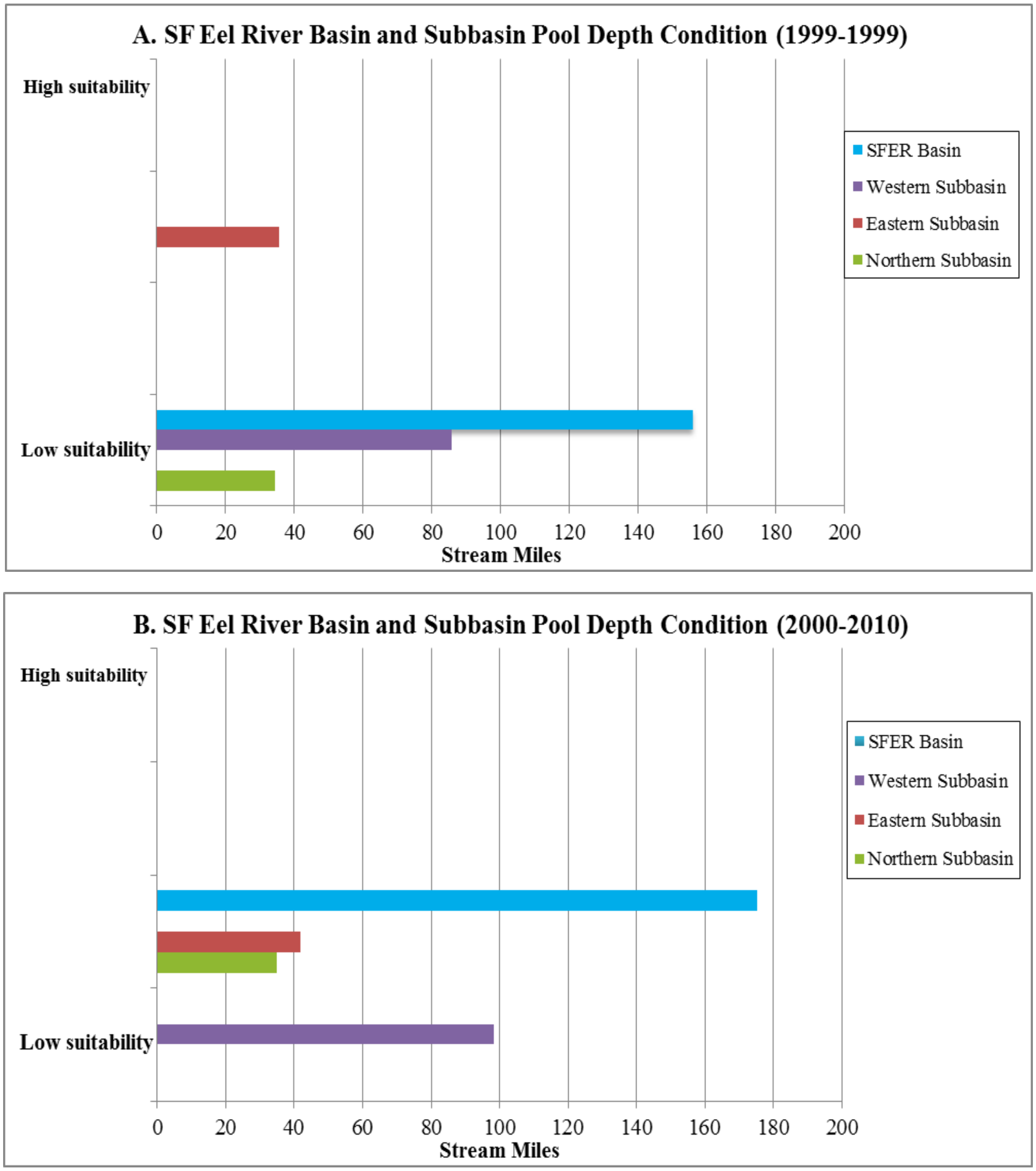


Figure 66 A, B. Pool depth condition by stream miles in the SF Eel River Basin and subbasins from 1990-1999 (A) and 2000-2010 (B).

al. 1996). Northern and Western subbasin streams had reduced pool depth conditons due to unstable geology resulting in high sediment input from landslides, particularly in Northern Subbasin streams in the upper Bull Creek drainage, and due to basin wide damage from historical flood events. The 1955 and 1964 floods caused extensive landsliding with associated increased sediment inputs; stream channel migration, aggradation, and scour; widespread loss of riparian vegetation; and fine sediment deposition on floodplains throughout the SF Eel River Basin, resulting in degradation of pool habitat. Conditions are slowly improving over time in most streams due to natural process combined with restoration projects such as riparian habitat improvement, upslope restoration, and instream habitat improvement (including LWD placement) designed to increase both pool frequency and depth.

Pool depth suitability scores were generally lower in habitat typed reaches in SF Eel River Basin streams during the 1990s (*Figure 67*) than in the early 2000s (*Figure 68*). There were limited areas with high suitability pool depth (Canoe, Redwood, Indian, Tenmile, and the upper SF Eel River near Branscomb) during the early 2000s, but most streams had low suitability during both time periods.

In the Northern Subbasin, pool depth suitability increased slightly in a few sampled reaches in Salmon, Canoe, and Butte creeks but remained in low suitability categories in most streams. In Eastern Subbasin streams, scores decreased in most tributaries sampled during both time periods (Cahto, Big Rock, McCoy, Milk Ranch, Bear Canyon, and SF Bear Canyon creeks), and the only areas of improvement in pool depth scores in the entire subbasin were seen in a few reaches of middle and upper Tenmile Creek. In SF Eel River headwaters streams (Redwood, Kenny, and Mud creeks) in the Western Subbasin, pool depth suitability decreased over time. There was some improvement in suitability scores in the mainstem SF Eel River near Branscomb, but overall pool depth scores were still low in Western Subbasin streams during both sampling periods.

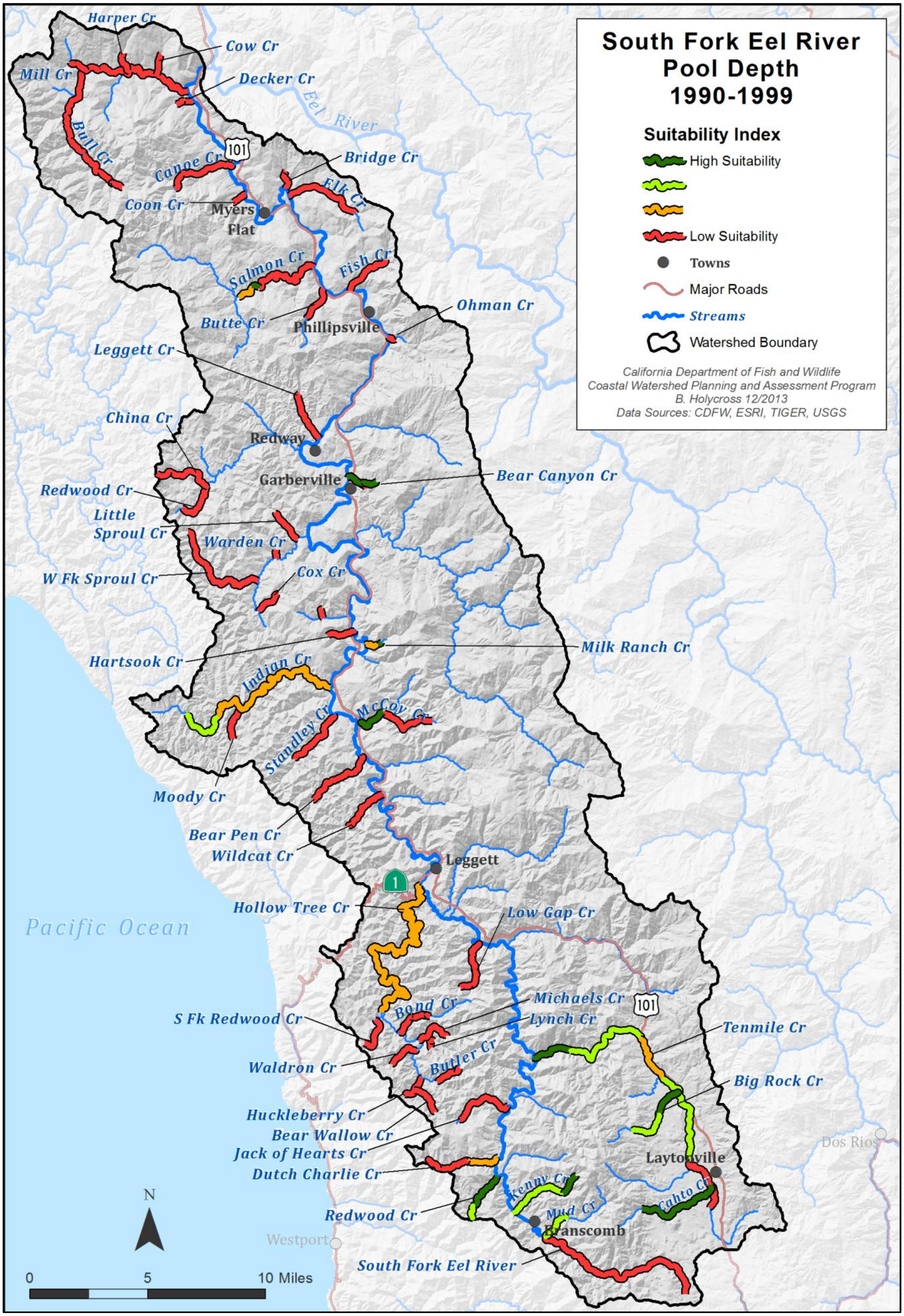


Figure 67. Pool depth suitability in SF Eel River Basin streams from habitat typing data collected between 1990 and 1999, as determined by the EMDS-based analysis.

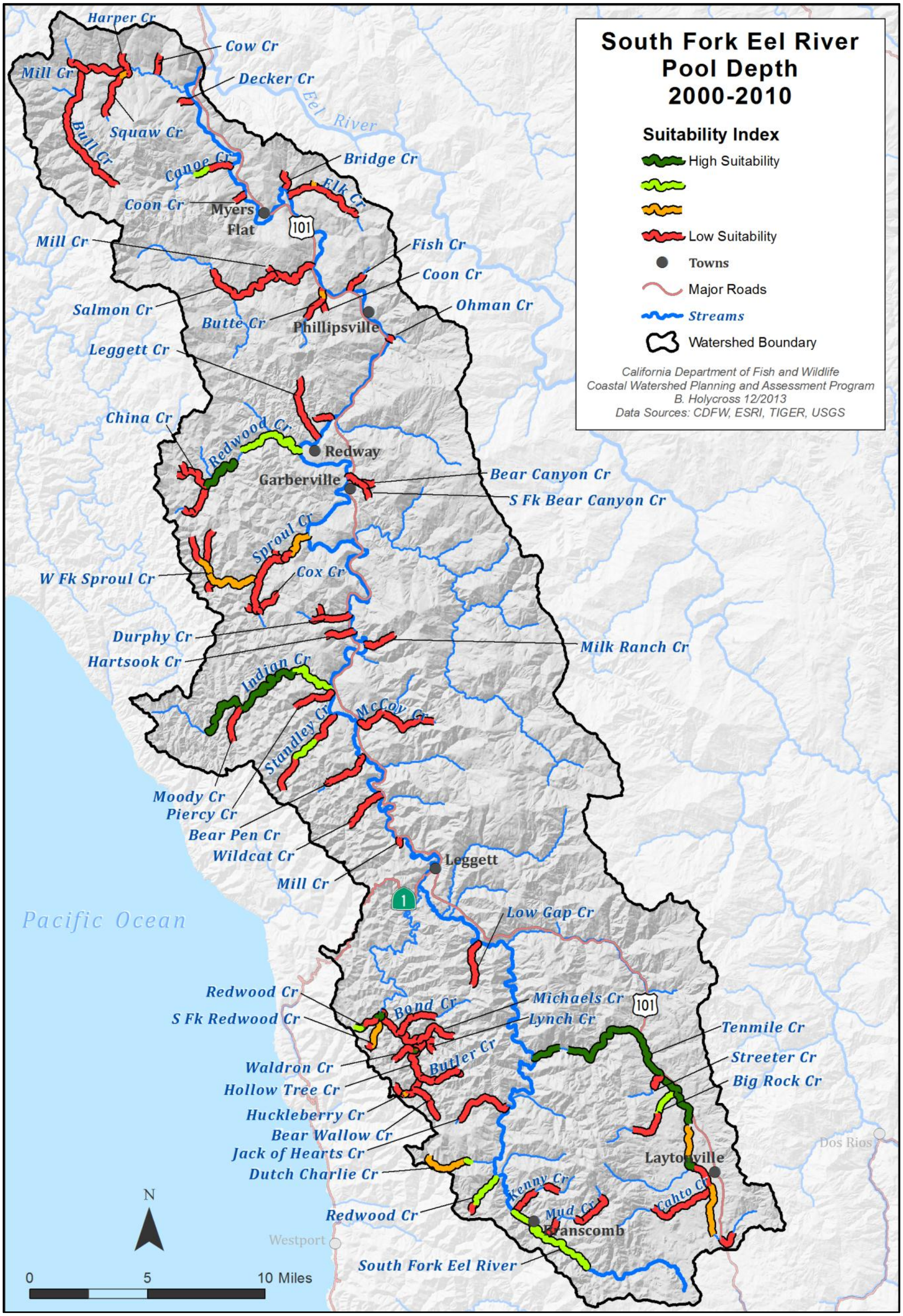


Figure 68. Pool depth suitability in SF Eel River Basin streams from habitat typing data collected between 2000 and 2010, as determined by the EMDS-based analysis.

Pool Shelter

Pool shelter provides protection from predation and rest areas from high velocity flows for 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. Shelter ratings of 100 or less (out of a possible 300) indicate that shelter/cover enhancement should be considered.

The average mean pool shelter rating for the SF Eel River Basin was 49.20 in the 1990s and 36.74 using habitat data collected between 2000 and 2010 (*Figure 69*). These values are well below the target pool shelter value of 100 for salmonids, and because these values are decreasing with time, restoration projects should target streams with particularly low pool shelter values and potential salmonid presence.

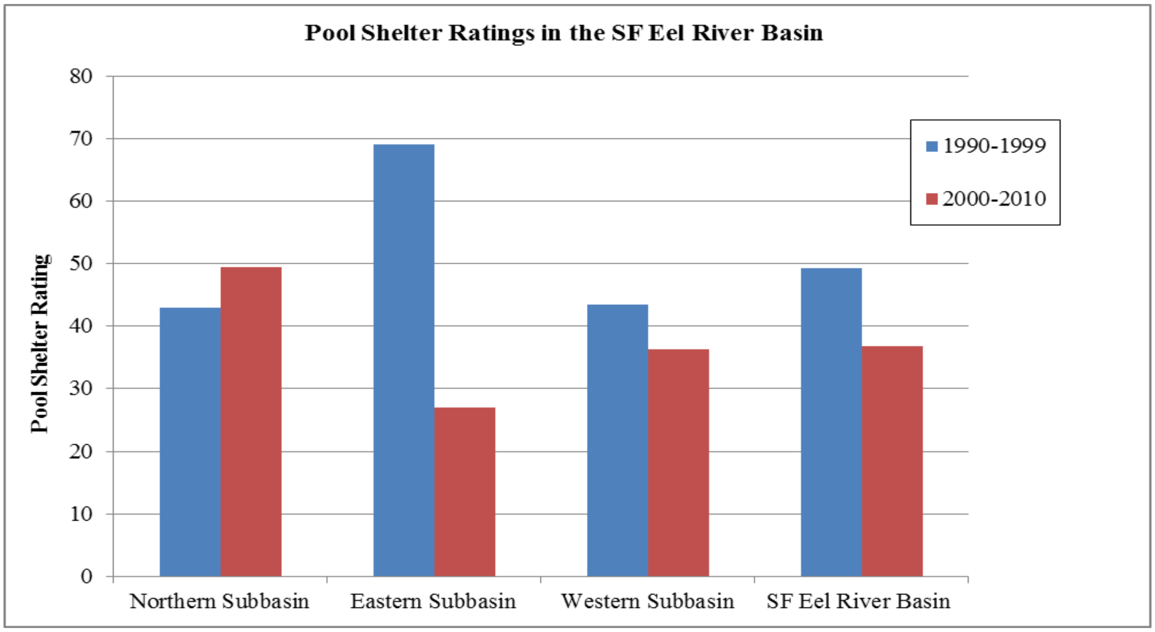
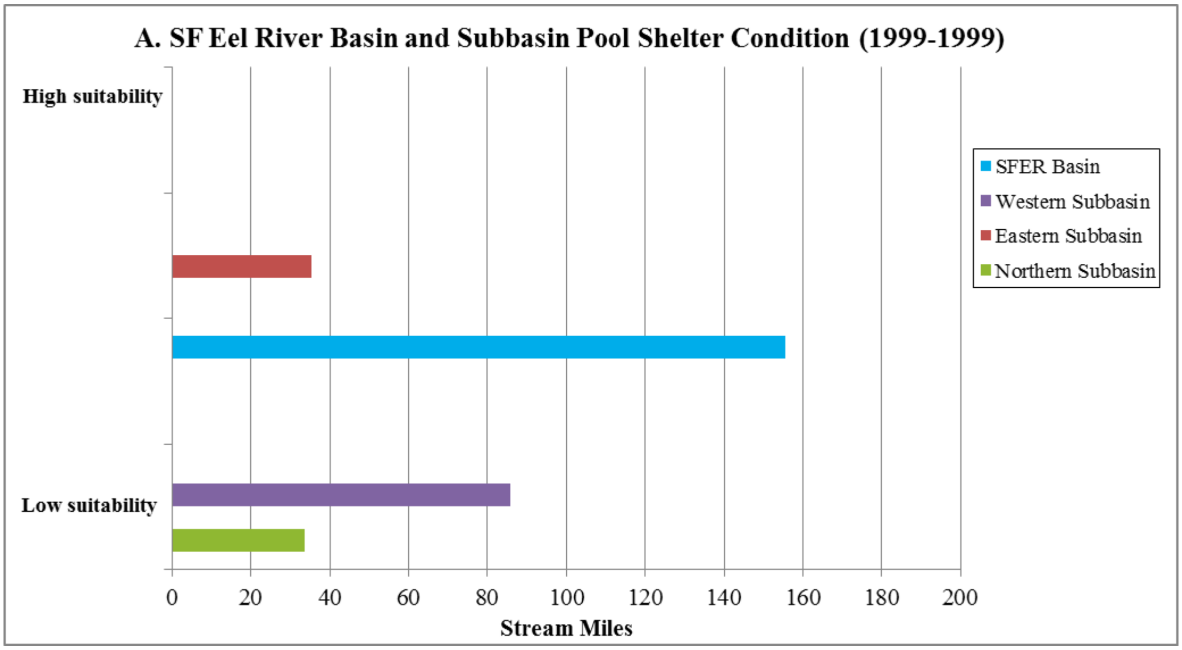


Figure 69. Pool shelter values in SF Eel River Basin and subbasin streams during two sampling decades: 1990-1999 and 2000-2010.

Pool shelter suitability ratings for subbasins and for the entire SF Eel River Basin were low for all except the Eastern Subbasin streams during the 1990s; suitability scores decreased over time in most subbasins, and in the entire SF Eel River Basin (*Figure 70 A, B*).

Pool shelter suitability increased slightly in many Northern Subbasin streams, but overall levels were still below target values and therefore suitability was low during both sampling periods. In the Eastern Subbasin, suitability went from high to low over time in Tenmile Creek, and also worsened in Western Subbasin streams in upper Hollow Tree Creek tributaries (*Figure 71*, *Figure 72*). Pool shelter conditions improved slightly over time in the Sproul Creek drainage in the Western Subbasin.



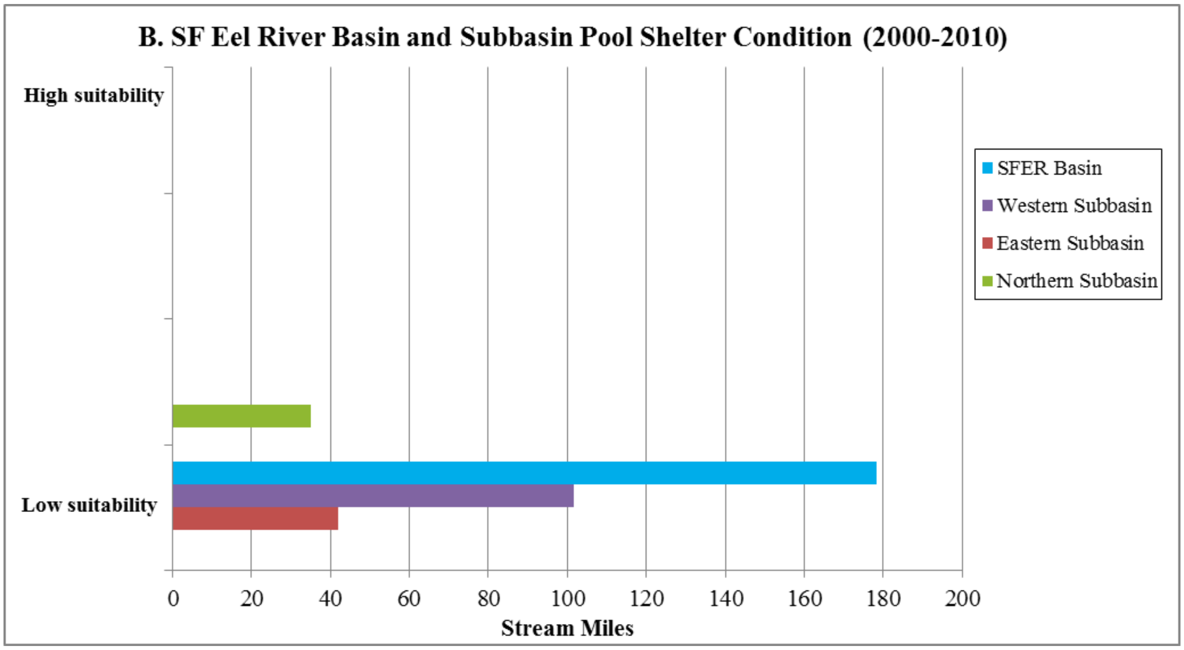


Figure 70A, B. Pool shelter condition by stream miles in the SF Eel River Basin and subbasins from 1990-1999 (A) and 2000-2010 (B).

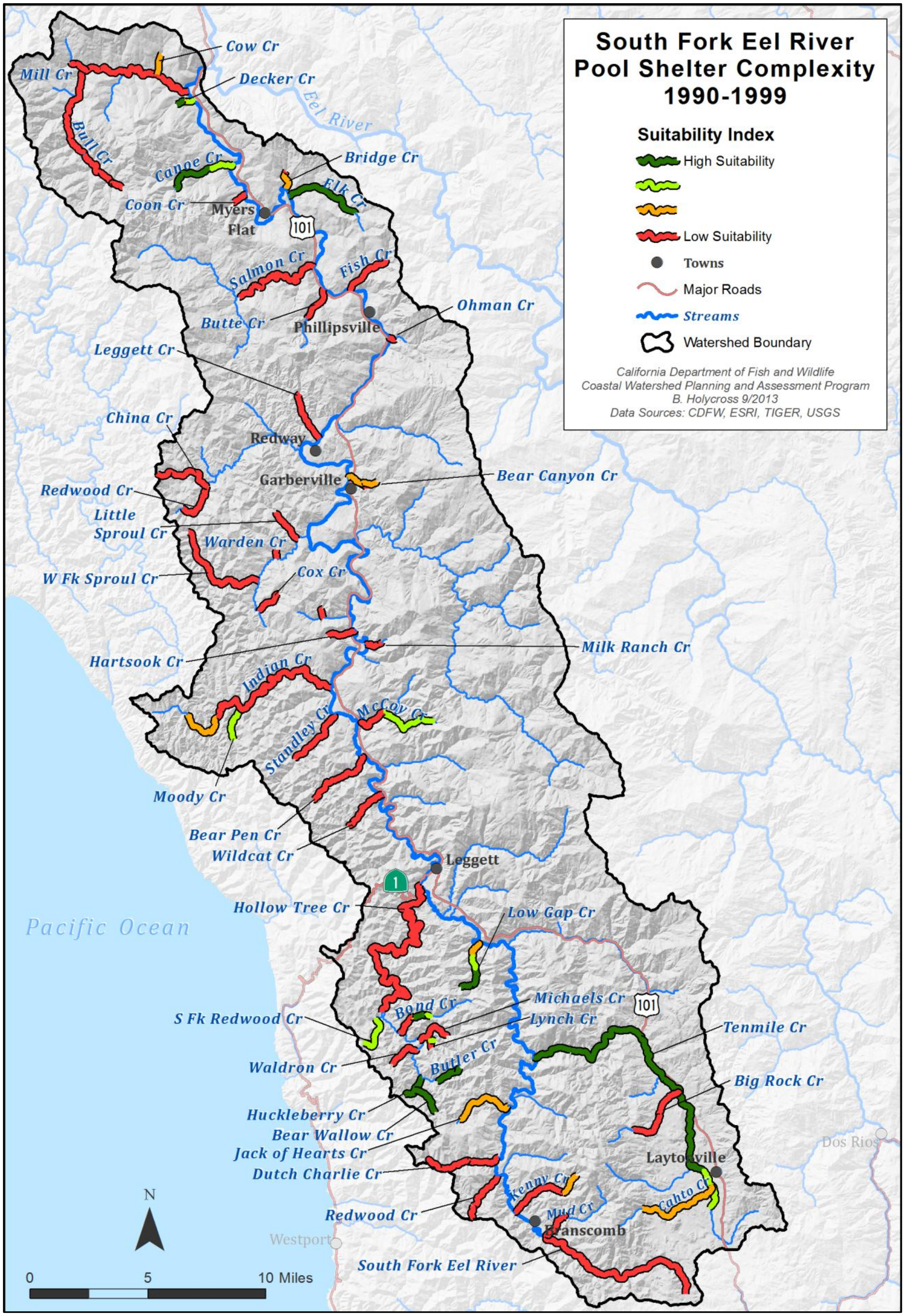


Figure 71. Pool shelter complexity suitability in SF Eel River Basin streams from habitat typing data collected between 1990 and 1999, as determined by the EMDS-based analysis.

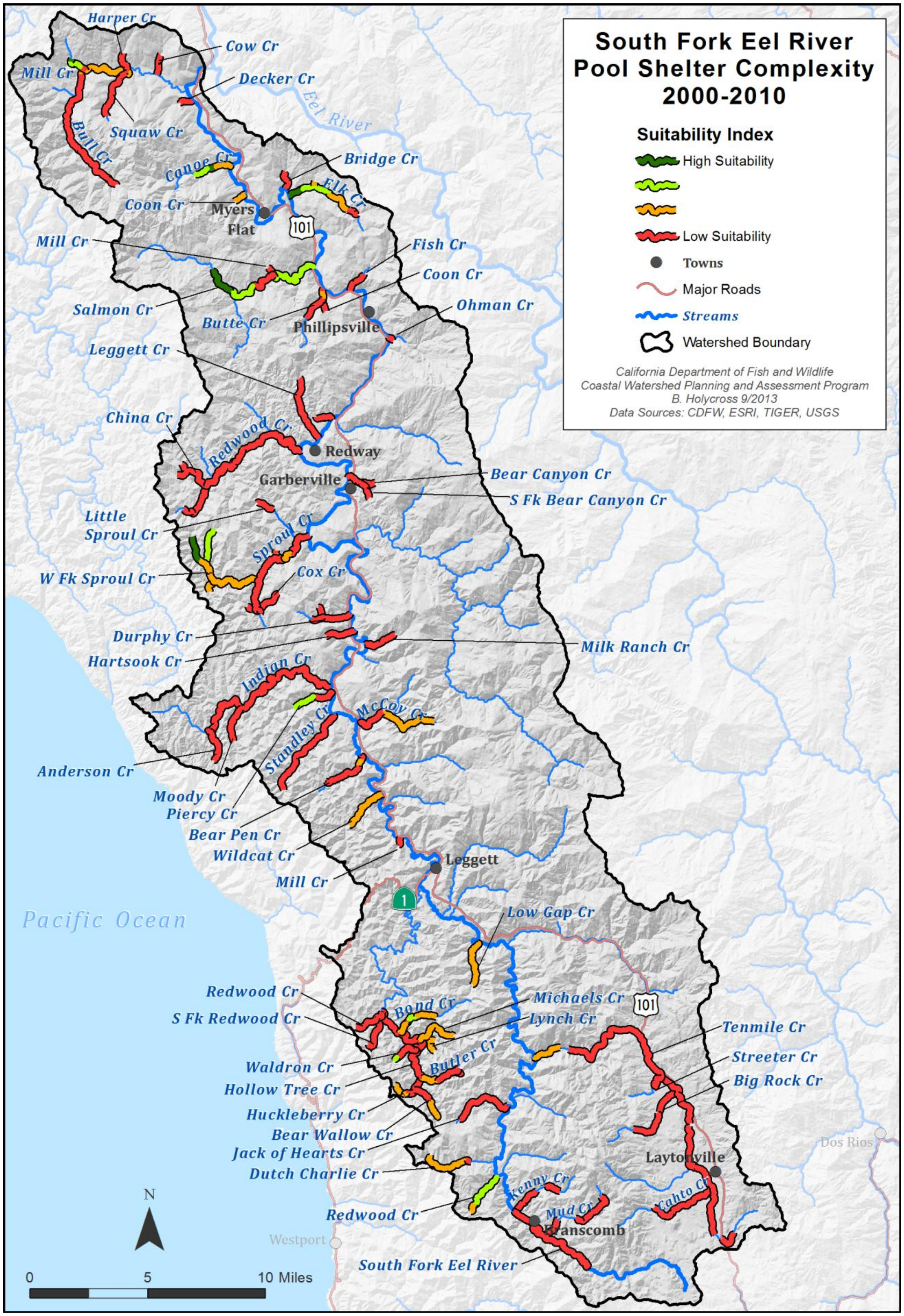
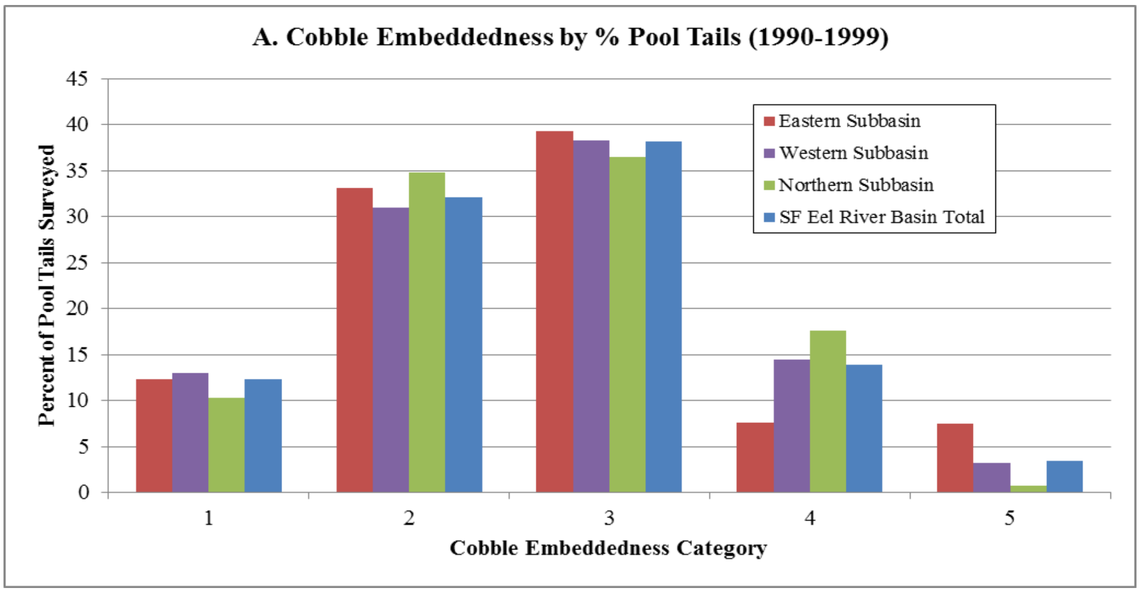


Figure 72. Pool shelter complexity suitability in SF Eel River Basin streams from habitat typing data collected between 2000 and 2010, as determined by the EMDS-based analysis.

Substrate Embeddedness

Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments decrease successful spawning and incubation. 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. The bars furthest to the right in *Figure 73* A and B represent tail-outs deemed unsuited for spawning due to inappropriate substrate like sand, bedrock, log sills, boulders or other considerations (category 5) and were not included in the analysis.

Cobble embeddedness condition improved in most SFER streams over time. The percent of pool tails surveyed in cobble embeddedness category 1 nearly tripled in all subbasins in 2000-2010 compared to 1990-1999. 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 (*Figure 73 A, B*).



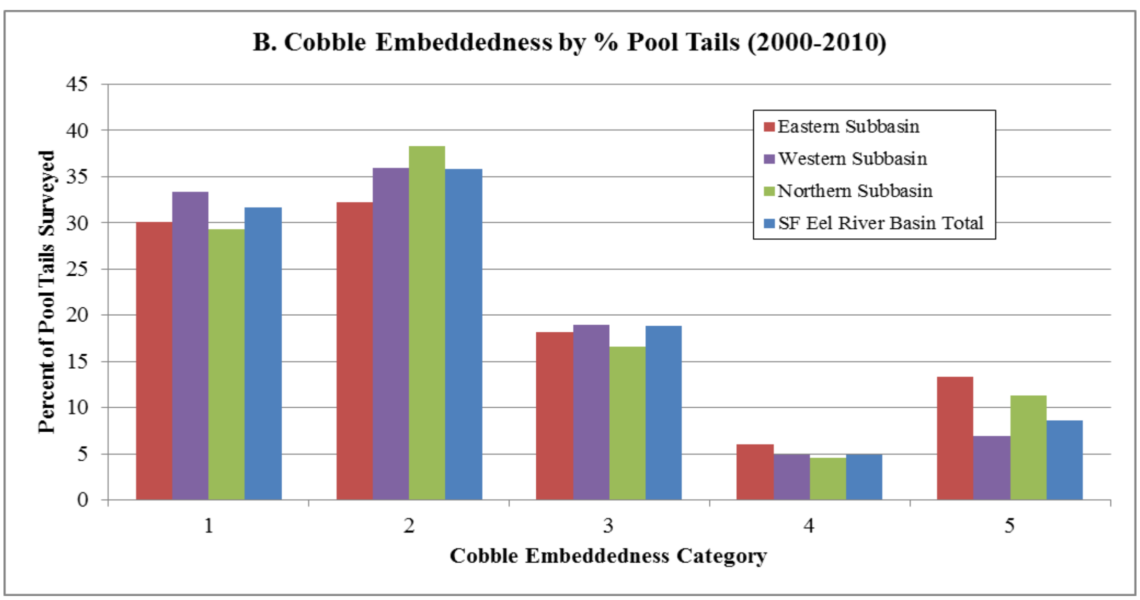
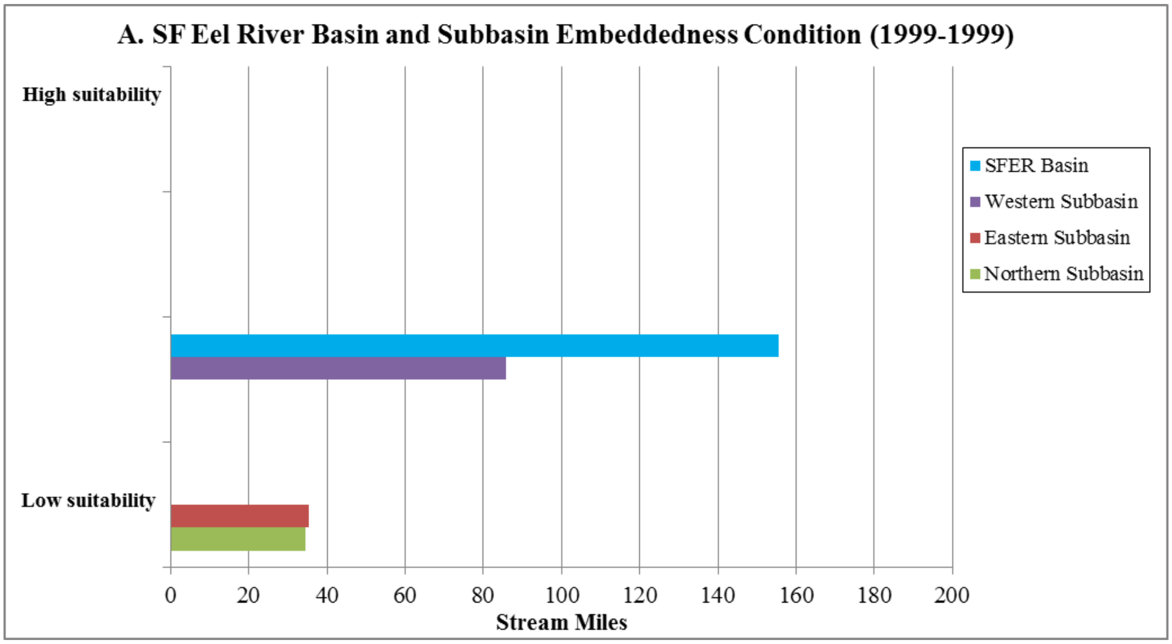


Figure 73 A, B. Cobble embeddedness in the SF Eel River Basin and subbasins from 1990-1999 (A) and 2000-2010 (B).

Using data collected in the 1990s, all subbasin and basin embeddedness condition scores were below target values (low suitability), but all showed positive suitability scores using data collected between 2000 and 2010 (*Figure 74 A, B*).



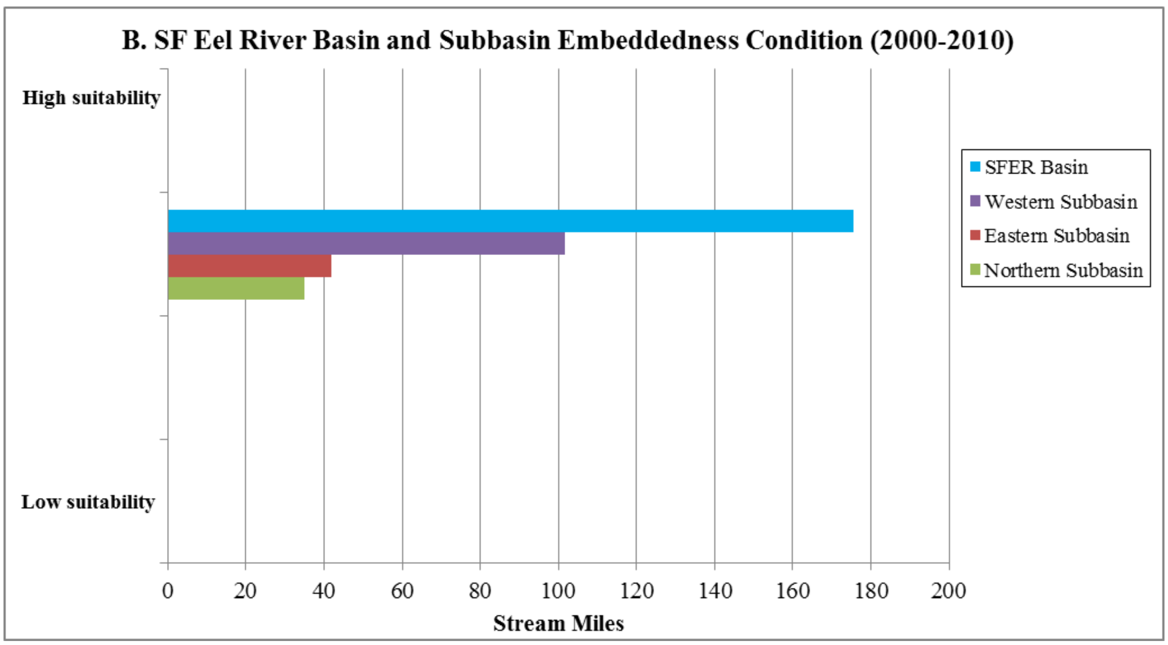


Figure 74 A, B. Substrate embeddedness condition by stream miles in the SF Eel River Basin and subbasins from 1990-1999 (A) and 2000-2010 (B).

Substrate embeddedness suitability increased over time in many of the larger tributaries in each subbasin, including Bull and Salmon creeks in the Northern Subbasin, Indian Creek and Hollow Tree Creek in the Western Subbasin, and Tenmile Creek in the Eastern Subbasin (*Figure 75*, *Figure 76*). Changes are due to: streams recovering from the effects of large historical flood events (with fine sediments naturally flushing out of systems); sediment reduction measures including restoration projects in upslope and riparian areas; and management policies designed to reduce sediment input from roads and timber harvest activities throughout the basin.

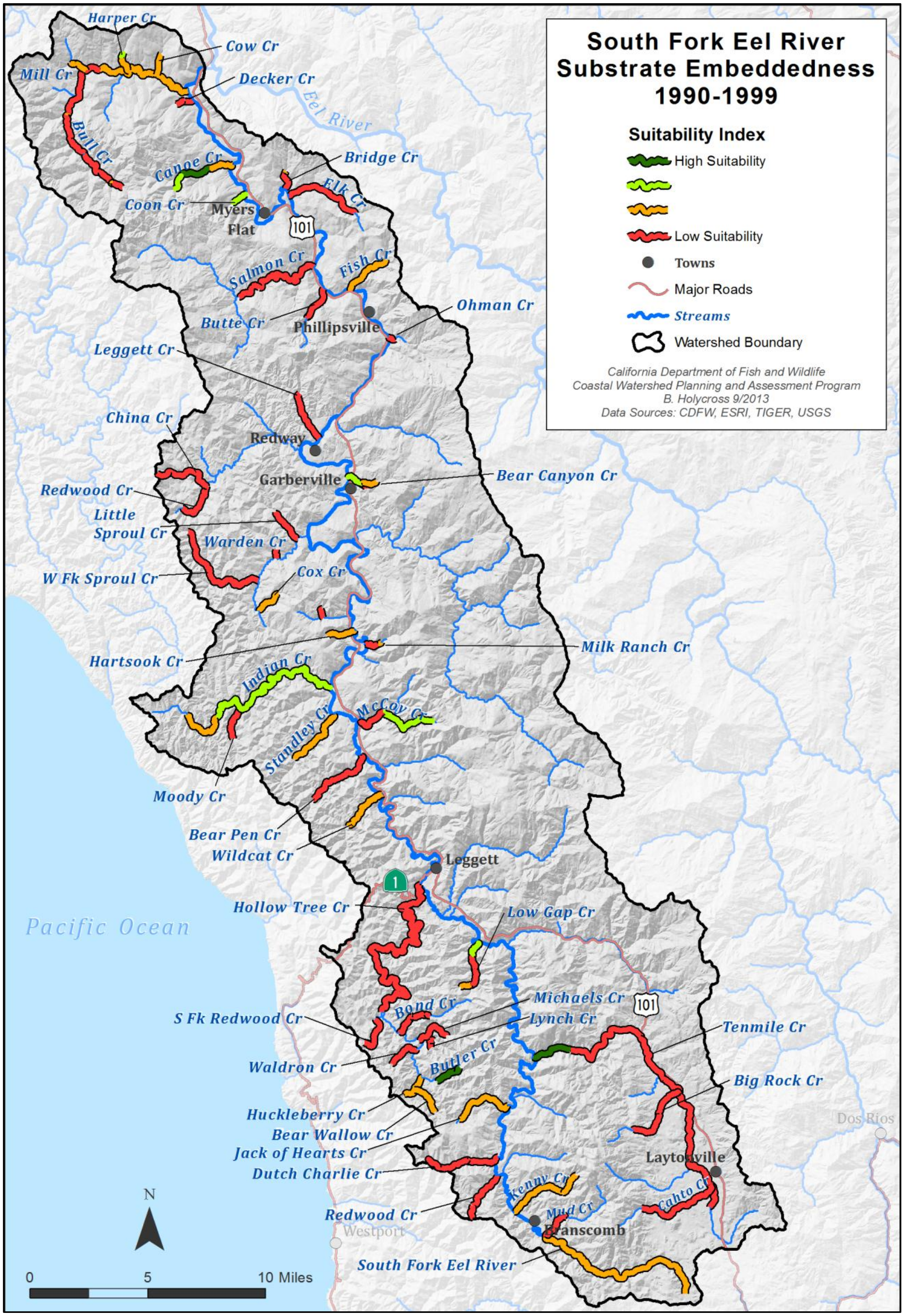


Figure 75. Substrate embeddedness suitability in SF Eel River Basin streams from habitat typing data collected between 1990 and 1999, as determined by the EMDS-based analysis.

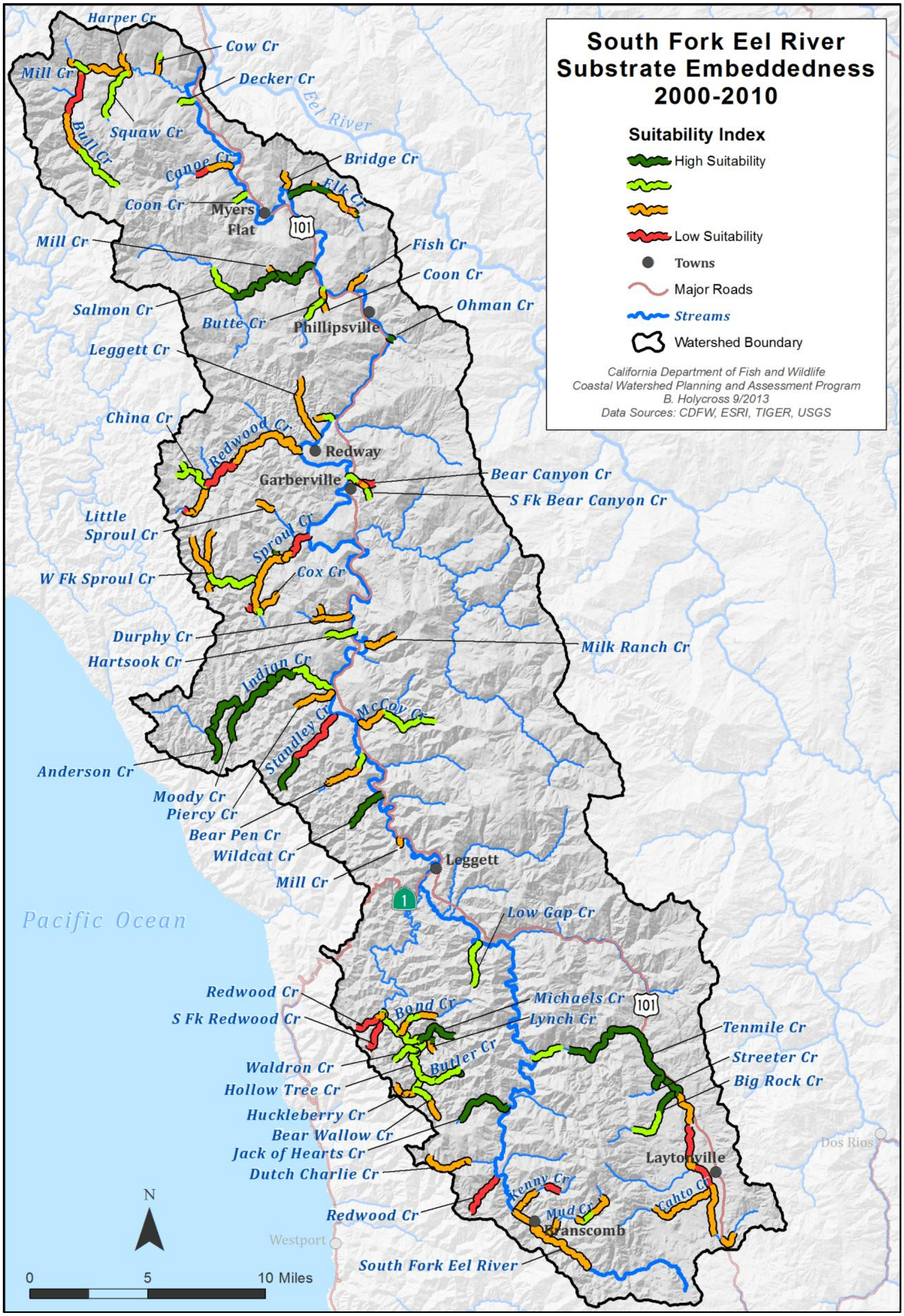


Figure 76. Substrate embeddedness suitability in SF Eel River Basin streams from habitat typing data collected between 2000 and 2010, as determined by the EMDS-based analysis.

In the analysis, embeddedness scores were combined with pool quality scores (a combination of pool shelter and depth scores), to create an in channel score for each reach, stream, and subbasin. Although embeddedness scores were positive for all subbasins using data collected between 2000 and 2010 (*Figure 74 B*), and were some of the highest individual factor suitability scores in the analysis, overall habitat suitability scores were still negative for all subbasins during both sampling periods.

Embeddedness measures subdominant fine sediments, but a recent study determined that dominant fine sediments, which have an inverse effect on coho presence, may be the best indicator (of the habitat typing variables measured) of adverse sediment effects in streams (Albin and Law 2006). The percent of dominant fine sediments in pools was not documented during habitat typing surveys in the 1990s, and were recorded on a limited number of surveys completed between 2000 and 2010 in SF Eel River streams. There were not enough data to analyze the effects of dominant fine sediments on habitat suitability and coho presence for this report, but this metric should be considered for inclusion in future assessments as habitat typing crews collect additional data.

Large Woody Debris (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).

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 SF Eel River Basin 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 SF Eel River streams in all subbasin reaches during both time periods (*Table 37*). Large woody debris increased as the dominant shelter type in all subbasin streams over time, and was the second most dominant shelter type in SF Eel River Basin streams between 2000 and 2010. The Northern and Western subbasins had more streams with LWD as the dominant shelter type, which was expected due to the predominance of coniferous and hardwood forest vegetation types compared to the Eastern Subbasin. Western Subbasin streams had the largest increase over time in LWD as the dominant shelter type, due to restoration efforts, management strategies, and natural LWD recruitment.

Table 37. Dominant shelter type by number of reaches surveyed in SF Eel River Basin and subbasin streams.

1990-1999	**Subbasin**			
Dominant Shelter Type	**Northern**	**Eastern**	**Western**	**SF Eel River Basin Total**
Boulders	30	13	32	75
Root masses	0	0	0	0
Terrestrial vegetation	0	2	2	4
LWD	2	0	3	5
SWD	1	1	4	6
Aquatic vegetation	0	1	0	1
Undercut banks	0	2	3	5
Whitewater	0	0	0	0
2000-2010				
Dominant Shelter Type	**Northern**	**Eastern**	**Western**	**SF Eel River Basin Total**
Boulders	31	20	39	90
Root masses	3	2	1	6
Terrestrial vegetation	2	3	3	8
LWD	9	1	20	30
SWD	1	2	14	17
Aquatic vegetation	0	1	0	1
Undercut banks	1	0	8	9
Whitewater	0	0	1	1

The average percent shelter from LWD in pools in each subbasin increased in Northern and Western subbasin streams between the two time periods (*Table 38*), and was highest for Western Subbasin streams during both the 1990s and 2000s, followed by Northern Subbasin streams in the 2000s and Eastern Subbasin streams in the 1990s. Percent shelter from LWD decreased in Eastern Subbasin streams between the two time periods, due primarily to a much lower prevalence of conifer and hardwood forest habitat to provide woody debris input to streams in this subbasin. Higher percent shelter values from LWD in Northern and Western subbasin streams may also be due 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 average percent shelter from LWD values are higher in Northern and Western subbasins, all values are relatively low (<5%), indicating the need for additional large wood as vital rearing and holding habitat components in all SF Eel River Basin streams.

Table 38. Total pool habitat length and average percent shelter from LWD in SF Eel River Basin and subbasin streams from 1990-1999 and 2000-2010.

Subbasin	**Total length of pool habitat (mi)**	**Avg % shelter from LWD**
1990-1999		
Northern	6.86	2.09
Eastern	7.74	3.20
Western	27.08	3.52
SF Eel River Basin Total	41.68	3.23
2000-2010		
Northern	8.57	3.31
Eastern	13.29	0.96
Western	34.35	4.00
SF Eel River Basin Total	56.21	3.18

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 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 ratio (1:1) 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.

The percent of pool habitat in SF Eel River Basin streams ranged from 20-35%, and the percent of riffle habitat ranged from 20-41% of all habitat surveyed. Pool riffle ratios met or exceeded optimal levels in Eastern and Western subbasin streams, but were below optimal in Northern Subbasin streams (*Table 39*). 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 the Northern Subbasin, particularly in the Bull Creek drainage.

Table 39. Percent pool and riffle habitat, and pool riffle ratios for SF Eel River subbasin streams (from habitat typing data collected between 1990 and 1999, and 2000 and 2010).

SUBBASIN	DATE	% POOL HABITAT	% RIFFLE HABITAT	POOL:RIFFLE RATIO
Northern	1990s	20	40	33 : 66
	2000s	24	41	37 : 63
Eastern	1990s	22	20	52 : 48
	2000s	34	22	61 : 39
Western	1990s	32	23	58 : 42
	2000s	34	23	60 : 40

In all three subbasins, the ratio of pool to riffle habitat improved (pool habitat increased) 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.

Although pool-riffle ratios were generally good, most pools sampled during both time periods were shallow, resulting in primary pool lengths below target values and corresponding low pool depth suitability scores (as discussed in the Pool Depth section, pgs. 115-119). These target values were developed based on summer flows and in order to meet the target values, pools are expected to have significant depth to benefit salmonids.

Winter Refugia Habitat

The amount of winter refugia habitat was defined by CWPAP as the percent of stream reach in backwater pools, side channel habitat, and deep pools (> 4' deep). Streams with greater than 10% winter refugia habitat are generally considered suitable for salmonids; these areas provide juvenile salmonids with low velocity holding and rearing areas with abundant terrestrial and aquatic food sources during times of high flow and cold water temperatures. Off-channel rearing habitat is particularly important for coho salmon juveniles that congregate in low gradient areas including backwater pools and side channel habitats after emerging from gravels (Bustard and Narver 1975, Sandercock 1991, Ebersole et al. 2006).

Backwater pools are defined in the *California Salmonid Stream Habitat Restoration Manual* as secondary channel pools, including boulder, root wad, and log formed pools, and dammed pools (Flosi et al. 2010). Side channel habitats have clearly identifiable upstream and downstream connections to the main channel, and water can be derived from the mainstem at the upstream connection, or from groundwater or surface water sources outside the mainstem.

Measurements from field observations made by CDFW habitat typing crews are limited for deep pools, backwater pools, and side channel habitats. These measurements represent significantly lower amounts of these habitat types because:

- Habitat surveys are conducted during low flow times (summer) and do not represent stream conditions when salmonids would be found rearing and holding during high winter flow events;
- Data are not collected in side channels if any portion of the side channel habitat is dry; and
- Backwater pools have not been sampled consistently by field crews - some backwater

pools are combined with pool habitat data for the entire length of stream surveyed, while others are described individually.

Given these limitations, data collected on habitat typing surveys were not used to gain an understanding of the quality of existing winter refugia habitat in the SF Eel River Basin. Additional data should be collected during the winter months in order to assess winter refugia conditions and suitability for salmonids throughout the basin.

Barriers

During freshwater life phases, salmonids need free access to multiple stream habitats, from the mouth to the headwaters, as migratory corridors and rearing and spawning habitat. Barriers (natural or otherwise) exist on all streams. Some of these barriers will limit access to stream reaches with quality habitat for anadromous fish. Barriers fragment the range of salmonid habitat and may completely cut off their access to streams for spawning. Eventually, somewhere along their length, all streams will have gradient and flow barriers to fish passage (usually near the headwaters) as part of the natural physical stream morphology.

Of special concern are barriers that limit the naturally occurring range and distribution of salmonids, and of these, barriers resulting from human activities (anthropogenic) are especially significant.

Barriers may be broken up into several criteria describing the cause (natural - anthropogenic), life-span (temporary - permanent), and effectiveness (partial - total). See *Table 40* for more extensive descriptions of barrier types.

Log jams, referred to in this report as log debris accumulations (LDAs) that span the stream channel are prevalent on many forested streams within the SF Eel River Basin. These features can be massive; however, void spaces between logs and the buoyancy of the wood may allow fish to pass during various flow conditions. During large storm flows, LDAs may shift or become dismantled and are therefore considered temporary in nature, persisting from one year to more than a decade. Very large LDAs can trap sediment, fill in void spaces, and become total barriers to fish passage for decades (until the wood degrades or there is a sufficient flow event to blow out the structure).

The assessment team utilized features identified by field crews during stream inventories, field reconnaissance, and the CalFish Passage Assessment Database to locate, map, and discuss known barriers to salmonids (*Figure 77*).

Table 40. Categorical barrier descriptions.

Category	Description	Example
Total:	A complete barrier to fish passage for all anadromous species at all life stages at all times of year.	Hanging culvert, dam, large bedrock waterfall
Partial:	Only a barrier to certain species or life stages.	5% gradient reach, 3’ plunge
Temporal:	Only a barrier at certain times of year.	Dry channel reach, LDA (floating)
Temporary:	Barrier will likely dissipate within a year or two, bank-full flow has the ability to modify it.	LDA, small debris-flow deposit
Persistent:	Barrier may persist for several years to several decades, a large flow event is needed to modify feature (e.g. 100 year flood event).	Large LDA, landslide deposit
Permanent:	Barrier will likely exist for centuries or longer.	Large bedrock waterfall, gradient transition to headwaters, large hydro-electric dam
Natural:	Barrier is formed by naturally occurring physical processes inherent to the basin.	Large bedrock waterfall, knickzone gradient
Anthropogenic:	Barrier is formed as a result of human activity.	Culvert, dam, failing road crossing

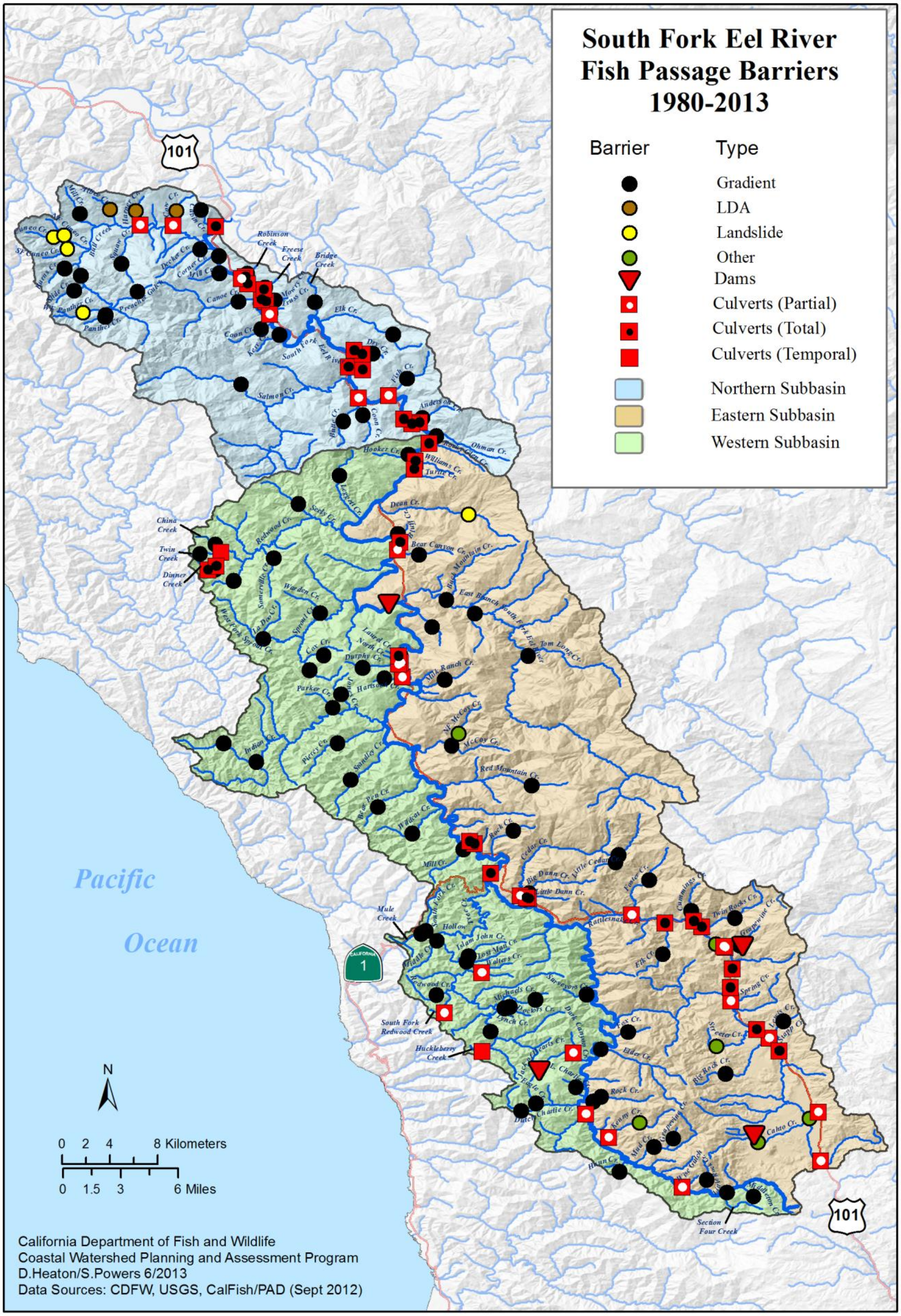


Figure 77. Fish passage barriers by type in the SF Eel River Basin.

Natural Barriers

Gradient

Stream reaches with a gradient over a given threshold that extend for 1000 feet are considered barriers to salmonids. Gradient barrier thresholds are species dependent and have generally been agreed upon as: 4% for Chinook, 6% for coho, and >10% for steelhead (Reeves et al. 1989; S. Downie, personal communication 2013). For the purposes of this assessment we have set general gradient barriers to anadromous fish at approximately 10% over 1,000 foot reach. In general, all barriers in the SF Eel River Basin may be lumped into categories of gradient, low-flow, and lack of habitat. Waterfalls make up about 17 percent of the identified barriers to fish passage and may be considered an extreme version of a gradient barrier as they have a vertical gradient of >90% percent. Natural gradient barriers (including waterfalls) account for 51 percent of the identified naturally occurring barriers within the surveyed streams (*Table 41*).

Landslide

Landslide deposits within the stream channels account for about five percent of the identified barriers. Landslide deposits contribute boulders and debris to the channel creating localized high-gradient boulder run/cascade reaches. Their permanence depends upon their magnitude and the type and nature of the deposit. Large rock slides tend to persist much longer than soil/debris failures which may be modified by normal winter flows within a year or two to allow fish passage.

LDA

LDAs composed only three percent of the observed barriers to salmonids. These LDAs tended to be very large and were retaining sediment. Water was either going subsurface or flowing over obstructions causing small waterfalls insurmountable to fish.

Anthropogenic Barriers

Culverts and Dams

Culverts or road crossings over streams create 34 known total barriers and 30 partial barriers to fish passage in the basin. Eight anadromous streams within the basin have culverts that are considered total barriers that limit the potential length of anadromous channel by about five miles (*Table 42*). Eight additional streams have culverts or dams that are considered partial barriers to anadromous fish (CalFish 2012). The bulk of these barriers are associated with highways 101 and 254.

There are two dams that are permanent, total barriers to fish passage in the SF Eel River Basin. Both are located in the southern part of the basin, one on Grapevine Creek and one on Jack of Hearts Creek ("Walden Pond Dam", currently set for removal). These dams constitute only one percent of the barriers, and are located near the headwaters so they do not seem to shorten the stream length of anadromy significantly. There are three dams that are classified as temporal barriers in the Basin, two on Red Mountain Creek and one at Benbow (RM 40); these were not included in *Table 41* because they are no longer installed in the summers and are not barriers to fish passage. One dam located on Cahto Creek (*Figure 77*) was identified by CalFish (2012) but was also not included in *Table 41* because its status is currently "unassessed".

Table 41. SF Eel River Basin barrier types.

SF Eel River – tributary barriers		
Barrier	**Quantity**	**Percent**
Gradient	61	35%
Waterfall	34	19%
Landslide	6	3%
Other	6	3%
LDA	4	2%
Culvert	64	36%
Dams	2	1%
Total:	**177**	**100%**

Table 42. Total Barriers – distance between downstream anthropogenic barrier and upstream natural barrier.

Stream miles of anadromy lost by anthropogenic barriers		
Stream	**1st barrier**	**2nd barrier**
Anderson Creek	0.47	
Big Dan Creek	0.27	
Cabin Creek	1.23	
Dry Creek	0.40	
Elk Creek	1.90	
Feese Creek	0.11	
Mowry creek	0.58	0.37
Robinson Creek	0.39	0.18
Total:	**5.35**	

Water Quality

The USEPA has recognized portions of the SF Eel River watershed as impaired due to sediment, temperature, and aluminum as defined by Section 303(d) of the Clean Water Act. Because of this, the USEPA and Water Board are implementing a total maximum daily load (TMDL) process in order to determine the watershed's capacity to assimilate pollution, in this case sediment, temperature (heat), and aluminum sources (*Table 43*). California ranks TMDLs as low, medium, or high priority based on the number and severity of the impairments and the importance of the beneficial uses; the SF Eel River was ranked medium priority (Winzler and Kelly 2007). Implementation of the TMDL process results in the creation of numerical targets, and provides the state with information on how to reduce pollution within the watershed in order to meet water quality standards. Some entities, like the HCRCD, are collecting and housing data in order to support this effort.

Table 43. SF Eel River list of water quality impairments and potential sources. From CA State Water Resources Control Board Final 2010 Integrated Report (CWA Section 303(d) List / 305(b)).

Pollutant	**Potential Sources**	**Year Listed**	**Year TMDL Developed**
Sediment	Erosion/siltation Flow regulation/modification Hydromodification Logging road construction/maintenance Nonpoint source Range grazing (riparian and/or upland) Removal of riparian vegetation Resource extraction Silviculture	1994	1999
Temperature	Erosion/siltation Flow regulation/modification Hydromodification Nonpoint source Removal of riparian vegetation	1996	1999
Aluminum*	Natural	2010	2021
* The listing for aluminum only applies to the mainstem SF Eel River, not its tributaries.			

Beneficial uses related to fisheries that will be protected by the TMDL process in the SF Eel River Basin include:

- Cold freshwater habitat;
- Migration of aquatic organisms;
- Commercial and sport fishing;
- Spawning, reproduction, and/or early development potential.

In 1994, the SF Eel River was listed under 303(d) as impaired due to sediment. A sediment source analysis was completed in 1999 by Stillwater Sciences, under contract to Tetra Tech, and results were reported in the SF Eel River TMDL (USEPA 1999). Several beneficial uses were determined to be affected by sediment within the watershed, and were described in detail in the Eel River Watershed Management Area section of the Watershed Planning Chapter produced by the NCRWQCB (2005).

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).

Warm summer water temperatures have been documented historically throughout the Eel River Basin, and in 1996, the SF Eel River was listed under 303(d) as temperature impaired. The State of CA established two water quality objectives that must be met for temperature in the SF Eel River Basin:

1) Alterations in temperature must not adversely affect beneficial uses (native cold water fish); and
2) Cold water temperatures must not increase more than 5˚F from natural receiving water temperatures in a particular area of the stream.

With these objectives in mind, the USEPA evaluated the role of vegetation changes in altering natural stream temperature by modeling vegetation (relative shade) and temperature conditions at three locations in the basin: Elder Creek (considered relatively undisturbed or "natural"), Bull Creek, and Rattlesnake Creek, using the Stillwater Sciences Temperature (SST) model (USEPA 1999). These locations were selected to represent the range of conditions found throughout the SF Eel River Basin. Water quality standards targeted summer (July and August) temperatures, which were considered the most problematic for SF Eel River salmonids; most streams had the highest recorded maximum weekly average temperatures (MWATs) during the last week of July (USEPA 1999).

Stream temperature targets were established for each of the three representative locations and translated into heat loads. Effective shade allocations, which varied with stream width and vegetation type, were then established to show the percentage of shading necessary in each stream segment to attain the heat loading capacity and stream temperature targets. Effective shade allocations were applied to the entire basin, not just the three representative subbasins. The length of stream habitat under natural conditions (85% relative shade, developed using current conditions in Elder Creek) provides limited good and marginal cool water habitat; therefore, the natural condition cannot be increased in the basin without affecting beneficial uses. The USEPA used the natural condition scenario as the water quality objective when generating loading capacity and allocations in the TMDL. When targets were compared to current and natural conditions, the USEPA determined that improvements were needed in order to meet the first water quality objective.

The USEPA also used the SST model to map changes in temperature between current and idealized potential vegetation in order to address the State's second water quality objective. They found that a five degree increase was not a concern in SF Eel River streams and since the second objective was not exceeded, it was not investigated further in the TMDL analysis.

The SST model was developed to estimate stream temperature changes at a basin scale because there were limited quantitative data available for streams in the SF Eel River Basin. Although the model estimates are useful, it is important to remember that topography and vegetation in an area are not the only factors influencing stream temperatures – retention time, watershed area and aspect, existence and influence of cold water springs and seeps, and diversions upstream of the sampled area all affect stream temperatures. Ideally, model outputs and estimated stream temperatures should be verified by data collected in the field.

In 1997, the HCRCD, with the cooperation of 21 supporting agencies, individuals, and landowners, completed two field seasons of temperature monitoring and biological sampling in the Eel River Watershed, including many sites in the SF Eel River Basin (Friedrichsen 1998). Data were collected from 216 gauges in 1996 and 227 gauges in 1997 (*Figure 78*). Friedrichsen (2003) provided X,Y coordinates for some gauge locations, and others were digitized using HCRCD map data where available. Site data for 43 gauges were not included in HCRCD maps and reports and, therefore, were not included in *Figure 78*. The goal of the HCRCD study was to compare results of water temperature findings throughout the entire Eel River Basin with those of Kubicek (1977), who studied summer water temperatures and their effects on salmonid abundance and distribution throughout the Eel River Basin. Biological (invertebrate) sampling data collected by Friedrichsen (1998) will be discussed in the Water Quality: Aquatic Invertebrates section of this report.

The HCRCD continued to monitor temperatures after the initial study, and completed data collection during eight field seasons from 1996-2003 (Friedrichsen 2003). Water temperatures were continuously measured at 121 locations throughout the SF Eel River Basin: 30 sites in the Northern Subbasin, 26 in the Eastern Subbasin, 53 in the Western Subbasin, and 12 in the mainstem SF Eel River (Friedrichsen 2003) (*Table 44*). The exact locations of these stations and number of years of data collection at each site are provided in the subbasin sections of this report. Data loggers were generally deployed from June through October, and not all sites were sampled in every year; some sites had only one season of data.

Table 44. Ranges of MWATs and seasonal maximum temperatures collected from 1999-2003 throughout the SF Eel River Basin (data from Friedrichsen 2003).

Subbasin	**Number of Sites**	**MWAT Range (°F)**	**Average MWAT (°F)**
Northern	30	60-74	65.5
Eastern	26	55-76	65.0
Western	53	55-73	61.2
Mainstem SF Eel River	12	62-76	71.6

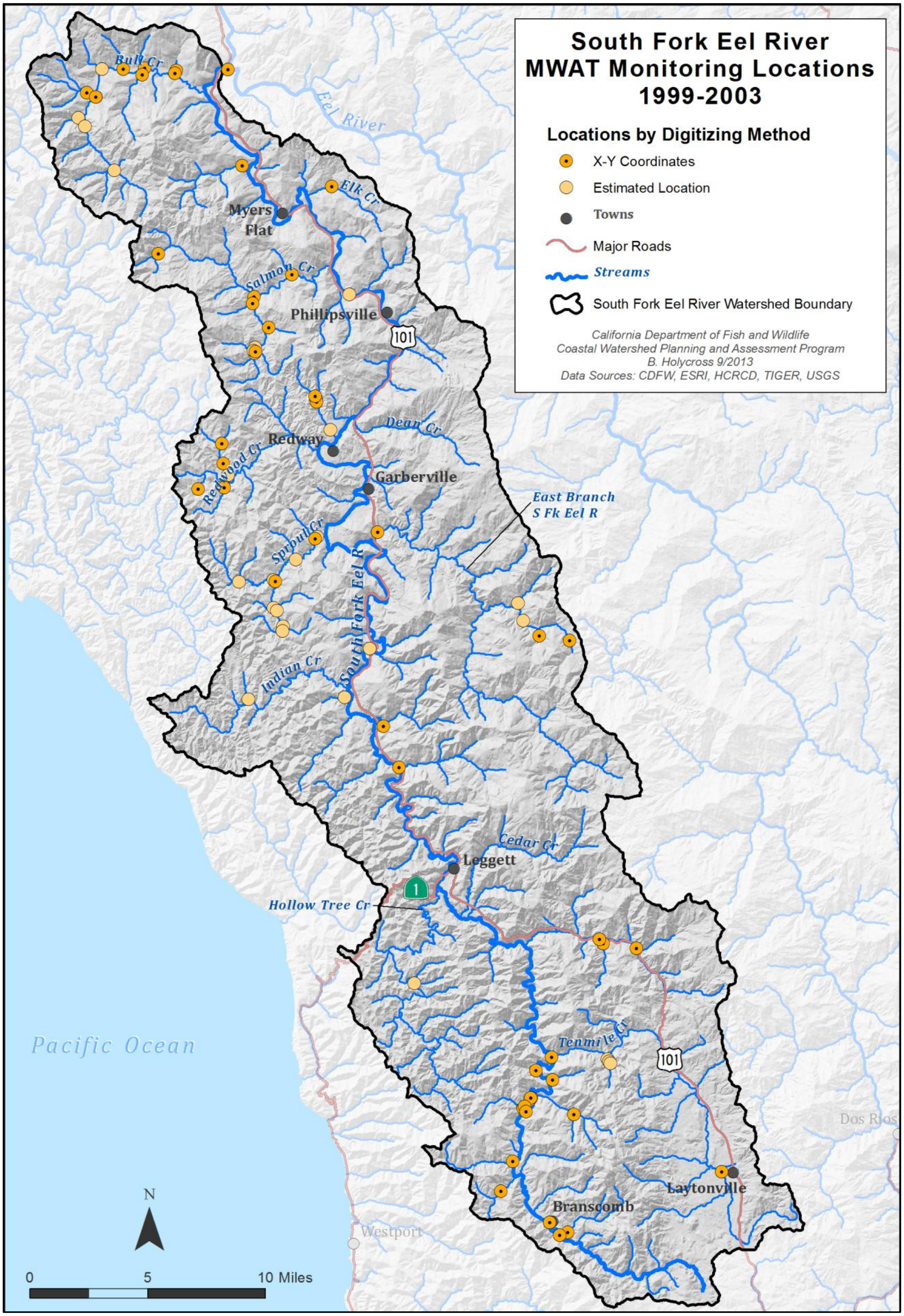


Figure 78. MWAT monitoring locations in the SF Eel River Basin, from HCRCD studies completed between 1999 and 2003 (Friedrichsen 1998, 2003). Not all gauge locations are included (no site data for 43 gauges).

Temperatures were recorded in SF Eel River habitats from Dyerville (RM 0, at the confluence of the SF and mainstem Eel Rivers) upstream to RM 93 near Branscomb, and temperatures ≥20˚C (68˚F) were considered stressful for salmonids. Attempts to interpret findings were beyond the scope of the project in 2003, but Friedrichsen (1998) concluded:

- The upper SF Eel River near Branscomb provided one of the few cold water refuge areas for Eel River Basin salmonids. Temperatures were highly suitable at Branscomb, and only rose above stressful levels for one week in 1997;
- Temperatures remained highly suitable above Elder Creek (RM 88);By the time the SF Eel River met Rattlesnake Creek (RM 75), water temperatures were significantly warmer and exceeded lethal limits during some of the study period (maximum recorded temperature 28˚C (82˚F));
- Warm temperatures remained high from Rattlesnake Creek downstream to below Miranda (RM 17), where temperatures decreased slightly (maximum recorded temperature 26˚C (79˚F)) before the SF Eel joined the mainstem Eel River.

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

UC Berkeley graduate student Keith Bouma-Gregson collected temperature data as part of a larger blue-green algae study in the Eel River Basin. The first year of data were collected during the summer of 2013, as part of an ongoing study. Bouma-Gregson sampled cyanotoxins, nutrients (nitrogen and phosphorous), and temperature at seven Eel River Basin sites, including four in the mainstem SF Eel River: Phillipsville (RM 22), Richardson Grove (RM 49), Standish-Hickey SRA (RM 66), and Angelo Reserve (RM 89) (*Figure 79*). 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.

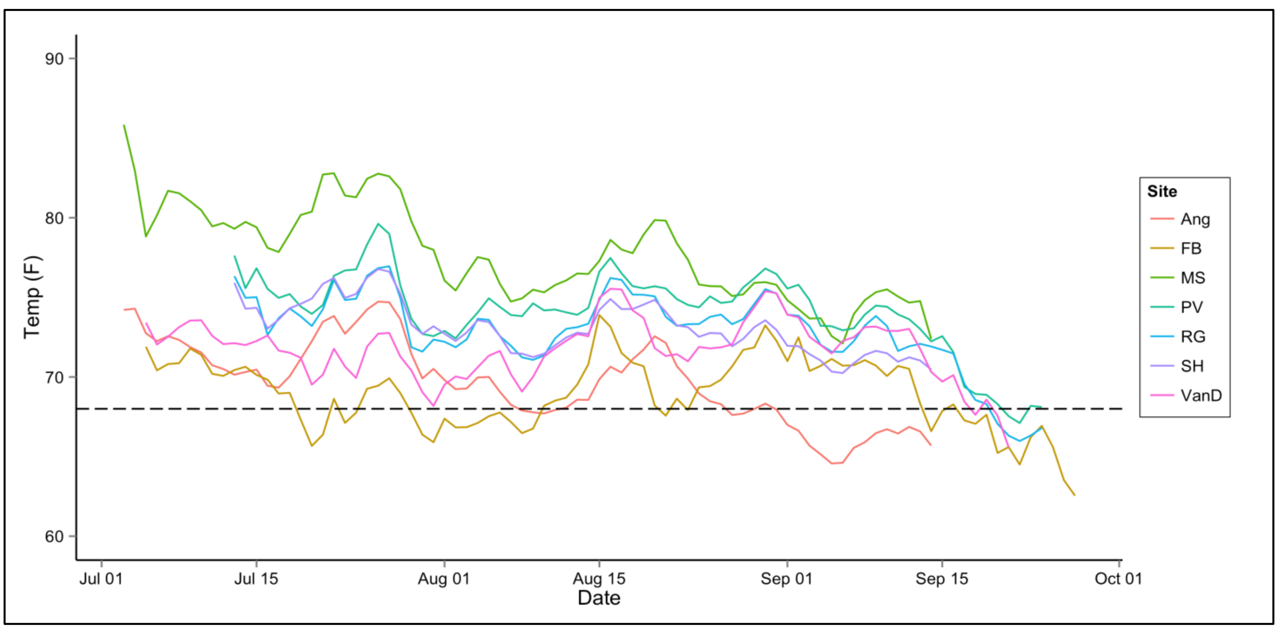


Figure 79. Daily average temperatures (degrees F) from July 3 through September 24, 2013, recorded at 7 sampling locations in the Eel River Basin. Data and graph provided by Keith Bouma-Gregson (UC Berkeley, 2014). Ang = Angelo Reserve; FB = Fernbridge; MS = Mainstem Outlet Creek; PV = Phillipsville; RG = Richardson Grove; SH = Standish-Hickey SRA; VanD = Van Duzen River.

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).

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 45*). 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 lethality is ≥75°F.

Table 45. CWPAP-defined salmonid habitat ratings for MWATs.

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

Western Subbasin streams had the highest percentage (40%) of sites sampled with low MWAT values (good stream temperatures) compared to other subbasin and mainstem locations (*Figure 80*). Western Subbasin streams also had the fewest number of sites with of poor stream temperatures based on MWATs compared to other subbasins and mainstem locations. This is due to the predominance of shade from high canopy densities, relatively good flow (except in heavily diverted streams such as those in the Redwood Creek drainage), and to cooler climate conditions due to aspect and location in the coastal fog belt in Western Subbasin streams. This subbasin also had the greatest number of sites sampled compared to other subbasins and the mainstem SF Eel River (*Table 44*).

Northern Subbasin streams had more poor stream temperatures than Eastern and Western subbasin streams, due to the relatively large number of sampling locations (27 of 30 Northern Subbasin MWAT sampling locations) in the Bull and Salmon Creek drainages. 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 diversions.

Eastern Subbasin streams had similar numbers of sampling locations with poor and good stream temperatures. MWAT data were collected in streams with a variety of habitat conditions. Some streams had good canopy and flow, and were similar in aspect to many Western Subbasin streams (e.g. Elder, Bear, and Taylor creeks); those streams had good temperatures for salmonids. Other streams such as Tenmile Creek, Red Mountain Creek, and areas of the East Branch SF Eel River had poor stream temperatures due to very low canopy density values, and high levels of diversion and fine sediment input. Temperature data for specific streams will be discussed further in the subbasin sections of this report.

The mainstem SF Eel River had the fewest locations with good stream temperatures (10 out of 12 sites had poor stream temperatures) compared to tributary streams, which was expected due to due to increased solar exposure and longer residence times in the mainstem. Of greater concern were recorded water temperatures of 75-76ºF on the mainstem at the Miranda Bridge and Piercy sites in 2000, and at the Sylvandale site in 1999, 2000, 2001, and 2003. These temperatures are potentially lethal for salmonids if cooler refuge areas are not available. Maximum weekly average temperatures are momentary high points, and are useful for general discussion. However, it would be more important to capture the duration that salmonids are exposed to stressful or lethal temperatures on a reach by reach basis throughout the basin, and to document the availability of cool water refugia areas near locations where lethal MWAT values have been recorded.

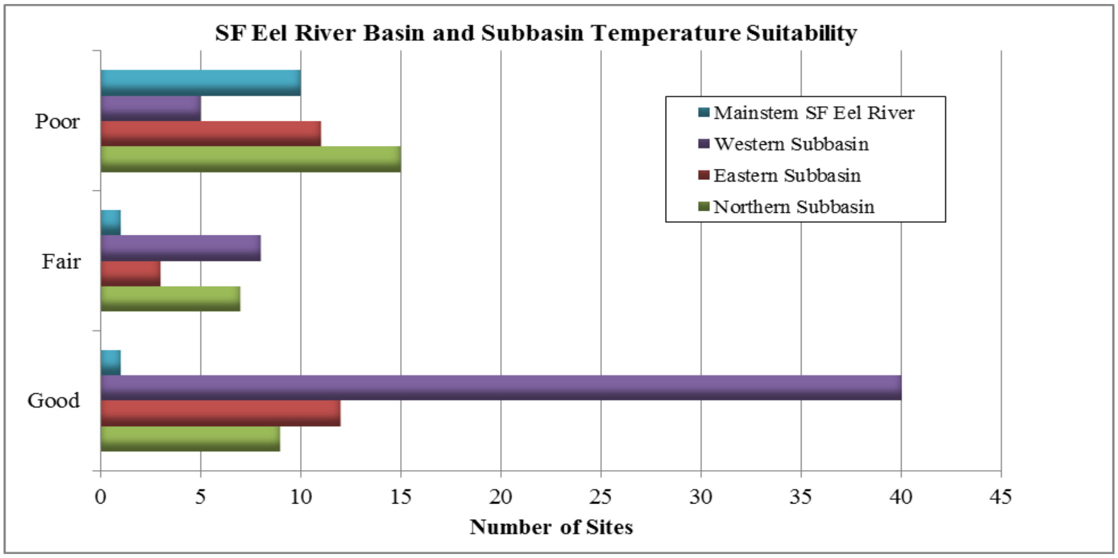


Figure 80. Number of sites with average MWAT values in CWPAP temperature suitability categories in SF Eel River mainstem and subbasin tributaries.

Salmonids may seek refuge in thermally stratified pools or in localized refugia provided by surface and groundwater interactions when mainstem and tributary temperatures reach stressful or even lethal temperatures (Nielsen et al. 1994). These cool water refugia are particularly important in areas where high temperatures result in increased primary productivity (algal blooms), low dissolved oxygen concentrations, and conditions favoring invasive species such as Sacramento pikeminnow. Both spatial and temporal changes in stream temperatures are concerns in the SF Eel River Basin. 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).

USGS temperature monitoring data is available for two SF Eel River gauge locations: Elder Creek data is available from April 2012 to present (provisional data from December 2012 to present); and Cahto Creek temperature data is available from October 2007 to present (no provisional data) (*Figure 81*, *Figure 82*). Gaps in the Cahto Creek temperature record indicate times with no flow at the recording gauge. Temperatures at both locations were unsuitable for salmonids in the late summer months during each year of record, but did not reach lethal levels (≥ 75˚F) at any time.

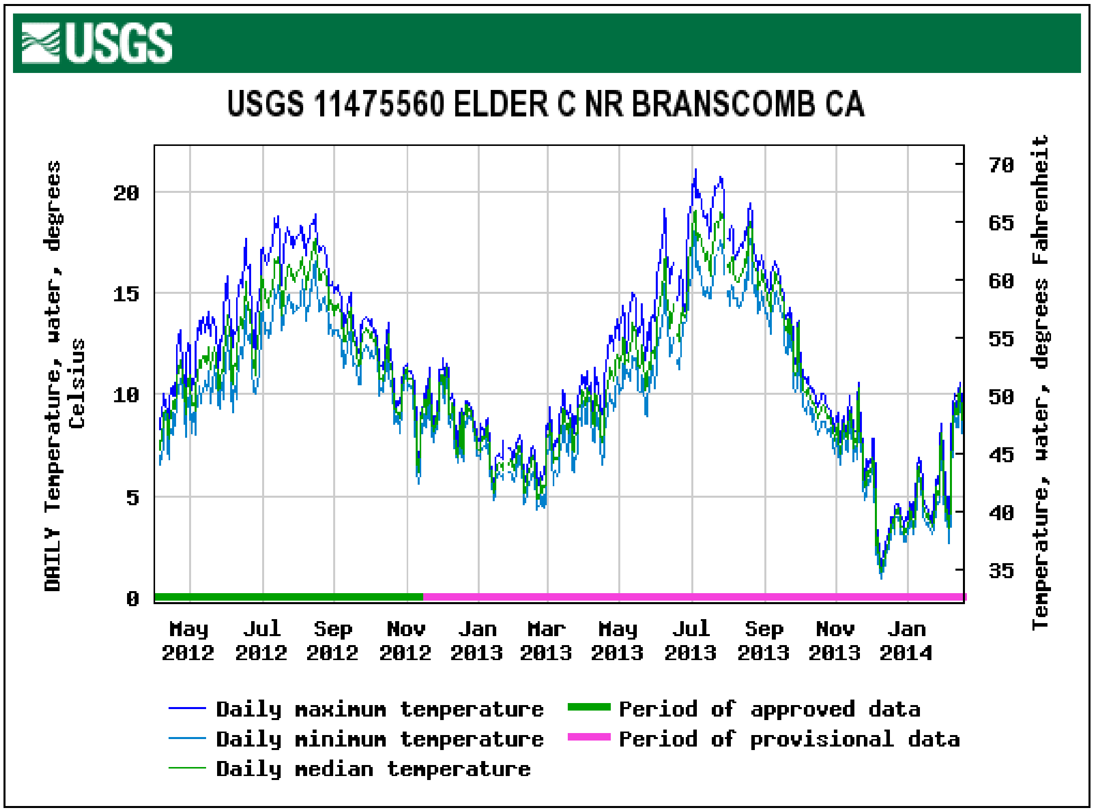


Figure 81. Water temperature recordings from USGS gauge located at Elder Creek between April 2012 and present.

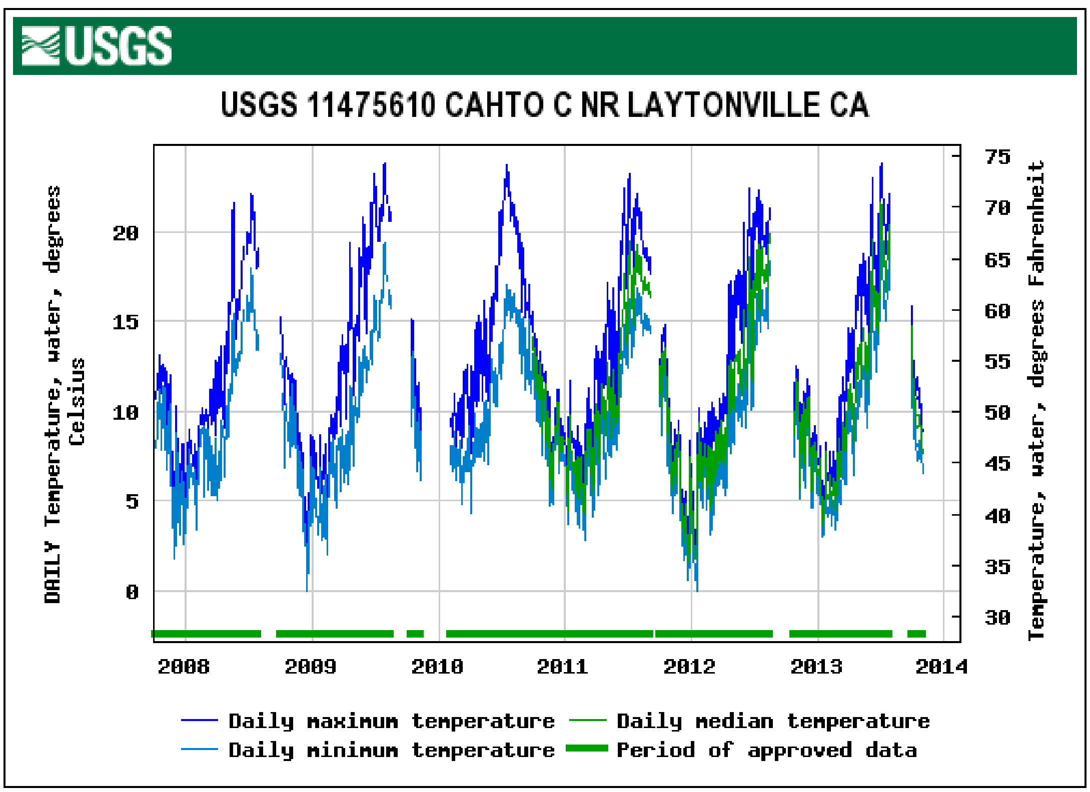


Figure 82. Water temperature recordings from USGS gauge located at Cahto Creek between December 2012 and present.

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 SF Eel River Basin 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 five locations in the SF Eel River Basin: Elder Creek (RM 88), Cahto Creek (located at RM 16 on Tenmile Creek, which meets the SF Eel River at RM 84), SF Eel River at Leggett (RM 68), 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. Flow data from the Cahto Creek gauge is not included in this section because Cahto Creek is dry for much of the year, and discharge data are limited. The other four SF Eel River gauge locations 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 83* through *Figure 86*). These low flows may be caused by an increase in both the number of diversions and the quantity of water diverted from SF Eel River Basin streams and tributaries for agricultural and domestic uses.

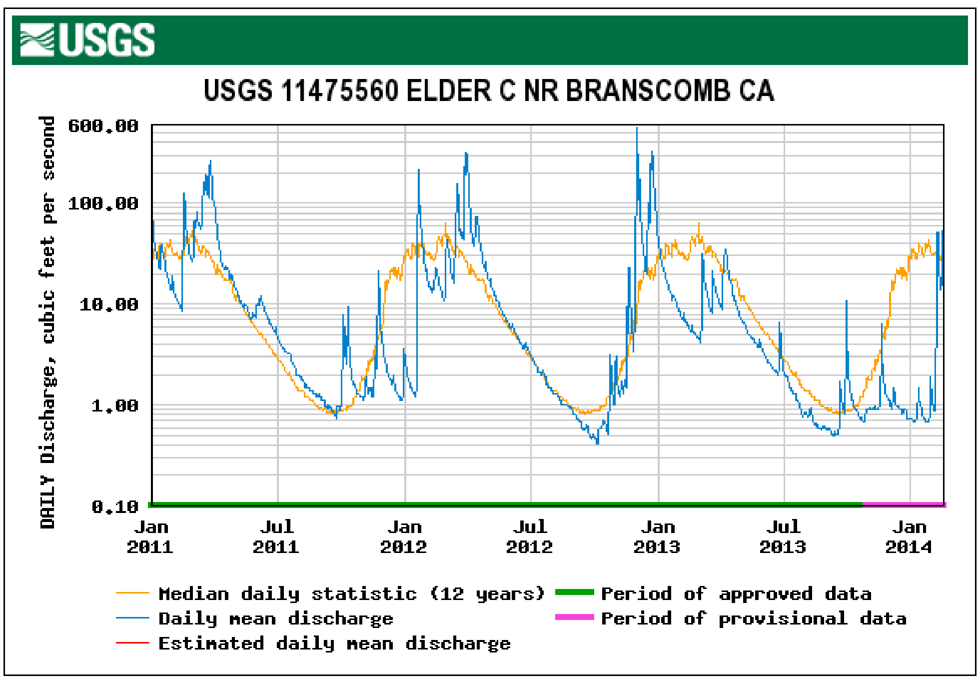


Figure 83. Daily mean discharge (in cfs) and mean daily discharge (45-year average in cfs) for USGS gauging station at Elder Creek, showing 2011-2014 data.

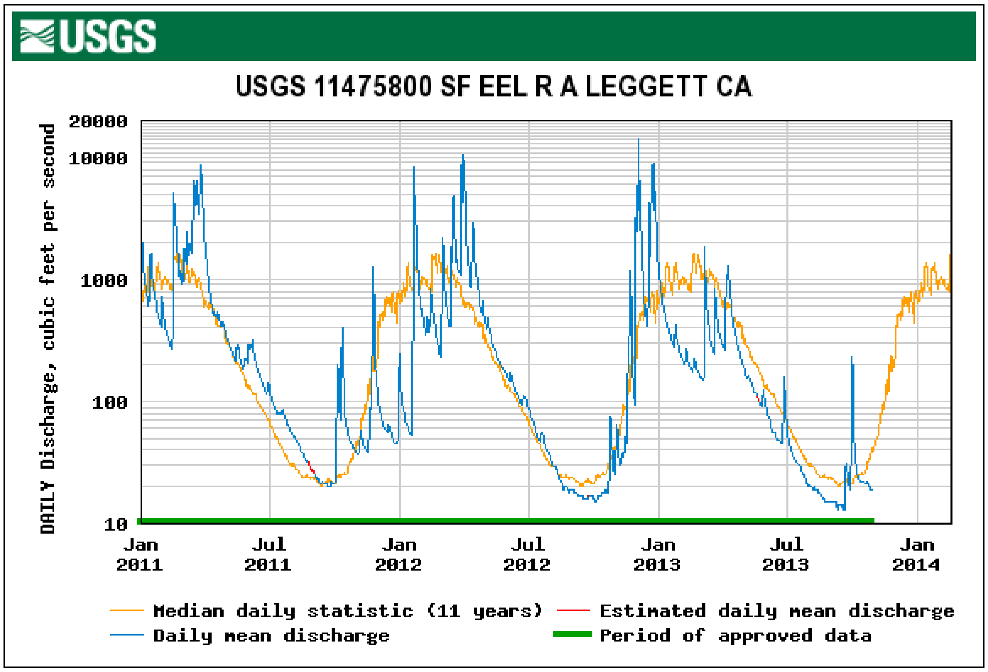


Figure 84. Daily mean discharge (in cfs) and mean daily discharge (40-year average in cfs) for USGS gauging station at SF Eel River near Leggett, showing 2011-2014 data.

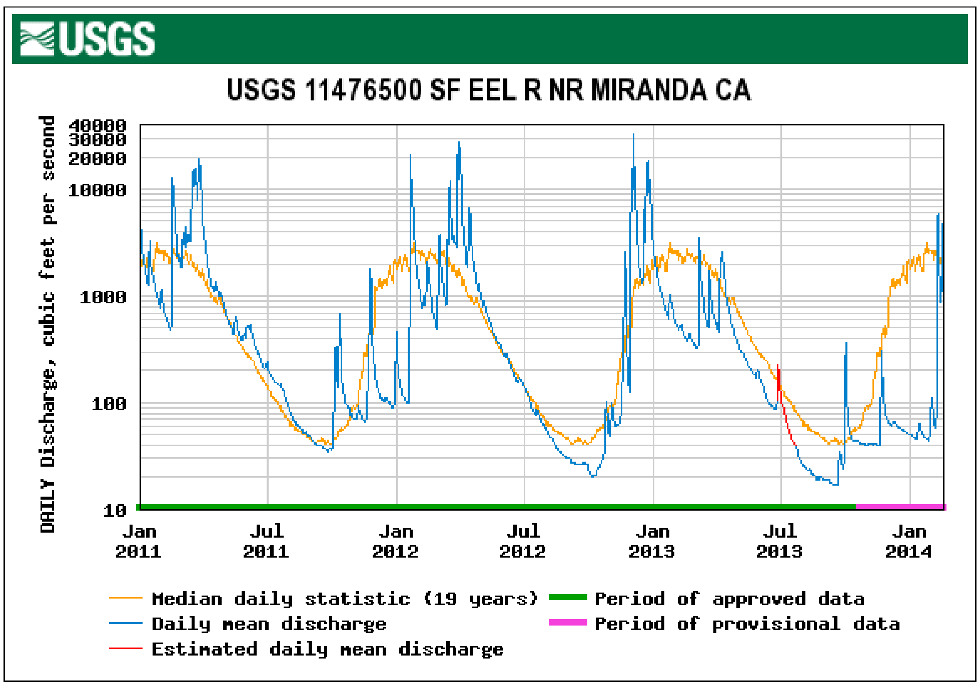


Figure 85. Daily mean discharge (in cfs) and mean daily discharge (73-year average in cfs) for USGS gauging station at SF Eel River near Miranda, showing 2011-2014 data.

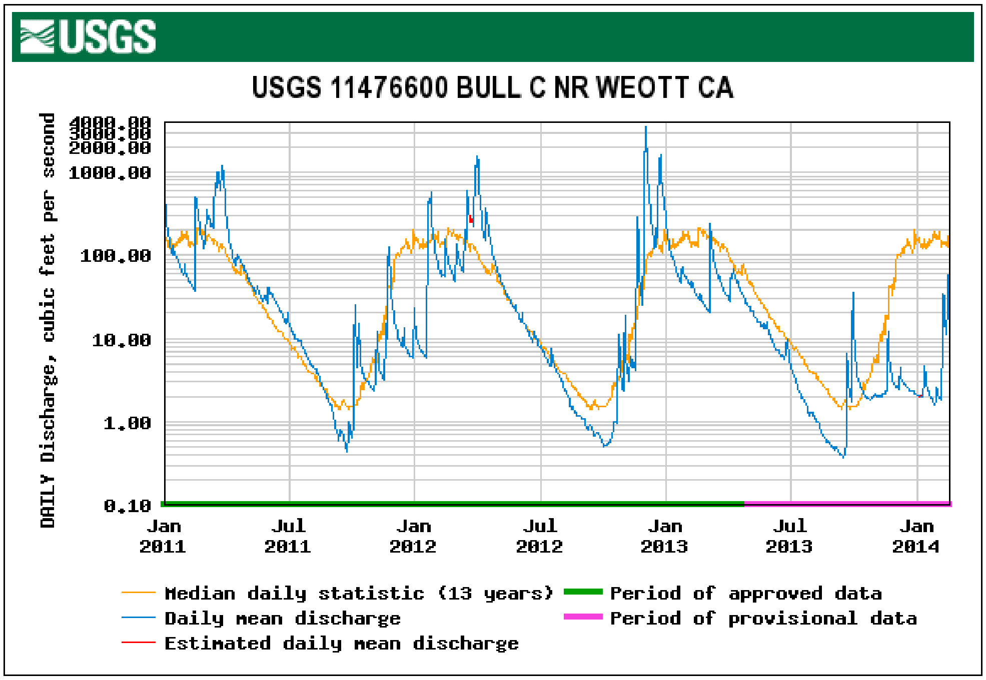


Figure 86. Daily mean discharge (in cfs) and mean daily discharge (52 year average in cfs) for USGS gauging station at Bull Creek, showing 2011-2014 data.

Friedrichsen noted in 2003 that water diversions throughout the SF Eel River Basin were cause for concern, particularly in areas with increased urbanization and unregulated diversions during summer months, in drainages such as Salmon, Sproul, Redwood, and Bull creeks. Higgins (2013) mapped streams that were dry in 2012, including one section of Tenmile (Higgins refers to it as Ten Mile) Creek in the SF Eel River Basin that was perennial as recently as 1997 (Friedrichsen 1998) and dry in 2012, suggesting that flows have diminished in some areas within the basin.

CWPAP staff conducted a brief low flow study during August and September 2013, collecting information at 5 mainstem SF Eel River sites and in 39 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 an increase in the number of diversions) throughout the basin, and to compare conditions in streams that are heavily diverted with those that have light diversion pressure and those with no known diversions. In streams with no diversion (n = 13) and in streams that were not heavily diverted (n = 20), flows were typical of those seen in very low water years. In heavily diverted streams (n = 6), conditions ranged from dry or isolated pools only in 4 streams (Redwood, Tenmile, Cahto, and Little Charlie creeks), to connected streams with very low flow in the remaining 2 streams (Salmon Creek and East Branch SF Eel River). 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 87 A*, *B*).


Figure 87 A, B. View of Salmon Creek from Maple Hills Road bridge on 8/27/2013 (left) and on 9/19/2013 (right). Flow was diminished but the stream channel was connected in August, but only one isolated pool was present below the bridge when field crews returned three weeks later.

Water Diversion and Voluntary Conservation

The effect of diversions, and their impact on low flows and warm water temperatures on salmonids are major concerns in streams throughout the SF Eel River Basin. , Diversions and their associated impacts are being addressed using a variety of techniques to increase public awareness and understanding, and to involve community members in efforts to improve instream and riparian conditions for salmonids during all life stages. Utilizing CDFG's Fishery Restoration Grant Funding, the Salmonid Restoration Federation (SRF), in conjunction with a graduate student at Humboldt State University (HSU), initiated a study in 2013 to determine the feasibility of implementing a voluntary water conservation and storage program in the Redwood Creek watershed. This study is modeled after Sanctuary Forest's water storage and forbearance program in the Mattole River headwaters, where participating landowners store water in tanks during high flows for use during low flow conditions, thereby reducing diversions and maintaining flows to improve fish habitat and water quality during the low flow season. Flows increased by substantially in the one-mile section of the Mattole River where water conservation occurred (SRF 2013). Due to the success of the program in the nearby Mattole River Basin and commonalities between the watersheds (land use and settlement patterns) SRF and HSU applied a similar design when developing the Redwood Creek Water Conservation Project.

There are two phases in the Redwood Creek study:

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

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

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

In addition to survey questionnaire/analysis and community outreach events, SRF also collected baseline streamflow data in the Redwood Creek watershed during the late summer/early fall months of 2013. Data were collected at eleven sites in the watershed, from the upper watershed 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 (*Figure 88*);
- 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 in the watershed were reconnected and remained flowing until the next rainstorm on November 18.

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

This study emphasizes the need for specific information on water diversions and flow in many SF Eel River Basin drainages, and it is an example of successful community involvement in fisheries habitat monitoring and restoration efforts. Similar voluntary conservation programs could be applied in the future in other watersheds throughout the basin.

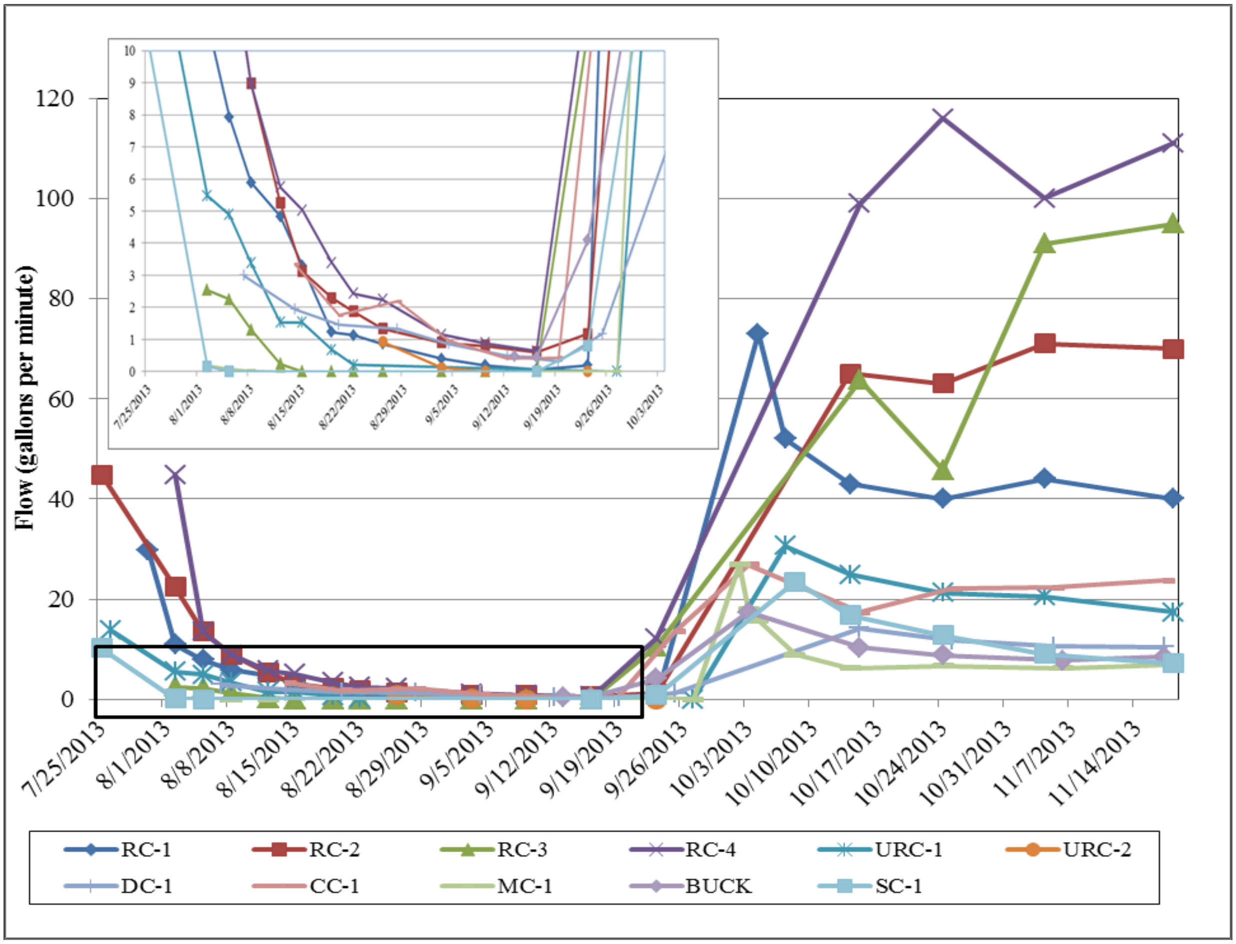


Figure 88. 2013 summer streamflow in Redwood Creek (near Redway), with inset showing low flow from July through September (data and figure from SRF 2013). RC = Redwood Creek; URC = Upper Redwood Creek (Pollock Creek); DC = Dinner Creek; CC = China Creek; MC = Miller Creek; BUCK = Buck Creek; SC = Seely Creek.

Water Chemistry

Sediment

Sediment modifies aquatic habitat in various ways, affecting salmonids both directly and indirectly; coarse sediment, fine sediment, and suspended sediment may adversely affect adult and juvenile salmonids by modifying channel structure and affecting production. Some examples of how sediment affects salmonids and their environment include the following:

- Natural spawning areas contain approximately 10% fine sediment, and survival of salmonid eggs to emergence is inversely correlated with percent fines over the natural level. Survival rate to emergence decreases rapidly with each one percent increase above the 10% level (Cederholm et al. 1980);
- Suttle et al. (2004) found that steelhead growth decreased sharply and linearly with increasing fine sediment concentrations, and aggressive behavior increased as invertebrate prey availability and visual acuity decreased.
- Input of coarse sediment modifies stream morphology and results in structural changes which may detrimentally affect salmonid populations (USEPA 1999).
- Cederholm et al. (1980) found that gravel roads used primarily for logging produced sediment at 2.6-4.3 times the natural rate, and efficiency of spawning environments was lowered by logging-related sedimentation;
- Increased sediment delivery may lead to a reduction in spawning and rearing habitat quality and quantity, and increased turbidity

may affect the ability of juveniles to feed; these changes have led to a decrease in the carrying capacity of salmonid streams (NOAA RC 2011).

The SF Eel Basin was listed by the USEPA as an impaired water body for sediment (USEPA 1999). In the TMDL analysis, EPA interpreted water quality standards, calculated existing sediment loads, set loading capacities, and established load allocations. 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 determine the amount of sediment that will not adversely affect salmonids, USEPA developed a set of indicators: percent fines, turbidity, V*, and the thalweg profile. Stillwater Sciences (1999) then completed a sediment source analysis, which was used to set TMDL loading capacity and allocations for the SF Eel River Basin. TMDL allocations were developed to assess the maximum allowable amount of sediment received by a stream while still meeting water quality requirements (*Table 46*).

Table 46. United States Environmental Protection Agency 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 calculated that existing sediment loading in the Basin 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 47*). According to the USEPA, this calculation was low compared to other studies, but the conclusions are the same: most sediment is from anthropogenic sources, and roads are the primary source of sediment in the Basin.

Table 47. United State Environmental Protection Agency 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		**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		**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 SF Eel River Basin 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 or road between 1998 and 2003 (PWA 2005). The study area included 12.23 miles of decommissioned roads in the Bull Creek drainage in the 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 these sites. At landslide sites and road drainages, protocols were determined to be effective and were being followed, and 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 be monitored over time.

Aquatic Invertebrates

Aquatic macroinvertebrates (*Figure 89*) are good indicators of stream health because they are directly affected by physical, chemical and biological stream conditions, and because they may show impacts from 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 levels of fine sediment input from unstable hillslopes and land use activities, similar to those found throughout the SF Eel River Basin.

Figure 89. Larval stage of a mayfly, an aquatic macroinvertebrate in the order Ephemeroptera (photo courtesy of CDFW Aquatic Bioassessment Laboratory).

Friedrichsen (1998) sampled macroinvertebrate communities in the spring and fall of 1996 in 22 Eel River Basin streams. 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: Elk, Salmon, Little Sproul, Cedar, Redwood (Branscomb), and Tenmile creeks, and the East Branch SF Eel River. Five metrics (explained in detail by Plafkin et al. 1989) of macroinvertebrate assemblages and community structure were calculated (one score for spring and one score for fall at each location) 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. When assessing how macroinvertebrate communities respond to disturbances, current communities are usually compared to those in a reference stream (Fore et al. 1996). Although no control stream was available for this study, Friedrichsen (1998) found that when all metric results were considered, the least impacted streams of those sampled in the SF Eel River Basin were Redwood and Salmon creeks. Redwood Creek invertebrate communities were characterized by taxa that are associated with cooler summer water temperatures. In the East Branch SF Eel River and Tenmile Creek, the most abundant taxa were adapted to warm water temperatures, but more information is needed to determine invertebrate species tolerance levels for both pollution and elevated water temperatures throughout the Eel River Basin, and to assess the effects of increased diversions on invertebrate populations. Conditions have changed in both Salmon Creek and Redwood Creek since Friedrichsen's study was completed; both are now 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 these grow operations may be polluted with fertilizers, diesel fuel, rodenticides, and fine sediment, affecting water quality and, therefore, instream invertebrate communities.

Many invertebrate research projects have been completed or are ongoing at Angelo Coast Range Reserve, managed by the University of California (UC) Natural Reserve System and the UC Berkeley campus. In one study, Power (2003) investigated the effects of fine sediment on river habitat, invertebrate communities, and juvenile steelhead growth and survival. As fine sediment levels increased, steelhead growth decreased linearly due to a shift in invertebrate communities from grazers and predators, which were available as prey to foraging salmonids, to unavailable burrowing taxa. A list of publications for research completed at the reserve, or using specimens collected at the reserve, can be found at:
http://cbc.berkeley.edu/angelo/publications.htm.

Additional invertebrate abundance and benthic community diversity studies on specific SF Eel River streams would further our understanding of instream conditions, overall stream health, and potential salmonid food sources throughout the SF Eel River Basin.

Blue-Green Algae Blooms

Blue-green algae, or cyanobacteria, are naturally occurring photosynthetic bacteria present in warm, slow-moving surface waters in the South Fork Eel River and its tributaries during temperate months in the late summer and early fall (*Figure 90*). Some forms of blue-green algae produce harmful toxins that may attack the liver (hepatotoxins) or the nervous system (neurotoxins). Toxins are released into the environment when cells rupture or die, and are concentrated during algal blooms (Hoehn and Long 2008, Blaha 2009).

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

Figure 90. Blue-green algae bloom in lower SF Eel River, August 2013 (photo courtesy of ERRP).

In order to minimize the proliferation of blue-green algae, preventative measures should be designed to control the 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).

In recent years, blue-green algae blooms have become common in Eel River streams, including the SF Eel River during the late summer, when flows are at a minimum and air temperatures are high (>100˚F). In response to these blooms the Humboldt County Department of Health and Human Services (HCDHHS) has issued warnings notifying recreational users of the South Fork Eel to avoid exposure to neurotoxins and liver toxins found in blue-green algae in these rivers (HCDHHS, Division of Environmental Health, 2011). The County also 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 – this soil 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. These plants prevent erosion, filter water, and do not require fertilizers or pesticides.
- Keep livestock out of surface waters and prevent surface runoff from agricultural areas.
- 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 temperatures are high (>100˚F). These conditions are prevalent in the lower mainstem areas of the SF Eel River. Community groups such as ERRP have been 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.

A graduate student in the Department of Integrative Biology (UC Berkeley) recently completed a preliminary study of blue-green algae toxins (microsystins and Anatoxin-a), temperature, nitrogen, and phosphorous in the Eel River Basin. He obtained weekly average concentrations of dissolved cyanotoxins, nitrogen, and phosphorous at seven sites in the Eel River Basin from July-September, 2013 (for a description of sampling locations, see the Temperature section of this overview). Cyanobacteria were present at all sites except Fernbridge. The sites with the highest concentrations of toxins were located in the SF Eel River, with the highest concentrations of Anatoxin-a recorded at Phillipsville in August and September 2013 (Bouma-Gregson, personal communication, 2014). Additional studies are necessary to address the frequency of blue-green algae blooms, conditions that promote blooms, levels of toxins, nutrients and pollutants present in SF Eel River streams, current sources of input, and ways to reduce the input of these and other harmful substances in order to improve salmonid habitat.

Conclusions and Limiting Factors Analysis

Although instream habitat conditions for salmonids varied across the SF Eel River Basin, several generalizations can be made. Canopy conditions have improved over time throughout the basin when comparing data collected in the 1990s and data from 2000-2010 (*Table 48, Figure 91*). Canopy density was suitable in the basin and in all subbasins, during the most recent time period, and both the percent canopy and the contribution of coniferous vegetation to overall canopy density increased in each subbasin over time. However, current canopy density measurements do not take into account differences between smaller, younger riparian vegetation and larger microclimate controls that are provided by old growth forest canopy.

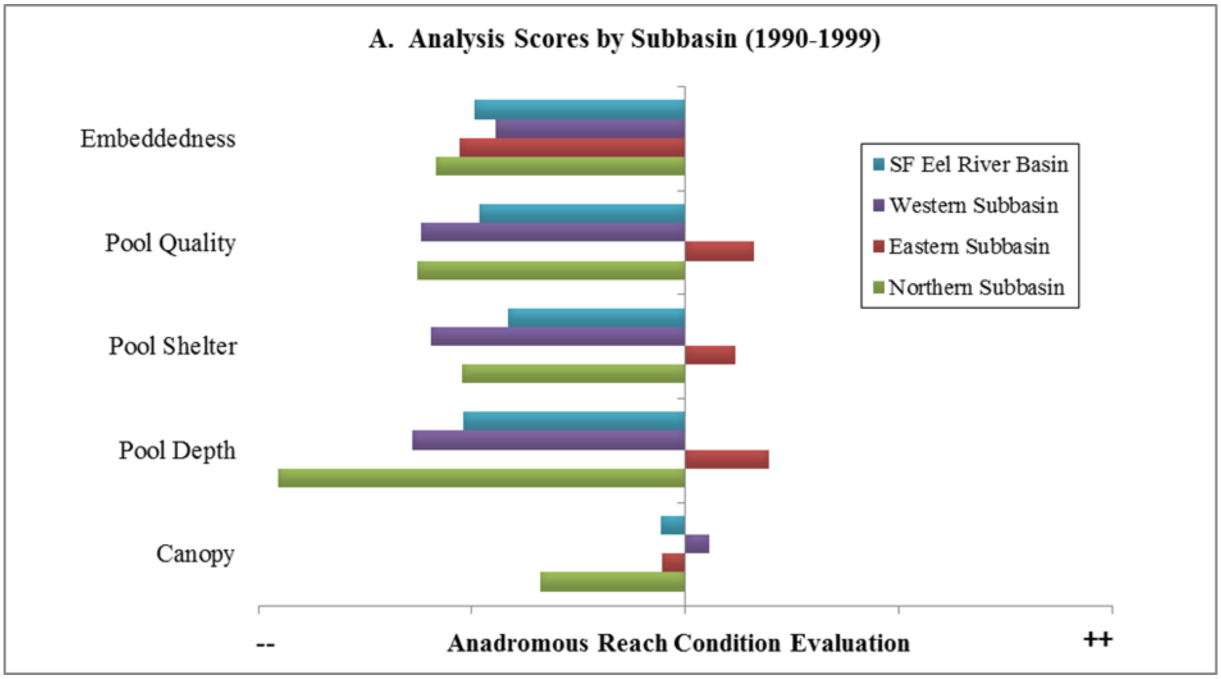
Cobble embeddedness condition, as an indicator of fine sediment impacts, also improved in all subbasins, and in the entire basin, when comparing conditions during the two time periods (*Table 48*). Using data collected between 2000 and 2010, conditions were evaluated as suitable, and both cobble embeddedness and canopy density are probably not limiting factors to salmonid populations in the SF Eel River Basin and subbasins.

Table 48. Anadromous Reach Condition analysis results for the SF Eel River Basin.

1990-1999 Subbasin	**Canopy**	**Pool Quality**	**Pool Depth**	**Pool Shelter**	**Embeddedness**
Northern	-	--	--	--	--
Eastern	-	+	+	+	--
Western	+	--	--	--	-
SF Eel River Basin	-	-	--	-	-
2000-2010 Subbasin	**Canopy**	**Pool Quality**	**Pool Depth**	**Pool Shelter**	**Embeddedness**
Northern	+	--	--	-	+
Eastern	+	--	-	--	+
Western	++	--	-	--	+
SF Eel River Basin	++	--	-	--	+

Key: + ++ = High Suitability - -- = Low Suitability

Overall pool quality, pool depth, and pool shelter were generally unsuitable in surveyed streams throughout the basin in the 1990s, except in the Eastern Subbasin where conditions were somewhat favorable for salmonids (*Table 48*). Bear in mind that Western Subbasin tributaries generally have better conditions and correspondingly larger salmonid populations than Eastern Subbasin streams; however, the structure and distribution of streams sampled in the Eastern Subbasin influenced the results of pool depth, pool shelter, and pool quality in the analysis. In the 1990s, nine Eastern Subbasin streams were sampled, with a total surveyed length of 35.5 miles (*Table 35*). Nearly half (44%, or 15.8 miles) of habitat surveyed was located on Tenmile Creek, one of the largest streams in the subbasin (second in drainage area only to the East Branch SF Eel River), and the only third order stream sampled. Pool quality and pool shelter suitability decreased over time in the Eastern Subbasin, going from the second highest to the lowest suitability category in most of Tenmile Creek. These unsuitable habitat factors are likely limiting to salmonid populations throughout the basin.



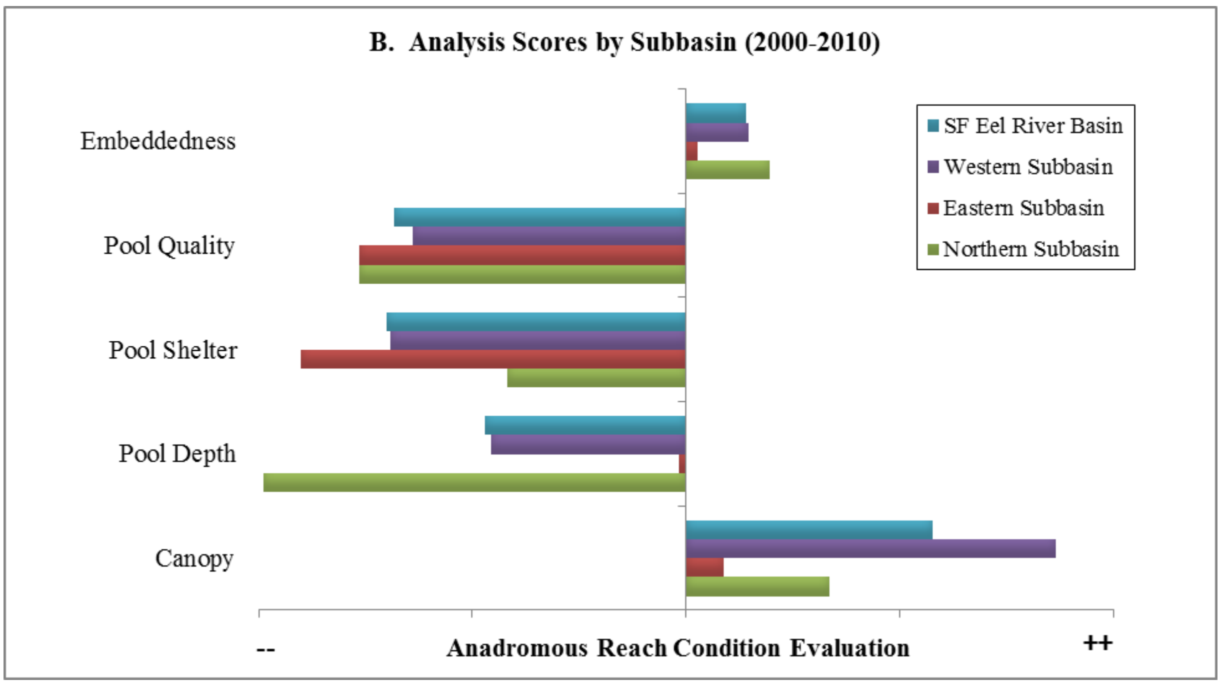


Figure 91 A, B. Anadromous Reach Condition truth values for SF Eel River Basin and subbasins from 1990-1999 (A) and 2000-2010 (B).

Water temperature measurements, although not currently evaluated by the EMDS-type analysis, were available as MWAT data collected between1999 and 2003 (Friedrichsen 2003). Western Subbasin streams had the most suitable temperatures (75% of sites sampled), and mainstem SF Eel River sites had the most low suitability locations (83% of sites sampled). Forty eight percent of locations sampled in Northern Subbasin streams had poor temperatures, and temperatures at sites in Eastern Subbasin streams were evenly distributed between good and poor (46% good and 42% poor). Two tributaries in the Eastern Subbasin and three locations on the mainstem SF Eel River had temperatures above lethal limits for salmonids. Therefore, water temperature is likely a limiting factor for salmonids in many SF Eel River tributaries and in the mainstem.

Fish passage barriers are not currently evaluated by the EMDS-type analysis. There are 199 known natural and antropogenic barriers to salmonid passage in the basin and these barriers are likely limiting salmonid production.

Water quality issues of concern in the SF Eel River Basin include fine sediment inputs from unstable geology and land use practices, excessive diversions (resulting in lower than normal flows), and nutrient/pollutant inputs in all subbasins, particularly those with extensive marijuana cultivation activity (e.g. Salmon and Redwood creeks). Each of these issues negatively impacts salmonid populations at all life stages throughout the basin, therefore water quality is likely a limiting factor, specifically excess sediment, low flow, pollutants, and low dissolved oxygen.

Fish Restoration Programs

Restoration efforts throughout the SF Eel River Basin have been ongoing since the early 1970s. Like many other areas in the region, early efforts were largely volunteer (Vaughn 1999) and included removal of large debris accumulations, small hatchery operations, and riparian tree planting. Restoration efforts are now more diverse, inclusive, and better funded. Since 1982, more than 300 restoration projects, totaling more than 25 million dollars have been funded to improve watershed conditions in the SF Eel River Basin (*Table 49*).

Table 49. SF Eel River Basin projects and funding totals by basin, subbasin, and restoration categories, 1982–2012.

	Northern Subbasin		Eastern Subbasin		Western Subbasin		Basin-wide Or Multiple Basin		SFER Basin Totals	
Project Type	# of Projects	Total Project Funding	# of Projects	Total Project Funding	# of Projects	Total Project Funding	# of Projects	Total Project Funding	# of Projects	Total Project Funding
Bank Stabilization	10	$1,107,529	11	$644,168	17	$470,741	1	$81,500	39	$2,303,938
Cooperative Rearing	3	$72,548	2	$55,853	39	$1,232,404	2	$64,360	46	$1,425,165
Fish Passage Improvements	1	$319,848	6	$461,906	15	$715,554	0	–	22	$1,497,308
Instream Habitat Improvement	8	$513,810	6	$367,613	30	$1,224,544	0	–	44	$2,105,967
Land Acquisition	0	$0	0	$0	1	$715,554	0	–	1	$715,554
Monitoring	3	$122,412	1	$17,887	4	$308,416	2	$317,635	10	$766,351
Other *	8	$168,556	10	$386,608	4	$167,781	1	$173,000	23	$895,945
Riparian Habitat Improvement	1	$35,743	8	$238,013	2	$30,843	2	$152,347	13	$456,946
Upslope Watershed Restoration	24	$4,389,170	14	$1,299,181	34	$7,203,745	0	–	72	$12,892,096
Watershed Evaluation, Assessment & Planning	10	$568,939	6	$150,113	14	$1,206,457	1	$634,976	31	$2,560,485
Total	**68**	**$7,298,556**	**64**	**$3,621,341**	**160**	**$13,276,039**	**9**	**$1,423,818**	**301**	**$25,619,754**

* - "Other" includes education/outreach, training, capacity building and public involvement.

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 SF Eel River Basin.

Most of the restoration projects completed in the basin have been upslope watershed restoration projects (72 out of 301), and more than half of all restoration projects have been completed in the Western Subbasin (160 out of 301) (*Table 49*). Upslope watershed restoration projects have also been allocated considerably more funding (nearly 13 million dollars) than all other project types, followed by bank stabilization (approximately 2.3 million dollars) and instream habitat improvement (approximately 2.1 million dollars).

The Western Subbasin is the second largest of the three subbasins, but it contains more streams with known fish distribution than either the Northern or Eastern subbasins. The Western Subbasin also has the greatest percentage of land use in timber harvest and more roads (many of which are improperly located, constructed, or maintained) than any other subbasin. Therefore, it is not surprising to see more upslope restoration projects in a watershed with these land use issues, combined with the unstable geology and very high sediment inputs (both natural and anthropogenic) found throughout the basin. Many of the problems that SF Eel River Basin salmonids face are related to high sediment loads and warm water temperatures during low flow times. Restoration projects such as upslope restoration (including road decommissioning), bank stabilization, and instream habitat improvement (the three most common restoration activities) have been designed to mitigate the effects of these problems in areas where fish are present (*Figure 92*).

In addition to the projects listed above that have received funding, many more restoration efforts are occurring throughout the basin as landowners and community organizations seek to preserve or repair the natural integrity of their property. More detail on specific projects that have received funding can be found in the subbasin sections of this report.

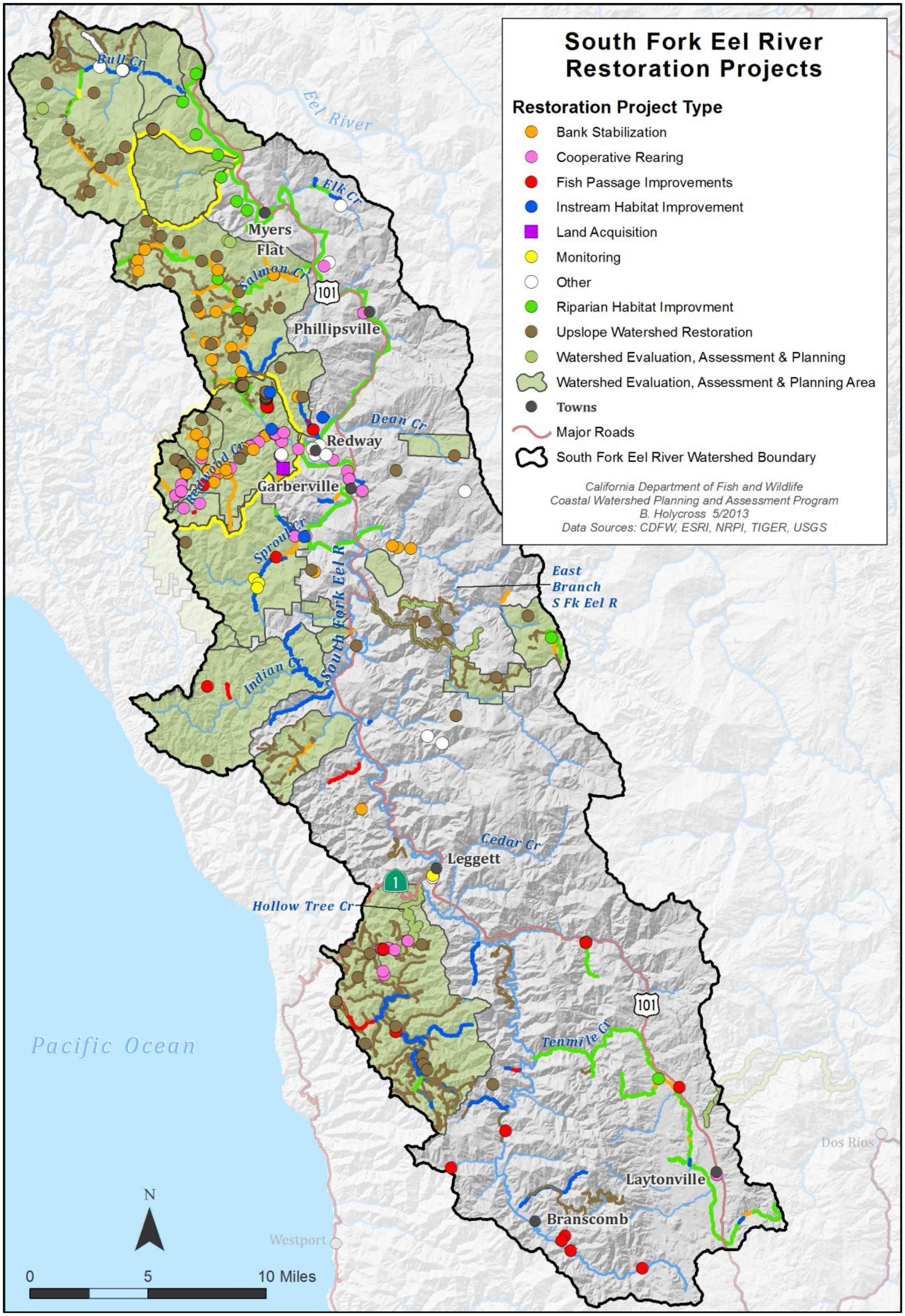


Figure 92. SF Eel River Basin restoration projects funded from 1982 through 2012(some projects are represented by multiple features on the map, indicating multiple restoration sites within projects).

Integrated Analysis

Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFW stream inventories provide a list of recommendations that address those conditions that did not reach target values (see Basin Fish Habitat Section). In the SF Eel River Basin, 213 surveys totaling 546 miles were conducted on 76 streams between 1989 and 2010, and recommendations for each stream were selected and ranked by a CDFW biologist (*Table 50*). The tributary recommendation process is described in more detail in the Program Introduction and Overview, and in the Fish Habitat Relationship section for each subbasin.

Table 50. Occurrence of recommendations in surveyed streams of the SF Eel River Basin.

Subbasin	Number of Surveys	Survey Length (miles)	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Live-stock	Fish Passage
Northern	58	108	27	3	14	25	40	40	0	4	0	7
Eastern	46	178	16	6	7	36	29	33	1	2	0	1
Western	109	260	53	19	7	57	56	89	0	19	2	9
Total SF Eel River Basin	**213**	**546**	**96**	**28**	**28**	**118**	**125**	**162**	**1**	**25**	**2**	**17**

In order to compare tributary recommendations within the basin, the recommendations of each stream were collapsed into five target issue categories (*Table 51*). The top three recommendations of each stream are considered to be the most important, and are useful as a standard example of recommendations for the entire stream. 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. When examining recommendation categories by number of tributaries, the most important target issue in the Northern, Eastern, and Western subbasins is instream habitat (*Table 52*). Riparian/water temperature recommendations were the second most important category in the Northern and Eastern subbasins, and erosion/sediment was the second most important category in Western Subbasin tributaries.

However, comparing recommendation categories between subbasins can be confounded by differences in the number of tributaries and the total length of streams surveyed in each. Therefore, CWPAP staff calculated the number of stream miles within each subbasin assigned to various recommendation categories in order to determine the frequency of each type of recommendation (*Figure 93*). Instream habitat is the most important target issue for the Northern and Western subbasins, and for the SF Eel River Basin as a whole; riparian/water temperature is the most important issue in the Eastern Subbasin. Riparian/water temperature, instream habitat, and erosion/sediment are the most important target issues in the entire SF Eel River Basin, and in all three subbasins when evaluated individually.

Table 51. Consolidation of habitat inventory report recommendations into basin-wide target issue categories.

Tributary Report Recommendations	Basin Wide Target Issue Category
Bank/Roads	Erosion/Sediment
Canopy/Temp	Riparian/Water Temp
Pool/Cover	Instream Habitat
Spawning Gravel/LDA	Gravel/Substrate
Livestock/Barrier	Other

Table 52. Distribution of basin-wide recommendation target issues in the SF Eel River Basin.

Subbasin	Erosion/ Sediment	Riparian/ Water Temperature	Instream Habitat	Gravel/ Substrate	Other
Northern	30	39	80	4	7
Eastern	22	43	62	3	1
Western	72	64	145	19	11
Total SF Eel River Basin	124	146	287	26	19

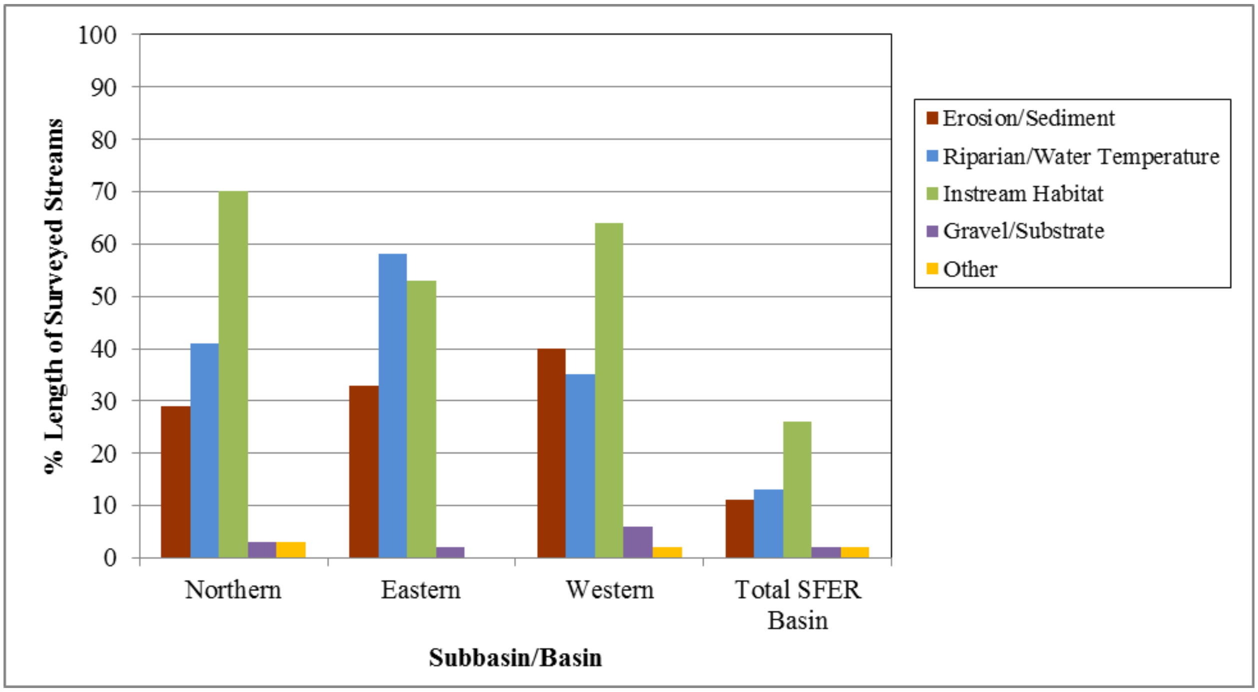


Figure 93. The frequency of recommendation target issues in SF Eel River Basin surveyed streams.

Refugia Areas

The CWPAP interdisciplinary team identified and characterized refugia habitat in the SF Eel River Basin using expert 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, timber harvest and other land uses, land ownership, diversion, 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-type analysis at the stream reach scale. The most complete data available in the basin were for tributaries surveyed by CDFW. However, many of these tributaries were still lacking data for some factors considered by the CWPAP team; and final category determinations were made using a combination of all available data and professional judgment when rating each stream. Refugia ratings were determined primarily with coho salmon in mind, since they are listed as threatened and have the most limited distribution in the watershed; however, the CWPAP team also considered the importance of streams to Chinook and steelhead in the refugia rating process.

One hundred streams throughout the SF Eel River Basin 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.

For a more detailed description of the refugia rating process and refugia categories, see the Program Introduction and Overview section.

Six large streams were divided into two sections because of significant differences in conditions and salmonid use between lower and upper areas:

- Ohman Creek – lower 1,800' of stream, from confluence with SF Eel River, and upper area from 1,800' to headwaters;
- Redwood Creek (Redway) – lower area from confluence with SF Eel River to Somerville Creek, and upper area from Sommerville Creek to headwaters (also known as Pollock Creek, or Upper Redwood Creek);
- Connick Creek – lower area from confluence with SF Eel River upstream 1 mile, and upper area from 1 mile to headwaters;
- East Branch SF Eel River - lower area from confluence with SF Eel River to Noble Butte (RM 15.8), and upper area from Noble Butte to headwaters;
- Hollow Tree Creek - lower area from confluence with SF Eel River to the old hatchery site (RM 9.0), and upper area from old hatchery to headwaters;
- Tenmile Creek - lower area from confluence with SF Eel River to Grub Creek (RM 4.3), and upper area from Grub Creek to headwaters.

Conditions were generally better for salmonids in Western Subbasin streams, where 38 of the 57 streams rated were high potential refugia areas and 5 of the 57 were high quality refugia (*Table 53*). In the Eastern and Northern subbasins, the majority of streams were rated medium potential. The Northern Subbasin had the most low quality refugia streams (5 of 18 rated streams), due primarily to sediment issues (in Cuneo Creek) and diversion and water quality concerns (in Salmon, Fish, and Ohman creeks).

The Western Subbasin streams were the highest quality refugia areas, particularly in Sproul, Indian, and Hollow Tree Creek basins, and in the headwater tributaries of the SF Eel River (*Figure 94*). High quality and high potential refugia areas in the Northern Subbasin are found in the Bull Creek drainage (especially above Burns Creek), with low quality areas in Salmon, Fish, Cuneo, and Ohman creeks. Eastern Subbasin streams were generally medium potential and low quality due primarily to lack of canopy, warm temperatures, and unstable geology; Dean Creek, East Branch SF Eel River, Cummings Creek, Fish Creek (near Benbow), and Cahto Creek were classified as low quality refugia (*Figure 94*). Refugia streams and ratings will be discussed in more detail in the individual subbasin sections of this report.

Table 53. Number of streams in each salmonid refugia category in SF Eel River Basin and subbasins.

Subbasin	**Refugia Categories:**				
	High Quality	**High Potential**	**Medium Potential**	**Low Quality**	**# Streams/Sections Rated**
Northern	1	1	11	5	18
Eastern	1	2	22	6	31
Western	5	38	12	2	57
Total SF Eel River	7	41	45	13	106

Figure 94. Stream refugia in the SF Eel River Basin.

Key Basin Issues

- Low flow and warm water temperatures during late summer and early fall are critical concerns throughout the SF Eel River Basin. Low flows and high temperatures are due in part to increases in illegal water diversions (many for marijuana cultivation) and longer dry periods in the winter and early spring;
- Streams throughout the basin experience excessive sediment input from both anthropogenic and natural sources;
- The morphology of the SF Eel River Basin has been changed due to erosion and aggradation;
- Historic and current land use has altered natural watershed processes and conditions;
- Alterations to watershed processes have affected the basin both socially and economically;
- Fish and wildlife have been adversely impacted by current watershed conditions in the basin.

Responses to Assessment Questions

What are the history and trends of the size, distribution, and relative health and diversity of fish populations in the SF Eel River Basin?

Findings and Conclusions:

- The SF Eel River Basin supports populations of Chinook salmon, coho salmon, and steelhead trout;
- There is one long-term data set for salmonid populations in the SF Eel River Basin, from Benbow Dam (with counts occurring from 1938-1975). Trend lines for Chinook salmon, coho salmon, and steelhead trout abundance show significant (more than 80%) declines throughout the sampling duration;
- 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. Coho salmon have been documented in 59 tributaries (137 miles), Chinook salmon in 85 tributaries (195 miles), and steelhead trout in 120 tributaries (308 miles) throughout the basin;
- The Western Subbasin has the most widespread distribution of all three salmonid species, followed by the Eastern and Northern subbasins;
- The SF Eel River is one of six watersheds in CA that is recognized as a salmon stronghold under the North American Salmon Stronghold Partnership (NASSP). Steelhead trout and coho salmon populations within the basin have been identified as "strong populations". The health of stronghold watersheds must be maintained and enhanced if recovery is to succeed in the state of California;
- The NMFS listed northern California runs of SONCC coho salmon (1997), CC Chinook (1999), and NC steelhead (2000) as threatened under the federal Endangered Species Act. The California Fish and Game Commission also listed coho salmon as threatened in 2005;
- The SF Eel River population of SONCC coho salmon is considered by NMFS to be a "functionally independent core population". These core populations are critical to recovery of salmon and steelhead throughout the ESU;
- Sacramento pikeminnow, which were introduced into Lake Pillsbury in 1979, have been observed in many SF Eel River Basin surveys. Pikeminnow feed on juvenile salmonids, particularly outmigrating salmonids (Moyle 2002), and compete with juvenile salmonids for food. Pikeminnow prefer warmer water temperatures than native salmonids, therefore changes in the habitat that promote warmer water temperatures (such as loss of riparian vegetation, reduced pool depths, and reduced river flows) could promote Sacramento pikeminnow over salmonid species;
- Adult SF Eel River salmonids use the lower mainstem Eel River as migratory route, and juveniles use the lower mainstem and estuary as rearing habitat. South Fork Eel River Basin salmonids depend on these areas outside the basin boundaries, and further information on watershed conditions in downriver habitat can be found in the *Lower Eel River Basin Assessment Report* (http://coastalwatersheds.ca.gov/Watersheds/NorthCoast/EelRiverLower/EelRiverLowerBasin/EelRiverLowerAssessmentReport/tabid/669/Default.aspx).

What are the current salmonid habitat conditions in the SF Eel River Basin? How do these conditions compare to desired conditions?

Findings and Conclusions:

Flow and Water Quality

- Streamflow has been altered by both legal and illegal water diversion in riparian and upslope areas. Recent flow trends indicate that late summer flows are significantly lower than the historical running average, due to increases in both the number of diversions and quantity of water diverted from streams. Marijuana production is currently unregulated throughout the basin, and is thought to be responsible for an increasing amount of diversion, particularly during low flow times;
- 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;
- Low summer flows and poor water quality are stressful to salmonids in tributaries;
- Excessive inputs of nutrients and pollutants, primarily from marijuana cultivation sites, are harmful to salmonids at all life stages in SF Eel River streams;
- In 1999, the USEPA listed the SF Eel River as impaired due to elevated sedimentation/siltation and temperature;
- Turbidity levels are high during winter rains, due to both anthropogenic and natural sediment inputs. These winter rainfall events correspond to spawning season for SF Eel River salmonids.

Erosion/Sediment

- Soils in surveyed reaches of streams in the South Fork Eel Basin are prone to erosion, and small- and large-scale slides have been observed to contribute fine sediment to the streams;
- Sediment from improperly constructed roads and construction around marijuana grow sites enters watercourses throughout the rainy season;
- Several tributaries are usually isolated from the mainstem S.F. Eel River by subsurface flows in late summer and early fall due in part to aggregation of bedload materials at the confluence;
- Many SF Eel River streams are still recovering from substantial sediment input from historical land use practices (such as intensive industrial timber harvest) and from the 1955 and 1964 flood events.

Riparian Condition/Water Temperature

- The Humboldt County Resource Conservation District collected water temperatures in the SF Eel River mainstem and selected tributary locations between 1996 and 2003, and reported mostly suitable temperatures in Western Subbasin streams and unsuitable/poor conditions for salmonids in most Northern and Eastern subbasin streams, and mainstem locations (maximum temps ranged from 73ºF–76ºF);
- The USGS monitors instream temperature at two locations in the SF Eel River Basin: Cahto Creek (tributary to Tenmile Creek, which meets the SF Eel River at RM 82) and Elder Creek (which meets the SF Eel River at RM 88), both in the southern part of the basin. Data is available beginning in October 2007, and temperatures at both locations were unsuitable for salmonids during late summer months, but did not reach lethal levels (≥75˚F) at any time;
- Upper tributaries near Branscomb provided cold water refugia areas for SF Eel River salmonids;
- Temperatures recorded in the lower mainstem SF Eel River near Phillipsville and Miranda were highly stressful for salmonids;
- Salmonids 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;
- Nearly 75% of the total length of tributary reaches surveyed by CDFW crews between 2000 and 2010 met the target value of 80% canopy coverage. Riparian canopy density suitability increased in all

surveyed subbasin streams between 1990-1999 and 2000-2010;
- Deciduous trees made up a greater percentage of canopy vegetation than coniferous trees in all subbasins, and the relative proportion of coniferous vegetation to deciduous vegetation increased in all subbasins over time.

Instream Habitat

- Overall habitat suitability (based on canopy density, pool depth, pool shelter complexity, and substrate embeddedness values) was low in all subbasins during the two time periods (1990-1999 and 2000-2010), but scores improved in Western and Northern Subbasins (and in the SF Eel River Basin as a whole) over time;
- Pool depths were considered poor for salmonids in all CDFW surveyed streams in the basin, although suitability increased slightly over time in Western Subbasin streams;
- Quality pool structure is lacking in streams throughout the Basin; no surveyed streams met standards for pool shelter, and pool shelter values decreased in nearly all streams over time;
- Average percent shelter from LWD was low (<5%) in all three subbasins, indicating a lack of holding and rearing habitat for adult and juvenile salmonids during low and high flow times;
- Large woody debris is generally lacking in many areas of the basin, particularly in Eastern Subbasin streams.

Gravel/Substrate

- Both fine and coarse sediment input are concerns in the basin, with sediment input from both natural and anthropogenic sources, and from large historical flood events;
- SF Eel River stream beds have been described as heavily silted due to increased sedimentation, and natural stream morpology has been altered by aggradation throughout the basin;
- The percent of pool tails surveyed with category 1 embeddedness values nearly tripled in all subbasins in 2000-2010 compared to 1990-1999, but values were still below target values (50%) during both time periods;
- Cobble embeddedness suitability increased in all subbasins and in the SF Eel River Basin as a whole, with positive suitability values in all subbasins in the 2000-2010 time period.

Refugia Areas

- There are few high quality refugia streams in the SF Eel River Basin: one in the Northern Subbasin (Squaw Creek), one in the Eastern Subbasin (Elder Creek), and three in the Western Subbasin (Indian, Low Gap, and Upper Hollow Tree creeks);
- Western Subbasin streams provide the most high potential refugia areas, especially in the Hollow Tree Creek Basin;
- Eastern Subbasin streams provide mostly medium potential and low quality stream refugia, with more low quality areas in the northern part of the subbasin, and medium potential areas in most southern streams in the Tenmile Creek and Rattlesnake Creek Basins;
- The Northern Subbasin contains a variety of refugia streams, ranging from high potential in Bull Creek, to low quality in Salmon, Fish, and Ohman creeks.

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

Findings and Conclusions:

- The SF Eel River Basin receives highly variable precipitation throughout the year. High levels of winter precipitation can lead to widespread flooding throughout the basin. The drainage capacity of the SF Eel River has been drastically altered due to excessive sedimentation, which can exacerbate flood events;
- The catastrophic floods of 1955 and 1964 impacted the basin by depositing large amounts of sediment in

the channel;
- Friable soils, steep upstream terrain, and high levels of rainfall result in numerous landslides. Saturated soils are highly vulnerable to sliding during the many earthquakes that characterize the basin;
- The basin is located in a tectonically complex area, resulting in part from transpression generated by Triple Junction tectonics between the Gorda and North American Plates, and related regional uplift;
- Bedrock underlying the basin is mechanically weak due to a long history of accretionary land forming processes, folding, faulting, fracturing, and shearing creating a landscape prone to mass wasting and erosion and very sensitive to disturbance.

How has land use affected these natural processes and conditions?

Findings and Conclusions:

- Residential development and marijuana cultivation operations (both legal and illegal) have resulted in increased water diversion from tributary streams, resulting in elevated instream temperatures and drastically reduced flows, particularly during the summer months;
- Timber production is the principal land use in the basin, accounting for 44% of the basin area. Timber harvest may result in increased sediment delivery to streams (from road construction, existing networks, and improperly maintained legacy roads), changes in light, temperature, and flow regimes, reduction in stream flow associated with road dust/sediment control, loss of invertebrate food and organic debris, and changes in channel morphology;
- Most of the land in the Northern Subbasin, is publicly owned by the CA State Parks; forest habitat has been preserved and fisheries habitat restoration have been priority management actions since the land (primarily in the Bull Creek drainage) was purchased between the 1920s and the 1970s;
- Gravel mining occurs at a three relatively isolated locations in the mainstem SF Eel River, and the extracted volume is relatively low compared to other north coast streams. Gravel mining activities are not considered a large threat to salmonids in the SF Eel River Basin;
- Sedimentation and in-filling as a result of urbanization, land subdivision activities, gravel mining, and timber harvesting practices have resulted in an overall reduction in channel area, and consequently in available salmonid habitat;
- Because of the geologic characteristics, the SF Eel River Basin is affected by highly variable runoff rates. Disturbance of the basin's already unstable soils by land use activities has altered runoff rates.

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

Findings and Conclusions:

Based on available information for the SF Eel River Basin, the CWPAP team believes that salmonid populations are limited by:

- Low summer flows;
- High summer water temperatures;
- High levels of fine sediments in streams;
- Reduced pool quality (depth and complexity);
- Lack of pool shelter and pool-forming LWD in all subbasins;
- Chemical, fertilizer, and sediment input from marijuana cultivation sites;
- 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?

Recommendations:

<u>Flow and Water Quality Improvement Activities</u>

- Protect stream flows from diversion, particularly in low flow summer months. Programs that will encourage landowners to store water during periods of high flow, and to stop diverting from streams during periods of low flow are being developed by SRF and HSU in Redwood Creek, and could be expanded to other areas in the basin;
- Reduce fertilizer, pesticide, and fine sediment input from marijuana cultivation operations;
- Reduce fine sediment input and restrict illegal grading operations from unpermitted residential development sites;
- Support ongoing efforts by timber harvest review agencies to quantify water usage by industrial timber companies for dust abatement, and support actions designed to encourage efficient use of water;
- Where necessary, identify barriers to fish migration in the form of large debris accumulations, culverts, etc. and modify them.

Erosion and Sediment Delivery Reduction Activities

- Continue to support and expand the scope of road decommissioning projects funded through FRGP and other sources, in order to reduce fine sediment input to streams from unused roads;
- Expand on upslope erosion inventory on subbasin streams in order to identify and map stream bank and road-related sediment sources. Sites should be prioritized and improved in order to decrease sediment contributions throughout the basin;
- Identify and rehabilitate illegal road grading, construction, or clearing activities associated with residential development and/or marijuana cultivation operations in order to reduce the amount of fine sediment entering streams;
- Continue to work with timber companies to ensure that sediment reduction plans are in place for harvested areas, roads, and surrounding areas;
- Support ongoing efforts by timber harvest review agencies to quantify water usage by industrial timber companies for road dust abatement/sediment control, and support actions designed to encourage efficient use of water;
- Reduce the potential for fine sediment input following catastrophic fires by using prescribed burns to reducing fuel loads.

Riparian and Habitat Improvement Activities

- "Riparian right" water diversions should be monitored and storage requirements modified so diversion is not taking place during low flow conditions;
- Voluntary conservation programs designed to reduce diversions, similar to those being developed by SRF and HSU in Redwood Creek, should be expanded and applied in additional streams with known fish presence throughout the SF Eel River Basin;
- Enforce grading ordinances in Humboldt and Mendocino Counties to protect riparian vegetation, and to protect against sediment delivery from unpermitted development sites. Grading ordinances have been developed and are currently in effect but many developments throughout the SF Eel River Basin are unpermitted and therefore unregulated;
- Riparian buffer should be allowed to grow/re-grow along streambanks – in areas with exposed stream banks, riparian planting projects could be completed to increase bank stability;
- Programs to increase riparian vegetation should be implemented in areas where shade canopy is below the target value of 80% coverage, particularly in areas of Tenmile Creek in the Eastern Subbasin;
- In creeks where fish spawning and rearing habitat is limited, pool enhancement and instream structures should be added to increase complexity;
- In streams where pool habitat is limited, enhancement structures such as LWD or boulders that encourage scour should be added to increase the amount of pool habitat and depth in existing pools;
- In streams where spawning area is limited, projects should be designed to trap and sort spawning gravels in order to expand and enhance redd distribution;
- Log debris accumulations in streams that retain high levels of fine sediment should be assessed, and carefully modified or removed where appropriate.

Education, Research, and Monitoring Activities

- Develop long-term flow monitoring studies to better understand water usage and diversion patterns for residences and industrial marijuana growing operations, particularly during low flow times;
- Partner with private agencies, community groups, local residents, and academic institutions to educate residents about water usage patterns and trends, and to develop conservation and/or storage plans to reduce diversion and improve water quality and quantity;
- Because water quality data are limited, monitoring of summer water temperatures should be performed over at least a three to five year period at indicator sites identified by CDFW;
- Support the HCRCD and Eel River Recovery Project in their ongoing efforts to monitor and improve habitat and water quality in the basin;
- Water quality data, including temperature and dissolved oxygen, should be consistently collected by land owners and responsible agencies throughout the year, for several years, in order to accurately characterize instream conditions;
- Develop studies to evaluate and monitor environmental impacts associated with climate change and their effects on salmonids in the basin;
- Implement biological monitoring of invertebrate abundance, benthic community diversity, and food web dynamics studies on specific SF Eel River streams to further our understanding of instream conditions, overall stream health, and potential salmonid food sources throughout the SF Eel River Basin;
- CDFW stream habitat surveys provide information only for reaches accessible to anadromous salmonids. Additional surveys above the limits to anadromy are necessary to identify upstream conditions that affect fish bearing downstream reaches, including riparian canopy condition or sediment delivery sites that may benefit from erosion control treatments;
- Where necessary, identify barriers to fish migration in the form of large debris accumulations, culverts, etc. and modify them to allow fish passage;
- Continue to conduct habitat and fish inventories on streams in the Northern, Eastern, and Western subbasins on a decadal schedule, to assess changes in habitat suitability over time;
- Reduce the risk of human-caused fire by limiting access to high fire danger areas, in conjunction with annual prescribed fire treatment in high use areas and public education efforts;
- Continue to support local educational programs such as the June, 2013 construction of a "willow wall" to increase bank stabilization and improve salmonid habitat in Bull Creek. This project was completed by the CCC Watershed Stewards program staff and the Eel River Watershed Improvement Group as part of the Creek Days Environmental Education Fair;
- Partner with local academic institutions and private agencies as a means to encourage the study of the fish and corresponding habitat.

Basin Conclusions

The California Department of Fish and Wildlife's Coastal Watershed Planning and Assessment Program considered a great deal of information regarding basin processes related to stream conditions in the SF Eel River Basin. Existing scientific studies and reports that portray physical and biological watershed characteristics were combined with the multidisciplinary investigations and integrated synthesis performed by the CWPAP team. This relatively large database provided a considerable amount of information for analysis, interpretation, and for addressing the CWPAP assessment questions and making recommendations to improve stream habitat conditions.

The SF Eel River Basin contains runs of Chinook and coho salmon, and steelhead trout. Current salmon and steelhead populations are considerably smaller and less well distributed compared to their historic range. To maintain or increase these remaining populations is critical to the recovery of salmon and steelhead along the entire North Coast. Opportunities exist in each of the subbasins to help improve habitats and to increase the viability of salmonid resources of the SF Eel Basin. These include efforts of local interest groups and programs that provide public education and develop additional actions to improve the habitat and physical conditions for salmonids throughout the SF Eel River Basin.

Although current salmonid populations are reduced in abundance and distribution compared to historical populations, the SF Eel River Basin has been recognized by the North American Salmon Stronghold Partnership as one of six salmon stronghold watersheds. These watersheds contain approximately 70% of California's remaining salmon and steelhead diversity, and must be maintained and enhanced for recovery to be successful. Coho salmon and steelhead trout in the SF Eel River Basin were identified as "strong populations" within the watershed.

The NMFS considers the SF Eel River SONCC coho salmon population a core, functionally independent population. Core populations are likely to become viable more quickly compared to non-core populations. Functionally independent populations have a high likelihood of persisting in isolation over a 100-year time scale, and population dynamics and extinction risk are not substantially altered by immigration from other populations.

The fishery resources in the SF Eel River Basin 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. Reduced flow, particularly during the dry summer months, due to an increase in the magnitude and number 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. Sedimentation and in-filling as a result of timber harvesting practices, land subdivision activities, and road construction associated with industrial and residential uses have resulted in increased fine sediment in streams and an overall reduction in channel area, with a corresponding decrease in available salmonid spawning and rearing habitat.

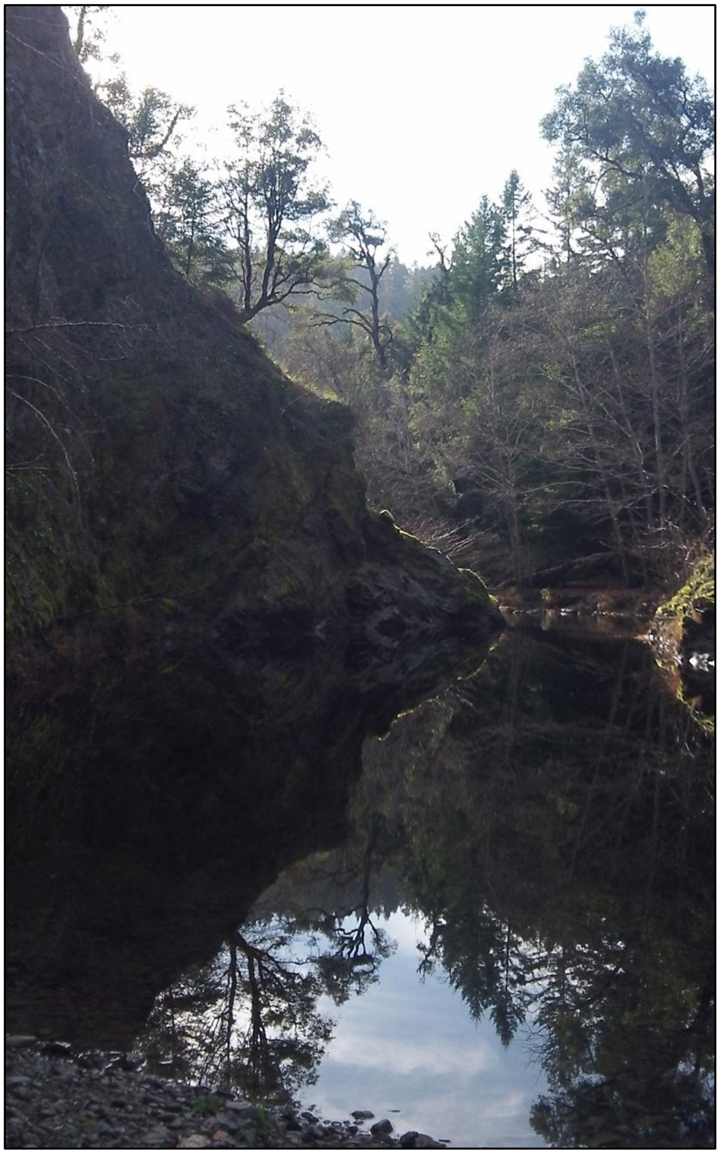
Habitat typing data were collected throughout the SF Eel River Basin during two time periods (1990-1999 and 2000-2010) and analyzed to determine changes in habitat suitability for salmonids over time. Although values for select factors (canopy density, embeddedness, percent primary pool habitat, and pool shelter complexity) appear to be improving with time, the overall suitability scores are still low for all subbasins during both time periods. Individual factor scores and corresponding suitability values were low for all variables except canopy density and embeddedness in the early 2000s.

Reduced streamflow due to unpermitted and/or unregulated diversions are a source of significant concern throughout the Basin. Water drafting as a dust abatement measure by industrial timber companies is largely un

Marijuana cultivation operations are a particular concern in the SF Eel River Basin. These operations have increased dramatically in both number and magnitude in recent years, and these numerous operations result in significantly reduced water quality and quantity throughout the basin. Streamflow has decreased due to the diversion of large quantities of water from tributary streams, particularly in dry summer months. Water quality has been reduced due to the input of pollutants including: pesticides, herbicides, rodenticides, and diesel fuel; fine sediment input has 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 basin.

All SF Eel River salmonids migrate to and from the ocean through the mainstem Eel River and the Eel River estuary, and residence time in these downstream habitats varies with species and life stage. The estuary is particularly important as a rearing environment for juvenile salmonids, and as an important holding area for adult steelhead during upstream migrations; habitat condition and availability of food in the estuary and lower river environment may affect salmonid survival rates in upstream areas. The importance of these migratory corridor habitats and the impact of changes in these habitats on SF Eel River salmonids are discussed in the Lower Eel River Watershed Assessment (CDFG 2010).

Diminishing runs of salmon and to a lesser extent steelhead in SF Eel River Basin streams are susceptible to being reduced to remnant populations. Regulations addressing environmental impacts and their effect on salmonids in the basin have primarily addressed timber harvest practices (and associated impacts from legacy and new roads) and ranching activities, and these rules and guidelines have resulted in decreased riparian impacts, decreased sedimentation from roads, and improved instream conditions in many areas of the basin. However, many regulations that are designed to help protect the basin's salmonid stocks, water resources, and associated stream habitats have not provided sufficient protection since the recent rapid expansion of marijuana cultivation throughout the basin, particularly in areas dominated by residential land use. While land acquisition by state and federal agencies and restoration efforts by public and private entities have helped improve certain areas within the basin, they have not been on large enough spatial or temporal scales to provide significant improvements to the overall habitat conditions and ecosystem function necessary to restore salmonid populations to desirable numbers or ranges. The SF Eel River Basin contains critical habitat and runs of salmonids to help in the statewide recovery of salmonids. Basin-wide concerted efforts are needed to address diversions and fine sediment input, primary actions necessary to improve and expand spawning and rearing habitat for salmonids as well as overall ecosystem function in the SF Eel River watershed.



Hollow Tree Creek, tributary to SF Eel River.