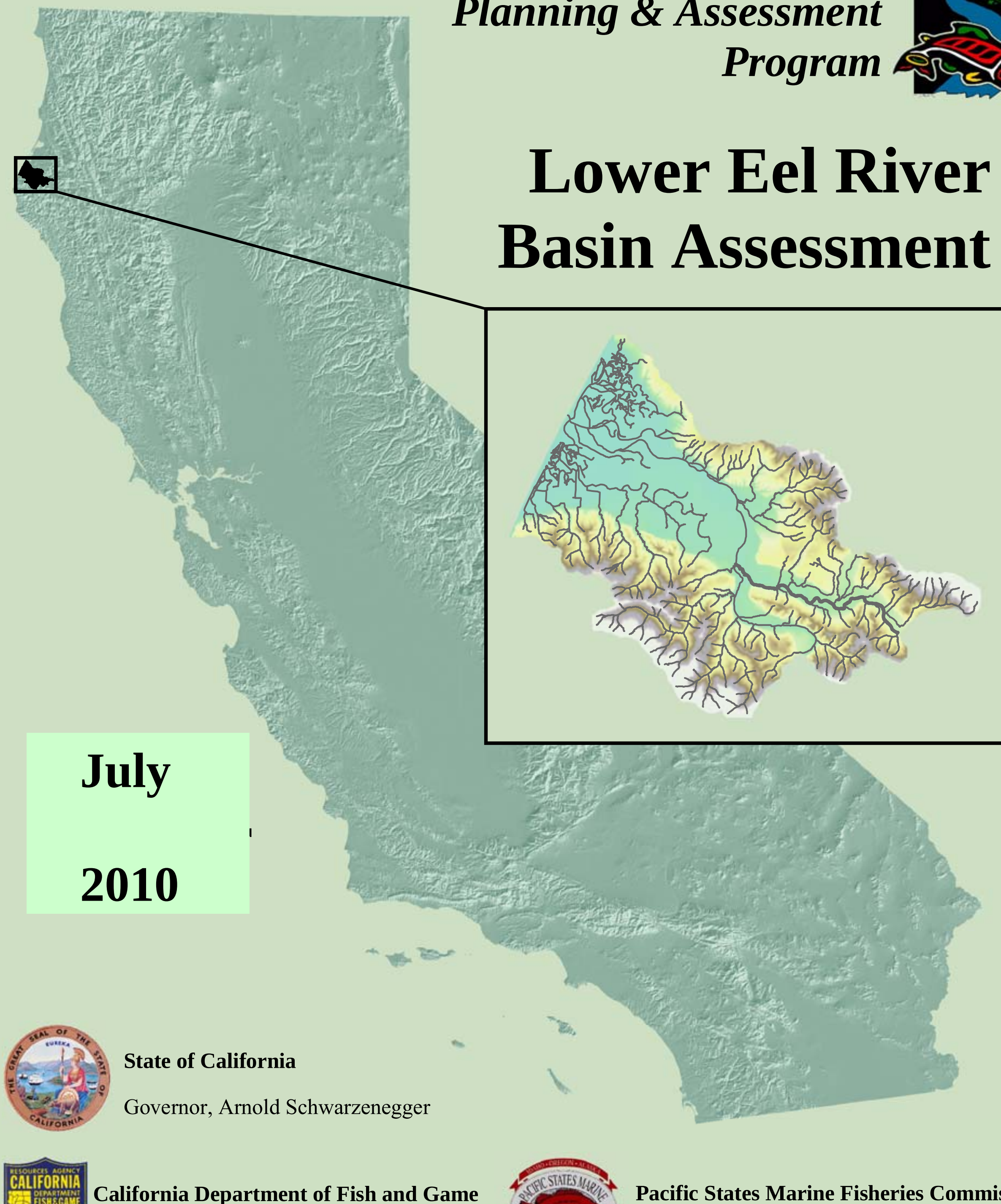
Coastal Watershed
Planning & Assessment
Program

Lower Eel River Basin Assessment



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State of California

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California Department of Fish and Game

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Pacific States Marine Fisheries Commission

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Lower Eel River Watershed Assessment

Prepared through a cooperative effort by

California Department of Fish and Game
Coastal Watershed Planning and Assessment Program

Pacific States
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California Coastal Watershed Planning and Assessment Program

The Lower Eel River Basin Assessment Report is a project of the Coastal Watershed Planning and Assessment Program (CWPAP). The Coastal Watershed Planning and Assessment Program is a California Department of Fish and Game program that conducts fishery-based watershed assessments along the entire California coast. The Lower Eel River Basin was chosen as an area for assessment because of its high fishery value to anadromous salmonids. This report was guided by following the outlines, methods, and protocols detailed in the CWPAP methods manual. The program's work is intended to provide answers to the following assessment questions at the basin, subbasin, and tributary scales in California's coastal watersheds:

- What are the history and trends of the size, distribution, and relative health and diversity of salmonid populations?
- What are the current salmonid habitat conditions; how do these conditions compare to desired conditions?
- What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions?
- How has land use affected these natural processes and conditions?
- Based upon these conditions, trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead production?
- What watershed management and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?
- The assessment program's products are designed to meet these strategic 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 CDFG Fishery Restoration Grants Program, 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.

General Assessment Approach

The general steps in our large-scale assessments include:

- Determine logical assessment scales;
- Discover and organize existing data and information according to discipline;
- Identify data gaps needed to develop the assessment;
- Amass and analyze information;
- Conduct Integrated Analysis (IA);
- Conduct Limiting Factors Analysis (LFA);
- Conduct refugia rating analysis;
- Develop conclusions and recommendations;
- Facilitate implementation of improvements and monitoring of conditions.

Scale of Assessment and Results

The assessment team used the California Watershed Map (CalWater version 2.2.1) to delineate the Lower Eel River Assessment Basin (Figure 1). The area was further partitioned into four subbasins for the purpose of analysis: the Estuary, Salt River, Middle, and Upper subbasins. In general, the CalWater 2.2.1 Planning Watersheds (PWs) contained within each of these assessment subbasins have common physical, biological, and/or cultural attributes. However, there is enough variance among the areas' attributes that they were delineated as separate subbasins. Demarcation in this logical manner provides a large, yet common scale for conducting assessments. It also allows for the reporting of findings as well as making recommendations for watershed improvement activities that are generally applicable across this relatively homogeneous area.

Assessment Products

This report and its appendices are intended to be useful to landowners, watershed groups, agencies, and individuals to help guide restoration, land use, and management decisions. Assessment products are as follows:

- Collection of Lower Eel River Basin historical and sociological information;
- Description of historic and current vegetation cover and change, land use, geology and fluvial geomorphology, water quality, and instream habitat conditions;
- Evaluation of watershed conditions affecting salmonids;
- An interdisciplinary 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 productivity;
- Monitoring recommendations to improve the adaptive management efforts;
- Ecological Management Decision Support system (EMDS) models to help analyze data;
- Databases of information used and collected;
- A data catalogue and bibliography;
- Web based access to the Program's products: http://coastalwatersheds.ca.gov, http://www.calfish.org, http://imaps.dfg.ca.gov, http://bios.dfg.ca.gov, and ArcIMS site.

Salmonids, Habitat, & Land Use Relationships

There are several factors necessary for the successful completion of an anadromous salmonid's life history. In their freshwater phases, adequate flow, good water quality, free passage, good stream habitat conditions, and proper riparian function are essential for survival. Stream condition includes several factors: adequate stream flow, suitable water quality, appropriate stream temperature, and complex, diverse habitat. Adequate instream flow during low flow periods is essential to provide juvenile salmonids free forage range, cover from predation, and utilization of localized temperature refugia from seeps, springs, and cool tributaries. Important aspects of water quality for anadromous salmonids include water temperature, water chemistry, turbidity, and sediment load. Habitat diversity for salmonids is provided by a combination of deep pools, riffles, and flatwater habitat types.A functional riparian zone helps to control the amount of sunlight reaching the stream, and provides vegetative litter and invertebrate fall. 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).

Geology, climate, watershed hydrologic responses, and erosion events interact to shape freshwater salmonid habitats. "In the absence of major disturbance, these processes produce small but virtually continuous changes in variability and diversity against which the manager must judge the modifications produced by nature and human activity. Major disruption of these interactions can drastically alter habitat conditions" (Swanston 1991). Major watershed disruptions can be caused by catastrophic events, such as major floods or earthquakes. They can also be created over time by multiple small natural and/or human disturbances.

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 include large flood events such as occurred in 1955 and 1964 (Lisle 1981a), and locally, 1974 (U.S. EPA 2001). Major human disturbances associated with post-European expansion such as dam construction, agricultural and residential land development, and timber harvesting practices used particularly before the implementation of the 1973 Z'Berg-Nejedly Forest Practice Act have occurred over the past 150 years (Ice 2000).

Salmonid habitat was also degraded during parts of the last century by well-intentioned but misguided restoration actions such as the removal of large woody debris from streams (Ice 1990). More recently, efforts at watershed restoration have been initiated at the local and state levels by such major programs as CDFGs Fishery Restoration Grants Program (FGRP). For example, several California counties, with FGRP funding, have addressed fish passage problems associated with their roads' stream crossings, opening many miles of historic habitat to salmonids. For additional information on stream and watershed recovery opportunities and project types, see the publication by the Federal Interagency Stream Restoration Working Group (FISRWG 1998).

Thus, a main component of large-scale assessment is to identify curable problems that limit production of anadromous salmonids in North Coast streams and watersheds, and prioritize them for treatment. That process begins with the identification of limiting factors, which can be anything that constrains, impedes, or limits the growth and survival of a population. Limiting factors analysis (LFA) provides a means to evaluate the status of key factors that affect anadromous salmonid life history. This information is useful to understand the underlying causes of stream habitat deficiencies and help determine if watershed processes are being overly influenced by landuse activities, and if so, what can be done to reduce their impacts.

Lower Eel River Basin

The present name for the Eel River reflects the abundance of so called lamprey eels (*Lampetra tridentata*) that Euro-American settlers observed being collected by the native peoples in the area. However, it is with these native people that the Eel River shares its original name of Wiyot. "…Eel River is called by the Indians, Weott [sic] - plenty- from the immense quantities of Salmon obtained by them every fall in that stream…" (Humboldt Times, September 23, 1854). Indeed, upon settling in the area, Euro-Americans established an extremely lucrative commercial salmon fishery, targeting the "vast number of salmon which, so they say, used to impede traveling over the fords" (Ferndale Enterprise May 4 1987). The incredible success of the commercial fishery and canning operations eventually led to the creation of hatcheries to replace depleted stocks, and an inevitable ban to commercial fishing in 1926.

The Eel River is California's third largest river system with a watershed area of approximately 3,680 square miles, and as such is one of its most important anadromous salmonid habitats. The Lower Eel River Basin is located approximately 200 miles north of San Francisco and encompasses approximately 172 square miles. This report's assessment area includes both the Lower Eel River, from its mouth to RM 21, and the Lower Van Duzen River, from its mouth to RM 9. For the purpose of assessment, this catchment has been divided into four subbasins: Estuary, Salt River, Middle, and Upper (Figure 1).

The Estuary Subbasin is approximately 24 square miles in area and includes approximately 7 miles of the mainstem from the mouth to Fernbridge, and about 40 miles of tidally driven sloughs. This subbasin makes up approximately 14% of the total assessment area.

The Salt River, which once functioned as a significant part of the Eel River estuary, has been assessed by the CWPAP team in a separate report (Downie and Lucey, 2005). Because the Salt River is such an integral part of the Eel River estuary, it is difficult to assess the watershed without it. Therefore, the Salt River is included as a subbasin of the Lower Eel watershed assessment. At 49 square miles, the Salt River Subbasin makes up approximately 29% of the Lower Eel Basin. In total, the Salt River Subbasin includes approximately 42 miles of tidally driven sloughs and freshwater tributaries.

The Middle Subbasin makes up approximately 14% of the total assessment area with an area of 24 square miles. In total, this subbasin contains approximately 40 miles of stream, as well as approximately 6 miles of the mainstem Eel, from Fernbridge to the mouth of the Van Duzen River. The Middle Subbasin includes the city of Fortuna, which is the assessment area's largest population center.

The Upper Subbasin is the largest in the assessment area at 75 square miles, comprising 43% of the total. This subbasin includes all Eel River tributaries along 7.5 miles of the mainstem Eel River from Barber Creek to Dean Creek. It additionally includes tributaries to the Van Duzen River from its mouth to Cummings Creek (approximately 9 miles). The Upper Subbasin includes approximately 133 miles of permanent and intermittent stream.

The Lower Eel River Basin can be described as highly dynamic. The Basin experiences high levels of sedimentation due to natural hillslope processes, erodible soils and high levels of precipitation (Reynolds et al. 1981). Additionally, the area is situated in a tectonically complex area resulting in part from compression generated by convergence and subduction between the Gorda and North American Plates, which is further enhanced by accelerated uplift from the

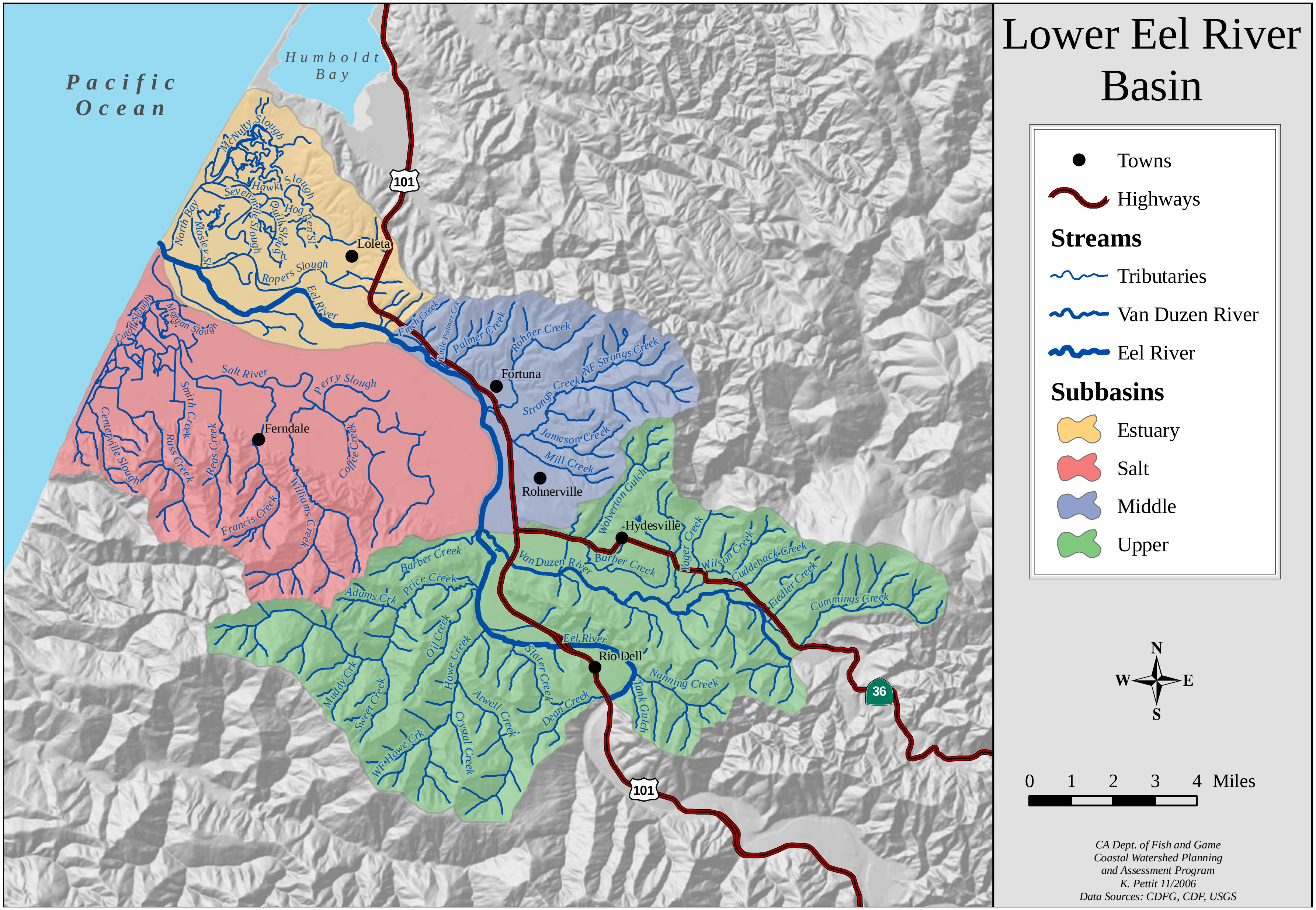

Figure 1: Lower Eel River Basin with subbasins, and streams.

encroaching Mendocino Triple Junction. These natural processes, in combination with land use, have greatly altered the size, shape and watershed processes of the Basin. Land use has had a major effect on the Eel's watershed processes. Historically, the Basin's fertile delta soils attracted settlers to the area. Land clearing and conversion for the purposes of agriculture began as early as the 1850s. With the success of grazing, came the creation of innovative creameries. As trees were felled to make room for these pasture lands, a productive and profitable timber harvesting industry began to develop. The Eel River also supported several salmon canneries and packing plants with its highly successful commercial salmon fishery. Export of the Basin's products was available via commercial ships at the Eel River estuary's Port Kenyon on the Salt River, and through Humboldt Bay, located 5 miles to the north. The area's rich natural resources enticed settlers to the area and effectuated the eventual name of the Basin's population center, Fortuna.

Today, the Eel River as a whole has the highest recorded average suspended sediment yield than any other U.S. river its size (Brown and Ritter 1971). Landslides and erosion introduce large quantities of sediment to streams, and are exacerbated by the region's climate, geology, topography and land use. In 2002, the Environmental Protection Agency listed the lower portion of the Eel River as an impaired water body due to sediment and temperature. The Lower Eel Basin is the depositional zone for the entire 3684 square mile basin. In this capacity, it is characteristic of the status of watershed processes throughout the catchment. These processes determine the stream conditions encountered by fish and wildlife at all levels.

Assessment Sample Base

Studies of the fishes and habitat throughout the Lower Eel River Basin are somewhat limited. This assessment was based on the following data:

- The CDFG has conducted 24 habitat inventories on 21 streams within the Lower Eel Basin between the years of 1991 and 2004. Long-running CDFG data for spawning surveys of Cummings Creek, and several other spawning observations were also available for tributaries in the Lower Eel Basin;
- A search of the CDFG libraries located in the Humboldt County Fisheries Management Unit Office in Eureka and the North Coast California Coho Salmon Investigation Office in Arcata produced various historical, anecdotal, and scientific records of fish sampling throughout the Lower Eel River Basin;
- The CDFG and Humboldt State University have surveyed the Eel River estuary on several occasions, with comprehensive studies occurring in 1951, 1977, and 1995;
- The Pacific Lumber Company (PALCO) has conducted several biological surveys on Cummings Creek of the Upper Subbasin beginning in 1998 and extending into the 2000s. They also performed biological surveys on Nanning Creek in the summer of 2001;
- The Fortuna high school's Fortuna Creeks Project has collected water quality data for streams in the Middle Subbasin since 1997;
- The Humboldt County Resource Conservation District has conducted a number of studies within the Eel River Delta including: biological conditions, vegetation surveys, habitat types and associated fishes and invertebrates, animal waste assessment project, channel elevation surveys, and water quality collections.

Lower Eel River Basin Management Issues

Initial analyses of available data by watershed experts developed this working list of general issues and/or concerns:

The morphology of the Lower Eel River Basin has been changed due to erosion and aggradation:

- The Lower Eel River Basin has undergone considerable sedimentation and deposition, which has resulted in:
  - An overall decrease in tidal prism and shallowing of the estuary and riverbed (Williams 1988);
  - Loss of estuarine habitat area and diversity;
  - Loss of spawning area for salmonids due to excess siltation of gravel beds (Reynolds et al., Stream Inventory Reports, CDFG spawning surveys);

  - o Intermittent and periodically dry reaches in tributaries and lower mainstem Van Duzen River during low summer and autumn flows (Williams 1988), (Reynolds et al. 1981) (CDFG field surveys);
  - o Highly channelized streams (Reynolds et al. 1981);
  - o Reduction of riparian vegetation on stream banks;
- The Lower Eel Basin is very seismically active, resulting in extensive surface erosion, uplift and landslides (Reynolds et al. 1981, PALCO Van Duzen Watershed Analysis, 2002);
- Large seasonal storms result in flooding and stream channel modification.

Historic and current land use has altered watershed processes and conditions:

- Agricultural lands now dominate what was historically forested riparian, and wetland habitat throughout the Lower Eel River Basin (Williams 1988, Monroe et al. 1974, Roberts 1992);
- There has been an overall change in species of grass for the purposes of grazing, which has reduced the root strength of prairie vegetation, increasing slumping in upper reaches of the system, like the North Fork Eel River (Reynolds et al. 1981);
- Livestock have unrestricted access in some streams of the Lower Eel Basin causing stream bank erosion and riparian vegetation damage (ERWIG, P. Halstead pers. comm.);
- Filling, draining and diking of streams has been required to allow for residential development in the Middle Subbasin (Roberts 1992);
- Most of the streams of the Middle Subbasin run through urban areas and as such, are subject to input of polluted storm runoff and garbage (Halstead pers. comm., Yazzolino pers. comm.);
- Basin-wide disturbance activities, including timber harvesting practices, gravel mining, road construction, residential development, land subdivision activities and grazing have caused an increase in sedimentation in the entire Eel River Basin (Williams 1988, Monroe et al. 1974, CDFG 1997 [Eel River Action Plan]);
- Dredging and filling, gravel and sand mining, dams and water diversions have contributed to the Eel River estuary's dynamic position of its main channel (Puckett 1977);
- Water quality is degraded through runoff from dairy operations, urban wastewater,and urban storm water (Roberts 1992, Monroe et al. 1974, Yazzolino pers. comm.);
- Streambank erosion above and below Fernbridge has caused loss of pasture and could be a threat to the bridge and the Humboldt Creamery's Wastewater Treatment Plant.

Alterations to watershed processes have affected the basin both socially and economically:

- The Salt River of the Eel River estuary is no longer navigable by sea-going ships;
- Seasonal drainage problems are becoming more frequent in residential and business areas, which can prove costly for private land owners and public entities (Downie and Lucey 2005);
- In order to address drainage issues, the city of Fortuna would need to spend approximately $10 million, which is well beyond the available budget (approximately $300,000). State and federal funding that the city does receive is already earmarked for mandated sewage and drinking water regulations (W. Yazzolino, pers. comm.);
- Fortuna and Loleta have lost substantial tourism dollars because they can no longer advertise as major fishing venues due to low flows and reduced salmon numbers (W. Yazzolino, pers. comm.);
- Increased development has introduced construction wastes to the watershed through storm drains. The city of Fortuna is not monitoring water quality changes with regards to storm runoff, though it is beginning to address these issues associated with development through the creation of regulatory programs.

Fish and wildlife have been adversely impacted by current watershed conditions in the Basin:

- Stream channelization, water control practices, barriers to fish migration in the form of levees and dikes, and sedimentation have resulted in a decreased ability of the Basin to support anadromous fisheries (Monroe et al. 1974);
- Spawning areas are affected by sediments trending toward increasing fines, and decreasing geometric mean particle size, and compaction of spawning gravel (PALCO Van Duzen Watershed Analysis 2002, Monroe et al. 1974);

- Stream aggradation has resulted in loss of rearing habitat in the estuary, as well as increased water temperatures resulting in decreased dissolved oxygen (Monroe et al. 1974);
- Aquatic macroinvertebrates are affected by increased sedimentation in streams and loss of estuary habitat (Monroe et al. 1974, Williams 1988);
- Riparian vegetation has been reduced throughout the study area, resulting in a decrease in shade canopy and recruitment of large wood to streams, rivers, and the estuary (Reynolds et al. 1981);
- Upstream migration of fish is restricted during early autumn dry periods, particularly in the Eel River just above the Van Duzen confluence. This has led to stranding mortality in early fall Chinook salmon;
- Fish passage is additionally affected by culverts, tide gates, channel narrowing, increased stream flows, and reduced floodplains.

Responses to Assessment Questions

This assessment uses six guiding assessment questions (page 1) to organize its issues, findings, conclusions and recommendations. The following discussion of the assessment questions and recommendations for improvement activities specific to subbasins, streams, stream reaches, and in some cases potential project sites, are included in each subbasin section of this report. The CDFG appendix contains more specific assessment methods, findings, conclusions, and recommendations for stream and watershed improvements.

What are the history and trends of the size, distribution, and relative health and diversity of fish populations in the Lower Eel River Basin?

Findings and Conclusions:

- Historical accounts of the recreational fishery in the Eel River estuary describe excellent salmon and steelhead fishing over the entire delta, with anglers gaining access to catch "from boat to shore" (Haley 1970). Large commercial harvest of salmon and steelhead were taken from the estuary from 1860 to 1926. The commercial fishery has been eliminated and the recreational fishery has been significantly reduced and is now catch and release only (zero bag limit);
- The 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;
- Salmon populations are considerably smaller and less well distributed compared to historic range. Coho salmon have been documented in 13 tributaries across the basin and Chinook salmon in six tributaries. Steelhead trout have been documented in 21 tributaries and cutthroat trout in eight tributaries. In addition, all four species of salmonids use the mainstem Eel River and estuary as critical migration routes and use the estuary as rearing habitat;
- These remaining populations are critical to recovery of salmon and steelhead along the entire North Coast;
- The most comprehensive studies of the estuary were year-long investigations preformed in 1951, 1977, and 1995. These studies indicate the presence of juvenile Chinook salmon from spring to fall (March through November), coho salmon from spring through summer, and year-round presence of steelhead. Adult Chinook salmon and steelhead hold in the estuary until sufficient flows allow upstream migration in the fall;
- Three tributaries in the Middle Subbasin have been inventoried in 1993 and 2004 by CDFG. These data have confirmed, in addition to other fish studies, the presence of coho salmon, steelhead, and coastal cutthroat, among other species. Some historical and anecdotal accounts (dating back to the early 1950s) list the presence of these salmonid species in several Middle Subbasin tributaries;

- Stream inventories conducted by CDFG on fourteen tributaries in the basin between 1991 and 2002, as well as other fish sampling data, have documented the presence of Chinook salmon, coho salmon, and steelhead. Historical recorded data show that these salmonid species were being collected in fish rescue operations in the late 1940s;
- Coastal cutthroat trout were present in a 1984 survey of Centerville Slough, a tributary to the Salt River, indicating presence in the Eel River estuary. Cutthroat trout have also been observed during surveys of the Middle Subbasin between 1984 and 1995, but have not been confirmed present in the Upper Subbasin. The Eel River is the current southern extent of coastal cutthroat trout (Miller and Lea 1972);
- Tidewater goby, a species listed as endangered under the federal Endangered Species Act (ESA), were collected by the United States Fish and Wildlife Service in an unnamed slough of the Eel River estuary near Cannibal Island in August 2004;
- Sacramento pikeminnow, which were introduced into Lake Pillsbury in 1979, have been observed in many surveys of the Lower Eel River Basin from the estuary to RM 21 at Scotia. Pikeminnow predate on juvenile salmonids, particularly outmigrating salmonids (Moyle 2002);
- The Salt River Subbasin once supported populations of coho salmon, Chinook salmon, steelhead, and coastal cutthroat. Recent surveys have found small numbers of these salmonids in a more limited distribution than in the past.

What are the current salmonid habitat conditions in the Lower Eel River Basin? How do these conditions compare to desired conditions?

Findings and Conclusions:

Flow and Water Quality

- Stream and tidal flow has been altered by tide gates and levees constructed along streams and slough channels;
- Water quality is being impacted by cattle waste in estuary sloughs and in streams of the Middle and Upper Subbasins;
- Low summer flows may be stressful to salmonids and dry or intermittent reaches on the Van Duzen River prevent connection with the Eel River and impede passage to spawning grounds;
- In 1992, the EPA listed the Lower Eel River as impaired due to elevated sedimentation/siltation and temperature. The NCRWQCB has continued to identify the basin as impaired in subsequent listing cycles, the latest in 2006;
- Turbidity levels are high during winter rains, which correspond to salmon spawning season.

Erosion/Sediment

- Excessive sedimentation within the watershed has resulted in an overall loss of rearing and feeding habitat for salmonids within the estuary;
- The Van Duzen River is usually isolated from the Eel River by subsurface flows in late summer and early fall due in part to increased bedload materials at the confluence;
- Livestock have unrestricted access to many of the Lower Eel River tributaries and estuary sloughs, resulting in stream bank erosion;
- Soils in surveyed reaches of streams in the Lower Eel Basin are prone to erosion, and slides have been observed to contribute fines to the streams.

Riparian Condition/Water Temperature

- Much of the Lower Eel Basin has been cleared of riparian vegetation to create pasture land for cattle;

- Though water temperatures in CDFG surveyed reaches of streams in the Lower Eel Basin were suitable for salmonids, water temperature data are limited, and therefore inconclusive;
- Water temperatures of the mainstem collected by the Humboldt County Resource Conservation District (1998) in the summers of 1996 and 1997 within the basin, found unsuitable conditions for salmonids (maximum temps ranged from 73ºF–77ºF);
- Water temperatures collected by the Fortuna Creeks Project over a six-year sample period demonstrate stressful (above 68ºF) and occasionally lethal (above 75ºF) conditions, particularly on Rohner Creek;
- The majority of the surveyed tributary reaches in the Lower Eel Basin (70%) met the target value of 80% canopy coverage, but lack larger conifer overstory.

<u>Instream Habitat</u>

- Quality pool structure is generally lacking in streams throughout the basin; no surveyed streams met standards for pool shelter. Eight of the seventeen reaches surveyed obtained ratings considered fully unsuitable;
- On average, pool depths were considered poor for salmonids in all CDFG surveyed streams in the basin;
- Large woody debris is generally lacking in many areas of the basin.

<u>Gravel/Substrate</u>

- Due to increased sedimentation, stream beds have been described as heavily silted in many CDFG habitat inventories throughout the basin;
- Only 7% of pool tails in the Lower Eel Basin have cobble embeddedness in category one, which meets spawning gravel targets for salmonids;
- Areas of suitable spawning gravel are very limited throughout the Basin.

<u>Refugia Areas</u>

- The Middle and Upper subbasins provide medium potential refugia;
- The Salt River Subbasin provides lower quality stream refugia;
- The Estuary Subbasin and lower 3.4 miles of the Salt River provides critical estuarine rearing habitat for juvenile salmonids and other valuable fishery resources.

<u>Other</u>

- When flows are sufficiently high, the Eel River floods into treatment ponds of the Fortuna Wastewater Treatment Plant;
- A culvert on Mill Creek, tributary to Strongs Creek, in the Middle Subbasin does not meet CDFG and NOAA Fisheries fish passage guidelines. Other creeks with possible fish passage problems include Palmer Creek, Dean Creek, Price Creek, Adams Creek, and Barber Creek on mainstem Eel (RM 10).

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

<u>Findings and Conclusions:</u>

- The Lower Eel 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 Eel River has been drastically altered due to excessive sedimentation, which can exacerbate flood events;
- The floods of 1955 and 1964 catastrophically 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 compression generated by convergence between the Gorda and North American Plates, underplating and accretionary tectonics along the Cascadia Subduction Zone and further enhanced by accelerated uplift from the encroaching Mendocino Triple Junction;
- Estuarine conditions extend from the mouth to Fernbridge (RM 7); tidal influence, evidenced by water movement, continues beyond this point, possibly to the mouth of the Van Duzen River;
- The basin's vegetation has been historically and is currently composed of primarily coniferous forest, predominantly of the Redwood Alliance. However, on all surveyed tributaries in the Upper Subbasin, deciduous canopy was more prevalent than coniferous. Reclaimed pasturelands are now also prevalent in the basin.

How has land use affected these natural processes and conditions?

<u>Findings and Conclusions:</u>

- Tideland reclamation and the construction of dikes and levees for agricultural purposes have changed the natural function of the estuary considerably. Slough and creek channels that once meandered throughout the delta are now confined by levees, sufficiently slowing flow to a point that many have become filled with sediment. Remnant slough channels are visible throughout the delta. It is generally accepted that the estuary and tidal prism has been reduced by over half of their original size;
- Riparian vegetation in the basin was cleared, and salt marsh vegetation was converted in order to create pastures for cattle. This change in species of grass has reduced the strength of prairie vegetation, causing soils to be more susceptible to slumping;
- Wastes from the dairy industry, as well as urban storm runoff have affected the water quality;
- 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 within the Lower Eel, the basin is affected by highly variable runoff rates. Disturbance of the basin's already unstable soils by landuse activities has disturbed 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?

<u>Findings and Conclusions:</u>

- Based on available information for the Lower Eel 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;
  - Shortage of areas with suitable spawning gravel in tributaries;
  - Decreased channel capacity;
  - Loss of estuarine habitat;
  - Competition with Sacramento pikeminnow.

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

Recommendations:

Flow and Water Quality Improvement Activities

- Increase the tidal prism to help maintain existing channels and help remove excessive fine sediment accumulations;
- Conduct an inventory of tide gates and levees in the watershed;
- Where necessary, identify barriers to fish migration in the form of large debris accumulations, culverts, etc. and modify them;
- Protect summer stream flows from summer diversions;
- Livestock management fencing should be placed in areas where cattle have unrestricted access to streams.

Erosion and Sediment Delivery Reduction Activities

- The impact of property subdivision on streams of Lower Eel Basin should be minimized through the use of better land management practices. Opportunities to acquire conservation easements should be examined;
- Conduct an upslope erosion inventory on streams in the Middle and Upper subbasins 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 within the basin;
- Encourage the use of cattle exclusion fencing along streams where livestock have unrestricted access;
- 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.

Riparian and Habitat Improvement Activities

- Identify and prioritize locations within the delta where vegetation can be returned to salt tolerant species, thus increasing salt marsh around slough channels and providing a buffer to adjacent lands during inundation;
- Develop a grading ordinance to protect riparian vegetation. Ripparian buffer should be allowed to grow/re-grow along estuarine channels;
- Programs to increase riparian vegetation should be implemented in streams where shade canopy is below target values of 80% coverage. Additionally, those streams that are vegetated with exotic species should be considered for native plant restoration;
- In order to protect riparian vegetation, and decrease stream bank erosion due to unrestricted access of cattle to streams, use of livestock management fencing should be prescribed;
- In creeks where fish spawning and rearing habitat is limited, pool enhancement and instream structures should be added to increase complexity;
- 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 removed where appropriate.

Education, Research, and Monitoring Activities

- Improve educational outreach to community;
- Encourage and partner with Fortuna Creeks Project's urban stream clean-up, habitat restoration and monitoring;
- Support the HCRCD in its efforts to monitor and improve habitat and water quality in the basin;
- Because water quality data are limited, monitoring of summer water temperatures should be preformed over at least a three to five year period;
- Water quality data, including temperature and dissolved oxygen, should be consistently collected throughout the year, for several years, in order to accurately characterize conditions in the streams. Salinities should be collected in the estuary and upstream to determine the extent of brackish conditions;
- Conduct habitat and fish inventories on urban streams of the Middle Subbasin, including Palmer, Jameson, and Rohner Creeks and unnamed tributaries to Strongs Creek;
- Partner with local academic institutions and private agencies as a means to encourage the study of the fish and habitat.

Subbasin Issue Summaries

Estuary Subbasin

The Estuary Subbasin is made up of the Eel River alluvial floodplain, excluding the Salt River drainage, from the Eel River's mouth to approximately 7 miles upstream at Fernbridge. This subbasin only encompasses part of the Eel River estuary - it does not include the Salt River, which is discussed as a separate subbasin.

The Estuary Subbasin is 24 square miles in size and contains approximately 40 miles of meandering sloughs and three miles of intermittent freshwater tributaries. The estuary is a sand bar built estuary that typically remains open to tidal exchange year-round. Tides are mixed diurnal, with two lows and two highs of unequal size generally occurring within a 24-hour period. Elevations are generally very low, but reach approximately 700 feet in areas near Table Bluff on the northwest margin of the subbasin. The town of Loleta is located at the base of rolling hills at an elevation of approximately 50 feet above sea level.

Findings and Issues

Fishery and Other Natural Resources:

- The lower Eel River from the mouth to the confluence with the Van Duzen River was once one of the most popular areas in the basin to fish for salmon;
- Major declines in salmonid abundance and changes in the fishing regulations have contributed to large reduction in angling effort and the salmonid catch in the estuary;
- The majority of fish found in the estuary are considered marine or anadromous species that utilize the estuary for spawning and/or juvenile rearing habitat. Many of these fish are also considered estuarine dependant because they require an estuarine ecosystem to complete a critical life history phase. Juvenile salmonids have been observed in the estuary on a year-round basis;
- While the overall amount of habitat available has been greatly reduced and the ecosystem altered, nonetheless, the Eel River estuary provides critical rearing habitat for juvenile anadromous salmonids and several other valuable fishery resources;
- The Eel River estuary is of great value as habitat for resident and migratory wildlife;

- Much of the historic tidal wetland habitat held in the public trust in the north sloughs area is managed for water fowl hunting opportunities.

Natural Processes of the Estuary:

- Tidal inflows make major contributions to the estuary ecosystem;
- Tidal influence extends to upstream of Fernbridge;
- Tidal flows help maintain cool water temperature in the estuary;
- The Eel River delta is naturally susceptible to flooding and winter floods in this low relief, alluvial delta are not unusual;
- The Salt River is an important component of the Eel River estuary.

Land Use Impacts on the Estuary:

- Since the estuary is located at the bottom of the Eel River Basin, it is susceptible to watershed cumulative effects. Therefore, the condition of the estuarine environment is influenced by conditions of the Eel River Basin as a whole;
- Beginning in the late 1800s, the physical structure and natural processes have been altered by conversion of riparian forests and wetlands to farming and pasture lands;
- Estuarine channels were once cleared of LWD to promote navigation by boats. A relative paucity of woody debris in the estuary may limit shelter habitat needed by juvenile salmonids during large winter runoff flows and also limits cover to escape from predators;
- The Eel River estuary receives sediment loads, turbidity, and other aspects of water quality and quantity from the entire basin;
- Large scale erosion and associated sediment inputs to streams of the Eel River Basin and Salt River Basin have contributed to excessive sediment accumulations in the Eel River estuary, including the main estuarine channel;
- As a combined result of a reduction in tidal prism and excessive amounts of sediments delivered to the estuary, the overall amount of habitat area and its complexity have been altered/reduced, adversely impacting the fishery resources. Moreover, channels have filled in and become more prone to overflow their banks;
- Channel and bank modifications within the Eel River estuary have also altered estuarine morphology, hydrologic and fluvial processes. The reduction in salt marsh habitat area and loss of channel connectivity and complexity has altered the natural ecosystem process involved with nutrient cycling, food production, and resulted in a loss of habitat area and diversity;
- The loss of approximately 90 percent of original wetland habitat and tidal prism is from land reclamation and the affects of levees and tide gates. The network of levees and tide gates in the Eel River estuary has reduced channel connectivity and blocked the ebb and flood of the ocean tides;
- Levees also reduce capacity of flooded delta lands to drain and prolong the effects of flooding;
- Dairy and cattle waste products have potential to degrade water quality in the estuary;
- Cattle have access to many estuarine channels and contribute to bank erosion and degrade water quality;
- Efforts have been made to reduce dairy wastes from entering the network of estuary channels, but monitoring studies have not been implemented to gauge effectiveness of the dairy waste management;
- Water temperature in the upper estuary is above desired levels.

Management:

- There is no comprehensive management plan for the Eel River estuary;

- In the estuary there are competing interests by multiple users for a limited amount of public lands.

Recommendations

Flow and Water Quality Improvement Activities:

- Insure the supply of freshwater inflows are provided for maintaining estuarine habitat diversity and to drive ecosystem processes that fish, wildlife, and vegetative communities depend on for part or all of the life history cycles;
- Use levee set backs, reconfiguration, or levee removal strategies to develop a wider flood plain that restores natural sinuosity, improves connectivity with sloughs and adjacent wetlands in North Slough channels or other areas constricted by levees;
- Increase tidal prism by modifying tide gates to restore tidal and riverine flow and connectivity between the main channel and slough channels and adjacent wetlands;
- Continue to prevent or reduce cattle waste and agricultural and dairy by-products from entering stream and slough channels;
- Take measures to insure that water treatment facilities in Fortuna, Loleta, Ferndale and other nearby areas do not contaminate estuarine waters.

Erosion and Sediment Delivery Reduction Activities:

- Land managers should work to maintain and/or establish adequate streamside protection zones to encourage growth of riparian vegetation to help stabilize stream banks;
- Increase slough channel scour potential by restoring tidal prism in historic tidal wetland areas;
- Continue efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with all land use activities throughout the Eel River basin to reduce sediment delivery to the estuary;
- Armour eroding banks near Fernbridge or other such areas with bioengineered techniques that secure large wood pieces into banks and integrate live trees into the stabilization project.

Riparian and Instream Habitat Improvement Activities:

- Where feasible, restore or improve width of riparian vegetation stands with native vegetation (Sitka spruce, cottonwood, redwood, alder willow) along the banks of lower Eel River and slough channels;
- Work to restore natural functioning tidal and drainage patterns within the McNulty Slough portion of the Ocean Ranch Wildlife Area and other north slough area channels and wetlands. The project should address water temperature, water flow regimes and other parameters needed to promote seasonal and/or year round use by fishery resources;
- Candidate sites for levee removal include both sides of McNulty Slough and its tributaries, and the land west of McNulty slough. The northwestern delta should be expanded rapidly outward from earlier project sites;
- Consider conservation easements or land acquisitions that would promote the removal or modification of tide gates and levees in order to restore tidal prism and tidal wetlands;
- Develop policy or regulations that prohibit or reduce wood removal from within the estuarine channel banks (0.25 mile upstream from the Fernbridge to river mouth) and out to 50 feet from the high tide shore line of the North Bay. Such regulations should protect wood pieces on stream banks needed to reduce potential from further bank and beach erosion, provide instream shelter during high flows for fish, and protect bank restoration projects;

- Develop plans to eradicate or control the spread of invasive Spartina densiflora. An optimal strategy for low to medium sized budgets is to remove Spartina in areas where it grows in low density subpopulations.

Education, Research, and Monitoring Activities:

- Develop an inclusive estuarine (Salt and Eel River estuary) ecosystem management and monitoring plan that works with natural processes restore tidal connectivity to wetlands and increases tidal prism;
- Investigate potential impacts form sea level rise, increased storm intensity and other impacts to the estuary related to climate change;
- Add to baseline data regarding habitat utilization by all estuarine species;
- Study and assess the status of estuarine conditions needed to complete specific life history requirements for salmonids and other estuarine dependant fish and invertebrate species;
- Continue and expand water quality monitoring (including temperature and D.O).of nutrient levels that may be elevated from runoff from cattle pastures, sewage treatment facilities or other sources;
- Monitor the progress of natural succession (biotic and abiotic) and fish and wildlife resource utilization within the Ocean Ranch wildlife area. This should include the estuarine area and the fresh water impoundment;
- Determine the percentage of adult Chinook returning to the Eel River that show extended estuary rearing patterns by using scale analysis or other means;
- Investigate operations of tide gates on McNulty Slough, Hawk Slough, Centerville Slough and others to determine effects and/or loss of properly functioning saltwater/freshwater ecotone;
- Investigate dynamics of breaching the seaward levee at the south end of McNulty Slough to increase tidal prism and develop connectivity between wetlands and other sites to restore wetland connectivity.

Salt River Subbasin

The Salt River Subbasin is the southern portion of the Eel River estuary. In its 49 square miles, it contains 42 miles of sloughs and freshwater tributaries. This subbasin is composed of two significant ecological units: the delta, identified by the alluvial floodplain, and the Wildcat Range, which describes the tributaries that originate in the Wildcat Hills and flow across the delta. As does the Estuary Subbasin, the Salt River Subbasin provides valuable areas for juvenile and adult estuarine fish species. The Wildcat tributaries provide habitat for freshwater fish, including coho, Chinook, and steelhead.

Issues and Findings

General Management Issues:

- Hydrologic energy in the Salt River has been reduced through the:
  - Loss of tidal prism through historic agricultural conversion of wetlands, sloughs and salt marshes;
  - Exclusion of periodic Eel River flood waters by the Leonardo Levee;
  - Diversion of the eastern 42% of the watershed into Perry Slough and Old River;
  - Prolific growth of nuisance instream vegetation, lessening water velocity and resulting in further sediment deposition;
- Highly erodible soils dominate the upper watershed;
- Seismically very active area and close proximity to the Mendocino Triple Junction;
- Potential of subsidence and uplift within in the Eel River Delta.

Socio-economic

- The Salt River is no longer a navigable waterway;
- Flooding has increased because a reduction of channel capacity of all watercourses in the Salt River Basin due to sediment deposition;
- Degradation of Francis Creek and the Salt River channel has resulted in the Ferndale Wastewater Treatment Plant to be in violation of water quality regulations leading to a cease and desist order issued by the North Coast Water Quality Control Board in 2008 and will most likely be re-permitted once it reaches a resolution;
- Health hazards are posed through water quality degradation;
- Agricultural production and land values are decreased by flooding;
- Most domestic and irrigation wells are less than 30 feet deep. Nitrates and fecal contaminants could easily contaminate the shallow ground water.

Land use

- The majority of Salt River Delta is in agricultural production;
- Livestock has access to streams in many locations within the Basin resulting in: stream bank erosion, no recruitment of riparian plant growth, direct input of fecal and urine contaminants, and trampling of stream banks;
- There have been negative impacts to streams and fish habitat from historic timber harvest practices;
- Channel realignment in the trans-delta reaches of some of the Wildcat tributaries from a distributory flow regime to a channelized flow regime has resulted in greater input of sediment in the mainstem Salt River;
- Urbanization and channelization has altered discharge and sediment deposition patterns of Francis Creek;
- Dairy farm waste management infrastructure is, in places, inadequate;
- Unknown, but suspected high quantities of nutrients from agricultural land may present water quality problems in the mainstem of the river as well as in the estuary;
- Erosion from roads and stream banks in the Salt River tributaries is a significant by indeterminate source of suspended sediment;
- Extensive system of levees and berms throughout the basin disrupt channel connectivity with adjacent floodplain;
- Sand quarries may have had a negative impact on the amount of sediment in the Salt River.

Fish and Wildlife

- Canopy cover and riparian vegetation is lacking in some portions of the Wildcat tributaries;
- 2,900 acres of tide land in the Salt River Basin were reclaimed in the late 1800’s;
- Salmonid access into the Salt River system is severely impaired, and access to Williams Creek and Coffee Creek has been eliminated;
- Salmonid habitat throughout the entire basin is poor;
- Aquatic macroinvertebrate populations in basin indicate instream sediment impairments;
- Potential large woody debris (LWD) recruitment is generally poor;
- Spawning habitat is inadequate due to excess fine sediments;
- Mercury contamination has been found in the flesh of fish in the Eel River system (Stokes, 1981).

Middle Subbasin

The Middle Subbasin includes the area east of the Eel River from the confluence of Finch Creek to upstream of the confluence with Strongs Creek as well as a narrow strip west of the Eel River parallel. Stream elevations range from approximately 40 feet at the confluence of the Eel River with Finch Creek to approximately 1,700 feet in the headwaters of the tributaries.

The subbasin encompasses 24 square miles, occupying 14% of the total basin area. Lower elevations areas are mostly held in private parcels less than 40 acres in size while much of the higher elevation areas are owned by large timber companies and are managed for timber production. The streams in the Middle Subbasin are heavily affected by urbanization, as many flow directly through Fortuna, the area's population center. Fish surveys of the streams in this basin have identified coho, steelhead, and coastal cutthroat trout.

Issues and Findings

Altered flow regimes:

- Low summer flows are exacerbated by land and stream disturbances and result in dry or intermittent reaches on streams, which are stressful to salmonids;
- Fortuna operates five groundwater extraction wells near the Eel River;
- Increased development in Fortuna, especially in the southern and eastern parts of the city, has increased runoff from newly created impervious areas (FEMA 1981, cited in Mintier and Associates 2006);
- Many of the storm drains and culverts in Fortuna are undersized (Winzler and Kelly 2005), increasing the velocity of flows during precipitation events;
- Strongs and Rohner creeks have been modified where they flow through Fortuna to eliminate their floodplains, increasing the volume and velocity of flows during precipitation events;
- Winter floods are increasingly common due to high winter precipitation levels, increased runoff, and undersized storm water drainage structures. Areas with current flooding include the North Fortuna Drainage Area, Rohner Creek, the lower reaches of Strongs Creek, and Jameson Creek at the confluence with Strongs Creek (Winzler and Kelly 2005);
- Undersized drainage capacity has also been identified in several areas including Rohner Creek and the Mill Creek drainage. Rohner Creek has the highest potential for serious flooding (Winzler and Kelly 2005).

Addition of pollutants:

- When flows are sufficiently high, the Eel River floods into treatment ponds of the Fortuna Wastewater Treatment Plant;
- The Fortuna Wastewater Treatment Plant received a cease and desist order in 1997. The issue was resolved and the order was rescinded that same year;
- The treatment plant had three chlorine limit violations - one maximum and two minimum values that violated the permit level in 2004. Sewer overflows that occurred in the system were caused by high flows and collection system stoppages;
- Increased development in Fortuna, especially in the southern and eastern parts of the city, has increased runoff from newly created impervious areas (FEMA 1981, cited in Mintier and Associates 2006). Although no specific tests of chemicals have been conducted in Fortuna's streams, urban runoff in general is known to mobilize chemicals such as trace elements, pesticides, copper, and volatile organic compounds (Hamilton et al. 2004);
- Livestock grazing likely occurs in 23% of the subbasin and has been noted along Strongs and North Fork

Strongs creeks. Although no specific tests of nutrients and/or coliform bacteria have been conducted in these creeks, levels of these constituents often exceed water quality standards in areas with extensive livestock use;

Fish passage barriers where roads cross streams:

- A culvert on Mill Creek (RM 1.3) and Rohnerville Road may not meet CDFG and NOAA Fisheries fish passage guidelines;
- A culvert on Jameson Creek and Rohnerville Road does not meet CDFG and NOAA Fisheries fish passage guidelines;
- Palmer Creek has problems with fish passage due to a barrier in the 800 foot culvert under Highway 101.

Natural processes effects stream conditions:

- Natural erosion rates are high due to:
  - The major rock underlying the subbasin is alluvium, which constitutes 70% of the subbasin. The other bedrock, also sedimentary, is Pliocene marine. Both of these geologic types are highly erodible;
  - Rapid incision rates of the mainstem and its tributaries have left a series of river terrace deposits perched steeply above the current stream channels which contribute fine sediments through slope instability and dry ravel;
  - The Little Salmon fault cuts through this basin, weakening bedrock and increasing the potential for seismic triggering of landslides;
  - During the winter rainy season, heavily silted water flows through the steep upstream terrain, which affects turbidity and sediment levels in streams.

Changes in basin due to land use:

- Sedimentation and in-filling as a result of land development and subdivision activities, gravel mining and timber harvesting practices have resulted in an overall reduction in channel area, and consequently in available salmonid habitat;
- Fortuna grew from one square mile in 1950 to 4.68 square miles in size in 2006. This represents a change from approximately 4% to 19.5% of the subbasin;
- The Fortuna annual average population growth rate from 1980 to 2005 was 1.6%. If the city continues to grow at this rate the population will rise from 11,250 to approximately 17,000 in the next 25 years (Mintier and Associates 2006);
- There were 4,729 housing units in Fortuna in 2005. If current growth rates continue, Fortuna will require 2,298 new housing units by 2030 (Mintier and Associates 2006);
- Additionally, it is projected that there will be a need for an additional 852,866 square feet of commercial, retail, and manufacturing space by 2030 (Mintier and Associates 2006).

Possible effects seen in stream conditions:

- Instream habitat conditions for salmonids are thought to be poor;
- Projects related to the expansion of Fortuna's urbanization have adversely affected the area's streams in both water quality and riparian and instream habitats;
- Development of the commercial shopping center along Mill Creek has greatly reduced the riparian area and hydrology of the stream channel. During large precipitation events, the stream overflows its banks and has caused stranding of steelhead in the adjacent fields;
- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing, and feeding

habitat for salmonids. High sediment levels are confirmed by embeddedness measurements in surveyed reaches. Moreover, none of the surveyed streams met target values of pool depth;

- The Fortuna Creeks Project found that stressful turbidity levels are reached during the rainy winter months. These high levels of turbidity, which are particularly apparent in Strongs and Rohner creeks, occur during spawning season;
- Quality pool structure is generally lacking in Middle Subbasin streams; no surveyed streams met standards for pool shelter. Pool shelter ratings ranged from fully unsuitable to somewhat unsuitable levels;
- Spawning gravels in Strongs and North Fork Strongs creeks are found in only a limited number of reaches. Additionally, crowded and superimposed redds have been observed during spawning surveys;
- None of the CDFG surveyed streams of the Middle Subbasin met target values for cobble embeddedness.

There is concern about unrestricted stream access of livestock in agricultural areas:

- Impacts from livestock grazing have been noted during stream surveys on Strongs and North Fork Strongs creeks;
- Livestock grazing operations occur in approximately 23% of subbasin.

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

- The impact of previous techniques and harvest amounts are evident in the braiding of the Eel River from the mouth of Van Duzen River to Fernbridge that has occurred since 1956. A general flattening and widening of the river bed is also apparent (Humboldt County 1992);
- Timber harvest, while less of an issue than in the past, still occurred in the headwaters of all of the creeks in this subbasin from 1988 to 2005. Erosion related to timber harvest on unstable soil is a concern, such as the recent timber harvesting in the headwaters of Strongs and North Fork Strongs creeks. This area is made up of the Wildcat Formation, which is largely comprised of fine sediment and is highly erosive.

There is concern about the impacts of historic and current gravel mining operations on the mainstem Eel River:

- There are eleven gravel mining sites in this subbasin that remove over 5,000 cy/yr of aggregate. The volume of aggregate removed has decreased significantly since 1996. Prior to 1996, average extraction volumes ranged from 500,000cy/yr to 700,000cy/yr;
- The USACE has concluded that sand and gravel mining extractions are not excessive or occurring at rates that are too high to negatively impact channel morphology in the basin based on the increase of shoreline sediment. However, as bed-load data are not well known, it is difficult to set adequate extraction rates and volumes;
- Most of the concern in managing gravel mines is in the reconfiguration of the low flow channel. To this end, trench, alcove, or wetland pit mining are recommended over bar skimming, which has been shown to increase low flow channel width (USACOE 2003). Without the revision of extraction amounts and techniques, impacts to salmonids would be significant and would likely include loss of deep holding pools during adult migration, and loss of cover, suitable temperature, and complex habitat for juvenile salmonids.

Upper Subbasin

The Upper Subbasin includes the watershed area along the Eel River from Barber Creek to Dean Creek. It also includes the Van Duzen River from its mouth to Cummings Creek, approximately 9 miles above its confluence with the Eel. Stream elevations range from approximately 40 feet at the confluence of the Eel River with Barber Creek to approximately 2,160 feet in the headwaters of the tributaries. This subbasin is the largest of the Lower Eel Basin at 75 square miles, 43% of the total basin area. This subbasin is mostly held in private parcels 40-500 acres in size with large sections owned by large timber companies and managed for timber production. Chinook, coho, and steelhead have each been documented in fish surveys of the Upper Subbasin.

Issues and Findings

Sediment level in streams is high and creates a multitude of problems for fish habitat:

- Filling of pools by sediment is an issue in every creek surveyed in this subbasin. The majority of streams were of the lowest suitability in terms of pool depth and frequency;
- Pool shelter is a widespread issue in the subbasin. Every stream surveyed in this subbasin with the exception of Oil Creek has pool shelter values that were below suitable and none met target values. Sedimentation of coarse material can affect recruitment of large woody debris, and both fine and coarse sediment can fill in hiding places around shelter components such as boulders and logs;
- Substrate embeddedness was very high on Wolverton Gulch, Wilson Creek, Dean Creek, Nanning Creek, and Westfork Howe Creek. With the exception of Oil Creek, all streams surveyed were poorly suited for spawning;
- The two most common geologic formations in this subbasin are the Wildcat Formation, which is comprised of uniformly fine sediment and is highly erosive, and the Coastal Belt Melange Formation, which is even more erosive but contains a wide range of sediment sizes from boulders to silt;
- Logging occurs (1989-2005) in both the Wildcat Formation and the Coastal Belt Melange Formation. Some areas have been entered more than once, and different yarding and harvesting methods have been used across the subbasin; these all influence the impact logging can make on a watershed;
- Kelsey (1977) posits that the Van Duzen River has aggraded significantly since the 1964 flood upstream of, but likely applying to this study area. This has probably exacerbated the broadening of the low flow channel near the mouth.

Gravel mining practices have created a seasonal fish passage barrier at the mouth of the Van Duzen River:

- Bar skimming had been the preferred method of gravel extraction on the Lower Van Duzen River up until 1996. This method has been shown to widen channels thus creating a shallow, braided reach;
- In 2001, 136 adult migrating salmonids were stranded at the mouth of the Van Duzen River due to years of widening of the low flow channel from gravel mining and aggradation;
- The lower four miles of the Van Duzen River are purposefully blocked to salmonids by three temporary culverts from the time the first adults arrive at the mouth until flows increase enough to ensure upstream passage.

Accessibility to habitat is potentially blocked at various points in the subbasin:

- The mouth of the Van Duzen River, if left alone, creates a barrier to adult fish passage due to its broad, braided and shallow low flow channel;
- Log debris accumulations occur on Cummings, Dean, Atwell, West Fork Howe, Adams, and Nanning creeks, and Wolverton Gulch;
- Culverts on Adams and Oil creeks may be barriers to fish passage;
- Rock dams occur on Price Creek and may pose as barriers to fish passage;
- The mouth of Dean Creek is a perched sediment delta and potentially acts as a barrier to fish passage;
- Connectivity at the mouths of Fiedler and Cummings creeks and Wolverton Gulch may be an issue due to sedimentation.

Urban and agricultural wastewater disposal poses a problem to aquatic ecosystems in the mainstem Eel River:

- In 2003, Rio Dell's wastewater treatment facility received a 'cease and desist' order from the Regional Water Quality Control Board for problems arising from sludge removal and summer discharge into the Eel River through gravel bar percolation. These problems are ongoing, and the city has until 2009 to correct them;
- Livestock grazing operations occur in 11% of basin;
- Water temperatures are stressful to salmonids in the mainstem Van Duzen and Eel rivers and are unsuitable in some tributaries;
- A 1998 study done by Humboldt County RCD showed maximum weekly temperatures above 20 degrees Celsius (68°F) in the Eel River at the confluence with the Van Duzen River from July 1st through mid September, 1996, as well as in the Van Duzen River at the 101 bridge during that same timeframe;
- Sites monitored in Howe and Price creeks in were found unsuitable, recording maximum weekly temperatures above 65°F in June through October over several years.

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Basin Profile and Synthesis

The Eel River is located in northern California, approximately 200 miles north of San Francisco at latitude 40° 38' 32" N, longitude 124° 18' 43" W (Figure 1). The Eel River catchment lies predominantly in Humboldt and Mendocino Counties and also extends into Trinity, Glenn and Lake counties.

The mainstem Eel River is approximately 197 miles in length and receives flow from 832 tributaries – adding up to 3,526 miles of stream. It is the third largest river in California with a drainage basin of 3,684 square miles (CDFG 1997). Elevations on the mainstem range from sea level at the mouth to over 6,700 feet at the headwaters. 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, it has been divided into several basins for assessment (Figure 2). This report assesses the Lower Eel Basin. The Outlet Creek, Van Duzen River, and South Fork Eel River basins have been or are also currently being assessed by the CWPAP team.

The Lower Eel Basin assessment area is composed of less than 5% of the entire Eel River catchment at approximately 172 square miles and is defined as the watershed area from the river'smouth, upstream approximately 21 miles. As the Lower Eel Basin comprises the most downstream and depositional section of the entire Eel River catchment, any discussion of watershed processes within the basin must be considered within this larger context.

While the name of the Eel River reflects the number of so-called lamprey eels (*Lampetra tridentata*) that Euro-American settlers observed being collected by the native peoples in the area, its Native American name summarizes once healthy salmon runs: "…Eel River is called by the Indians, Weott [sic] – plenty-from the immense quantities of salmon obtained by them every fall in that stream…" (Humboldt Times September 23, 1854). These large salmon runs allowed Euro-American settlers to establish a lucrative commercial fishery, which by 1858 was supplying canned and salted salmon 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 the state. 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).

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 (CDFG 1997 [salmon and steelhead action plan]). Defining and quantifying the causes of this decline can be difficult, though most surely they are a result of cumulative effects of human impacts in a dynamic system. Anadromous salmonids currently present with the Lower Eel River Basin are coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss*), and coastal cutthroat trout (*Oncorhynchus clarki*). The 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 Lower Eel River Basin is the depositional zone for the entire Eel River catchment, and as such responds to the watershed delivery processes throughout the system. As part of this highly dynamic environment, the Lower Eel experiences high levels of sedimentation due to natural hillslope processes including very erodible bedrock and high levels of precipitation (Reynolds et al. 1981). Additionally, the area is situated in a tectonically active area. Landslides and erosion introduce large quantities of sediment to streams, and are exacerbated by the region's climate, geology, topography and land use.

The Eel has the highest recorded average suspended sediment yield of any U.S. river its size (Brown and Ritter 1971), and in 2002, the US Environmental Protection Agency (EPA) listed the lower portion of the Eel River as an impaired water body due to excessive sediment and high summer water temperature. The EPA defined the lower portion of the Eel River as the watershed area of the Eel River downstream from the confluence with the South Eel, excluding the Van Duzen River.

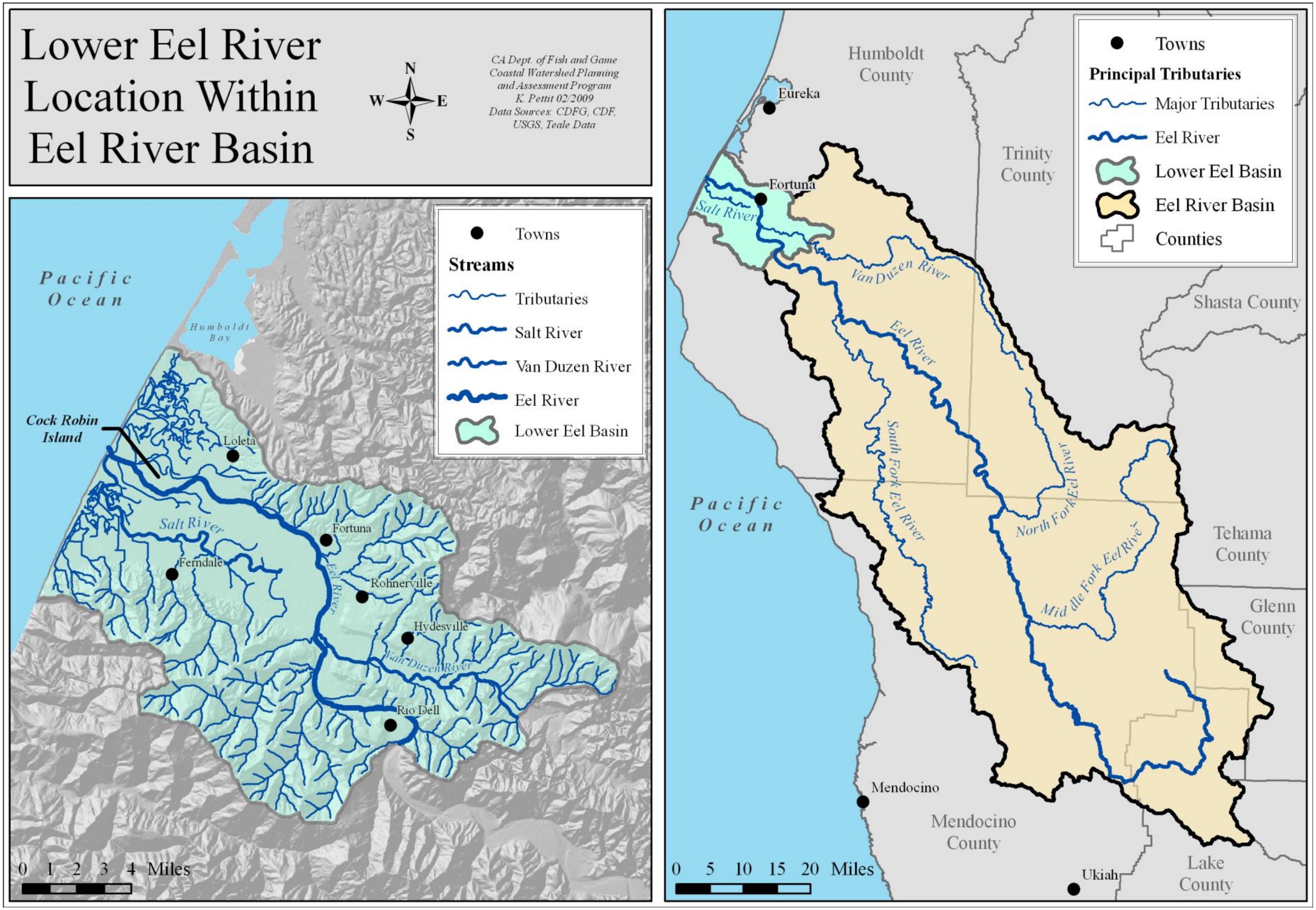

Figure 1. Location of the Lower Eel Basin within the Eel River Basin.

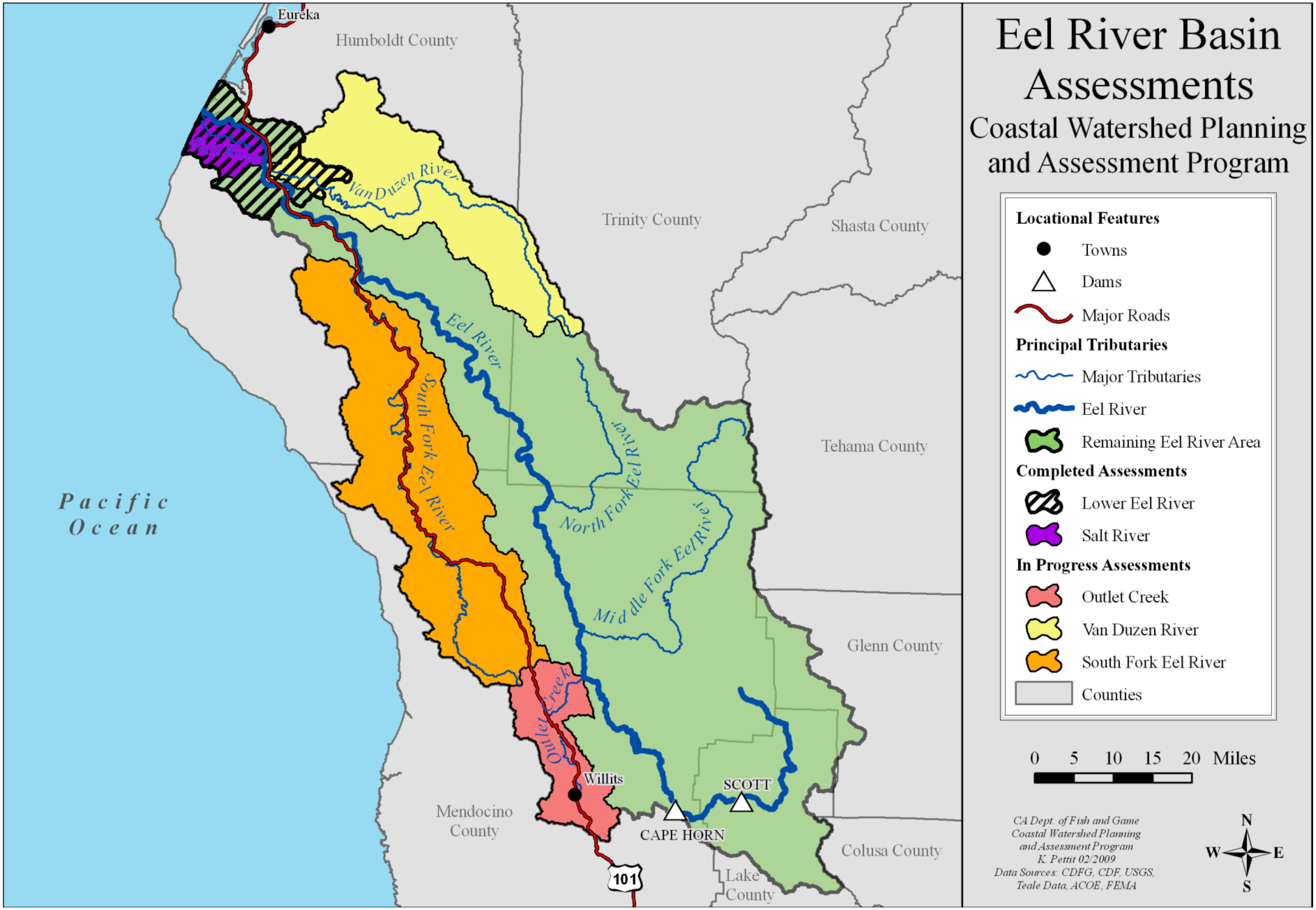

Figure 2. CWPAP assessment areas within the Eel River catchment.

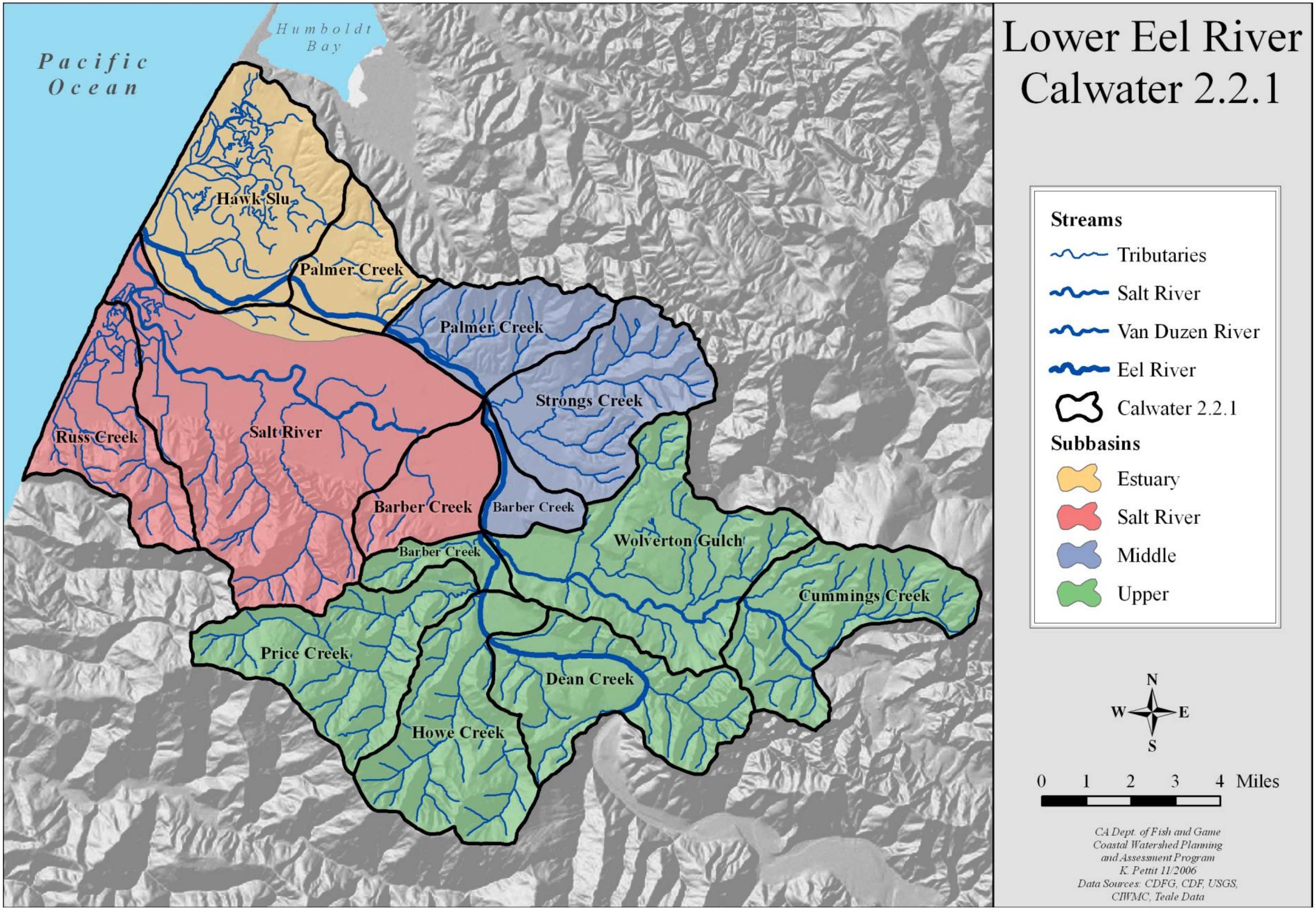

Figure 3. Lower Eel Basin subbasins delineated using CalWater 2.2.1.

Subbasin Scale

For purpose of this assessment and analysis, the Lower Eel Basin was divided into four subbasins (Estuary, Salt River, Middle, and Upper) comprised of a total of 11 CalWater 2.2.1 Planning Watersheds (PWs) (Figure 3 [above], Table 1). Subbasins were designated based on several attributes, including geography, geology, climate patterns, and land use. Original PW boundaries were edited to more accurately reflect the drainage patterns and watershed processes within the Lower Eel Basin when defining subbasins.

The Eel River estuary was divided into two subbasins: the Estuary Subbasin and the Salt River Subbasin. The Salt River drainage was previously assessed separately by Downie and Lucey (2005) in order to assist key entities with impending management decisions. Findings and recommendations from the Salt River Watershed Assessment have been incorporated into the Salt River Subbasin section. For this Lower Eel River watershed assessment, the Estuary and Salt River subbasins are viewed as two integral parts, which describe the Eel River estuary as a whole.

The Estuary Subbasin is the northern most portion of the Eel River estuary. It is 24 square miles in area and includes approximately 7 miles of the mainstem from the mouth to Fernbridge, as well as nearly 40 miles of predominantly brackish water sloughs and 3 miles of intermittent streams. The area receives sediment transported from the entire Eel River Basin, and responds dynamically in size and shape. The estuary is a nursery, feeding and holding area for variety of freshwater, marine, estuarine, and anadromous fish, including juvenile coho salmon, Chinook salmon, steelhead, and coastal cutthroat.

The Salt River Subbasin is the southern portion of the Eel River estuary. In its 49 square miles, it contains 42 miles of sloughs and freshwater tributaries. As is detailed in the Salt River watershed assessment (Downie and Lucey 2005), this subbasin is composed of two significant ecological units: the delta, identified by the alluvial floodplain, and the Wildcat Range, which describes the tributaries that originate in the Wildcat Hills and flow across the delta. As in the Estuary Subbasin, the Salt River Subbasin provides valuable areas for juvenile and adult estuarine fish species. The Wildcat tributaries have historically provided spawning and rearing habitat for freshwater fish, including coho salmon, Chinook salmon, steelhead, and coastal cutthroat.

The Middle Subbasin contains approximately 46 miles of permanent and intermittent stream, including the mainstem, in a 24 square mile area. This subbasin contains the largest human population, with the principle community of Fortuna. Fish surveys of the streams in this subbasin have identified coho salmon, Chinook salmon, steelhead, and coastal cutthroat.

The Upper Subbasin is the largest subbasin in the assessment area at 75 square miles. This subbasin includes approximately 7.5 miles of the Eel River mainstem from Barber Creek to Dean Creek. It also includes the Van Duzen River from its mouth to Cummings Creek, approximately 9 miles above its confluence with the Eel River. There are approximately 133 miles of permanent and intermittent streams in this subbasin. Chinook salmon, coho salmon, and steelhead have been documented in fish surveys.

Table 1. General attributes of the Lower Eel River Basin.

Attribute	Estuary Subbasin	Salt River Subbasin	Middle Subbasin	Upper Subbasin
Area (square miles)	24	49	24	75
Percent of Basin	14	29	14	43
Miles of Stream (permanent + intermittent)	43 miles	42 miles	40 miles	133 miles
Principal Communities	Loleta, Fernbridge	Ferndale	Fortuna, Rohnerville	Hydesville, Carlotta, Rio Dell
Predominant Geology	Alluvium	Alluvium	Unconsolidated river terrace deposits	Wildcat Group
Predominant Vegetation	Grassland	Grassland	Conifer	Conifer
Predominant Land Use	Agriculture	Agriculture	Urban, Agriculture, Mining	Forestry, Agriculture, Mining
Salmonid Species	Coho, Chinook, Steelhead, Coastal Cutthroat	Coho, Chinook, Steelhead, Coastal Cutthroat	Coho, Steelhead, Coastal Cutthroat	Coho, Chinook, Steelhead

Climate

A long rainy season and foggy summer season are characteristic of the climate in the Lower Eel Basin. The rainy season, which generally begins in October, and lasts through April, accounts for 90% of the river's mean annual runoff (Monroe et al. 1974).

California Department of Water Resources (DWR) has precipitation data for Eureka, located approximately 14 miles north of the Eel River mouth, from water years (WY) 1906 to the present. Data is also available from Scotia, located just south and outside of the basin, from WY 1926 to 2005. Eureka receives a mean annual precipitation of 38 inches and Scotia receives 47 inches. An isohyetal contour map of the Lower Eel Basin shows that mean annual precipitation is lowest in the Estuary Subbasin (40 inches per year) and highest in the upper elevations of the Upper Subbasin (80 inches per year) (Figure 4).

Throughout the year, the Eel River Basin receives highly varied precipitation. While average monthly precipitation ranges from less than 1 inch to greater than 9 inches over the period of record, monthly maximum precipitation has reached over 27 inches at Scotia, and over 23 inches at Eureka (both maxima occurred in December 2002) (Figure 5).

The dry season, generally May through September, is usually defined by morning fog and overcast conditions. On average, only about 78 days out of the year are clear, with the remaining 287 days being either cloudy or partly cloudy. The average annual temperature is 53°F, and average temperatures range very little throughout the year, from 48° F in January to 58°F in August (Western Regional Climate Center, www.wrcc.dri.edu).

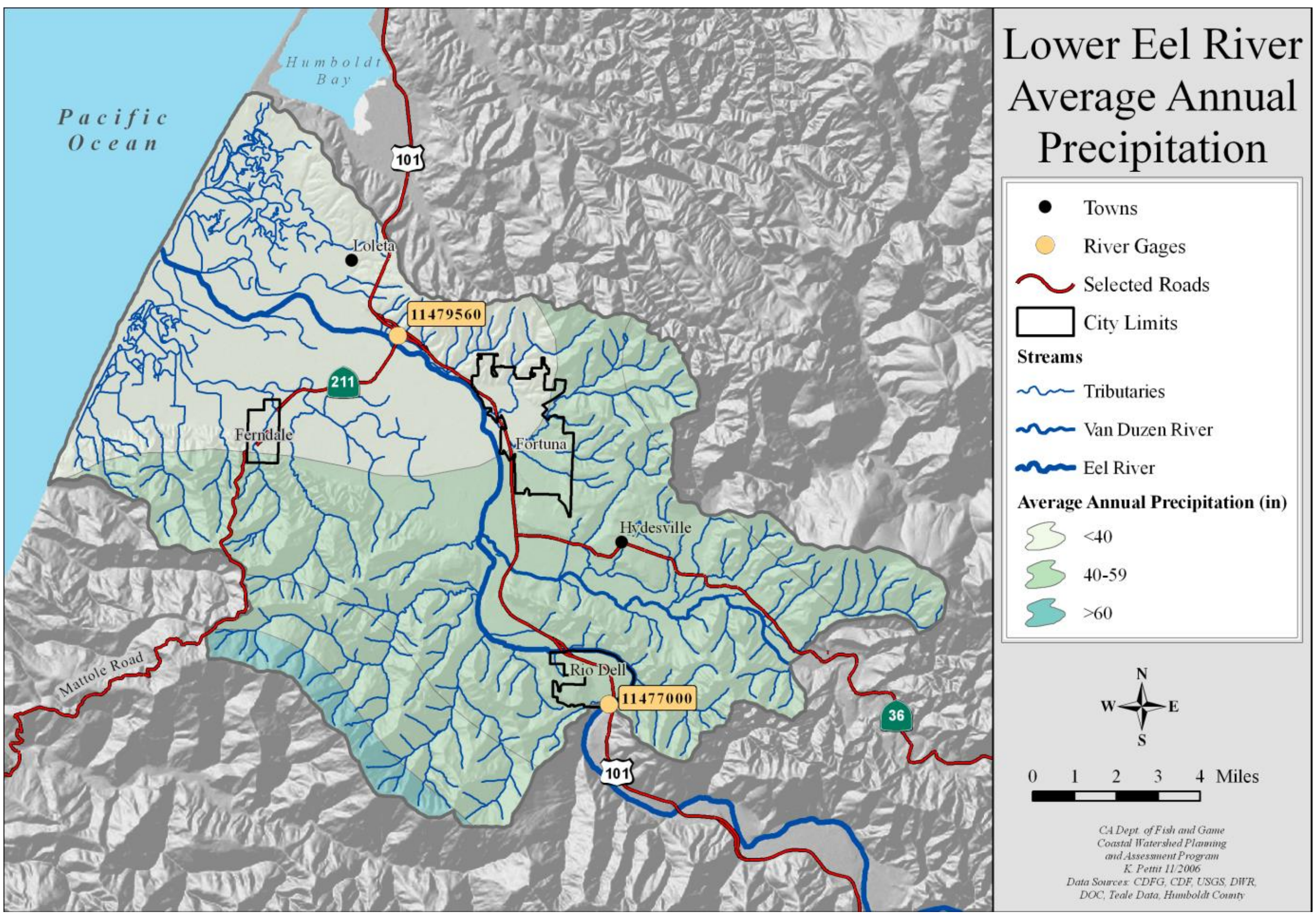

Figure 4. Average annual precipitation and river gage locations within the Lower Eel Basin.

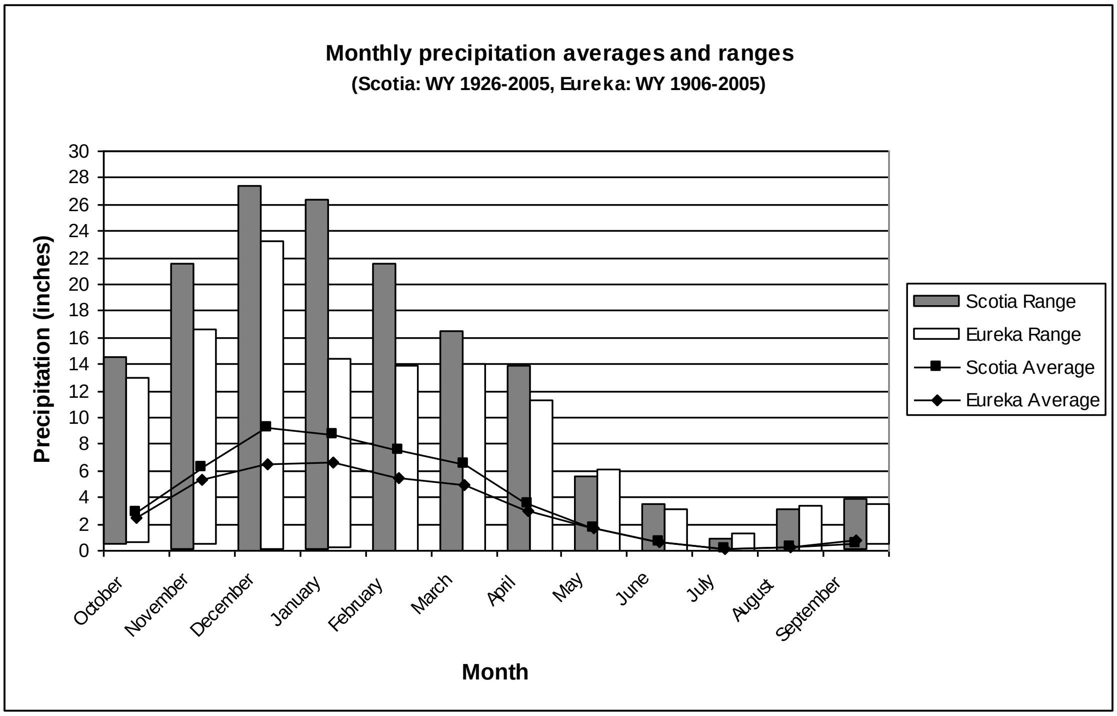

Figure 5. Monthly precipitation statistics over the period of record in the Lower Eel Basin.

Hydrology

The Eel River is the third largest river in California with a catchment area of 3,684 square miles square miles. The Lower Eel Basin has a catchment area of 172 square miles. The Lower Eel River Basin includes tributaries to the Eel River from its mouth upstream approximately 21 miles, as well as Van Duzen River tributaries from its confluence with the Eel upstream to RM 9. There are approximately 300 miles of stream within the Lower Eel Basin. Lengths of individual streams and river mile locations are detailed 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 un-branched tributary to appear on a 7.5-minute USGS quadrangle (1:24,000 scale) (Leopold et al. 1964). This system includes only perennial streams (i.e. those with sufficient flow to develop biota). 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 mainstem Eel River is a sixth order stream in the Lower Eel Basin, while the Van Duzer River is classified as a fifth orders stream. Most tributaries in this basin are intermittent or first or second order (Figure 6).

There are two USGS river gages located within the basin: at Scotia (USGS ID 11477000) and Fernbridge (USGS ID 11479560) (Figure 4 [above]). The Scotia gage (WYs 1911 to present, excluding WYs 1915 and 1916) measures gage height and discharge while the Fernbridge gage (WY 1911 to present) only measures gage height for flood-warning purposes.

Annual mean discharge at the Scotia gage over the period of record was 7,335 cfs. Monthly mean discharge ranged from approximately 140 to 20,000 cfs (Table 2). While maximum mean monthly discharge ranged from approximately 420 to 84,400 cfs, maximum mean daily discharges are far greater, ranging from 2,540 to 648,000 cfs. As a point of reference, in 1974 the Eel River channel had a capacity of approximately 150,000 cfs (Monroe et al.).

Because the Eel River Basin receives highly varied precipitation and has extremely 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 19 cfs was once recorded in the late summer of 1924 at Scotia, while over the period of record, 35 years have recorded at least 1 day with a mean daily discharge greater than 150,000 cfs (Data from USGS 2005) (Table 3). Moreover, there have

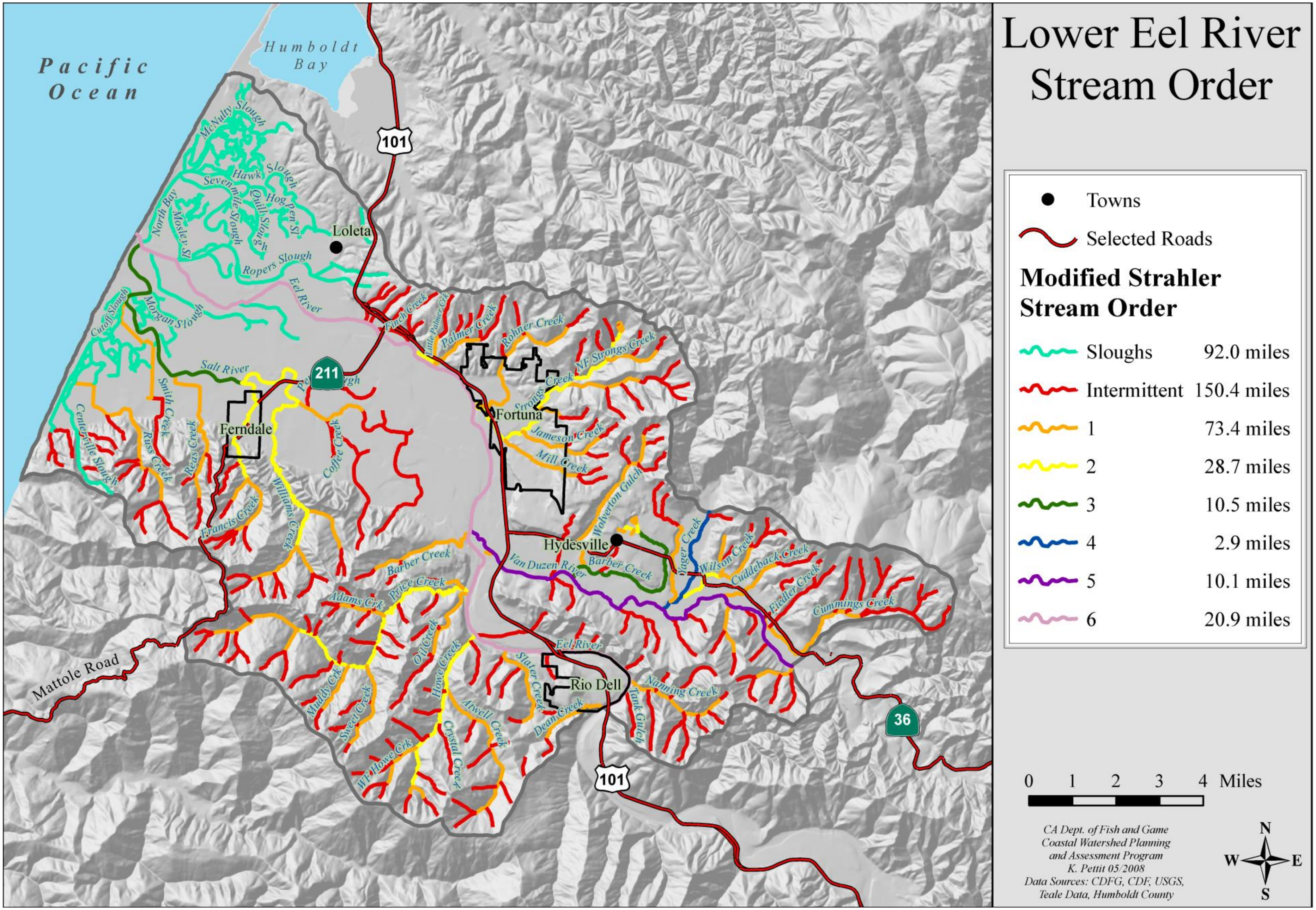

Figure 6. Stream order in the Lower Eel Basin.

Table 2. Statistics of mean monthly discharge for Eel River at Scotia over the period of record, WY 1911 to 2005.

Month	Mean Discharge (cfs)	Maximum Mean Discharge (cfs)	WY	Minimum Mean Discharge (cfs)	WY
October	642	10,910	1963	51	1930
November	4,934	38,690	1974	59	1930
December	14,220	84,420	1965	168	1977
January	20,050	69,950	1970	659	1977
February	19,920	77,680	1958	389	1920
March	14,290	51,150	1983	946	1924
April	8,884	39,190	1982	703	1924
May	3,803	14,000	2005	278	1924
June	1,308	7,511	1993	76	1924
July	347	1,182	2005	25	1924
August	151	422	1983	22	1924
September	141	735	1986	19	1924

Data from USGS (2005).

Table 3. Water years with mean daily discharge at Scotia greater than the channel's 1974 capacity of 150,000 cfs.

WY	Number of days with discharge >150,000 cfs	Maximum mean daily (cfs)	Range (cfs)
1914	4	231,000	66,000
1917	1	218,000	
1927	2	179,000	7,000
1928	1	166,000	
1936	2	182,000	14,000
1938	4	316,000	145,000
1940	2	261,000	91,000
1942	2	184,000	23,000
1943	2	208,000	21,000
1946	3	186,000	34,000
1951	2	199,000	43,000
1952	3	188,000	16,000
1953	1	158,000	
1954	1	213,000	
1956	6	433,000	281,000
1958	1	174,000	
1960	2	261,000	60,000
1963	1	212,000	
1965	5	648,000	472,000
1966	2	261,000	64,000
1969	4	190,000	39,000
1970	3	267,000	100,000
1971	3	195,000	22,000
1974	4	324,000	149,000
1975	3	186,000	31,000
1978	1	157,000	
1980	2	194,000	10,000
1982	3	232,000	57,000
1983	2	229,000	57,000
1986	4	304,000	124,000
1993	1	200,000	
1995	3	284,000	67,000
1997	3	316,000	54,000
2003	3	173,000	22,000
2004	1	173,000	

The period of record is WY 1911 to 2005

also 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 Scotia was 648,000 cfs; the maximum peak flow was 752,000 cfs (USGS data). On December 23, 1964, the river gage at Fernbridge was 9.5 feet above flood stage

(20 feet), and discharge at 840,000 cfs was nearly six times the normal channel capacity (Monroe et al. 1974).

Changes in the watershed, including increased impervious surfaces, road drainage and vegetation removal, have altered the basin's response to heavy precipitation. Heavy sedimentation has changed Eel River channels from deep, wide, and stable to aggraded, shallow, and shifting (Roberts 1992). These factors combined with the rugged terrain, elevations within the Eel River catchment reach over 6,700 feet, and loss of riparian vegetation in upstream tributaries cause water to be delivered rapidly downstream. During periods of extensive or intensive rain, river levels rise rapidly and flooding often occurs in the lower Eel River and estuary. Periods of intensive or extensive rain often occur during winter months and flooding becomes an issue throughout the basin.

Geology

The Lower Eel River Basin is located on the Coastal Belt of the Franciscan Complex of the Coast Ranges geomorphic province. In this area the Coastal Belt is overlain by Cenozoic sedimentary rock types. Specific rock units within the basin include the following: Pliocene – Pleistocene marine deposits of the Wildcat Group, Quaternary alluvium, river terrace deposits and older river terrace deposits, Coastal terrane, and Eocene marine deposits of the Yager terrane (Table 4).

The geologic setting in which the basin lays greatly contributes to very high sediment yields within the river system. Bedrock that has gone through a complex process of tectonic deformation, as part of the accretionary process resulting from collision and subduction of the Farallon/Gorda Plate, has made it relatively incompetent. 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.

Accelerated uplift during the last 500,000 years has allowed the river to carve down into what was once a wide floodplain leaving large predominantly unconsolidated gravel terraces steeply perched above the active stream channel. These perched sediments tend to slump, slide, and ravel into the watercourses contributing to the high rate of sedimentation of this region.

This river system has also cut into "soft" poorly cemented sedimentary rock types of the Wildcat group. The majority of the Wildcat group is made up of weakly cemented, fine grained, shallow marine sediments that filled the plunging Eel River syncline during the Pleistocene and Pliocene (see the Estuary Subbasin geology section for a detailed explanation of synclines). The sequence of sediments within the Wildcat group is well over 10,000 feet thick attesting to the highly erodable nature of the surrounding countryside.

The unstable geology, dynamic tectonism, steep topography, and high precipitation rates of this region combine to make it one of the most erosion prone areas in the United States.

The erosion rates within the basin are most affected by:

- Composition of bedrock–soft sedimentary rock and sheared matrix mélange are easily eroded;
- Incompetence of bedrock–folded, faulted, and sheared rock is easily eroded;
- Abundance of unconsolidated alluvium and river terrace deposits–contribute fine sediments to the streams through slope instability and dry ravel;
- High rate of uplift–increases the erosion potential of the area;
- Seismic activity–triggers landsliding within the basin and liquefaction of unconsolidated sediments in the gently sloped areas;
- Climate–saturation of steep slopes by heavy sustained seasonal rain triggers landsliding within the basin;
- Land use practice–grazing, timber harvest, road building, vegetation change, etc., increases the amount of surface erosion as well as landsliding.

Table 4. Rock types of the Lower Eel Basin.

Rock Type	% of Basin	Description
Alluvium	26.6	Unconsolidated river sediments within the active influence of streams.
Dunes	1.5	Windblown sand deposited along the shoreline as dunes.
Landslides	3.2	Large landslide features mapped as Quaternary Landslides
Terrace deposits	21	Unconsolidated, poorly sorted river sediments that have been uplifted above the active stream influence.
Wildcat Group	37	A series of 5 formations; 4 consisting of poorly cemented, fine-grained, shallow marine sediments and one consisting of courser, poorly consolidated, predominately nonmarine sediment.
Yager Terrane	1.8	Moderately-well consolidated, locally sheared, sandstone, argillite, and conglomerate.
Coastal Belt Sandstone/argillite	.5	Well consolidated, locally sheared, metasandstone, meta-argillite, and conglomerate.
Coastal Belt mélange	8.5	A pervasively sheared argillaceous matrix containing mappable blocks of varying rock types.

A spatial overview of the Lower Eel Basin's surface geology can be found in the USGS Geology of the Cape Mendocino, Eureka, Garberville, and Southwestern part of the Hayfork 30 x 60 Minute Quadrangles and Adjacent Offshore Area, Northern California geologic map of California. Using these data, the entire lower Eel River Basin is composed of 8 differing lithologies (Figure 7, Table 4).

The "Scotia Slide" broke loose in the winter of 2005/2006. This was a very wet winter and there were a few large seismic events which could have helped trigger the slide. It appears from the photos that although re-vegetating somewhat, the slide has continued to move in the relatively dry winter of 2006/2007. A few trees have come down and previously downed trees have become buried. The toe of the slide while eroding back by tens of feet is somewhat thicker. On the same bank of the river a sand bar has built up in response to the position of the toe. The sand that makes up this bar seems to be completely derived from the eroded toe of this slide.

The bedrock underlying the Lower Eel Basin has undergone substantial uplift, compression, and deformation, and is composed of fine grain depositional materials. The uplifting and faulting of the Franciscan Complex produced landscapes with steep slopes and narrow canyons trending in a southeast-northwest direction, which is also reflected in the drainage patterns of the basin (Brown Ritter 1971).

Scotia Slide 4/2006

Scotia Slide 4/2007

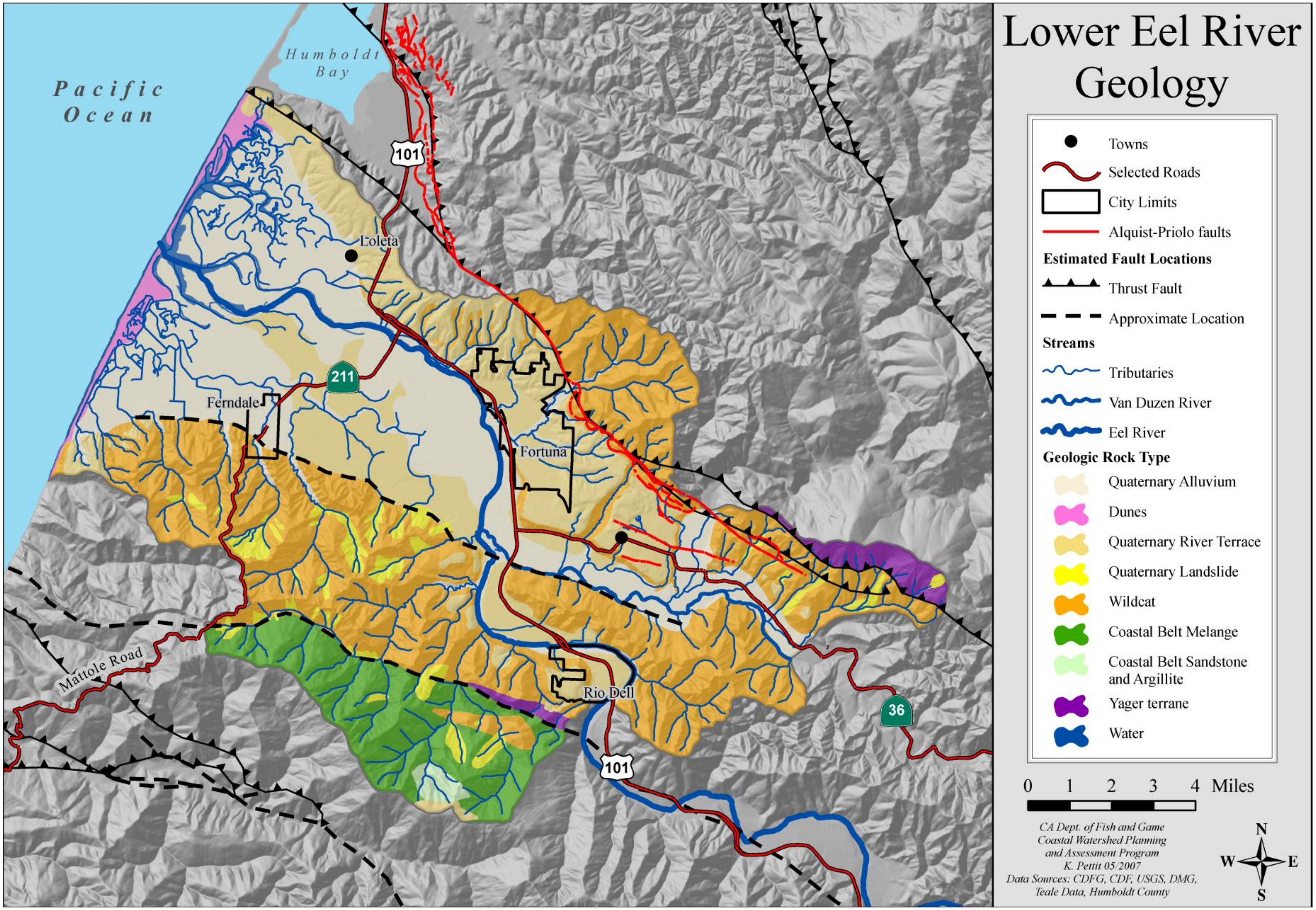

Figure 7. Geology of the Lower Eel Basin

Although the focus of the geological sections within this report relates to the negative impact and causes of sediment related issues, most naturally occurring geologic processes outlined herein have positive aspects as well:

- Naturally occurring landslides within forested lands supply large woody debris, large boulders, and spawnable gravels to the river system balancing out to some extent their contribution of fine sediments;
- Terrace deposits tend to store fine sediments for hundreds to hundreds of thousands of years helping to regulate sediment discharge pulse events;
- The high uplift rate and its corresponding seismicity are what have provided the land on which the rivers run;
- Folding and faulting of the bedrock gives rivers their trend and morphologic characteristics;
- The heavy rainfall in this region is responsible for the many streams that can and have historically supported salmonids;
- The nature of the bedrock and its soils give rise to the lush forested environment that is crucial to the health of the streams.

Tectonics

The Lower Eel Basin is located in an area that is extremely tectonically active. The interaction of three lithospheric plates causes this area to be in a constant state of movement. The forces generated from this triple junction of plates are currently causing the land in the immediate area to rise at an immense rate.

Three basic processes are thought to be causing the majority of uplift:

- Crustal thickening caused by the northward migration of the triple junction;
- Underplating and accretionary tectonics along the Cascadia Subduction Zone;
- Compression generated by convergence of the North American Plate and the Gorda Plate.

Compression is causing this area to buckle either upwards or downwards, much like the hood of wrecked car. If the land bends too far it breaks in a series of faults, which causes the land to thrust under itself – shortening laterally and thickening vertically.

Many of these folds and faults cut through the Lower Eel Basin, weakening the bedrock, making it even more susceptible to erosion and landsliding. Also, as the land rises the rivers gain more potential energy which helps them erode the landscape at an accelerated pace. The faster the rivers cut into the landscape the steeper and higher the banks become, further increasing landslide activity.

Faults can enhance erosion by generating large earthquake events as well as disrupting and weakening bedrock. The Lower Eel Basin contains several faults that disrupt and shear bedrock and are capable of producing earthquakes. Major faults within or in near proximity to the Lower Eel Basin include: Little Salmon fault, Yager fault, Ferndale fault, Russ fault, Cascadia Megathrust, and San Andreas fault.

Earthquakes and Faults

The Eel River Delta is located upon a complex tectonic setting near the junction of three crustal plates known as the Mendocino Triple Junction (MTJ). The MTJ is where the Pacific and the Gorda Oceanic plates meet the North American plate. The Cascadia Subduction Zone (CSZ) is an area just offshore where the Juan de Fuca and the Gorda plates are under thrusting beneath the North American Plate. The CSZ originates at the Mendocino Triple Junction and extends north through Oregon and Washington running parallel to the Pacific Northwest coast line. The complex tectonic structure contributes to a high concentration of earthquakes in the north coast region. The Salt River area has experienced hundreds of earthquakes of significance ($M \geq 4$ on Richter scale) in the past 120 years (USDA 1993).

Movement along the myriad of local faults produces frequent earthquakes. A good number of these earthquakes are quite large. In January of 1700 there was a magnitude 9 earthquake along the coast in this area resulting from subduction of the Gorda Plate. The earthquake in April of 1906 along the San Andreas fault, which is associated mostly with San Francisco, was one of the most devastating earthquakes to hit the Lower Eel Basin in historic times (Dengler 2006). There have been over 16 earthquakes of at least magnitude 6 in the county in the past 30 years, the largest, a 7.2, occurring in 1923.

More recently, a magnitude 6.5 earthquake occurred on January 9th, 2010 approximately 20 miles off the coast west of Ferndale. While there were no major injuries reported, the earthquake caused a significant amount of damage, especially in the Eureka area. The county was declared a "state of emergency" as 251 buildings were damaged and the governor estimated over 43 million dollars in total damage (Greenson 2010). Of greater significance was the 1992 "Cape Mendocino" earthquake. This M7.1 earthquake occurred on April 25th, 1992 and was followed up with two M6.5 aftershocks that rattled the towns located in the Lower Eel River Basin causing injury and extensive damage. This earthquake caused significant ground shaking, landslides, coastal uplift, and liquefaction. The magnitude of this event caused the whole coastline near Cape Mendocino to raise several feet and resulted in a two foot tsunami in Crescent City (Carver, et al. 1994). The center of Ferndale was severely impacted with significant damage to buildings, but Ferndale citizens were fortunate as there were no major injuries reported. Countywide a total of 356 injuries were reported with five people being admitted to the hospital. All told the earthquake resulted in $61 million dollars in losses in Humboldt County as it destroyed 159 homes and caused major damage to 150 businesses and public offices (Cox 1992). Due to the extensive damages and economic costs Humboldt County was declared a Federal Disaster area.

Large earthquake events on the north coast not only cause injury and extensive damage to the local communities, they also tend to trigger landslides especially during periods when the steep basin slopes are saturated by heavy, seasonal rain. Within the last 200 years earthquakes along the Humboldt County coastline have unleashed approximately a quarter of California's historic earthquake energy.

Soils

Bedrock throughout the basin is considered to be soft to very soft, producing soils that are highly erodible and prone to landslides. Nearly all of the soils are loamy, and range from 20 to 60 inches in depth (Table 5). 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).

Nearly all of the soils in the basin have parent rock sources that share similar characteristics. The U.S. Natural Resources Conservation Service (NRCS) is currently mapping the soils of Humboldt County, with a projected completion date of 2010. Based on NRCS draft data (no date), the Lower Eel River Basin contains very fine soil, both silty and loamy. All soils are very deep, and most are considered to be very poorly drained. The NRCS has classified most of the soils in the Lower Eel Basin as being used either for pasture or hay production, or wetland wildlife habitat.

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

- Soil sediment size, consolidation, cohesion and compaction;
- The terrain – soils move more easily on steep slopes;
- Climate – soils are easily saturated by sustained, heavy rain and are more prone to sliding and surface erosion;
- Type and amount of vegetation cover;
- Land use practices – grazing, timber harvest, roads, etc. increase erosion.

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. The soils present within the Lower Eel River Basin generally range from loam to sand, the majority being in the silt loam and the silt clay loam category and range from 20 to 60 inches in depth.

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 mantled with sensitive 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 sediment stability and erodibility. 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).

Table 5. Soils of the Lower Eel Basin.

Soil Type	% of Basin	Composition
Tramway-Irmulco-Empire	29	Loam
Udifluvents	15	Silt loam
Riverwash-Loleta-Ferndale-Bayside	13	Loam/silt loam/silty clay loam
Timmons-Rohnerville-Hookton-Carlotta-Arcata	13	loam/silty clay loam/fine sandy loam
Fluvents-Riverwash complex	6	Loam
Weott	6	Silt loam
Arlynda	2	Peat/silty clay loam
Ferndale	2	Silt loam
Occidental	2	Peat/silty clay loam
Russ	2	Loam
Yorktree-Kneeland variant-Kneeland-Kinman	2	Loam/gravelly loam/clay loam
Barbercreek	1	Silty clay loam
Dungan	1	Silt loam
Fluvaquents	1	Sandy loam
Loleta	1	Loam
Somoa-clambeach-dune land complex	1	Sand
Swainslough	1	Peat/silty clay loam
Beaches-sanoma-dune land complex	<1	Sand
Canalschool	<1	Silt loam
Grizzlybluff	<1	Loam
Madriver	<1	Loam
Swainslough-Occidental complex	<1	Peat/silty clay loam
Vandamme-Tramway-Irmulco-Hotel-Dehaven	<1	Loam/clay/gravelly loam
Waldport family-Dune land-Beaches	<1	Fine sand
Wigi	<1	Silt clay loam
Wigi complex	<1	Silt clay loam
Worswick	<1	Loam/sandy loam

Fluvial Geomorphology

Discussion of fluvial processes in the lower Eel River must be considered within the larger context of the whole Eel River drainage area. Hillslopes in the basin range from very low in the low, flat alluvial floodplain to steep slopes in the Wildcat Mountains and the bluffs across the Eel River from Rio Dell (Figure 8). The wide, flat area of the lower mainstem contains a preponderance of very low gradient depositional reaches, which respond to watershed processes that occur upstream throughout the entire drainage system.

The Eel River has the highest recorded average suspended sediment yield of any U.S. river its size (Brown and Ritter 1971). In 2002, the EPA listed the lower portion of the Eel River as an impaired water body due to sediment and temperature.

Stream gradients were classified within the watershed using the 1/3 arc second digital elevation model (DEM) from the USGS National Elevation Dataset. This dataset uses the best available elevation data in any given geographic area. The analysis showed 389 miles of blue-line streams (those shown as blue lines on USGS topographic maps) within the Lower Eel Basin. About 33 percent (127 miles) of the 389 miles of stream consists of source reaches having gradients greater than 20%; 19% (about 76 miles) consists of transport reaches having gradients greater than 4 percent and up to 20%; and 48% (about 186 miles) consists of depositional reaches having gradients of 4% or less. In fact, 33% (about 128 miles) comprise the very lowest gradient depositional reaches – those equal to or less than 1(Table 6, Figure 9).

Table 6. Miles of blue- line stream in different gradient classes in the Lower Eel Basin.

Gradient Class	Total Miles	Estuary	Middle	Salt River	Upper	Percent
≤ 1%	128.06	57.28	7.58	41.57	21.62	33.00
>1% and ≤ 4%	57.84	11.18	8.65	17.43	20.58	15.00
>4% and ≤ 20%	76.26	4.85	16.46	14.71	40.24	19.00
> 20%	126.79	3.37	16.36	21.72	85.34	33.00
Totals	**388.94**	**76.68**	**49.05**	**95.43**	**167.78**	**100.00**

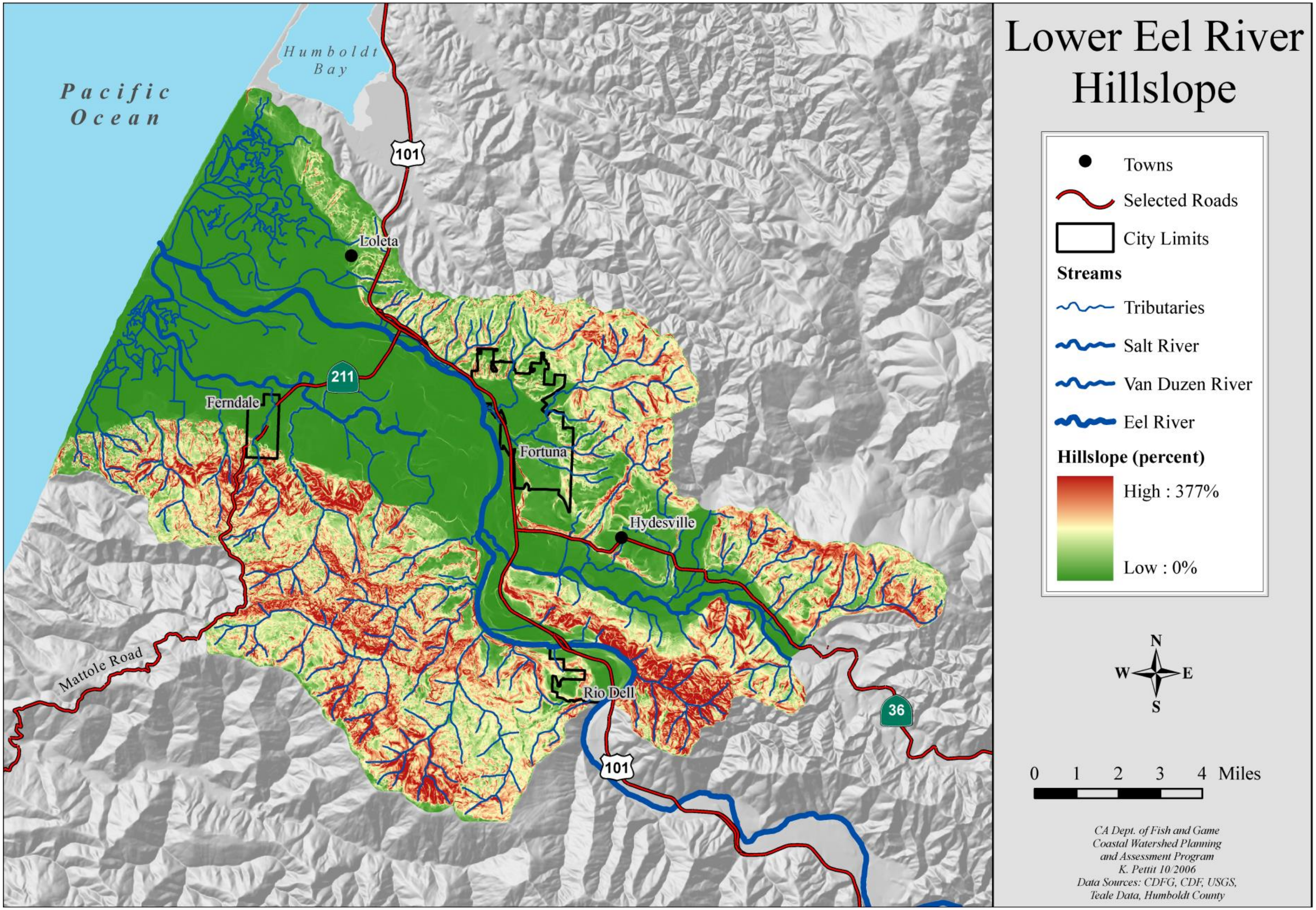

Figure 8. Hillslope of the Lower Eel Basin.

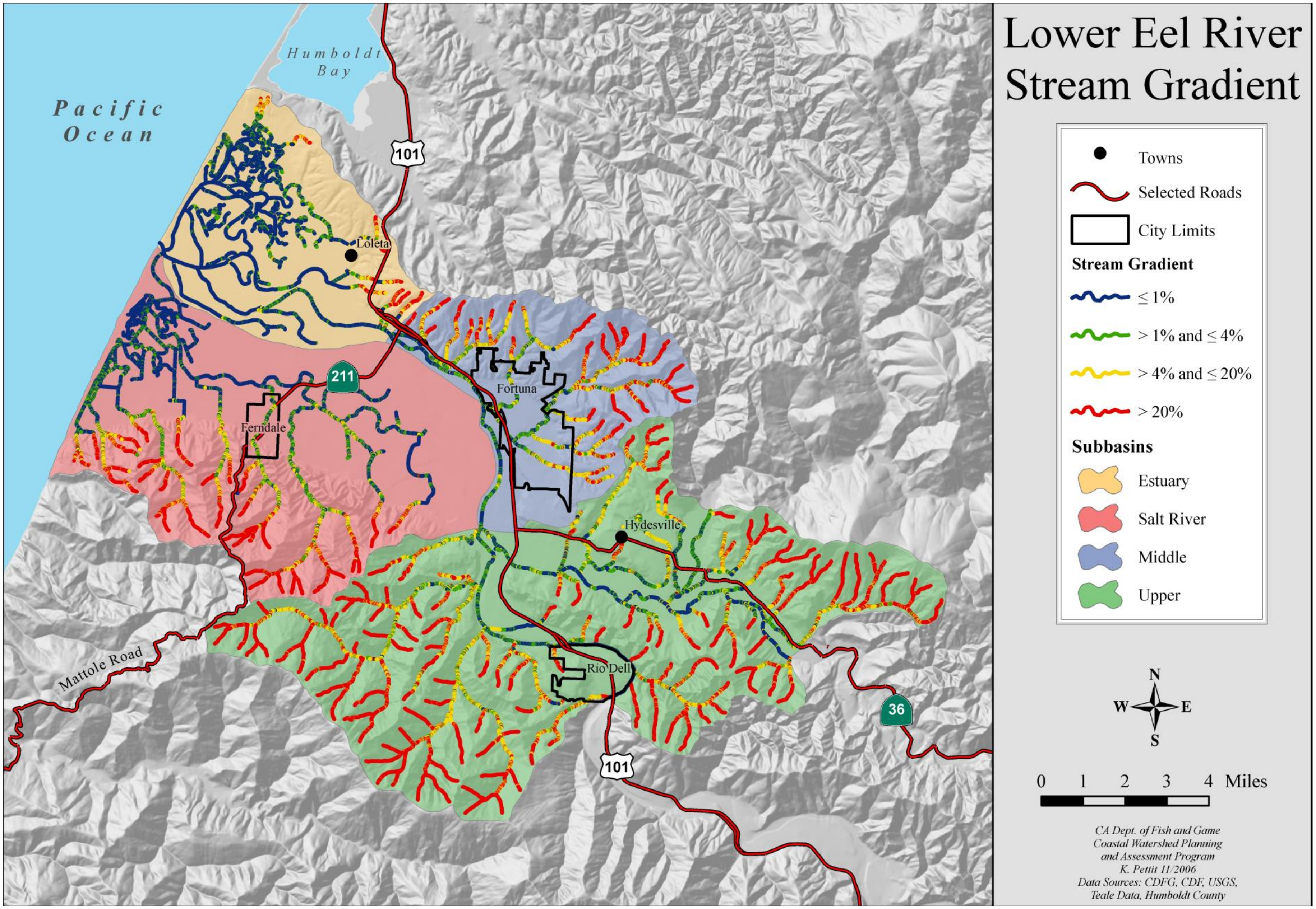

Figure 9. Stream gradients in the Lower Eel Basin.

Vegetation

The USDA Forest Service (USFS) CALVEG vegetation data were used to describe basin-wide vegetation. This classification 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 Lower Eel Basin is conifer forest at 32% (Figure 10). Of this cover type, 41% is described as redwood alliance, and 32% is redwood – Douglas-fir alliance (Table 7). Redwood occurs primarily upstream of the estuary, in small pockets of the Middle Subbasin, as well as in concentrations in the Upper Subbasin in the Van Duzen River tributaries, and southern-most Eel River tributaries. 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. Residual redwood stands in the Lower Eel River Basin are limited and are generally concentrated in small protected areas, such as Rohner Park in Fortuna.

Vegetation that commonly occurs in stands of redwood and Douglas-fir often includes redwood sorrel, western sword fern, Sitka spruce, and madrone, among others. All coniferous forest in the Lower Eel River Basin except for the Pacific Douglas-fir alliance is considered by the USFS as productive timberland capable of producing 10% cover of industrial tree species. Conifer forest increases in area with increased distance from the mouth of the Eel River. The Upper Subbasin contains the most area classified as conifer forest; less than 1% of the vegetation in the Estuary Subbasin is coniferous (made up entirely of the Sitka spruce alliance).

Agricultural land makes up 28% of the Lower Eel Basin, and increases in area with increased proximity to the mouth. This vegetation cover type dominates the Eel River delta, within the estuary and also in smaller concentrations in the low-lying areas along the mainstem Van Duzen and Eel Rivers. Agriculture land, as defined by the USFS, is that which is used to produce food and fiber. Within the Lower Eel Basin, pastures used for grazing of livestock may not be included in this vegetation designation since land use is often difficult to remotely ascertain. For this reason, it can be assumed that areas mapped as annual grasslands may also be agricultural in nature. Grasslands that are not mapped as agricultural are given the classification of herbaceous vegetation, which is the third most abundant category in the Lower Eel Basin at 14% of the total area.

Ninety-three percent of the herbaceous vegetation in the Lower Eel Basin is considered annual grass, which as described above, is most likely used for agricultural purposes. This vegetation may be made up of either native or nonnative species. Pickleweed comprises 7% of this category, and is found solely in the estuary. The remaining vegetation in the Lower Eel Basin is composed of: mixed conifer/hardwood forestland, hardwood, barren lands, urban lands, or shrubs. Like the previous vegetation types, these classifications vary in abundance by subbasin.

This USFS classification describes current vegetation as of the mid to late 1990s. However, vegetation in the Lower Eel Basin has changed considerably over time. For example, in the estuary, salt marsh was aggressively drained, and riparian vegetation cleared in order to convert tidelands to pasture. In addition, native bunch grasses have been replaced over time by European annual grasses in pasture lands throughout the Lower Eel Basin. This has in turn reduced the strength of prairie vegetation and increased slumping in the system (Reynolds et al. 1981, Kelsey 1977). 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 (PALCO Van Duzen Watershed Analysis 2002). More details of these activities are in the Land Use and Subbasin sections of this report.

Table 7. USFS classification of vegetation of the Lower Eel Basin.

Vegetative Cover Type	Percent of Basin	Primary Vegetation Type	Percent of Cover Type
Conifer	32	Redwood Alliance	41
		Redwood – Douglas-fir Alliance	32
		Douglas-Fir – Grand fir Alliance	16
		Sitka spruce Alliance	4
		Pacific Douglas-fir Alliance	4
		Sitka spruce – Grand fir Alliance	1
		Sitka spruce – Redwood Alliance	1
		Monterey Cypress Alliance	<1
Agriculture	28	Agriculture	100
Herbaceous	14	Annual Grass/Forb Alliance	93
		Pickleweed – Cordgrass Alliance	7
		Nonnative/Ornamental Grass Alliance	<0.5
		Tule/Cattail Alliance	<0.1
Mixed (conifer stand with hardwood	11	Douglas-fir – Grand fir Alliance	31
		Sitka spruce Alliance	20
		Redwood – Douglas-fir Alliance	19
		Sitka spruce – Grand fir Alliance	14
		Redwood Alliance	10
		Pacific Douglas-fir Alliance	4
		Sitka spruce – Redwood Alliance	2
Hardwood	7	Red Alder Alliance	82
		Black Cottonwood Alliance	7
		Mixed Riparian Hardwoods Alliance	5
		Willow Alliance	4
		Fremont cottonwood Alliance	1
		California Bay Alliance	<0.5
		Tan Oak (Madrone) Alliance	<0.5
		Eucalyptus Alliance	<0.5
Barren	3	Barren	81
		Dunes	19
Urban	3	Urban	100
Shrub	2	Willow (riparian scrub) Alliance	33
		North Coastal Shrub Alliance	27
		Salal-California huckleberry Alliance	20
		Blueblossom Alliance	18
		Coyote brush Alliance	2

These statistics exclude the classification of water

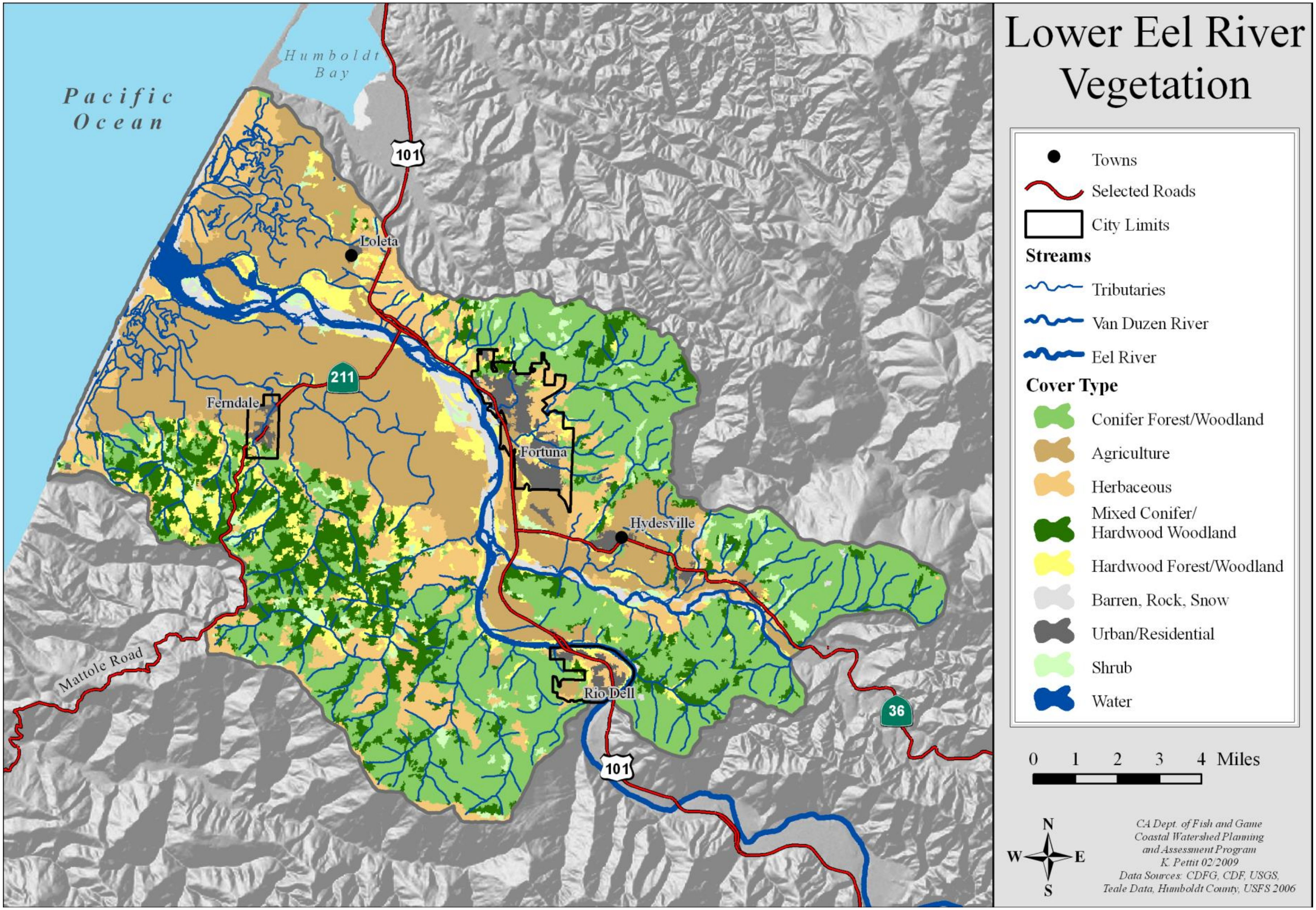

Figure 10. Vegetation of the Lower Eel River Basin.

The CALVEG classification also describes crown diameters of conifers, which are ordered into groups based on average visible diameter (Table 8). In the Lower Eel Basin, crown diameters of all primary coniferous vegetation range from saplings to greater than 40 feet (Table 9). The most common crown diameter for redwoods is in the medium range, or 24 to 40 feet. Canopy density is also expressed by CALVEG, and is given as a percentage of crown closure. Using these data, conifer canopy density described as 90 to 100% crown closure makes up the greatest amount of area in the Lower Eel Basin (Figure 11, Table 10). However, these areas, which are primarily in the headwaters of the Upper Subbasin, only represent 31% of the land covered by conifers. Canopy density directly over streams in the Lower Eel Basin is discussed in the tributary analysis sections of this report.

Table 8. USFS CALVEG classification of conifer crown diameter.

Classification	Tree Size Description	Average Visible Crown Diameter
0	Seedling	Derived from plantation age
1	Sapling	Derived from plantation age
2	Pole	Crown diameter less than 12 feet
3	Small	Crown diameter from 12 feet to 24 feet
4	Medium	Crown diameter from 24 feet to 40 feet
5	Large	Crown diameter greater than 40 feet

Table 9. Crown diameter of vegetation classified as primarily conifer forest in the Lower Eel Basin.

Conifer Alliance	Size Range Classification	Most abundant by area
Redwood	Sapling to Large	Medium
Redwood – Douglas-fir	Sapling to Large	Medium
Douglas-fir – Grand fir	Sapling to Large	Small
Pacific Douglas-fir	Sapling to Medium	Small
Sitka spruce – Redwood	Sapling to Large	Medium
Sitka spruce	Sapling to Large	Small
Sitka spruce – Grand fir	Sapling to Large	Small

Table 10. Canopy density classifications and percentages of the vegetation classified as conifer in the Lower Eel Basin.

Percent Crown Closure	Percentage of Conifer Vegetation
10 to 19	2
20 to 29	5
30 to 39	7
40 to 49	3
50 to 59	9
60 to 69	13
70 to 79	13
80 to 89	17
90 to 100	31

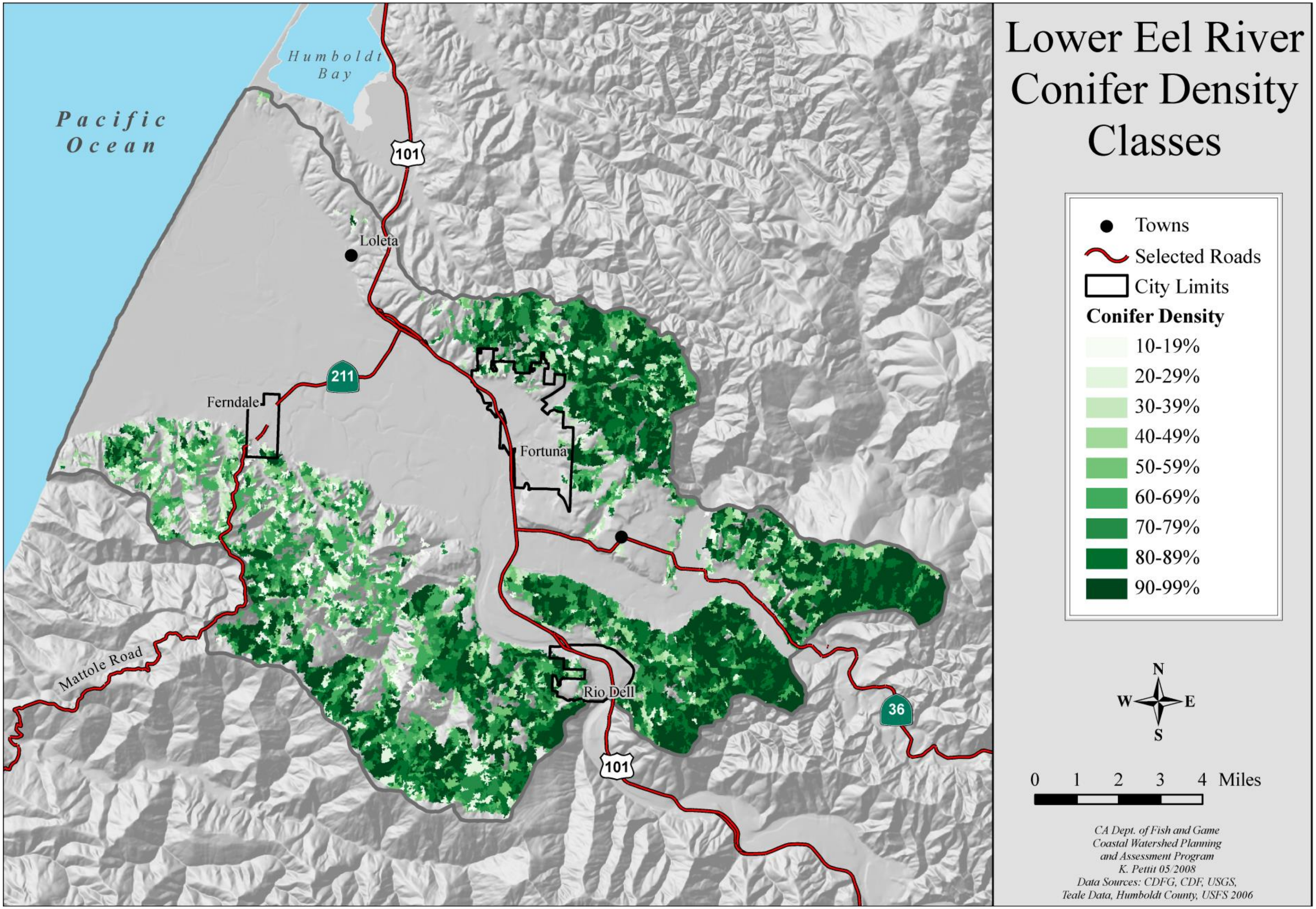

Figure 11. Conifer canopy density of the Lower Eel River Basin (2005).

Land and Resource Use

Long before written descriptions of the Eel River valley were made by Euro-American settlers, the Wiyot people inhabited the lands from Little River in the north to Bear River in the south. They concentrated in centers around Humboldt Bay and nearby rivers. The tribe takes its name from the Wiyot name for the Eel River (which is Wiyot). In the Lower Eel River Basin, the tribe's territory extended inland to Wolverton Gulch on the Van Duzen River, and occupied land that would eventually become the towns of Loleta, Ferndale, Fortuna, and Rohnerville (Kroeber 1976, Wiyot website). While the majority of the Lower Eel River Basin lies within what was Wiyot territory, it also enters portions of lands inhabited by tribes of the Athabascan family, namely the Mattole and Nongatl. The Mattole people's territory extended onto the Eel River and the Van Duzen River "immediately above the Wiyot" (Kroeber 1976). The Nongatl, which was the northernmost Athabascan tribe, were settled along the Eel River near Yager Creek on the Van Duzen River (Kroeber 1976).

Most of the Euro-American settlers who first came to the Eel River valley in the early 1850s were former gold prospectors looking for another way of life. The fertile soils in the Eel River delta were attractive, and soon the surrounding lands were being converted for agricultural purposes. Initially, agricultural production in the area was centered on row crops. As time passed, settlers began to realize that lands that had been cleared for crops were capable of producing lush grass. By the early 1900s, agriculture in the Eel River delta had been almost completely converted for the purposes of grazing livestock (Parry 1963). Individual dairy farmers soon began to consolidate their creameries forming the largest cooperative creameries in the state. Several towns in the area, such as Loleta and Ferndale, soon prospered due to the success of their innovative creameries and the export of dairy products.

In order to create pasture lands, considerable amounts of tidal marshland were reclaimed and riparian vegetation was cleared. Some of the first timber production in the area was a result of this land clearing. However, it was not until transportation improved that these felled trees became an important commodity. In the area near Rohnerville, a mill was constructed to convert timber that had been cleared for agriculture into shingles, shakes, and rough wood (Genzoli 1976). By the late 1800s to the early 1900s, several timber mills were established as timber harvesting was occurring in areas around Fortuna, and Rohnerville, and also along the Van Duzen and Eel River tributaries near Rio Dell.

The Eel River was once deep enough to accommodate shipping vessels. This fact was first realized when a vessel entered the estuary in 1850, mistaking it for Humboldt Bay. Soon after, a port was established within the estuary on Salt River at Port Kenyon and was used to ship goods. Through the improvement of roads and the construction of bridges to Eureka and Humboldt Bay, as well as the completion of the Northwestern Pacific Railroad, the area was able to more efficiently export crops, dairy products, cattle, timber products and salmon. By the early 1900s, towns like Ferndale and Springville (now Fortuna) became quite affluent, touting several stores, luxury hotels, fairgrounds, and racetracks.

Population

Several small towns lie within the basin; the major population center is the city of Fortuna (Table 11). The total Lower Eel Basin resident population estimated from the year 2000 census was 21,516 people (Table 12). Over half of the population lives in the Middle Subbasin, which contains Fortuna. The second most populous subbasin is the Upper, which includes the small towns of Hydesville and Rio Dell. Population density is sparse in the Estuary, Salt River, and Upper subbasins; it is much higher in the Middle Subbasin, reflecting the more urban nature of Fortuna. However, the majority of people in all of the subbasins except for the Estuary Subbasin live in towns.

Table 11. Available 2000 and 2004 data from the U. S. Census Bureau for communities in the Lower Eel Basin.

Principal Communities	2000 Census	2004 Census
Ferndale	1,382	1,406
Fortuna*	10,497	10,995
Rio Dell	3,174	3157
Hydesville	1,209	N/A
Loleta	750	N/A

* Census data for Fortuna include the Rohnerville area.

Table 12. Population and population density of the Lower Eel Basin by subbasin (2000 Census).

Subbasin	Population	Area (Square Miles)	Population Density (Population/Square Mile)	% of Population in Towns
Estuary	1,900	24	79.2	39.5
Salt River	2,507	49	51.2	55.1
Middle	12,906	24	537.8	81.3
Upper	5,667	75	75.6	77.3
Total	22,980	172	133.6	74.0

Ownership

Landownership in the basin is primarily held in private parcels of 40 to 500 acres in size (47%) followed by private parcels of ≤ 40 acres (23%) (Figure 13). Less than 4% of the area is public property. Private timber companies, including the Humboldt Redwood Company (formerly Pacific Lumber Company) and Green Diamond Resource Company, make up the remaining area.

General land use across the basin includes timber harvest, agriculture, grazing, residential, and commercial (Figure 12). The major cities and towns in the basin are Fortuna, Ferndale, Loleta, Hydesville, and Rio Dell.

Forest Management

Historic

The Pacific Lumber Company began logging the Lower Eel Basin in the 1890s in the Strongs Creek watershed, which today includes the Fortuna area. Until 1890, teams of horses or oxen were used to pull logs over skid trails and by 1892 steam donkeys were in full use hauling downed timber (Wood 1956). By 1920, Strongs Creek had been fully logged (HartCrowser 2004). Most timber harvest by Palco remained on the north side of the Lower Eel River until 1930, when their operations expanded to Atwell Creek across the river. By this time, other local timber companies had begun harvest operations, among them: E.J. Dodge Company in Atwell/Howe and Hammond Lumber Company and Holmes-Eureka Company in Cummings Creek. Mills were located on the Salt River, on Cummings Creek, in historic Newberg near Fortuna, and in Metropolitan on the Eel River. The Eel River had a brief run as a lumber shipping port from 1876 until 1909 at Port Kenyon before Humboldt Bay became established as the more reliable port. After that, timber products were either sold locally or were transported south via the Northwest Pacific Railroad.

Around 1944, tractor yarding and truck hauling became the predominant timber harvest and log transport methods replacing steam donkey cable yarding and railroad hauling (HartCrowser 2004). Peak timber harvest year for Humboldt County was 1959 (Downie 1995). Following WWII, timber harvest was characterized by an extensive increase in heavy machinery, namely bulldozers, and little thought was given to ground disturbance, water quality or habitat protection. 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. Since 1973, with the passage of the Z'Berg-Nejedly Forest Practice Act, environmental regulations have increased which has improved timber harvest practices. There has also been a general decline in Humboldt County timber production. Land conversion to grazing or residential development has also contributed to the decrease in timber production (Downie 1995; Hackett 2002).

Current

Records of logging activity from 1991 to present are available in digital format for all subbasins in the Lower Eel River. Earlier logging information is available in paper records from CDF but, at this time, remains largely unanalyzed. Since 1991, logging operations have occurred in each of the Lower Eel subbasins except for the Estuary Subbasin, which has very little timber land. Based on these same data, basin-wide logging operations have ranged in size from a low of 654 acres in 1991 to as much as 3557 acres in 1994, averaging 1,825 acres per year. That amounts to an annual average of 1.7% of the basin's area in harvest for the 16-year period. The total acreage that is currently zoned for timber production (TPZ) in the basin is 41,456 ac or 38.6% of the basin. By percentage, this is the dominant zoned land use for the study area. Most harvested areas were cut once or twice between 1991 and 2006, but there are some areas that have been harvested as many as six times within that period (Figure 14).

There are many different types of silviculture and yarding methods utilized by timber operators. They all have different levels of disturbance on the landscape. In general, clear-cutting has the highest level of disturbance of any of the silviculture methods. This disturbance can be thought of as soil exposure and instability due to the removal of trees and aquatic disturbance due to the removal of shade and large woody debris contribution. Commercial thinning is the least disturbing silviculture method. Felling and bucking (cutting timber into segments) is done 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 carry the highest level of disturbance. Tractor and skidder yarding is limited to gentle slopes to reduce the potential damage the machine's tracks have on the soil. A tractor or skidder's weight plus the weight of logs will cause soil compaction which increases runoff and the treads will cause soil disturbance, introducing sediment into the runoff. Cable yarding, where logs are pulled uphill by cable to a road or landing, is commonly used in areas with slopes too steep for tractors or skidders. Skyline cable, balloon, or helicopter 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 single tree selection (38% of the harvested area or 701 ac/yr) followed by clear cut (27% of the harvested area or 497 ac/yr) and commercial thinning (18% of the harvested area or 329 ac/yr) (Figure 15). The most frequent yarding method is tractor or skidder yarding (53% of the harvested area or 961 ac/yr) followed by cable system (22% of the harvested area or 396 ac/yr) and the tractor or cable option (14% of the harvested area or 247 ac/yr) (Figure 16). Balloon or helicopter yarding only occurs on 6% of the harvested area (103 ac/yr) in the basin.

All timber operations must conform to California Forest Practice Rules. Some companies operating in the basin have created more complex and sophisticated management plans to guide their timber harvest operations. For example, both Humboldt Redwood Company and Green Diamond Resource Company have developed Habitat Conservation Plans (HCP) which focuses on keeping the forest ecosystem functional concurrent with timber harvest.

In July, 2008 the Pacific Lumber Company was officially transferred over to Mendocino Redwood Company and Marathon Structured Finance Fund LP, a Palco creditor (The Forestry Source 2008). Society of American Foresters Mendocino Redwood Company shortly thereafter renamed Palco as Humboldt Redwood Company. This transfer of ownership will have a significant affect on the management of the 220,000 acres of land in Humboldt County now managed by Humboldt Redwood Co. 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 bd. ft. in 2006, and fell to 77 million bd. ft. last year. Under the new management of the Humboldt Redwood Co, annual harvesting will be limited to 55 million bd. ft. per year for the next decade and a no-cut policy for old growth will be observed (http://www.building-products.com/readNews.aspx?ID=4893).

The State of the Eel (Downie 1995) did not indicate timber harvest as a threat to the Lower Eel River ecosystem but did mention two related issues–erosion and livestock. Roads and road building are one source of erosion and livestock exacerbate the problem as they trample roads and road grade approaches (Koch 2007). The geological setting in which logging occurs in this basin–steep slopes, rapid uplift, and unstable soils–creates more erosion from acceptable logging practices and from relic logging road and railroad beds. Compared to other land use practices, forest roads are more problematic than grazing, fire, and poor logging practices (Barnhart No Date). In a study carried out by the USFS in California watersheds, converting only 0.6% of a watershed into low standard roads increased sediment by 24% (Anderson 1971). Unless old roads are storm proofed or decommissioned, they will continue to release sediment into water courses.

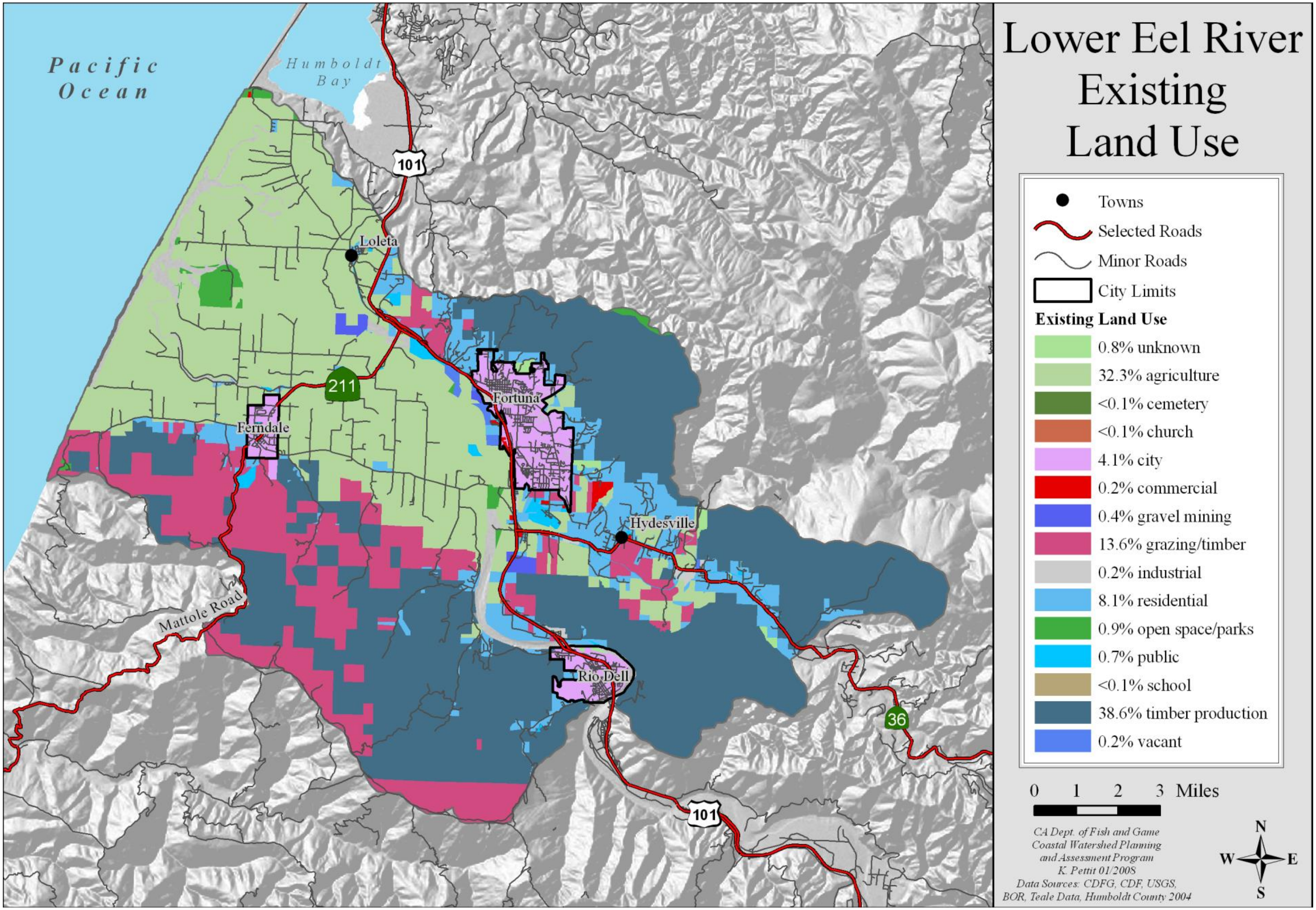

Figure 12. Landuse in the Lower Eel River Basin

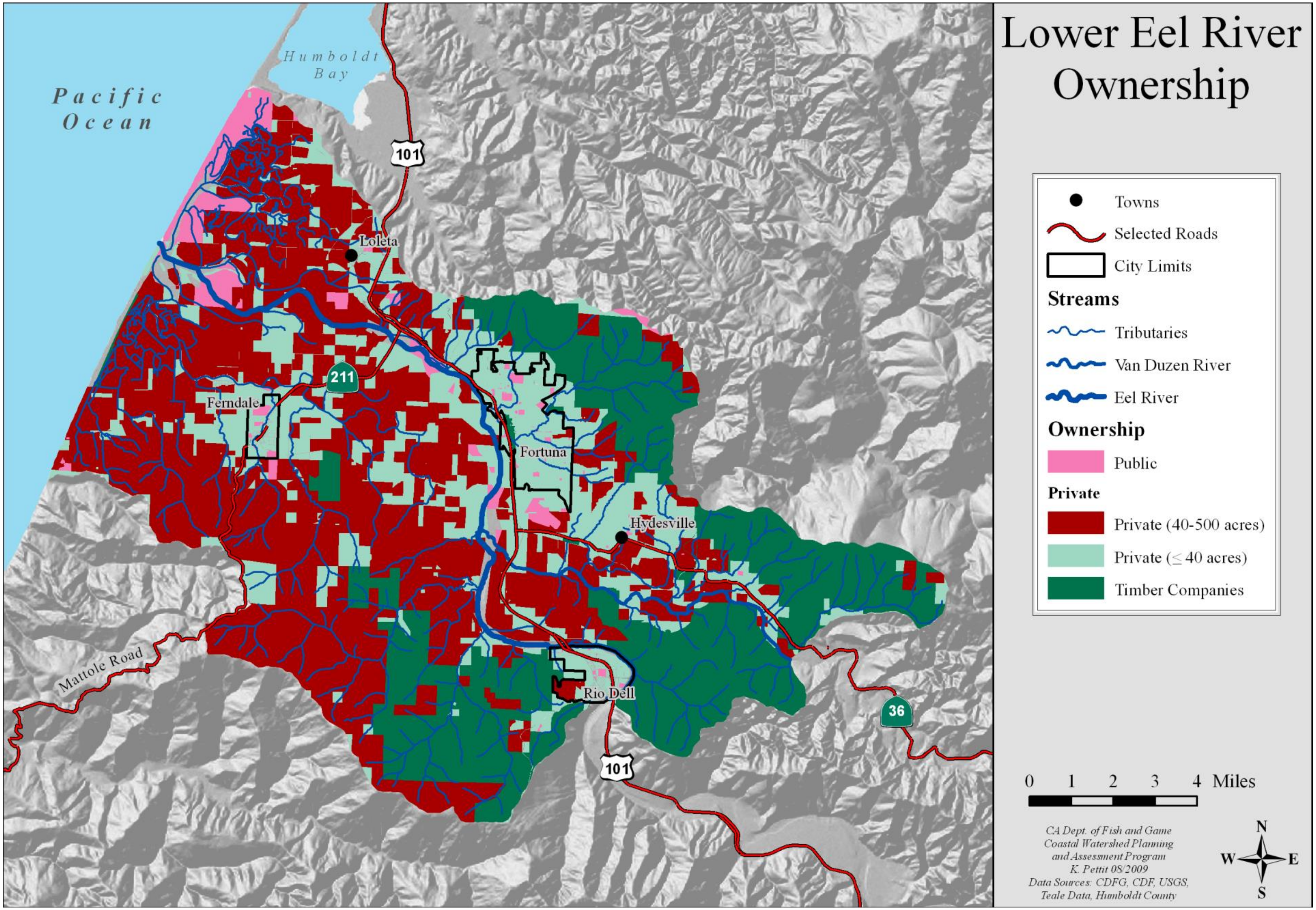

Figure 13. Landownership in the Lower Eel Basin.

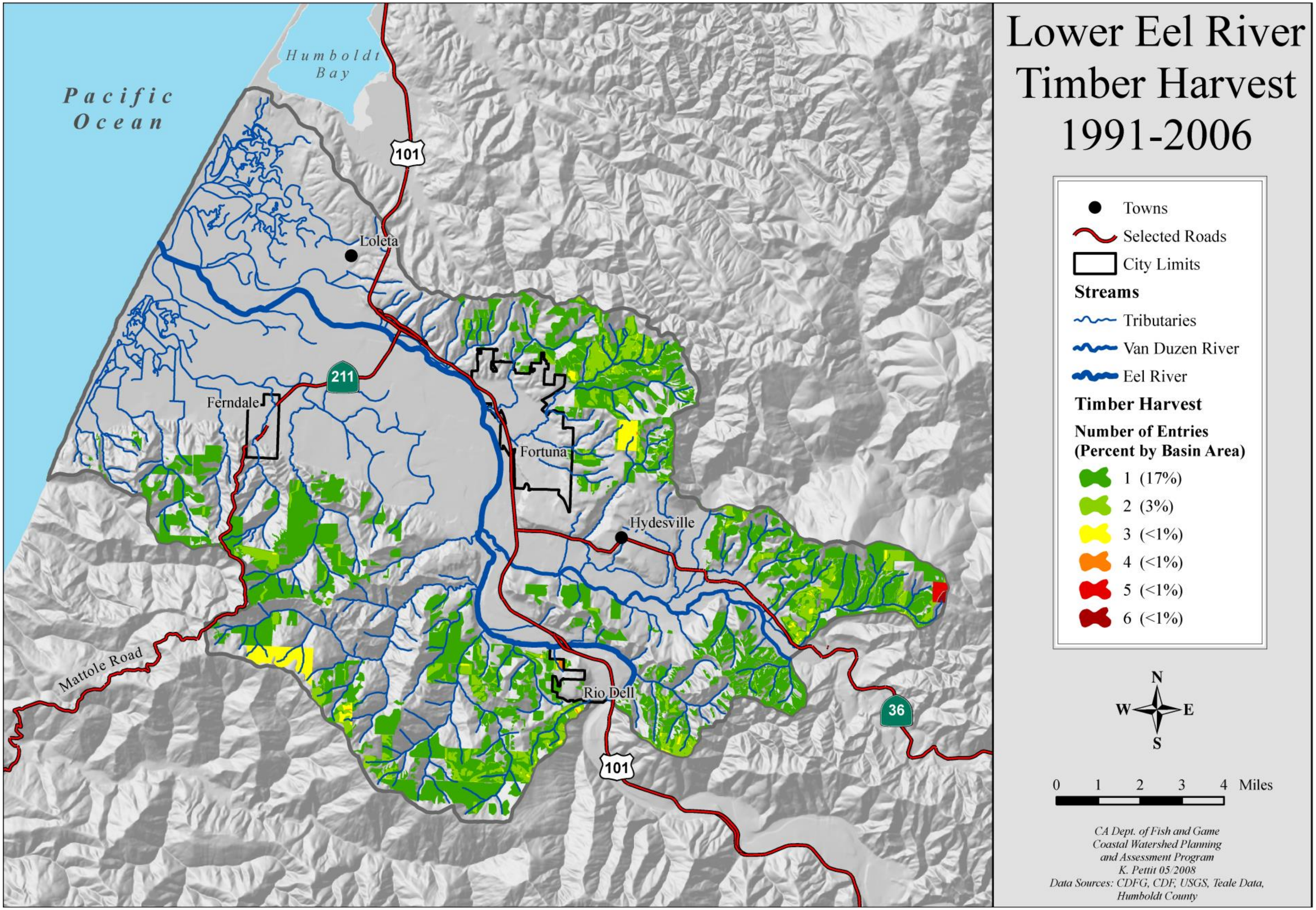

Figure 14. Timber harvest activity by frequency for the Lower Eel River Basin.

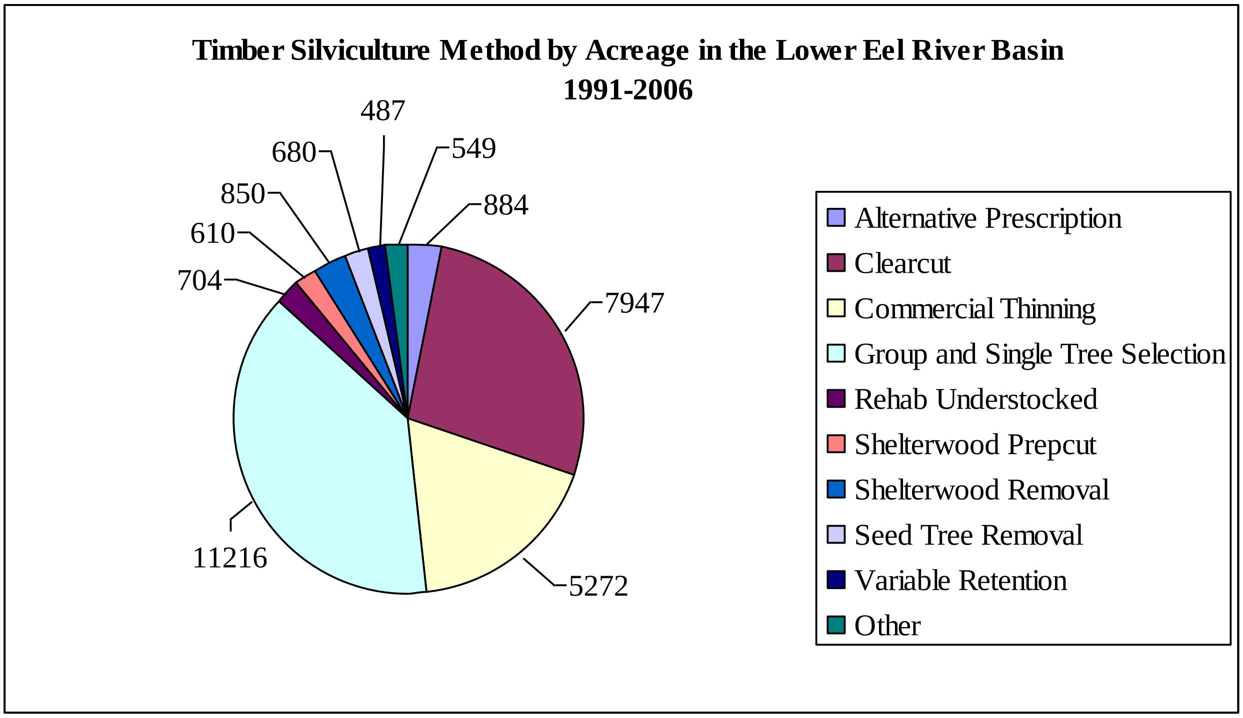

Figure 15. Number of acres in various silviculture methods across the basin from 1991-2006 (CDF data).

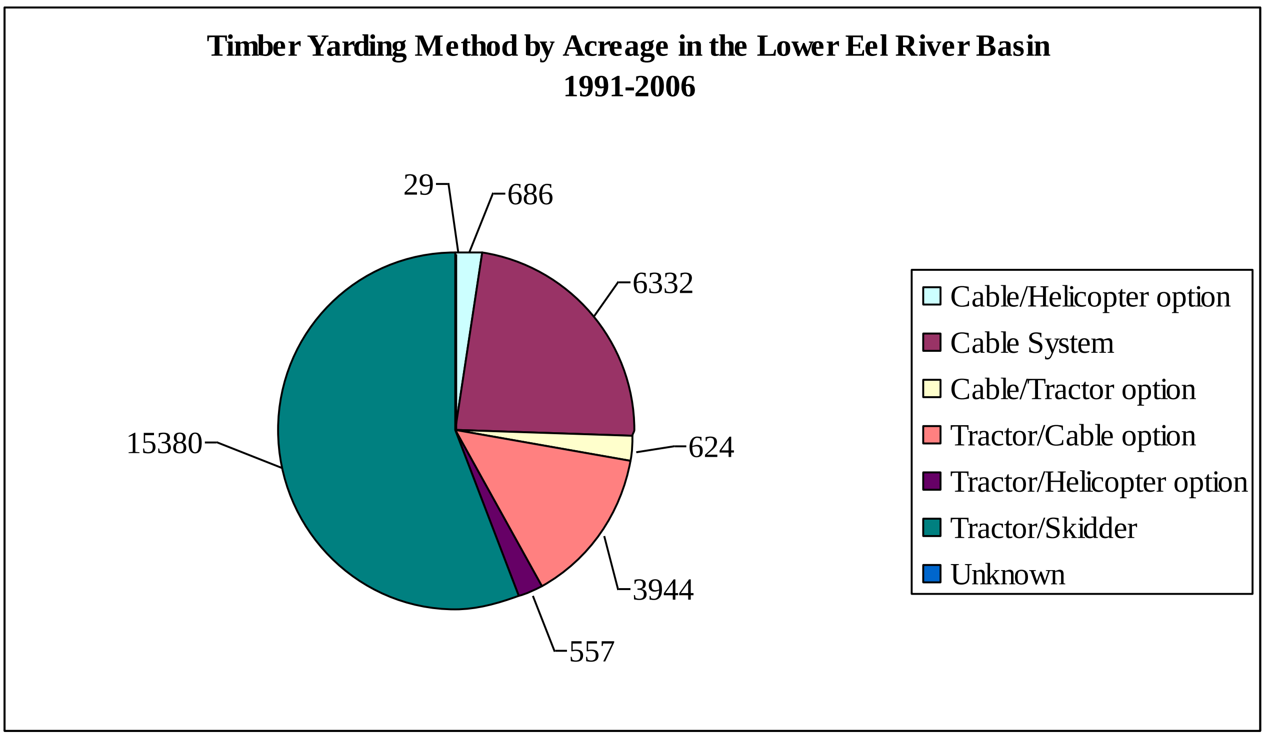

Figure 16. Number of acres in various yarding methods from 1991-2006 (CDF data).

In Pacific Lumber Company's Cumulative Effects Report (HartCrowser 2004), background surface erosion from soil creep to streams in the Lower Eel Basin was estimated to be 330 tons/mi^2/yr. An additional 312 tons/mi^2/yr of surface erosion is contributed through current timber harvest-related activities (57 tons) and current road use conditions (255 tons).

Roads and Railroads

As the Lower Eel was settled in the late 1800s, transportation routes grew and expanded. Trails became roads and roads were upgraded into railroads and highways.

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 streams. Stream crossings can create fish passage barriers or sediment sources. Roads that run along streams can also act as sediment sources as well as possibly stopping the ability of a stream channel to migrate across its floodplain. Additionally, many roads added sediment to streams as they were built.

Roads and railroads serve to transport people and goods throughout the basin (Figure 17). In forested upland areas many logging roads and seasonal railroads were built to facilitate access to and transport of timber. Most of these logging roads are not paved and many are not mapped.

Highway 101 runs through the basin from north to south. It was built from 1909 to 1923 and crosses the mainstem Eel River and several tributaries in the Lower Eel Basin. In addition, Highway 36 starts near the mouth of the Van Duzen River and runs east along the river. This highway was completed in 1912 and crosses the Van Duzen River and several of its tributaries.

The defunct Northwest Pacific Railroad runs along the Eel River, north to Eureka. A major defunct railroad runs along the Eel River and then towards Eureka. There is also a railroad line along the Van Duzen River and several smaller railroad lines built specifically for timber removal in isolated areas, such as along Yager, Lawrence and Cummings creeks.

The main north to south railroad along the Eel River was part of the Northwestern Pacific Railroad line. The Eel River and Eureka Railroad was built in 1884 to provide shipping from the lower Eel River to Humboldt Bay. In 1885, the railroad laid track through the town of Fortuna to Eureka and a railroad depot was built in 1891 in Fortuna. The Pacific Lumber Company built a railroad from Scotia to the Eel River and Eureka line in 1885 and logging branches of this railroad extended eight miles up the Eel River by 1902. An additional line extending up the Van Duzen River to Carlotta was built by a subsidiary to the Eel River and Eureka Railroad called California Midland Railroad in 1902.

Various local railroad companies merged into the Northwestern Pacific Railroad in 1907. The entire line that connected Eureka to Willits and all points south of there was completed in 1914.

Frequent winter flooding caused major maintenance issues for the railroad through the Eel River canyon. For example, the line was shut down from December 1964 to June 1965 due to the 1964 flood when one third of the railroad had to be rebuilt (www.Northcoastrailroad.org).

The North Coast Rail Authority (NCRA) bought line in 1992. The NCRA was founded in 1989 to ensure continuation of service in Northwestern California. However, the line was shut down in 1997 due to major floods and landslides through the Eel River Canyon and has not reopened. There is an ongoing discussion of reopening; however, reopening the line would require a major overhaul as most of the line is derelict. Within the Lower Eel Basin, the section of railroad across the river from Rio Dell no longer has the railroad ties on the grade (Figure 18). 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.

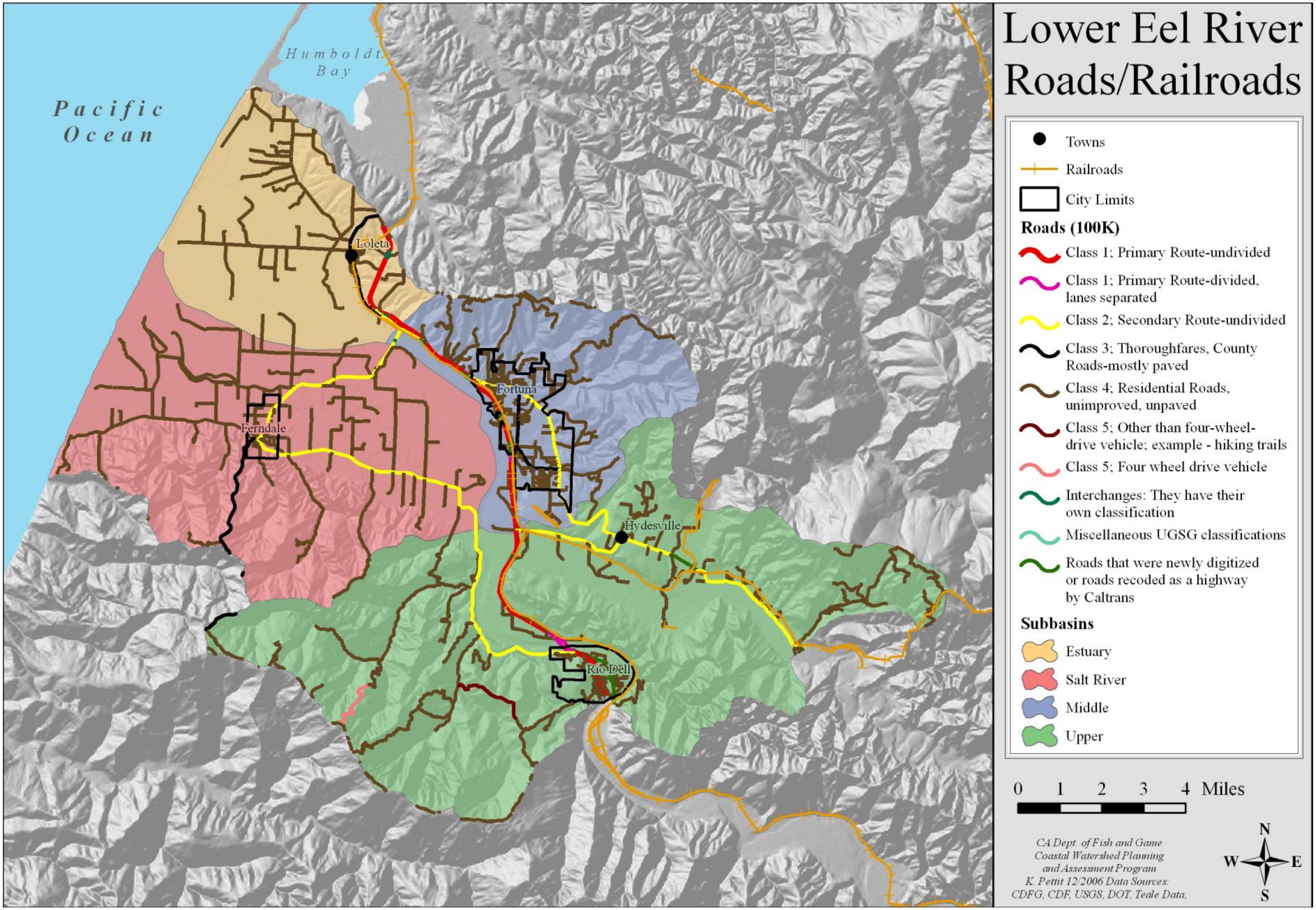

Figure 17. Roads and Railroads in the Lower Eel Basin.

Figure 18. Railroad along Scotia Bluffs July 2008.

Mining

The Lower Eel River holds one of the two highest concentrations of commercial instream aggregate mines and one of the two highest cumulative volumes of instream aggregate extracted on the west coast of the United States (the other is on the Mad River, CA) (Laird et al. 2000) (Figure 19). In light of the high quality of this instream aggregate, there is potential for this resource area to experience elevated demand pressure, especially if transport becomes more cost effective.

In general, gravel mining can have serious impacts on stream channels. Possible effects include the following:

- Altered channel morphology;
- Increased sediment input;
- Changed 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 2000, USACOE 2003). 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 steelhead migration, and creating potential for fish entrapment (NOAA Fisheries 2004).

Additional impacts to salmonids can occur due to destruction of riparian zones, decreased food (macroinvertebrates) in impacted stream channels, and toxic chemical spills that could occur during mining activities (NOAA 2004).

Earliest accounts of gravel extraction from the lower Eel River date to 1911 and are linked with road surfacing needs of the time. Instream mining continued throughout the early part of the century and increased in the 1950s and 1960s. Between 1956 and 1987, from 500,000 to 700,000 cubic yards (cy) were extracted annually from the Eel River between its confluence with the Van Duzen River down stream one mile below Fernbridge (Humboldt County Public Works Department 1992). Gravel harvests increased further to average around 700,000 cy from 1987 to 1996. Problems of over extraction and threats to the fisheries led to a system of monitoring and adaptive management.

In 1992, the County of Humboldt formed a scientific review team–CHERT–to address the complexities in properly managing instream gravel mining in the Mad River. In 1996, CHERT expanded to review most riverine gravel mining operations in Humboldt County that remove 5,000 cy or more annually.

Monitoring of the Lower Eel Basin began in 1996 and divides the Lower Eel Basin into two reaches. One is the Lower Eel River reach which extends from Fernbridge to the confluence of the Van Duzen River (six miles in total); the other is the Lower Van Duzen reach which extends from the confluence with Eel River to five miles upstream (five miles in total).

There are also five instream gravel mines just upstream of the Lower Eel Basin owned and operated by Humboldt Redwood Company. Each of these sites is permitted to remove an average of 15,000 cy over 10 years and no more than 30,000cy during any given year. Any effects these mines have on water quality and fluvial geomorphology directly affect the Lower Eel Basin. Figure 19 shows the locations of gravel mines within the basin and the five above mentioned extra-basin mines.

For each reach, CHERT estimates the mean annual recruitment (MAR) of bedload in relation to the surrounding instream mining operations. From the MAR, they set recommended limits on the amount of aggregate that should be harvested each year. It has been suggested by other local gravel mining consultants that "average annual extraction should not exceed 75% of MAR in salmonid-bearing rivers and streams," and only if thorough analysis has been done to determine the MAR for that particular reach, otherwise 25% of the estimated MAR should be the guideline (Laird et al. 2000). From 1997 through 2007, the average volume extracted in both the Lower Eel River reach and the Lower Van Duzen reach has remained less than 75% of the volume recommended by CHERT (Table 13). Currently, annual extraction volumes average around 200,000 cy in the Eel River and a little over 100,000 in the lower Van Duzen River (CHERT 2007). Note that the table below presents the recommended volume and not necessarily the MAR. Yearly extraction data are presented at the subbasin assessment sections of this report.

CHERT monitors twelve sites on both the Lower Eel River reach and on the Lower Van Duzen reach. However, Trinity Associates (Laird et al. 2000) identified 34 sites that extract over 1,000 cy annually on the lower Eel River (geographic description of the "lower Eel River" was not given), and 43 sites on the Van Duzen River with an additional 40 sites that extracted less than 1,000 cy annually. (Table 13) (CHERT 2007).

The Eel River naturally has one of the highest sediment yields in the world for any river of its size. Clearly, channel aggradation from past floods and poor land practices would seem to be more of a problem than downcutting due to over extraction of gravel. At least three separate studies have used historical cross-section data and aerial photographs to determine if elevational changes have occurred on either the bed of the Lower Eel River or the Van Duzen River.

These reports monitoring streambed height levels in the basin and just upstream of the basin, Van Duzen River, have varied in their conclusions. One study shows aggradation above the area of this watershed assessment on the Van Duzen River between 1941 and 1977 (Kesley 1977). A separate study done by the Humboldt County Planning Department states that no significant change in stream bed elevation has occurred at Fernbridge, while a small to moderate amount (10 feet) of downcut has occurred at the Highway 101 Bridge on the Van Duzen River (Humboldt County Public Works Department 1992). Most recently, a 1999 study by the Army Corps of Engineers concludes that although moderate degradation has occurred on the Lower Eel River and mild aggradation has occurred on the Van Duzen River since 1968, this is not sufficient evidence that gravel mining has had a detrimental impact (USACOE 1999).

While gravel mining in the Lower Eel Basin may have only minimally impacted stream bed elevation changes, it has likely contributed to braiding and flattening of the Eel River between the confluence with the Van Duzen River to one mile downstream of Fernbridge (Humboldt County Public Works Department 1992). This type of shallow and wide channel morphology provides less cover from predation, less food, and higher water temperatures for juvenile fish as the channel is decoupled from riparian vegetation. Historically, the mining activities on the Lower Van Duzen River and mainstem Eel River below S.F. Eel River confluence created migration barriers for adult fish, sometimes leading to stranding on shallows and mortality. Since, mining operators cooperating with the regulatory agencies of the NMFS, USFWS, CDFG, and USACOE have prevented these types of incidents from reoccurring. 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.

Table 13. Lower Eel and Lower Van Duzen River Extraction (1997-2007) (CHERT).

Reach	Annual Average	Recommended Volume (cy)	Extracted Volume (cy)	Percent Extracted
Lower Eel River	(1997-2007)	334,217	206,723	62%
Lower Van Duzen	(1997-2007)	159,902	111,347	70%

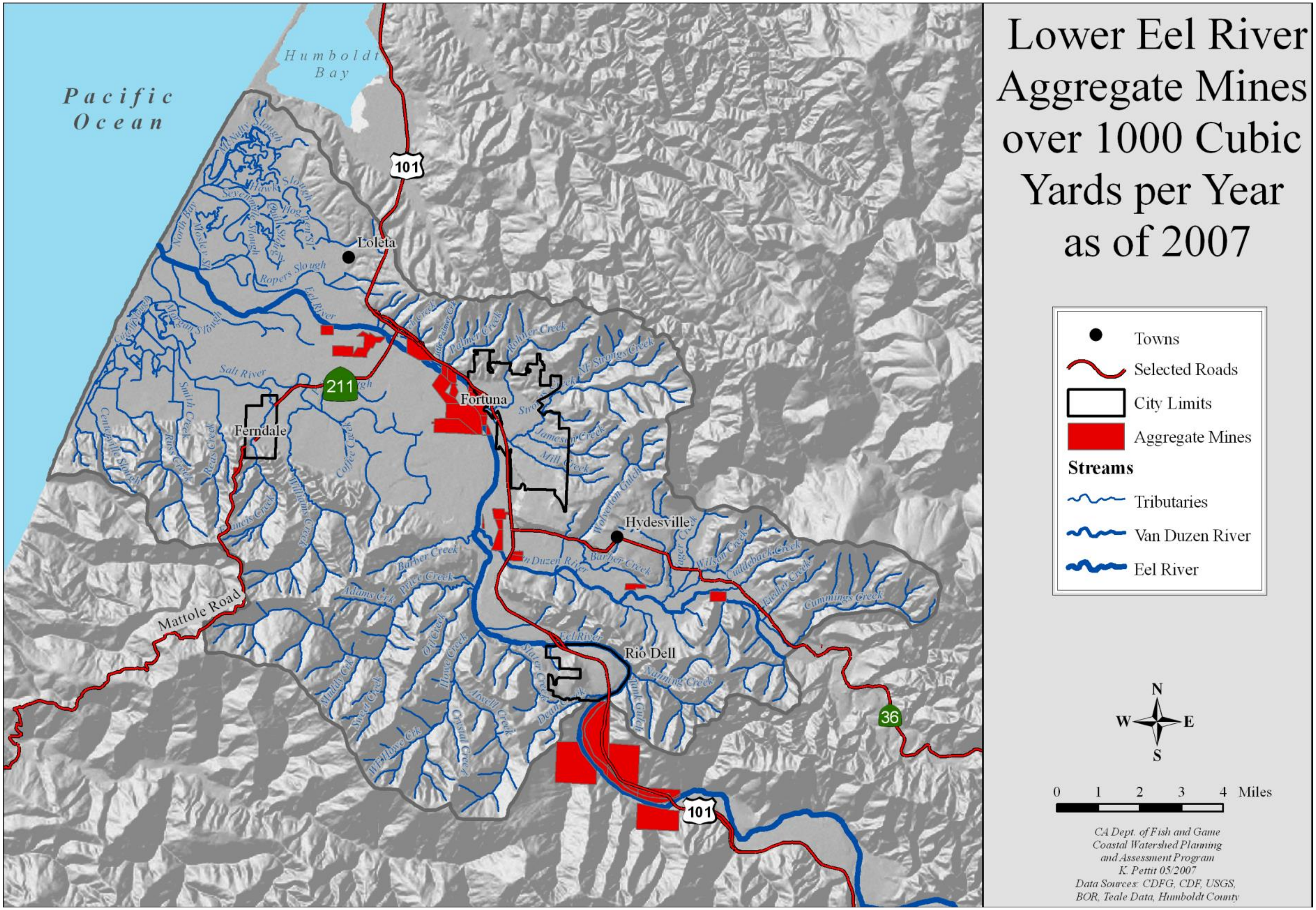

Figure 19. Lower Eel Basin aggregate mine locations.

Water Use: Diversions, Dams, and Power Generation

There are 25 licensed, permitted, or pending water rights within the Lower Eel River Basin (Table 14) (WRIMS 2007). This number does not include riparian users and other diversions that are not registered with the State Division of Water Rights. Water rights permits exist on streams as well as for groundwater in the basin. It is important to remember that groundwater and surface water are connected and will rise and fall together (TU 2007).

Most rights are for direct diversions, although there is one right for diversion storage in the Estuary Subbasin. Diverted water is primarily used for irrigation, stock watering, domestic use, and municipal use by the cities of Fortuna and Rio Dell.

Table 14. Water rights in the Lower Eel Basin (WRIMS 2007).

Creek	Application Number	Direct Diversion	Maximum Application Direct Diversion	Diversion Storage	Purpose
Estuary Subbasin (1)					
McNulty Slough Tributary	A029374			300 afy	Fish and wildlife protection and/or enhancement
Salt River Subbasin (11)					
Near Russ Creek	A013822	0.57 cfs	139.06 afy		Irrigation
Russ Creek	A011118	10000 gallon/day	10000 gallon/day		Stock watering
	A010177	0.21 cfs	57.9 afy		Irrigation
Reas Creek	A020346	0.2 cfs	60.7 afy		Irrigation
Francis Creek	A010052	0.25 cfs	76.37 afy		Irrigation
	S000389		0 afy		Irrigation
	S000145		7200 gallon/day		Irrigation
Francis Creek Tributary	D030417R	1200 gallon/day	0.5 afy		Domestic
Near Francis Creek	S014391	2880 gallon/day			
	A022563	10700 gallon/day	10700 gallon/day		Irrigation
	D030414R	4500 gallon/day	2 afy		Domestic
Middle Subbasin (2)					
Eel River Underflow	A019124	3 cfs	1642 afy		Municipal
Upper Subbasin (13)					
Tributary to Wolverton Gulch	S008687		0 afy		Irrigation
Yager Creek Tributary	C000110		1 afy		Stock-watering
Cooper Mill Creek	A025146	0.93 cfs	360 afy		Fish culture
Fielder Creek	A005194	0.1 cfs	72.39 afy		Irrigation, Domestic
Price Creek	A015581		700 gallon/day		Stock watering
	A019631		300 gallon/day		Stock watering
	A015444	0.39 cfs	82.77 afy		Irrigation
Kemp Creek	A012956		500 gallon/day		Domestic
Eel River	A012319	0.44 cfs	121.31 afy		Irrigation
Eel River Underflow	A023196	0.62 cfs	304 afy		Domestic, Municipal
Eel River Tributary	A008824	0.067 cfs	20.47 afy		Irrigation
Dean Creek Tributary	A023197	0.09 cfs	65.16 afy		Municipal

No major dams or power generating facilities are located within the Lower Eel Basin. However, the Potter Valley Project near the headwaters of the Eel River (Figure 2) consists of two dams, which function to transfer water from the Eel River to the Russian River. Scott Dam at RM 147 forms Lake Pillsbury and blocks anadromous fish passage. The lake has a maximum water elevation of 1,925 feet and a storage capacity of 73,000 acre feet and supports both warm and coldwater fisheries (CDFG 1997).

Twelve miles downstream from Scott Dam is Cape Horn Dam. Cape Horn Dam forms Van Arsdale

Reservoir, which has a storage capacity of 700 ac-ft (FERC 1983). There is a fish ladder on Cape Horn Dam, facilitating anadromous salmonid passage. Upstream of Van Arsdale is an inter-basin hydroelectric operation owned and operated by the Pacific Gas and Electric Company. There is a 9,258 foot tunnel which diverts water from the Eel River to the Russian River. The project generates some electricity but mainly provides water for municipal and agricultural interests in Mendocino and Sonoma counties (CDFG 1997).

The average annual diversion of the Potter Valley Project is 160,000 acre-feet of water. However, the amount of water diverted varies from month to month. Diversion records have been published for the 91 years from 1910 to 2000. During the high flow months of January, February, and March approximately only 6%, 20%, and 15% of unimpaired flows have been diverted, respectively. During the lower flow months of June, July, August, and September, 81%, 88%, 69%, and 64% of the unimpaired flows are diverted, respectively (CEED 2002). The combination of diversions from Potter Valley Project and all the other diversions along the river impacts the amount of flows in the Lower Eel Basin, especially during low flow periods. These lower flows may cause the loss of connectivity between the estuary and the rest of the basin and delay/prevent adult fish from reaching portions of the Eel River Basin during their fall spawning migrations. Moreover, less water would be available for agricultural production in the Lower Eel Basin.

Flow requirements from the Potter Valley Project were issued by the Federal Energy Regulatory Commission (FERC) in 1983 and updated in 2004 during the re-licensing process. The updated requirement included a 30% reduction in the diversion of water to the Russian River and variable flow in the summer based on whether it is a wet or dry year. Therefore, flows in Eel River increased 15% on an annual basis relative to pre-2004 and 30% since 2004. Additionally, summer flows will now vary from 3 to 35cfs rather than remaining steady at 5cfs (USEPA 2007). In addition to these regulations, the CDFG has water in reserve that can be used for fall attraction flows for adult migration and spring flushing flows.

Fishing

Historic

A commercial salmon fishery was established in the Eel River estuary in the early 1850s and continued until 1922. The early fishery was started by a few men that claimed fishing sites in the lower Eel River estuary. They organized companies or teams of fishermen to perform commercial fishing activities. The fishery quickly grew and by the late 1850's the salmon catch from the Eel River was greater than that of the Sacramento River (Reynolds et al. 1981). The growing commercial fishery brought a significant numbers of jobs and revenues to Humboldt County. In 1859 there were seven or eight fishing and packing companies working along the lower six miles of the river.

Salmon catches varied from year to year. The reported yearly harvest of Chinook salmon 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, 160,000 pounds or approximately 13,600 coho salmon was reported caught and as many as 62,500 steelhead (500,000 lbs) were caught. Factors influencing the size of the harvests were river conditions, the size and timing of salmon runs, the fishing effort, market demand, and fishing regulations. Fishing regulations were introduced in the 1890s as there was concern about depletion of the fishery. Attempts to regulate the commercial fishery with various rules and laws were implemented by the State Fish and Game, which eventually became the CDFG. The laws included net restrictions (most salmon fishing involved employing large seine nets in the river), shortened seasons and closed areas. The last records documenting commercial harvests from the estuary are from 1918 (Report of Commissioner of Fish and Fisheries) and the commercial fishery on the Eel River was closed by legislation in 1922.

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 tell of 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. Newspaper articles were substantiated by reviews of various reports by the U.S Fish Commission, the State Fish Commission, and the CDFG. 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. Further details of the commercial fishery are described in *Land Use* within the Estuary Subbasin section of this report.

In addition to commercial fishing, recreational fishing has also played an important role on the Eel River and estuary. Historically, there was fishing for juvenile trout in the summer and adult trout and salmon in the fall and winter. Historical 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). Fishing also occurred along the mainstem Eel River throughout the basin. The recreational fishery has now been significantly reduced and is catch and release.

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 1953, Anders 1953, Pister 1956).

Historically, there was fishing for coho salmon in the fall as well. However, the bulk of the coho salmon runs usually occurred as the turbidity of the water increased in November and December and made fishing more difficult (Murphy and DeWitt 1953).

Current

The Eel River has diminished from once being considered a world class fishery to one that can no longer support a commercial fishery and whose sport fishery's economic contribution to the region is almost non-existent. Presently, salmon and trout fishing in the Eel River targets Chinook salmon and steelhead trout as fishing for coho is prohibited. Chinook salmon fishing usually begins in August and intensifies in October when the first rains increase the number of migrating fish (Murphy and DeWitt 1953, Day 1966). While there are often half-pounder steelhead trout in the river before August, the prime fishing period for them is from August to November. In October, larger winter-run steelhead trout enter the catch, and are often 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. Both Chinook and steelhead are taken either from the shore or using drift boats, trolling in larger flatwater and pools.

An additional small fishing resource in the basin is the American shad (*Alosa sapidissima*) fishery. Sport fishing for shad occurs from April to June, mostly on riffles immediately downstream from the mouth of the Van Duzen River (Puckett 1975).

In addition to salmonid fishing, there is a marine fishery in the lower estuary. Prior fishing within the lower estuary varied from occasional harvests of Pacific herring (*Clupea harengus pallasii*)and Pacific sardines (*Sardinops sagax*) and surfsmelt species by beach seines in the late 1800s and early 1900s; to dependable catches of pile surfperch (*Damalichthys vacca*) in the early 1950s (Murphy and DeWitt 1953); to mainly redtail surfperch (*Amphistichus rhodoterus*) in the mid 1970s (Puckett 1975). Fish caught today include a variety of surfperch, starry flounder, and netting for surfsmelt species. Native tribal members actively fish along the banks in the estuary for Pacific lamprey (*Lampetra tridentata*). Dungeness crab (*Metacarcinus magister*) is also an additional sport fishery in the estuary with crabs being caught in the fall prior to the rainy season.

Fish Habitat Relationship

Fishery Resources

The Eel River is the third largest producer of salmon and second largest producer of steelhead in the state. The salmonid fishery resources of the Lower Eel Basin include coho salmon, fall-run Chinook salmon, steelhead, and coastal cutthroat trout. The basin provides important habitat for all the life history stages of each species, including the vital migration route to and from the ocean for all of the anadromous fish of the entire Eel River Basin.

In addition to salmonids, there are many additional fish species that inhabit the Lower Eel Basin (Table 15). Most of the marine or estuarine dependent species utilize the estuary as a nursery area and are generally limited to the juvenile stages of their life cycles. Several non-native freshwater species of fish, such as the Sacramento pikeminnow (*Ptychochelis grandis)* and Sacramento sucker (*Catostomus occidentalis*) have been introduced to the basin and have spread throughout the Eel River and some of its tributaries.

Table 15. Fishery resources of the Lower Eel River Basin.

Common Name	Scientific Name
Anadromous	
Coho Salmon	Oncorhynchus kisutch
Chinook Salmon	Oncorhynchus tshawytscha
Steelhead Trout	Oncorhynchus mykiss
Coastal Cutthroat Trout	Oncorhynchus clarkii
Chum Salmon	Oncorhynchus keta
Eulachon	Thaleichthys pacificus
Pacific Lamprey	Lampetra tridentata
Green Sturgeon	Acipenser medirostris
White Sturgeon	Acipenser transmontanus
American Shad,	Alosa sapidissima
Longfin Smelt	Spirinchus thaleichthys
Threespine Stickleback	Gasterosteus aculeatus
Coastrange Sculpin	Cottus aleuticus
Prickly Sculpin	Cottus asper
Freshwater	
California Roach*	Hesperoleucas symmetricus
Sacramento Sucker*	Catostomus occidentalis
Brown Bullhead*	Ameiurus nebulosus
Sacramento Pikeminnow*	Ptychochelis grandis
Green Sunfish*	Lepomis cyanellus
Marine or Estuarine Dependent	
Pacific Herring	Clupea harengus pallasii
Pacific Tomcod	Microgadus proximus
Topsmelt	Atherinops affinis
Bay Pipefish	Sygnathus leptorhynchus
Red-tail Surfperch	Amphistichus rhodoterus
Pile Surfperch	Damalichthys vacca
Walleye Surfperch	Hyperprosopon argentum
Shiner Surfperch	Cymatogaster aggregata
Pacific Sardine	Sardinops sagax
Northern Anchovy	Engraulis mordax
Surf smelt	Hypomesus pretiosis
Kelp greenling	Hexagrammos decarammus
Cabezon	Scorpaenichthys marmoratus
Pacific staghorn sculpin	Leptocottus armatus
Ringtail snailfish	Liparis rutteri
Jack mackeral	Trachurus symmetricus
Saddleback gunnel	Pholis ornata
Pacific sandlance	Ammodytes hexapterus
Tidewater goby	Eucyclogobius newberryi
Bay goby	Lepidogobius lepidus
Sand sole	Psettichthys melanostictus
English sole	Parophrys vetulus
Speckled sanddab	Citharichthys stigmaeus
Starry Flounder	Platicthys stellatus
Amphibians	
Pacific Giant Salamander	Dicamptodon tenebrosus
Northwestern Salamander	Amybstoma gracile
Rough-skinned newt	Taricha granulosa
Tailed Frog	Ascaphus truei
Pacific treefrog	Hyla regilla
Red-legged Frog	Rana aurora
Foothill Yellow-Legged Frog	Rana boylei
Bullfrog	Rana catesbeiana
Western Toad	Bufo boreas

* Indicates non-native species introduced to the basin.
From: Murphy and De Witt 1951, Puckett 1977, Boles 1977, Cannata and Hassler 1995, Franklin and Mitchell 1984, Goldsmith 2004, Monroe et al. 1974, Gilroy 2002.

There are no long-term fish population data sets specifically collected within the Lower Eel Basin. However, Eel River basin-wide data provide trend information about salmonids. Additionally, historic accounts, past stream surveys, and estuary studies provide records of fish species and populations within the basin.

There are two long-term fish count data sets for the Eel River Basin: CDFG fish ladder counts at Benbow Dam and Cape Horn Dam. These counts reflect an over 80% decline in coho salmon, Chinook salmon, and steelhead trout populations over the span of the last century (Figure 20, Figure 21). Therefore, it is likely that salmonid populations within the Lower Eel Basin declined similarly over this time period. The NMFS has listed northern California runs of Chinook (1999), coho (1997), and steelhead (2000) as threatened under the federal Endangered Species Act.

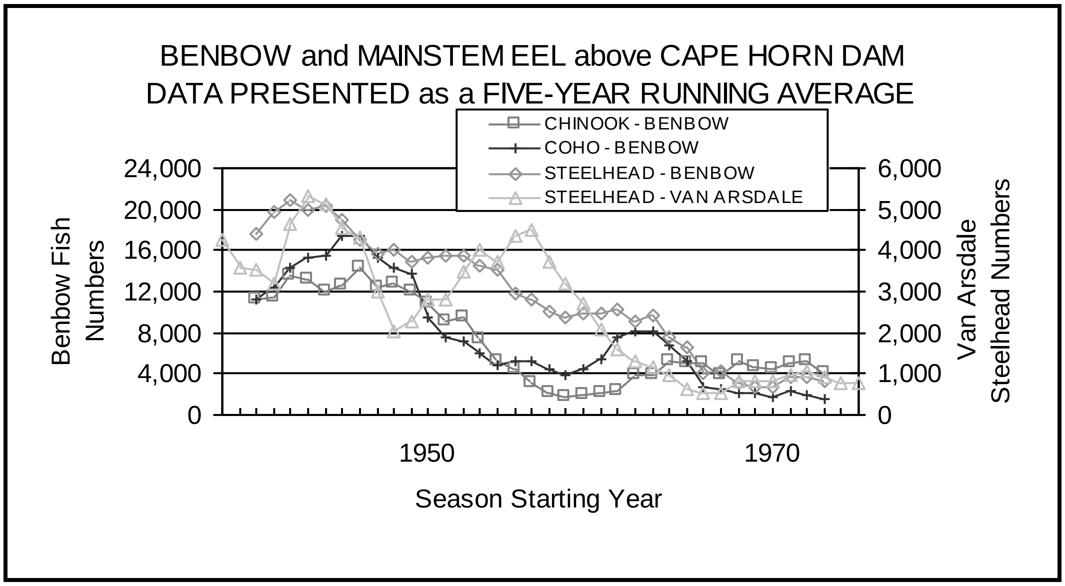

Figure 20. Five-year running average of salmonids at Benbow Dam, South Fork Eel River, and mainstem Eel River above Cape Horn Dam.

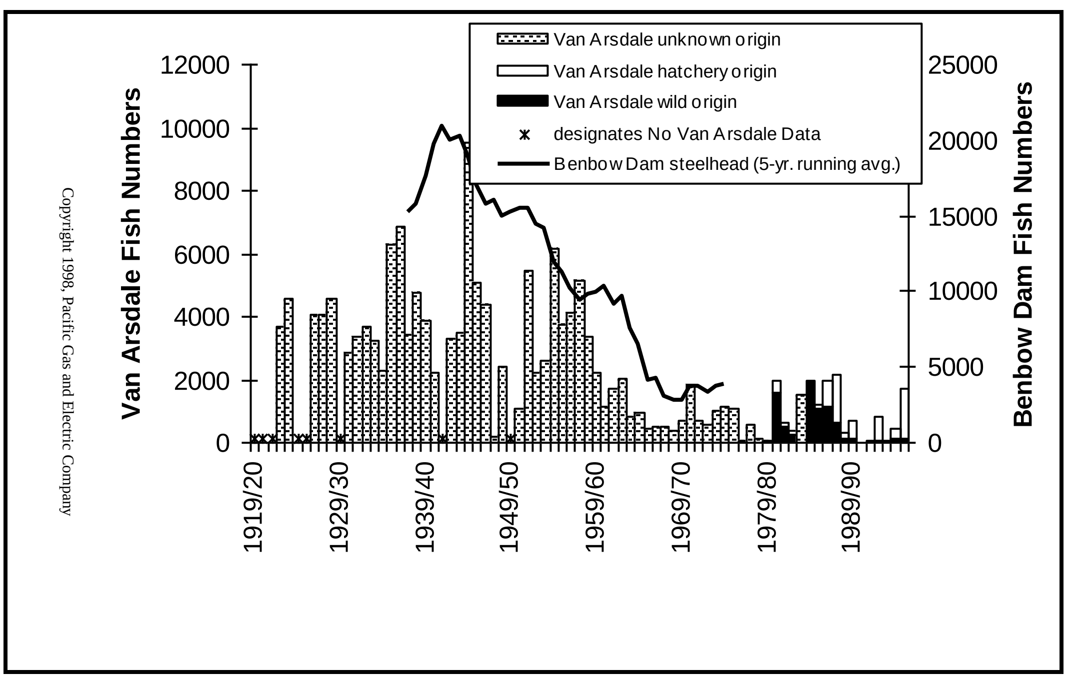

Figure 21. Historical steelhead trout ladder counts at Van Arsdale Fisheries Station, mainstem Eel River, and Benbow Dam, South Fork Eel River.

Coho salmon have been documented in 13 tributaries across the basin and Chinook salmon in six tributaries (Table 16). Steelhead trout have been documented in 21 tributaries and cutthroat trout in eight tributaries. These cutthroat represent the southern extent of coastal cutthroats on the West Coast. In addition, all four species of salmonids use the mainstem Eel River and estuary as critical migration routes and many use the estuary as rearing habitat. Due to the non-comprehensive nature of historic accounts, it is likely that not all streams that once provided habitat for salmonids have documentation of that fact. Therefore, estimates of historic salmonid distributions have been made. Figure 22 through Figure 25 depict the estimated historic and documented current distributions of coho salmon, steelhead trout, Chinook salmon and cutthroat trout, respectively. Current ranges are based on documented presence reports by CDFG since the 1990s (approximately). Salmonids may be present in sites where they have not been documented due to a lack of data or imperfect sampling techniques.

Salmon distribution in the basin was initially estimated using a stream gradient model. The limits of the estimated historic range of steelhead trout, the most athletic of the Lower Eel River salmonids, was initially defined to be a stream reach of 1000 feet or more with a gradient in excess of 10%. The limits of the coho and Chinook salmon range estimates were defined as reaches of 1000 feet or more with a gradient in excess of 5%. These estimates were based on 30 meter digital elevation model (DEM) analyses. The preliminary range estimates were then reviewed by a team of CDFG fishery biologists. The limits of the estimated historic range of coastal cutthroat trout were based on historic accounts of presence and expert opinion.

The preliminary estimates (Figure 22 through Figure 25) are not a definite indication that salmon were historically present in the indicated reaches, rather they indicate the possibility that salmonids were present. Additionally, the estimates do not conclusively prove that salmonids were not historically present in areas above the estimated gradient barriers. Other factors that affect salmonid distributions, such as flow limitations, channel shape and size, and barriers (e.g. waterfalls) could not be incorporated into this gradient-based analysis. Additionally, the 30 meter DEM may not provide enough accuracy for definitive analysis.

Chinook Salmon, *Oncorhynchus tshawytscha*

Today, the Eel River supports a fall run of Chinook salmon. Three to four year-old Chinook salmon generally enter the Eel River estuary between September and February. Creel surveys in the estuary have historically documented angling for adult Chinook salmon in the fall. Two year-old precocious males (jacks) also enter. Spawning occurs in tributary streams on gravel with diameters of 0.5 to 5 inches, with less than 5% fines. Prime spawning water velocities range between 1 to 3.5 feet/second. Optimal spawning water temperatures range between 42ºF to 56ºF. Considerable egg mortality can occur at temperatures greater than 57.5ºF. Eggs that are deposited in redds commonly hatch in 40 to 60 days.

Juvenile Chinook salmon often outmigrate at 3 to 6 months old and have been observed in the estuary in most studies. Puckett (1977) noted that juvenile Chinook salmon were present throughout the Estuary Subbasin in all but the winter months. In documenting that juveniles increased in size with season and proximity to the mouth, he stated 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, possibly leading to increased reliance on the estuary (Higgins in Roberts 1992).

Coho salmon, *Oncorhynchus kisutch*

The Eel River has one run of coho salmon (three year-old adults) that generally occurs between September and February; arrival in the upper reaches of the river peaks in November-December (Baker and Reynolds 1986). Within the Eel River system, coho salmon are most abundant in the South Fork. However, they are found in streams of the Lower Eel as well and use the estuary and mainstem Eel as critical migration routes.

Optimal spawning conditions are similar to Chinook salmon, but coho salmon usually spawn in smaller streams than those used by Chinooks. Young 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).

Table 16. Documented salmonid presence across the Lower Eel Basin.

Streams	Chinook Salmon	Coho Salmon	Steelhead Trout	Cutthroat Trout	Unidentified salmonids	Source(s)
Estuary Subbasin						
Estuary	X	X	X	X		Murphy 1951, Pucket 1977, Cannata1995
Salt River Subbasin						
Reas Creek		X	X	X		CDFG 1972, 1984, 2001-2004, Downie 2007
Francis Creek		X	X	X	X	CDFG 2000, 2001, 2003-2005
Coffee Creek						CDFG 2005
Centerville Slough		X		X	X	CDFG 1984
Unnamed Tributary to Centerville Slough				X		CDFG 1968
Russ Creek				X		CDFG 1938, 1968, 2001-2005
Williams Creek				X		CDFG 1999, 2003
Middle Subbasin						
Palmer Creek		X	X		X	Hallock et al 1952, Geppert 2004, CDFG 1982, 2000, 2005 HCRCD 1997
Rohner Creek		X	X		X	CDFG 1952, 1972, 1982, 2005, Lewis 1964, Day 1964
Strongs Creek		X	X	X	X	CDFG 1951, 1968, 1969, 1982, 1993, 1995, 2005
North Fork Strongs Creek			X	X		Franklin and Mitchell 1984, CDFG 1993
Mill Creek					X	CDFG 2004
Unnamed Tributary (to Strongs Creek)						CDFG 1980, 2005
Upper Subbasin						
Barber Creek (Eel)			X			CDFG 1973
Barber Creek (Van Duzen)			X		X	CDFG 1965, 1988, Franklin and Mitchell 1984
Wolverton Gulch		X	X	X	X	CDFG 1963, 1965, 1978, 1993, 1994, 1997, 2005, Franklin and Mitchell 1984, Rose 1993, Harris 1997
Wilson Greek	X		X		X	CDFG 1991, 2005, Froland 2001
Cuddeback Creek	X	X	X		X	Shapovalov 1940, CDFG 1963, 1987, 1988, 2005, Froland 2001, 2002
Fiedler Creek	X	X	X		X	Hallock et al. 1952, CDFG 1964, 1965, 1967, 1987, 2005, Froland 2001
Cummings Creek	X	X	X		X	CDFG 1938, 1952, 1961, 1962, 1964, 1966, 1985, 1987- 1992, 1994- 1997, 2000, 2005, Murphy 1950, Hallock 1952, Kimsey 1953, Brown and Moyle 1987, Preston 1993, 1994, PALCO 1998-2000, 2003, Froland 2001, Donker 1987, and Donker 1987
Price Creek	X		X		X	Rinehart 1964, CDFG 1966, 1998, 1999, 2005, Brown 1980, Ganz-Haggard 1981, Froland 1986, Donker 1987, USFS 1995, Harvey et al. 2002
Sweet Creek			X			CDFG 1938, 1981
Oil Creek		X	X		X	CDFG 1977, 1990, 1999, 2002
Howe Creek	X	X	X		X	Kimsey 1952, Brown 1980, CDFG 1980, 1998, 2001, 2005, Moody 1987, Yoshioka 1999, Downie 2007
West Fork Howe Creek			X			CDFG 1998
Atwell Creek	X	X	X		X	Brown 1980, CDFG 1980, 1993, 1999, 2005
Slater Creek						
Nanning Creek			X			CDFG 1973, 1992, Brown 1980, PALCO 2001
Dean Creek			X			CDFG 1992

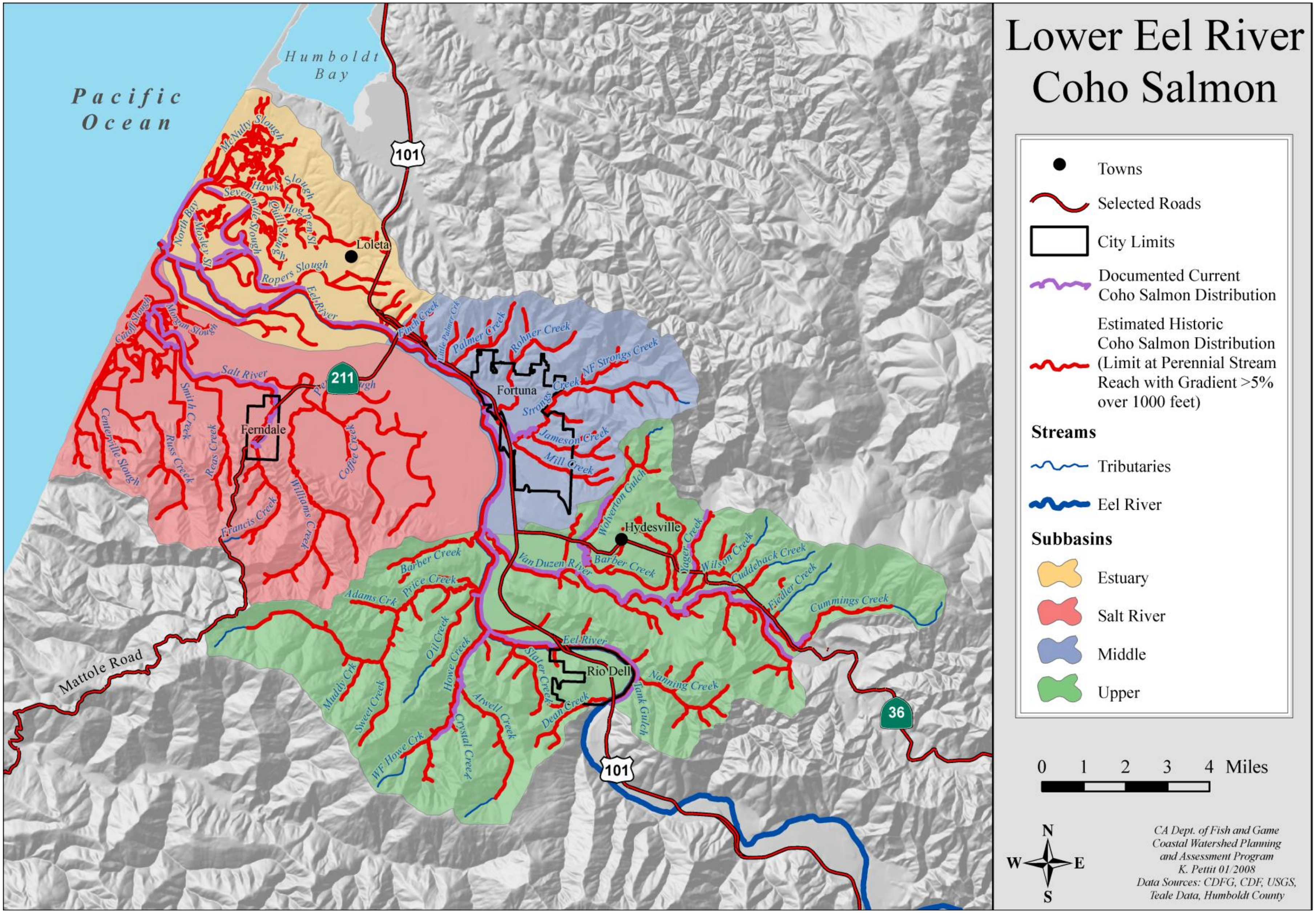

Figure 22. Lower Eel Basin coho salmon estimated range.

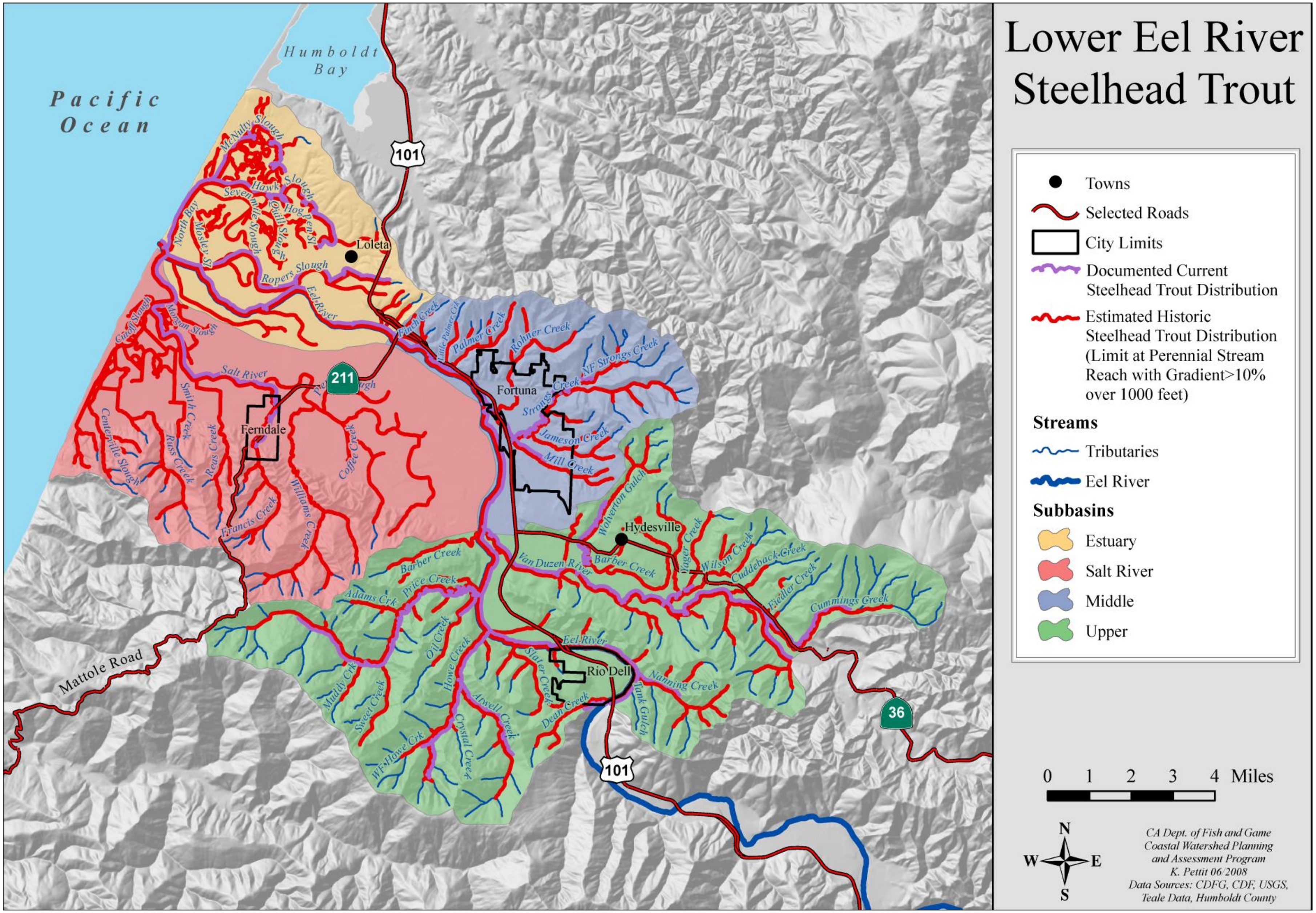

Figure 23. Lower Eel Basin steelhead trout estimated range.

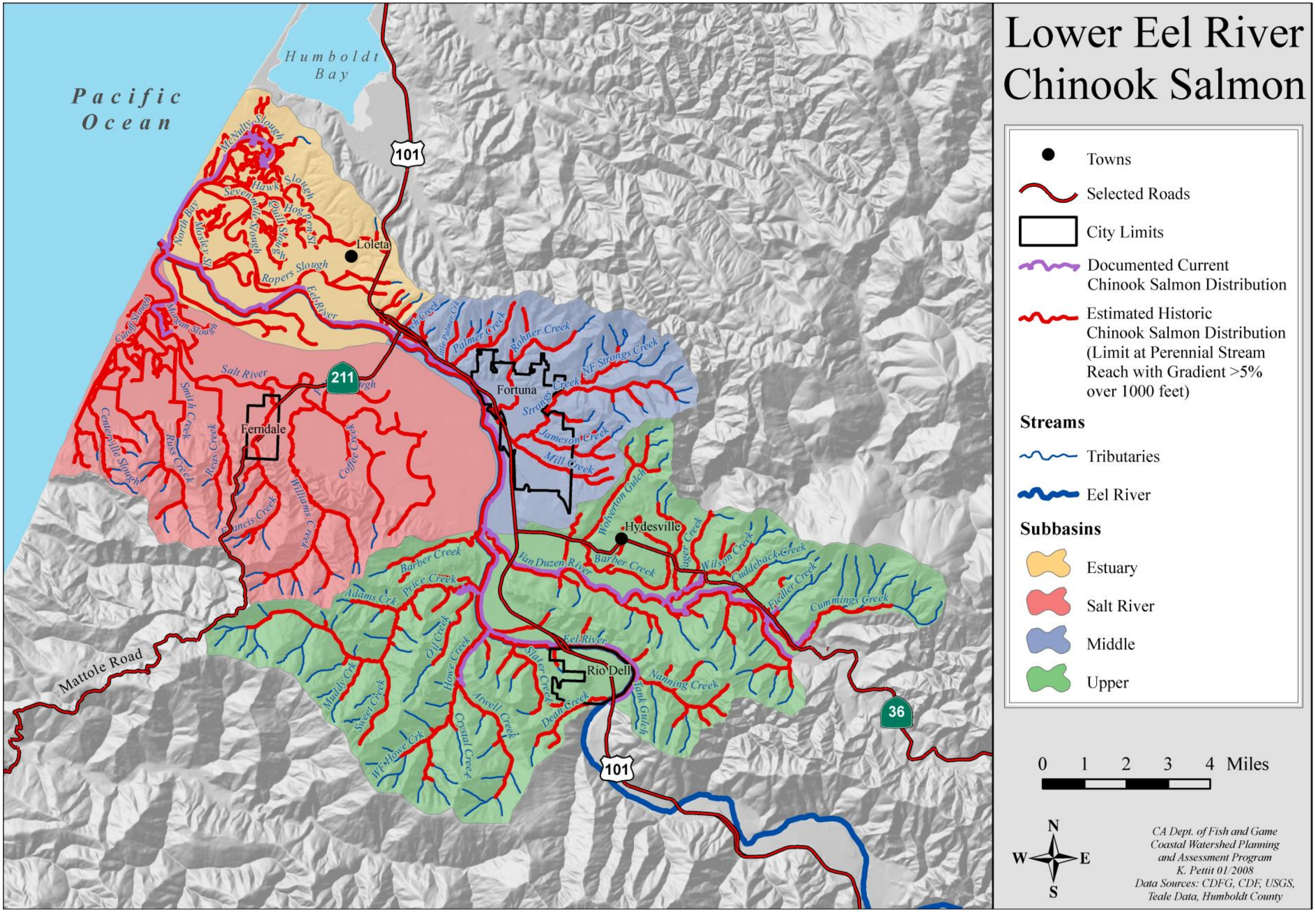

Figure 24. Lower Eel Basin Chinook salmon estimated range.

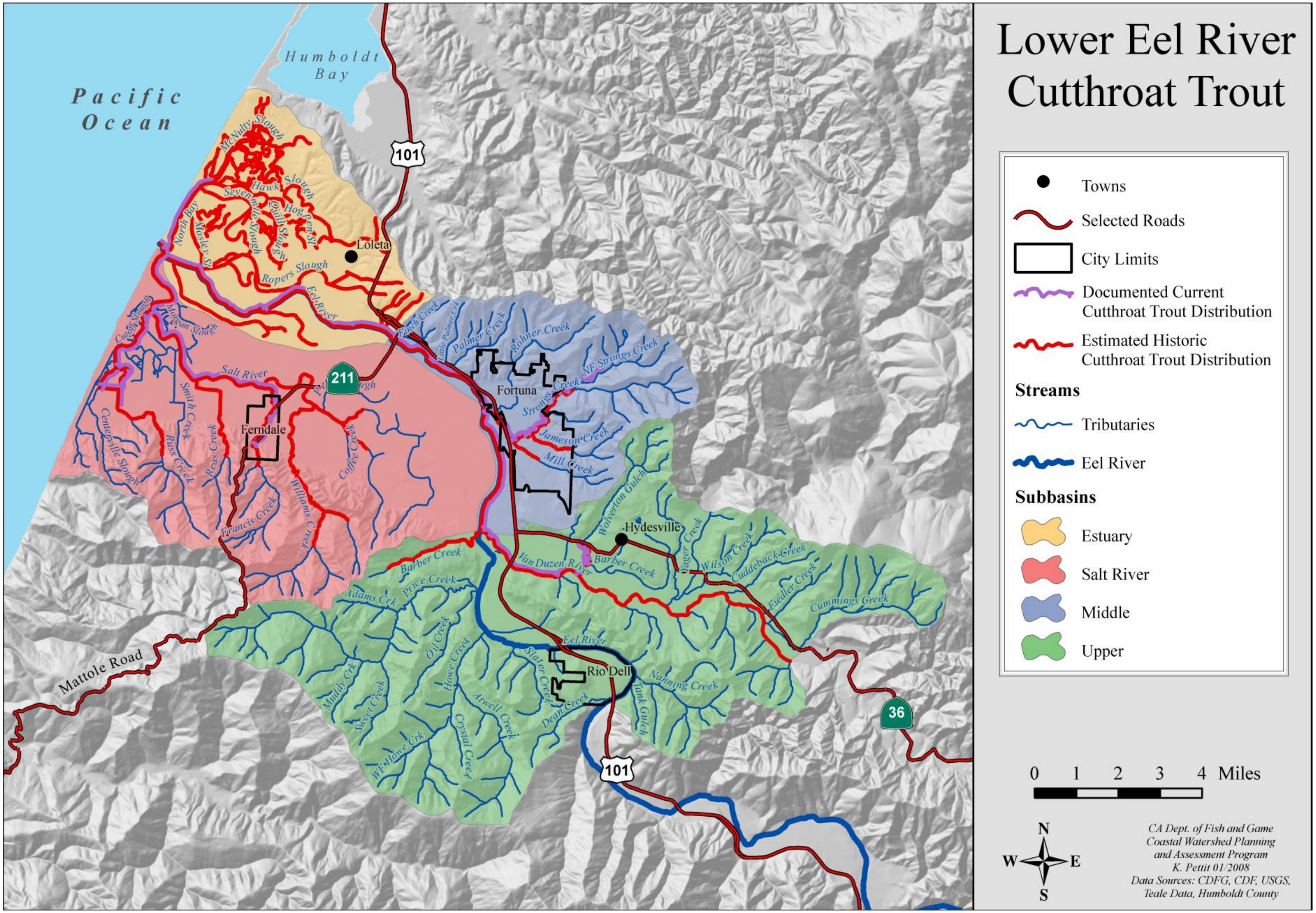

Figure 25. Lower Eel Basin cutthroat trout estimated range.

Juvenile coho salmon then remain in freshwater 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 Estuary Subbasin has been documented (Murphy and DeWitt 1951, Puckett 1977, Cannata and Hassler 1995). After entering the ocean, coho salmon typically spend two years feeding, growing, and sexually maturing before returning to their natal streams to spawn.

Steelhead, *Oncorhynchus mykiss*

There are three runs of steelhead in the Eel River: winter-run, fall-run (also referred to as half-pounders), and spring or summer-run. Unlike Pacific salmon, steelhead do not necessarily die after spawning, and can make multiple spawning runs. Winter-run steelhead adults (4 to 5 years old or 2 to 12 lbs) enter the Eel River beginning in September to spawn. The run continues through May, with a peak in February (Eel River Action Plan Doc 082). Steelhead referred to as fall-run 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. 1995). In general, they 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, Jones 1980). Spawning doesn't occur then till late December through April (Moyle et al. 1995).

Ideal steelhead spawning conditions include water temperatures between 49ºF and 55ºF, water velocities of 1.5 feet/second, and gravel diameters between 0.25 and 3 inches, with few sediment fines. 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 3 to 4 years of age.

Juvenile steelhead have been noted in nearly all fish surveys of the Lower Eel Basin. This species, like other anadromous salmonids, uses the upstream system in their juvenile and adult migrations. Puckett (1977) observed juvenile steelhead year round throughout the estuary, noting that they were most abundant in the summer and fall.

The estuary serves as a holding area for adult steelhead during upstream spawning migrations (Murphy and DeWitt 1951). During these migrations, the estuary and rivers support a catch and release (0-bag limit) sport fishery for adult steelhead.

Coastal cutthroat trout, *Oncorhynchus clarki clarki*

The Eel River serves as the southern extent of the coastal cutthroat trout range. In California most populations of coastal cutthroat are weakly anadromous and migrate mainly between large and small streams or between rivers and estuaries (Gerstung 1997). Their presence has been noted in the Eel River Estuary by Murphy and DeWitt (1951). These fish were collected by recreational fishermen in 1950. It is interesting to note that the cutthroat collected in this study were described as having "only faint evidence of the cutthroat mark" (Murphy and DeWitt 1951).

More recently, Franklin and Mitchell (1984), and electrofishing in 2004 (CDFG 2005) have documented cutthroat trout in tributaries to the Salt River. Cutthroat have also been observed in Strongs Creek in the Middle Subbasin (CDFG 1993) and were found in Barber Creek (mainstem) in the Upper Subbasin in 1950 (DeWitt 1952). Cutthroat trout remaining in the basin are largely limited to upland portions of delta tributaries and appear to be resident. The population in Strongs Creek is believed to be the southernmost limit of the species; however, if cutthroat remain in Barber Creek (mainstem) or Wolverine Gulch that would constitute the limit (Downie 1993; Gerstung 1996).

Sacramento pikeminnow, *Ptychocheilus grandis*

The Sacramento pikeminnow is a large piscivorous cyprinid (minnow) that was introduced into the Eel River system in Pillsbury Lake 1979 (Brown and Moyle 1997). 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). Undercut banks and aquatic vegetation are good cover. Pikeminnow prefer water temperatures ranging from 64.4 to 82.4°F, though they are capable of withstanding extremes up to 100.4F.

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). Pikeminnow are predaceous and move from smaller prey such as aquatic insects to crustaceans and fish as they grow bigger.

Pikeminnow become sexually mature at age three or four. Spawning mainly occurs in April through May, when water temperatures reach a range of 59-68°F. Spawning is in riffles and pool tails with gravel substrate in small tributary streams. 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 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, shallowing of streams, 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 in the estuary, and were documented in surveys conducted in the mid to late 1990s (Cannata 1995 and USFWS 1997). Pikeminnow have been documented as present in several surveys (Middle Subbasin) beginning in the late 1990s. Pikeminnow were first reported in the mainstem Van Duzen in 1988 and have been observed in tributaries throughout the Upper Subbasin since the late 1990s. Studies have shown that pikeminnow move long distances throughout the Eel River system, thus any small scale local control efforts are likely to be thwarted by individual pikeminnow movements throughout the basin (Harvey and Nakamoto 1999).

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 rapidly increased on Eel River stocks. Declining fishery production in the late 1800s gave rise to a hatchery program to augment salmonid stocks (Brown and Haley 1974). Hatchery operations eventually expanded to occur throughout the entire Eel River drainage.

While hatchery operations have varied over the years, a substantial number of salmon and steelhead have been planted throughout the Eel River Basin. Hatchery records indicate more than 39 million Chinook salmon, 9 million steelhead and millions of coho have been planted in the Eel River Basin since 1900 (Steiner Environmental Consulting 1998). However, a century of hatchery operations have only lead to mixed results as their effectiveness in potentially restoring salmonid populations in the Eel River has been unsubstantiated.

Similar to the historic management practices of hatchery programs throughout the state, Eel River salmonid stocks were also supplemented with brood stock raised outside the basin. Other sources of fish planted include hatcheries on Battle Creek, Mill Creek, and McCloud River of the Sacramento River system, Prairie Creek (of Redwood National Park), Klamath River, Mad River, Gibson Creek of Russian River, some eggs from Oregon and Washington and potentially other additional sources.

While fish were stocked throughout the Eel River, this report, however, will only detail the hatchery operations that occurred previously within the Lower Eel River basin.

Hatchery operations became established in the Eel River Basin in the late 1800s. Public perception of declining salmon stocks prompted requests to State Fish and Game for a hatchery on the Eel River. Thus, after general reconnaissance studies the first hatchery was built on Price Creek (RM 15) in 1897. The hatchery was unsuccessful in obtaining ripe eggs from Eel River Chinook or coho salmon stocks; therefore, Chinook salmon eggs were obtained from Battle Creek and Mill Creek of the Sacramento River system (CDFG Commission Report No. 23, 1912-1914 in CDFG 1997). Over most of the following 15 years, the Price Creek hatchery received between 885,000 and 9,000,000 Chinook salmon eggs per year from the Sacramento Basin. The eggs were hatched and released as fry. In 1910, 47,000 coho salmon fry from Santa Cruz were released into Price Creek (CDFG 1910). The hatchery was eventually abandoned in 1916 due to low water and siltation.

A dam constructed at the Newburg Mill on Strongs Creek, near Fortuna created a fish passage barrier approximately 2.5 miles upstream from mouth. At the close of the mill in 1931, the ponds were used for rearing steelhead trout, since the runs in Strongs had decreased due to the dam. Steelhead and Dolly Varden trout were stocked in the 1930s, followed by cutthroat trout in 1962, 1964, 1965, 1966, and 1972.

More recently, the Pacific Lumber Company (PL) began operating fish-rearing facilities in 1972 to augment Eel and Van Duzen River stocks. Fish were initially raised in concrete ponds in Scotia. A hatchery and rearing facility was built on Cooper Mill Creek (tributary to Yager Creek, tributary to the Van Duzen River) in 1976, and use of the Scotia pond also continued. Additional facilities on Corner Creek and South Fork Yager Creek were built in 1993 for rearing and acclimating fish for release. Fish were released at various locations throughout the Yager Creek drainage such as Lawrence, Cooper Mill, Shaw, Corner, and Blanton creeks. Records from 1990 to 2002 show that in years that fish were released, between 2,973 to 20,360 steelhead trout and 3,400 to 100,350 Chinook salmon were released per year. The facilities ceased operations in 2002.

Currently there are no active hatchery or fish collecting operations in the Eel River Basin.

Fish Rescue

Fish rescue is a technique sometimes used to remove fish from habitat in which they are sure to die and move them to more suitable habitat. Efforts at fish rescue in Del Norte, Humboldt, and Mendocino Counties were catalogued in 1949 (Table 17, Table 20).

The vast majority of rescued fish were steelhead trout. Although, overall, more fish were rescued from the Eel River system and transplanted to other rivers, and more coho salmon and Chinook salmon were planted in the Eel Basin than were rescued within the basin. A total of 391,277 fish were rescued in the basin and 171,934 rescued fish were planted in the basin.

Table 17. Rescued fish in 1949.

Stream	Steelhead	Coho Salmon	Chinook salmon	Total
Eel River – Humboldt	1,560		760	2,320
Cummings Creek	900			900
Baechtel Creek		5,629		5,629
Bloody Run Creek				
Cold Creek (Middle Fork)	43,865			43,865
Short Creek (Middle Fork)	175,220			175,220
Tomki Creek	135,678	16,815		152,493
Town Creek (Middle Fork)	10,850			10,850
Eel River Total	**368,073**	**22,444**	**760**	**391,277**

Table 18. Rescued fish plantings in 1949[1].

Stream	Steelhead	Coho Salmon	Chinook salmon	Total
Eel River – Humboldt	6,125	355	2,400	8,880
Van Duzen River	900			900
Eel River – Mendocino	36,395	19,374		55,769
Middle Fork Eel River	24,713			24,713
Outlet Creek	972			972
Black Butte River (Middle Fork)	11,160			11,160
Asbill Creek (North Fork)	8,280			8,280
Burger Creek	8,990			8,990
Cold Creek (trib to Black Butte River)	8,786			8,786
Hull Creek	10,810			10,810
Shields Creek (trib to Black Butte River)	18,434			18,434
Turners Gulch (trib to Mill, trib to Middle Eel)		3,840		3,840
Woodman Creek	10,400			10,400
Eel River Total	**145,965**	**23,569**	**2,400**	**171,934**

[1] Murphy, G. I. 1950. "Fish rescue and stream improvement work in the north coast area in 1949." California Department of Fish and Game, Sacramento: 11 p.

Habitat Overview

In order to meet the needs of the life stages of anadromous salmonids, the Lower Eel River Basin must provide appropriate diverse stream flow regimes, suitable water quality, high quality gravel substrate for spawning and incubation of eggs, suitable in-channel and riparian conditions, and adequate food supplies within the fish bearing reaches throughout the basin. High quality instream and riparian habitat is most important for coho salmon and steelhead as they spend a year or more rearing in streams.

The advent of timber harvesting in the Eel River Basin in 1850 brought changes to stream channels across the basin due to land use activities. These changes from historic stream conditions resulted in reductions of salmonid habitat quality. Identifying salmonid life history strategies at the 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 by their trends of abundance. Some species or life history strategies may already belost or rarely observed due to changes from historic stream conditions. By gaining insight into the relationships between the diverse life history strategies, fishery population dynamics and status, and by assessing stream habitat condition, efficient recommendations for recovery of depressed populations can be made.

Historic Conditions

There are approximately 36 named streams in the Lower Eel Basin. Surveys have been conducted at various points in time on some of 18 creeks from 1938 to 1989 (Table 19). 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. The data from these stream surveys provide a snapshot of the conditions at the time of the survey.

Summary tables appear in the subbasin sections of this report. In general, surveys described a range of habitat conditions. The earliest stream surveys were conducted in 1938 on six creeks. These surveys generally indicated good spawning and pool conditions. Surveys in later years described fish passage problems in the Middle Subbasin and silty conditions across the basin.

Table 19. Streams surveyed by CDFG in the Lower Eel Basin from 1938-1989.

Year	Salt River Subbasin	Middle Subbasin	Upper Subbasin
1938	Russ Creek		Cummings Creek, Oil Creek, Price Creek, Howe Creek, Sweet Creek
pre-1951			Price Creek
1952		Rohner Creek	Cummings Creek
1961			Cummings Creek
1962			Cummings Creek
1963			Wolverton Gulch, Cuddeback Creek
1964			Fiedler Creek, Cummings Creek, Price Creek
1965			Barber Creek (Van Duzen), Wolverton Gulch, Fiedler Creek
1966			Cummings Creek
1972	Reas Creek	Rohner Creek	
1973	Coffee Creek		Barber Creek (Eel), Nanning Creek
1977			Oil Creek
1979			Nanning Creek
1980		Unnamed Trib to Strongs Creek	Howe Creek
1981			Price Creek, Sweet Creek
1982		Rohner Creek, Strongs Creek	
1984	Reas Creek	North Fork Strongs Creek	Barber Creek (Van Duzen), Wolverton Gulch
1985			Cummings Creek
1986			Price Creek
1987			Cuddeback Creek, Price Creek, Fiedler Creek, Howe Creek, Cummings Creek
1988			Barber Creek (Van Duzen), Cuddeback Creek, Cummings Creek
1989			Cummings Creek

Current Conditions

Within the Lower Eel Basin, CDFG inventoried 21 tributaries between the years of 1991 and 2004. The data collected during these inventories are compared to the target values defined in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) to determine if habitat conditions within the streams are limiting to salmonid production. Data collected during these habitat inventories describe the canopy density, cobble embeddedness of pool tails, length of primary pools, and mean pool shelter coverage along surveyed reaches within the Lower Eel Basin. Additionally, the CWPAP evaluates these habitat data using the Ecological Management Decision Support (EMDS) system software. The EMDS system can evaluate stream reach conditions for salmonids based on water temperature, riparian vegetation, stream flow, and in channel characteristics. More details of how the EMDS functions are in NCWAP Methods Manual. Habitat data collected in the Lower Eel Basin that can be used in the EMDS are: canopy, pool quality, pool depth, pool shelter, and embeddedness (Figures 26–34). Calculations and conclusions made in the EMDS are pertinent to surveyed streams and are based on conditions existing at the time of survey. Tributary EMDS results are presented in the subbasin sections.

Three of the four Lower Eel subbasins have had habitat inventories completed by the CDFG over the past fifteen years (Table 20). Based on USGS 7.5 minute topoquads, the Estuary Subbasin does not contain any permanent freshwater tributaries, and therefore has no completed habitat inventories. The Upper Subbasin, which has the longest length of stream miles, has had the most inventories completed; three streams in this subbasin have had repeat surveys.

Table 20. Habitat surveys completed in the Lower Eel River Basin from 1991 to 2004.

Subbasin	Years of survey	Number of streams surveyed	Number of surveys	Total length of survey (miles)	Percent of permanent stream surveyed
Estuary	N/A	0	0	0	0
Salt River	2003, 2004	4	4	9.2	29
Middle	1993, 2004	3	3	2	10
Upper	1991-2002	14	17	30.3	58

Canopy

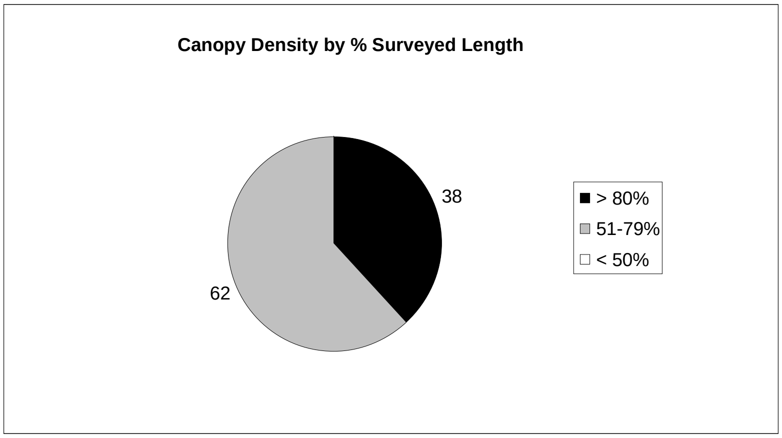

Figure 26. Canopy density in the Lower Eel Basin.

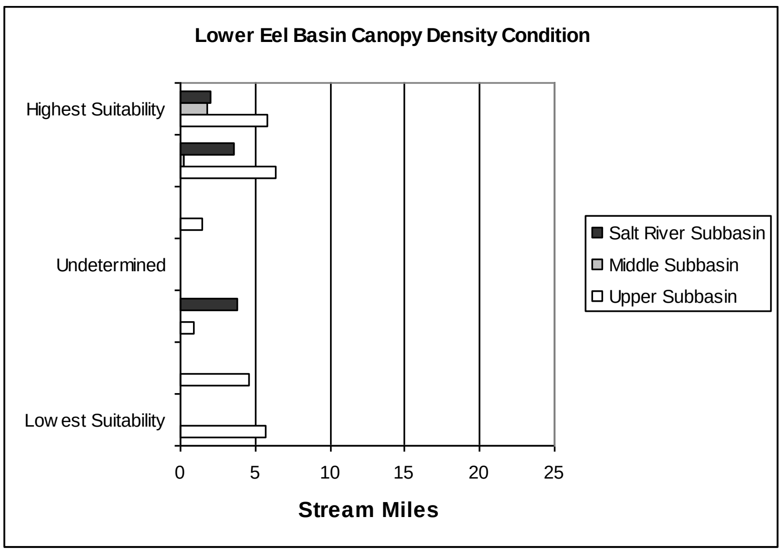

Figure 27. EMDS canopy results for the Lower Eel Basin by surveyed stream miles.

Where there was more than one year of survey data, the most recent data was used for this graphic.

Significance: Canopy density is one of the measurements estimated during CDFG habitat surveys. These measurements, which are given as a percentage of shade canopy over the stream, provide an indication of potential recruitment of organic debris to the stream channel, as well as insulating capacity of the stream and riparian areas during winter. Canopy density may also contribute to microclimate conditions that help moderate air temperature, an important factor in determining stream water temperature. Stream canopy relative to the wetted channel normally decreases in larger streams as channel width increases due to increased drainage area. The CDFG Restoration Manual establishes a target of 80% for shade canopy along coastal streams (Flosi et al. 1998). The CDFG recommends areas with less than 80% shade canopy as candidates for riparian improvement efforts.

Findings: All of the surveyed streams recorded measured canopy above 50%. Nine streams (10 surveys) did not meet the target value of 80% measured canopy and are therefore evaluated as lower suitability by the EMDS. Streams with lower suitability scores were in the Upper and Salt River subbasins.

Pool Depth

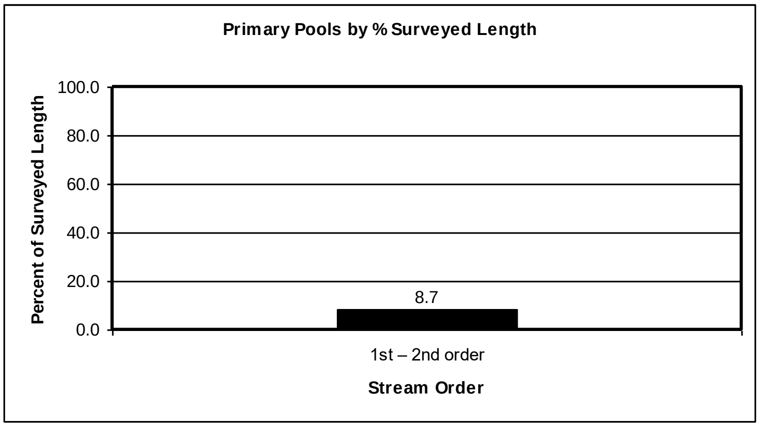

Figure 28. Primary pools in the Lower Eel Basin.

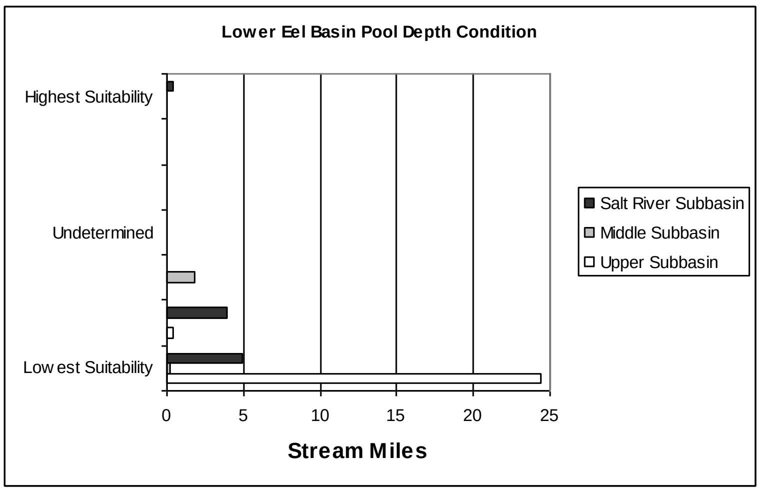

Figure 29. EMDS pool depth results for the Lower Eel Basin by surveyed stream miles.

Where there was more than one year of survey data, the most recent data was used for this graphic.

Significance: Primary pools provide 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 – 55% of its length in primary pools to be suitable for salmonids. In first and second order streams, a primary pool is described as being at least 2 feet deep.

Findings: The percent of primary pools by length in the Lower Eel Basin is generally below target values for salmonids. The majority of stream miles with the lowest suitability scores for pool depth as evaluated by the EMDS were in the Upper Subbasin. Some stream length with suitable scores for pool depth was in the Salt River Subbasin.

Pool Shelter

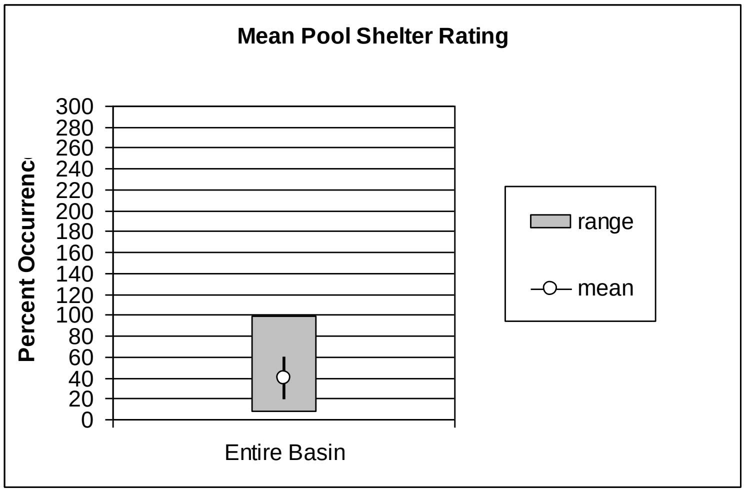

Figure 30. Pool shelter in the Lower Eel Basin.

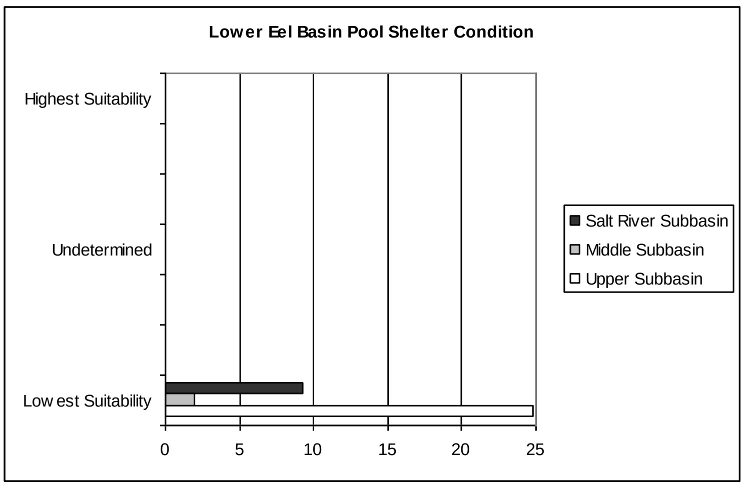

Figure 31. EMDS pool shelter results for the Lower Eel Basin by surveyed stream miles.

Where there was more than one year of survey data, the most recent data was used for this graphic.

Significance: 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 wads, undercut banks, bubble curtains, and submersed or overhanging vegetation in pool habitats. Shelter ratings of 100 or less indicate that shelter/cover enhancement should be considered.

Findings: The average mean pool shelter rating for the Lower Eel Basin is 39.2. This is below the shelter target value for salmonids. All surveyed stream miles across the basin had the lowest suitability ratings for pool shelter as evaluated by the EMDS.

Cobble Embeddedness

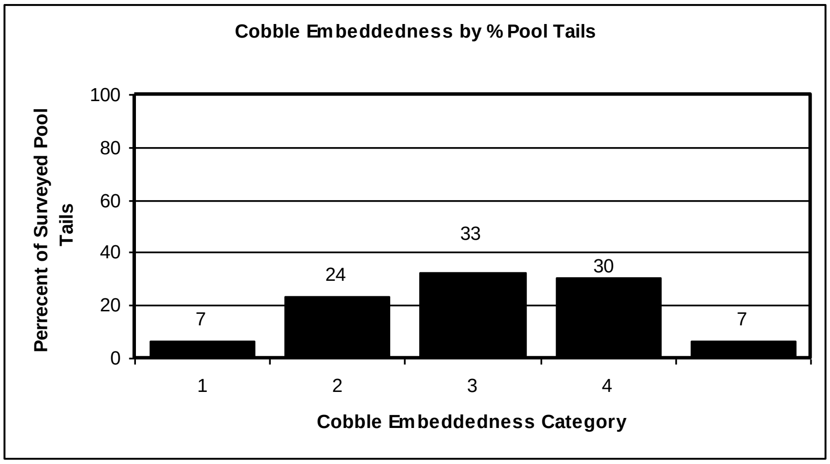

Figure 32. Cobble embeddedness in the Lower Eel Basin.

Cobble embeddedness will not always sum to 100% because Category 5 (not suitable for spawning) is not included.

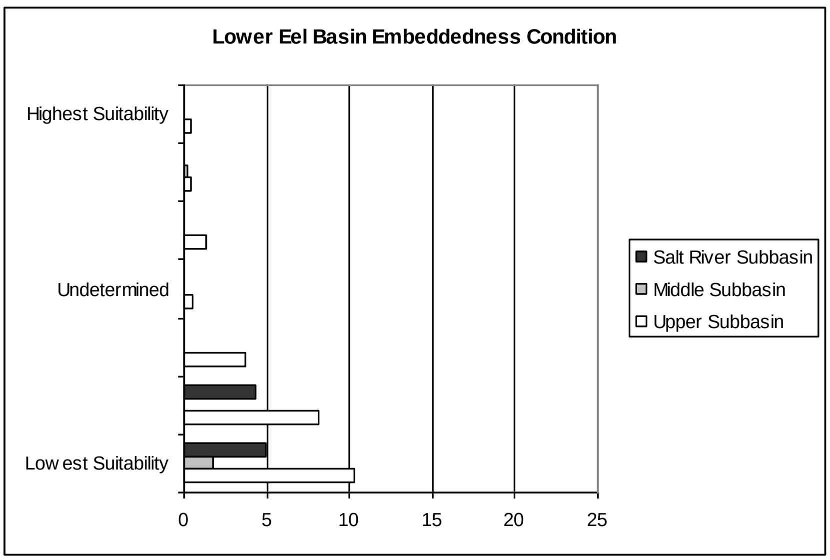

Figure 33. EMDS cobble embeddedness results for the Lower Eel Basin by surveyed stream miles.

Where there was more than one year of survey data, the most recent data was used for this graphic.

Significance: Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments decrease successful spawning and incubation. Cobble embeddedness is the percentage of an average sized cobble piece at a pool tail out that is embedded in fine substrate. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded, and category 4 is 76-100% embedded. Cobble embeddedness categories 3 and 4 are not within the fully supported range for successful use by salmonids. The bar furthest to the right in Figure 32 represents tail-outs deemed unsuited for spawning due to inappropriate substrate like sand, bedrock, log sills, boulders or other considerations.

Findings: Only 7% of pool tails in the Lower Eel Basin have cobble embeddedness in category one, which meets spawning gravel targets for salmonids. Streams miles evaluated as suitable by the EMDS were located in the Upper and Middle subbasins.

LWD

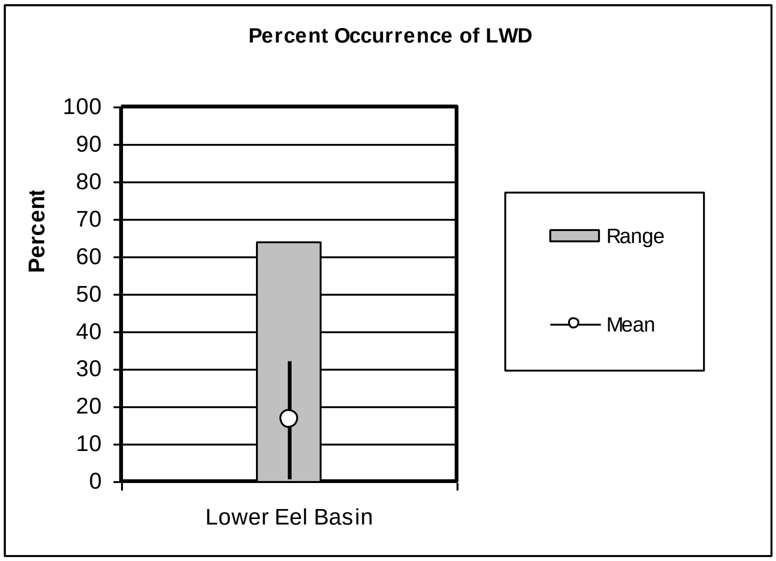

Figure 34. Large Woody Debris (LWD) in the Lower Eel Basin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, etc.) is described in CDFG surveys. The dominant shelter type is determined and then the percentage of a stream reach in which the dominant shelter type is provided by organic debris is calculated.

Significance: Large woody debris shapes channel morphology, helps a stream retain organic matter, and provides essential cover for salmonids. There are currently no target values established for the percent occurrence of LWD.

Findings: The percent occurrence of LWD in a stream as calculated by CDFG in the Lower Eel Basin represents a measure of the amount of woody debris that was found in the wetted width of a stream channel during stream surveys that can be used by fish for cover as compared to other types of fish cover present. The average percent occurrence of LWD for the Lower Eel Basin is 16.4%. The dominant shelter type recorded in most stream reaches was boulders, while small woody debris was the second most common dominant shelter type. This average percent occurrence of LWD is higher than that recorded for the nearby Mattole River Basin (6.6 +/- 6.2 percent).

Barriers

During their freshwater life phases, salmonids need free access to a variety of stream habitats from the headwaters to the mouth, as both migratory corridors and habitat for rearing and spawning. Barriers to migration between these habitats have proved disastrous to salmonid populations throughout their range. Types of barriers include dams, culverts, diversions, flood control channels, flow dynamics, water quality, and natural features such as waterfalls and bedrock chutes. Barriers lead directly to the fragmentation of salmonid habitat and may completely eliminate anadromous salmonids from accessing a stream to spawn.

Twenty structures considered potential barriers to fish passage were evaluated within the Lower Eel Basin, and reported in the Passage Assessment Database (2005) (Figure 35). From this total, sixteen structures were considered partial barriers, meaning they are only barriers to certain species, or life stages; three were considered temporal and/or partial barriers, meaning it is only a barrier to certain species, or life stages, and only at certain times of the year; and another three structures were assessed as total barriers, which is a complete barrier to all anadromous fish species, at all life stages at all times of the year. The majority of these structure barriers are road crossings. In addition to road crossings, four barrier structures are described as flow diversions, two are tide gates, and one is a grade control bedrock chute. Eleven structures were determined to not pose a threat to fish passage, while thirty five are described as "unknown." All of these potential barriers occur in the tributaries and not on the mainstem Eel River. However, the Eel River experiences low flow conditions in the late summer into the early fall, which causes returning adult salmon to hold in large pools in the lower river until sufficient rains increase overall flow conditions. More details about barriers are presented in the subbasin sections of this report.

All tide gates in the Eel River estuary were not evaluated in the fish passage study. The USFWS is currently assessing tide gates in the Humboldt Bay watershed. A similar assessment within the Eel River estuary is both pertinent and necessary, as many of the tide gates are non-operational and may function as barriers to fish migration and lead to loss of high quality estuarine habitat.

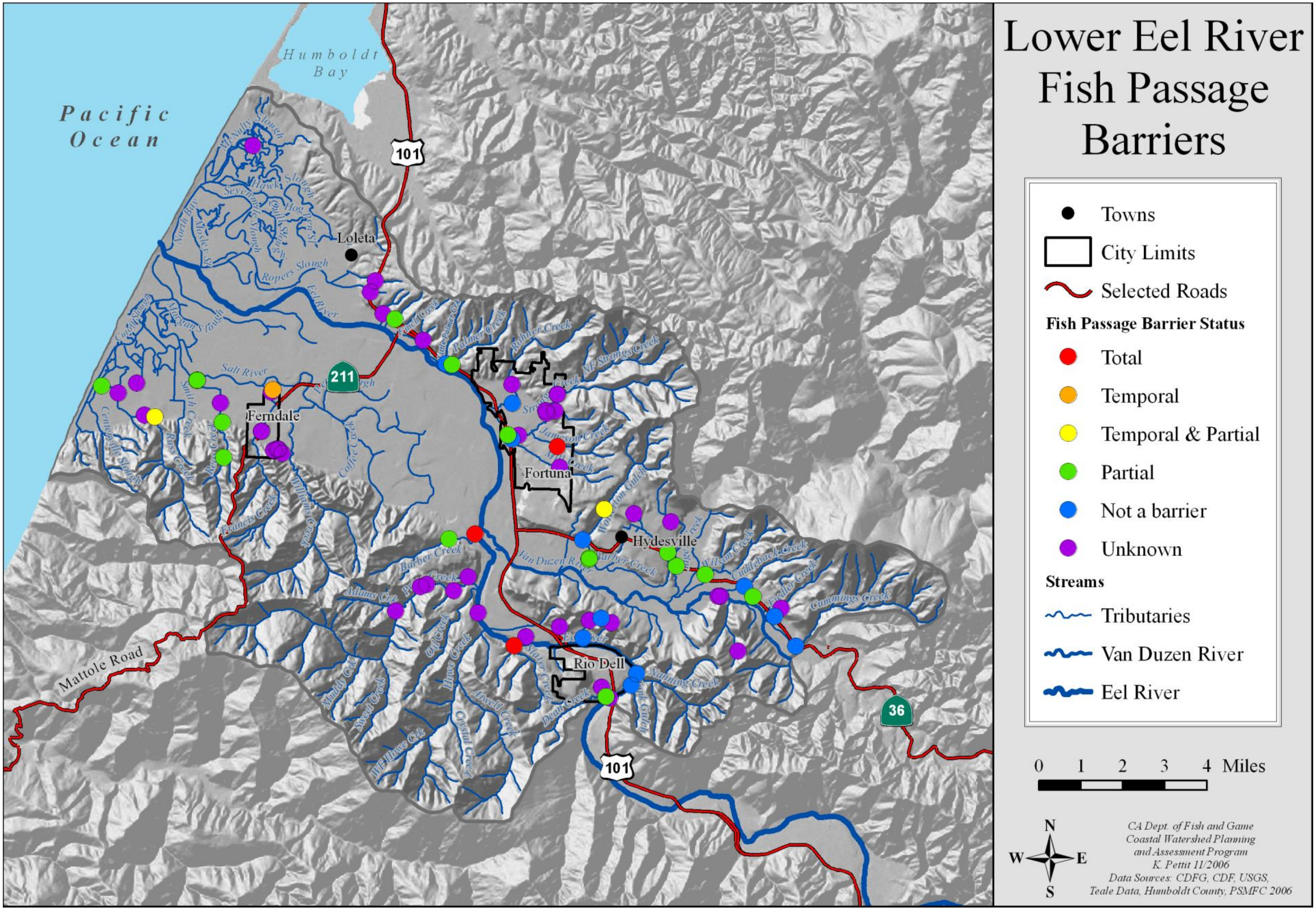

Figure 35. Fish passage barriers in the Lower Eel River Basin.

Water Quality

The EPA has recognized portions of the Lower Eel River watershed as impaired due to sediment and temperature as defined by Section 303(d) of the Clean Water Act. Because of this, the EPA 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 and temperature sources. This 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; those data are presented here.

Beneficial uses related to fisheries that are to be protected by the TMDL process in the Lower Eel and Van Duzen Rivers include:

- Cold freshwater habitat;
- Migration of aquatic organisms;
- Preservation of rare, threatened, or endangered species;
- Aquaculture;
- Commercial and sport fishing;
- Spawning, reproduction and/or early development potential.

In 1992, the Van Duzen River was listed under 303(d) as impaired due to sediment. A sediment source analysis was completed, and results were reported in the Van Duzen River and Yager Creek TMDL in 1999 (PWA 1999). Several beneficial uses were determined to be affected by sediment within the watershed, and were described in the Van Duzen River Basin plan produced by the NCRWQCB. (USEPA 1999)

Water Temperature

The CWPAP has created suitability ranges for maximum weekly average temperatures (MWATs) considering temperature's effect on salmonid viability, growth, and habitat fitness (Table 21). This metric is calculated from a seven-day moving average of daily average temperatures. The maximum daily average is also used here to illustrate possible stressful conditions for salmonids. The instantaneous maximum temperature that may lead to salmonid lethality is ≥75°F.

Table 21. CWPAP-defined suitability ratings for MWATs.

MWAT Range	Description
50-60°F	Fully suitable
61-62°F	Moderately suitable
63°F	Somewhat suitable
64°F	Undetermined
65°F	Somewhat unsuitable
66-67°F	Moderately unsuitable
≥68°F	Fully unsuitable

Water temperatures were continuously measured at 27 locations within the basin (Table 24). The locations of these stations are indicated in the subbasin sections of this report. Data loggers were generally deployed from June through October, and include most years from 1996 to 2005. Background data for temperatures collected in 1996 and 1999 for example site location and condition are incomplete. Because of this, exact locations of temperature loggers are not available, and were derived from recorded field descriptions of the site. Not all sites were sampled in every year; some sites have only one season of data.

In general, most tributaries in each subbasin obtained temperatures within the suitable range, and no seasonal maximum temperatures reached lethal limits. However, 10 locations did record temperatures considered unsuitable in the MWAT range. The highest logged temperatures were recorded in the Middle Subbasin. These data are expected, as three of the five monitors were located in the mainstem. The Upper Subbasin, which was consistently surveyed over the longest period of time, had the highest percentage of tributary locations with data that fell within the unsuitable range. Estuary locations had the greatest MWAT range, with 2 of the 8 stations reaching fully unsuitable temperatures. These data are discussed in further detail in the subbasin profiles.

The USEPA (EPA) has set TMDL targets for temperature in the Lower Eel Basin. The EPA defined the Lower Eel Basin as the area from the confluence with the South Fork Eel River to the ocean, except for the Van Duzen River which is a separate TMDL study area. The EPA concluded that a temperature TMDL was not needed for the main channel of the Lower Eel River. However, the EPA did find that tributary streams did not meet water quality standards for temperature, therefore temperature TMDLs were established to achieve those standards (USEPA 2007).

Table 22. Ranges of MWATs and seasonal maximum temperatures collected throughout the Lower Eel Basin.

Subbasin	Water Body	Number of Sites	Years of Sample	MWAT Range (°F)	Seasonal Maximum Range (°F)
Estuary	Major Sloughs and Mainstem	7	1996, 2005	56-71	57-72
Salt River	Slough and Tributaries	6	2000-2002, 2004	58-74	NA
Middle	Tributaries	2	2002-2003	57-59	58-59
	Mainstem	3	1996	68-72	69-73
Upper	Tributaries	8	1996-2003	59-67	58-68

The EPA set TMDLs based on natural shade for two distinct tributary areas: the tributary reaches in the Salt River subbasin and all the remaining tributary reaches. The shade allocation for tributary reaches for the Salt River subbasin is a 59% reduction of total global solar radiation, or the equivalent of a minimum 59% shade. This is approximately 14% more shading than existed under 2005 conditions. Shade allocation for all remaining tributary reaches is 83% shade (approximately 3% more shading than existed under 2005 conditions) (USEPA 2007).

Water Chemistry

Water quality studies have been undertaken in the basin to address issues associated with the dairy and cattle industry, turbidity and sedimentation, and nutrients. As a follow up to the Animal Waste Assessment Project in the Eel River Delta (Anderson 1997), the Eel River Delta Animal Waste Demonstration Project (Q&A Agriculture Service 2001) monitored water quality at twelve locations: two in the Estuary Subbasin and ten in the Salt River Subbasin. The sites were tested to see if there was any change to water quality after improvements had been made to waste management. Often, due to the season or because the waste was diverted elsewhere, the sites were too dry to test post-project. However, multiple sites showed high levels of ammonia, high pH, and low dissolved oxygen pre-project.

Turbidity and sedimentation have been studied in the Middle Subbasin tributaries, and extensively in the Salt River Subbasin. Turbidity is the muddiness or cloudiness of water caused by individual particles suspended in the water column. These particles will deflect (or scatter) light as it passes through the water. Turbidity increases as more and more light is deflected. Turbidity is often measured by an instrument called a nephelometer, in Nephelometric Turbidity Units (NTU). High turbidities have been associated with negative effects on salmonids (Newcombe and McDonald 1991, Waters 1995). NCRWQB established basin wide regulations that turbidity should not be increased more than 20 percent above naturally occurring background levels (NCRWQCB 2001).

Turbidity and sedimentation have been studied in the Middle Subbasin tributaries, and extensively in the Salt River Subbasin. The Fortuna Creeks Project found that over a six year monitoring period, turbidity levels in Strongs, Mill and Rohner creeks were higher than 30NTUs for most of the year and were associated with high flows. Salmon Forever has been monitoring Francis Creek since January 2007, and preliminary results show maximum turbidity levels have reached 2200NTU during a single storm. Combined with flow data, 2200 NTU is equivalent to 8.5 tons of sediment moving downstream every 10 minutes (Fenton, Salmon Forever, personal communication).

In the Salt River and Estuary subbasins, nutrients were studied to determine the amount of mixing that occurs in the estuary to understand what type of habitat was available throughout the year (i.e. mostly saline, brackish mostly freshwater, or stratified). The estuary appears to be mixing during the dry months and is stratified, or creates a “salt wedge” during wetter months (Gossard 1986). Nutrients were also studied indirectly by the HCRCD via macroinvertebrate surveys. Williams and Francis creeks in the Salt River Subbasin, Strongs Creek in the Middle Subbasin and Cummings, Price, and Howe creeks in the Upper Subbasin were sampled in the spring and fall of 1996. Francis and Strongs creeks scored consistently in the impaired ranges, and Williams, Price and Howe creeks were rated as highly impacted in terms of invertebrate diversity (HCRCD 1998).

The Lower Eel Basin was also listed by the EPA as an impaired water body for sediment (USEPA 2007). Significant sources of sediment found in the watershed included roads, timber-harvest related activities, and natural sources.

A sediment TMDL was set for all stream reaches as equal to the sediment load that corresponds with

125% above natural sediment loading. This was calculated to be 898 tons/square mile/year or 2.5 tons/square mile/day on a 15 year running average (Table 23). Overall these load allocations are a 77% reduction of the sediment loading found in a study of levels from 1955 to 2003 (USEPA 2007).

Table 23. United State Environmental Protection Agency sediment load allocations for the Lower Eel Watershed (USEPA 2007).

Sediment Source		Average Annual		Average Daily		Percent Reduction over 1955-2003 Period
		1955-2003 Loading (tons/square mile/year)	Load Allocation (tons/square mile/year)	1955-2003 Loading (tons/square mile/day)	Load Allocation (tons/square mile/day)	
Natural Load Allocation		718	718	2.0	2.0	0
Road	Episodic	43	9	0.1	0.02	80
	Chronic	115	17	0.3	0.05	85
Timber Harvest		590	147	1.6	0.4	75
Skid trail		7	1	0.02	0.5	90
Bank Erosion		21	6	0.1	0.03	70
Total Human-related Load Allocation		775	180	2.1	0.5	77
Total Load Allocations (Natural and Human)		1,493	898	4.1	2.5	

Although nonpoint sources were found to contribute most of the sediment loading within the watershed, point sources also discharged some sediment. Diffuse permitted sources within the watershed, such as municipal and industrial stormwater discharges, California Department of Transportation facilities construction sites, and municipalities have waste load allocations equivalent to the load allocations for nonpoint sources. For current individual point sources within the watershed, waste load allocations were expressed as total dissolved solids (TSS) in mg/l andsettleable solids in ml/l monthly average concentration (Table 24).

For all of these facilities except for Ferndale, the weekly maximum TSS was set at 45 mg/l and for all facilities the daily maximum TSS was set at 60 mg/l.

Table 24. United State Environmental Protection Agency waste load allocations for non-diffuse point sources in the Lower Eel Watershed (USEPA 2007).

Point Source	TSS (mg/l)	Settleable Solids (ml/l monthly average concentration)
Ferndale	95	0.1
Fortuna	30	0.1
Loleta	30	0.1
Rio Dell	30	0.1
Scotia	30	0.1

The EPA did not set specific watershed indicators for the sediment TMDL in the Lower Eel watershed. However, there are instream indicators with target values (USEPA 2007) (Table 25).

Table 25. United States Environmental Protection Agency sediment indicators and targets for the Lower Eel Watershed (USEPA 2007).

Indicator	Target	Purpose
Substrate composition – percent fines	<14%<0.85 mm ≤30% <6.4mm	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 (also included in Basin Plan)	Indirect measure of fish feeding/growth ability related to sediment, and impacts from management activities
Riffle embeddedness	<25% or improving (decreasing) trend toward 25%	Indirect measure of spawning support; improved quality & size distribution of spawning gravel
Residual pool filling (V*)	<0.21	Estimate of sediment filling of pools from disturbance
Macroinvertebrate community composition	Improving trends	Estimate of salmonid food availability, indirect estimate of sediment quality
Thalweg profile	Increasing variation from the mean	Estimate of improving habitat complexity & availability
Pools	Increasing trend in the number of backwater, lateral scour pools. Increasing trend in the number of stream reaches where the length of the reach is composed of ≥40% in primary pools	Estimates improving habitat availability

Wastewater Treatment Facilities

There are five wastewater treatment facilities that discharge into the Lower Eel Basin:

- Humboldt Redwood Company;
- The City of Rio Dell;
- The City of Fortuna;
- Humboldt Creamery Association;
- Loleta Community Services District; and
- The City of Ferndale.

In this report we will include the Humboldt Redwood Company treatment facility in Scotia because of its proximity to, and direct influence on, the Lower Eel Basin.

There are no tertiary treatment facilities in the Lower Eel Basin; all wastewater receives secondary treatment only. All six of these facilities are permitted and regulated by the NCRWQCB which enforces federal and state water quality requirements. Permit renewal for surface water discharge occurs every five years as required by the federal Clean Water Act, and groundwater discharge, regulated by state law, is reviewed less frequently. When facilities are re-permitted, requirements on the facility, operations, and monitoring may be amended. A Cease and Desist order may be used to require upgrades between permitting cycles.

The water quality standards used for regulating these wastewater treatment facilities are based on protecting the beneficial uses of the receiving water bodies as determined by the NCRWQCB (NCRWQCB 2006d). An amendment to this region's Basin Plan has been drafted that would take into account the biological requirements of anadromous salmonids in discharge restrictions. The proposed amendment would revise the existing objectives for water temperature and dissolved oxygen to meet requirements of the federal and state Endangered Species Act and the Porter Cologne Water Quality Control Act. The amendment must be approved by the State Water Board before being implemented (draft document summary available at: http://www.waterboards.ca.gov/northcoast/waterissues/programs/basin_plan/basinplan.shtml).

To preserve the beneficial uses of the Eel River, direct surface water discharge may only occur between October 1st and May 14th. During the summer these facilities must use percolation ponds or other terrestrial discharge sites. The wastewater treatment facilities in Scotia and Rio Dell have recently received new permits, and Fortuna's permit was recently drafted and went into effect June 2007. These three facilities discharge summer waste onto gravel bar percolation ponds located adjacent to the Eel River. The new permits prohibit this practice and require an alternative by the next permit cycle. Additionally, all new permits will now require monitoring of receiving waters to ensure that effluent regulations are effective in preserving water quality. Permits for Humboldt Creamery were adopted in September, 2008; the Loleta wastewater treatment facility will be drafted and implemented in 2009. The Ferndale facility is in the process of complying with a Cease and Desist order and will likely be re-permitted once it reaches a resolution. More detail on each of these facilities is presented in the subbasin sections of this report.

Storm water is also regulated by the NCRWQCB and requires individual permits for any construction or industrial site greater than one acre and municipal permits for cities with populations of 10,000 or greater. Fortuna is the only municipality in this basin that has a city-wide storm water management plan. Storm water runoff can be a major source of pollutants and sediment that impair surface waters.

Conclusions and Limiting Factors Analysis

Although instream habitat conditions for salmonids varied across the Lower Eel Basin, several generalities can be made (Table 29, Figure 36). In general, canopy conditions in the basin are evaluated as suitable in surveyed streams across the basin. However, current canopy density measurements do not take into account differences between smaller, younger riparian vegetation versus the larger microclimate controls that are provided by old growth forest canopy conditions. Water temperature measurements, although not currently evaluated by the EMDS, showed that three tributaries and three locations on the mainstem Eel River and two locations in the estuary had temperatures unsuitable for salmonids. Therefore, water temperature is likely a limiting factor for salmonids at these locations.

Pool quality, pool depth, pool shelter, and cobble embeddedness were generally evaluated as unsuitable across surveyed streams in the basin–thus these habitat factors are likely limiting to salmonid populations.

Fish passage barriers are not currently evaluated by the EMDS. There are sixteen known partial barriers to salmonid passage in the basin and these barriers are likely limiting salmonid production.

Macroinvertebrate data indicate that creeks in the Salt River and Upper subbasins are highly impacted systems. Additionally, farm waste water quality problems have been identified in the Salt River Subbasin and conductivity, turbidity, and dissolved oxygen may be limiting factors in the Middle Subbasin. Therefore, water quality is likely a limiting factor, specifically nutrient enrichment, excess sediment, and dissolved oxygen.

Table 26. EMDS Anadromous Reach Condition Model results for the Lower Eel Basin.

Subbasin	Canopy	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Salt River	+	--	--	---	--
Middle	++	--	-	---	--
Upper	+	--	--	---	--

Key: + ++ +++ = Highest Suitability U = Insufficient Data or Undetermined - -- --- = Lowest Suitability

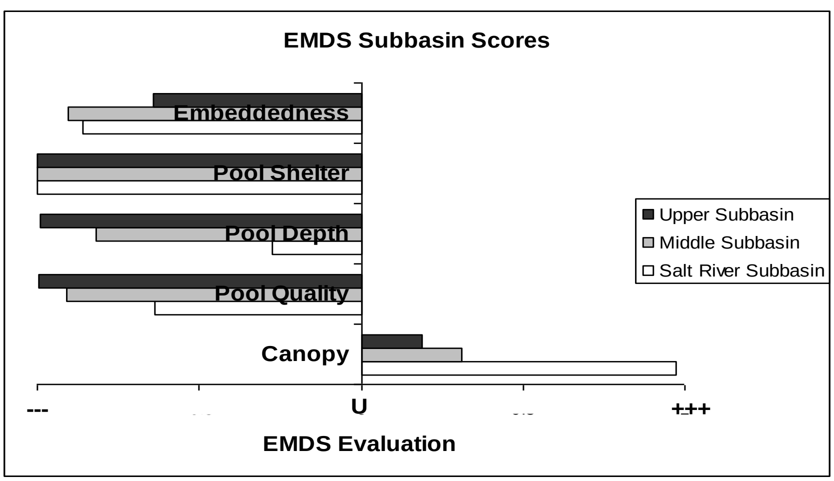

Figure 36. EMDS truth values for the Lower Eel Basin by stream miles.

Table 27. Findings of CDFG habitat inventories for streams in the Lower Eel Basin, and associated target values.

Stream	Survey Year	Survey length (miles)	Mean Canopy Density (%)	Category 1* Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Shelter Cover Rating
TARGET VALUES			>80	>50	>40	>100
Estuary Subbasin						
No surveys were conducted in the Estuary Subbasin						
Salt River Subbasin						
Francis Creek tributary	2003	0.2	92	0	2	24
Russ Creek	2004	2.2	79	0	16	79
Francis Creek	2003	2.7	87	3	14	32
Williams Creek	2003	4.1	63	14	26	34
Middle Subbasin						
Mill Creek	2004	0.2	80	33	3	27
North Fork Strongs Creek	1993	1.2	93	0	31	55
Strongs Creek	1993	0.6	90	0	29	52
Upper Subbasin						
Muddy Creek	2002	0.8	82	13	1	32
Adams Creek	2002	0.8	88	4	0	20
West Fork Howe Creek	1998	0.4	86	0	<1	8
Oil Creek	1999	0.8	83	0	18	90
	2002	0.5	94	73	19	44
Crystal Creek	2002	0.5	77	0	0	40
Wilson Creek	1991	0.5	80	<1	0	27
Sweet Creek	1999	0.9	60	0	0	43
Dean Creek	1992	1	94	<1	3	45
Wolverton Gulch	1997	2.5	89	0	7	25
Nanning Creek	1992	1.4	71	0	3	58
Atwell Creek	1993	1.6	95	2	8	33
	1998	2.4	83	2	10	22
Cummings Creek	1991	3.4	70	<1	3	66
	1996	2	77	0	3	27
Howe Creek	1998	4	57	2	3	14
Price Creek	1999	6.9	52	12	4	45

Fish Restoration Programs

Restoration efforts throughout the Eel River Basin have been ongoing since the early 1970s. Like many other areas in the region, early efforts included removal of large debris accumulations, small hatchery operations, and riparian tree planting and were largely volunteer (Trees Foundation website). Restoration efforts are now more diverse, inclusive, and better funded. Since 1981, CDFG's Fisheries Restoration Grants Program (FRGP) alone has invested 22.5 million dollars in projects improving watershed conditions in the Eel River Basin (Williams 2007). Currently, within the Lower Eel Basin, watershed improvement projects range from public education to barrier modifications to scientific environmental assessments to instream structure placement and are found throughout the basin.

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 FRGP projects and other projects with which CDFG has been involved. The CHRP data is available through CalFish (www.calfish.org) and has included some projects from agencies and programs outside of CDFG. 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 (Table 28).

Table 28. Lower Eel Basin projects by subbasin and restoration categories, 1981–present (CHRPD, NRPI).

Number of projects that include this type of restoration (many projects contain more than one)	Subbasin				Total Number of Projects that include this restoration type (projects will be represented in more than one restoration type)
	Estuary Subbasin	Salt River Subbasin	Middle Subbasin	Upper Subbasin	
Road and Stream Crossing Upgrades		1		63	64
Bank Stabilization		5		53	58
Livestock Exclusion	1	2		46	49
Instream Habitat Improvement			1	37	38
Assessments and Studies	1	20	1	12	34
Re-vegetation	2	4	1	27	34
Public Involvement	2	5	9	7	23
Upslope Management			5	13	18
Fish Passage Improvements			2	3	5
Land Acquisition				1	1
Total Projects	4	28	18	177	
Ongoing Projects as of 2007 (included in Total)	1		5	60	

Three quarters of the restoration projects in the basin have focused on the Upper Subbasin (Figure 37). The Upper Subbasin is the largest subbasin and it has had a large amount of improvement work done associated with the progressive management of Howe Creek Ranch. Many of the issues that the Lower Eel Basin faces relate to high sediment loads, so it is not surprising to see road and stream crossing upgrades are included more times (64) in restoration projects than any other type (Table 28). Under-maintained dirt roads are common throughout most of the subbasins and are a major sediment source. The next most common restoration activities are bank stabilization and livestock exclusionary fencing. These also address sediment input issues and occur 58 and 49 times, respectively, in restoration projects throughout the basin.

Assessments and public involvement projects are not displayed on the map (Figure 37) but make up a large part of the restoration efforts in the basin. Assessments include surveys and studies to determine fish passage barriers, sediment sources and water quality among other parameters and are included in 34 separate restoration projects. Two thirds of these studies and assessments have been conducted in the Salt River Subbasin–mostly to address drainage and fish passage issues. Public involvement can include education, public workshops, and outreach in general and is included in 23 separate restoration projects.

In the Lower Eel Basin, public outreach is focused in the largest population center, Fortuna, and also in the Salt River Subbasin where the impaired state of the watershed affects the majority of the community, including Ferndale.

In addition to the projects listed above that have received funding, many more restoration efforts are occurring throughout the basin as landowners seek to preserve or repair the natural integrity of their property. More detail on the projects that have received funding can be found in the subbasin sections of this report.

Wildlife Habitat Relationships

The value of the Eel River Delta for fish and wildlife is high because of the diversity of habitat types, such as shallow water bays, deep water sloughs, freshwater marshes, salt marshes, tidal mudflats, riparian woodland, sand dunes, gravel bars, well drained pasture, and poorly drained pasture (Monroe et al. 1974). Many of these natural habitat types have been significantly reduced in size and function.

The Eel River Delta is home to more than 200 bird species (resident and migrant), 61 species of mammals, 15 species of crustacean, 40 species of fish, 7 amphibians, and 170 plant species (Gilroy 2002; Bivin, Eicher 1991). The Eel River Delta also serves as an important stopover on the Pacific Flyway for migratory waterfowl, shorebirds, wading birds, and other water-associated birds (Monroe et al. 1974).

The Eel River Delta has a growing residential population, which is concentrated in the communities of Fortuna, Ferndale, Loleta, and Fernbridge. Land area in the Eel River Delta is largely privately owned and predominantly dedicated for agricultural purposes.

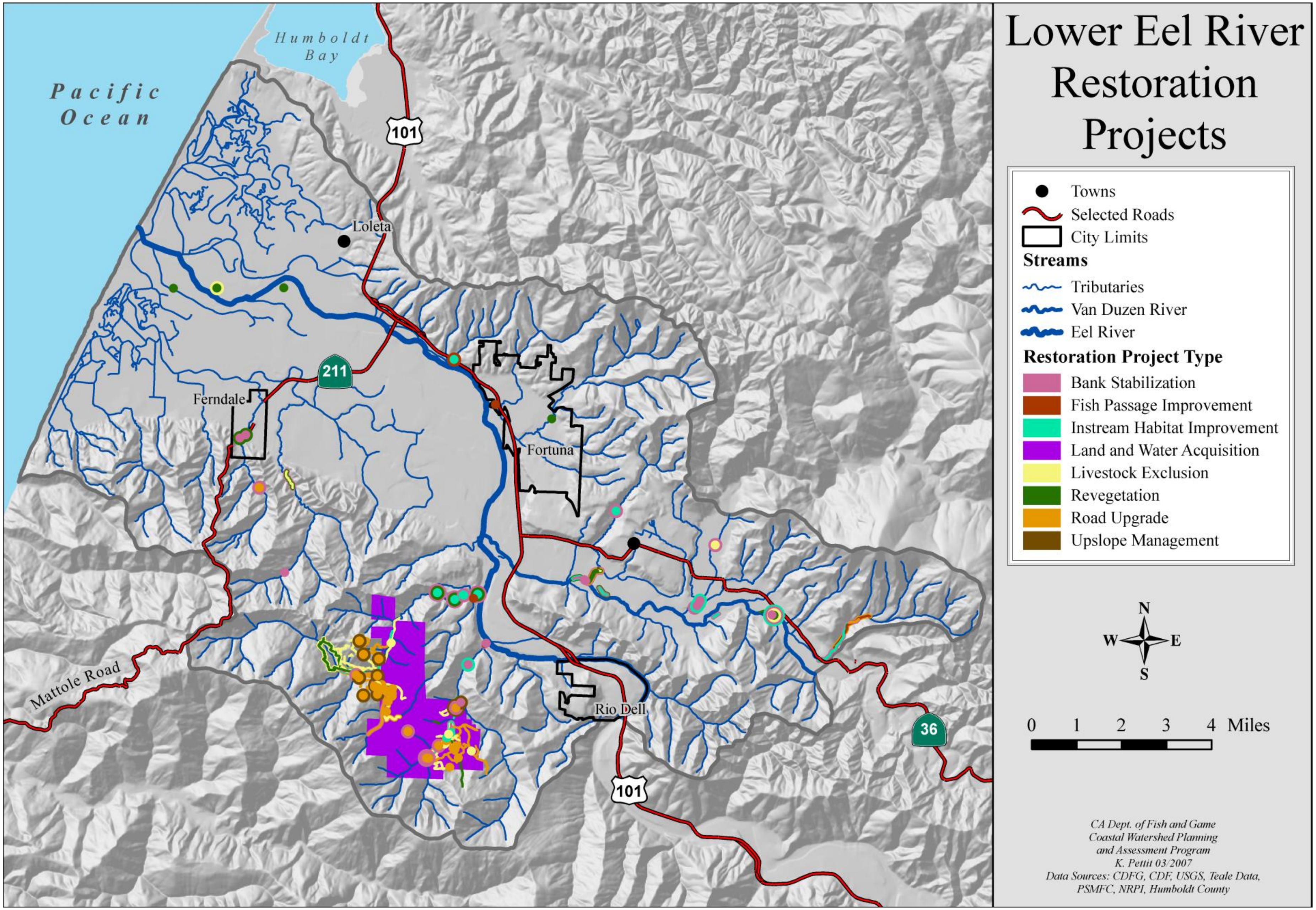

Figure 37. Lower Eel restoration projects locations.

Integrated Analysis

Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFG stream inventories provide a list of recommendations that address those conditions that did not reach target values (see Basin Fish Habitat Section). In the Lower Eel Basin, 24 surveys were conducted on 21 streams, and recommendations for each were selected and ranked by a CDFG biologist (Table 29). The tributary recommendation process is described in more detail in the Fish Habitat Relationship section of each subbasin.

In order to compare tributary recommendations within the basin, the recommendations of each stream were collapsed into five target issue categories (Table 30).

The top three recommendations of each stream are considered to be the most important, and are useful as a standard example of the stream. When examining recommendation categories by number of tributaries, the most important target issue in the Middle and Upper subbasins is Erosion/Sediment (Table 31).

However, comparing recommendation categories between subbasins can be confounded by the differences in the number of tributaries and the total length of survey in each. Therefore, the number of stream miles within the subbasin assigned to various recommendation categories was calculated (Figure 38). Erosion/sediment is the most important target issue, both in each of the subbasins, as well as for the basin as a whole. At the basin-level instream habitat and riparian/water temperature were each also important target issues.

Table 29. Occurrence of recommendations in the first three ranks in surveyed streams.

Subbasin	Number of Surveys	Survey Length (miles)	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Live-stock	Fish Passage
Salt River	4	9.2	2	1	1	0	2	3	0	0	0	1
Middle	3	2	2	2	1	0	0	0	0	2	1	1
Upper	17	30.3	12	7	3	2	11	7	1	4	1	1
Lower Eel Basin	24	41.6	16	10	5	2	13	10	1	6	2	3

Table 30. 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 31. Distribution of basin-wide recommendation target issues in the Lower Eel River Basin.

Subbasin	Erosion/ Sediment	Riparian/ Water Temperature	Instream Habitat	Gravel/ Substrate	Other
Salt River	3	1	5	0	1
Middle	4	1	0	2	2
Upper	19	5	18	5	2
Lower Eel Basin	23	6	18	7	4

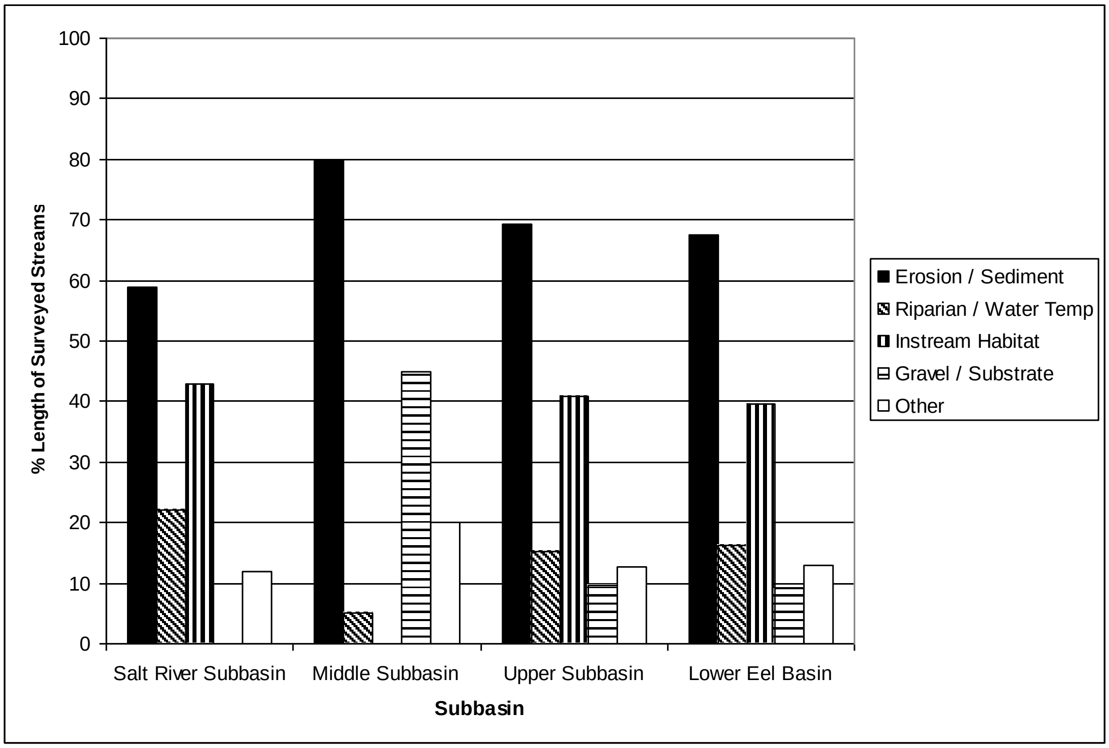

Figure 38. The frequency of recommendation target issues in Lower Eel River Basin surveyed streams.

Refugia Areas

The CWPAP interdisciplinary team identified and characterized refugia habitat in the Lower Eel Basin by 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, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. The team also used results from information processed by the EMDS at the stream reach scale.

The most complete data available in the basin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered by the CWPAP team. Salmonid habitat conditions in the Lower Eel Basin are generally better in the Middle and Upper subbasins. The Estuary Subbasin and the Salt River Subbasin, below Reas Creek (RM 3.4) provides critical estuarine rearing habitat. The remaining portion of the Salt River Subbasin provides low quality refugia (Table 32. Figure 40).

Table 32. Subbasin salmonid refugia area ratings in the Lower Eel Basin.

Subbasin	**Refugia Categories:**				**Other Categories:**		
	High Quality	**High Potential**	**Medium Potential**	**Low Quality**	**Non-Anadromous**	**Critical Contributing Area/Function**	**Data Limited**
Estuary						x	
Salt River				x			x
Middle			x				x
Upper			x				x

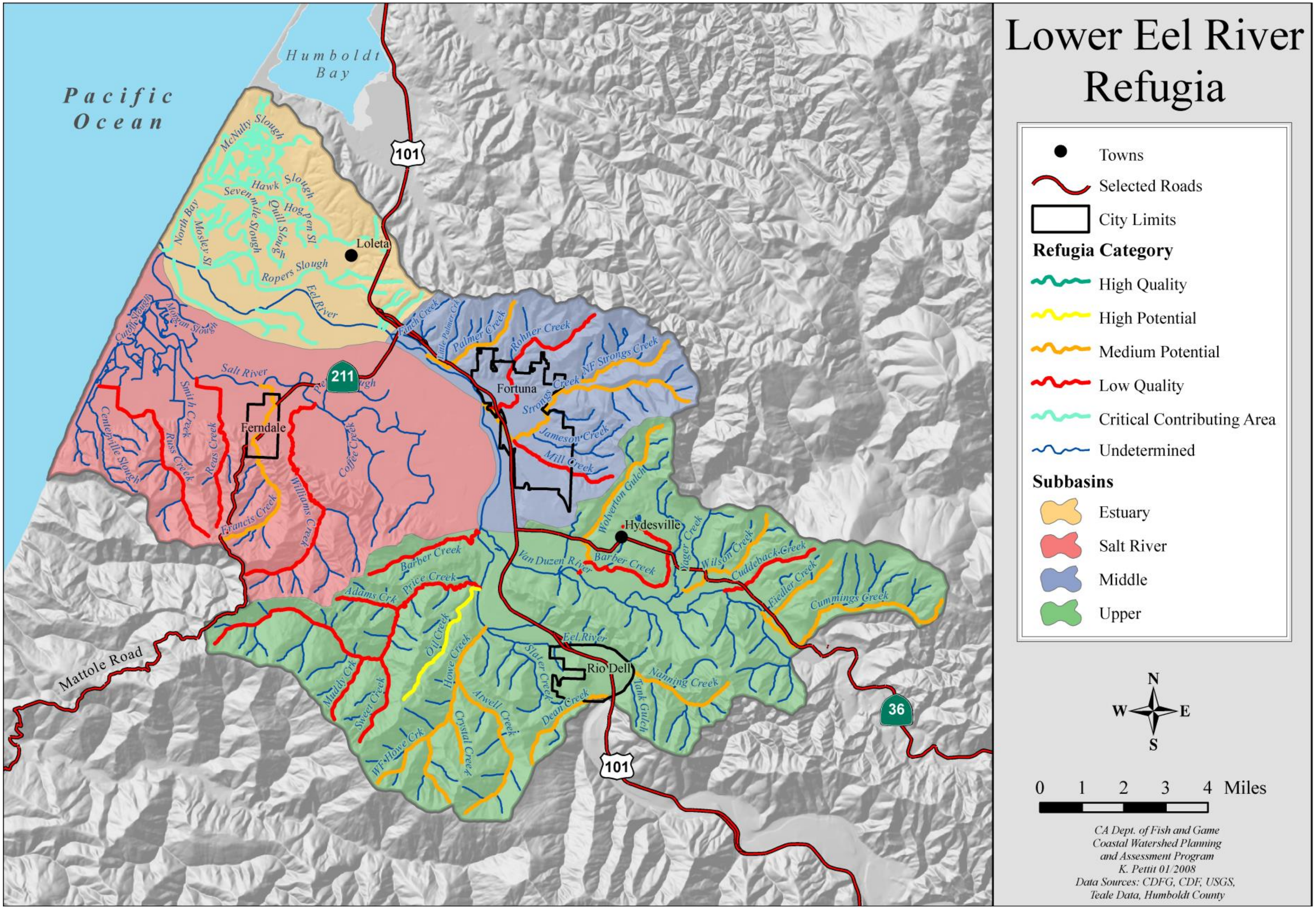

Figure 39. Stream refugia in the Lower Eel Basin.

Key Basin Issues

- The morphology of the Lower Eel River Basin has been changed due to erosion and aggradation;
- Historic and current land use has altered 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 Lower Eel River Basin?

Findings and Conclusions:

- Historical accounts of the recreational fishery in the Eel River estuary describe excellent salmon and steelhead fishing over the entire delta, with anglers gaining access to catch "from boat to shore" (Haley 1970). Large commercial harvest of salmon and steelhead were taken from the estuary from 1860 to 1926. The commercial fishery has been eliminated and the recreational fishery has been significantly reduced and is now catch and release only (zero bag limit);
- The 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;
- Salmon populations are considerably smaller and less well distributed compared to historic range. Coho salmon have been documented in 13 tributaries across the basin and Chinook salmon in six tributaries. Steelhead trout have been documented in 21 tributaries and cutthroat trout in eight tributaries. In addition, all four species of salmonids use the mainstem Eel River and estuary as critical migration routes and use the estuary as rearing habitat;
- These remaining populations are critical to recovery of salmon and steelhead along the entire North Coast;
- The most comprehensive studies of the estuary were year-long investigations preformed in 1951, 1977, and 1995. These studies indicate the presence of juvenile Chinook salmon from spring to fall (March through November), coho salmon from spring through summer, and year-round presence of steelhead. Adult Chinook salmon and steelhead hold in the estuary until sufficient flows allow upstream migration in the fall;
- Three tributaries in the Middle Subbasin have been inventoried in 1993 and 2004 by CDFG. These data have confirmed, in addition to other fish studies, the presence of coho salmon, steelhead, and coastal cutthroat, among other species. Some historical and anecdotal accounts (dating back to the early 1950s) list the presence of these salmonid species in several Middle Subbasin tributaries;
- Stream inventories conducted by CDFG on fourteen tributaries in the basin between 1991 and 2002, as well as other fish sampling data, have documented the presence of Chinook salmon, coho salmon, and steelhead. Historical recorded data show that these salmonid species were being collected in fish rescue operations in the late 1940s;
- Coastal cutthroat trout were present in a 1984 survey of Centerville Slough, a tributary to the Salt River, indicating presence in the Eel River estuary. Cutthroat trout have also been observed during surveys of the Middle Subbasin between 1984 and 1995, but have not been confirmed present in the Upper Subbasin. The Eel River is the current southern extent of coastal cutthroat trout (Miller and Lea 1972);
- Tidewater goby, a species listed as endangered under the federal Endangered Species Act (ESA), were collected by the United States Fish and Wildlife Service in an unnamed slough of the Eel River estuary near Cannibal Island in August 2004;

- Sacramento pikeminnow, which were introduced into Lake Pillsbury in 1979, have been observed in many surveys of the Lower Eel River Basin from the estuary to RM 21 at Scotia. Pikeminnow predate on juvenile salmonids, particularly outmigrating salmonids (Moyle 2002);
- The Salt River Subbasin once supported populations of coho salmon, Chinook salmon, steelhead, and coastal cutthroat. Recent surveys have found small numbers of these salmonids in a more limited distribution than in the past.

What are the current salmonid habitat conditions in the Lower Eel River Basin? How do these conditions compare to desired conditions?

Findings and Conclusions:

Flow and Water Quality

- Stream and tidal flow has been altered by tide gates and levees constructed along streams and slough channels;
- Water quality is being impacted by cattle waste in estuary sloughs and in streams of the Middle and Upper Subbasins;
- Low summer flows may be stressful to salmonids and dry or intermittent reaches on the Van Duzen River prevent connection with the Eel River and impede passage to spawning grounds;
- In 1992, the EPA listed the Lower Eel River as impaired due to elevated sedimentation/siltation and temperature. The NCRWQCB has continued to identify the basin as impaired in subsequent listing cycles, the latest in 2006;
- Turbidity levels are high during winter rains, which correspond to salmon spawning season.

Erosion/Sediment

- Excessive sedimentation within the watershed has resulted in an overall loss of rearing and feeding habitat for salmonids within the estuary;
- The Van Duzen River is usually isolated from the Eel River by subsurface flows in late summer and early fall due in part to increased bedload materials at the confluence;
- Livestock have unrestricted access to many of the Lower Eel River tributaries and estuary sloughs, resulting in stream bank erosion;
- Soils in surveyed reaches of streams in the Lower Eel Basin are prone to erosion, and slides have been observed to contribute fines to the streams.

Riparian Condition/Water Temperature

- Much of the Lower Eel Basin has been cleared of riparian vegetation to create pasture land for cattle;
- Though water temperatures in CDFG surveyed reaches of streams in the Lower Eel Basin were suitable for salmonids, water temperature data are limited, and therefore inconclusive;
- Water temperatures of the mainstem collected by the Humboldt County Resource Conservation District (1998) in the summers of 1996 and 1997 within the basin, found unsuitable conditions for salmonids (maximum temps ranged from 73ºF–77ºF);
- Water temperatures collected by the Fortuna Creeks Project over a six-year sample period demonstrate stressful (above 68ºF) and occasionally lethal (above 75ºF) conditions, particularly on Rohner Creek;
- The majority of the surveyed tributary reaches in the Lower Eel Basin (70%) met the target value of 80% canopy coverage, but lack larger conifer overstory.

Instream Habitat

- Quality pool structure is generally lacking in streams throughout the basin; no surveyed streams met standards for pool shelter. Eight of the seventeen reaches surveyed obtained ratings considered fully unsuitable;
- On average, pool depths were considered poor for salmonids in all CDFG surveyed streams in the basin;
- Large woody debris is generally lacking in many areas of the basin.

Gravel/Substrate

- Due to increased sedimentation, stream beds have been described as heavily silted in many CDFG habitat inventories throughout the basin;
- Only 7% of pool tails in the Lower Eel Basin have cobble embeddedness in category one, which meets spawning gravel targets for salmonids;
- Areas of suitable spawning gravel are very limited throughout the Basin.

Refugia Areas

- The Middle and Upper subbasins provide medium potential refugia;
- The Salt River Subbasin provides lower quality stream refugia;
- The Estuary Subbasin and lower 3.4 miles of the Salt River provides critical estuarine rearing habitat for juvenile salmonids and other valuable fishery resources.

Other

- When flows are sufficiently high, the Eel River floods into treatment ponds of the Fortuna Wastewater Treatment Plant;
- A culvert on Mill Creek, tributary to Strongs Creek, in the Middle Subbasin does not meet CDFG and NOAA Fisheries fish passage guidelines. Other creeks with possible fish passage problems include Palmer Creek, Dean Creek, Price Creek, Adams Creek, and Barber Creek on mainstem Eel (RM 10).

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

Findings and Conclusions:

- The Lower Eel 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 Eel River has been drastically altered due to excessive sedimentation, which can exacerbate flood events;
- The floods of 1955 and 1964 catastrophically 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 compression generated by convergence between the Gorda and North American Plates, underplating and accretionary tectonics along the Cascadia Subduction Zone and further enhanced by accelerated uplift from the encroaching Mendocino Triple Junction;
- Estuarine conditions extend from the mouth to Fernbridge (RM 7); tidal influence, evidenced by water movement, continues beyond this point, possibly to the mouth of the Van Duzen River;
- The basin’s vegetation has been historically and is currently composed of primarily coniferous forest,

predominantly of the Redwood Alliance. However, on all surveyed tributaries in the Upper Subbasin, deciduous canopy was more prevalent than coniferous. Reclaimed pasturelands are now also prevalent in the basin.

How has land use affected these natural processes and conditions?

Findings and Conclusions:

- Tideland reclamation and the construction of dikes and levees for agricultural purposes have changed the natural function of the estuary considerably. Slough and creek channels that once meandered throughout the delta are now confined by levees, sufficiently slowing flow to a point that many have become filled with sediment. Remnant slough channels are visible throughout the delta. It is generally accepted that the estuary and tidal prism has been reduced by over half of their original size;
- Riparian vegetation in the basin was cleared, and salt marsh vegetation was converted in order to create pastures for cattle. This change in species of grass has reduced the strength of prairie vegetation, causing soils to be more susceptible to slumping;
- Wastes from the dairy industry, as well as urban storm runoff have affected the water quality;
- 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;
- Projects related to the expansion of Fortuna's urbanization have adversely affected the area's streams in both water quality and riparian and instream habitats;
- Because of the geologic characteristics within the Lower Eel, the basin is affected by highly variable runoff rates. Disturbance of the basin's already unstable soils by landuse activities has disturbed 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 Lower Eel 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;
- A shortage of areas with suitable spawning gravel in tributaries;
- Decreased channel capacity;
- A lack of pool shelter and pool-forming LWD;
- Loss of estuarine habitat;
- Competition with 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>

- Increase the tidal prism to help maintain existing channels and help remove excessive fine sediment accumulations;
- Where feasible, livestock management fencing should be placed in areas where cattle have unrestricted access to streams;
- Protect summer stream flows from diversion.

Erosion and Sediment Delivery Reduction Activities

- The impact of property subdivision on streams of Lower Eel Basin should be minimized through the use of better land management practices;
- Conduct an upslope erosion inventory on streams in the Middle and Upper subbasins 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 within the basin;
- Encourage the use of cattle exclusion fencing along streams where livestock have unrestricted access;
- Opportunities to acquire conservation easements should be examined.

Riparian and Habitat Improvement Activities

- Identify and prioritize locations within the delta where vegetation can be returned to salt tolerant species, thus increasing salt marsh around slough channels and providing a buffer to adjacent lands during inundation;
- Develop a grading ordinance to protect riparian vegetation. Ripparian buffer should be allowed to grow/re-grow along estuarine channels;
- Programs to increase riparian vegetation should be implemented in streams where shade canopy is below target values of 80% coverage. Additionally, those streams that are vegetated with exotic species should be considered for native plant restoration;
- In order to protect riparian vegetation, and decrease stream bank erosion due to unrestricted access of cattle to streams, use of livestock management fencing should be prescribed;
- In creeks where fish spawning and rearing habitat is limited, pool enhancement and instream structures should be added to increase complexity;
- 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 removed where appropriate.

Education, Research, and Monitoring Activities

- Improve educational outreach to community;
- Encourage and partner with Fortuna Creeks Project's urban stream clean-up, habitat restoration and monitoring;
- Conduct an inventory of tide gates and levees in the watershed;
- Where necessary, identify barriers to fish migration in the form of large debris accumulations, culverts, etc. and modify them;
- Support the HCRCD in its efforts to monitor and improve habitat and water quality in the basin;
- Because water quality data are limited, monitoring of summer water temperatures should be preformed over at least a three to five year period;
- Water quality data, including temperature and dissolved oxygen, should be consistently collected

throughout the year, for several years, in order to accurately characterize conditions in the streams. Salinities should be collected in the estuary and upstream to determine the extent of brackish conditions;

- Conduct habitat and fish inventories on urban streams of the Middle Subbasin, including Palmer, Jameson, and Rohner Creeks and unnamed tributaries to Strongs Creek;
- 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 Game's Coastal Watershed Planning and Assessment Program considered a great deal of information regarding basin processes related to stream conditions in the Lower 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 data base 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 Lower Eel River Basin contains runs of Chinook and coho salmon and steelhead and coastal cutthroat trout. 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 vitality of salmonid resources of the Lower Eel Basin. These include efforts of local interest groups and programs that provide public education and develop additional concern and actions to preserve one of the most valued assets of Fortuna's urban creeks and the other streams of the Lower Eel River.

Located within the basin is the Eel River estuary, which is a critically important nursery serves as rearing and transition habitat for juvenile and adult salmonids and other valuable fishery resources. Nine fish species that utilize the estuary receive protection under the Federal or State endangered species acts, emphasizing the significance of this unique ecosystem.. Cumulative effects from land use actions in the Eel River Basin and within the estuary coupled with dynamic flood events have altered the morphology of the estuarine channels. The result is a reduction of valuable habitat area, loss of unique habitat complexity and degraded habitat quality for fishery and wildlife resources. The gain of tidal prism by re-establishing functional wetlands is likely the most feasible and practical action to achieve immediate benefits to increase productivity and restore fishery habitats.

The fishery resources in the rest of the basin have also been adversely impacted by land use and resource development. These streams historically provided important spawning and juvenile rearing grounds that enabled salmon and steelhead populations to thrive in the past. 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. Riparian habitats have been reduced or removed due to agricultural activities and urban development. Moreover, road building as a result of the development and expansion of the city of Fortuna created fish passage barriers, some of which have yet to be properly addressed through mitigation.

Diminishing runs of salmon and steelhead in the Lower Eel River Basin streams are highly susceptible to being reduced to remnant populations. Regulations developed over the years to help protect the basin's salmonid stocks, water resources and associated stream habitats have not provided sufficient protection, been loosely enforced, or in some cases were ignored altogether. While restoration efforts have helped improve certain areas within the basin, they have not been on a 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 range. The Lower Eel River Basin contains critical habitat and runs of salmonids to help in the state wide recovery of salmonids. Basin-wide concerted efforts are needed to improve/expand spawning and rearing habitat for salmonids as well as overall ecosystem function of the lower Eel River watershed.

Estuary Subbasin

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Estuary Subbasin

Eel River estuary downstream from Fernbridge (RM 7).

Introduction

The Eel River estuary is located approximately 13 miles south of Eureka in Humboldt County. The Estuary Subbasin includes approximately 24 square miles of delta wetlands, pastures and hillsides that form the Hawk Slough and portions of the Salt River and Palmer Creek CalWater 2.2 Planning Watersheds (Figure 1). Fernbridge, at river mile (RM) 7 is located at the upper extent of the Estuary Subbasin channel. Elevations in the subbasin range from sea level at the river mouth to approximately 700 feet in upland areas near Table Bluff. Most of the delta lands are relatively flat. The town of Loleta is located at the base of rolling hills at an elevation of approximately 50 feet above sea level. The location of Loleta helps prevent the town from flooding during large winter storms that periodically inundate the delta lands. The Estuary Subbasin does not include the Salt River or its tributaries. The Salt River watershed, although hydrologically connected to the Eel River estuary, is treated as a distinct assessment subbasin in this report.

Hydrology

The Eel River estuary is a sand bar built estuary that typically remains open to tidal exchange year-round. Tides are mixed diurnal, with two lows and two highs of unequal size generally occurring within a 24-hour period. Because of the influence of tides, estuaries are mixing zones where freshwater and sea water meet. More specifically, Cowardin et al. (1979) defines estuaries as tidal habitats and adjacent tidal wetlands that are semi-enclosed by land and have open access to the ocean, with ocean-derived water at least occasionally diluted by freshwater runoff from the land. The upstream limit of estuaries can be defined where salinity measures less than 0.5 parts per thousand (ppt) during the period of average annual low flow (Day et al. 1989). By this definition, the Eel River estuary extends inland to at least Fernbridge where salinities of 2-11ppt. have been measured (Cannata 1995). The pulse of high tides can be observed above Fernbridge and it has been noted that the affect of tides can extend to the confluence with the Van Duzen River (Van Kirk 1996). There is a lag time of approximately one hour for high tides to extend from the river mouth to Fernbridge.

The Estuary Subbasin contains five freshwater tributaries connected to 30 miles of named slough channels. Another 30 miles of unnamed sloughs (shown on USGS topographic maps) meander throughout its floodplain (Table 1). Tidal flows are contained on major sloughs by levees and tide gates built by settlers to the area in the latter 1800s and early 1900s. Thus natural tidal connectivity and drainage patterns between slough channels, freshwater streams and their adjacent wetlands have been altered for many decades by the levee and tide gate systems.

The estuary receives runoff from approximately 3,500 miles of stream channels that drain nearly 3,700 square miles of the mountainous Eel River Basin. Stream flows into the estuary are measured at the USGS gauging station at Scotia. Mean annual discharge to the estuary is approximately 5.4 million acre-feet. The highest recorded annual discharge into the estuary was 12.6 million acre feet in 1983 and the lowest was 410,000 acre feet in the drought of 1977. The peak flow or maximum discharge into the estuary was recorded on December 23, 1964 when the gauging station near Scotia measured 752,000 cubic feet per second (USGS website). The Land Use section of this report (pgs. 11-12) addresses the effects of levees and tidegate development and the altered hydrology of the estuary.

Table 1. Length of named sloughs located in the Eel River Estuary assessment area.

Slough name	Length of freshwater (miles)	Length of brackish water (miles)	Total length (miles)
Mosley Slough	0	1.4	1.4
Sevenmile Slough	0	3.8	3.8
McNulty Slough	4.8	3.4	8.2
Hawk Slough	2	3.6	5.6
Quill Slough	2.2	2.8	5
Hogpen Slough	1.8	1.2	3
Ropers Slough	1.4	1.2	2.6
Total Length	**12.2**	**17.4**	**29.6**

The estuary is vulnerable to sea level rise and increasing storm intensity associated with projected climate change. Specific impacts include saltwater inundation of grazing land, and loss and/or landward migration of tidal marshes. In addition, increased winter storm intensity could increase freshwater inflows and sediment delivery,and also initiate higher ocean wave and flood generated erosion. The complex interactions of climate change may alter the size, shape and ecologic functions of the estuary (Heberger et al. 2009; Scavia et al. 2002).

Geology

The estuary is located in a broad alluvial valley formed within the NW-SE trending Eel River syncline (Figure 2). The syncline is formed by active tectonic forces inherent to the region. The syncline is subsiding in elevation by an average of 1-3 mm per year while Table Bluff (anticline) rises by a similar amount. Although the average annual delta subsidence rate is relatively small, major movements of 1 or 2 meters may occur during large earthquakes that occur in intervals of 200 to 500 years (Li and Carver 1992) or lesser movements occur with smaller events.

The hills on the estuary's northern, eastern, and southern sides are composed of Quaternary river terrace deposits and sedimentary formations of the Wildcat group (Figure 3). The hills composed of the Wildcat Group are unstable and very susceptible to erosion. The western edge is bordered by sandy beaches forming a sand spit composed of marine shoreline deposits and sand dunes. The subbasin's subsurface geology consists of sedimentary formations of the Wildcat Group to a depth of over 9,000 feet.

Faulting and Seismicity

The estuary is located in a seismically active area where frequent earthquakes occur due to the complex interactions of the Mendocino Triple Junction. This junction is where the Gorda, North American, and Pacific plates meet. The convergent boundary between the North American and Gorda plates, called the Cascadia Megathrust, is located offshore and adjacent to the subbasin. It is the current subduction zone and complex tectonic structure is responsible for many small earthquakes and infrequent large-scale earthquakes. The Cascadia Megathrust, which is believed to have an earthquake recurrence rate of roughly 500 to 600 years (Witter and Patton 2006) can generate earthquakes of magnitude 8 and greater. Megathrust earthquakes cause very rapid uplift or subsidence of the coastal land in adjacent areas and could create large tsunamis. It is estimated from Japanese tsunami records that in January of 1700 a magnitude~9 earthquake was generated along the Cascadia Megathrust.

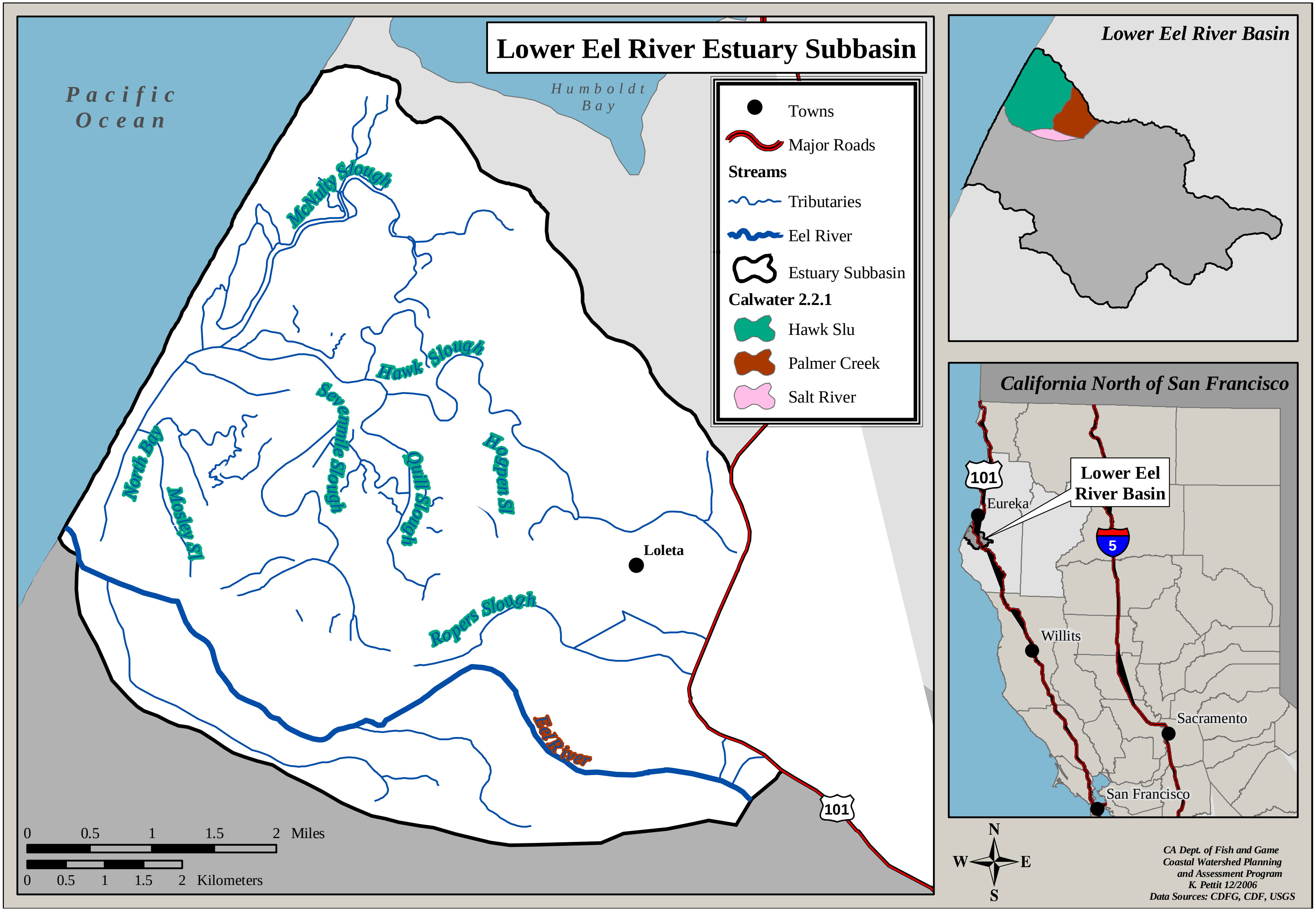

Figure 1. Estuary Subbasin locator map and CalWater Units.

In addition to the Mendocino Triple Junction, the Little Salmon Fault runs along the northern boundary of the subbasin. It may cause earthquakes, which can initiate landsliding and liquefaction. The Little Salmon Fault is believed to have an earthquake recurrence rate of roughly 600 to 700 years (Witter & Patton 2006).

The 1906 San Francisco earthquake (estimated magnitude 7.9), which ran along the San Andreas Fault from San Juan Bautista to Cape Mendocino, caused significant morphological modifications to the estuary including subsidence of several acres of land of over one foot at several sites especially on Cock Robin and Cannibal islands. It was reported that all along the Salt River land slid into the river (Dengler 2006).

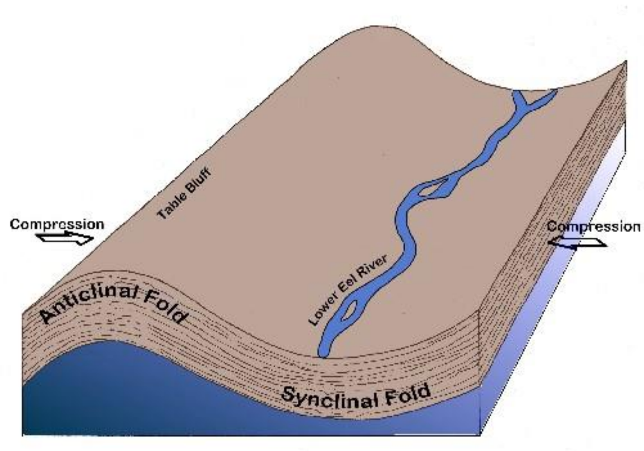

Figure 2. Eel River Syncline

Fluvial Geomorphology

The Eel mainstem flows approximately eight miles from Fernbridge to the river mouth. Because the Eel River Delta and estuary are relatively flat landscapes, the river and slough channels have very low stream gradients. Low gradient reaches of rivers and streams are depositional reaches because they tend to accumulate sediments delivered from higher gradient reaches upstream.

The estuarine channels were once deep enough to allow 12-foot draft shipping vessels access into Port Kenyon and barges up the Eel River past Fernbridge. A review of bathymetry maps produced in 1869 showed that depths near the river mouth were 10 to 16 feet and the North Bay and lower portions of McNulty Slough ranged between 9 to 13 feet. The North Bay channel ranged from 10 to 14 feet deep, and the river thalweg and pools around Cock Robin Island were from 25 to 31 feet deep.

A comparison of bathymetry maps produced in 1888 and 1921 show a decreasing trend in depth of the lower main river channel thalweg, pools and the lower Salt River (Laird et al. 2007). The levees along the Salt River were considered a cause for the loss of depth, and the subject of a lawsuit of the 1890s. It was thought that the levees blocked tidal flows into wetlands, reduced tidal prism and promoted accumulation of sediments in navigation channels (Swickard 1899; Roberts 1992). The tidal prism is the volume of water that is exchanged within the estuary between high and low tides. The exchange of tide water scours sediment and transports it to the sea which helps maintain depths of estuarine channels. After an appeal, the court agreed that the construction of levees and the ensuing reduction of the tidal prism were responsible for the filling of the channels.

However, no actions were taken to restore the tidal prism. Instead, additional levees were built to confine the north slough channels and other areas. Consequently, the Salt River channel continued to fill with sediments, which eventually stopped navigation to Port Kenyon. Today it is generally accepted that the natural morphology and function of the Eel River estuary has been altered by the presence of levees, tide gates, and the associated decrease of tidal prism (SCS 1993).

In addition to the tidal prism, estuarine channels are also scoured by the surge of winter storm flows during outgoing tides. The combination of outgoing tides and large river flows is a major force in estuarine channel maintenance. Inspection of aerial photographs show the channel has remained in a similar configuration since the 1964 flood event, which shifted the main channel flow from the south to the north side of Cock Robin Island. The flood delivered large volumes of sediments that accumulated in the main estuary channel filling deep pools and raised channel bed elevations. Significant changes in channel depths occurred in the four to five miles of main river below Fernbridge to Cock Robin Island. In this section of the river channel established deep pools, such as Singley Pool, and others once used by salmon and their anglers, filled in from the accumulated sediments. The flood events of 1955 and 1964 also eroded large amounts of shoreline and widened the estuary main channel (Van Kirk 1996).

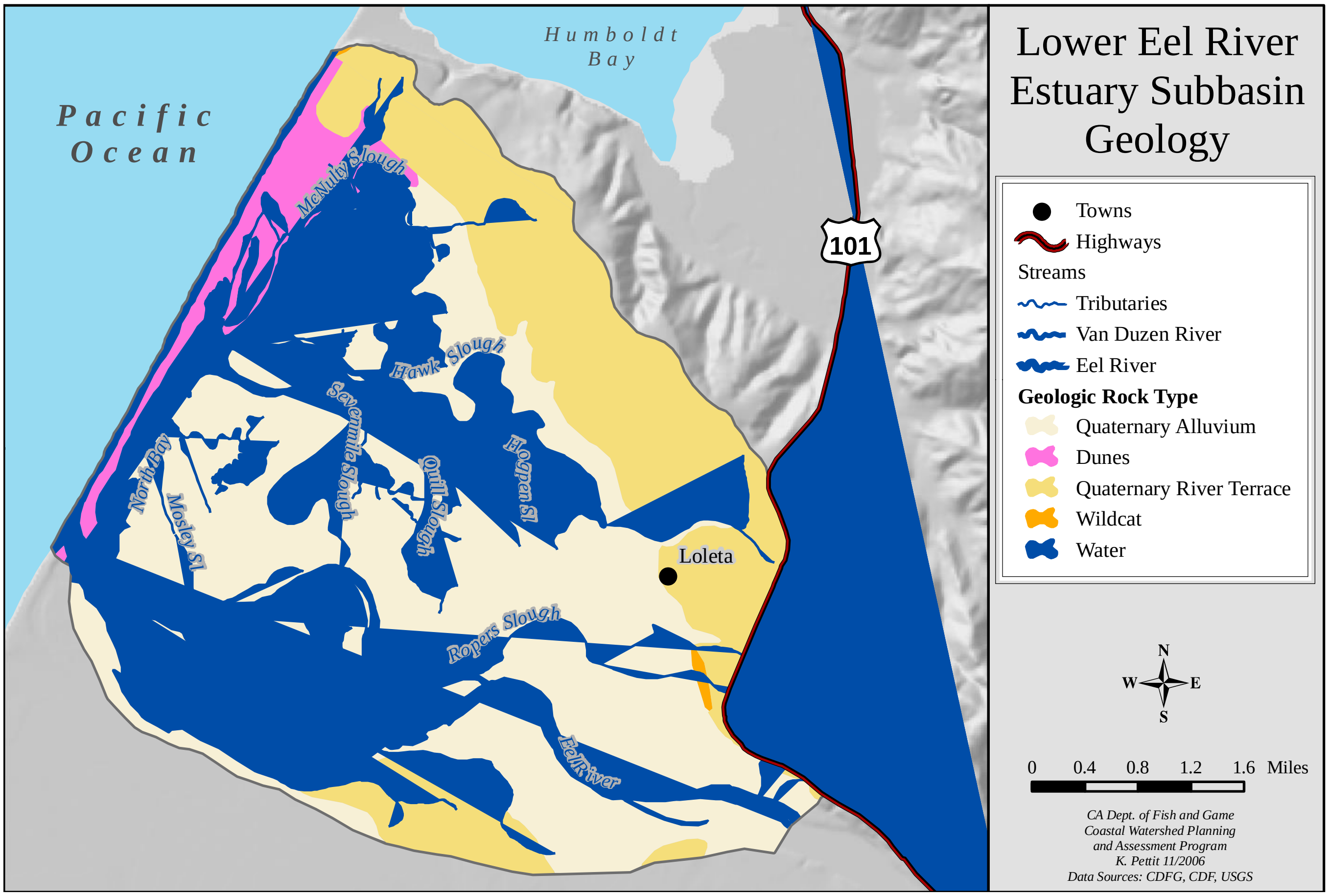

Figure 3. Geology of the Estuary Subbasin..

It has been over forty years since the 1964 flood and the channel still lacks the deep pools that once existed. This suggests that excessive sediments are still transported into the estuary from upstream sources. In contrast to the main channel, depths in the North Bay were similar to bathymetry maps produced in the 1800s. In 1994, maximum depths in the North Bay were from 10 to 14 feet deep during a moderated high tide (Cannata, 1995). The depths of the North Bay likely fluctuate with dynamic annual changes in estuarine morphology including the location of the river mouth.

The location of the estuary mouth has migrated north and south along the sand spit over recent years. The mouth location affects drainage dynamics, sediment deposition and wave action within the estuary. Movement of the mouth is likely related to variations of longshore transport of sands from ocean currents, but also related to debris accumulations, tides, and flood flows. During the 1990s, the river mouth migrated along the sand spit approximately 1.5 miles to the north (across from Sevenmile Slough) and 0.3 mile to the south of Crab Park. After the New Year's flood of 1997 and during the summer of 1997, McNulty Slough and Hawk Slough channels were isolated from the North Bay by a dry sand bar that formed between the two water bodies. At that time the Eel River channel flowed slightly to the north of Crab Park and the sloughs formed a separate channel to the sea nearly two miles to the north. The intervening sand bar formation was associated with large amounts of wood debris that accumulated in the area during the years winter storms.

The location of the mouth also affects how the lower delta drains during winter floods and where wave action will strike the shore. Observations indicate that flood waters drain slower from the southern estuary area if the mouth is located in its northern extent compared to when the river flows to sea across from Crab Park (Bruce Slocum, personnel communication). When the main river channel flows into the northern estuary area, flood flows must bend around Crab Park to reach the mouth located to the north, increasing the distance and time for flood flows to reach the sea. The location of the mouth also directs ocean waves that enter and strike the estuarine shoreline. This wave energy can cause significant erosion of loosely consolidated or sandy shorelines that do not have protection provided by woody debris, riparian or salt marsh vegetation.

Vegetation

Prior to Euro-American settlements, vegetation surrounding the estuary included redwood, spruce, fir and hardwood forests, native grass, and salt marsh plants (Roberts 1992). Most of the original forest stands were cleared and converted to farm lands and livestock grazing pastures by early settlers. A comparison of maps made in 1855 and 2005 show large expanses of wetland and salt marsh vegetation have also been converted to pasture (Figure 4). Approximately 10 percent of the original salt marsh remains today representing a change from 5,740 acres of salt marsh in 1855 to 560 acres in 2005. This does not include changes in the Salt River Subbasin, which shows a similar decline of wetlands.

Based on estimates provided by the USFS CALVEG classification scheme, 55 percent of the land in the Estuary Subbasin is now agricultural vegetation (mostly grass pastures) (Figure 4, Table 2). Approximately 23 percent of the area is composed of herbaceous vegetation, which is mostly composed (~74%) of grass pastures. Together herbaceous grass lands and agricultural land comprise over 70 percent of the Estuary Subbasin. The remaining portion of the herbaceous vegetation is salt marsh vegetation which covers approximately 6 percent of the subbasin.

Cottonwood, alder, and willow form a narrow belt of riparian trees that line much of the main river banks. The riparian belt once extended much further landward forming large forest stands. The largest remaining old growth riparian forest survives between the main channel and Roper's Slough (B. Slocomb personnel communication). The original stands of redwood, spruce, and Douglas fir, are now nearly absent.

At least two exotic and invasive plants, dense-flowered cordgrass (*Spartina densiflora)* and dwarf eelgrass (*Marina japonica*) have been introduced to the Eel River estuary. The cordgrass has spread across much of the estuarine wetlands. It tends to displace native marsh species, can exacerbate sediment accumulations in wetlands, and may cause other undesirable changes to the estuarine ecosystem. Taylor and Hastings (2004) state that plants growing at low densities are able to spread vegetatively rapidly. To control the spread of cordgrass they recommend removal of low density subpopulations over high density subpopulations. Eradication projects have had success in clearing areas of invasive cordgrass around Humboldt Bay with gas powered weed eaters. No efforts have been planned to control *S. densiflora* in the Eel estuary.

Dwarf eelgrass was first observed in May 2008 in McNulty Slough (S. Schlosser, Calif. Sea Grant). Dwarf eelgrass may grow quickly on intertidal mudflat areas, some of which were previously free from any form of vegetation. Once established it binds and accumulates sediments at a higher rate than native eelgrass. This may dramatically alter the natural habitat and change the types and numbers of animal species living in the mud. The settlement of dwarf eelgrass can also change the feeding area and food content for many shorebirds and waterfowl. In addition, the sediment accumulation resulting from the growth of dwarf eelgrass on mudflats could allow the invasive dense-flowered cordgrass (S. densiflora) to colonize additional habitat. This is of concern because the invasive cordgrass can decrease bay and estuary fringes, mudflats, and important feeding areas for waterfowl and shorebirds (Kirsten Ramey CDFG personal communication).

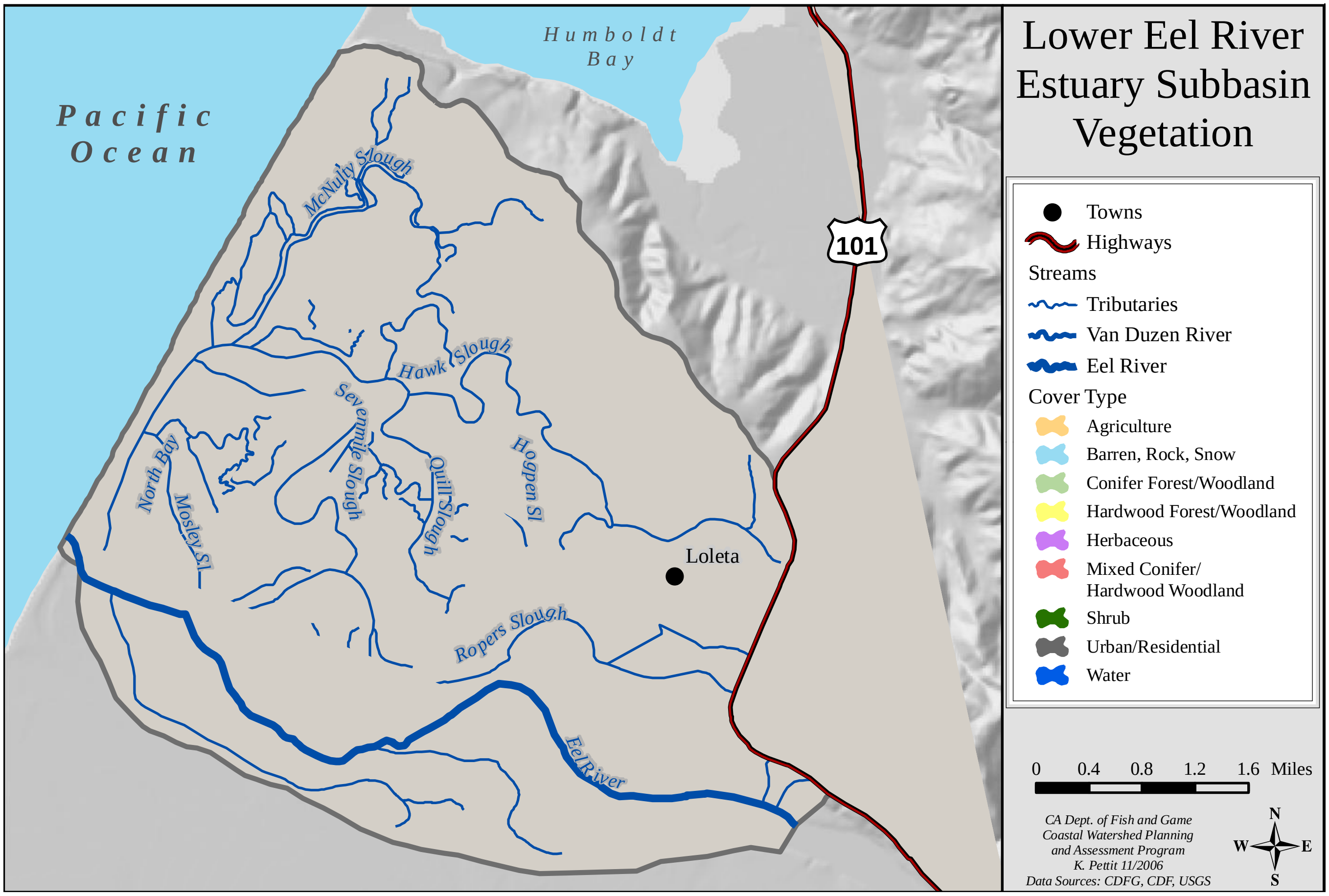

Figure 4. Vegetation of the Estuary Subbasin

Table 2. Vegetation of the Estuary Subbasin. These statistics exclude the classification of water. Data from CALVEG, USFS

Vegetative Cover Type	Percent of Subbasin	Primary Vegetation Type	Percent of Cover Type
Agriculture	55	Agriculture	100
Herbaceous	23	Annual Grass/Forb alliance	74
		Pickleweed – Cordgrass Alliance	25
		Tule/Cattail Alliance	<0.1
Barren	9	Barren	71
		Dunes	29
Hardwood	9	Red Alder Alliance	43
		Mixed Riparian Hardwoods Alliance	20
		Willow Alliance	20
		Black Cottonwood Alliance	16
		Eucalyptus Alliance	1
Shrub	2	Willow (Riparian Scrub) Alliance	100
Urban	1	Urban	100
Conifer	1	Sitka Spruce Alliance	100
Mixed (conifer stand with hardwood)	<1	Sitka spruce Alliance	100

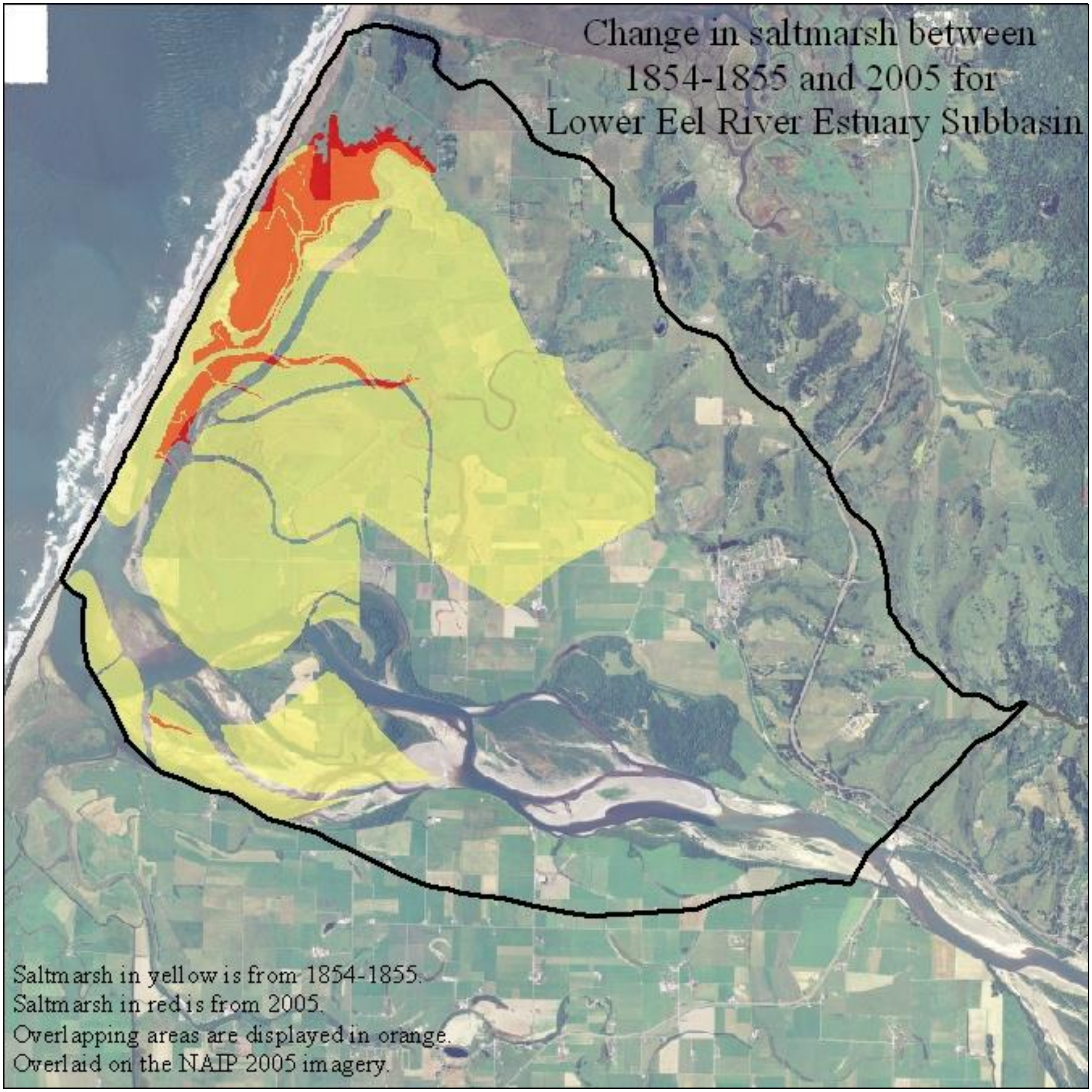

Figure 5. Change in saltmarsh habitats from 1854 to 2005

Land Use

Native Americans

In the 1850s, there were approximately 1500 to 2000 Wiyot people living around Humboldt Bay and the Eel River estuary. The abundant fishery resources including salmon, and plant foods available along the coast were sufficient to provide a local food supply for the Wiyot. When Euro-Americans began to settle and develop coastal areas of Humboldt County, the Wiyot way of life was changed. Many Eureka area settlers thought the only way to remedy the differences between cultures was to drive the Wiyot off their traditional lands, effectively forcing them to abandon traditional hunting, fishing and gathering methods and onto reservations in or outside of Humboldt County. The February 25, 1860, early morning massacre of Wiyot people on Indian Island combined with simultaneous raids on villages on the Eel River and the south spit of Humboldt Bay killed a large portion of the Wiyot Tribe. By 1910 only 100 Wiyot people remained within Wiyot territory (Van Kirk 1996, Wiyot website: http://www.wiyot.com/ history.htm). Today, there are approximately 150 Wiyot people residing in the Table Bluff Reservation and there are over 300 Wiyot people enrolled with the tribe who reside elsewhere (Wiyot website).

Agriculture, Pastures, and Dairies

Many early settlers in the Eel River delta built farms on the area's fertile soil. Among those were Seth and Stephen Shaw and Willard Allen who settled in Loleta in 1851. Loleta was originally called Swauger's Station; its current name is Indian-derived, meaning "pleasant place at the end of the water" (Loleta Chamber of Commerce 2006). The Shaw brothers soon crossed the Eel River to settle in Ferndale (Parry 1963). Ferndale received its name from the luxuriant growth of ferns that stood in the prairie country on the Shaw farm. It was noted that while "riding on horseback, the ferns reached such a height that at times it was impossible to see your way out" (Van Kirk 1996). Initially potatoes and other row crops were cultivated in areas around Loleta, and Ferndale. Wheat and oats were also crops grown in the lower regions of Table Bluff (Parry 1963).

Soon, the fertile soils of the delta were found to produce grasses excellent for livestock grazing. By the 1870s, coincident with a decline in potato prices, grazing of cattle for dairy farming became the major land use within the area, giving Ferndale its first nickname of "Cream City." By the end of 1917, there was one cow for every 1.5 acres of cultivated land (Parry 1963). Many creameries that started up as individual farms consolidated into the Diamond Springs Creamery between 1884 and 1917. Later the Diamond Springs Creamery became the Loleta Creamery. Then in the late 1980s, the Humboldt Creamery Association purchased Loleta's creamery. Most of the land in the Estuary Subbasin is still used for production of dairy and beef products. The rich delta grasslands continue to produce high quality beef and dairy products that are economically important to the area. Some row crops are still planted and pasture grasses are bailed for winter feed, but grazing dairy and beef cattle remains the most common use of land.

In order to convert the delta's forest and marsh lands to farm and grazing land, much of the Estuary Subbasin's riparian and forested/scattered trees were cleared and miles of levees were built to contain slough channels. Although much of the lower delta was originally designated as Salt marsh tidelands by 1885 (Figure 6) and was not eligible for claiming for homesteads, work was done to develop and claim these lands. The salt marsh tideland designation was somehow changed to overflow lands, which led to further development of the salt marsh. By 1870, most of the arable land had been claimed and cleared (nearly 12,000 acres). While most of the salt marsh area near Table Bluff had been claimed, it was not until 1889 that these areas began to be drained (Van Kirk 1986).

Changes to Estuarine Habitat from Land Use

The large scale conversion of tidal marshes to pastures did not come without a cost. The construction of levees and tide gates to drain salt marsh changed drainage patterns, reduced tidal prism and decreased habitat and food supply for fish and wildlife throughout the estuary. The reduction of tidal prism allowed the estuary channels to accumulate sediments, which added to flooding problems (Williams 1988). Swickard (1899) estimated a reduction of tidal prism of about 877,000 cubic yards (about 543 acre feet) that was caused by damming the southern salt marshes by early settlers to the area. Roberts (1992): states "It is my impression that the area of salt marsh north of the river was larger than the area addressed by Swickard, and the diking which occurred east of McNulty Slough probably reduced the tidal prism even more than did the actions addressed in Swickard's deposition". Recommendations for delta improvements in Roberts (1992) focus strongly on increasing the tidal prism and include levee removal as the best option to obtain this objective. Roberts

(1992) states the best candidate sites for levee removal include both sides of McNulty Slough and its tributaries, and the land west of McNulty slough. Roberts also recommends further restorations to extend in the northwestern delta should be expanded rapidly outward from earlier project sites.

In addition, many of the dairies experienced problems with waste management and non-point source pollution to the estuary channels and delta grounds water. Waste often flowed into low lying areas, and former slough channels. During times of heavy precipitation, these sloughs often became active transporting waste into the estuarine wetlands. The Humboldt County Resource Conservation District (HCRCD) established a program to assist local dairy farmers to manage dairy waste. The HCRCD program helped dairies to increase the size of constructed liquid waste lagoons and helped develop systems to deliver manure to fields, and help manage overflow problems due to floods.

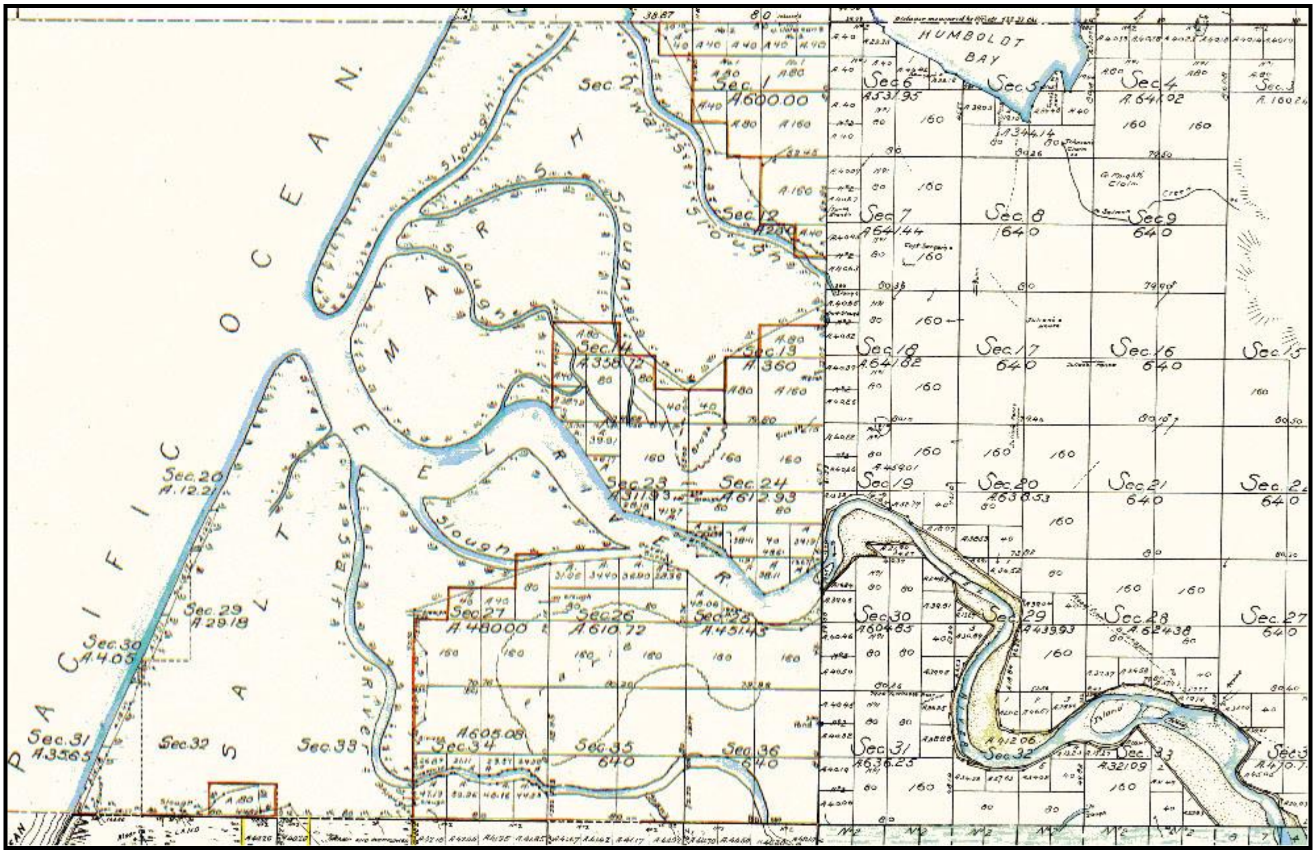

Figure 6. Eel River estuary 1884 map showing salt marsh designation and sections of converted wetlands and forest lands

Navigation and Shipping

The Eel River was first considered navigable by the General Morgan party in 1850. Later that year, the estuary was first entered from the sea when the schooner Ryerson mistakenly crossed the Eel River bar while searching for the entrance to either the Klamath River or Humboldt Bay (Van Kirk 1996). Over the following years, several trips into the river were made by various ships carrying supplies to and exporting goods from Eel River Delta settlements. The ships sailed from the estuary into the tidal Salt River where they found safe harbor at Port Kenyon. The trade prompted the formation of the Eel River Navigation Company in October, 1865 (Van Kirk 1996). Although the entrance to the Eel River was shallow and at times impassable, Port Kenyon soon became an important port for the shipping of crops, dairy products, cattle and salmon to San Francisco.

In 1878 the steamer Thomas Whitelaw was built to make regular runs between the Eel River and San Francisco carrying mail, passengers and cargo (Van Kirk 1996). Later, other vessels made Port Kenyon and Ferndale a regular port of call, but the entrance to the Eel River proved hazardous to navigation as ships occasionally ran aground or were stranded on the sand bar across the river mouth (Van Kirk 1996). The passage into the river was eventually judged too risky for ships and Humboldt Bay soon became the only harbor in the county.

Commercial Fishing in the Estuary 1853-1922

Commercial fishing for salmon and steelhead began in the Eel River estuary by 1853 and continued until 1921. Over the years, the fishery involved several hundred fishermen, salt packing facilities, smoke houses, canneries, fresh fish merchants, shipping and a fish hatchery. Based on the reported catches annual Chinook salmon harvests ranged from approximately 20,000 in the early years of the fishery to near 150,000 caught in 1904. Harvests of up to 500,000 pounds of steelhead and near 400,000 pounds of coho per year also were reported (U.S. Commision of Fish and Fisheries 1887; Wilcox 1896; Cobb 1930). The commercial fishery closed in the estuary in 1921 (Bureau of Commercial Fisheries 1928; Parry 1959, Van Kirk 1996). A more detailed review of the commercial fishery is presented in the Fishery Resource section of this report (pp. 23-31).

Eel River Wildlife Areas

In the mid to latter 1800s wildlife was noted as abundant in the Eel River Delta (Van Kirk 1996). At that time grizzly bears and elk roamed the delta area. While species diversity has decreased from the late 1800, the area contains numerous ecologically significant habitat regions. More recently, Monroe et al. (1974) noted that over 40 species of mammals and 200 species of birds use the delta area. Several bird species and most mammals are residents, while large numbers of migratory birds depended on the area for seasonal feeding and resting grounds, including shore birds, wading birds, tundra swans, ducks, and raptors. Nesting areas exists for cormorants, egrets, herons and numerous additional bird species in sparse clumps of riparian forests located along the estuary channel. Federal and state protected species including bald eagles, peregrine falcons and snowy plover find refuge in the estuary area. Aleutian geese, a species that has recovered from near extinction, utilize the area's grasslands for feeding.

The California Department of Fish and Game manages wildlife areas to allow for public use while maintaining wildlife populations and habitat. The Eel River Wildlife Areas consist of the Table Bluff Ecological Preserve and the Ocean Ranch, Cannibal Island, and Cock Robin Island management units. These areas are seasonally open to waterfowl hunting, and open year round for fishing, hiking and other opportunities for public use.

Water Quality

Effects from Land Use Upstream

The water quality and sediment supply of the estuary are linked to watershed characteristics and events that occur in the 3700 square mile Eel River Basin. One of the most significant events affecting the estuary was the December rain on snow event which caused the flood of 1964. At that time, approximately one – half of the basin's naturally erosive terrain was disrupted by clear cut tractor logging. Hill slopes and soils were destabilized by the removal of trees, construction of roads and tractor skid trails. During the rain on snow storm event, the disrupted hill slopes eroded and added enormous amounts of sediments to the stream network. Much of the huge sediment load was transported by storm flows to the estuary. By the end of the 1965 rainy season, the deep pools of the lower river and estuarine channel that once held large runs of salmon were filled with sediments (Fisk et al. 1966). After many years pools and structural features have re-established, but not to pre-flood conditions. The procession of natural restoration of channel bed features to the pre-flood condition is impeded by localized erosion and delivery of excessive amounts of sediments generated by past and present land (USEPA 2007).

Salinity and Temperature

Primary factors affecting fish distribution within the estuary are salinity and water temperature. These water quality parameters are influenced by complex relationships between seasonal changes in freshwater flows, ocean tides, channel morphology, land use, and coastal fog climate. In general, the main channel (Eel River) has three zones: 1) freshwater, 2) brackish water or mixing zone; and 3) a marine (sea water) zone. The extent of these zones is controlled by the seasonal mixing patterns of river and tidal flows. The mixing of these distinct water masses affects water temperature, salinity, and fish distribution.

Salinity in the estuary is strongly related to the changes in seasonal discharge of river flows and daily high and low tides. Salinty in the estuarine waters ranges from fresh, river flow (salinity < 0.5ppt) to hypersaline, sea water (salinity >35 ppt) (Cannata 1995). Flood flows caused by large winter rain storms can temporally inundate the estuary with freshwater, but after peak flows subside, high tides move a mass or wedge of sea water back into the lower estuary. The mixing of river flows and tidal seawater produces salinity gradients that extend vertically from the surface to the bottom waters and horizontally upstream from the river mouth. (Figure 5). Thus, the highest salinity is generally found near the mouth and the lowest salinity is found near Fernbridge, approximately 7 miles upstream.

The decrease in river flow during the summer/fall season allows greater influence by marine tides which shifts the conditions in the upper estuary channel from predominantly fresh to include tidally driven brackish water (1-15 ppt.). A high tide of summer/fall can push brackish water in the main river channel upstream of Fernbridge. A salinity measurement of 11 ppt was made near Fernbridge in October, 1994 (Cannata 1995). In the 1800s, tidewater was noted to extend to the confluence with the Van Duzen River (RM 14) (Van Kirk 1996). It is unclear whether the tidewater referred to in 1880's newspapers was freshwater under the influence of tides or brackish water. During the warm summer season, when evaporation rates are high, the sea water can become hyper-saline or saltier that sea water in slough channels where reduced exchange of water occurs between tides.

Like salinity, water temperatures in the Eel River estuary vary depending on the season, location, channel depth, heights of tides and river discharge. Seasonal water temperature can range from ambient sea water (~50-55 F) to ambient river water (~38-75 F) (Puckett 1977 and Cannata 1994-95 field notes). During the winter, the coldest water is usually found on the surface when river flows exposed to cold air flow into the estuary. Conversely, in summer as river flows decline, the coldest water is delivered by ocean tides. Tides push a wedge of cold seawater up the main estuarine channel that mixes with the warmer fresh or brackish water of the middle and upper estuary zones.

In 1996 and 2000 the Humboldt County Resource Conservation District (HCRCD) continuously monitored sites in major slough channels, and the lower mainstem for water temperature in the Eel River estuary. Maximum weekly average temperatures (MWAT's) collected from those sites ranged form 56 to 71°F (Table 4). No locations within the estuary obtained seasonal maxima considered lethal for anadromous salmonids (≥ 75°F). The HCRCD data were collected from a single depth at each location. However, a vertical profile of the water column is most desired when collecting temperature data in an estuary.

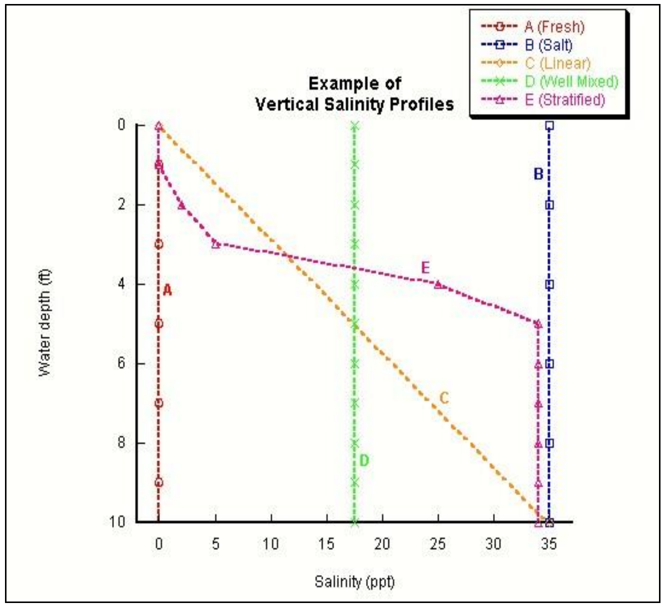

Figure 7. Examples of various sality profiles.

Vertical salinity profiles collected in the estuary 1994-95 show that large differences in salinity can occur between the surface and bottom waters.

Water Chemistry

Nutrients are often limiting factors in the biological capacity of a freshwater stream. However, estuaries are naturally high in nutrients as they receive sources of carbon, nitrogen and phosphates from both fresh and sea water sources. The mixing of fresh and sea water helps to precipitate nutrients and keeps them within the estuary. The abundance of dissolved nutrients fuels primary productivity beginning the food web. Decaying algae and wood in the estuary add to the food and nutrient supply.

An excess of nutrients can degrade water quality by fueling toxic algal blooms that increase biological demand either through respiration or decomposition. Typically, tidal exchange prevents high concentrations of nutrients from causing toxic blooms or eutrophication. However, areas with poor circulation or delivery of high loads of nutrients such as dairy waste or agricultural runoff can become toxic zones. Other sources of nutrients and pollutants are commonly municipal and industrial wastewater facilities, storm runoff, and agricultural operations. Pollutants are a concern where they interfere with the biological function of aquatic organisms, or where they could be a threat to those that consume them. Naturally occurring heavy metals are often found in much smaller concentrations.

The North Coast Regional Water Quality Control Board (NCRWQCB) has set water quality objectives for the following parameters in estuaries of the North Coast: Dissolved Oxygen (above 5.0 mg/L 100% of the time);Fecal Coliform (no more than 10% of samples in a 30 day period should exceed 400 per 100mL); pH: between 6.5 and 8.5 (NCRWQCB 2006d).

The Wiyot Tribe has sampled water quality in McNulty Slough since December 2004 (Figure 9 and Figure 10). The sampling location is at the seaward side of the tide-gate located just south of McNulty Lane, adjacent to the old Wiyot Rancheria. The site is sampled for physical parameters every two weeks during mid and high tides; a water quality sonde device is deployed for approximately ten minutes and samples for 3-5 minutes at four-second intervals. Additionally, chemical sampling is performed quarterly.

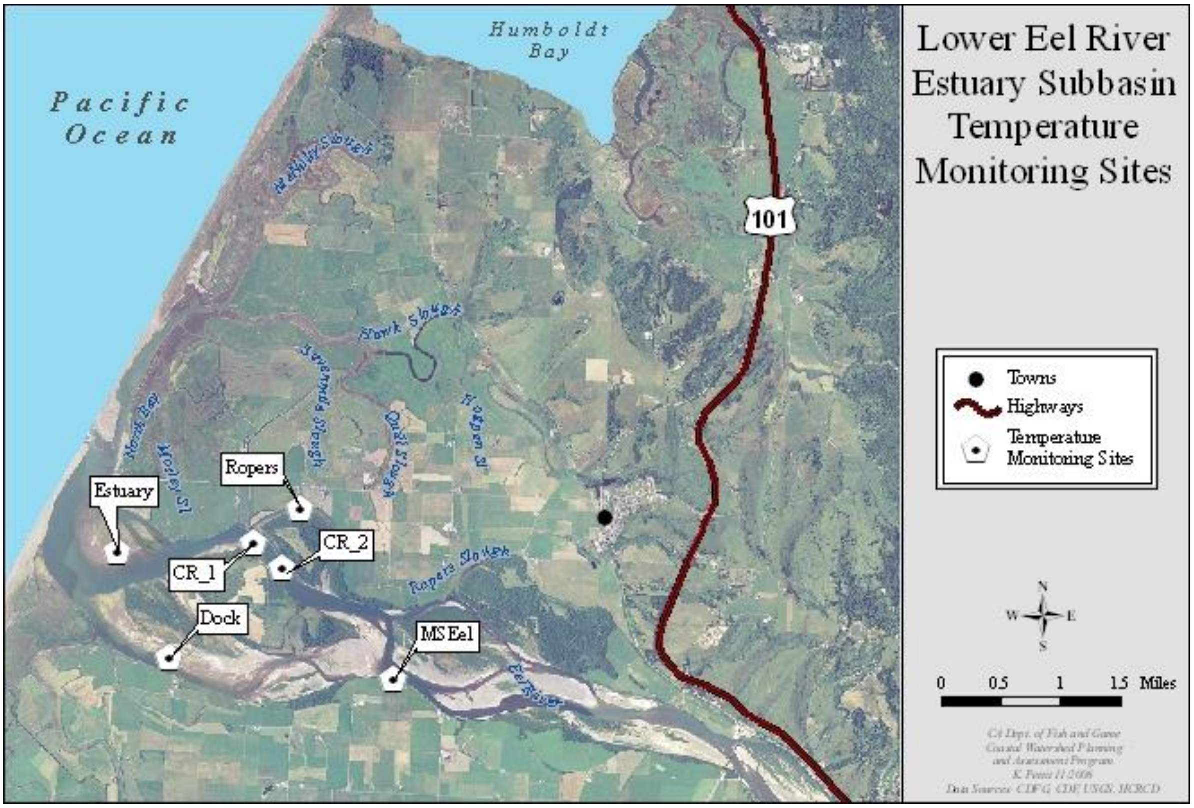

Figure 8. Locations of temperature monitoring sites in the Estuary Subbasin.

Table 3. Maximum weekly average temperatures and maximum daily average temperatures collected in the Estuary Subbasin. See map above for temperature site.

Site	MWAT (°F)	Max Daily Average (°F)	Years of Data
1552_1	56	57	1
1552_2	56	57	1
Est	57	58	1
Dock	59	60	1
CR_2	62	62	1
Ropers	62	63	1
CR_1	68	69	1
MSEel	71	72	1

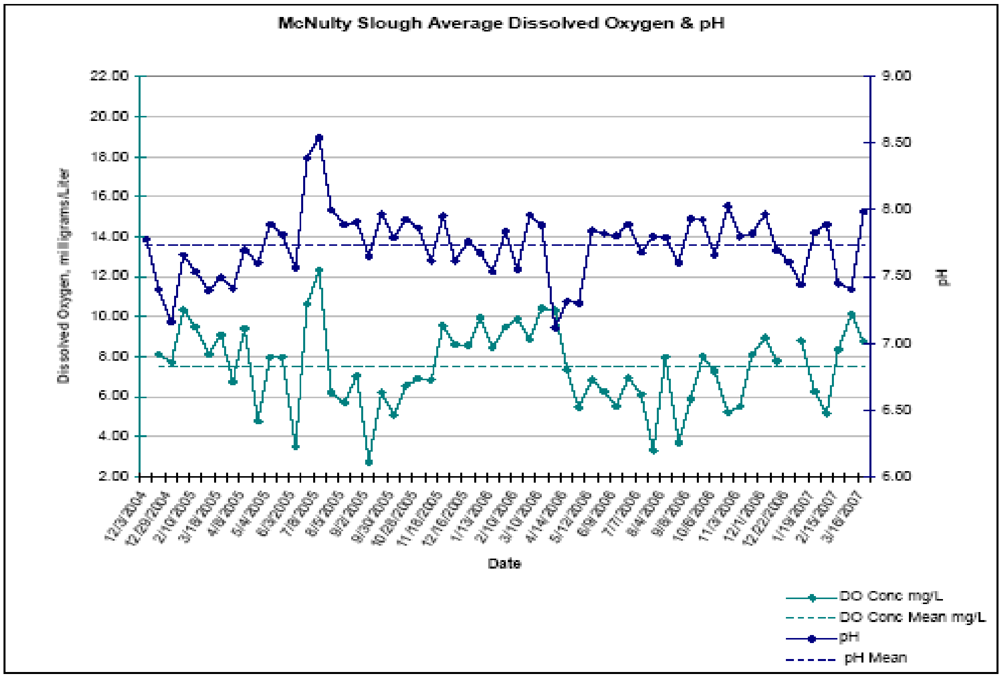

Figure 9. McNulty Slough dissolved oxygen and pH results from 2004-2007, Wiyot Tribe 2007.

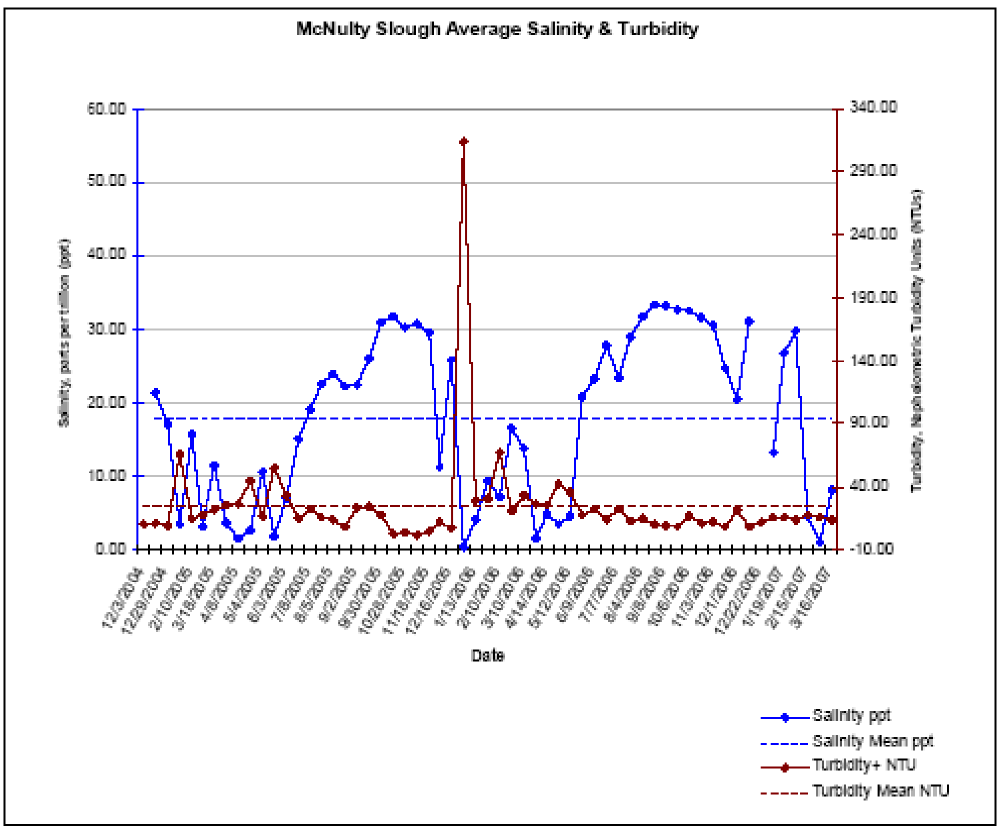

Figure 10. McNulty Slough salinity and turbidity results from 2004-2007, Wiyot Tribe 2007.

Table 4. Chemical testing in McNulty Slough 2005-2006, Wiyot Tribe 2007.

		Sample Medium			Sample Analysis Results											
					Coliform							TPHCs				
Sample Site	Date	Water Column	Sediment	Tissue	Total (Coliform/100m	Fecal (Coliform/100m	Total Nitrogen (mg/L)	Total Phosphorus (mg/L	TSS (mg/L)	Dioxin	PCBs	Gasoline (ug/L)	Diesel (ug/L)	Oil (ug/L)	Priority Metals	SVOCs (ug/L)
McNulty Slough	5/4/2005	X			300	50	1.2	0.12				ND	ND	ND	ND	
McNulty Slough	8/19/2005	X			300	60	1.3					ND	ND	ND	ND	
McNulty Slough	12/2/2005	X			≥1600	1600	ND	0.087				ND	ND	ND	ND	
McNulty Slough	3/17/2006	X			≥1600	900	1.4	ND				ND	ND	ND	ND	
McNulty Slough	7/20/2006	X			50	17	ND	0.022				ND	ND	ND	ND	
McNulty Slough	11/3/2006	X			170	110	ND	0.18	16			ND	ND	ND	ND	

PCBs	Poly Chlorinated Biphenols	TPHCs	Total Petroleum Hydrocarbons
SVOCs	Semi Volatile Organic Compounds	TSS	Total Suspended Solids

ND = Not Detected

Dissolved oxygen levels in McNulty Slough fell below 5.0mg/L three times in 2005 and twice in 2006. The levels recorded for pH were within the range deemed suitable by the Water Board except for one occasion in July 2005, where pH was recorded above 8.5. Turbidity remained either below or slightly above 30 ntu for most of the study period. In January 2006, turbidity levels jumped from near 20 ntu to 320 ntu in two weeks, later to fall back to 30 ntu in another two weeks (Wiyot Tribe 2007).

The Wiyot Tribe has also conducted quarterly fecal coliform and chemical testing at the McNulty Slough site for the past two years (Table 4). Fecal coliform was low for most of the sample dates; however, coliform levels greatly exceeded the Water Board's recommendation of 400/100mL in December 2005 and March 2006.

There were no hydrocarbons or priority metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, or zinc) detected in the water column at the McNulty Slough site (Wiyot Tribe 2007).

The Eel River Delta Animal Waste Project was funded to improve farm waste management practices at participating dairies. Two sites in the Estuary Subbasin were sampled during this project: Peterson Ditch at Copenhagen Road (PD) and a tributary to Quill Slough, south of Cannibal Island Road (QS). Temperature, pH, conductivity, salinity, and dissolved oxygen measurements were collected twice before improvements were made to nearby dairies; the results are presented in Table 6.

Dissolved oxygen levels are barely above the Water Board targets of 5.0 mg/L for saline waters at the tributary to Quill Slough (QS) in 1998 and 2000. Sampling was conducted again after animal waste management improvements had been made but there was not enough flow to test water quality (Ziemer and Anderson 2001).

Table 5. Water chemistry results in the Estuary Subbasin (Ziemer and Anderson 2001).

Site	Date	Time	pH	Conductivity	Salinity (ppt)	Dis. O2 (mg/L)
Tributary to Quill Slough	10-1-1998	11:00	8	379 µS	.01	5.0
Tributary to Quill Slough	2-9-2000	10:00	7.8	297 µS	.01	5.2
Peterson Ditch	3-2-1996	17:00	7.8	11.58 mS	0.7	9.0
Peterson Ditch	3-28-1996	09:25	-	-	11.2	8.0

Wastewater Treatment Facilities

The Estuary Subbasin contains two wastewater treatment facilities that discharge into the Eel River Basin: the Loleta municipal wastewater treatment facility and the Humboldt Creamery, located at Fernbridge. A third facility, the Ferndale wastewater treatment facility, is located in the Salt River Subbasin and discharges into the Salt River about three miles upstream form the confluence with Eel River. As of 2008 all of these facilities are being reviewed as part of the permit renewal process.

In addition to municipal wastewater, the Loleta wastewater treatment facility accepts wastewater from both the Humboldt Creamery facility located in Loleta and the Loleta Cheese Factory; both are considered "high strength" waste. The facility is designed to process 100,000 gallons per day (gpd), and ranges from 56,000gpd to 522,000gpd over the year (NCRWQCB 2004b). The facility currently discharges year-round into an oxbow, essentially a wetland, of the Eel River. During the winter, these percolation/evaporation ponds overflow into the Eel River. The new permit mentioned above will address alternatives to discharging into this wetland, such as pasture irrigation during the summer and upgrading the facility or piping effluent to the Eel River during winter months. A Cease and Desist order was issued in 2004 for facility operations compliance, which was later resolved and rescinded.

Currently, Humboldt Creamery discharges between 63,000 and 160,000 gallons per day (gpd) of "non-contact condensate" to the Eel River. This is a very low volume discharge of basically clean, drinking quality water that is regulated because it is warmer than the Eel River (NCRWQCB, 2002, L. Bernard NCRWQCB, personal communication). Temperature is monitored in Eel River to a depth of 10 feet and no adverse conditions have been detected thus far. Wastewater that contains milk solids from the cleaning of equipment is used for irrigation on a nearby agricultural pasture (249,000gpd – 450,000gpd). Investigation into the impacts to groundwater will be conducted during the re-permitting process (L. Bernard, NCRWQCB, personal communication).

Fish and Habitat Relationships

Estuarine Habitats

The estuary can be divided into four zones based on channel characteristics and mixing regimes of tidal marine water with freshwater river flows: (1) a marine dominated lower estuary zone (North Bay) that extends from the river mouth upstream to near Cock Robin Island bridge; (2) North Slough channels and associated salt marsh. These include McNulty, Hawk, Sevenmile and other slough channels located to the north of the mains river channel; (3) a middle estuary zone, subject to strong salt and fresh water mixing. This includes the channel from Cock Robin Island bridge upstream to where Fulmor Road dead ends near the main channel; and (4) an upper estuary zone that is more riverine and characterized by fresh water and/or brackish water into the summer, but subject to daily tidal action. This is the area from approximately one mile above Fulmor Road to just above Fernbridge. The actual limits between these zones are variable, and are subject to seasonal change in the river discharge and daily tidal cycles. The distribution of estuarine fish is largely related to the salinity and water temperature of these zones.

Within these generalized zones occur more specific habitat types including small, meandering slough channels, intertidal mudflats, intertidal sandflats, intertidal gravel/cobble, eel grass beds and emergent marsh. These diverse habitats play important roles in reproduction, feeding, rearing, and for physiologic adaptations for fish that utilize the estuary. A brief description of the estuary's habitat types adapted from Cowardin (1979) and Simenstad and Tanner (1991) are presented below.

Intertidal Mudflats: This habitat type consist of unvegetated, mud substrate shores covered and exposed by high and low tidal cycles. Mudflats are found in the slough channel areas including the Salt River and often occur between vegetated, emergent marsh habitats and subtidal channels. Mudflats can be steepened shores in areas where slough channels are confined by levees.

Intertidal Sandflats: These sandflats are unvegetated, gentle sloped, sand substrate shores covered and exposed by high and low tidal cycles. Sandflats and sandy beaches are found in the North Bay in the vicinity of Crab Park. Sand flats also occur where McNulty slough joins the North Bay and what may be referred to as muddy sands border northern edges of Cock Robin Island.

Intertidal Gravel/Cobble: This habitat can be steep or gently sloped shores covered and exposed by high and low tidal cycles. Gravel and cobble bottoms are found in the more riverine portions of the upper and middle zones of the Eel Estuary including just above the Cock Robin Island Bridge to Fernbridge. Gravel and cobble often provides substrate for growths of macroalgae including Ulva spp. Gravel and Cobble can form large bars in the more riverine areas of the upper estuary zone.

Emergent Marsh: Includes intertidal shores of unconsolidated mud or sand colonized by rooted plants that are periodically inundated with flood and/or tidal water. Emergent marsh is found along the eastern shore of the North Bay, and along banks of the Salt River, and in most of the slough channels throughout the estuary.

Eel Grass Beds: Eel grass (*Zostera pacifica*) is a rooted vascular plant that grows in shallow mud and sand bottoms. Eel grass is found in areas where brackish water or sea water predominates year round. Most of the known eel grass grows in the Salt River and its tributary slough channels, although small patches have been observed in McNulty slough (J. Mello, CDFG, personal communication).

Subtidal Soft Bottom: Includes unconsolidated sand, mud, and gravel/cobble bottoms that remain submerged during tide cycles. Subtidal sand, mud, and gravel/cobble are generally found in the estuary adjacent and the similar intertidal substrate type noted above. Subtidal bottoms in the north slough channels and Salt River often support growths of the macroalgae *Gracilaria* spp. and *Ulva* spp. and rooted aquatic plants such as pond weeds (*Potomageten* spp.)

Water Column: the habitat considered from just off the streambed bottom to the water surface. The water column is directly linked to most other habitat types in the estuary and is a connection between them. Pelagic fish spend most of their time swimming in the water column.

Fishery Resources

The importance of maintaining the diversity and dynamics of aquatic habitats within the Eel River Estuary for anadromous salmonids and other fish and wildlife is well documented (Murphy and Dewitt 1951, Monroe et al. 1974, Puckett 1976, Roberts 1992, Higgins in Roberts 1992, and Hassler and Cannata 1995). Although natural processes of the estuary ecosystem have been altered or impaired by land management, the estuary still provides essential spawning, nursery and feeding grounds to several commercially and recreationally important species. No major port or industrial developments have occurred that pose additional threats to the ecosystem. At least forty-five fish species have been collected from the Eel River estuary (Table 7) and several invertebrates including the commercially important Dungeness crab (*Cancer magister*). Many of these fishery resources depend on the estuary habitats to complete a critical life history stage such a spawning or juvenile rearing. The estuary provides critical habitat for eight fish species listed under the federal and/or state endangered species acts or are state special concern species.

All but five species collected from the estuary are native to the system. The five non-native introductions are the anadromous American shad (*Alosa sapidissima)* and freshwater species: Sacramento pikeminnow (*Ptychochelis grandis)*, California roach (*Hesperoleucas symmetricus*) brown bulhead (*Ameiurus nebulosus*) and green sunfish (*Lepomis cyanellus*). No non-native marine fish species have been collected from the estuary.

Chinook salmon

Chinook salmon are among the most valuable and popular fish that rely on the Eel River estuary for essential habitat. Once abundant, populations estimated at over 500,000 fish historically returned to the Eel River to spawn (NOAA 2002). As a part of their anadromous lifecycle, these fish migrate through or reside in the estuary twice: once as juveniles and again as spawning adults. Present populations are not precisely known, but Eel River Chinook salmon numbers are likely less than five percent of the historic estimate provided by NOAA (2002).

Chinook salmon use the estuary as transitional habitat as they move between sea water and fresh water during upstream and downstream migrations. As adults, the salmon hold in the estuary for weeks or longer until fall or winter rains augment river flows enough to promote passage into upstream spawning grounds. Juveniles acclimate to seawater during seaward migrations and also find nursery area where they feed and grow in the relative safety of the estuary before entering the ocean.

The use of the Eel River estuary by juvenile Chinook was first noted by Murphy and Dewitt (1951). They reported seeing “incredible numbers” of juvenile Chinook in the lower Eel River during late June and July, then the numbers “generally declined as the season progressed”. They captured juvenile Chinook near Fernbridge (RM 7) using beach seines up until August 15 in 1950. They also noted the presence of “large numbers” of juvenile Chinook in the tidewater and at the mouth of the estuary. Subsequent studies detailing juvenile Chinook use of the estuary were Puckett (1977) and Cannata and Hassler (1995). Both of these studies noted that the Eel River estuary is critical habitat for all juvenile salmonid species and that juvenile Chinook were most abundant during June and July. However, the large numbers of Chinook juveniles reported as visible by Murphy and Dewitt (1951) were not observed in the latter studies.

Table 6. Fish species observed from the Eel River Estuary. Observers are also shown.

Species	Murphy and De Witt (1951)	Monroe et al. (1974)	Puckett (1977)	Cannata and Hassler (1995)
ANADROMOUS SPECIES				
Pacific lamprey, *Lampetra tridentata*	x	x	x	x
[1] Green sturgeon, *Acipenser medirostris*	x	x		x
[1,2]White Sturgeon, *Acipenser transmontanus*				
American shad, *Alosa sapidissima*	x	x	x	x
[1]Coastal cutthroat trout, *Oncorhynchus clarkii*	x	x		x
[1]Steelhead, *Oncorhynchus mykiss*	x	x	x	x
[1]Chinook salmon, *Oncorhynchus tshawytscha*	x	x	x	x
[1]Coho salmon, *Oncorhynchus kisutch*	x	x	x	x
Eulachon, *Thaleichthys pacificus*				
[1]Longfin smelt, *Spirinchus thaleichthys*		x	x	x
MARINE or ESTUARINE SPECIES				
Pacific herring, *Clupea harengus*	x	x	x	x
Pacific sardine, *Sardinops sagax*	x	x		x
Northern anchovy, *Engraulis mordax*		x	x	x
Surf smelt, *Hypomesus pretiosis*		x	x	x
Pacific tomcod, *Microgadus proximus*	x	x		
Topsmelt, *Atherinops affinis*	x	x	x	x
Bay pipefish, *Syngnathus leptorhynchus*	x	x	x	x
Kelp greenling, *Hexagrammos decarammus*		x		
Cabezon, *Scorpaenichthys marmoratus*		x	x	x
Pacific staghorn sculpin, *Leptocottus armatus*	x	x	x	x
Coastrange sculpin *Cottus aleuticus*		x	x	x
Prickly sculpin *Cottus asper*		x	x	x
Buffalo sculpin *Enophrys bison*			x	x
Tidepool sculpin *Oligocottus maculosus*				x
Ringtail snailfish, *Liparis rutteri*				x
Threespine stickleback, *Gasterosteus aculeatus*	x	x	x	x
Jack mackerel, *Trachurus symmetricus*				x
Redtail surfperch *Amphistichus rhodoterus*		x	x	x
Walleye surfperch *Hyperprosopon argenteum*			x	x
Shiner surfperch *Cymatogaster aggregate*	x	x	x	x
Silver surfperch *Hyperprosopon ellepticum*				x
Pile surfperch *Rhacochilus vacca*	x	x		
Saddleback gunnel *Pholis ornata*		x	x	x

Species	Murphy and De Witt (1951)	Monroe et al. (1974)	Puckett (1977)	Cannata and Hassler (1995)
Pacific sandlance *Ammodytes hexapterus*			**x**	
[1,3]Tidewater goby *Eucyclogobius newberryi*				
Bay goby *Lepidogobius lepidus*				**x**
Sand sole *Psettichthys melanostictus*			**x**	**x**
English sole *Parophrys vetulus*			**x**	**x**
Starry flounder *Platichthys stellatus*	**x**	**x**	**x**	**x**
Speckled sanddab *Citharichthys stigmaeus*		**x**		**x**
FRESHWATER SPECIES				
California roach *Hesperoleucas symmetricus*		**x**	**x**	**x**
Humboldt sucker *Catostomus occidentalis humboldtiensis*	**x**	**x**	**x**	**x**
Brown bullhead *Ameiurus nebulosus*	**x**	**x**	**x**	
Sacramento pikeminnow *Ptychochelis grandis*				**x**
Green sunfish *Lepomis cyanellus*	**x**			

[1] *threatened or endangered under ESA; CESA orCalifornia special concern species.*

[2] *Observation by Michelle Gilroy CDFG.*

[3]*Observation made by Greg Goldsmith, USFWS*

Puckett (1977) and Cannata and Hassler (1995) research demonstrated that Chinook salmon increased in size in the estuary over spring and summer months (Figure 11). In June 1994, Chinook smolts captured near Fernbridge had an average 85 mm mean fork length (FL). Smolts captured in June from the middle and lower estuary averaged over 100 and 120 mm FL respectively. Size appears to be a factor governing the movement into higher salinity water and their movement to sea. It may also influence their arrival timing to the estuary. Specimens collected from the middle and lower estuary continued to increase in size over the summer. In 1994, the peak abundance of juvenile Chinook catches in the estuary was in July. The peak period of ocean entry occurred by August as catch per unit effort was much lower then compared to earlier months (Figure 12) and no salmon were collected in the upper estuary after mid July. This suggests that the seaward migration from the river to the estuary was complete by mid July, which is consistent with previous downstream migrant studies (Puckett et al. 1968; 1976).

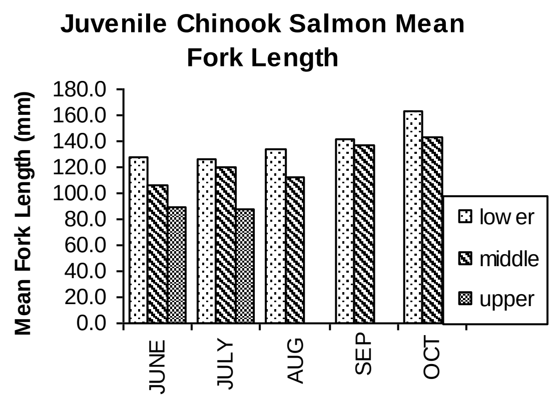

Figure 11. Mean fork lengths of juvenile Chinook salmon captured from lower, middle and upper sampling sites in the Eel River estuary 1994.

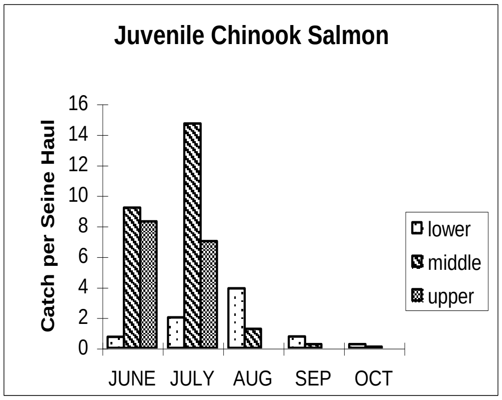

Figure 12. Catch per seine haul of juvenile Chinook salmon from lower, middle and upper estuary sampling sites 1994.

Three criteria have been suggested by Healey (1982) to evaluate the specific importance of estuarine habitats for juvenile salmon: (1) the existence of alternate nursery habitats; (2) the proportion of the population that utilizes alternate habitats opposed to estuarine habitats; and (3) the length of residence in estuarine habitats. By evaluating these criteria, Eel River Chinook strongly depend on the estuarine habitat. Alternate rearing habitat is scarce, as much of the Eel River is thermally lethal to salmonids during the summer and juveniles utilize the estuary for nursery areas for extended periods before entering the ocean phase of their life cycle.

Research has shown that Chinook in Oregon rivers seldom return as adults if they enter the ocean at a size less than 100 millimeters in length (Nicholas and Hankin 1988) and that estuaries often provide the habitat where juveniles obtain the size needed to increase the chances of survival (Riemers 1976, Puckett 1977, Cannata and Hassler 1995).

Coho salmon

Counts made by CDFG 1938-1975 at Benbow Dam on the South Fork Eel River indicate a significant decline in the Eel River coho population size over the last several decades. Counts averaged 10,000 coho per year from 1938-1963 with a peak count of approximately 25,000 coho in 1947 and a low count of 2,120 in 1959. Counts averaged approximately 2,200 from 1964-1975 with a peak of 14,300 in 1963 low count of 509 coho in 1975, which was the last year of counts on record. Considering the significantly reduced size of the coho population and the habitat alterations of the estuary, it is difficult to determine how the estuary historically functioned as coho habitat by studies of present conditions.

During fish studies of the estuary (1973-74 and 1994-95), relatively small numbers of juvenile coho salmon were observed during winter, spring and summer seasons. In 1974, coho were observed most often in the middle and upper estuary zones but were also found in Salt River and North Slough channels (Puckett 1977). During 15 months of fish sampling in 1994-95 Cannata and Hassler observed only five juvenile coho. This small sample may reflect a decline in coho populations in the Eel River Basin compared past years. In December 1994, a single juvenile coho was a captured in December near Crab Park (lower estuary) and 1+coho were captured in February 1995 after a large flood event. These coho appeared to be seeking shelter from high river flows. They were captured in calm areas of the lower estuary near the confluence with Salt River. Presence of juvenile coho in December and February suggests that the estuary provides an important refuge area for coho that may be flushed from tributaries during high winter storm runoff, or Eel River coho naturally move to the estuary during winter months. Coho presence and wide distribution across estuarine habitats also suggests the estuary is a rearing area and an important transition area between freshwater and the marine environment

Studies of other estuaries have shown coho rearing in estuarine habitats for a range of days to months before migrating to sea or moving back into freshwater habitat to over-winter (Tschaplinski 1982, Maahs and Cannata 1998, Cannata 1998, Miller and Sadro 2003 and Wallace 2007). It is unclear how modifications to wetland habitats have altered juvenile coho utilization patterns in the Eel River estuary, but the loss of salt marsh and freshwater ecotones may deny coho use of critical habitat.

Adult coho also depend on the Eel River estuary as staging areas and acclimating between the sea water and fresh water during upstream spawning migrations. Although coho were part of the commercial salmon harvest from the estuary 1850s to 1922, they were not always counted separately in catch records. A review of sport fishing census records (1966 to 1987) shows that adult coho were seldom reported caught by anglers in the Eel River estuary (Day 1966, Lee 1976, McCloud 1986 and Preston 1987). Apparently adult coho moved through the estuary quickly during upstream migrations.

Steelhead

Juvenile and adult steelhead can by found in the Eel River estuary year-round. A review of historic sport fishing and commercial fishing records show peaks of adult steelhead entering the estuary in winter and spring. These peaks represent the onset of winter and summer run fish respectively. However, records show that adult steelhead were also caught in the fall and summer months. The winter run stock has the largest population in the basin and based on sport fishing records, the summer run fish have shown a decline from historic numbers and they are now rarely caught in the estuary. There is a half-pounder run in mid to late summer that is a popular sport fishery. Half-pounder steelhead range in size from about ten to seventeen inches.

Juvenile steelhead are mostly found in the upper estuary zone during the summer and fall seasons. They seem to prefer the fresh and slightly brackish waters found there. However, juvenile steelhead were found by Puckett (1977) and Cannata (1994-95) in all areas of the estuary over their study periods.

The importance of steelhead estuarine rearing is less studied than for the Chinook and coho. But, studies of the esturaries and/or lagoons of the Gualala, Garcia, Navarro, Mattole, and Eel rivers, Redwood Creek and Humboldt Bay tributaries show that steelhead use these habitats year-round indicating that estuarine rearing is an important life history pattern (Zedonas 1992; Higgins 1995, Ridenhour and Hofstra 1994; Cannata 1998; Anderson 2000, ECORP 2004 and Wallace 2007). Studies of the Navarro River observed accelerated growth rates for steelhead that rear in the estuary/lagoon compared to upstream areas (Cannata 1998 and R.Bush, UCD written communication).

Commercial Fishing in the Estuary 1853-1922 and Price Creek Hatchery 1897-1915

The Early Fishery

The early commercial salmon fishery was started by a few men that organized companies or teams of fishermen. They claimed fishing sites along the lower estuary channel adjacent to a deep pool or deep reach where salmon would congregate. Beach seines of 360 to 480 feet long and 20 to 26 feet deep were used to catch salmon (Wainwright 1965 and Van Kirk 1996). To accommodate a large net, the fishing sites were first cleared of large wood snags, often with the help of local Weott tribesmen. The tribesmen dove deep into the water and attached ropes necessary to haul out the snags (Wainwright 1965). To catch the salmon, beach seines were set into the river, swept through the pool containing fish and hauled ashore by teams of men or with the aid of teams of horses. A Humboldt Times (December 1857) article provides one of the first descriptions of the salmon fishery in the estuary:

"The net spoken of in my last, on Eel River, has actually taken from October l8th to Nov. 5 (in all eighteen days) l6,000 salmon filling 880 barrels of 200 pounds each and the balance of three fisheries on the river have had a fair share of success"

The "three fisheries" referred to in the above article were separate companies with fishing sites along the lower estuary channel. Each company employed 10-14 men. They built barrels for packing salted salmon, cleared the river of snags, and hauled seine nets to capture fish. Barrels holding approximately 200 pounds of fish and half barrels holding 100 pounds of fish were used to ship salmon to San Francisco (Van Kirk 1996). Using the information provided in the 1857 newspaper article, the average weight per fish for those 16,000 salmon packed into barrels was approximately eleven pounds. Salmon packed into barrels were first processed to remove the head, viscera, gills, and prepared for market. Processing removed approximately 30 percent by weight from the round fish (Scofield W. 1926; Z. Grader, PCFFA, personnel communication). The average whole fish was likely near sixteen pounds when caught. A similar article recorded in the November 9, 1861 edition of the Humboldt Times stated that a single seine haul netted 2,600 salmon equal to 140 barrels at 200 pounds each (average dressed weight of ~11 pounds per salmon).

The first reported catches did not note differences between the salmonid species. The catch was likely dominated by Chinook salmon but also may have included some numbers of coho salmon and steelhead. Chinook salmon began to enter the estuary in August, but the fishing season usually began in October when fish were present in sufficient numbers for harvesting. Most of the harvesting was over by the end of November and before the peak runs of coho salmon and steelhead entered the river (Van Kirk 1996).

The first regulated season was from September 15 to November 25, 1859 (Wainwright 1965). However, enforcement of the regulations was difficult. The river conditions and the number of barrels available for packing generally limited the numbers of salmon caught by each fishing company in a season.

In many years, high river flows or floods made it impossible to fish with large nets. Such seasons occurred in 1859 and 1860 when floods came to the estuary at the same time as the main runs of salmon. The bulk of the salmon run passed freely to upstream spawning grounds escaping the commercial fishery. In January 1862 a flood hit the estuary causing bank erosion, damage to fish houses, smoke houses and property loss including hundreds of barrels of packed salmon that were washed away (Wainwright 1965; Van Kirk 1996). It became evident early on in the fishery that river conditions at the time fish were present would influence annual harvests.

The early commercial fishery brought significant numbers of jobs and revenues to Humboldt County. In 1859, there were seven or eight fishing and packing companies working along the lower six miles of the river (Van Kirk 1996). Over the next 20 years the business of salmon fishing continued to grow, the number of fishermen increased, but the numbers of salmon harvested and prices paid for fish varied considerably (3 to 10 cents per pound for salted fish). Prices and demand also influenced the annual fishing effort and harvests. In 1861 prices dropped to three cents per pound and in 1862 fishing effort on the Eel River was "not extensive" "owing to the decline in prices", (Wainwright 1965). In 1868, Titus F. Cronise wrote in *The Natural Wealth of California. H.H. Bancroft & Co., S.F.*:

"The salmon-fishery at the mouth of this river [Eel] is the most prolific in the State; and the fish are said to have a finer flavor than those caught either to the north or south of this point. The annual catch here, which ranges from eleven hundred to three thousand barrels, might be greatly enlarged were there more of a local consumption or better facilities for shipping the fish to a market".

It is important to note that packing companies referred to in Wainwright's (1965) and Van Kirk's (1996) compilations of newspaper articles were not canneries. The fishing companies caught and packed salmon into barrels. Packing salmon in salt preserved the fish and allowed for shipping to San Francisco and other ports. When ice became available, fresh salmon was shipped from Port Kenyon to San Francisco. Prior to the widespread availability of ice there were times when the catch was so large the fish could not be processed before they spoiled. These likely were not included in catch records. The Weekly Humboldt Times wrote on November 10, 1877, "We learn that the fisheries on Eel River are taking salmon in immense quantities--more and faster than can be taken care of."

The Canneries and the Boom Years

During research for this report, we found reference to only three canneries that operated in the estuary. Dungan and J. B. Requa built the first cannery on the Eel River in 1869. However, no available records estimated the number of fish they packed into cans. The Pacific Coast Packing Company built by the Cutting and Packing Company of San Francisco in 1877 operated until 1889. It was located in Ramseyville on Cock Robin Island. The Port Kenyon salmon processing and cold storage plant, later renamed the Tallant cannery operated from 1906 to 1911 (Parry 1959). There may have been smaller canneries that operated in addition to those mentioned above, but no records were found to document their participation in the fishery. The U.S. Commission of Fish and Fisheries (1887) notes only one cannery on the Eel River for 1877-78. However, Van Kirk (1996) provided this quote from *History of Humboldt County California 1882. Wallace W. Elliot & Co. Publishers:*

"There are four canneries on Eel River, where are annually put up large quantities of salmon in cans. Cutting & Co. have the largest establishment with a capacity of 200 cases per day. In 1880 the number of cases put up amounted to 3,000"

Canneries did not operate continuously during the life of the fishery. There were many years when the fishermen had to sell to other markets. But while in operation, a cannery provided a local market where fishermen could easily sell salmon and get back to the business of fishing. The commercial fishery had changed from limited by the number of barrels on hand for salt packing and the fresh fish market to a nearly unlimited demand of fish for canning purposes (Parry 1959, Van Kirk 1996). Approximately fifty to sixty percent and as much as 70 percent of the annual salmon catch was sold to a cannery if they were buying. The remainder was packed in barrels, smoked, or sold as fresh. In 1887, the Pacific Coast Packing Company Cannery received 266 tons (70%) of the 375 tons (~50,000 fish) reported harvested that year. Those 266 tons yielded 7,500 cases of cans and each case held 48 one-pound cans. The canning process attained approximately 67 percent yield by weight of whole fish. Such a high yield may be attributed to large fish having less waste than smaller fish. Typical salmon canning yields range from 55 to 65 percent depending on fish size. In some years catches were so large that the cannery could not can all of the salmon they received. These surplus supplies were salted and packed in barrels, while some spoiled before they were processed (Van Kirk 1996). It was soon evident, that even with a cannery in place; markets could be saturated with such a large supply of salmon coming from the Eel River.

The prices paid for fish were often a contentious issue between fishermen, cannery operators and fresh fish markets. Fresh fish either sold to local Eureka markets or shipped by steamer to San Francisco out of

Port Kenyon or Eureka. Some fish was smoked locally. In most years, it was more profitable to sell salted fish or sell to a fresh fish buyer rather than sell to a cannery. Only the few long-established fishing companies were set up to salt and pack their catch in barrels and the fresh fish market price could change suddenly based on supply and demand. It was practical for many fishermen to sell to the cannery at a price below the fresh and salted fish market levels and get back to the fishing grounds quickly. Another cannery was built at the foot of F Street in Eureka in 1881 to meet the growing market. The Eureka cannery received salmon from the Eel River, Humboldt Bay and Mad River.

The canneries expanded the market for Eel River salmon and allowed more fishermen to participate in the fishery. Most of these were gill net fishermen. They harvested salmon and steelhead as far upstream as Price Creek near RM 12 on the Eel River. In 1886, there were 12 seines and 70 gill nets working in the estuary. The fishery included a second run (late fall) of Chinook salmon harvested in December and January. Steelhead were harvested until the end of March. Sometimes salmon undesirable for human consumption were caught. They were near spawning condition, reducing their quality as food. These fish should have been allowed to go upstream to spawn. The fishermen and public were aware of this waste of fish which brought attention to the lack of regulations on the fishery (Van Kirk 1996).

Market forces, weather, floods and unpredictable salmon runs were part of the venture of the commercial fishery. In some years the fishing business was less prosperous due to smaller runs of salmon entering the river, or early floods would allow the majority of a run to pass upstream before river conditions were suited for fishing. Then a boom year would arrive and saturate markets. Politics of labor relations was also an issue. The cannery preferred to employ Chinese people, but the people of Humboldt County did not approve of bringing in foreigners, claiming the loss of jobs for locals. Many discussions between cannery management and local politicians were in regards to cannery labor (Wainwright 1965 and Van Kirk 1996).

A summary of cannery records from the Pacific Coast Packing Company 1877-1887 printed in the Ferndale Enterprise in 1887 showed the cannery produced an average of 8,140 cases per year with a range of 3,500 cases (18,500 fish) in 1877 to 12,500 (67,000 fish) in 1886. Each case contained 48 one-pound cans of salmon. The cannery did not operate in 1879 because of a large pack of 11,900 cases from the prior year still flooded the market (Van Kirk 1996).

After 1885 turned out a low salmon catch, local citizens and sport fishers began to suspect the fishery was in decline due to excessive harvests. However, in 1886 an estimated 2 million pounds of salmon (~125,000 fish) was caught from the beginning of November to December 12th. The 1886 harvest was one of the largest ever taken from the estuary. The cannery paid 30 dollars per ton, received half of the harvest and canned 12,500 cases of salmon. At 48 one pound cans per case those 12,500 cases weighed 600,000 pounds which equals a sixty percent yield from the reported one million pounds sold to the cannery. The fresh fish market brought as high as 60 dollars per ton and the salt packed salmon brought about 45 dollars per ton (Van Kirk 1996).

Based on the relatively low harvests of 1882 to 1885 (annual average of ~40,300 fish), the US Board of Fish Commission in 1888 reported that the salmon catches on the Eel River were beginning to decline (USBFC 1888-1890). However, in 1888 a large run of salmon produced large harvests once again. The cannery did not operate leaving the markets flooded with fish. Fresh fish sold for as little as one cent per pound (20 cents/ton) (Van Kirk 1996). As presented in Van Kirk (1996), a November 3, 1888 newspaper article from the Ferndale Enterprise stated "Salmon in Abundance"; this article described the large salmon runs of 1888 and its influence on the market:

> "*An immense run of salmon started in Eel River and fish have been more than plentiful in that stream ever since. Swett & Fulmore have been making enormous hauls, they having already caught about all they are prepared to take care of and intend ceasing fishing this week. Wm. Ellery tells us that there are more fish in Eel River this year than he ever saw before and he has been fishing on that stream about 30 seasons. The fact of the cannery not running limits the market and those not prepared to salt are left to either ship to San Francisco fresh or sell their fish for what they can get to those who can handle them"*.

In 1889, another large run of salmon entered the estuary. There were days when the number of fish caught exceeded the canning process capabilities, causing excess fish to spoil. The cannery pack was over 12,000 cases of salmon (approximately 900,000 pounds of whole fish). In addition to the cannery pack, over one million pounds of fish was either sold to fresh markets or salted and packed into barrels (Wilcox 1896).

The large salmon and steelhead runs continued in 1890 as over 1.1 million pounds of salmon and 311,000 pounds of steelhead were reportedly harvested (Wilcox 1905). Van Kirk (1996) presented an excerpt from the Ferndale Enterprise, dated 03 Nov 1888, which described the abundant salmon run:

> "*Since last Thursday night, Eel River has been literally alive with salmon and the fishermen on the river have had all the fish they could handle. Sunday night the Legg Bros. caught 30 tons at one draw, probably the largest haul ever made on the river. Since then five to ten ton hauls have been of frequent occurrence*".

Due to a saturated canned market from the previous year's catch, the cannery in 1890 was once again not in operation. An excerpt from the Ferndale Enterprise dated March 21, 1890 reported that there was still "about 400 tons of canned and barreled salmon at the cannery awaiting shipment" from the Eel River (Van Kirk 1996). Without a cannery willing to buy fish, the large catches flooded the fresh fish market and drove down prices. With such an abundance of salmon on the market, fishing effort would slow or cease altogether until the demand and prices for fresh fish increased (Parry 1959; Wainwright 1965 and Van Kirk 1996). According to Wilcox (1896) between 1889 and 1892 over one million pounds per year of salmon was harvested in Humboldt County. The Eel River was the principle source of these fish.

In 1891, catches of salmon (~74,000 fish reported) dropped again compared to recent years of large harvests. The high demand for fresh fish at good prices in San Francisco markets made less fish available for canning. Consequently, the cannery owned by Pacific Coast Packing Company closed. In 1892 the lack of fall rains may have contributed to fewer salmon available to the fishery resulting in below average (~55,000 fish reported) harvest. The following five years had some good salmon catches but overall the season's harvests were below the late 1880s average.

In the early 1890s, large runs of steelhead in December through March became an important source of income for the fishermen. For example, approximately 500,000 pounds of Eel River steelhead sold outside the county in 1892 (Wilcox 1899-1900). An excerpt from the Ferndale Enterprise (Dec. 17, 1886) describes this steelhead run: "Now comes the run of what is known as steel-heads, which will continue until the lst of April… A good number of the Eel River fishermen expect to catch a large number of these during the next three months". These large runs of steelhead may have helped fishermen to offset the reduced salmon runs during this period.

The percent harvest of the Eel River salmon spawning run is not known. Harvest rates certainly increased in the 1880s over the early years of the fishery as the numbers of fishermen increased. Unregulated harvest estimates from Oregon coastal rivers range from 35 to 88 percent depending on stocks (Gresh et al. 2000; Meengs and Lackey 2005). During the mid 1890s, the State Fish and Game increased regulations on the commercial fishery with various rules and laws. The laws included net restrictions, shortened seasons and closed areas. The management of the commercial salmon fishery, declining catches, and less opportunity for profits led to a decline in the number of commercial fishermen. Although the laws were difficult to enforce, commercial fishing effort reduced and the goal of allowing greater numbers of salmon to escape to spawning grounds was achieved (Wilcox 1899-1900; Van Kirk 1998).

It is unclear if regulations alone were responsible for the declining catches or if there were other factors at work. For example, in 1895, 376 fishermen caught 277,000 pounds of Chinook (17,300 fish or 46 fish per fisherman), 136,000 pounds of coho (~13,600 fish) and 409,000 pounds of steelhead. In 1899, there were only a 185 fishermen; they caught 176,000 pounds of Chinook (11,000 fish or 60 fish per fisherman), 60,000 pounds of coho and 114,000 pounds of steelhead (Wilcox 1899-1900). Occasionally, harvests of Pacific herring, Pacific sardines and smelt were taken in beach seines and Dungeness crabs were also harvested from the estuary to supplement commercial fishermen's incomes.

Price Creek Hatchery 1898-1915

In the 1890s, public opinion of declining salmon stocks prompted requests to State Fish and Game for a hatchery on the Eel River. After reconnaissance studies a hatchery site was selected on Price Creek, a tributary located about 12 miles upstream of the Eel River mouth. The Price Creek Hatchery was built in 1897. In January of 1898, the hatchery received its first shipment from the Battle Creek hatchery in Shasta County of 8 million Chinook salmon eggs. Over the following 15 years, the Price Creek hatchery annually received between 885,000 and 9 million Chinook salmon eggs from hatcheries on Battle Creek and Mill Creek in the Sacramento Basin. The eggs were released soon after hatching as fry in Price Creek and the lower Eel River (Van Kirk 1996).

1900 -1921 The Last Years of the Salmon Fishery

Wilcox (1900) reported that "fish were more plentiful in 1900 than at any time since 1895" and the 1901 season produced a harvest of 851,000 lbs of salmon by Eel River fishermen. This run coincided with the third year of hatchery releases, the first year of expected returns to the hatchery and after several years of regulations that shortened the season and closed areas to commercial fishing. In 1904, the commercial fishery harvested over 2.2 million pounds of Chinook, 133,000 pounds of coho, and 53,000 pounds of steelhead (Wilcox 1907 Report of Commissioner of Fish and Fisheries). Since there was no cannery, the great majority of salmon sold to fresh fish markets. People believed that the large harvest could be attributed to both "artificial propagation and legal protection" (Wilcox 1907). However, the relatively large harvest of coho salmon, which were not part of the hatchery project, suggests natural production of salmon was high for these year classes and the large harvest may be part of the cyclic pattern of population dynamics similar to earlier years. The relatively small catch of steelhead may be attributed a shortened season which ended January 31 1905 instead of extending until April as in past years of large harvests. The large winter storms in of 1904-05 also made fishing for steelhead difficult (Van Kirk 1996).

The last cannery built on the Eel River estuary was in 1905-06. The cannery and a cold storage plant was added to the existing Port Kenyon packing plant located near the confluence of the Eel and Salt rivers. One reason for building the cannery was many fish caught by the fishermen were below the minimum size (15 lbs) or were below the minimum quality desired for mild curing, which was performed to create the highly desirable product of salmon lox. The mild curing process used only high quality, large fish. These fish were often only a portion of a fisherman's catch (Scofield 1925). A cannery operation combined with packing and cold storage facilities could allow a company to buy a fisherman's entire catch, mild cure the large high quality fish and process into cans the small or lesser quality fish. This had benefits for both the fishermen and the cannery and resulted in less waste of fish (Scofield 1925, Parry 1959). However, in 1908, there was low demand for mild cured salmon, so the entire Port Kenyon facility closed for that year. The Port Kenyon cold storage plant operated in 1909 and during 1910 and 1911, the cannery was leased to and operated by N.W. Tallant. The facility referred to as the Tallant Cannery was closed after the 1911 season, not for the lack of fish but because of disputes over wholesale prices paid by the cannery, operating costs that controlled cannery profits and the increasing competition and increased demand for fresh fish in San Francisco (Parry 1959, Van Kirk 1996).

Meanwhile a shortage of eggs at the Sacramento hatcheries reduced shipments to the Price Creek Hatchery. There were attempts to obtain ripe eggs from Eel River Chinook and coho salmon, but these efforts were unsuccessful. Beginning in 1902, steelhead fry from the Outlet Creek hatchery and from the Snow Mountain Egg Collecting Station (both located in the Upper Eel River basin) were released from the Price Creek hatchery (Report of Board of Fish and Game Commissioners 1910). In 1910, 47,000 coho fry from Santa Cruz were released into Price Creek.

The Price Creek Hatchery closed in 1915 due to a landslide that damaged the diversion dam needed to provide the facility's water supply. A new hatchery site on Steelhead Creek near Alderpoint was thought a better location for propagating Eel River salmon. Thus, in 1916, the hatchery buildings from Price Creek were moved to a site near the mouth of Steelhead Creek allowing the Fort Steward Hatchery to begin operations. The Fort Seward Hatchery operated from 1916-1942.

The addition of stocked salmon by the Price Creek Hatchery was viewed with varying degrees of success. In his annual report to the State Fish and Game Commission (1915), W.H. Shelbley, Superintendent of Hatcheries, speaks of the Price Creek hatchery as follows:

> "*Price Creek hatchery has been under the supervision of Mr. W.O. Fassett, who has successfully operated this station for the past fourteen years. We are pleased to note that the salmon are yet plentiful in Eel River and do not show any signs of a decrease, although the fishing has been as heavy as in past years".*

Others felt that releasing salmon fry immediately after hatching in the lower river did not give these small fish much of a chance for survival; however, there were large commercial catches in the early 1900s that coincided with hatchery releases. Five years after hatchery releases of salmon the commercial harvest increased to over 1,500,000 pounds. However, these larger catches were in sync with cyclic patterns of natural variation in run sizes seen throughout the commercial fishery. The increased harvest trend of coho salmon during the same years was without assistance from the hatchery. Coho were not reared in the hatchery until 1910.

After further gear restrictions, other management actions and public interventions the commercial fishery closed on the Eel River by California legislation in 1922. The closure was also related to the growing presence of the ocean troll salmon fishery that harvested high quality fish at sea. State Fish and Game managers felt that the salmon populations would be at risk from the combined ocean and in-river harvests. The Report of Commissioner of Fish and Fisheries (1918) and the Division of Fish and Game Fish Bulletin No. 20 (1929) presents the last records found that document the commercial harvests from the Eel River estuary**.** The average reported harvest for the years 1918-1921 was 31,200 fish.

Another management consideration for the closure of the commercial fishery was the construction of Cape Horn Dam in the upper Eel River by the Snow Mountain Electric Company. The dam blocked access to important spawning grounds for anadromous salmonids and the water diversion reduced important flows needed for fish passage into the upper basin to spawn. Lastly, there was the public concern of using taxpayer money to pay for hatchery operations, but having the canneries receiving the profitable benefits. An excerpt from the State Board of Fish Commission (1988-90) remarks these sentiments, “the business of the canneries should cease or else the government should abandon stocking”.

Table 7 presents the reported number of barrels, and the pounds of fresh fish sold by Eel River fishermen and the reported amount of fish canned for years where adequate data was available. Note that these figures are mostly below the actual annual salmon harvest because they do not always include the number of fresh, smoked, or salted fish that were also harvested each year, which may amount to an additional 25-35 percent of the catch (Report of Board of Fish and Game Commissioners 1910). These harvest data give us some idea of how many fish were caught and sold. In addition, sport fishermen and spear fishermen harvested an untold number of fish annually that are not accounted for in the overall totals.

Supplementary Findings and Fishery Synopsis

A substantial amount of anecdotal information describing run size, run timing, species composition and harvest records is presented in past newspaper articles summarized by Wainwright (1965) and Van Kirk (1996). These articles tell of at least two fall runs of Chinook in the Eel River: 1) an early Fall run often caught in the estuary from as early as August, but mostly caught 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. The newspaper articles also tell of adult steelhead caught in the estuary year round mostly by sportfishers. The steelhead fishery had peaks in April, May, June representing a summer run and a winter run that peaked in December thru March. The steelhead half pounder run was strongest in August and September. The harvest records reported in newspaper articles were supported by reviews of published reports by the U.S Fish Commission, State Fish Commission, Bureau of Fisheries, CDFG, and others.

The commercial harvest that took place for nearly seventy years was certainly an early perturbation to the Eel River salmon stocks. A close examination of harvest records and detailed review of historic information show that market factors, labor disputes, and annual variation of run size were significant factors contributing to the harvest history of the commercial fishery.

The introduction of Chinook salmon from Price Creek Hatchery was from Sacramento Basin stocks. According to recent genetic studies, the Eel River stocks appeared to be distinct from Sacramento Basin stocks. Any contribution in numbers or genetic markers from hatchery stocks from outside the Eel Basin appears lost over time (Good, et al 2005).

Historic Chinook Salmon Population Estimate

Historic salmon population estimates for rivers along the west coast have been based on in-river commercial harvests involving cannery production and other sources of catch data. The methods used to make historic run size estimates include the following: 1) converting the reported annual harvests from cannery records etc. to a number of fish caught for each year; 2) selection of a time series to best predict run size; 3) approximate and apply annual harvest rates; and 4) the addition of unreported harvests and spoiled or waste fish to reported catch (Lichatowich 1989; Gresh et al. 2000; Meengs and Lackey 2005).

Methods used to estimate the historic Chinook salmon run size in the Eel River were adapted from those described above. The reported harvests of salmon salted in barrels, cases of cans, or pounds sold to fresh fish markets were converted to numbers of salmon as shown in Table 7. Synthesizing information on the fishery proved challenging because of the various ways salmon was processed and marketed and the inconsistent reporting records. Many years have incomplete data so they underestimate the actual catch.

Table 7. Annual reported commercial catches of Chinook salmon from the Eel River estuary1857-1922. ***.*** *The amount of fresh fish sold to local and San Francisco markets was not available for most years which represented at least a 25 percent addition to cannery and/or salted totals shown (report of Board of Fish and Game commissioners 1910). Little or no catch data was found for years 1861- 1873 and 1905-1909. The weight of fish sold to canneries is based on the number of cans produced and reflects a yield of 60% to cans from whole fish. The estimated number of Chinook salmon harvested was derived by dividing the estimated pounds of fish harvested by 16 pounds per salmon.*

Year	Estimated Pounds Sold to Cannery	Reported Number of Cases of Cans	Reported Number of Barrels	Reported Pounds Packed in Barrels	Estimated Pounds Caught for Packing in Barrels	Reported Pounds Sold Fresh	Estimated Total Pounds Harvested	Estimated Number of Salmon Harvested
1857			1,200	240,000	300,000	na[1]	300,000	18,750
1858			2,000	400,000	500,000	na	500,000	31,250
1859								
1860			1,100	220,000	275,000		275,000	17,200
1874			3000 a	300,000	375,000		375,000	23,450
1876			3000	600,000	750,000	138,000	750,000	46,875
1877	680,000	8,500	2763	276,300	345,400	na	1,025,400	64,090
1878	952,500	11,900	3,600a	360,000	450,000	na	1,402,000	87,625
1880	672,000	8,400	1,237	123,700	154,600	60,000	886,600	55,400
1881	488,000	6,100	564	56,400	70,500	278,000	836,500	52,300
1882	696,000	8,700	na	na	na	na	696,000	43,500
1883	720,000	9,000	na	na	na	na	720,000	45,000
1884	640,000	8,000	na	na	na	na	640,000	40,000
1885	448,000	5,600	na	na	na	89,000	537,000	33,550
1886	1,000,000	12,500	na	na	na	1,000,000	2,000,000	125,000
1887	532,000	7,500	3,000	30,000	37,500	188,000	757,000	47,300
1888	Big runs,	huge	catches	noted , but no		harvest	numbers	available
1889	960,000	12,000	na	na	435,600	na	1,400,000	87,500
1890							>1,000,000	62,000
1891	na	na	na	na	na	na	1,110,000	69,375
1892	na	na	na	na	na	na	825,000	51,560
1895			na	na	na	277,325	277,325	25,875
1899			na	na	na	258,000	258,000	15,175
1901			na	na	na	na	851,000	53,190
1902			na	na	na	na	1,100,000	68,750
1904			na	na	na	na	2,300,000	143,750
1910		6,000	na	na	na	na	430,000	26,875
1911		8,400	na	na	na	na	600,000	37,500
1912		11,000	na	na	na	na	790,000	49,375

Year	Estimated Pounds Sold to Cannery	Reported Number of Cases of Cans	Reported Number of Barrels	Reported Pounds Packed in Barrels	Estimated Pounds Caught for Packing in Barrels	Reported Pounds Sold Fresh	Estimated Total Pounds Harvested	Estimated Number of Salmon Harvested
1914			na	na	na	na	1,120,000	70,000
1915			na	na	na	586,000	586,000	36,625
1916			na	na	na	na	950,00	59,375
1917			na	na	na	na	700,000	43,750
1918			na	na	na	na	400,000	25,000
1919			na	na	na	na	800,000	50,000
1920			na	na	na	na	370,000	23,125
1921			na	na	na	na	300,000	18,750

[1] Not available with sufficient data to be included or separated from reported totals.

The second highest five-year mean harvest (1878, 1886, 1889, 1902, 1914) was selected with the assumption that large harvest years occurred with large runs and optimal fishing conditions and high harvest rates through most of November. The record reported harvest in 1904 of 143,750 Chinook salmon were not included in the five years averaged for highest reported harvest because returns from Price Creek Hatchery releases may have contributed to the year's catch. A review of the five years of catch data shows that the great majority, if not all the catch came before December, making the harvest predominantly of fall runs of Chinook salmon. Markets, especially the cannery, were often saturated by the large catches in November. The large catches and saturated market reduced or stopped fishing efforts later in the season. Fishing seasons also limited the harvest to the fall run.

Historical reports, as in the Ferndale Enterprise November 22, 1889, note that rains and high river flows in late November and into winter often allowed much of the later fall Chinook run and coho run to pass freely upstream (Van Kirk 1996). Therefore, based on the selected harvest years for analysis, the number of late fall Chinook run entering the river December and January would not be included in the historic population estimate as the great majority of harvest were concluded before December for those years.

To account for wasted or spoiled fish and other unreported catches, 20 percent of the annual catch is added to each year (Gresh et al. 2000; Meengs and Lackey 2005). This may be conservative as The Report of Board of Fish and Game Commissioners (1910) estimated that unreported salmon sold to the fresh fish market composed 25 percent of the annual catch from the Eel River.

Three harvest rates 35, 60 and 80% were divided into the mean catch total ± 95% CI (2nd highest five year mean = 105,330 ±34,000) to produce total run sizes. The three catch rates should encompass the actual catch and Chinook salmon run size during the years of the Eel River commercial fishery (Table 8). However, because the larger harvest years were used, the harvest rates of 60 and 80 percent likely produce the best approximate historic run size of fall run Chinook salmon.

*Table 8. Estimated historic fall Chinook run size based on commercial harvest data.**

Harvest Rate (%)	Estimated Run Size
35%	300,940 ± 97,150
60%	175,550 ± 56,665
80%	131,660 ± 42,500

* Estimates primarily include late fall run (fish caught after December 1st).

For a historical run size estimate comparison, Meengs and Lackey (2005) used a 23-pound average per Chinook and predicted a historic run of 154,000 Chinook over a similar time period for the Rouge River. The Rouge River is a 5,200 square mile basin with 220 miles of mainstem channel compared to the 3,600 square mile Eel River Basin with 200 mainstem miles.

Other Fishery Resources

In addition to the anadromous salmonids, several marine, resident estuarine and freshwater fish species also rely on the diversity of habitats and the productive estuarine waters for spawning, feeding, and rearing. These include special concern species such as the federally listed as threatened green sturgeon, longfin smelt and tidewater goby. However, juvenile nursery habitat is one of the areas most important attributes. The Eel River estuary is utilized for juvenile nursery areas by several important fishery resources including Dungeness crabs. English sole, starry flounder surfperch spp, sturgeon, smelt spp. and Pacific herring.

Many fish show preferences to specific areas while others spread widely across the estuary and some are only occasional visitors or are drawn in by tidal currents. Less conspicuous species such as federally endangered tidewater goby rely on unique protected areas for year round habitat. Chamberlain (2006) suggests that preferred tidewater goby habitats may be areas with low velocity tidal currents and/or stable areas with infrequent tidal exchange. Such habitats can be found in upper and lateral extents of tidal sloughs and marshes.

A few species are very abundant for a period of time, mostly spring to fall (surf smelt, top smelt, anchovies, English sole, sardines, herring). Some are present year round (salmonids, starry flounder, staghorn sculpin, stickleback) and species that are represented by a relatively few individuals that occasionally find their way in the estuary eg. jack mackerel). Most of the occasional visitors are marine species. Some species may be seldom found in the estuary because their populations are far below historic numbers (green sturgeon, white sturgeon, and longfin smelt). The comparison shown in Table 8 of the fish observations of Puckett (1973-74) and Cannata and Hassler (1994-95 field data) help to show spatial and temporal relationships of fish and estuarine habitats. Fish presence is related to variables, such as seasonal river discharge, salinity regimes, tides, water temperature, bottom substrate and migratory or reproductive strategies. The physical conditions are constantly changing due to the dynamic nature of the estuary. Due to salinity gradients, it is possible to catch a freshwater fish and a marine fish at the same site where fresh water flows on the surface and seawater flows along the bottom.

It is important to consider all of the species and habitat types that are found in the estuary when developing management plans. Maintaining viable populations of this diverse group of fishery resources depends on the estuarine ecosystem to retain natural processes and diversity of habitats. Thus, maintaining and improving habitat diversity, such as properly functioning tidal marshes, will likely benefit the estuarine ecosystem and its fishery and wildlife resources. Simenstad (1983) states:

"…it is only at the community level that ecological relationships among biotic and abotic components can be interpreted in terms of the functional processes which effect the dynamics of the systems structure and production. Thus the role of riverine inputs, estuarine circulation, salinity gradients, nutrient and material fluxes, and sediment structure in determining the composition, distribution, and standing stock of estuarine biota can be translated into management recommendations for the maintenance of key processes."

Table 9. Seasonal and spatial distribution of fish captured in Eel River estuary. Captured by Puckett in 1973-74 (P), Cannata and Hassler 1994-95 (X), or both (O). W = Winter (December - February); Sp = Spring (March – May); S = Summer (June-August); and F =Fall (September - November). North Slough= McNulty and Hawk Slough channels; Lower Channel= North Bay to Cock Robin Island Bridge; Middle Channel= main channel from Cock Robin Island Bridge to Fulmor Road; Upper Channel= main channel from Fulmor Road to Fernbridge.

Fish Species		North Sloughs				Lower Channel				Salt River				Middle Channel				Upper Channel			
		W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
Anadromous	Juvenile Chinook salmon		X	P	P		X	O	O		X	O	P	X	O	O	O		O	O	P
	Juvenile Coho salmon		P	P	P	X	O			X		P			P				P		
	Juvenile Steelhead trout	P	O	P	P	P	P	O		P		O	P	P	P	X	O		P	O	O
	Juvenile Cutthroat trout											X									
	Green sturgeon															X					X
	Pacific lamprey	P				X									X						
	American shad															X				O	X
	Longfin smelt	X	O			O	X	X		P				P							
Estuarine or Marine	Surf smelt		O	O	O	O	O	O	O	O	O	O	O			O	O				O
	Pacific herring		O	O	O			O	O			O	O			O	X			O	P
	Pacific sardine							X	X			X				X	X				
	Northern Anchovy		P		O			X								X	X				
	Top smelt			O	O			O	X		P	X	O			O	O				
	Staghorn sculpin	O	O	O	O	O	O	O	O	P	X	O	O	P	X	O	O			X	
	Prickly sculpin	O				O	X	X	P	P		O	X			X	X		P	X	X
	Bay pipefish		P	O	P			X	X			O				O	X				
	Shiner surfperch		O	O	O		O	X		P	X	O	O		P	O	O				P
	Redtail surfperch		P	P	P	O		P	O	P		P			P	P					
	Walleye surfperch			P					X												
	English sole		O	O	X			O	X			X	X			O	X				
	Starry flounder	O	O	O		O	P	X	O	P	P	O	O	P	P	O	O			O	O
	Sand sole								O												
	Cabezon							O	X												

Fish Species		North Sloughs				Lower Channel				Salt River				Middle Channel				Upper Channel			
		W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
	Saddleback gunnel		O	O					P			P				O	P				
	Stickleback		O	X	P	X	O	X		X	O	O	X		O	O	X		O	O	O
	Tidepool sculpin								X												
	Bay goby								X												
	Ring-tail snailfish								X												
	Buffalo sculpin								X												
	Jack mackerel								X												
Freshwater	Sacramento sucker	P				P				P			P	P	P				O	O	O
	California roach				P	X				X					X	X			P	O	O
	Sacramento pikeminnow		X	X		X	X	X			X	X			X	X			X	X	

Responses to Assessment Questions

What are the history and trends of the size, distribution, and relative health and diversity of salmonid populations?

- Juvenile salmonids of the Eel River use an estuarine rearing life history strategy. They have been observed in the estuary on a year-round basis;
- Spawning runs of adult Chinook salmon begin to enter the estuary in August and hold there until fall rains provide sufficient flows to allow upstream passage to spawning grounds. Adult Chinook continue to enter the estuary through January;
- Adult coho salmon generally enter the estuary November to February on their way to upstream spawning areas;
- From 1853 to 1922 the estuary supported a large commercial fishery. Reported peak annual harvests was 2.3 million pounds of salmon (~150,000 fish) and over 500,000 pounds of steelhead (~62,500 fish);
- Anecdotal reports from the mid 1800s to early 1900s tell of adult steelhead found in the estuary year-round. Today winter steelhead runs typically range between November to April and summer runs generally range from March to June;
- Due to declining populations Chinook, coho and steelhead receive protection under either or both state and federal endangered species acts;
- Data collected from fish counting stations at Van Arsdale and Benbow show significant declines of Eel River salmonid populations. The rate of decline increased after floods of 1955 and 1964.

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

- A diverse group of fishery resources including salmonids depend on the estuarine ecosystem to retain most of its natural function and diversity of habitats;
- The Eel River estuary provides critical habitat and nursery area for anadromous salmonids and several other important fishery resources;
- The loss and alterations of salt marsh and freshwater ecotones may deny coho use of critical habitat;
- Water temperature is generally suitable for anadromous salmonids year round. Although the upper channel reach near Fernbridge can warm above 70F during summer months;
- Dissolved oxygen levels can drop below 5ppm in McNulty and other slough channels. This may be a signal of nutrient loading and/or poor circulation;
- The reduction in tidal connectivity and loss of area due to sedimentation, levees, and flood gates has contributed to an overall loss in the estuary tidal prism;
- Roberts (1992) estimated that salt marsh surrounding the estuary once covered at least 15 square miles or close to 10,000 acres;
- Approximately ten percent of the original tidal wetlands and salt marsh habitats remain in the Estuary Subbasin;
- In the past, the estuarine channels were deeper, more diverse, and more complex compared to present conditions;
- There is a shortage of large wood needed to help scour accumulated sediments and for structural and shelter elements for salmonids. Large wood is removed by salvage operators and firewood collectors.

What are the past and present relationships of geologic, vegetative, and fluvial processes to estuarine habitat conditions?

- The Eel River is composed of soft Franciscan rock, fragile soils, widespread tectonic deformation of the underlying rocks, recent rapid uplift, and high winter and spring rainfall and subsequently carries the second highest suspended sediment load per drainage area in the world;

- Since the estuary receives runoff from the entire Eel River Basin, it is influenced by cumulative watershed effects such as river discharge, water temperature and rates of sediment deposition;
- High rates of sedimentation in the estuary are related to severe erosion in the upstream subbasins;
- The morphology of the estuary channels and adjacent lands are continually changing as result of high flows that erode, channel banks and deliver sediments. Seismic movement, land use activities, wind and wave action, and longshore currents also influence estuary morphology;
- Many formerly deep pools in the estuary are now filled by excessive sediment delivered by flood events;
- The delta area is naturally prone to flooding during high winter flows;
- Ocean tides and river floods play a major role in shaping estuarine channels;
- The tidal prism is significantly reduced compared to historic conditions;
- The location of the mouth affects lower delta drainage during winter floods and where wave action will strike the shore;
- Riparian vegetation plays an important role to help stabilize estuarine channel banks;
- Much of the native redwood, spruce and other conifers that once lined the channel banks have been removed;
- Climate change may initiate cumulative interactions between sea level rise, sediment delivery from upstream sources and local erosion.

How has land use affected these natural processes?

- The estuarine main channel has widened and shallowed from excessive sediment delivery linked to land use upstream and destabilization of channel banks from removal of riparian vegetation;
- The loss of approximately 90 percent of original wetland habitat and tidal prism is from land conversion and the affects of levees and tide gates. The network of levees and tide gates in the Eel River estuary has reduced channel connectivity and blocked the ebb and flood of the ocean tides;
- Swickard (1899) estimated a reduction of tidal prism of about 877,000 cubic yards (about 543 acre feet) that was caused by the early damming the southern salt marshes;
- The diking which occurred east of McNulty Slough probably reduced the tidal prism even more than did the actions addressed in Swickard's deposition;
- The reduction in salt marsh habitat area and loss of channel connectivity and complexity has altered the natural ecosystem process involved with nutrient cycling, food production, and resulted in a loss of habitat area and diversity.

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

- A loss of channel connectivity due to levees and tide gates adjacent wetlands and sloughs, limits rearing area, nutrient cycling, food production, and habitat diversity available to salmonids and other valuable fishery resources;
- A loss of channel depth may limit the carrying capacity for adult salmon holding in the estuary before rains allow passage upstream to spawning areas;
- The reduction of tidal prism limits available wetland habitat and limits scour potential needed to maintain slough channel functions;
- A relative paucity of woody debris in the estuary may limit shelter habitat needed by juvenile salmonids during large winter runoff flows and also limits cover to escape from predators.

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

Flow and Water Quality Improvement Activities:

- Insure the supply of freshwater inflows are provided for maintaining estuarine habitat diversity and to drive ecosystem processes that fish, wildlife, and vegetative communities depend on for part or all of the life history cycles;

- Use levee set backs, reconfiguration, or levee removal strategies to develop a wider flood plain that restores natural sinuosity, improves connectivity with sloughs and adjacent wetlands in North Slough channels or other areas constricted by levees;
- Increase tidal prism by modifying tide gates and/or removing leveesto restore tidal and riverine flow and connectivity between the main channel and slough channels and adjacent wetlands;
- Continue to prevent or reduce cattle waste and agricultural and dairy by-products from entering stream and slough channels;
- Take measures to ensure that water treatment facilities in Fortuna, Fernbridge, Loleta, Ferndale and other nearby areas do not contaminate estuarine waters.

Erosion and Sediment Delivery Reduction Activities:

- Land managers should work to maintain and/or establish adequate streamside protection zones to encourage growth of riparian vegetation to help stabilize stream banks;
- Increase slough channel scour potential by restoring tidal prism in historic tidal wetland areas;
- Continue efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with all land use activities throughout the Eel River basin to reduce sediment delivery to the estuary;
- Armour eroding banks near Fernbridge or other such areas with bioengineered techniques that secure large wood pieces into banks and integrate live trees into the stabilization project.

Riparian and Instream Habitat Improvement Activities:

- Where feasible, restore or improve width of riparian vegetation stands with native vegetation (Sitka spruce, cottonwood, redwood, alder willow) along the banks of lower Eel River and slough channels;
- Work to restore natural functioning tidal and drainage patterns within the McNulty Slough portion of the Ocean Ranch Wildlife Area and other north slough area channels and wetlands. The project should address water temperature, water flow regimes and other parameters needed to promote seasonal and/or year round use by fishery resources;
- Candidate sites for levee removal include both sides of McNulty Slough and its tributaries, and the land west of McNulty slough. The northwestern delta should be expanded rapidly outward from earlier project sites;
- Consider conservation easements or land acquisitions that would promote the removal or modification of tide gates and levees in order to restore tidal prism and tidal wetlands;
- Develop policy or regulations that prohibit or reduce wood removal from within the estuarine channel banks (0.25 mile upstream from Fernbridge to the river’s mouth) and out to 50 feet from the high tide shore line of the North Bay. Such regulations should protect wood pieces on stream banks needed to reduce potential from further bank and beach erosion, provide instream shelter during high flows for fish, and protect bank restoration projects;
- Develop plans to eradicate or control the spread of invasive *Spartina densiflora*. An optimal strategy for low to medium sized budgets is to remove *Spartina* in areas where it grows in low density subpopulations.

Education, Research, and Monitoring Activities:

- Develop an inclusive estuarine ecosystem management and monitoring plan that works with natural processes to restore tidal connectivity to wetlands and increases tidal prism;
- Investigate potential impacts form sea level rise, increased storm intensity and other impacts to the estuary related to climate change;
- Add to baseline data regarding habitat utilization by all estuarine species;
- Study and assess the status of estuarine conditions needed to complete specific life history requirements for salmonids and other estuarine dependant fish and invertebrate species;

- Continue and expand water quality monitoring (including temperature and D.O).of nutrient levels that may be elevated from runoff from cattle pastures, sewage treatment facilities or other sources;
- Monitor the progress of natural succession (biotic and abiotic) and fish and wildlife resource utilization within the Ocean Ranch wildlife area. This should include the estuarine area and the fresh water impoundment;
- Determine the percentage of adult Chinook returning to the Eel River that show extended estuary rearing patterns by using scale analysis or other means;
- Investigate operations of tide gates on McNulty Slough, Hawk Slough, Centerville Slough and others to determine effects and/or loss of properly functioning saltwater/freshwater ecotone;
- Investigate dynamics of breaching the seaward levee at the south end of McNulty Slough to increase tidal prism and develop connectivity between wetlands and other sites to restore wetland connectivity.

Subbasin Conclusions

The Eel River estuary is a critically important nursery, rearing and transition habitat for juvenile and adult salmonids and other valuable fishery resources. Nine fish species that utilize the estuary receive protection under the Federal or State endangered species acts, which emphasize the importance of the estuarine habitat for fishery resources. Even with a major loss of wetland area from a system of levees and tide gates, the estuary has retained much of its natural character. No major port or large industrial development projects presently impact the character of the Eel River Delta. However, cumulative effects from land use actions in the Eel River Basin and within the estuary coupled with dynamic flood events have altered the morphology of the estuarine channels. The result is a reduction of valuable habitat area, loss of unique habitat complexity and degraded habitat quality for fishery and wildlife resources.

The increase of tidal prism by re-establishing functional wetlands is likely the most feasible and practical action to achieve immediate benefits to increase productivity and restore fishery habitats.

A large portion of the North Slough channels and lower river are designated wildlife areas managed by CDFG. These areas are prime locations for estuarine ecosystem improvement projects. Options for improvements on private lands should be fully explored through an adaptive Eel River estuary management plan. The plan should consider maintenance of existing land use while promoting restoration of fundamental estuarine ecosystem functions, promote community level ecological relationships among biotic and abiotic components and protect against degradation of existing upland and wetland delta habitats. The plan or any developed projects should also consider potential effects from the rise in sea level and other factors associated with climate change.

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Middle Subbasin

Figure 1. Middle Subbasin. View of Eel River and the communities of Fortuna and Rohnerville.

The Middle Subbasin includes the area east of the Eel River from the confluence of Finch Creek (RM 7.8) to upstream of the confluence with Strongs Creek (RM 10.1) as well as a narrow parallel strip west of the Eel River (Figure 1). Stream elevations range from approximately 40 feet at the confluence of the Eel River with Finch Creek to approximately 1,700 feet in the headwaters of the tributaries. The subbasin encompasses 24 square miles, occupying 14% of the total assessment basin area. Lower elevations areas are mostly held in private parcels less than 40 acres in size while much of the higher elevation areas are owned by large timber companies and are managed for timber production. This subbasin contains the largest human population in the basin within the town of Fortuna. Fish surveys of the streams in this basin have identified the presence of coho, steelhead, and coastal cutthroat.

Hydrology

The Middle Subbasin is made up of sections of three CalWater Units (Figure 1). There are seven named tributaries (Table 1) and 20.5 permanent stream miles in this subbasin. Strongs Creek and North Fork Strongs Creek are second order streams using the Strahler (1964) classification. The other tributaries are first order streams. Drainage areas range from less than one to 16 square miles.

Table 1. Major streams in the Middle Subbasin.

Stream	Tributary to	River Mile	Drainage Area (square miles)	Stream Order	Permanent (miles)	Intermittent (miles)
Unnamed tributary	Eel River	6.7	0.43	Int	0.0	1.3
Finch Creek	Eel River	7.0	0.64	Int	0.0	2.3
Palmer Creek	Eel River	8.1	2.19	2	1.8	1.3
Little Palmer Creek	Eel River	0.5	0.50	1	0.6	1.1
Strongs Creek	Eel River	10.1	16.43	2	5.6	1.4
Rohner Creek	Strongs Creek	0.2	3.77	1	4.0	0.7
Unnamed tributary (Mill Creek)	Strongs Creek	1.3	2.04	1	2.0	0.8
Jameson Creek	Strongs Creek	1.8	1.60	1	2.2	0.6
North Fork Strongs Creek	Strongs Creek	3.7	3.26	2	2.5	0.4

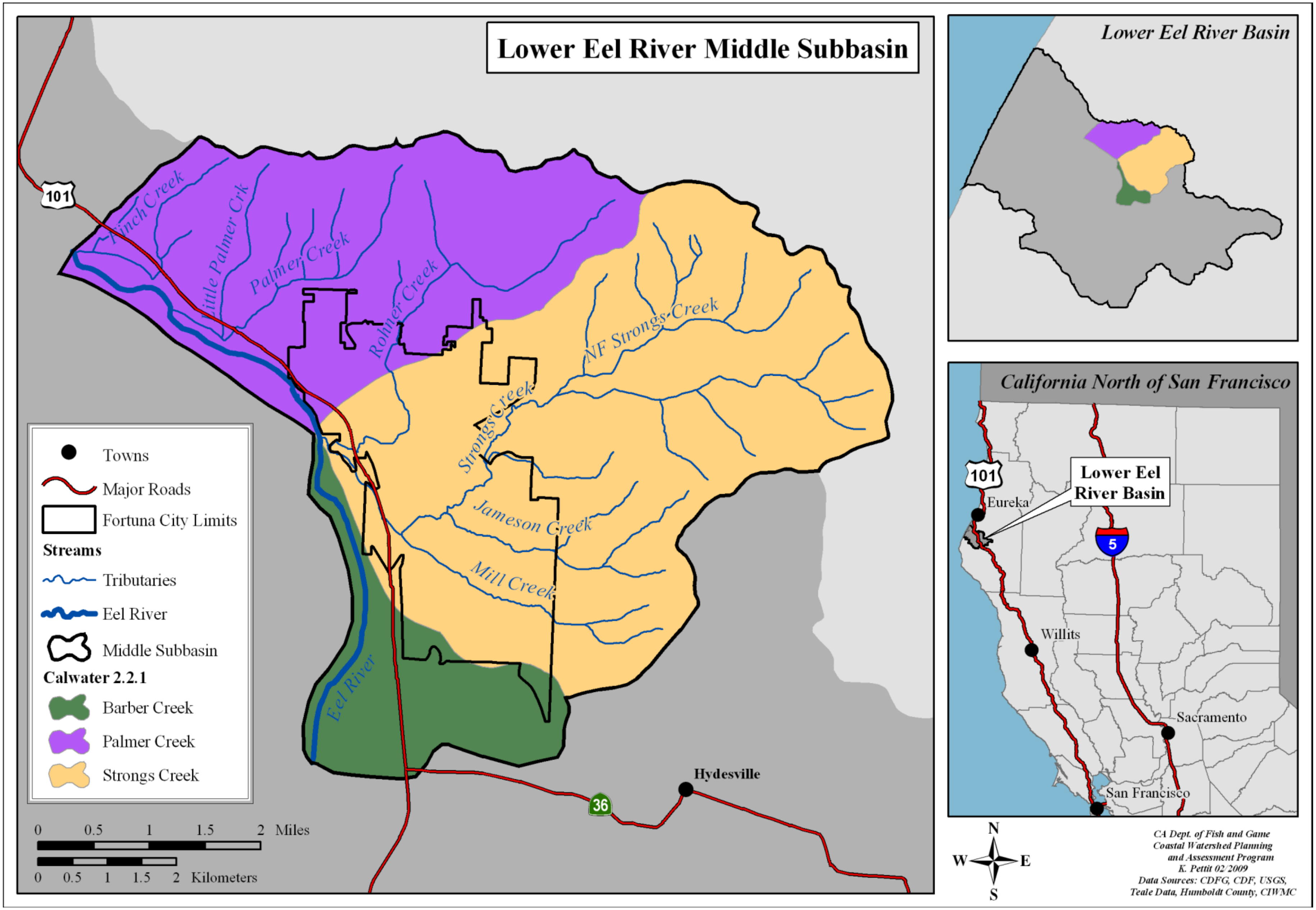

Figure 2. Middle Subbasin locator map and CalWater Units.

Strongs, Rohner, Mill, Jameson, and North Fork Strongs Creeks all flow through the city of Fortuna for part of their length. The Eel River forms the western margin of much of the city as well. Some development has occurred on all of these stream's floodplains (Figure 2).

Sections flowing through town have often been modified to accommodate development. Modifications include bank armoring, construction of stream crossings such as culverts and bridges, and channelization. Often, these modifications decrease or eliminate natural stream floodplains. This has increased the volume and velocity of flows during the rainy season, as is evidenced by Fortuna's flooding and drainage issues (Table 2).

Another factor contributing to flooding issues is the increase in impervious cover as the city of Fortuna has grown. Newly created impervious areas increase runoff to streams and aggravate flooding problems (FEMA 1981 as cited in Mintier and Associates 2006).

In addition, many of the storm drains and culverts within the city are considered inadequate (undersized for the 25 year design flow) (Winzler and Kelly 2005). A 2005 Storm Drain Master Plan update found that approximately one third of the improvements recommended in the 1982 Storm Drain Master Plan have been partially or fully completed (City of Fortuna 2005).

Fortuna's 2005 Storm Drain Master Plan combined drainage structure deficiencies and recommended 55 improvement projects. These included two culvert replacements on Mill Creek, one creek widening project and one creek re-routing project on Rohner Creek, and one stream bank protection project on Strongs Creek (Table 3, Figure 3). These types of flood control projects have the potential to impact salmonid upstream and downstream migration as well as juvenile rearing habitat.

Table 2. Drainage problems in Fortuna

Drainage Area	Noted Problems
North Fortuna	Drainage facilities generally acceptable; however, there are several areas subject to frequent flooding during relatively minor storm events and there is potential for significant flood problems.
Rohner Creek	Has more potential than any other creek in the city to cause serious flooding damage. Lower reaches flowing through city subject to bank erosion and heavy growth of vegetation, which contribute to a serious reduction in channel capacity.
Hillside Creek	Majority of drainage facilities considered undersized for a 25-year storm event.
Strongs Creek	Development is recommended to be conducted with setbacks corresponding to 100-year floodplain. So far this is occurring. During extreme floods, the Eel River causes flooding in the lower reaches.
Jameson Creek	Only floods at the confluence with Strongs Creek.
Mill Creek	Along with recent development, there has been a significant increase in the amount of runoff entering the drainage causing flooding in the lower reaches.

(2005 Storm Drain Master Plan, City of Fortuna 2005, Mintier and Associates 2006)

Table 3. Recommended storm drainage improvement projects on creeks in the Fortuna Storm Drain Master Plan (2005)

Project Type	Name	Priority
Culvert replacement	Mill Street Project - Mill Creek	Medium
	School Street Project No.2 - Mill Creek	Low
Creek Widening	Rohner Creek Widening Project (City Project No. 9600)	High
Creek Rerouting	Rohner Creek Bypass Project (City Project No. 9601 & City Project No. 9704)	High
Stream Bank Protection	Maxwell Lane Slope Stabilization Project - Strongs Creek	High

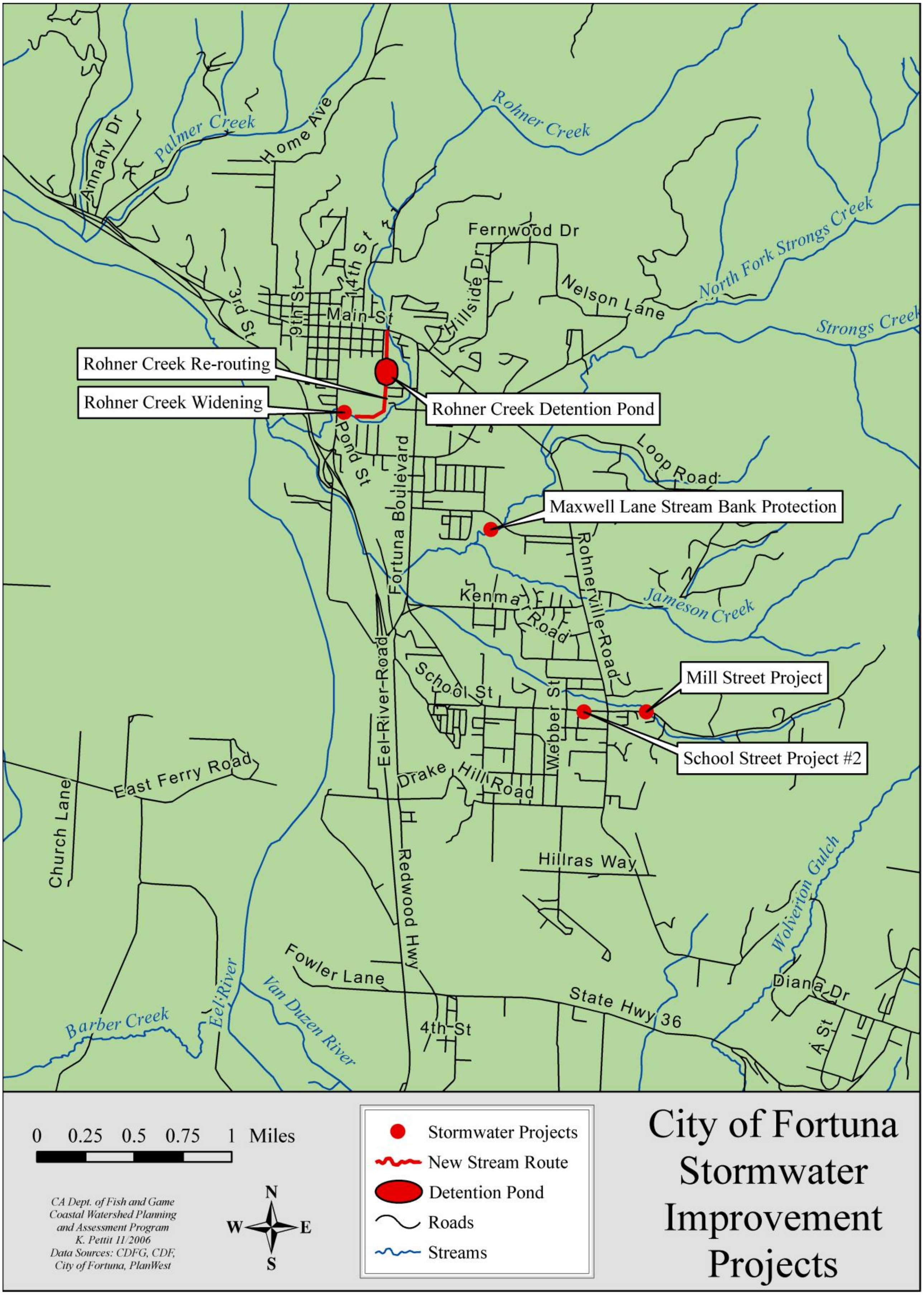

Figure 3. Proposed City of Fortuna stormwater improvement projects on creeks (City of Fortuna 2005).

Geology

Compositional Overview

River terrace deposits make up a large amount of the Middle Subbasin (Table 4 & Figure 4). The towns of Fortuna and Rohnerville are built on the remnants of an ancient, uplifted, unconsolidated floodplain deposit of Eel and Van Duzen River sediments termed the Rohnerville Formation. Above this gently sloping surface are earlier terrace deposits of the Hookton formation, which consist of poorly consolidated marine and river sediments. The Hookton Formation makes up a good portion of the hills above Fortuna and Rohnerville.

To the northeast of the Hookton and Rohnerville formations is the sedimentary bedrock of the Wildcat group. A series of terraces (including the Hookton and Rohnerville formations) have been uplifted from just above the current floodplain to hundreds of feet above the current floodplain and corresponding incision by the streams has occurred. These steeply incised canyons have exposed conglomerate and sandstone of the underlying Carlotta formation. To the northwest of the terrace deposits have been juxtaposed against Wildcat Group sediments by the Little Salmon Fault, Wildcat Group

The Wildcat Group is a sequence of five geologic formations that consist of Miocene to Pleistocene marine sediments grading to non-marine sediments in the uppermost formation (Ogle 1953). The majority of the Wildcat Group formed as sediments washed into and filled a forearc basin (the Eel River syncline) from about 13 to 1.48 million years ago (Ogle 1953). The sedimentary sequence of this infilling inlet reached a thickness of over ten thousand feet. As uplift of the western edge of Northern California occurred these sedimentary beds were lifted and tilted to their present position.

Table 4. Rock types of the Middle Subbasin.

Rock Type	% of Subbasin	Description
Alluvium	15.2	Unconsolidated river sediments within the active influence of streams.
Terrace deposits	43.4	Unconsolidated, poorly sorted river sediments that have been uplifted above the active stream influence.
Wildcat Group	41.5	A series of 5 formations; 4 consisting of poorly cemented, fine-grained, shallow marine sediments and one consisting of courser, poorly consolidated, predominately nonmarine sediment.

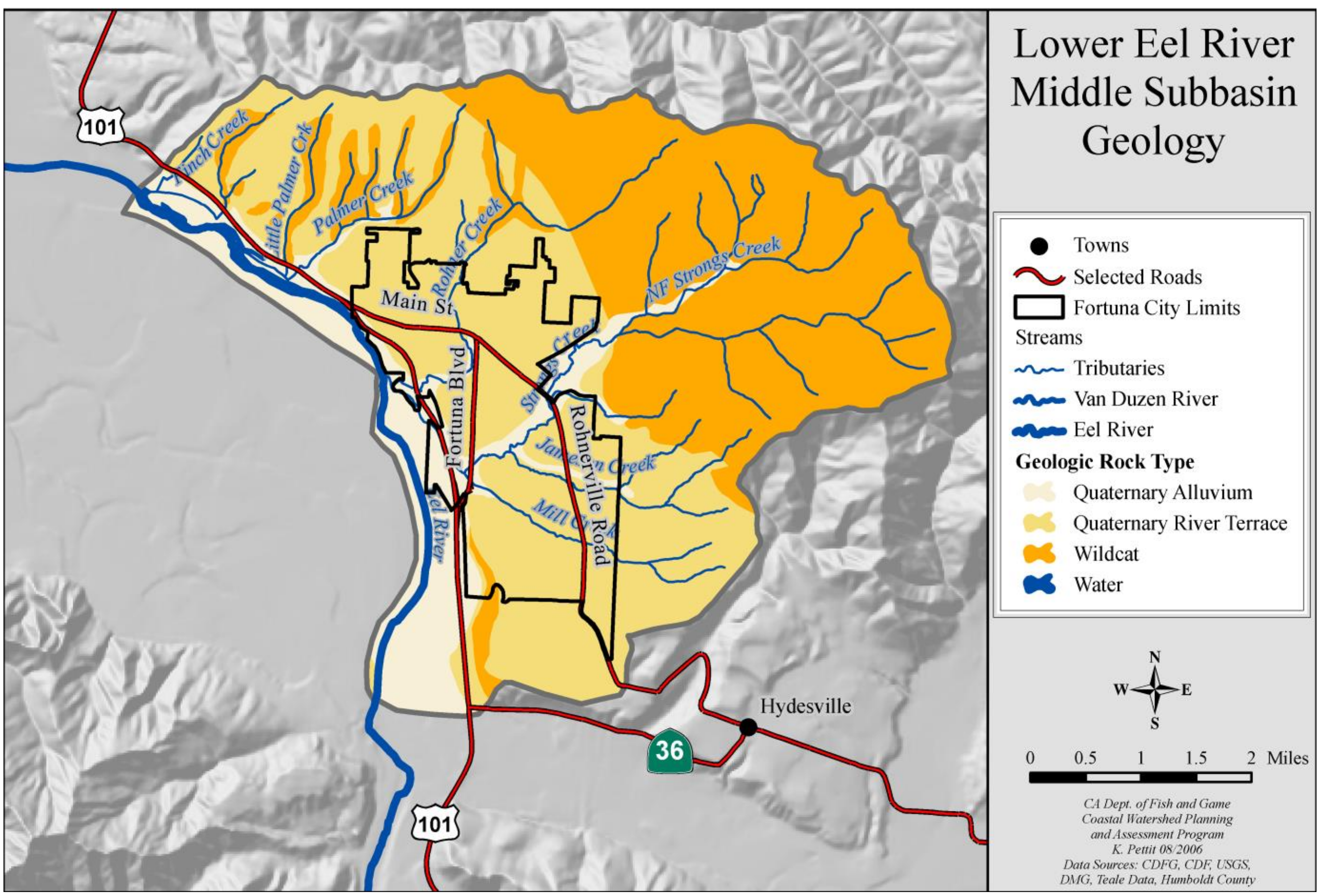

Figure 4. Geology of the Middle Subbasin.

Soils

A series of loamy soils has developed upon a flight of ancient, unconsolidated Eel River terrace deposits as well as portions of the current floodplain and on the steeper slopes of soft sedimentary bedrock of the Wildcat group in this subbasin (Table 5). Although all of these soils are sensitive to erosion they are especially so upon steep slopes or in areas denuded of vegetation.

Streams within this subbasin tend to incise steep banks into the soil/bedrock. Dry ravel, shallow landslides, and slumping are common along these steep banks.

Table 5. Soil types in the Middle Subbasin.

Soil Type	% of Middle Subbasin	Composition
Tramway-Irmulco-Empire	43	Loam
Timmons-Rohnerville-Hookton-Carlotta-Arcata	30	loam/silty clay loam/fine sandy loam
Riverwash-Loleta-Ferndale-Bayside	20	Loam/silt loam/silty clay loam
Fluvents-Riverwash complex	7	Loam

Earthquakes and Faults

The Little Salmon Fault cuts across this subbasin. The Little Salmon Fault is a relatively active fault that is capable of sizeable earthquakes that can trigger landsliding, liquefaction and modify the landscape. Past movement of this fault has disrupted bedrock leaving sheared zones that are somewhat more susceptible to erosion than their non-sheared bedrock counterparts. The Little Salmon Fault runs to the north of this subbasin and is capable of producing earthquakes that are large enough to trigger significant landsliding and/or liquefaction of the land within it. The Cascadia Megathrust and the San Andreas Fault have historically caused earthquakes large enough to alter the morphology of this subbasin.

Landslides

Quaternary river terraces, due to their unconsolidated nature, are subject to debris sliding especially when saturated by heavy rain. The Hookton formation is subject to gully erosion, debris slides, and earthflows (Kilbourne 1985). The Wildcat Group as a whole is made up of soft, poorly cemented fine sediments. Rapid rates of uplift and the “soft” nature of these rock types have allowed the stream channels to incise steep canyons. As well as uplift these formations have been steeply tilted and folded. Furthermore, these rock types have a relatively high porosity allowing them to absorb water during winter storms. When they become saturated they tend to fail along their steeply dipping bedding plains. Of the Wildcat Group the Rio Dell formation is one of the most susceptible to landsliding. Landsliding is most common in zones between mudstone and sandstone beds during super saturation. Landslides are historically common in this area - the original name of Fortuna was “Slide.”

Fluvial Geomorphology

The upstream boundary of the Middle Subbasin is delineated near the confluence of the Eel and Van Duzen River. At this point the Eel River enters a broad alluvial valley with very low gradient known as the Eel River Delta. The valley itself was formed by the down-warping of the Eel River syncline which subsequently filled in with a sequence of marine sediments and finally fluvial sediments. Middle Subbasin the main stem of the Eel River enters a classic depositional regime. The slope of the channel drops to 1-2% and the flow slows.

Since this valley filled in with sediments the area has gone through tectonic uplift creating a series of terrace deposits. At the junction of Yager Creek and the Van Duzen River (~80 feet elevation) a flight of 8 terraces rising in excess of 200 feet is preserved. These terraces have been correlated with high stands of sea level during the last 83 thousand years. This correlation yields an approximate uplift rate of between .8 to 1.2 millimeters per year (O’Dea 1992). Currently the upstream end of this subbasin is 40 feet above sea level and the downstream end is at an elevation of less than 10 feet.

Historically the estuarine/tidal influence was reported to reach as far upstream as the confluence with the Van Duzen River and is considered to be the beginning of the Eel River Delta. The earthquake of April 1906 reportedly raised the bed of the river channel by a couple feet and caused the estuarine/tidal influence to shift farther downstream

(Trinity Associates 1996). It is not specified if the channel change was due to uplift or aggradation. Most likely it was a combination of each. The beginning of estuarine/tidal influence is currently delineated at Fernbridge.

A levee exists on the right bank of the mainstem within this subbasin from the confluence of the Van Duzen through the city of Fortuna. The presence of this levee alters the naturally occurring fluvial processes along this stretch as well as downstream. Levees tend to keep low gradient streams from naturally migrating and meandering over time. If a river has a levee on only one side it tends to cause flooding to increase on the opposite side. This can lead to greater sediment deposition on the opposite side and entrenchment of the channel. Levees can also straighten the channel and allow faster flows causing local scour and deposition of sediment further downstream. This can further entrench the channel locally.

Tributaries in this subbasin are relatively steep and moderately incised. To the south of the main stem they drain the poorly cemented, fine-grained sedimentary rock of the Wildcat Group. To the north they drain uplifted, poorly consolidated terrace deposits. Both of these terrain types can contribute an abundance of fine grained sediments to the streams.

The morphology of individual streams within a system when taken in a fluvial geomorphologic context can be used to help understand the current and as past fluvial regime/sediment changes. Some basic morphologic stream patterns have been defined by D.L. Rosgen, Rosgen channel types (Figure 5).

Tributary surveys of three reaches in the Middle Subbasin found that all were different types of Rosgen B channels (Table 6). Note that the surveyed reach of Strongs Creek began at the confluence with the North Fork of Strongs Creek. Type B channels are wide, shallow, and single thread. They are moderately entrenched, moderate to steep gradient reaches, which are riffle-dominated with step/pool sequences.

Table 6. Channel types in surveyed streams of the Middle Subbasin.

Stream	Reach	Length (feet)	Channel Type
Mill Creek	1	942	B4
North Fork Strongs Creek	1	6,091	B5
Strongs Creek	1	3,372	B3

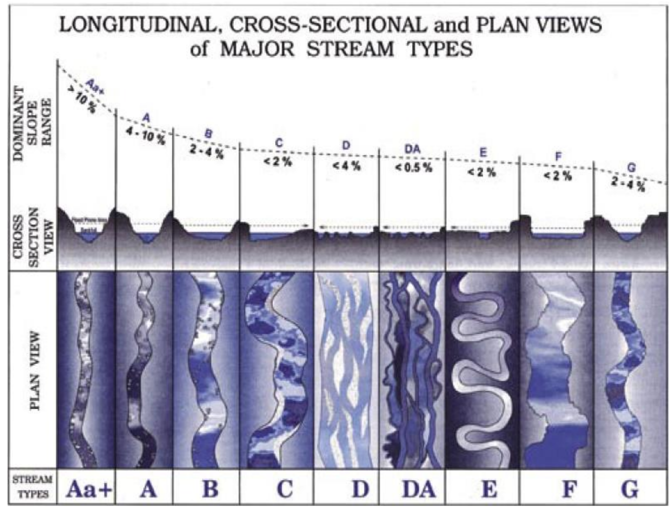

Figure 5. Illustration of how channel types A-G are delineated based on entrenchment, sinuosity, and slope (Rosgen 1996).

Vegetation

The vegetation description is based on USFS CALVEG data (2000). Forty-five percent of the vegetation in the Middle Subbasin is classified as conifer. Of this, 67% is composed of vegetation of the Redwood Alliance, followed by the Redwood – Douglas-fir Alliance (29%). Nearly all conifer cover in the Middle Subbasin lies in the headwaters of Rohner and Strongs Creeks. Redwoods in this subbasin are confined to the east side of the Eel River. The vegetation cover type designated "mixed" describes forest stands where conifers are the primary tree type; hardwoods are secondary. When this classification is combined with conifer, coniferous forest stands constitute over half of the Middle Subbasin at 52%. Under this CALVEG classification scheme, crown diameters of conifers are ordered into groups based on average visible diameter (Table 7).

Herbaceous vegetation composes 16% of the area. As it is difficult to remotely differentiate between grasslands used for agricultural purposes or otherwise, this in combination with land described as agriculture makes up 23% of the total, and more than likely describe the cattle grazing that occurs in the Middle Subbasin. Agricultural areas in the Middle Subbasin lie primarily to the east and west of the mainstem Eel River between Fortuna and the mouth of the Van Duzen River, with sections extending into the lower portions of Rohner and Strongs Creeks. The annual grasses occupy additional low-lying areas of the subbasin. The Middle Subbasin has the largest amount of land described as urban (10%) when compared to the other subbasins. The principal community and population center of the Lower Eel Basin is Fortuna, which is located in the Middle Subbasin.

Table 7. Crown diameter of vegetation classified as primarily conifer forest in the Middle Subbasin.

Conifer Alliance	Size Range	Most abundant by area
Redwood	Sapling to Large	Medium
Redwood - Douglas-Fir	Sapling to Large	Small
Sitka Spruce	Sapling to Medium	Small
Sitka Spruce - Redwood	Sapling to Medium	Medium
Sitka Spruce - Grand Fir	Pole to Medium	Small

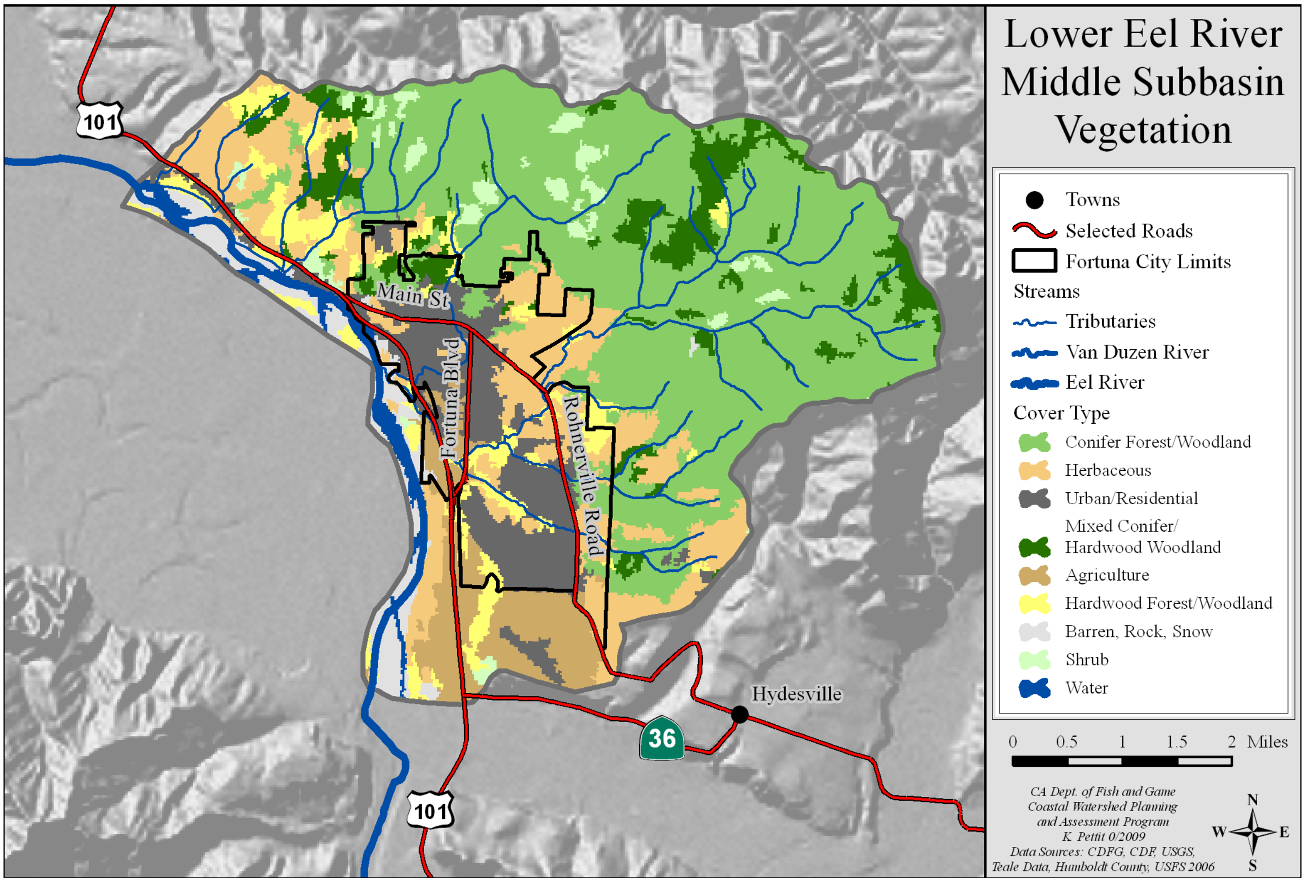

Figure 6. Vegetation of the Middle Subbasin.

Land and Resource Use

Historic Land Use

Henry Rohner, a former gold prospector, first settled the area of Rohnerville in 1850. Although he had purchased land to cultivate, he also opened a store that served as a supply center for miners traveling to the Trinity, Klamath, and Salmon Rivers. Rohnerville soon began to flourish, as it was located along the major transportation route to Humboldt Bay. The area also possessed fertile alluvial soils. For the purpose of claiming land for agriculture, trees were soon felled and processed into rough timber. With these profitable industries, by 1871 the town of Rohnerville was one of the largest in Humboldt County, with a population totaling 350 (Genzoli 1972). The town prospered, and supported several stores, a hotel, fairgrounds, a race track, as well as Mt. St. Joseph's College, a moderately sized school whose education was a draw to students from as far south as Santa Barbara, CA (Genzoli 1972).

Timber production quickly became an important industry. Rohnerville constructed a mill that processed timber in the summer and grain in the winter (www.sunnyfortuna.com/history/fortuna). In 1884, a mill was established in Newburg, which developed into the small town to the northeast of Fortuna. At this time, the Newburg mill was the largest mill in the Eel River valley. It produced 40,000 board feet/day, which is an indication of how prosperous all of the timber mills in the Middle Subbasin were. By 1924, this one mill had fully harvested timber from the Strongs Creek basin (1891), North Fork Strongs Creek basin (1896), South Fork Strongs Creek basin (1901), Jameson Creek, Wolverton Gulch, Yager Creek, and Howe Creek basins (by 1924). Along with the harvesting of these areas came the laying down of railroad track, and the construction of roads. The mill was very successful, and output increased to 65,000 board feet/day, and employed 250 people (Spinney c. 1976).

Some of the timber processed at the mill in Rohnerville was used to build a walkway into the town of Slide, crossing over Jameson and Strongs Creeks along the way. Slide was so named because of the large landslide in the area which often presented travelers with difficulty on journeys to Humboldt Bay. Slide was later renamed to Springville, which was the name of the mill that was constructed in 1874 at the foot of 2nd Street. Lumber mills were a major regulator of growth to the communities in the Middle Subbasin. People began to move into mill towns for the prospect of steady jobs and to settle with their families. Within four years of the Springville Mill's founding, the town was flourishing, and provided many services including a market, post office, two schools, a saloon, and grist mill (McCormick 1999). As transportation routes improved, timber production in the Eel River Valley mills increased.

Springville was renamed Fortuna and lived up to its prosperous name. The fertile Eel River delta soils provided for successful crops, and the quantity of timber available for production seemed endless. The town was also fortunate in another important way. In 1885, the Northwestern Pacific Railroad laid track through the town of Fortuna, as opposed to Rohnerville. The railroad greatly improved the area's transportation. Businesses that had been established in Rohnerville began to move to Fortuna (Genzoli 1972). By 1914, Fortuna was considered a major railroad stop between San Francisco and Eureka.

In addition, roads were built that connected Fortuna with other surrounding towns, like Ferndale, which gave it standing as a center of business. The bridge at Fernbridge was built in 1911, replacing the ferry crossings at the present day Fortuna River Lodge and Singley Ferry by the end of Drake Hill Road. Fortuna grew to such an extent, that people traveling to northern California often opted to take the train into Fortuna, rather than a ship into Humboldt Bay (www.sunnyfortuna.com/history/fortuna).

Since Fortuna was incorporated in 1906, it has grown by annexation of surrounding areas (Table 8). The largest addition to the city was the annexation of the Campton Heights-Rohnerville area between 1975 and 1980 (Mintier and Associates 2006). This represents a change in urban area from 4% to 19.5% of the Middle Subbasin.

Table 8. Fortuna annexation history.

Year	City Land Area (square miles)	Population
1950	1.0	1,763
1960	1.4	3,523
1965	1.4	ND
1970	2.0	4,314
1975	3.0	ND
1980	5.3*	7,591

(Mintier and Associates 2006)

* The current General Plan found the area of the city to be 4.68 square miles.

Land and Resource Use

Urbanization

Fortuna has continued to grow in importance. Even with Eureka's rise in political and economic standing because of Humboldt Bay, Fortuna had established itself as a major town in Humboldt County. The major land use issues facing the Middle Subbasin today are urban development and land subdivision, which are a direct result of Fortuna's economic and spatial growth.

The 2004 Census estimated the population of Fortuna to be 10,995. The California Department of Finance estimated the population of Fortuna to be 11,250 in 2005. The average annual; growth rate from 1980 to 2005 was 1.6% (Mintier and Associates 2006).

The number of housing units in Fortuna has increased from 3,711 in 1990 to 4,729 in 2005. It is estimated that by 2030, Fortuna will require 2,298 new housing units if current growth rates continue. In addition, it is projected that additional space will be needed in the city for commercial, retail, and manufacturing activities (Table 9) (Mintier and Associates 2006).

Table 9. Projected additional floor space needed in the City of Fortuna in 2030.

Type	Projected additional floor space needed in 2030 (square feet)
Commercial	322,411
Retail	423,455
Manufacturing	107,000

(Mintier and Associates 2006)

Land use within Fortuna's city limits is predominantly single family residential (Table 10 & Table 11). The 1993 Fortuna General Plan laid out future growth plans for 3,070 acres of build out in the city. This included 1,980 acres of residential, 615 acres of public, 150 acres of industrial, 195 acres of commercial, and 130 acres of agricultural lands (Figure 7 & Figure 8). Within the city limits, the majority of land was designated for Residential Single Family.

Fortuna currently occupies 3,114 acres or 4.68 square miles in size. Its sphere of influence (SOI) is 7,129.5 acres or 11.1 square miles in size. A SOI is a boundary surrounding cities and special service districts that is intended to represent the ultimate area into which the city or district may expand and extend public services. Additionally, there is a Fortuna Area Community Plan (1985), which encompasses an area of 8 square miles and is the long range statement of public policy for unincorporated public land and private lands around the city of Fortuna.

Fortuna's municipal water source originates from groundwater wells near the Eel River. The city operates five wells at the Corrosion Control facility located at 1575 Eel River Drive (Mintier & Associates 2006). Fortuna operates a wastewater treatment plant on 180 Dinsmore Drive, just west of Highway 101. This plant was constructed during the 1970s, though an earlier plant was constructed in the 1950s. Wastewater during average flows is treated to secondary treatment standards using an activated sludge process. Effluent is discharged into the Eel River at the confluence with Strongs Creek.

Table 10. Existing land uses in Fortuna (Mintier and Associates 2006).

Existing Landuse	City Limits		Sphere of Influence		Planning Area	
	Acres	%	Acres	%	Acres	%
Agriculture	6	0.2	934	13.6	1,557	20.0
Rural Residential	203	6.5	1,445	21.0	1,502	19.3
Single Family	1,651	52.5	1,805	26.3	1,822	23.4
Multifamily	71	2.3	85	1.2	87	1.1
Commercial	123	3.9	150	2.2	172	2.2
Industrial	144	4.6	171	2.5	175	2.2
Public	110	3.5	344	5.0	344	4.4
Open Space	220	7.0	571	8.3	725	9.3
Timber	0	0.0	220	3.2	220	2.8
Vacant	614	19.5	1,151	16.7	1,171	15.1
Total	3,142	100	6,877	100	7,775	100

Total only includes parcels provided with an existing land use.

Table 11. Fortuna 1993 General Plan landuse designations.

Land use Designation	Acres	Percent	Developable Acres 1*	Percent Available
Residential Estates	699	22.4	173	24.7
Residential Single Family	1,252	40.2	239	19.1
Residential Multifamily	148	4.8	35	23.7
Neighborhood Commercial	7	0.2	2	34.1
Retail Commercial	27	0.9	2	5.9
Commercial Thoroughfare	148	4.8	28	18.8
Freeway Commercial	56	1.8	24	43.7
Light Industrial	99	3.2	18	18.0
Heavy Industrial	75	2.4	7	9.8
Public Facilities	196	6.3	81	41.3
Agricultural Exclusive	88	2.8	14	15.5
Subtotal	2,796	89.8	623	22.3
Other/Unknown (Rights of Ways) 2*	318	10.2	5	1.4
Total (City Limits only) 3*	3,114	100	628	20.2

1* Developable lands include vacant, open space, and agricultural lands

2* Other/Unknown includes undesignated areas such as rights-of-ways for roads

3 *The total area covered by the 1993 General Plan is contained within the city limits

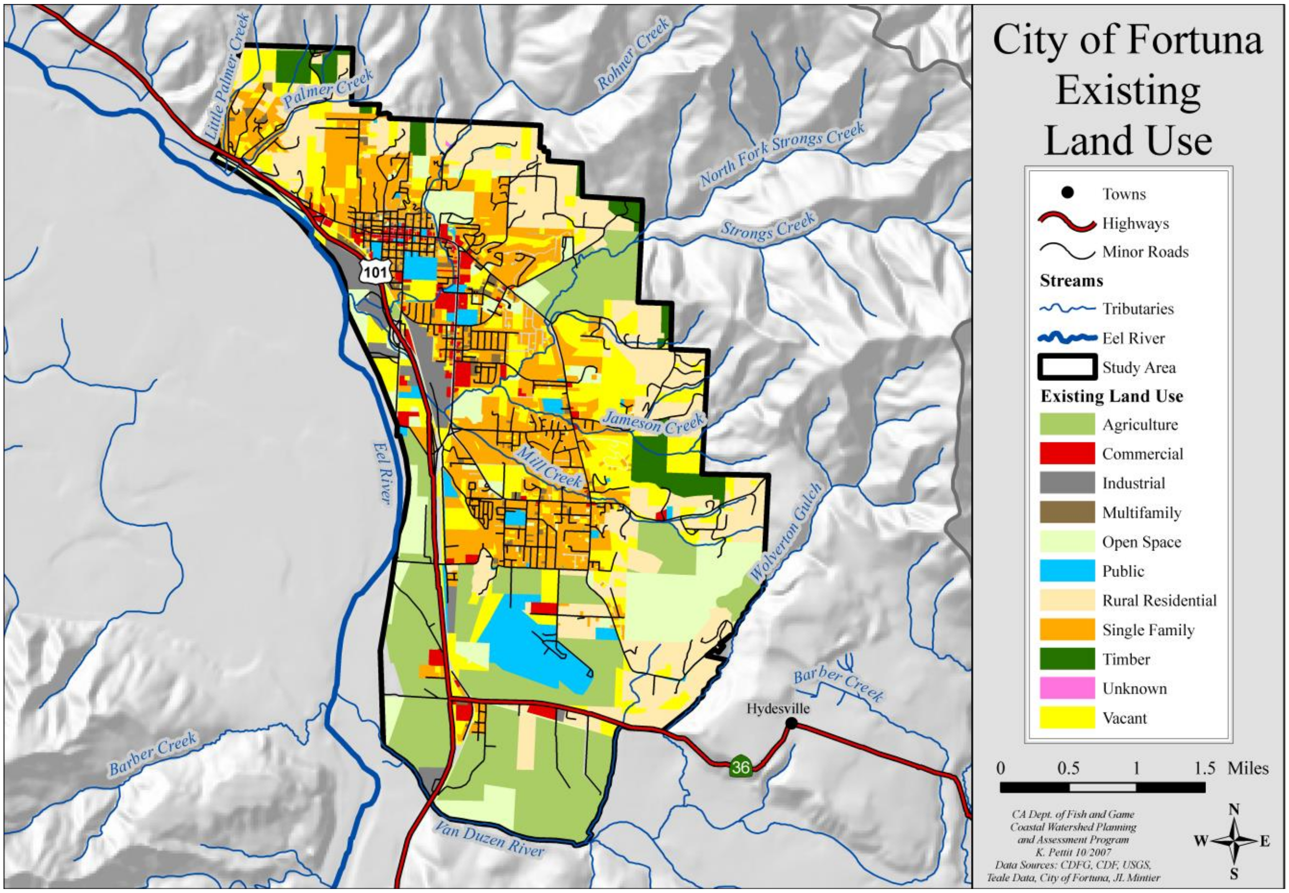

Figure 7. Existing land uses in Fortuna (Mintier and Associates 2006).

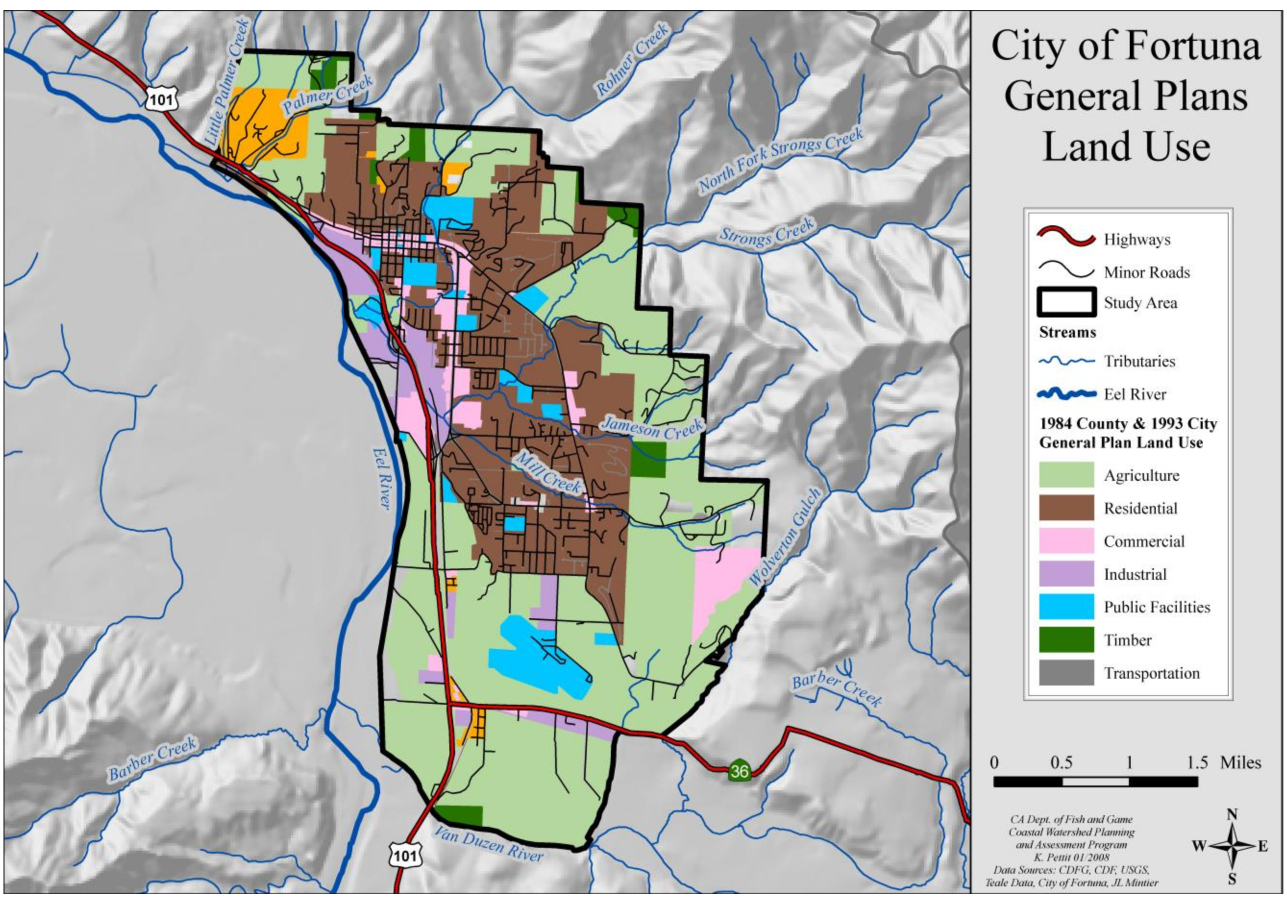

Figure 8. Fortuna 1993 General Plan land use designations.

In order to increase capacity during wet weather, the plant stores excess inflow in adjacent storage ponds. These ponds only had a one to two day capacity during wet weather and needed approximately one week of dry weather to recover (Mintier and Associates 2006). An upgrade to increase capacity was completed in March 2007.

When the Eel River reaches full capacity, river water floods the percolation ponds of the treatment plant. Managers attempt to forecast large rain events and stop discharging to the percolation ponds before saturation occurs. Treated Wastewater is discharged into Strongs Creek instead of the percolation ponds during these events. Water Board regulations also require the plant to discharge into Strongs Creek from September 15th through May 15th of the year; discharge is into the percolation ponds the remainder of the year (Cole 2003).

All of the fish producing streams in the Middle Subbasin flow directly through the city. The increase in hard surfaces, as well as the removal of riparian vegetation has significantly affected the watersheds abilities to respond to precipitation. Many of the streams have been extensively channelized, which has changed the direction and velocity of flow. Flooding has become a seasonal and persistent problem as described in the Hydrology section (page 3)

Forest Management

Timber harvest, while less of an issue than in the past, still occurred in the headwaters of all of the creeks in this subbasin from 1991 to 2006. Harvest in the headwaters of North Fork Strongs Creek was primarily second entry and occurs on Wildcat formation geology. Each year since 1991, an average of 2.2% of the Middle Subbasin has been included in a Timber Harvest Plan encompassing a variety of silviculture and yarding methods.

Gravel Mining

The County of Humboldt Extraction Review Team (CHERT) actively monitors six sites that remove over 5,000 cubic yards per year (cy/yr) of aggregate in the Middle Subbasin. Listed in the Final Program Environmental Impact Report (Humboldt County 1992) are 11 sites in this subbasin, including two that are downstream of Fernbridge by one mile. As mentioned in the basin section, there are also many smaller (less than 5,000 cy extracted per year) gravel mining sites on file with CDFG. Cumulative volumes taken out of this subbasin have significantly decreased since thorough scientific monitoring and management began in 1996 (Table 12). Before this time average volumes ranged from 500,000 cy/yr to 700,000 cy/yr. Currently, an average of 228,829 cy is extracted annually from this reach.

Since 1956, the general morphology of the river bed from the mouth of the Van Duzen River to Fernbridge has changed, based on the County of Humboldt's analysis of aerial photos (Humboldt County 1992). The annual removal of over 500,000 cy of aggregate from 1987 to 1992 alone "flattened the bed and caused the main low flow channel to split into two or three channels just below the mouth of the Van Duzen River" (Humboldt County 1992). It is also likely that the December 1955 flood set the stage for this consequence by filling pools and weakening banks.

Analyses of historic cross-sections have come up with disputed conclusions regarding the aggradation or degradation of the channel bed in the Eel River as well as the Van Duzen River (Kelsey 1977, USACOE 1999, and Humboldt County 1992). The most immediate channel morphology concern in this assessment area is in the reconfiguration of the low flow channel by its widening and shallowing. To this end, trench, alcove, or wetland pit mining are recommended over bar skimming between Fernbridge and the mouth of the Van Duzen River (USACOE 2003). A special concern with wetland pit mines has been fish stranding. Adults and juvenile salmonids have been documented in these river bar ponds along the Eel River by CDFG (1979). Currently, fish stranding is not a problem due to revised and improved gravel mining techniques.

As monitored, extraction amounts for the entire Lower Eel Basin have decreased from what they were in the last five or six decades. Without this decrease, impacts to salmonids would likely be significant and would include loss of deep holding pools during adult migration, and loss of cover, suitable temperature, and complex habitat for juvenile salmonids. Monitoring of these locations in particular is also important in regards to the hydraulic effects instream mining can have on the piers of bridge structures, in this case the historic Fernbridge and the bridges spanning the lower Van Duzen River.

Table 12. Lower Eel River Annual Extraction (1997-2005) (CHERT 2006).

Year	Recommended Volume (cy)	Extracted Volume (cy)	Percent of recommended volume extracted
1997	561,700	326,500	58%
1998	399,100	273,000	68%
1999	471,400	290,500	62%
2000	291,300	208,600	72%
2001	389,900	119,300	31%
2002	387,300	220,000	57%
2003	318,300	163,900	51%
2004	188,840	120,305	64%
2005	199,370	166,280	83%
Totals	3,207,210	1,601,800	50%
Averages	356,357	228,829	64%

Agriculture

Agriculture production occupies large areas of the Middle Subbasin. Approximately 23% of the subbasin is utilized for livestock grazing operations. The streams in the Middle Subbasin are affected by these agriculture productions. In parts of Strongs Creek, for example, livestock are allowed unrestricted access to the creek. Although no specific tests of nutrients and/or coliform bacteria have been conducted in these creeks, levels of these constituents often exceed water quality standards in areas with extensive livestock use. Not only does this pose a threat to chemical water quality, it increases the amount of sediment introduced into the watershed through bank erosion and as well as reducing or eliminating riparian vegetation.

The Humboldt Creamery operates a facility on the Eel River just downstream from Fernbridge. Dairy products are processed and the creamery has a wastewater discharge permit for discharge into the Eel River.

Fish Habitat Relationship

Fishery Resources

Other than anecdotal accounts, fish presence has been documented in the Middle Subbasin by observations made during stream surveys since 1938. However, stream survey efforts were neither specific nor standardized until 1990 when the *California Salmonid Stream Habitat Restoration Manual (*Flosi et al. 1998) was published. Most observations in stream surveys are not quantitative and have limited use.

Historically, coho salmon were found in Palmer and Strongs creeks and potentially Rohner Creek; however, in recent years they have only been detected (1995) in Strongs Creek. Steelhead trout were historically found in Palmer, Rohner, Strongs, and North Fork Strongs Creeks. In recent years, steelhead and coastal cutthroat trout observations have been limited to Strongs and North Fork Strongs Creeks. The Strongs Creek coastal cutthroat trout population is believed to represent the southernmost extent of the species (Gerstung 1996).

In addition to salmonid species other native freshwater fish species have been observed in the Middle Subbasin including pacific lamprey, threespine stickleback and coastrange and prickly sculpin. The invasive Sacramento pikeminnow has been detected in Rohner and Strongs creeks. Table 13 displays the documented fish presence from surveys in the streams of the Middle Subbasin from 1951 to 2006.

Table 13. Documented fish presence in surveys from 1951 to 2006 in the Middle Subbasin.
(NCCSI= North Coast California Coho Salmon Investigation - Bill Jong personal comm.)

Stream	Date Surveyed	Source	Survey Method	Fish Observations				Fish Comments
				Coho	Steelhead	Coastal Cutthroat	Salmonids	
Palmer Creek	05-07/1951	Hallock et al (1952)	Seine	X				
	1979	Geppert (2004)	Unknown		X			Steelhead observed by CDFG in 1979
	01/04/1982	CDFG 1982	Streamside observation					
	Summer 1997	HCRCD 1997	Streamside observation (assumed)		X			Stickleback also observed
	10/12/2000	CDFG 2000	Electrofishing					Lamprey spp. observed
	06/14 and 21/2001	CDFG NCCCSI 2005	Electrofishing					No salmonids observed. Lamprey spp. observed
	07/23/2002	CDFG NCCCSI 2005	Electrofishing					No salmonids observed. Lamprey spp. observed
	06/26 and 08/06/2003	CDFG NCCCSI 2005	Direct observation/ Electrofishing				X	Trout observed. Lamprey spp. observed
Rohner Creek	01/16/1952	CDFG 1952	Streamside observation					High water limited fish observation.
	04/19 and 22/1964	Lewis 1964, Day 1964	Streamside observation		X			Fish kill after copper iron spill from reservoir. Coho were found dead in the Eel below Rohner Creek confluence pool. Other observed fish mortalities: sticklebacks, lamprey ammocetes, sculpin, suckers.
	05/18/1972	CDFG 1972	Streamside observation					No fish observed.
	01/06 and 07/1982	CDFG 1982	Streamside observation					No fish observed during 1982 observation. However, author adds anecdotal comment that coho spawning was observed by wastewater treatment plant employee in 1980-81.
	09/07/2001	CDFG NCCCSI 2005	Electrofishing				X	California roach, Sacramento pikeminnow, lamprey spp., threespine stickleback, Cottid spp. observed
	07/24 and 25/2002	CDFG NCCCSI 2005	Electrofishing				X	Sacramento pikeminnow, lamprey spp., threespine stickleback, Cottid spp., observed
	07/02 and 08/06/2003	CDFG NCCCSI 2005	Electrofishing				X	California roach, lamprey spp., threespine stickleback, Cottid spp. observed
Strongs Creek	04/02/1951	CDFG 1951	Streamside observation				X	Dead trout and sculpins observed near pump intake due to electrical shock
	04/22/1968	CDFG 1968	Streamside observation					

Strongs Creek	04/29/1969	CDFG 1969	Streamside observation					"water was muddy"
	01/08/1982	CDFG 1982	Streamside observation					
	7/15/1993	CDFG Stream Inventory	Electrofishing		X	X		Steelhead ranged in size from 78 to 94 mm FL. Coastal Cutthroat ranged in size from 152 to 190 mm FL
	11/15/1995	CDFG 1995	Electrofishing	X			X	Coastal cutthroat trout, 1+ coho, prickly sculpin, brook lamprey, threespine stickleback, sculpin spp., unidentified salmonid observed. Comment that fishing was difficult due to habitat conditions
	07/24/2002	CDFG NCCCSI 2005	Electrofishing				X	Sacramento pikeminnow, threespine stickleback, Cottid spp., lamprey spp. observed
North Fork Strongs Creek	07/03/1984	Franklin and Mitchell (1984)	Electrofishing		X	X		Coastal cutthroat trout observed. Fish capture efficiency was poor due to poor water clarity and large amounts of woody debris.
	7/7 and 15/1993	CDFG Stream Inventory	Electrofishing		X	X		Steelhead ranged in size from 31 to 104 mm FL. Coastal Cutthroat ranged in size from 35 to 150 mm FL
Mill Creek	11/8/1997	CDFG 2004	Streamside observation				X	Juvenile salmonids observed approximately 600 feet downstream of Rohnerville road culvert
	04/1998		Streamside observation					Redd observed approximately 1800 feet from mouth (concluded to be steelhead based on time of spawning, size and shape of redd).
	03/1998		Streamside observation				x	An attempted fish rescue of juvenile salmonids, which were observed approximately 2000 feet from mouth and had been stranded in a pasture due to flooding.
	07/23/1999		Streamside observation				x	Juvenile salmonids observed approximately 1200 feet upstream of Rohnerville Road culvert (unknown whether resident or anadromous)
Unnamed Tributary (to Strongs Creek)	02/25/1980	CDFG 1980	Electrofishing					
	06/29/2005	CDFG 2005	Electrofishing					Threespine stickleback observed

Habitat Overview

Historic Conditions

Stream surveys were conducted by CDFG as early 1952; however, stream survey efforts were neither specific nor standardized until 1990 when the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) was published. Most observations in the historic stream surveys are not quantitative and have limited use in comparative analysis with current habitat inventories. However, data from these stream surveys provide a snapshot of conditions, including barriers limiting fish passage at the time of survey (Table 14).

Past habitat surveys indicate fish passage problems in Palmer Creek caused by the culvert under Highway 101 since 1979. This culvert was most likely a barrier since the construction of the highway in the 1960s. Spawning habitat is described as poor in Rohner Creek in 1952 and 1972, but small sections of good spawning were noted in 1982. Surveys in 1972 and 1982 also indicate that stream banks were stabilized with rocks and old car bodies. Early surveys of Strongs Creek note that the Highway 101 culvert did not block fish passage, though a barrier was noted on an unnamed tributary to Strongs Creek in 2005.

Table 14. Habitat observations made in the Middle Subbasin from 1952-2005.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Palmer Creek	1979	Geppert (2004)		Culvert at HWY 101 is barrier to fish migration (2004)
	01/04/1982	CDFG 1982		Fish cannot access creek above "storm drain" in first 500 feet
	Summer 1997	HCRCD 1997	Approximately 1 mile of good anadromous habitat above culvert	Culvert should be modified to allow fish passage
	10/12/2000	CDFG 2000	Maximum depth of pools was 2.5 ft. Cover was good and consisted of undercut banks and woody debris	No salmonids observed in this survey conducted upstream of HWY 101 culvert
Rohner Creek	01/16/1952	CDFG 1952	Bottom composed of mud, silt, organic debris. Few spawning areas, numerous pools, excellent shelter, numerous log jams	
	05/18/1972	CDFG 1972	Average stream depth was 6 inches. Steep banks, water clarity very muddy, bottom composition: fine sand, silt, rubble and boulders. No spawning substrate available. Rocks and automobiles used for bank stabilization.	Obstructions listed as logs, debris and automobiles.
	01/06 and 07/1982	CDFG 1982	Bottom composed of 100% sand and silt, water is silty. Gravel was described as good in small sections, ranging from "pea size to baseball size," and frequently compacted and covered with silt. Streambanks have been stabilized with rock rubble and crushed car bodies.	Four obstructions noted on stream: two considered possible barriers, 1 a probable barrier.
Strongs Creek	04/22/1968	CDFG 1968		Surveyors determined that HWY 101 culvert did not pose fish passage problem
	04/29/1969	CDFG 1969		HWY 101 culvert did not pose fish passage problem
	01/08/1982	CDFG 1982	Creek is 2 ft. wide and 6/8" deep, heavily silted, with little to no spawning gravel.	
	11/15/1995	CDFG 1995	Low-gradient riffle and trench pools, tannin-stained water. Submerged debris, terrestrial vegetation encroachment	
North Fork Strongs Creek	07/03/1984	Franklin and Mitchell (1984)	Second-growth redwood form 60% of canopy, bottom composed of mostly fine sediments, abundant log jams, no aquatic vegetation.	
Mill Creek	11/8/1997	Downie and Halstead	Urban garbage collected in creek included motorcycle and five gallon bucket of drain oil	
Unnamed Tributary (to Strongs Creek)	02/25/1980	CDFG 1980	Stream is heavily damaged from livestock, and may not flow during summer months	
	06/29/2005	CDFG 2005	Generally composed of pools less than 1 ft deep (max pool = 3 ft), silty banks and substrate. Low gradient, summer base flows probably create isolated pools with subsurface flow.	Rohnerville road stream crossing culvert is probably a complete barrier to juvenile salmonids

Current Conditions

Habitat inventories were conducted by CDFG on three of the tributaries in the Middle Subbasin. All three of these streams are contained in the Strongs Creek watershed (Table 15 & Figure 9). Strongs Creek and North Fork Strongs Creek were both sampled in 1993. An unnamed tributary to Strongs Creek, locally referred to as Mill Creek, was surveyed in 2004. Each of these inventories was completed in one reach.

Table 15. Middle Subbasin streams surveyed by CDFG.

Stream	Year of Survey	Survey length (miles)	Percent of stream surveyed	Number of Reaches
Mill Creek	2004	0.2	9	1
North Fork Strongs Creek	1993	1.2	46	1
Strongs Creek	1993	0.6	11	1

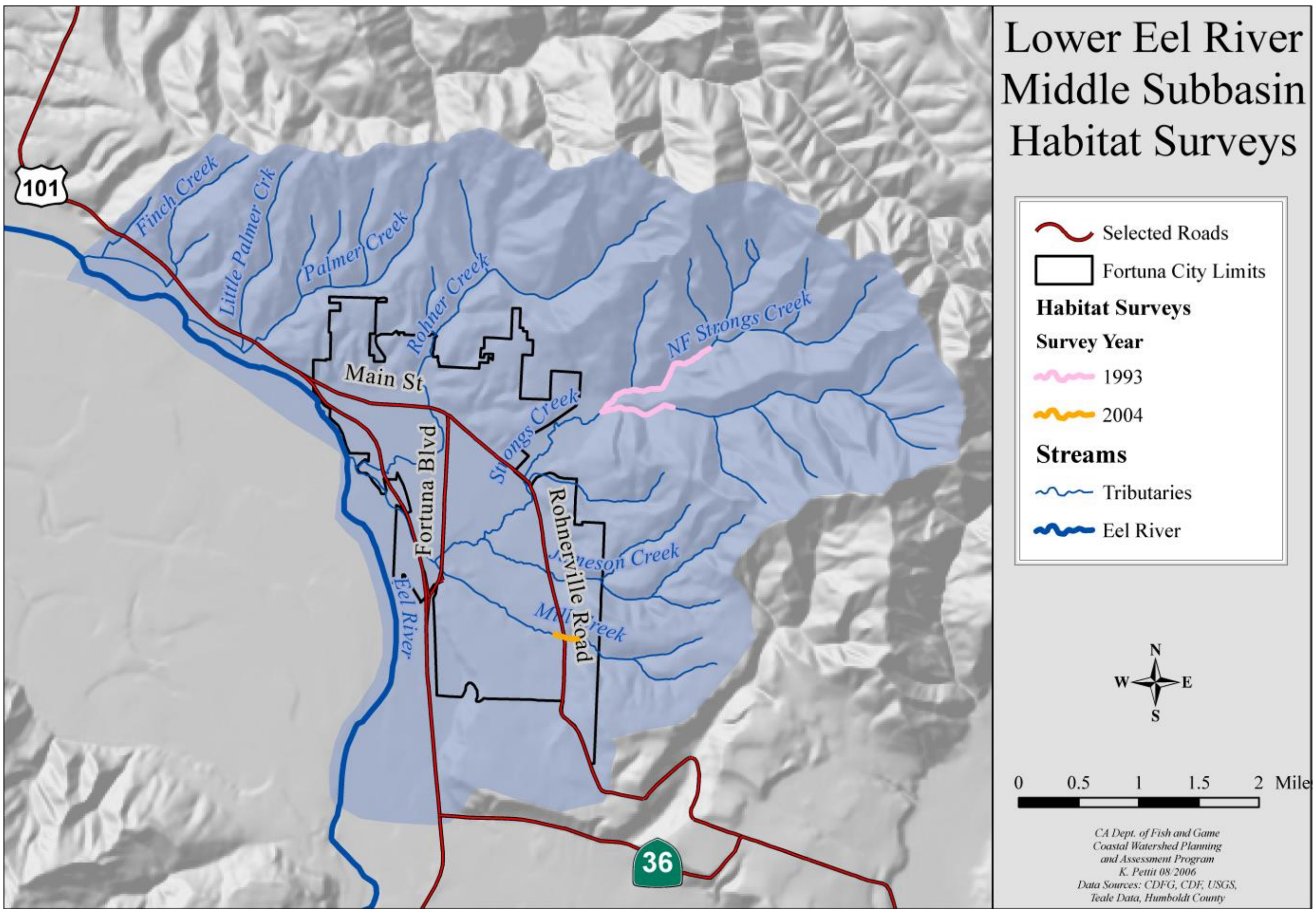

Figure 9. Habitat surveys were conducted by CDFG on three tributaries of the Middle Subbasin.

Canopy Density

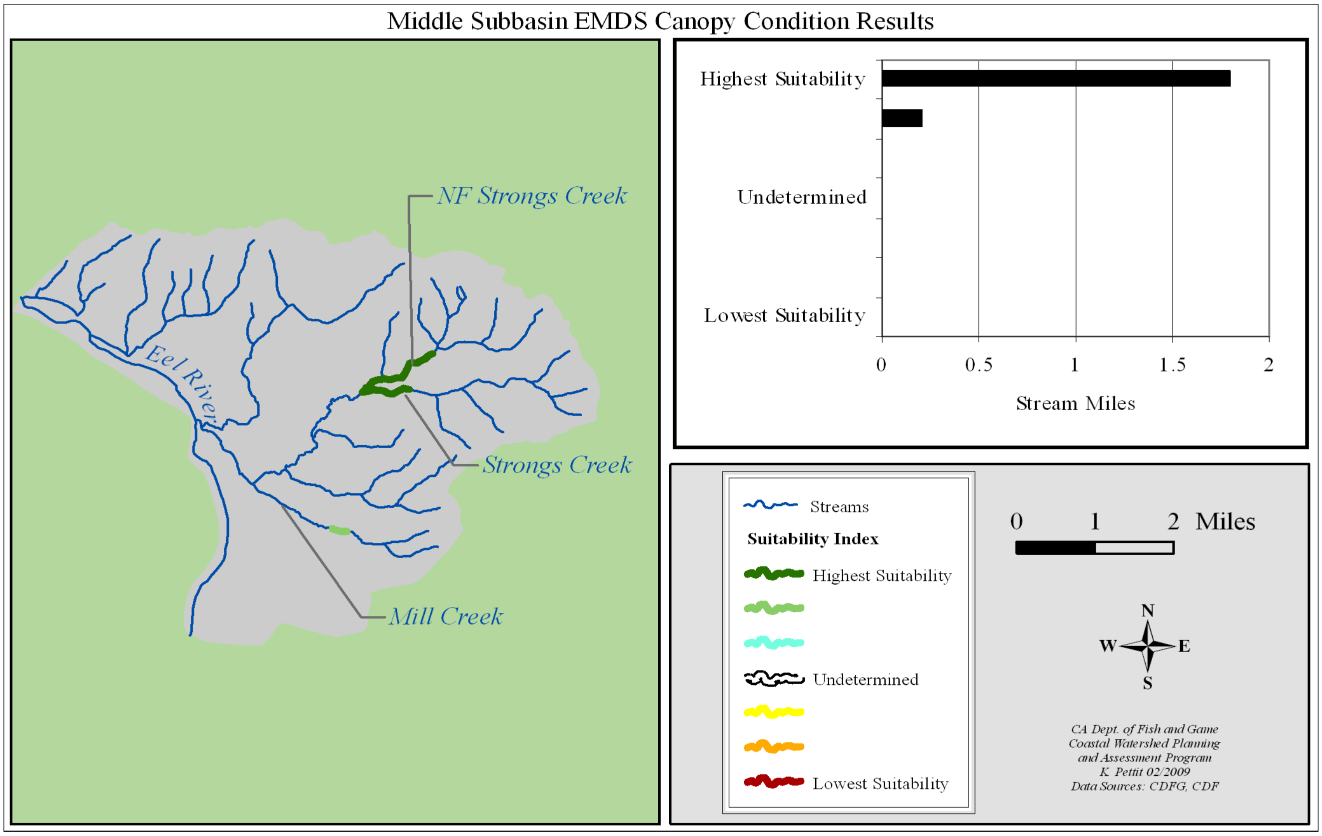

Figure 10. EMDS canopy results for the Middle Subbasin by surveyed stream miles.

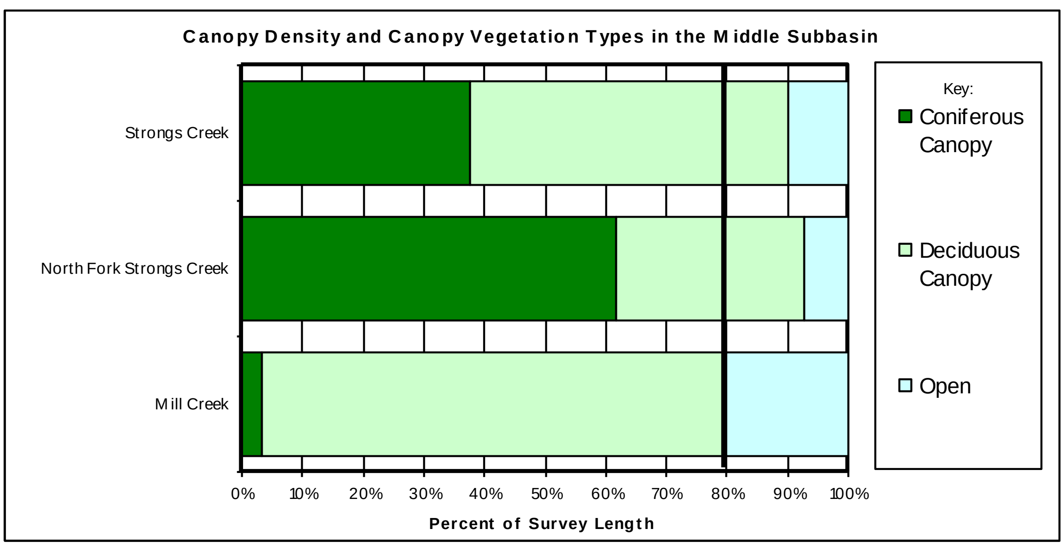

Figure 11. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Middle Subbasin.

Averages are weighted by unit length to give the most accurate representation of the percent of a stream under each type of canopy. Streams are listed in descending order by drainage area (largest at the top).

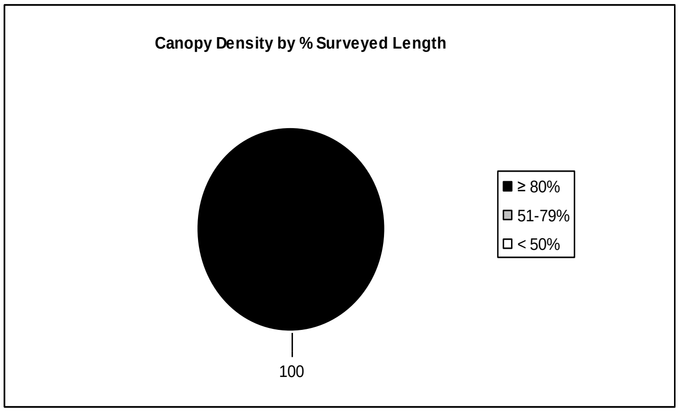

Figure 12. Canopy Density in the Middle Subbasin.

Significance: Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Stream water temperature can be an important limiting factor of salmonids. Generally, canopy density less than 50% by survey

Findings: Canopy density measurements of all three surveyed streams in the Middle Subbasin met or exceeded the CDFG's target value of 80%. North Fork Strongs Creek had the greatest canopy cover at 93%, followed by Stro Canopy Density in the Middle Subbasin.ngs Creek at 90%. Mill Creek met the target value of 80% canopy density

Habitat Categories

Table 16 Middle Subbasin percent occurrence and percent by length of pool, run, riffle, and dry habitats.

Stream	Stream Order	Survey Length (miles)	Pool, Riffle, Run % Occurrence	Pool: Riffle: Run % total length	Dry % Total Length	Culvert % Total Length
Mill Creek	1	0.2	39:30:26	18:19:48	0	15
North Fork Strongs Creek	1	1.2	54:21:24	56:18:26	1	0
Strongs Creek	2	0.6	46:26:28	45:24:32	0	0

Findings: All three of the surveyed tributaries had a greater number of pools by occurrence than riffles. Additionally, North Fork Strongs Creek and Strongs Creek had a greater length in pools than in riffles and had over 30% of their stream length in pools. Mill Creek had significantly less pool habitat when measured by length rather than

Significance: Productive anadromous streams are composed of a balance of pool, riffle and run habitat and each plays an important role as salmonid habitat. Looking cumulatively at pool, riffle, and run relationships helps characterize the status of these habitat types and also provides a measure of stream habitat diversity and suitability for fish.

Pool Depth

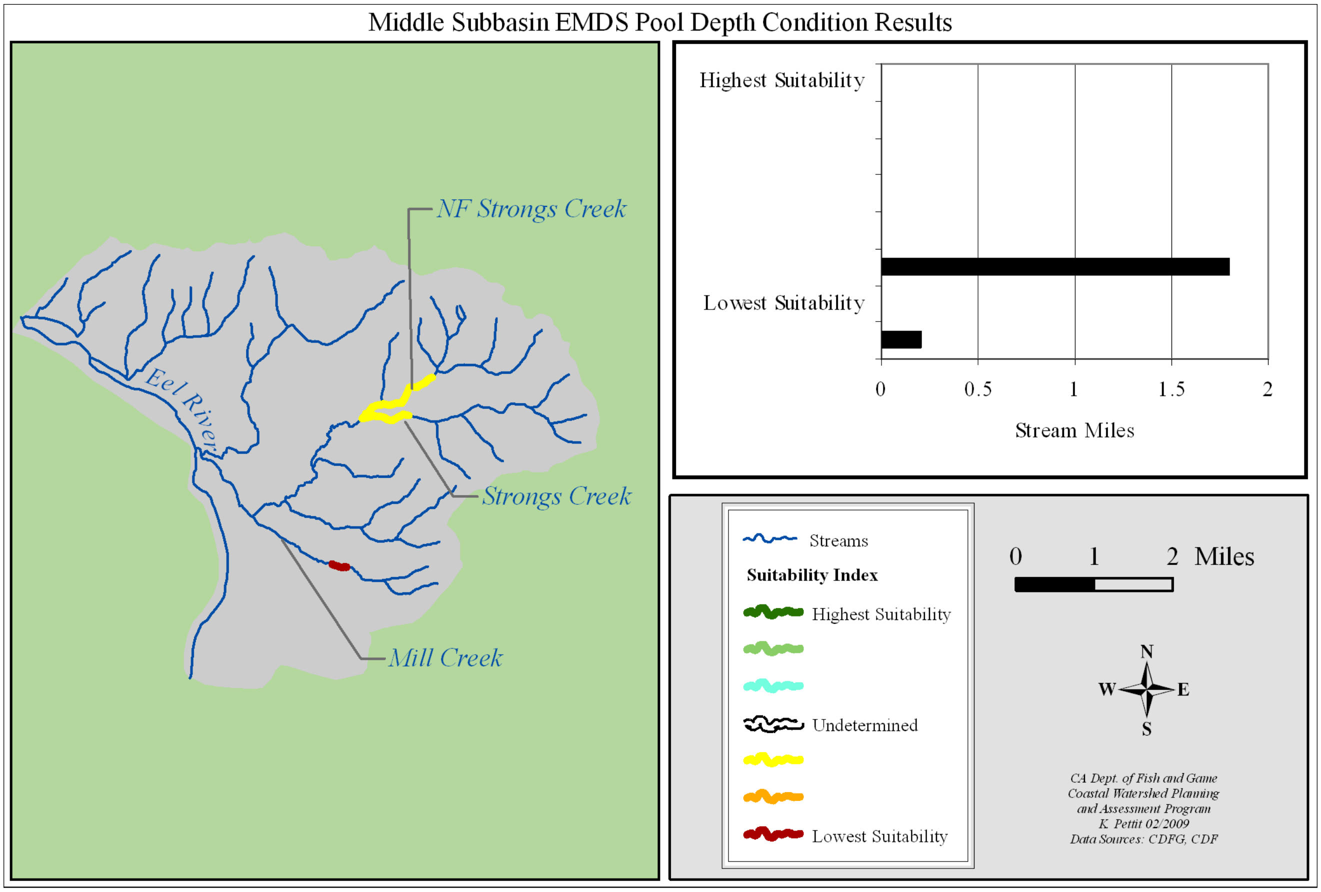

Figure 13. EMDS pool depth results for the Middle Subbasin by surveyed stream miles.

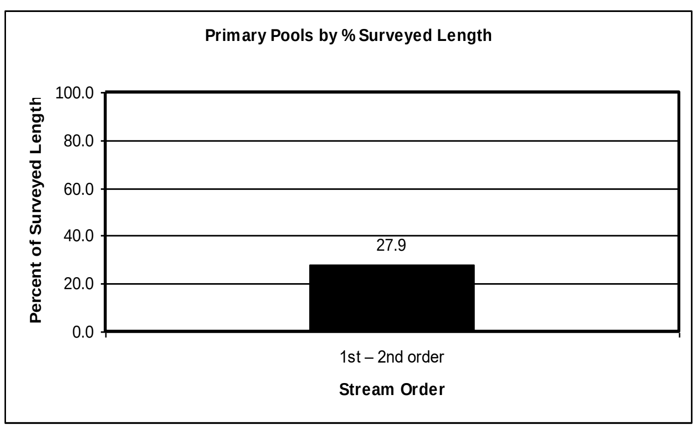

Figure 14. Primary Pools in the Middle Subbasin.

Table 17. Percent length of a survey composed of pools in the Middle Subbasin.

Stream	Stream Order	Percent all measured pools by survey length	Percent pools of depth <2 ft by survey length	Percent pools of depth 2 ft - 2.9 ft by survey length	Percent pools of depth 3 ft – 4 ft by survey length	Percent pools of depth > 4 ft by survey length	Percent pools within target range (>2 ft) by survey length
Mill Creek	1	15.23	12.68	2.55	0	0	2.55
North Fork Strongs Creek	1	55.08	23.64	20.16	5.96	5.32	31.44
Strongs Creek	2	43.32	14.74	16.16	11	1.42	28.58

Significance: Primary pools provide 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 – 55% of its length in primary pools to be suitable for salmonids. In first and second order streams, primary pools are those of greater than 2 feet deep.

Findings: All streams in the Middle Subbasin were below target values for primary pool depth. North Fork Strongs Creek had the most pools within the target range by survey length at almost 32%, followed by Strongs Creek at nearly 29%. Mill Creek had the lowest amount of target value pools at under 3%, and only 15% of its surveyed length being made up by pools in general.

Pool Shelter

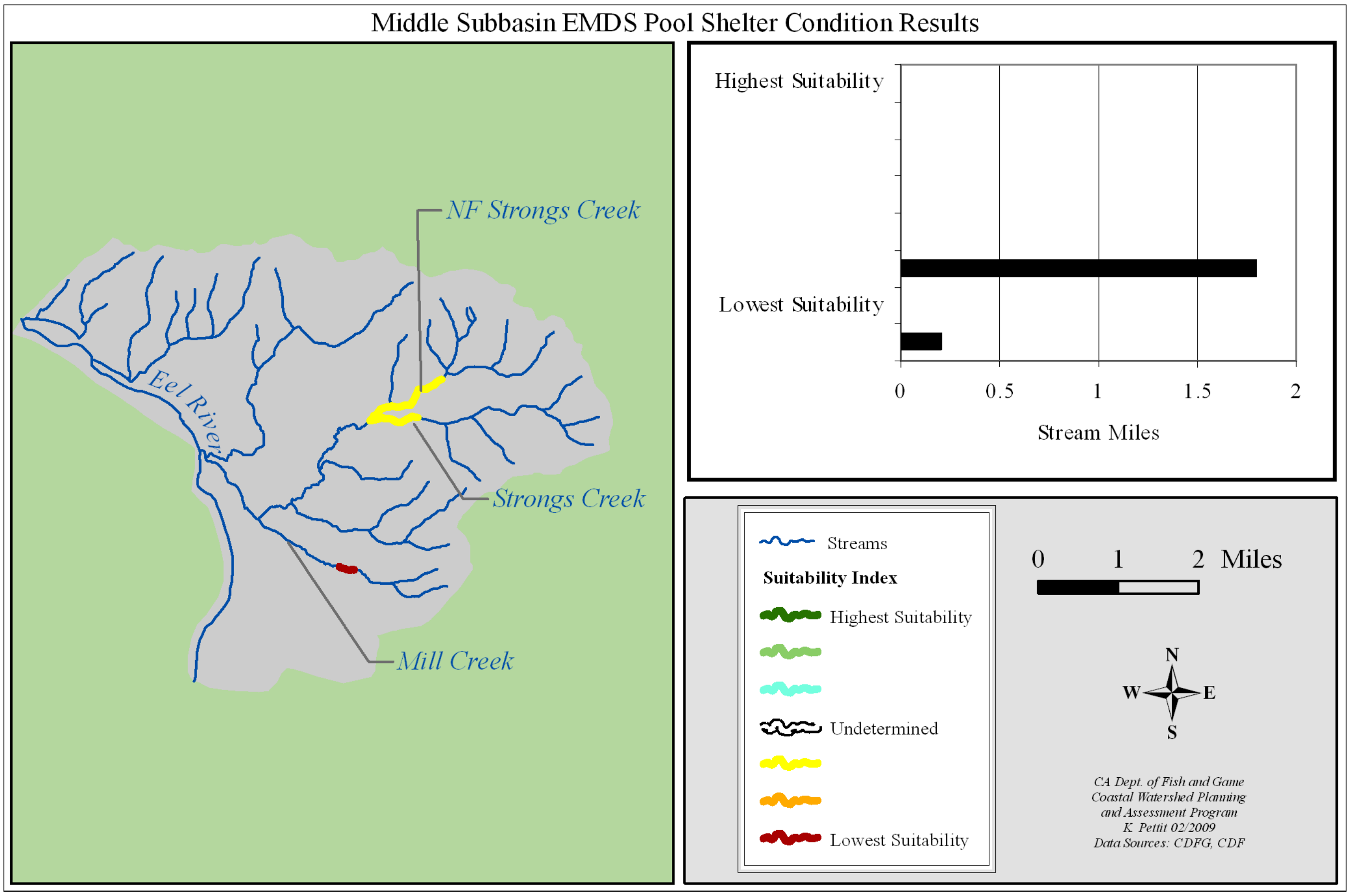

Figure 15. EMDS pool shelter results for the Middle Subbasin by surveyed stream miles.

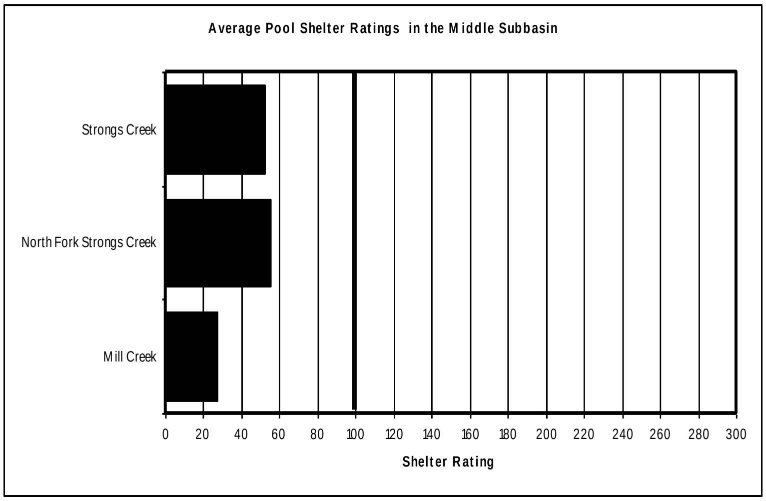

Figure 16. Average pool shelter ratings from CDFG stream surveys in the Salt River Subbasin.
Streams are listed in descending order by drainage area (largest at the top).

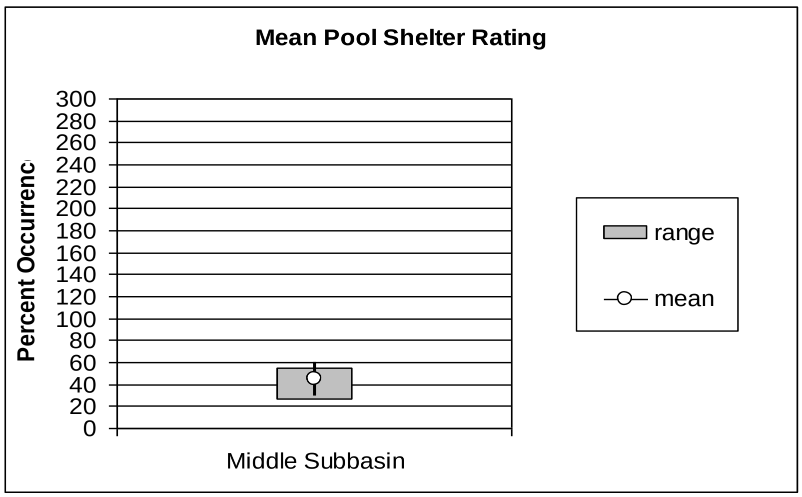

Figure 17. Pool shelter in the Middle Subbasin.
Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described and rated in CDFG surveys.

Table 18. Mean percent of shelter cover types in pools for surveyed tributaries in the Middle Subbasin.

Stream	Undercut Banks	Small Woody Debris	Large Woody Debris	Root Mass	Terrestrial Vegetation	Aquatic Vegetation	White Water	Boulders	Bedrock Ledge
Mill Creek	7.8	36.1	0	11.1	18.9	0	0	16.1	10
North Fork Strongs Creek	17.6	14.7	51.6	6.8	0.1	0	0.5	4.9	3.8
Strongs Creek	0	12	50.8	16.5	3.4	0	0	15	2.3

Significance: The pool shelter rating is a relative measure of the quantity and percent composition of small woody debris, root wads, boulders, undercut banks, bubble curtains, and submersed or overhanging vegetation in pool habitats. These elements serve as complex instream habitat with protection from predation, rest areas from high velocity flows, and separate territorial units to

Findings: Pools shelter ratings for surveyed streams in the Middle Subbasin were all well below the target value of 100%. North Fork Strongs Creek had the highest shelter rating at only 55%. Pool shelter rating in Mill Creek was 27%. Within the Middle Subbasin, the overall average pool shelter rating was less than 50%, which translates into primarily unsuitable conditions overall (over 1.5 miles of moderately unsuitable conditions.).

In addition to complexity rating, instream shelter composition is also collected during habitat inventories. Pool cover types are identified, and the measure of the area occupied within the habitat unit is given

LWD

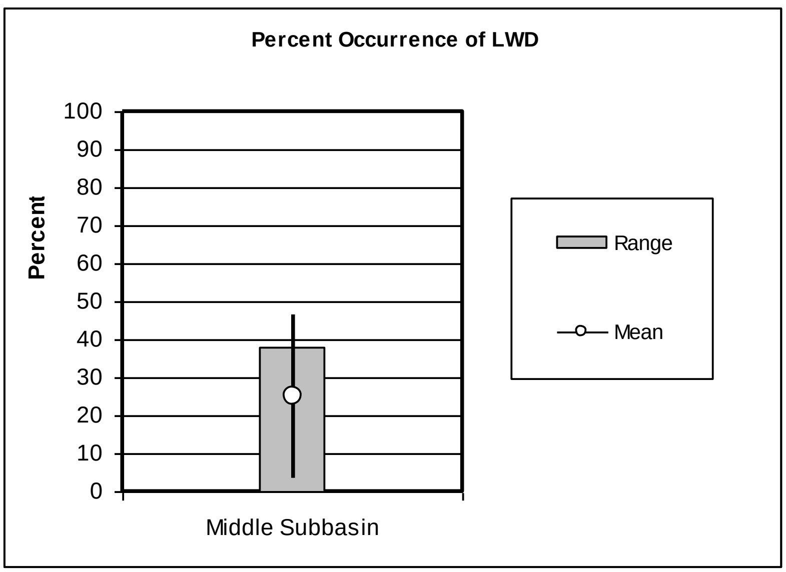

Figure 18. Large Woody Debris (LWD) in the Middle Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, etc.) is described in CDFG surveys. The dominant shelter type is determined and then the percentage of a stream reach in which the dominant shelter type is provided by organic debris is calculated.

Significance: Large woody debris shapes channel morphology, maintains organic matter, and provides essential cover for salmonids. There are currently no target values established for the % occurrence of LWD.

Findings: The average percent occurrence of LWD for the Middle Subbasin was 25. Large woody debris readings ranged from 0 to 38 over the three streams. The dominant shelter type recorded in most stream reaches was large woody debris.

Cobble Embeddedness

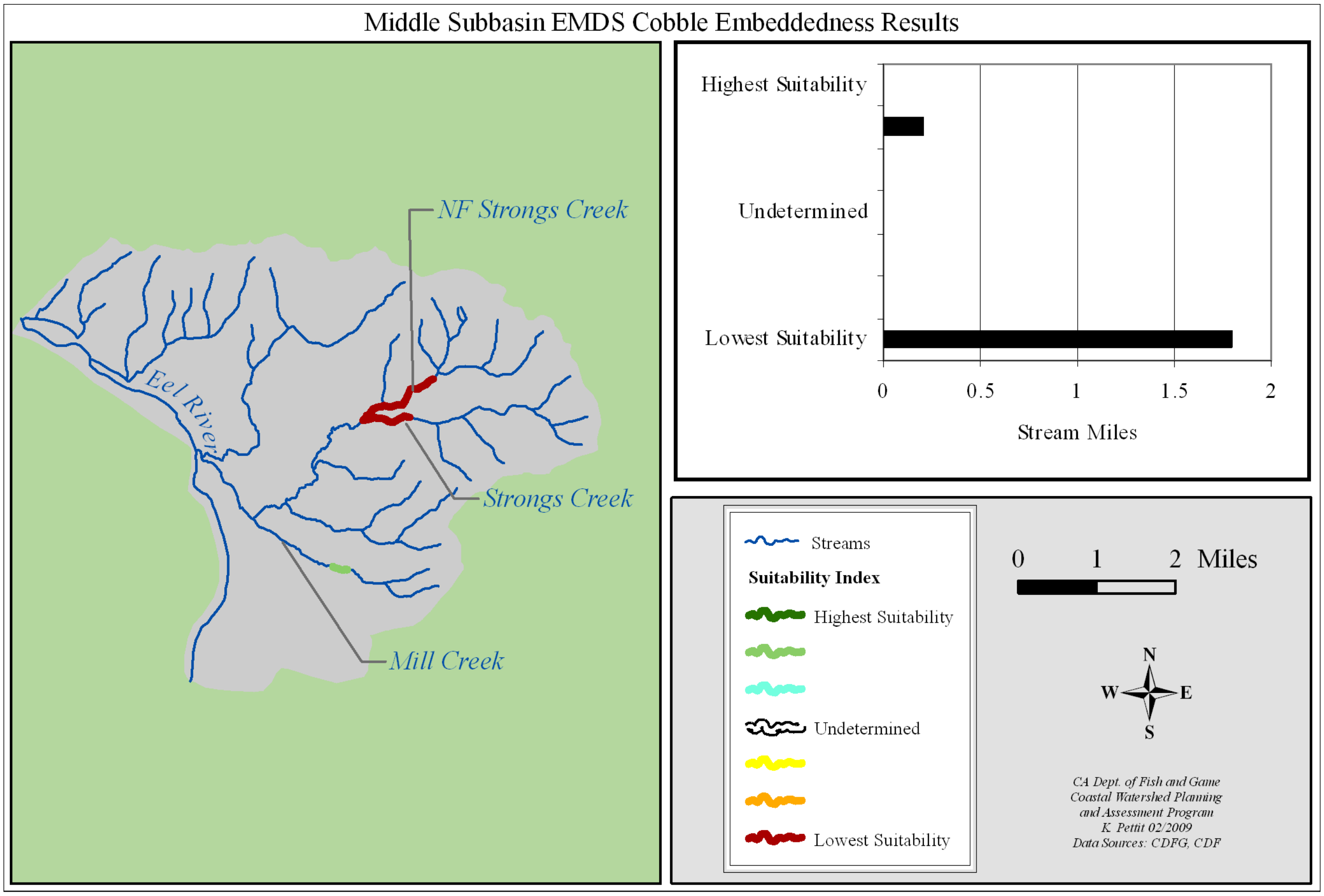

Figure 19. EMDS cobble embeddedness results for the Middle Subbasin by surveyed stream miles.

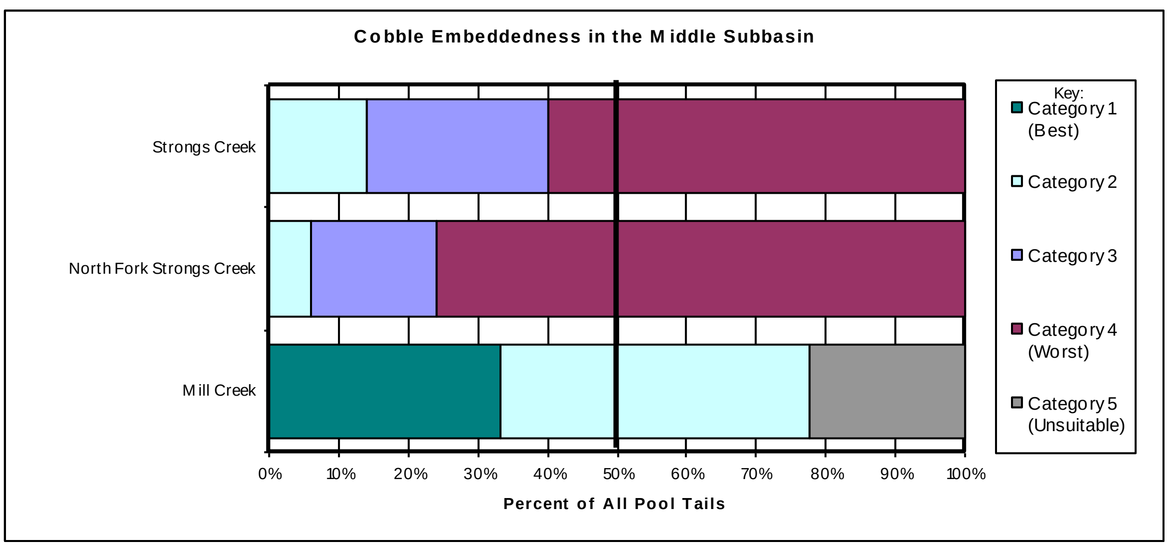

Figure 20. Cobble embeddedness categories as measured at every pool tail crest in surveyed streams in the Middle Subbasin. Streams are listed in descending order by drainage area (largest at the top).

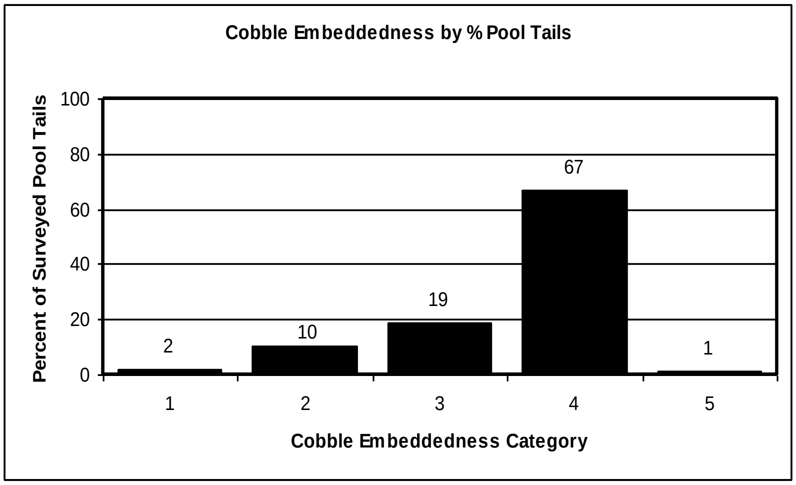

Figure 21. Cobble Embeddedness in the Middle Subbasin.

Cobble Embeddedness will not always sum to 100% because Category 5 (not suitable for spawning) is not included.

Significance: Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments decrease successful spawning and incubation. Cobble embeddedness is the percentage of an average sized cobble piece at a pool tail out that is embedded in fine substrate. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded, and category 4 is 76-100% embedded. Excessive accumulations of fine sediment (>50%) reduce water flow (permeability) through gravels in redds which may suffocate eggs or developing embryos. Excessive levels of fine sediment accumulations over gravel and cobble substrate also may alter insect species composition and food availability for growing fish. Consequently, cobble embeddedness categories three and four are not within the fully supported range for successful use by salmonids. Category five was assigned to tail-outs deemed unsuited for spawning due to inappropriate substrate like sand, bedrock, log sills, boulders or other considerations.

Findings: Of the three streams surveyed in the Middle Subbasin, none met the target value for cobble embeddedness. However, approximately 78% of Mill Creek does meet values considered suitable for salmonids (categories 1 and 2, combined). In contrast, 86% of Strongs Creek and 94% of North Fork Strongs Creek measurements are unsuitable for salmonid spawning. Category 4 embeddedness, considered the worst category by the target values, was the

Water Quality

Water Temperature

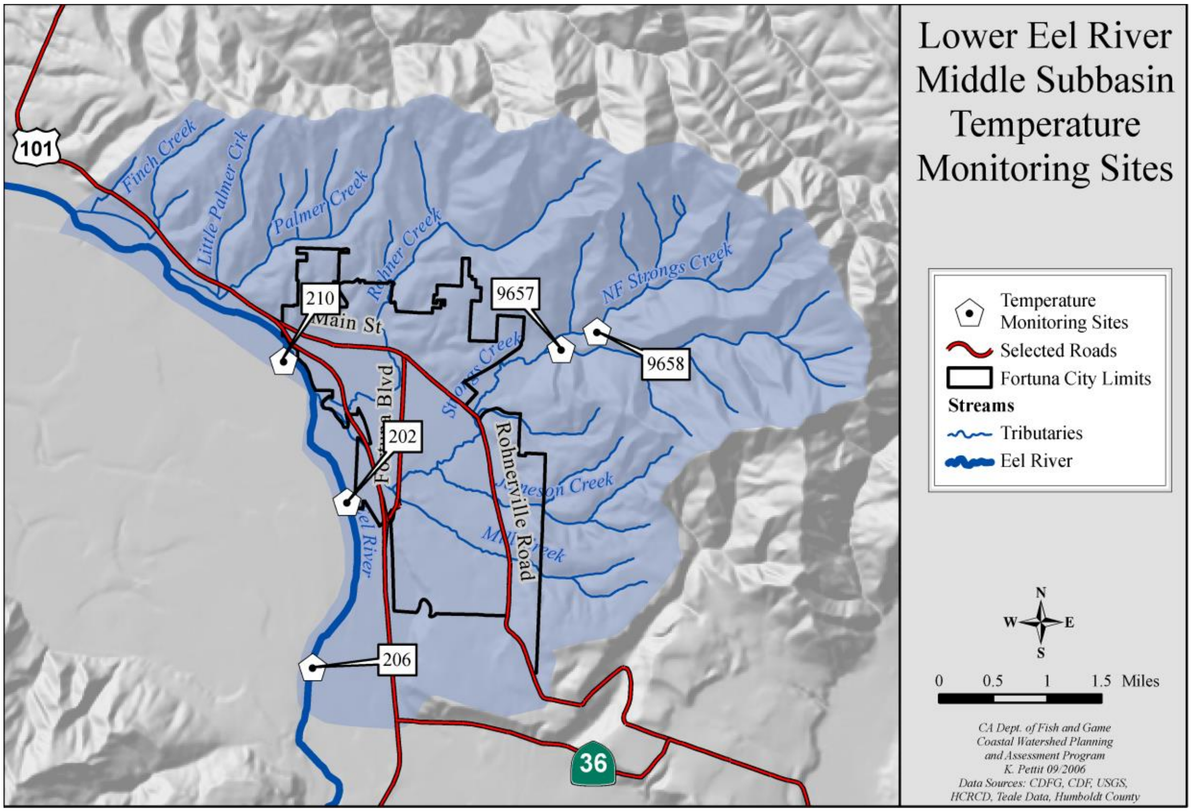

Figure 22. Locations of temperature monitoring sites in the Middle Subbasin.

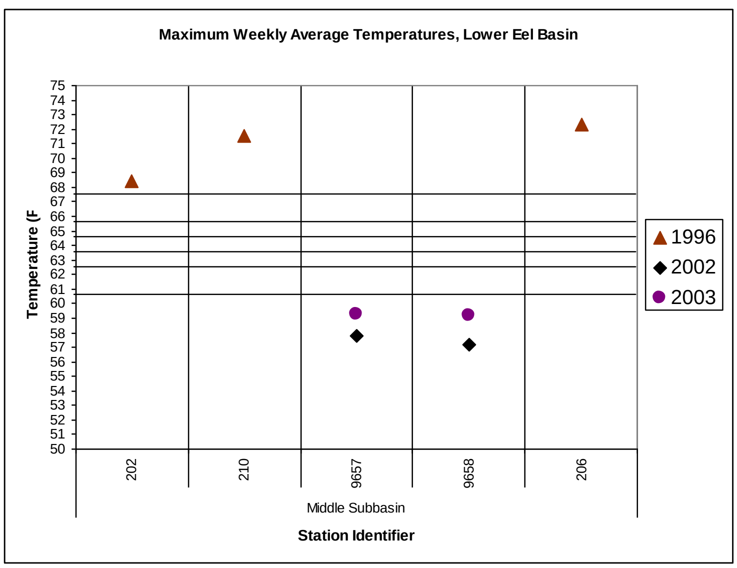

Figure 23. Maximum weekly average temperatures recorded at sites in the Middle Subbasin.

Table 19. Maximum weekly average temperatures and maximum daily average temperatures collected in the Middle Subbasin.

Creek	Site	MWAT Range (°F)	Max Daily Average (°F)	Years of Data
Fully Suitable (50-60°)				
Strongs Creek	9657	58-59	59	2
North Fork Strongs Creek	9658	57-59	59	2
Fully Unsuitable (≥68°)				
Mainstem Eel River	202	68	69	1
Mainstem Eel River	206	72	73	1
Mainstem Eel River	210	72	72	1

Significance: Water temperature affects salmonids during all life stages and can be a significant limiting factor for salmonid reproduction and survival. The CWPAP has defined suitability ratings for MWATs as: fully suitable at 50-60°, moderately suitable at 61-62°, somewhat suitable at 63°, undetermined at 64°, somewhat unsuitable at 65°, moderately unsuitable at 66-67°, and fully unsuitable at ≥68°.

Findings: Water temperature gages were deployed at five locations within the Middle Subbasin (Figure 22). Only two of these were deployed in Eel River tributaries and have more than one year of data. These two sites, located at Strongs Creek and North Fork Strongs Creek, were the only sites in the Middle Subbasin to acquire MWATs considered fully suitable (Table 19). The temperature data loggers on Strongs and North Fork Strongs Creeks were both deployed over the same period of time, and obtained similar results.

The other three temperature monitoring sites were located in the mainstem Eel, and therefore expectedly recorded overall temperatures that were much higher. These three locations were sampled over one season, and each obtained MWATs above 68°F. However, no locations within the Middle Subbasin obtained seasonal maxima considered lethal for fish (≥ 75°F).

The Fortuna Creeks Project has been monitoring water temperature since 1997 in Strongs, Mill, and Rohner Creeks and the Eel River. Temperatures are taken once per month with a handheld thermometer, and often the summer months are not sampled. Most of the averaged temperatures fell within the fully suitable range with the following exception (Cole 2003):

Water temperatures on Rohner Creek were recorded at 75ºF (August, only one year was sampled), this temperature is potentially lethal for salmonids if cooler refuge is not available.

Water Chemistry

Significance: Water chemistry interacts with basic trophic levels affecting the production and availability of food for aquatic organisms. Nutrients are often limiting factors in the biological capacity of a stream yet a proper balance is needed to prevent eutrophication. Pollutants are a concern where they interfere with the biological function of aquatic organisms, or can be a threat to those that consume them. Large sources of nutrients and pollutants are commonly municipal and industrial wastewater facilities, storm runoff, and agricultural operations. Naturally occurring nutrients and heavy metals are often found in much smaller concentrations.

Table 20. NCRWQCB water quality objectives for the Eel River (NCRWQCB 2006d).

Parameter	Standard
Dissolved Oxygen	Above 7.0 mg/L 100% of the time Above 7.5 mg/L 90% of the time Above 10.0 mg/L 50 % of the time);
Conductivity	Below 375 micromhos 90% of the time Below 225 micromhos 50% of the time
Total Dissolved Solids	Below 275 mg/L 90% of the time Below 140 mg/L 50% of the time
pH	Between 6.5 and 8.5

Findings:

Water Chemistry Studies

The Fortuna Creeks Project of Fortuna High School has been involved in water quality measurements on Mill, Strongs, and Rohner Creeks since 1997. After the Fortuna Creeks Project partnered with the Community Clean Water Institute in 2002 sampling began at two Eel River sites upstream and downstream of the Strongs Creek confluence (Cole 2003). There are a total of nine sampling sites with two sites on each of the above mentioned streams, an additional one on Strongs Creek near the confluence with Eel River, plus the two on the Eel River. Geographic coordinates are recorded for each site and are available on www.fortunacreeks.com.

Data is collected once per month on dissolved oxygen, temperature, conductivity, turbidity, and pH. In 2003, a student at Humboldt State University, Jennifer Cole, compiled the data up to that point and summarized the results (Cole 2003). The data she presented (with the exception of temperature) was averaged over the six years of study (1997 – 2003) and indicated that most creeks fell within acceptable ranges for coho salmon, the most sensitive of salmonids, with the following exceptions:

- Average conductivity in Rohner Creek was also above levels recommended for coho salmon (375 micromhos) from November through May; in Strongs Creek from June through October, and in Mill Creek in October and November;
- Average turbidity levels were above recommended levels for coho (30 NTUs) for 9 (Rohner Creek), 8 (Strongs Creek), or 4 (Mill Creek) months out of the year;
- Average dissolved oxygen fell below 7.0 in Rohner Creek in August, September and October, in Strongs Creek in August, and in Mill Creek in August.

The HCRCD studied water quality conditions in the Eel River in 1996 and 1997, including temperature and macro-invertebrate surveys. Macro-invertebrate communities are closely linked to water quality and are used to determine if a water body has been impacted and to what degree. Strongs Creek was surveyed in the spring and in the fall of 1996 for species richness and diversity and consistently scored in the “highly impacted” range. The reason proposed for this result is the urban watershed that feeds Strongs Creek (HCRCD 1998).

Another important water quality concern in this subbasin is the increased amount of chemical pollutants from urban runoff in Fortuna. Newly created impervious areas have increased runoff to urban streams (FEMA 1981 as cited in Mintier and Associates 2006). Impervious surfaces such as cement and pavement accumulate chemical pollutants from automobile traffic and other sources (Wheeler et. al 2005). When it rains, water running over these surfaces mobilizes chemicals. The chemicals are then brought into the storm water system and eventually streams. Although no specific tests of chemicals have been conducted in Fortuna’s streams, urban runoff in general is known to mobilize chemicals such as trace elements, pesticides, copper, and volatile organic compounds (Hamilton et. al 2004). Chemical pollutant testing has not been carried out in Fortuna’s creeks to assess the impact of urban runoff.

Findings:

Wastewater Treatment Facility

Fortuna operates a wastewater treatment facility on 180 Dinsmore Drive, just west of Highway 101. This plant was constructed during the 1970s, though an earlier plant was constructed in the 1950s. Wastewater during average flows is treated to secondary treatment standards using screening, grit removal, influent pumping, primary sedimentation, activated sludge processes, secondary sedimentation, chlorination, de-chlorination, as well as anaerobic biosolids digestion, dewatering and composting. The facility discharges between 1 and 5 million gallons per day (mgd) of effluent with a peak capacity of 7mgd, and averages 1.5mgd during dry months. Effluent is discharged into Strongs Creek at the confluence with the Eel River between October 1st and May 14th. During the winter season, if influent exceeds 3-4 mgd, it is diverted and stored in three equalization ponds before being returned for treatment during lower flows. Between May 15th and September 30th, treated effluent is discharged into gravel bar percolation ponds adjacent to the Eel River.

The equalization ponds only had a one to two day capacity during wet weather and needed approximately one week of dry weather to recover (Mintier and Associates 2006). An upgrade to increase capacity was completed in March 2007. A new permit will go into effect for this facility in June 2007 and will require the relocation of summer percolation ponds as well as a compliance schedule for the reduction of three priority pollutants (copper, chlorodebromomethane, and dichlorobromomethane). Priority pollutants are recognized has having heightened detrimental effects on living organisms. Additionally, the dilution ratio requirement of receiving bodies to effluent (100:1) is not being met at the discharge point in Strongs Creek. An alternative discharge location will be required through the new permit.

High flows in Strongs Creek were backing up discharge and damaging the chlorine contact chamber at the plant, spurring a Cease and Desist order in 1997. Fortuna constructed a new chlorine contact chamber to resolve the issue and the order was rescinded in 2001. However, in 2004, the treatment plant had three chlorine limit violations - one maximum and two minimum values that violated the permit level. Sewer overflows that occurred in the system were caused by high flows and collection system stoppages (Mintier and Associates 2006). Currently, the chlorine contact chambers are functioning properly and are not a threat to water quality (Lisa Bernard personal comm).

Fish Passage Barriers

Several fish passage barrier issues have been identified in the Middle Subbasin. The following discussion of road crossings or other naturally occurring structures were identified as the most significant fish passage barriers, hindering the upstream and downstream movement of adult and juvenile steelhead.

On Palmer Creek, the culvert located below Highway 101 was noted as a fish passage barrier in 1997 (HCRCD) and no fish were found upstream of this culvert by CDFG in 2000. Baffles were installed in the culvert in 2000 to improve fish passage. However, the 2005 Fish Passage database notes that this culvert was assessed as a partial barrier to salmonids. Moreover, the stream link between the culvert and the Eel River is also tenuous for fish passage. Just to the north in French Creek, the Highway 101 culvert is also a potential barrier to fish passage (CDFG 2005). Unlike Palmer Creek it has yet to be modified to improve fish passage.

Several possible barriers to fish passage were noted by CDFG on Rohner Creek in 1982. This survey is quite outdated and further investigation of possible barriers on Rohner Creek is necessary. The 2005 Fish Passage database notes a possible barrier at the stream crossing of Rohnerville Road.

Strongs Creek is crossed by many roads. Crossings at Rohnerville Road and South Fortuna Boulevard have not been assessed for potential fish passage problems. The Highway 101 culvert was assessed and found to be a partial barrier and ranked as medium priority for restoration. The railroad crossing bridge was found not to be a barrier to salmonids (CDFG 2005).

Two lower tributaries of Strongs Creek, Mill Creek and Jameson Creek have fish passage issues related to their culverts located under Rohnerville Road. The culvert on Mill Creek was identified as a likely complete barrier to juvenile salmonids (Figure 24) (CDFG 2005). North of Mill Creek, the culvert on Jameson Creek was considered a complete barrier to fish passage (2008). According to CDFG (2005) Jameson Creek contains two additional upstream culverts that are potential barriers to fish passage.

Sometimes, large debris accumulations in streams can cause fish passage barriers. These are noted in CDFG stream inventories. Stream inventories in the Middle Subbasin found possible problems of this sort on Strongs and North Fork Strongs Creeks.

Figure 24. Outlet of culvert where Rohnerville Road crosses Mill Creek, tributary to Strongs Creek, June 18, 2008.

Habitat Conclusions

Streams surveyed before 1990 and habitat inventories from 1993 and 2004 were compared to indicate changes between historic and current conditions. Data from older stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair, and poor are based on the judgment of the biologist or scientific aid who conducted the survey. The results of historic stream surveys are qualitative and cannot be used in comparative analyses with quantitative data provided by habitat inventory surveys with any degree of accuracy. However, the two data sets can be compared to show general trends.

Where habitat data were available from both older stream surveys and recent stream inventories it appeared that spawning habitat remained similar (Table 21). There was not enough information to draw conclusions about changes in canopy, pool depth, and pool shelter.

Instream habitat conditions were generally poor in this subbasin at the time of more recent CDFG surveys. Surveyed reaches fell below target values and were evaluated as unsuitable for salmonids by EMDS for pool quality, depth, and shelter (Table 22) - thus these habitat factors are likely limiting to salmonid populations.

Canopy density was suitable on all three surveyed creeks. However, current canopy density measurements do not take into account differences between smaller, younger riparian vegetation versus the larger microclimate controls that are provided by old growth forest canopy conditions. Summer water temperature measurements did show that water temperatures were suitable for salmonids in Strongs and the North Fork of Strongs Creeks. Summer water temperatures were unsuitable for salmonids in the mainstem Eel River.

Water temperature is likely not a limiting factor for salmonids in surveyed streams in this subbasin, though high water temperatures in the Eel River during the summer months likely limit salmonid productivity in the mainstem. Therefore, cooler pockets where tributaries enter the mainstem may provide important patches of cooler water for salmonids at these times.

Cobble embeddedness was suitable on Mill Creek and unsuitable in the other two surveyed tributaries. A lack of suitable spawning gravels is likely limiting salmonids in the subbasin.

Available water chemistry data from Rohner, Strongs, and Mill Creeks indicate that conductivity and turbidity levels were above those recommended for coho salmon. Moreover, dissolved oxygen was below the recommended level for coho salmon. Therefore, these conditions may be limiting factors for salmonid production.

Table 21. Comparison between historic habitat conditions with current habitat inventory surveys in the Middle Subbasin.

Stream	Canopy Cover		Spawning Conditions		Pool Depth/Frequency		Shelter/Cover		Summary of Changes from Historic to Current
	Historic	Current	Historic	Current	Historic	Current	Historic	Current	
Strongs Creek	ND	Fully suitable	Little to no spawning gravel	Fully unsuitable	Shallow	Fully unsuitable	ND	Unsuitable	Spawning habitat remained similar
North Fork Strongs Creek	Second growth redwood canopy	Fully suitable	Mostly fine sediment	Fully unsuitable	ND	Fully unsuitable	ND	Unsuitable	Spawning habitat remained similar

Where multiple years of historic streams surveys were available, the oldest surveys were used.

*ND is no data available

Table 22. EMDS Anadromous Reach Condition Model results for the Middle Subbasin.

Stream	Year	Canopy	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Mill Creek	2004	++	---	---	---	++
North Fork Strongs Creek	1993	+++	--	-	-	---
Strongs Creek	1993	+++	--	-	-	---
Middle Subbasin		++	--	-	-	--

Key: +++ = Highest Suitability U= Insufficient Data or Undetermined --- = Lowest Suitability

Restoration Projects

There have been eighteen restoration projects completed in the Middle Subbasin. Half of these fall into the public involvement category. These include conferences and workshops that are held at the Fortuna River Lodge, but may not necessarily pertain to the Middle Subbasin. Another prominent restoration activity is upslope management. Five ongoing forest management programs are being conducted by the CDF to improve forest and watershed health. Fish passage improvements have also been important in this urban watershed. These projects are listed below.

- CDF Timber/Forest Management Plan;
- CDF forest health improvement via thinning;
- Strongs Creek re-vegetation and removal of non-native plants and trash;
- Temperature and macro-invertebrate monitoring by HCRCD;
- Fish Passage inventory protocol training;
- Technical training for rural landowners to improve and maintain roads;
- Presentation on conditions of the Eel River watershed to local landowners;
- "Salmon in the Classroom" curriculum;
- Salmonid Restoration Federation Conference;
- Strongs Creek watershed restoration training;
- Rohner Creek culvert upgrade;
- Palmer Creek fish passage improvement under Highway 101.

More information such as date and specific location can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis.edu/nrpi/).

Another restoration program not captured in the above databases comes out of the Fortuna School District. Fortuna High School's Fortuna Creeks Project was established in 1989 to restore and maintain the riparian ecosystem along Rohner Creek. In 1995, the group expanded their scope to include the rest of the Fortuna streams – Palmer, Mill, and Strongs Creeks – and the Eel River. Throughout the years, students have participated in riparian vegetation planting, trash clean-ups, riparian bird nest-box installations, stream surveys for spawning salmonids and aquatic invertebrates, and water quality sampling. This program has focused on planting trees to create riparian habitat while creating strong working relationships between the program and the private landowners in the subbasin (Halstead 2007, Fortuna Creeks Project website).

Integrated Analysis

Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFG stream inventories provide a list of recommendations that address those conditions that did not reach target values (see the Fish Habitat section of this subbasin). In the Middle Subbasin, three streams were inventoried, and recommendations for each were selected ranked by a CDFG biologist (Table 23). The tributary recommendation process is described in more detail in the Synthesis section of the Basin Profile.

In order to compare tributary recommendations within the subbasin, the recommendations of each stream were collapsed into five target issue categories (Table 24). The top three recommendations of each stream are considered to be the most important, and are useful as a standard example of the stream. When examining recommendation categories by number of tributaries, the most important target issue in the Middle Subbasin is Erosion/Sediment.

However, comparing recommendation categories in the subbasin by number of tributaries can be confounded by the differences in the length of survey for each tributary. Therefore, the number of stream miles within the subbasin assigned to various recommendation categories was calculated (Figure 25). By examining recommendation categories by number of stream miles, the most important target issue remains Erosion/ Sediment. Gravel/Substrate, and recommendations involving livestock and fish passage are also an important target issues. Because of the high number of recommendations dealing with these target issues, high priority should be given to restoration projects that emphasize sediment reduction as well as livestock management and fish passage.

Table 23. Occurrence of stream habitat inventory recommendations for streams of the Middle Subbasin.

Stream	Survey Length (mile)	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Mill Creek	0.2	2		3							1
North Fork Strongs Creek	1.2	2	1	6		5		4	3	7	
Strongs Creek	0.6	4	3	7		6		5	1	2	

Table 24. Top three ranking recommendation categories by number of tributaries in the Middle Subbasin.

Middle Subbasin Target Issue	Related Table Categories	Count
Erosion / Sediment	Bank / Roads	4
Riparian / Water Temp	Canopy / Temp	1
Instream Habitat	Pool / Cover	0
Gravel / Substrate	Spawning Gravel / LDA	2
Other	Livestock / Barrier	2

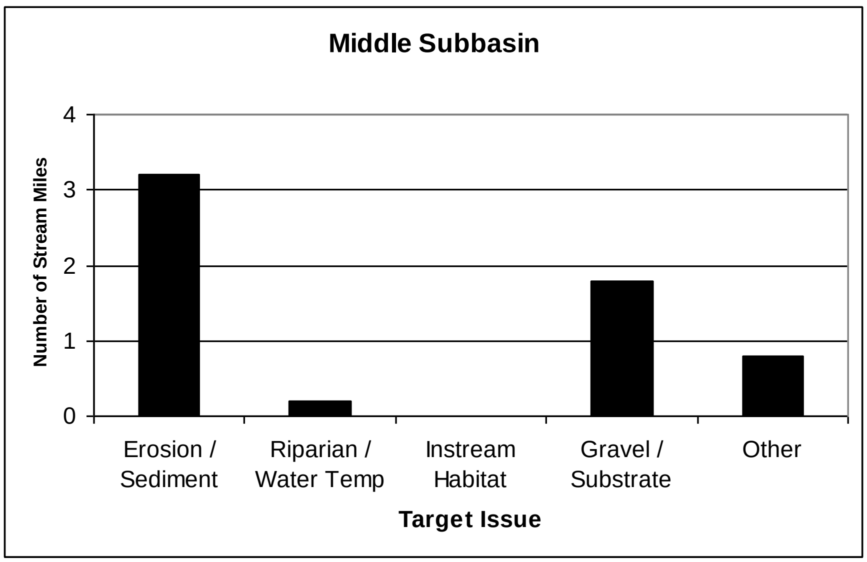

Figure 25. Recommendation target issues by stream miles for the Middle Subbasin.

Refugia Areas

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

The most complete data available in the Middle Subbasin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered. Salmonid habitat conditions in the Middle Subbasin on surveyed streams are generally rated as medium potential refugia. Palmer, Strongs, and North Fork Strongs Creeks provide the best salmonid habitat in this subbasin, while Rohner Creek and unnamed tributary provide low quality refugia. The following refugia area rating table summarizes subbasin salmonid refugia conditions.

Table 25. Refugia of streams of Middle Subbasin

Stream	Refugia Categories				Other Categories		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area	Data Limited
Palmer Creek			x				x
Strongs Creek			x				
Rohner Creek				x			x
Unnamed tributary (Mill Creek)				x			x
North Fork Strongs			x				x

Key Subbasin Issues

- Urbanization and increased residential development have generated negative effects on streams;
- Altered flow regimes;
- Addition of pollutants;
- Fish passage barriers where roads cross streams;
- Erosion from roads, construction wastes, and ground disturbance;
- There is concern about unrestricted stream access of livestock in agricultural areas;
- Erosion related to timber harvest on unstable soils is a concern;
- There is concern about the impact of gravel mining on the mainstem Eel River;
- Instream habitat conditions for salmonids are thought to be poor.

Responses to Assessment Questions

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

Findings and Conclusions:

- Three tributaries in the Middle Subbasin have been inventoried between 1993 and 2004 by the CDFG. These data, in addition to other fish studies have confirmed, among other species, the presence of coho and steelhead. Some historical and anecdotal accounts (dating back to the early 1950s) also list the presence of these salmonid species in several Middle Subbasin tributaries;
- Historically, coho salmon were found in Palmer and Strongs creeks and potentially Rohner Creek; however, in recent years they have only been detected (1995) in Strongs Creek;
- Steelhead trout were historically found in Palmer, Rohner, Strongs, and North Fork Strongs Creeks. In recent years, steelhead have only been detected in Strongs and North Fork Strongs Creeks;
- Cutthroat trout have also been observed during several surveys of Strongs and North Fork Strongs Creeks between 1984 and 1995. The Eel River is the current southern extent of coastal cutthroat trout (Miller and Lea). It is believed that Eel River cutthroat live out their entire lifecycle in fresh or brackish water;
- Sacramento pikeminnow have been documented as present in several surveys beginning in the late 1990s and are now common in areas of the lower river. Pikeminnow compete with and prey upon juvenile salmonids.

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

Findings and Conclusions:

Flow and Water Quality:

- Flow has been changed through the construction of hardened surface storm drain systems along streams. These changes in direction and flow are especially apparent on streams that run through the city of Fortuna during the rainy season, as is evidenced in flooding and drainage issues;
- Water quality is most likely impacted by cattle that have direct access to Strongs Creek;
- Low summer flows result in dry or intermittent reaches on streams in the Middle Subbasin, which may be stressful to salmonids;
- The Fortuna Creeks Project found that turbidity levels stressful to salmonids were reached during the rainy winter months. These high levels of turbidity, which are particularly apparent in Strongs and Rohner Creeks, occur during salmon and steelhead spawning season.

Erosion/Sediment:

- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing and feeding habitat for salmonids. High sediment levels are confirmed by embeddedness measurements in surveyed reaches;
- Livestock have unrestricted access to many of the Middle Subbasin tributaries, such as Palmer, Strongs, Mills, and Finch creeks, resulting in stream bank erosion;
- Soils in streams of the Middle Subbasin are prone to erosion, and slides and streambank failures have been observed to contribute fines to the streams.

Riparian Condition/Water Temperature:

- Water temperature data in the Middle Subbasin are not systematic and limited. Water temperatures collected over the six-year sample period demonstrate stressful (above 68ºF) and occasionally lethal (above 75ºF) conditions, particularly on Rohner Creek;
- Water temperature data collected during summer CDFG habitat inventories indicate acceptable water temperatures, however these data are limited and inconclusive;
- All surveyed reaches in the Lower Eel Basin tributaries met the target value of 80% canopy coverage. Coniferous canopy was most abundant on two streams; deciduous canopy was more abundant on one;
- The Fortuna Creeks Project found that stressful turbidity levels are reached during the rainy winter months. These high levels of turbidity, which are particularly apparent in Strongs and Rohner Creeks, occur during spawning season.

Instream Habitat:

- None of the surveyed streams met target values of pool depth;
- Quality pool structure is generally lacking in Middle Subbasin streams; no surveyed streams met standards for pool shelter (100). Pool shelter ratings ranged from fully unsuitable to somewhat unsuitable levels.

Gravel/Substrate:

- Spawning gravels in Strongs and North Fork Strongs Creeks are found in few reaches. Additionally, redds have been observed as crowded and superimposed during spawning surveys;
- None of the CDFG surveyed streams of the Middle Subbasin met target values for cobble embeddedness.

Refugia Areas:

- Salmonid habitat conditions were generally rated as medium potential refugia. Palmer, Strongs and North Fork Strongs Creeks provided the best salmonid habitat in this subbasin. Mill Creek has the potential to have quality habitat if restoration and barrier projects were implemented.

Barriers and other concerns:

- A culvert on Mill Creek (RM 1.3) and Rohnerville Road may not meet CDFG and NOAA Fisheries fish passage guidelines;
- A culvert on Jameson Creek and Rohnerville Road does not meet CDFG and NOAA Fisheries fish passage guidelines;
- Palmer Creek has problems with fish passage due to a barrier in the 800 foot culvert under Highway 101.
- When flows are sufficiently high, the Eel River floods into treatment ponds of the Fortuna Wastewater Treatment Plant;

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

Findings and Conclusions:

- Natural erosion rates are high due to:
  - The major rock underlying the subbasin is alluvium, which constitutes 70% of the subbasin. The other bedrock, also sedimentary, is Pliocene marine. Both of these geologic types are highly erodible;
  - Tectonic uplift has increased the erosion potential of the area and seismic activity remains strong in the Middle Subbasin. Though slopes are relatively stable, streams in the area are affected by sediment deposits from steep slopes in tributaries upstream;
  - Rapid incision rates of the mainstem and its tributaries have left a series of river terrace deposits perched steeply above the current stream channels which contribute fine sediments through slope instability and dry ravel;
  - The Little Salmon fault cuts through this basin, weakening bedrock and increasing the potential for seismic triggering of landslides;
- Floods periodically occur due to high winter precipitation levels and extremely altered runoff rates;
- During the winter rainy season, heavily silted water flows through the steep upstream terrain, which affects turbidity and sediment levels in streams;
- The predominant vegetation is conifer at 36%. Of this, 67% is composed of vegetation of the Redwood Alliance. Conifer canopy was greater than deciduous canopy over surveyed streams in this subbasin. Crown diameters of coniferous vegetation ranged from saplings to greater than 40 feet.

How has land use affected these natural processes?

Findings and Conclusions:

Changes in basin due to land use:

- Sedimentation and in-filling as a result of land development and subdivision activities, gravel mining and timber harvesting practices have resulted in an overall reduction in channel area, and consequently in available salmonid habitat;
- Fortuna grew from one square mile in 1950 to 4.68 square miles in size in 2006. This represents a change from approximately 4% to 19.5% of the subbasin;
- The Fortuna annual average population growth rate from 1980 to 2005 was 1.6%. If the city continues to grow at this rate the population will rise from 11,250 to approximately 17,000 in the next 25 years (Mintier and Associates 2006);
- There were 4,729 housing units in Fortuna in 2005. If current growth rates continue, Fortuna will require 2,298 new housing units by 2030 (Mintier and Associates 2006);
- Additionally, it is projected that there will be a need for an additional 852,866 square feet of commercial, retail, and manufacturing space by 2030 (Mintier and Associates 2006). Increased development in Fortuna,

especially in the southern and eastern parts of the city, has increased runoff from newly created impervious areas (FEMA 1981 cited in Mintier and Associates 2006);

- Projects related to the expansion of Fortuna's urbanization have adversely affected the area's streams in both water quality and riparian and instream habitats.

Possible effects seen in stream conditions:

Instream habitat conditions for salmonids are thought to be poor:

- Low summer flows are exacerbated by land and stream disturbances and result in dry or intermittent reaches on streams, which are stressful to salmonids;
- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing, and feeding habitat for salmonids. High sediment levels are confirmed by embeddedness measurements in surveyed reaches. Moreover, none of the surveyed streams met target values of pool depth;
- The Fortuna Creeks Project found that stressful turbidity levels are reached during the rainy winter months. These high levels of turbidity, which are particularly apparent in Strongs and Rohner creeks, occur during spawning season;
- Quality pool structure is generally lacking in Middle Subbasin streams; no surveyed streams met standards for pool shelter. Pool shelter ratings ranged from fully unsuitable to somewhat unsuitable levels;
- Spawning gravels in Strongs and North Fork Strongs creeks are found in only a limited number of reaches. Additionally, crowded and superimposed redds have been observed during spawning surveys;
- None of the CDFG surveyed streams of the Middle Subbasin met target values for cobble embeddedness.
- Winter floods are increasingly common due to high winter precipitation levels, increased runoff, and undersized storm water drainage structures. Areas with current flooding include the North Fortuna Drainage Area, Rohner Creek, the lower reaches of Strongs Creek, and Jameson Creek at the confluence with Strongs Creek (Winzler and Kelly 2005);
- Many of the storm drains and culverts in Fortuna are undersized (Winzler and Kelly 2005), increasing the velocity of flows during precipitation events;
- Strongs, Mill and Rohner Creeks have been modified where they flow through Fortuna to eliminate their floodplains, increasing the volume and velocity of flows during precipitation events;
- Development of the commercial shopping center along Mill Creek has greatly reduced the riparian area and hydrology of the stream channel. During large precipitation events, the stream overflows its banks and has caused stranding of steelhead in the adjacent fields. The riparian corridor needs to be expanded and a flow study developed to address the frequent stream bank overflow issues, which is impacting stream habitat and steelhead populations;
- Although no specific tests of chemicals have been conducted in Fortuna's streams, urban runoff in general is known to mobilize chemicals such as trace elements, pesticides, copper, and volatile organic compounds (Hamilton et al. 2004);

There is concern about unrestricted stream access of livestock in agricultural areas:

- Livestock grazing operations occur in approximately 23% of subbasin;
- Impacts from livestock grazing have been noted during stream surveys on Strongs and North Fork Strongs creeks. Although no specific tests of nutrients and/or coliform bacteria have been conducted in these creeks, levels of these constituents often exceed water quality standards in areas with extensive livestock use;

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

- The impact of previous techniques and harvest amounts are evident in the braiding of the Eel River from the mouth of Van Duzen River to Fernbridge that has occurred since 1956. A general flattening and widening of the river bed is also apparent (Humboldt County 1992);

- The impact of previous techniques and harvest amounts are evident in the braiding of the Eel River from the mouth of Van Duzen River to Fernbridge. These impacts were magnified by the 1955 and 1964 floods. A general flattening and widening of the river bed is also apparent (Humboldt County 1992);
- Timber harvest, while less of an issue than in the past, still occurred in the headwaters of all of the creeks in this subbasin from 1988 to 2005. Erosion related to timber harvest on unstable soil is a concern, such as the recent timber harvesting in the headwaters of Strongs and North Fork Strongs creeks. This area is made up of the Wildcat Formation, which is largely comprised of fine sediment and is highly erosive;

<u>There is concern about the impacts of historic and current gravel mining operations on the mainstem Eel River:</u>

- There are eleven gravel mining sites in this subbasin that remove over 5,000 cy/yr of aggregate. The volume of aggregate removed has decreased significantly since 1996. Prior to 1996, average extraction volumes ranged from 500,000cy/yr to 700,000cy/yr;
- The USACE has concluded that sand and gravel mining extractions are not excessive or occurring at rates that are too high to negatively impact channel morphology in the basin based on the increase of shoreline sediment. However, as bed-load data are not well known, it is difficult to set adequate extraction rates and volumes;
- Most of the concern in managing gravel mines is in the reconfiguration of the low flow channel. To this end, trench, alcove, or wetland pit mining are recommended over bar skimming, which has been shown to increase low flow channel width (USACOE 2003). Without the revision of extraction amounts and techniques, impacts to salmonids would be significant and would likely include loss of deep holding pools during adult migration, and loss of cover, suitable temperature, and complex habitat for juvenile salmonids;

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

Findings and Conclusions:

- Based on available information for this subbasin, it appears that salmonid populations are limited by:
  - Low summer flows;
  - High levels of fine sediments in streams;
  - Loss of habitat area and complexity;
  - Shortage of areas with suitable spawning gravel in tributaries;
  - High summer water temperatures;
  - Competition with Sacramento pikeminnow;
  - Restricted access by culverts.

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

Barriers to Fish Passage

Streams	**Draft Recommendation Activities XXX = Highest Priority**		
	Replace or modify culvert in order to meet CDFG and NOAA Fisheries fish passage guidelines	**Continue efforts to identify and alleviate fish passage impediments at culverts or other road crossings.**	**Carefully modify log debris accumulations in tributaries over time, with attention paid to resultant downstream sediment loading**
Palmer Creek		X	
Strongs Creek	XX	X	XXX
Rohner Creek		X	
Unnamed tributary (Mill Creek)	XX		

Jameson Creek	X	X	
North Fork Strongs		X	X

Flow and Water quality

Streams	Draft Recommendation Activities XXX = Highest Priority	
	Ensure that water diversions used for domestic or irrigation purposes bypass sufficient flows to maintain all needs of fishery resources	Ensure that inadequately treated wastewater is not discharged to streams
Eel River	X	X
Unnamed tributary	X	
Finch Creek	X	
Little Palmer Creek	X	
Palmer Creek	X	
Strongs Creek	XX	X
Rohner Creek	XX	
Unnamed tributary (Mill Creek)	XX	
Jameson Creek	XX	
North Fork Strongs	XX	

Runoff

Streams	Draft Recommendation Activities XXX = Highest Priority				
	Consider adopting a city ordinance in Fortuna to limit the amount of impervious cover in new developments	The Fortuna City Community Development Department should require development methods that incorporate on-site storm water detention and infiltration for all new developments to minimize the amount of runoff entering the drainage system. Methods include detention basins, vegetated swales, buffer strips, and other bio-retention methods.	The Fortuna City Community Development Department should require that new development not increase the existing estimated 25-year peak runoff volume from a site. Any increase in total runoff beyond the peak 25-year event resulting from new development should be retained or detained on site	Implement a channel and drainage basin maintenance program to ensure drainage channels and basin function as designed in Fortuna	Ensure that flood control projects, such as culvert replacement, creek widening, creek rerouting, and stream bank stabilization do not impair anadromous salmonid migration and juvenile rearing habitat.
Strongs Creek	X	XX	X	X	XX
Rohner Creek	X	XX	X	X	XX
Unnamed tributary (Mill Creek)	X	XX	X	XX	XXX
Jameson Creek	X	XX	X	X	
North Fork Strongs	X	XX	X	X	XX

Erosion and Sediment Reduction

Streams	Draft Recommendation Activities XXX = Highest Priority		
	Prevent livestock from accessing streams through the use of livestock management fencing	Conduct an upslope erosion inventory in order to identify and map stream bank and road-related sediment sources. Sites should be prioritized and improved	Stabilize eroding stream banks with appropriately designed structures and vegetation
Strongs Creek	X	XXX	X
Rohner Creek			X
Unnamed tributary (Mill Creek)			X
North Fork Strongs	X	XXX	X

Riparian and Instream Habitat

Streams	Draft Recommendation Activities XXX = Highest Priority			
	Consider replanting of native species, like willow, alder, redwood and Douglas fir in areas with exotic vegetation	**Consider thinning hardwoods to increase growth of conifers where riparian forest is strongly dominated by hardwoods and shade canopy will not be adversely affected**	**Increase depth, area or shelter complexity in pools, by adding LWD or combinations of boulders and LWD. This must be done where banks are stable, or in conjunction with stream bank armor to prevent erosion**	**Expand spawning area by trapping and sorting spawning gravels**
Strongs Creek	X		X	X
Unnamed tributary (Mill Creek)	X	X		
North Fork Strongs			X	X

Research and Monitoring

Streams	Draft Recommendation Activities XXX = Highest Priority				
	Monitor streams near land development activities for turbidity and drainage issues	**Consistently collect water quality data, including temperature, dissolved oxygen, and water chemistry throughout the year for several years in order to accurately characterize conditions**	**Conduct biological sampling to determine salmonid usage and populations**	**Inventory habitat in urban streams**	**Conduct substrate sampling to determine if gravels are suitable for salmonid spawning**
Palmer Creek		X	X	X	X
Strongs Creek	X				
Rohner Creek	X		X	X	X
Unnamed tributary (Mill Creek)	X		X		
Jameson Creek	X				
North Fork Strongs	X				

Education and Community Outreach

Streams	Draft Recommendation Activities XXX: Highest Priority			
	Support programs that participate in monitoring the state of urban streams, like the Fortuna high school's Fortuna Creeks Project	**Improve educational and community outreach by partnering with the City of Fortuna and through participation in events like Fortuna Creek Days**	**Consider a signage program for urban creeks to increase awareness of use by anadromous salmonids**	**Establish greenbelts along creeks in Fortuna**
Eel River	X	X	X	X
Strongs Creek	X	X	XX	XX
Rohner Creek	X	X	XX	XX
Unnamed tributary (Mill Creek)	X	X	X	X
Jameson Creek	X	X	X	X
North Fork Strongs	X	X	X	X

Subbasin Conclusions

Streams in the Middle Subbasin are heavily affected by urbanization, as many flow directly through Fortuna, the area's population center. As such, they are subject to degradation as a result of high levels of storm water runoff, addition of solid wastes, and erosion from roads. Residential development in the area is increasing, which brings with it watershed impacts in the form of construction wastes, and ground disturbance. Agricultural practices are also impacting the streams in this subbasin, and are evidenced primarily by the unrestricted stream access of livestock. The geology and climate of the area accentuate sediment delivery to the streams. Water quality data are lacking, and necessary in order to adequately compare current conditions with those of pre-development, as well as to monitor changes in the watershed. As such, streams in this subbasin face serious challenges typical of urban streams with native salmonids.

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Upper Subbasin

The Upper Subbasin includes the watershed area along the Eel River from Barber Creek to Dean Creek at the town of Rio Dell, a distance of 7.5 miles. It also includes the Van Duzen River from its mouth to Cummings Creek, approximately 9 miles above its confluence with the Eel River (Figure 1). This assessment area encompasses the upper delta agricultural lands. Stream elevations range from approximately 40 feet at the confluence of the Eel River with Barber Creek to approximately 2,160 feet in the headwaters of the tributaries. This subbasin is the largest of the Lower Eel Basin at 75 square miles, 43% of the total basin area. This subbasin is mostly held in private parcels 40-500 acres in size with some sections owned by large timber companies and managed for timber production. Chinook, coho, steelhead, and Coastal cutthroat trout have each been documented in fish surveys of the Upper Subbasin.

Hydrology

The Upper Subbasin is made up of sections of six CalWater Units (Figure 1). There are 21 named tributaries (Table 1) and 64.3 permanent stream miles in this subbasin. The mainstem Eel River is a sixth order stream, the Van Duzen River is a fifth order stream using the Strahler (1964) classification. The tributaries are first through third order streams. Stream and river drainage areas range from less than one within the subbasin to the 430 square mile Van Duzen River Basin and the 3,684 square mile Eel River Basin, which extend well beyond the subbasin.

Table 1. Major streams in the Upper Subbasin.

Stream	Tributary to	River Mile	Drainage Area (square miles)	Stream Order	Permanent (miles) (in Subbasin)	Intermittent (miles)
Van Duzen River	Eel River	13.3	31.61	5	10.1	0.0
Barber Creek	Van Duzen River	3.0	5.58	3	4.9	0.0
Wolverton Gulch	Barber Creek	0.4	2.82	1	4.1	0.5
Yager Creek	Van Duzen	5.7	5.29	4	2.9	0.0
Wilson Creek	Yager Creek	0.6	2.06	2	2.4	0.9
Cuddeback Creek	Van Duzen	7.5	1.35	1	1.6	1.1
Fiedler Creek	Van Duzen	0.3	1.39	I	0.0	2.2
Cummings Creek	Van Duzen	8.7	5.12	1	3.3	2.6
Barber Creek	Eel River	13.4	1.82	1	2.9	0.5
Price Creek	Eel River	15.0	13.24	2	8.3	0.6
Sweet Creek	Price Creek	4.1	2.03	1	2.1	0.2
Muddy Creek	Price Creek	4.6	1.14	1	1.2	0.6
Oil Creek	Eel River	15.0	1.75	1	1.9	1.7
Howe Creek	Eel River	16.0	10.97	2	4.4	0.7
Atwell Creek	Howe Creek	1.5	4.37	1	3.8	0.6
Unnamed tributary (Crystal Creek)	Howe Creek	2.4	0.64	I	0.0	1.3
West Fork Howe Creek	Howe Creek	3.2	1.67	1	1.2	0.7
Slater Creek	Eel River	16.8	2.36	1	2.2	0.3
French Gulch	Eel River	19.7	0.20	I	0.0	0.6
Nanning Creek	Eel River	20.0	4.02	1	2.5	0.3
Tank Gulch	Eel River	20.3	0.38	I	0.0	1.1
Dean Creek	Eel River	20.9	1.16	1	1.7	0.5

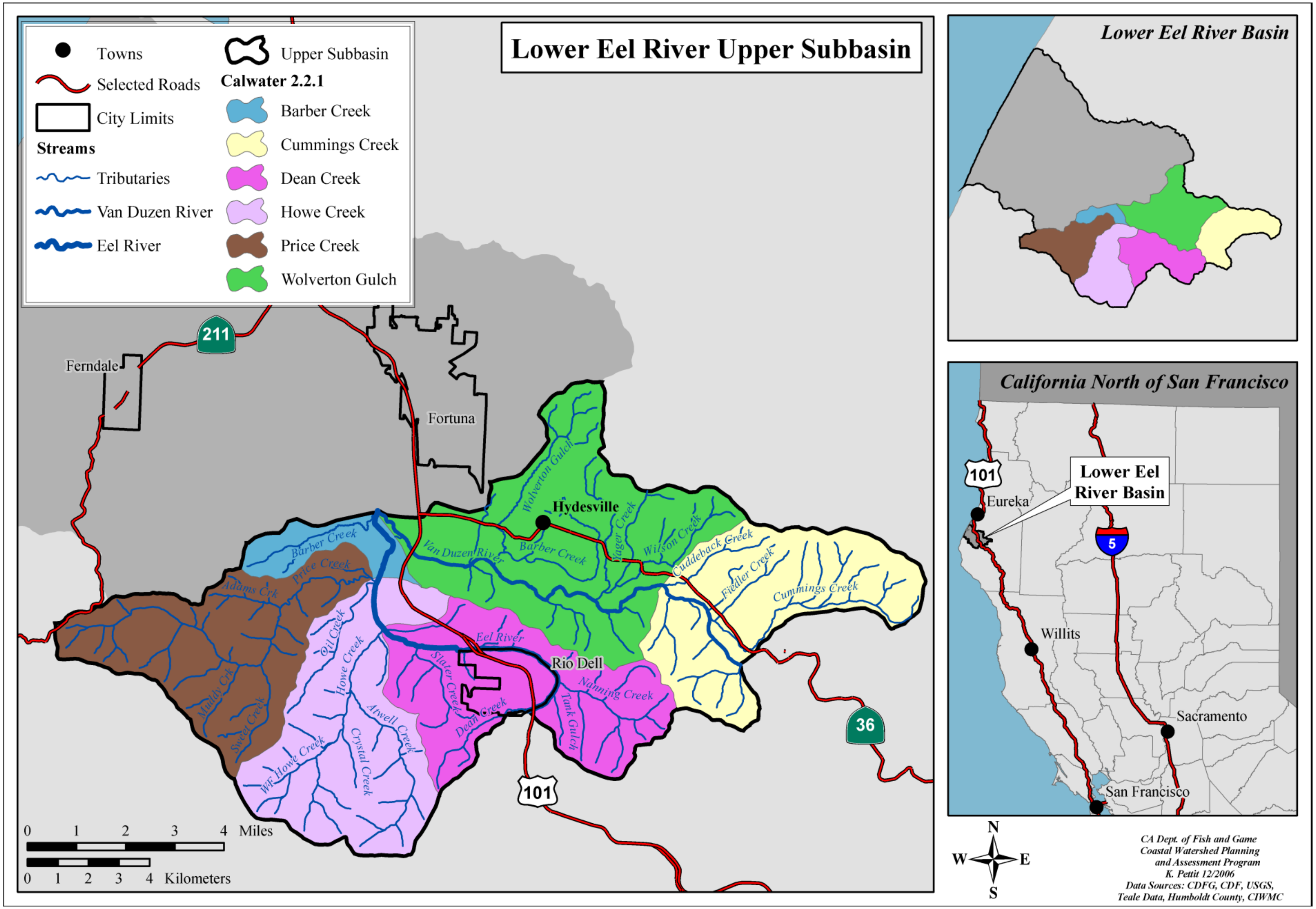

Figure 1. Upper Subbasin locator map and CalWater Units.

Although drainage issues were noted in the Hydesville area in the 1984 Humboldt County General Plan, no specific drainage plans were made. However, the following policies were developed:

- As development occurs throughout the planning area, storm water should be directed toward water courses without impacting adjacent parcels;
- Drainage plans should be required of development projects within the area of Hydesville;
- Drainage plans should be required to provide for the passage of storm water from upstream areas;
- Dedication of drainage easements to the County of Humboldt for the benefit of the general public may be required as a condition of a development permit;
- A community drainage plan should be prepared for the planning area with initial priority directed to establishing a specific drainage plan for the area.

The City of Rio Dell also calls for the preparation and adoption of a Drainage Master Plan that encourages on site retention, maintains current stream and drainage channel integrity, and reduces non-point pollution loads. The Rio Dell area has had sustained damage due to flooding in the past, largely to the lumber industry, railroad property, roads, and bridges. However, the majority of Rio Dell's developed land is currently outside of the 100 and 500-year floodplains (PlanWest 2006).

Rio Dell has the following policies (PlanWest 2006) related to hydrology and water resources:

- Identify improvements that can be made to municipal drainage facilities so they can better convey runoff and minimize flood impacts;
- Require new development projects to incorporate on-site drainage features such as retention and infiltration systems to reduce runoff and maximize infiltration;
- Use a combination of incentives, educational programs, and ongoing system audits to promote water conservation;
- New projects that affect the quantity and quality of surface water runoff shall be required to allocate land necessary for detaining post-project flows and/or for incorporating measures to mitigate water quality impacts related to urban runoff. To the maximum extent feasible, new development shall not produce a net increase in peak storm water runoff;
- New project designs shall minimize drainage concentrations, maximize permeable surfaces (such as unpaved parking areas) and maintain, to the extent feasible, natural site drainage conditions;
- The quality of runoff from urban and suburban development shall be improved through use of appropriate and feasible mitigation measures including, but not limited to, artificial wetlands, grassy swales, infiltration/sedimentation basins, riparian setbacks, oil/grit separators, and other best management practices (BMPs);
- Wetlands and drainage courses shall be carefully examined.

Geology

Compositional Overview

The Upper Subbasin is more geologically diverse than the other subbasins (Table 2). This subbasin is composed of five different rock types (Figure 2) (USGS Geology of the Cape Mendocino, Eureka, Garberville, and Southwestern part of the Hayfork 30 x 60 Minute Quadrangles and Adjacent Offshore Area, Northern California geologic map of California). Although this is the most varied subbasin, all of the rock types are sedimentary. The Wildcat group is the most abundant surface lithology. It occupies 47.79% of this subbasin. The rest of the basin consists of 19.2% Coastal Belt mélange, 12.55% river terrace deposits, 11.3% alluvium, 4.05% Yager terrane, and 1.14% Coastal Belt sandstone.

Ancient, uplifted, unconsolidated floodplain deposits of Eel and Van Duzen rivers make up a sizeable amount of the Upper Subbasin. Remnants of these floodplain deposits form a series of terrace deposits in the vicinity of Rio Dell, Scotia, Hydesville, and Carlotta. A series of smaller terrace deposits are scattered along the Eel and Van Duzen rivers. These terraces have been uplifted from just above the current floodplain to hundreds of feet above the current floodplain.

Hydesville is situated on the gently sloping surface of the Rohnerville formation which is a Pleistocene aged terrace. The hills above Hydesville are made of the Hookton formation, which consists of poorly

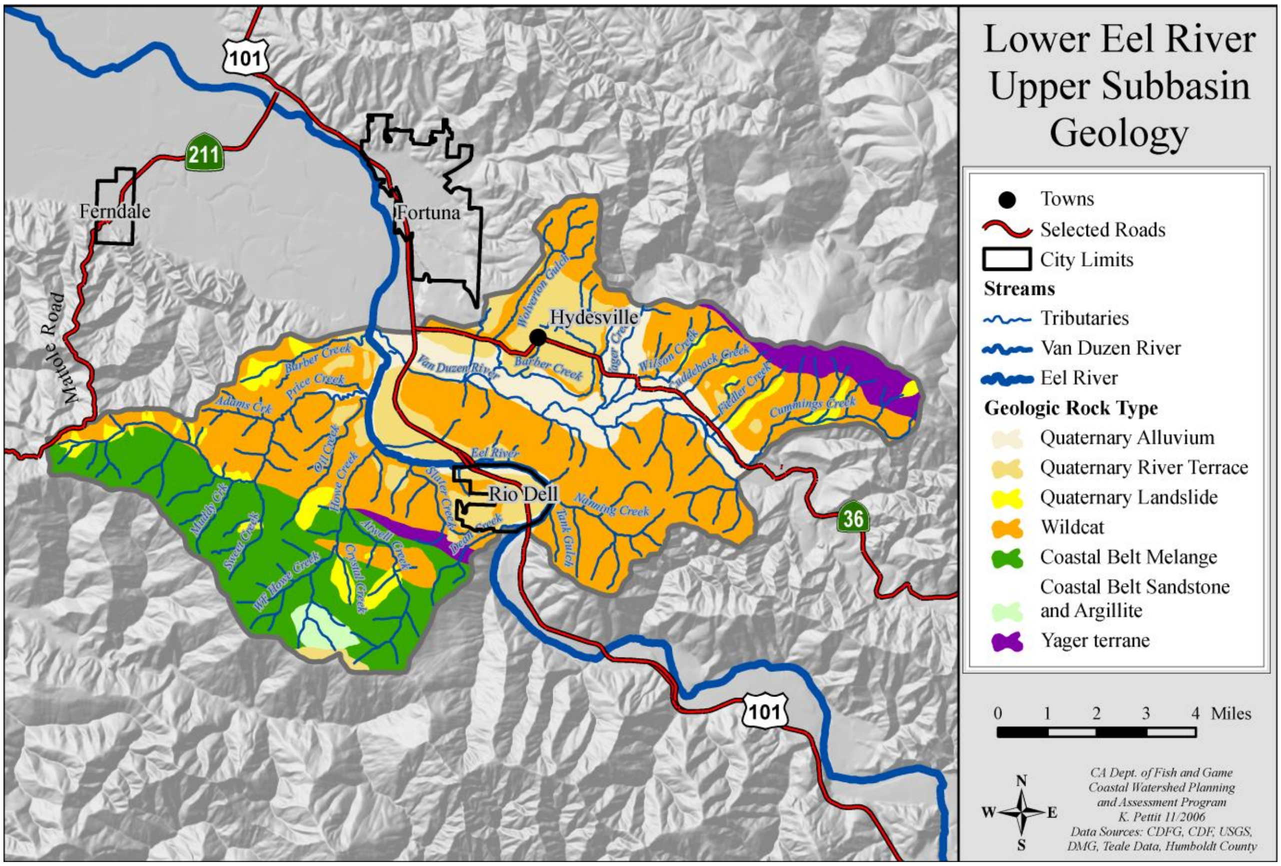

Figure 2. Geology of the Upper Subbasin.

consolidated marine through river sediments. To the northeast of the Hookton and Rohnerville formations have been juxtaposed against the sedimentary bedrock of the Wildcat group by the Little Salmon fault. Uplift of these terraces has corresponded with incision by the streams leaving steeply incised canyons that have exposed conglomerate and sandstone of the underlying Carlotta formation. The terraces, when steeply perched, are susceptible to small-scale, frequent slope failure, which introduces sediment to streams (Reynolds, Mills, Mensch 1981). Increased sediment deposition from erosion of these terraces can restrict upstream migration of salmonids during periods of low water (PALCO 2002). In addition to contributing to slope instability, the friable nature of local soils contributes to enhanced gullying in grassy areas (Brown and Ritter 1971).

To the northeast the Yager fault has juxtaposed the Wildcat with the Yager terrane. The Yager terrane is composed of marine sandstone through claystone that was deposited upon the continental slope around 34-55 million years ago. The sediment that makes up these deposits came from as far away as Idaho (Underwood and Bachman 1986). Although much harder than the Wildcat, the Yager terrane is more

Table 2. Rock types in the Upper Subbasin.

Rock Type	% of subbasin	Description
Alluvium	11.3	Unconsolidated river sediments within the active influence of streams.
Landslides	7.47	Unconsolidated, poorly sorted river sediments that have been uplifted above the active stream influence.
Terrace deposits	12.55	Unconsolidated, poorly sorted river sediments that have been uplifted above the active stream influence.
Wildcat Group	47.79	A series of 5 formations; 4 consisting of poorly cemented, fine-grained, shallow marine sediments and one consisting of courser, poorly consolidated, predominately nonmarine sediment.
Yager Terrane	4	Moderately-well consolidated, locally sheared, sandstone, argillite, and conglomerate.
Coastal Belt Sandstone	1.14	Well consolidated, locally sheared, metasandstone, meta-argillite, and conglomerate.
Coastal Belt mélange	19.2	A pervasively sheared argillaceous matrix containing mappable blocks of varying rock types.

brittle and therefore has many areas where the bedrock has become sheared and broken. Furthermore, the Yager terrane contains interbeds of argillite (claystone) that disintegrate when repeatedly wetted and dried. These argillite interbeds and shear zones are susceptible to enhanced erosion, landslides, and debris flows. In the southern portion of this basin the Russ fault has bound a sliver of the Yager terrane between the Wildcat and the Coastal terrane.

The Wildcat Group as a whole is made up of soft, poorly cemented fine sediments. Rapid rates of uplift and the "soft" nature of these rock types have allowed the stream channels to incise steep canyons. These formations have been steeply tilted, folded, and uplifted. Furthermore these rock types have a relatively high porosity allowing them to absorb water during winter storms. When they become saturated they tend to fail along their steeply dipping bedding plains. Of the Wildcat Group the Rio Dell formation is one of the most susceptible to landsliding. Landsliding is most common in zones between mudstone and sandstone beds during super saturation. A few sizable landslides were mobilized in the 2005/2006 storm season along the banks of the Eel River, near Scotia, which contributed fine sediment to the river. These slides serve as a good example of how the Wildcat sediments react to over saturation (Figure 3).

Landslides

Like the other Lower Eel River subbasins, the Upper Subbasin is mantled with unstable soils. Meadows and grasslands in the Upper Subbasin are often a result of unstable ground and are thus susceptible to surface erosion, headword erosion, and gullying.

The southernmost extent of the Upper Subbasin is made up of the Coastal terrane. The Coastal terrane consists mainly of sandstone, argillite, and minor conglomerate forming highly sheared mélange and sandstone with interbedded argillite. The mélange formed as deep oceanic sediments and bits of oceanic crust tectonically mixed with sediments washing off of the continent in a subduction trench that existed here roughly 65-40 million years ago. The sandstone was likely deposited above the mélange and was not as tectonically mixed before lithification. As the active subduction zone stepped westward towards its present position the Coastal terrane was uplifted and translated to its current position. The Coastal terrane is susceptible to shallow landslides in the inner gorge areas and to deep seated landslides and earthflows.

Figure 3. Photos of landslides on the Eel River, near Scotia following 2005/2006 storms.

Earthquakes and Faults

The Ferndale Fault, the Russ Fault, and the Little Salmon Fault cut across this subbasin. All of these faults disrupt bedrock and are capable of producing earthquakes that are large enough to trigger landsliding and/or liquefaction of the land within it. The Cascadia Megathrust and the San Andreas Fault have historically caused earthquakes that may have altered the morphology of this subbasin.

Soils

The Upper Subbasin contains a small variety of similar, loamy soils, which developed upon soft, sedimentary Wildcat Group geology as well as on ancient, uplifted, unconsolidated Eel River terrace deposits and on floodplains (Table 3). These soils are also composed of a silt/clay mixture as well.

Table 3. Soil types in the Upper Subbasin.

Soil Type	% of Upper Subbasin	Composition
Vandamme-Tramway-Irmulco-Hotel-Dehaven	36	Loam/clay/gravelly loam
Tramway-Irmulco-Empire	31	Loam
Riverwash-Loleta-Ferndale-Bayside	20	Loam/silt loam/silty clay loam
Timmons-Rohnerville-Hookton-Carlotta-Arcata	10	loam/silty clay loam/fine sandy loam
Yorktree-Kneeland variant-Kneeland-Kinman	4	Loam/gravelly loam/clay loam

Fluvial Geomorphology

The overall geomorphology of the Upper subbasin may be described by moderately steep tributaries with steeply incised valleys draining into a relatively low (~2-3%) gradient main stem. The Eel River along this reach has meandered and migrated back and forth within the valley and has, in the recent geologic past, entrenched itself in a series of large river floodplain/terrace deposits bordering the main stem. Rio Dell, Metropolitan, and Alton reside on these deposits. Similarly, Carlotta resides on the floodplain/terrace deposits of the lower Van Duzen River.

During large winter storms tributaries within the soft mudstones and sandstones of the wildcat to the south and semi-consolidated to non-consolidated terrace deposits to the north naturally erode and flush out large amounts of sediment into the main stem.

Within the Upper Subbasin the main stem of the Eel River acts as a sediment transport as well as sediment deposition reach. This section of the river has a general gradient of about 2 – 3%. During large storm events it has acted like a depositional reach causing some aggradation of the channel as well as over-bank deposition. This section of the river deposits and/or transports sediments due to the stream gradient, the amount and energy of flow, and the availability of sediment. In the last few years the river has cut down and exposed bedrock in several places within this reach. The majority of the tributaries that feed this section of the Eel River act as sediment source and sediment transport reaches. Large storm events tend to trigger more erosion and input more sediment to the streams. The sediment pulses from these storms migrate downstream but tend to affect the stream for tens of years. Anthropogenic land use can increase the rate of erosion and sediment input to the streams greatly and take upwards of a century for the stream to naturally flush out the sediment pulse.

The morphology of individual streams within a system when taken in a fluvial geomorphologic context can be used to help understand the current as well as past fluvial regime changes. Some basic morphologic stream patterns have been defined by D.L. Rosgen, Rosgen channel types (see Middle Subbasin Figure 5).

The most recent (1991 to 2002) stream surveys of 22 reaches in the tributaries of the Van Duzen River and Eel River within the Upper Subbasin found A, B, C, F, and G Rosgen channel types (Table 4). Type A reaches flow through steep V- shaped valleys, do not have well-developed floodplains, and have few meanders. Type B stream reaches are wide, shallow, single thread channels. They are moderately entrenched, moderate to steep gradient 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. Type C stream reaches are wide, shallow, single thread channels. They are moderately entrenched, low gradient reaches with riffle/pool sequences. Type C reaches have well-developed floodplains, meanders, and point bars. Type F stream reaches are wide, shallow, single thread channels. They are deeply entrenched, low gradient 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. Type G, or gully stream reaches, are similar to F types but are narrow and deep. With few exceptions, type G reach types possess high rates of bank erosion as they try to widen into a type F channel. Type G reach types are found in a variety of landforms, including meadows, developed areas, and newly established channels within relic channels (Flosi, et al. 1998).

Table 4. Channel types in surveyed streams of the Upper Subbasin.

Stream	Reach	Length (feet)	Channel Type
Van Duzen River	Not surveyed		
Wolverton Gulch	1	12,981	F4
Wilson Creek	1	716	C5
	2	1,765	B2
Cummings Creek	1	10,572	B4
Price Creek	1	10,235	F3
	2	12,895	G4
	3	6,094	B6
	4	7,077	B4
Adams Creek	1	3,308	B6
	2	693	A3
Sweet Creek	1	4,746	B4
Muddy Creek	1	3,261	F4
	2	869	G4
Oil Creek	1	2,127	G3
	2	2,742	F6
Howe Creek	1	17,016	F4
	2	3,959	A3
Atwell Creek	1	12,612	F4
Crystal Creek	1	2,600	G4
West Fork Howe Ck	1	2,342	A3
Nanning Creek	1	7,600	C3
Dean Creek	1	5,091	B6

Vegetation

The predominant vegetation cover type as described by the U.S.F.S. CALVEG data is coniferous forest at approximately 52%, which is more than any other Lower Eel subbasin (Figure 4, Table 5). Vegetation of the Redwood Alliance and Redwood – Douglas-Fir Alliance are the primary vegetation within this classification at 39% and 36%, respectively. Crown diameters of Upper Subbasin woodlands primarily composed of coniferous vegetation range in size from sapling to large, which is described as greater than 40 feet in crown diameter. Like in the Middle Subbasin, most of the redwood forests are composed of trees classified as medium, or between 24 to 40 feet in crown diameter (Table 6). Conifers are prevalent throughout the subbasin, and occupy nearly all areas except the low lands within the Eel River and Van Duzen River floodplain and urban areas including Hydesville and Rio Dell. The vegetation cover type classified as "mixed" is the third most abundant vegetation in this subbasin, and describes forests and woodlands where conifer is the primary vegetation and hardwoods are present secondarily. Conifer forests and these mixed conifer forests, when combined, are the major vegetation in the Upper Subbasin, making up nearly 64% of the total vegetation.

Herbaceous vegetation, primarily composed of annual grasses, is the second most abundant vegetative cover making up 14% of the total. This vegetation is found in small patches along the Van Duzen River, some of the low-lying lands on the mainstem Eel River, and along the southwestern margin of the subbasin along Bear River Ridge. Agriculture in the Upper Subbasin is the fourth most abundant vegetation land use classification composing 11% of the subbasin. However, pastures used for grazing of livestock may not be included in this vegetation designation since land use is often difficult to remotely ascertain. For this reason, it can be assumed that areas mapped as annual grasslands may also be agricultural in nature and the overall percentage of agricultural lands is more likely to be greater than 20%. This figure is still considerably less than the other subbasins within the Basin study area. Agricultural lands in this subbasin are primarily located in the low-lying areas near Metropolitan and Hydesville. This depiction of vegetation in the Upper Subbasin is an accurate display of the reduction in herbaceous and agricultural lands with increased distance from the Eel River mouth.

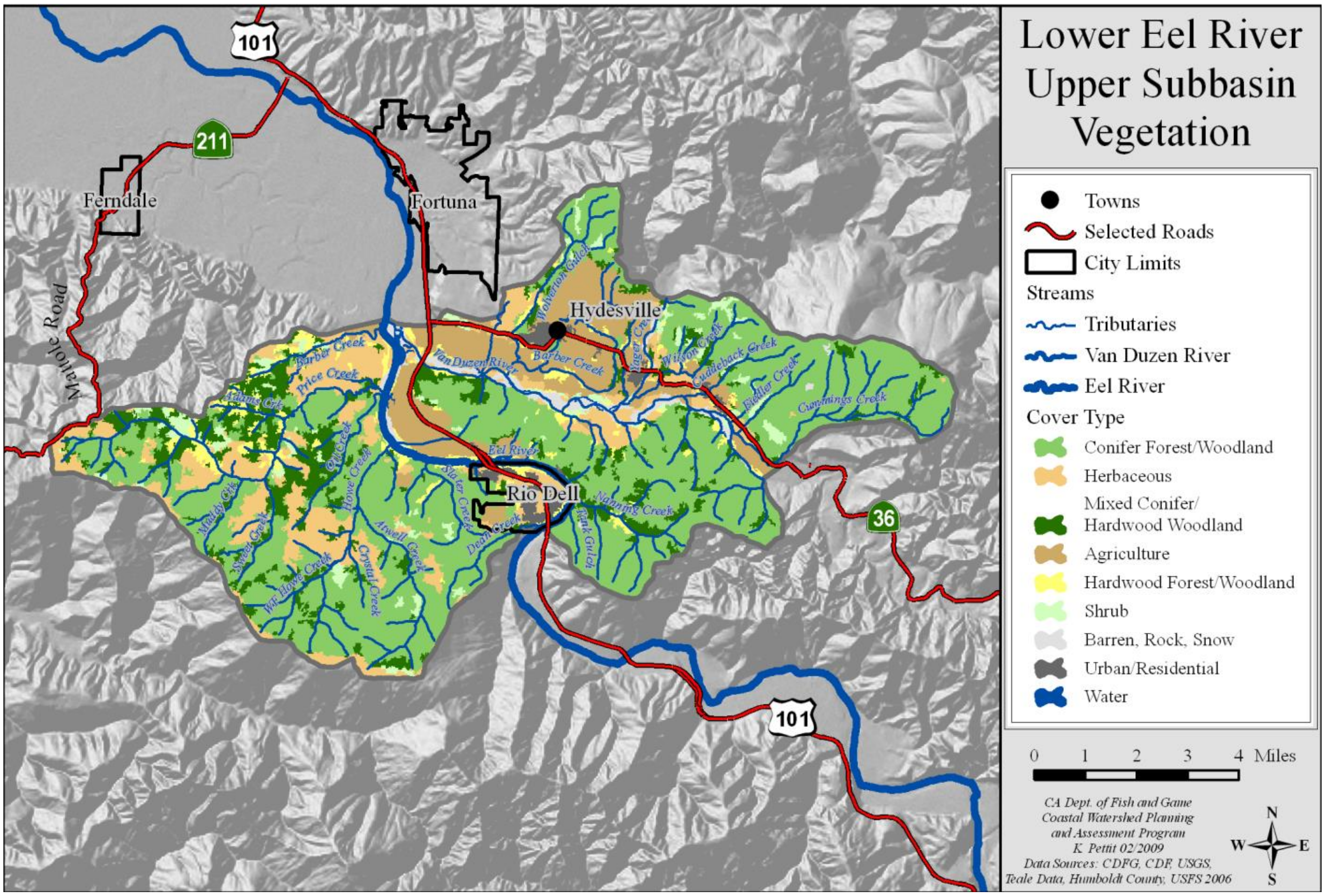

Figure 4. Vegetation of the Upper Subbasin.

Table 5. Vegetation of the Upper Subbasin.

Vegetative Cover Type	Percent of Subbasin	Primary Vegetation Type	Percent of Cover Type
Conifer	52	Redwood Alliance	39
		Redwood – Douglas-Fir Alliance	36
		Douglas-Fir – Grand fir Alliance	18
		Pacific Douglas-Fir Alliance	6
		Sitka Spruce – Redwood Alliance	1
		Sitka Spruce Alliance	<0.5
		Sitka Spruce – Grand Fir Alliance	<0.5
Herbaceous	14	Annual Grass/Forb alliance	100
		Nonnative/Ornamental Grass Alliance	<0.5
Mixed (conifer stand with hardwood)	12	Douglas-Fir – Grand fir Alliance	37
		Redwood - Douglas-Fir Alliance	29
		Redwood Alliance	20
		Pacific Douglas-Fir Alliance	8
		Sitka spruce – Grand Fir Alliance	6
		Sitka spruce Alliance	<0.5
Agriculture	11	Agriculture	100
Hardwood	4	Red Alder Alliance	95
		Black Cottonwood Alliance	3
		California Bay Alliance	1
		Mixed Riparian Hardwoods Alliance	<0.5
		Tan Oak (Madrone) Alliance	<0.5
		Willow Alliance	<0.5
Shrub	3	North Coastal Shrub Alliance	33
		Blueblossom Alliance	28
		Salal-California Huckleberry Alliance	22
		Willow (Riparian Scrub) Alliance	15
		Coyote Brush Alliance	3
Barren	2	Barren	100
Urban	2	Urban	100

Data from CALVEG, USFS
These statistics exclude the classification of water and may not = 100% due to rounding.

Table 6. Crown diameter of vegetation classified as primarily conifer forest in the Upper Subbasin.

Conifer Alliance	Size Range	Most abundant by area
Redwood	Sapling to Large	Medium
Redwood - Douglas-Fir	Sapling to Large	Medium
Douglas-Fir - Grand Fir	Sapling to Large	Small
Pacific Douglas-Fir	Sapling to Medium	Small
Sitka Spruce - Redwood	Sapling to Medium	Small
Sitka Spruce	Small to Medium	Medium
Sitka Spruce - Grand Fir	Sapling to Medium	Small

Land and Resource Use

Historic Land Use

Prior to Euro-American settlement, the Upper Subbasin was home to Native American people of the Wiyot, Kittel or Nongatl, Wailaki, and Lassics tribes. These people lived in villages or in groups of smaller satellite settlements located around central village sites. The people utilized acorns as a staple food, and also ate other vegetable foods, wild game, and depended on harvests of salmon and steelhead along the main river channels and tributaries. In winter and spring the villages were situated near the river where the people could cooperatively harvest salmon and lampreys. During the summer they moved to meadows located in higher grounds, but not far from the rivers. Their way of life required freedom to move throughout their territory with the seasonal changes in abundance of natural resources (Baxter 1981). Many of these small groups failed to survive the impact of Euro-American settlers of the mid 19th century.

The Van Duzen River was named in 1850 in honor of James Van Duzen. Van Duzen was one of the eight members of the Gregg-Wood party that were the first Euro-Americans to reach the Humboldt Bay coast by traveling overland from the gold mining areas of the upper Trinity River. Continuing their journey, the Gregg-Wood party left Humboldt Bay and traveling south were soon in need of food. The group came upon a river and nearby found two Wiyot tribesmen that shared baskets full of lampreys with the hungry travelers. The members of the Greg-Wood Party then camped along the river just below the Van Duzen confluence and feasted on "eels" (lamprey), for two days. The group named that river the Eel River (Wood 1932) for its abundance of "eels." The Eel River delta was called "Weeoot" by the Wiyot tribe, which referred to the immense quantities of salmon obtained from the Eel (Humboldt Times September 23, 1854).

As Euro-Americans moved into the area in the 1850s, they settled on the same sites that native tribes had used for decades as seasonal village sites or hunting and gathering grounds (CDPR 1981). To the settlers that occupied newly claimed land year round, the native people seemed as intruders upon their return to long-established seasonal sites. Conflicts over land soon lead to bloodshed and the eventual demise of the native peoples' way of life. The changes brought about by permanent farms and grazing of domesticated livestock depleted many of the wild food sources needed by native people. A few Native Americans were welcomed into early settler homes but most were gathered and sent to Fort Baker located approximately 14 miles east of Bridgeville prior to permanent delivery to a reservation in Round Valley. Others were hunted down and killed while some were sold into slavery. Their historic homeland was quickly claimed by the Euro-American settlers.

Early settlers started homesteads and began logging and farming cleared land. Several small communities sprang up throughout the subbasin. One of the first established communities was the town of Hydesville. Settler John Hyde gave a section of his land to a group of settlers in 1858, which then grew into the community of Hydesville. The town grew quickly, encompassing a Masonic Hall, a school, livery stable, hotel, blacksmith's shop, and general store, all by 1859 (Roberts 1943). A Post Office was established in 1861.

The Rio Dell bluffs and prairie land were discovered by settlers in the 1840s. A local farmer, Lorenzo D. Painter, started the small community of Eagle Prairie in the early 1870s in the area (McCormick 1981). The communities of Wildwood and Belleview grew up nearby. These three communities eventually merged and formed present day Rio Dell. Rio Dell was incorporated in 1965 (Steinberg 2002).

Across the Eel River from Rio Dell and just outside of the Upper Subbasin, the company mill town of Scotia began with the construction of a mill in the area known as Forestville, established in 1863 by Henry Weatherby and A.W. McPherson. The town name officially became Scotia in 1888, and a Post Office was established that same year. Scotia and Rio Dell have always had close ties, first connected by ferries and after 1914 by railroad and road bridges (PlanWest 2006).

Henry Brown Cuddeback and wife Martha homesteaded Cuddeback Creek in 1853. A Post Office was established in 1895 and merged with nearby Carlotta in 1914.

Outside of the small towns, historic livestock grazing utilized the native prairies and meadows. The native, perennial prairie bunch grasses that grew there were well suited for year round livestock grazing. To develop more livestock grazing lands, trees surrounding grasslands were often "ringed" and left to die. As sheep and cattle consumed or overgrazed much of the deep rooted bunch grasses, unstable soil was exposed and weaker, short rooted annual grasses moved in. Present gullies and slumping landscape appear to be recent features related to livestock grazing and the associated loss of deep rooted prairie grasses (Kelsey 1977).

Forest Management

Timber cutting began in the subbasin in the mid 1800s with the clearing of land by early settlers for farming, livestock grazing, and for wood products. The first saw mill was built by George and John Cooper along Yager Creek near Hydesville in 1854. The Cooper's mill was powered by a water wheel that received water via over a mile of ditches. The mill operated for only a few years and was abandoned soon after the death of George Cooper who was shot in a territorial battle with natives (Roberts 1943).

The timber industry continued to grow and soon became a major land use. Early logging was done with hand saws, steam donkeys, cable systems, and rail systems.

Atwell Creek was logged from 1920 to 1960, facilitated by the construction of a railroad trestle across the Eel River and the continuation of the railroad up the Howe and Atwell watersheds (HartCrowser 2004). By 1928, 200 million board feet had been removed from the areas that could be reached by a steam donkey (Hackett 2002). Cummings Creek watershed was logged through the 1930s and into the 1950s (Matson 2000). The Hammond Lumber Company railroad was constructed in 1934 in the Cummings Creek watershed and expanded up the creek in 1950 so that timber could be directly loaded onto flatcars (Matson 2000).

By the 1940s, land use in the Upper Subbasin, particularly Howe Creek and nearby tributaries, was beginning to change. First, a waning market infrastructure and demand for timber provided incentive to turn timberland into grazing land (Hackett 2002). Second, the timberlands that remained in use were subjected to increased disturbance as WWII technology moved into civilian industries; timber was more readily cleared and skidded downhill with bulldozer in watercourses became a common practice (Hackett 2002). Despite the limited local demand for timber, lands were still taxed to include the value of standing timber, providing further incentive to convert to grazing land.

Along with the rush to harvest timber from the Lower Eel and Van Duzen's forests came a tremendous disturbance to the basin's soils from clear cuts, building and use of an extensive network of logging roads, and the use of tractors over the landscape to move cut logs to truck landings. A review of air photos showed that a large amount of the basin's forests were cut by the 1960s. The timber boom removed trees that were an integral part of the riparian and stream ecosystem and damaged intricate root systems that helped resist erosion of unstable soils. In addition, miles of tractor skid trials and haul roads caused significant ground disturbance that contributed to hillslope instability and soil erosion.

The major flood events of 1955 and 1964 occurred during a period of intensive land use, primarily related to timber harvest. These floods exacerbated the impacts of extensive logging that had largely gone unregulated until the early 1970s. These factors caused much of the basin to destabilized, which in turn, produced large-scale soil erosion and sedimentation into the area's streams (CDFG 1997).

Current Land Use

The Upper Subbasin is currently mostly held in private parcels 40-500 acres in size with some sections owned by large timber companies and managed for timber production. Two other major land uses in the subbasin are gravel mining and grazing. There are two principal communities, Hydesville and Rio Dell.

Hydesville is located in the lower Van Duzen River watershed off of Highway 36 about three miles east of Highway 101. It is an unincorporated community of about 1,209 residents. Planning for this community is carried out by Humboldt County as part of the county General Plan process. The General Plan is currently being updated and the last available plan is from 1984. Hydesville falls within the Carlotta/Hydesville Planning Area and there is a specific Carlotta/Hydesville Area Community Plan. The major plan proposals and underlying principles of this plan specific to Hydesville are:

- To maintain the present level of resource protection for timberlands and provide additional zoning protection for agricultural lands on the Van Duzen River flood plain and the Yager Creek Valley;
- Reserve additional land suitable for industrial development in the vicinity of the existing lumber mills along Yager Creek;
- Preclude and/or limit the extent of additional residential development in high hazard areas (flooding and geologic fault rupture corridors);
- Direct residential development to existing urbanizing areas;
- Provide for adequate housing sites for the area's future growth;
- Planned residential densities in Hydesville are to be compatible with the continued use of on-site wastewater disposal systems.

Water is provided to about 450 connections in Hydesville by the Hydesville County Water District. Water is supplied from two, twelve inch wells located on District owned land near Yager Creek. These wells have pumps which are rated at a total of approximately 360 gallons per minute. The estimated average daily use for the entire District is approximately 100,000 gallons per day, and estimated existing maximum day demands are 300,000 gallons per day. The system is operating at approximately 58% of source capacity. The District is also planning to increase capacity by building an additional well. Sewer services are not provided by the District (HLAFC 2008), residents use individual septic tanks and leach fields (General Plan 1984).

Hydesville is a designated Urban Development Area. Most of the working residents of Hydesville commute to Fortuna, Eureka, or Arcata. There is a designated industrial area adjacent to existing sawmills on Highway 36 at Yager Creek (General Plan 1984).

Rio Dell is a small incorporated city of approximately 3,174 residents, located between Scotia and Fortuna just off of Highway 101. A Draft General Plan for the City was released in 2006. This plan covers the area of Rio Dell as well as neighboring Scotia.

Two main implementation Measures laid out in the General Plan related to water resources are:

- The City shall prepare and adopt a Water and Wastewater Master Plan that addresses build out identified in the General Plan;
- The City shall prepare and adopt a Drainage Master Plan that encourages on site retention, maintains current stream and drainage channel integrity, and reduces non-point pollution loads.

Proposed General Plan landuse and zoning within the Rio Dell City limits and within the Upper Subbasin (thus excluding Scotia) include Community Commercial, Neighborhood Center, Public Facility, Rural, Suburban, Town Center, and Urban Residential.

Rio Dell has the following policies related to Biological Resources:

- Ensure that environmentally sensitive habitat areas (ESHAs) such as the Eel River corridor, streams and drainage channels with riparian habitat, and forested areas that could potentially support sensitive species, are buffered to protect against any significant disruption of their habitat values;
- Maintain water quality in the City watersheds such as Dean Creek.

Forest Management

Timber harvest activities since 1991 have occurred in every tributary watershed except for Barber Creek in the Van Duzen Basin. Multiple areas have been entered two or three times, and one area in the Cummings Creek watershed has been entered six times since 1991. Each year, an average of 2.6% (>1,200 ac) of this subbasin was included in timber harvest plans with treatments ranging from selection cuts to clear cuts.

The Pacific Lumber Company completed a watershed assessment of their timberlands in 2002 and 2004 which included parcels in the Upper Subbasin. Among their findings was the indication of Cummings Creek watershed as a major sediment source within the Van Duzen River watershed, delivering 17,200 tons per year. In addition, it was calculated that there was an 8% increase in peak flows during 2 year hydrological events (commonly referred to as bankfull events). This is indicative of decreased water storage in soil and vegetation due to timber harvest.

Gravel Mining

Instream gravel mining in this subbasin occurs in the Lower Van Duzen River. The County of Humboldt Extraction Review Team (CHERT) monitors and makes recommendations on three sites that extract over 5,000 cubic yards (cy) annually. As mentioned in the basin assessment section of this document, more than 40 other sites in the Van Duzen River of at least 1,000cy in extracted volume are on file with CDFG. Estimates for the volume extracted before CHERT began monitoring are unavailable, but are most likely similar to trends in the Lower Eel River and have probably decreased significantly. Currently, an average of 113,057cy/yr is taken out of the Lower Van Duzen River (Table 7).

Three separate studies have addressed channel bed elevation changes in the Van Duzen River. Kelsey found that the Van Duzen River has aggraded since 1941, though his study site ended upstream of where ours begins (Kelsey 1977). Humboldt County determined that the river had downgraded at the Highway 101 Bridge across the Van Duzen River by 10 feet between 1941 and 1992 (Humboldt County 1992). The U.S. Army Corps of Engineers, seeing some slight aggradation in the Van Duzen River since 1968, concluded that these changes were not evidence of an impact by gravel mining (USACOE 1999).

Threats to salmonids come largely from the loss of a confined single-thread low flow channel at the mouth of the Van Duzen River at the start of adult migration. Additionally, a minimal low flow channel implicates a loss of deep holding pools for adult and juvenile migration, and loss of cover, suitable temperature, and complex habitat for juvenile salmonids. Fish stranding in wetland pit mines should also be monitored as this has been an issue for other subbasins in the study area.

Residual effects of aggradation due to the 1964 flood and early mining operations have left the mouth the Van Duzen River in a state that, without the intervention of land managers, would not support the early fall upstream migration of adult salmonids in most years. In 1996, the same year that CHERT began recommendations, 38 adult Chinook salmon died stranded on shallow, braided riffles in the lower half mile of the river. Braiding and channel widening had reduced the depth too much for the fish to continue upstream. In 2001, another 136 fall Chinook perished under the same conditions. Since 2001, a low flow channel has been maintained by seasonally creating a single thread channel in the lower two to four miles of river during gravel mining operations. Additionally, high gradient "barrier" culverts are installed by CDFG in the fall to prevent fish entry into the Van Duzen River until stream flows increase to about 150 cfs. Once flows increase to this point, stranding should not be a concern for the next four miles of aggraded channel, and the culverts are removed (S. Downie, personal communication). In the Army Corps of Engineers' Letter of Permission (USACOE 2003), bar skimming as a technique is disallowed in the lower two miles of the river, and trench, alcove, or wetland pit mining are the alternative and preferred methods. By utilizing these methods creatively, current gravel mining operations actually improve the functionality and shape of the low flow channel and facilitate fish passage. These measures have effectively prevented any salmon mortalities since the 2001 stranding event.

Table 7. Lower Van Duzen River Annual Extraction 1997-2007 (CHERT 2008).

Year	Recommended Volume (cy)	Extracted Volume (cy)	Percent of Recommended Volume Extracted
1997	120,000	81,600	68%
1998	119,100	103,700	87%
1999	159,900	108,800	68%
2000	194,800	121,300	62%
2001	161,700	85,600	53%
2002	202,500	167,400	83%
2003	175,100	123,000	70%
2004	179,045	92,610	52%
2005	159,090	123,170	77%
2006	134,910	104,750	78%
2007	152,773	113,184	74%
Totals	1,758,918	1,225,114	70%
Averages	159,902	111,374	70%

Fish Habitat Relationship

Fishery Resources

Other than anecdotal accounts, fish presence has been documented in the Upper Subbasin by observations made during stream surveys since 1938. However, stream survey efforts were neither specific nor standardized until 1990 when the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) was published. Most observations in stream surveys are not quantitative and have limited use.

Surveys prior to 1990 observed Coho salmon in Wolverton Gulch, Cuddeback, Fiedler, Cummings, and Howe Creeks in the past (Table 8). Since 1990 they have been detected in Cummings, Oil, Howe, and Atwell Creeks. In recent years, Chinook spawning has been observed in Wilson, Cuddeback, Fiedler, Cummings, Price, and Atwell Creeks, which matches observed historical presence. Steelhead trout were historically found in 13 creeks. In recent years, steelhead and have been detected in 10 streams: Wolverton Gulch, Wilson, Cummings, Price, Oil, Howe, West Howe, Atwell, Nanning, and Dean Creeks. Cutthroat trout were collected from Barber Creek in 1950 and represented the southernmost population for the species. More recently, they were observed in Wolverton Gulch at the Highway 36 Bridge (S. Downie personal communication).

Table 8. Documented fish presence in surveys from 1938 to 2006 in the Upper Subbasin.

Stream	Date Surveyed	Source	Survey Method	Fish Observations				Fish Comments
				Coho	Chinook	Steelhead	Salmonids	
Barber Creek (Eel)	1950	DeWitt 1952	Angling			x	x	Coastal cutthroat trout collected and abundant
	02/21/1973	CDFG 1973	Electrofishing			x		Below concrete falls steelhead and roach were collected
Barber Creek (Van Duzen)	07/15/1965	CDFG 1965	Streamside observation				x	Salmonids up to 3 inches in length
	07/02/1984	Franklin and Mitchell (1984)	Electrofishing			x		Largest steelhead collected in this 300 foot survey were in a HWY 36 culvert pool.
	01/23/1988	CDFG 1988	Electrofishing					Approximately 0.25 mile above HWY 36 culvert.
Wolverton Gulch	06/12/1963	CDFG 1963	Streamside observation				x	Trout observed
	circa 1965	CDFG	Streamside observation				x	Unidentified salmonids up to 8 inches, many 1 inch salmonids
	04/24/1978	CDFG 1978	Electrofishing	x				One inch coho observed 0.25 mile above Rohnerville Road. This is the only confirmed sighting of coho in Wolverton Gulch.
	07/02/1984	Franklin and Mitchell (1984)	Electrofishing			x		Steelhead, trout observed below HWY 36 culvert
	11/08/1993	CDFG 1993	Electrofishing				x	Stickleback observed
	02/07/1994	CDFG 1994	Spawning survey				x	Landowner observed steelhead spawning in creek. CDFG warden observed one redd.
	1994 (winter)	CDFG 1994	Streamside observation				x	S. Downie (CDFG) and M. Rose (CCC) observed cutthroat trout at Hwy 36 Bridge
	5/8/1997	CDFG Stream Inventory	Electrofishing			x		1+ and 2+ year classes of steelhead present.
	10/15/1997	Harris (1997)	Unknown				x	Unidentified yoy, 2+ salmonids, and threespine stickleback observed
	11/3/1997	CDFG Stream Inventory	Electrofishing			x		Steelhead yoy present and one steelhead 6.5mm FL. 3-spined stickleback and Pacific lamprey ammocoetes observed
	06/06 and 13 /2001	CDFG NCCCSI 2005	Electrofishing				x	California roach, threespine stickleback, trout, unidentified salmonids observed
	07/23/2002	CDFG NCCCSI 2005	Electrofishing				x	Lamprey spp., trout, threespine stickleback, sculpin spp. observed
	07/07/2003	CDFG NCCCSI 2005	Electrofishing				x	Lamprey spp., trout, threespine stickleback observed
Wilson Greek	9/6/1991	CDFG Stream Inventory	Electrofishing			x		Steelhead ranged in size from 71 to 305 mm FL. Stickleback also observed
	12/07/2001	Froland (2001 a/b)	Spawning survey		x			One spent Chinook adult
	06/05/2001	CDFG NCCCSI 2005	Electrofishing				x	Trout observed
	07/25/2002	CDFG NCCCSI 2005	Electrofishing				x	Trout observed
	06/17/2003	CDFG NCCCSI 2005	Electrofishing				x	Trout, threespine stickleback observed
Cuddeback Creek	06/27/1940	Shapovalov (1940)	Fish rescue	x		x		Coho and steelhead rescued from Cuddeback Creek and released into Van Duzen mainstem
	06/13/1963	CDFG 1963	Streamside observation				X	Unidentified salmonids from 1 to 6 inch in length found only 0.75 mile from mouth
	03/19/1987	CDFG (1987)	Spawning survey			x		Steelhead observed by locals, only redd observed by CDFG warden approximately 0.25 mile above HWY 36 crossing
	07/08/1988	CDFG 1988	Electrofishing			x		
	06/14 and 07/17/2001	CDFG NCCCSI 2005	Electrofishing				x	Trout observed
	12/06 and 07/2001	Froland (2001 a/b)	Spawning survey		x			Spawning Chinook and redds observed near mouth
	10/21/2002	CDFG NCCCSI 2005	Electrofishing				x	Trout observed
	12/17/2002	Froland (2002)	Spawning survey		x			Chinook observed spawning just downstream of HWY 36 crossing
	06/19 and 09/25/2003	CDFG NCCCSI 2005	Electrofishing		x		x	Chinook, Sacramento pikeminnow, trout observed.

Stream	Date Surveyed	Source	Survey Method	Fish Observations				Fish Comments
				Coho	Chinook	Steelhead	Salmonids	
	05-07/1951	Hallock et al (1952)	Seine	x				
	12/15/1964	CDFG (1964)	Spawning survey		x			Chinook observed spawning from mouth to HWY 36 bridge
	05/27/1965	CDFG (1965)	Streamside observation				x	1.5 to 4 inch unidentified salmonids observed just below HWY 36 bridge
	07/19/1965	CDFG (1965)	Streamside observation				x	Unidentified salmonids approximately 2 inch in length observed in lower 2/3 of stream. Residents note that juvenile salmonids die in stream each summer
Fiedler Creek	07/03/1967	CDFG (1967)					x	1.5 inch salmonids were observed from mouth to approximately 0.75 mile above HWY 36
Fiedler Creek	02/05/1987	CDFG (1987)	Spawning survey			x		Steelhead and steelhead redds observed approximately 400-500 ft above HWY 36
	06/05 and 06/2001	CDFG NCCCSI 2005	Electrofishing				x	Trout observed
	12/07/2001	Froland (2001 a/b)	Spawning survey		x			Chinook observed spawning approximately 50 and 100 feet above HWY 36 culvert. CDFG warden notes that some of these Chinook were "42 inch fish in a 36 inch wide stream!"
	07/22/2002	CDFG NCCCSI 2005	Electrofishing				x	Trout observed
	08/13/2003	CDFG NCCCSI 2005	Electrofishing				x	Trout observed
	08/16/1938	CDFG (1938)	Streamside observation			x		Many 1.5 to 2.5 inch steelhead observed
	07/06/1949	Murphy (1950)	Fish rescue			x		900 yoy steelhead rescued from unknown location
	05 to 07/1951	Hallock (1952)	Seine	x				Coho yoy and 1+
	01/14/1952	CDFG (1952)	Streamside observation					No fish observed due to high water
	07 to 08/1952	Kimsey (1953)	Fish rescue	x				Fish rescued from Cummings Creek planted into Strongs Creek
	06/1961	CDFG (1961)		x		x		
	01/29/1962	CDFG (1962)	Streamside observation					
Cummings Creek	12/15/1964	CDFG (1964)	Spawning survey		x			Chinook observed
	03/07/1966	CDFG (1966)	Streamside observation					No fish observed from HWY 36 crossing to 0.5 mile upstream
	02/05 and 07/1985	CDFG (1985)	Streamside observation			x	x	Steelhead, juvenile salmonids and roach observed during survey of 0.25 mile below HWY 36 to 2 miles above the HWY.
	03/15/1985	CDFG (1985)	Spawning survey					Redds observed
	1987	Brown and Moyle (1987)	Combination of the following: electrofishing, seining, snorkeling	x		x		California roach observed
	12/15/1987	CDFG (1987)	Spawning survey	x	x			Redds observed
	12/31/1987	CDFG (1987)	Spawning survey		x			Redds observed
	12/01 and 09/1988 and 01/17/1989	CDFG (1988)	Spawning survey		x			Chinook and redds observed
	04/19/1989	CDFG (1989)	Streamside observation		x	x	x	Juvenile Chinook, unidentified salmonids and 1+ steelhead observed, as well as redds
	06/26/1989	CDFG (1989)	Electrofishing	x		x		
	01/12 and 25/1990	CDFG (1990)	Spawning survey				x	One unidentified live fish observed
	9/3 and 6/1991	CDFG Stream Inventory	Electrofishing			X		Ranged from 36 to 170 mm FL.
	02/04/1992	CDFG (1992)	Spawning survey					Redds observed.

Stream	Date Surveyed	Source	Survey Method	Fish Observations				Fish Comments
				Coho	Chinook	Steelhead	Salmonids	
Cummings Creek	12/17, 21/1992 and 01/05, 12/1993	CDFG (1992)	Spawning survey		x		x	Live Chinook and carcasses, unidentified salmonids; redds observed
	07/07/1993	Preston (1993)	Electrofishing	x		x		
	08/02/1994	Preston (1994)	Electrofishing			x		
	11/28/1994 and 02/07/ 03/01/1995	CDFG (1994, 1995)	Spawning survey				x	Unidentified skeletons and redds observed
	11/28 to 03/01/1995	CDFG (1995)	Spawning survey				x	One unidentified skeleton, redd observed.
	01/08/1996	CDFG (1996)	Spawning survey					
	12/19/1997	CDFG (1997)	Spawning survey					
	10/19/1998	PALCO (1998)	Electrofishing			x		
	09/02/1999	PALCO (1999)	Electrofishing			x		
	12/8/1999 and 01/05/2000	CDFG (2000)	Spawning survey					
	09/06/2000	PALCO (2000)	Electrofishing			x		
	05/30/2001	CDFG NCCCSI (2005)	Electrofishing, direct observation				x	Trout observed
	09/13/2001	PALCO (2001)	Electrofishing			x		
	12/2001	Froland (2001)	Spawning survey		x			
	06/06 and 17/2002	CDFG NCCCSI (2005)	Direct observation		x		x	Chinook and trout observed
	06/17/2003	CDFG NCCCSI (2005)	Direct observation		x		x	Chinook, trout, Sacramento pikeminnow observed
	10/28/2003	PALCO (2003)	Electrofishing			x		
Price Creek	11/23/1964	Rinehart (1964)	Spawning survey		x			Chinook observed 2.5 miles from mouth. No carcasses. Stream survey from mouth to 4 miles upstream
	12/29/1966	CDFG (1966)	Spawning survey					.
	1975, 1976	Brown (1980)	Electrofishing, direct observation			x		California roach, Sacramento sucker, sculpin spp., threespine stickleback observed
	03/02, 03, 05/1981	Ganz-Haggard (1981)	Streamside observation			x		Only 1 steelhead observed in last 1 mile of stream. Water very murky, visibility was low.
	12/10/1986	Froland (1986)	Streamside observation					No fish data recorded. Anecdotal comment that fish population is "a shadow of its past productivity."
	12/14/1987	Donker (1987)	Spawning survey					No fish observed. Landowner notes that he hasn't seen a run of salmon since the 1964 flood.
	07, 08, 10/1995	USFS raw data	Electrofishing			x		California roach, threespine stickleback, coast range sculpin, Pacific lamprey observed
	07-08/ and 10/1995, 06-07/1996, 05/1997	Harvey, White, Nakamoto (2002)						California roach, threespine stickleback, sculpin spp. observed
	10/05/1998	CDFG (1998)	Electrofishing			x		Pikeminnow spp., sculpin spp., roach spp., sucker spp., stickleback, lamprey spp. observed
	7/27/1999	CDFG Stream Inventory	Electrofishing			x		0+, 1+, 2+, and 3+ size classes of steelhead present. California roach, threespine stickleback, Sacramento suckers, Sacramento pike minnow, and sculpin observed
	07/10, 12/2001	CDFG NCCCSI (2005)	Electrofishing				x	Trout, lamprey spp., sculpin spp., threespine stickleback, sucker spp., Cyprinid spp., observed
	07/23, 24/2002	CDFG NCCCSI (2005)	Electrofishing				x	Trout, Sacramento pikeminnow, sculpin spp., sucker spp., threespine stickleback, lamprey spp. observed

Stream	Date Surveyed	Source	Survey Method	Fish Observations				Fish Comments
				Coho	Chinook	Steelhead	Salmonids	
	08/11 and 10/06/2003	CDFG NCCCSI (2005)	Electrofishing		x		x	Chinook, trout, Sacramento pikeminnow, sculpin spp., threespine stickleback, lamprey spp., California roach observed
Sweet Creek	08/15/1938	CDFG (1938)	Streamside observation			x		1.5 to 3 inch steelhead common
	03/06/1981	CDFG (1981)	Streamside observation					
Oil Creek	06/15/1977	CDFG (1977)	Streamside observation			x	x	Steelhead fry and one 4-5 inch salmonid
	06/08/1990	CDFG (1990)	Electrofishing	x		x	x	Yoy salmonids, coho, steelhead, sculpin spp., lamprey spp. observed
						x		Sticklebacks observed
	10/15/1999	CDFG Stream Inventory	Electrofishing			x		0+, 1+, 2+, and 3+ size classes of steelhead and sculpin observed
	10/30/2002	CDFG Stream Inventory	Electrofishing	x		x		Yoy, 1+, and 2+ steelhead year classes observed
Howe Creek	1952	Kimsey (1952)						Salmon mortality at mouth
	1975, 1976	Brown (1980)	Electrofishing, direct observation	x		x		California roach, sculpin spp., threespine stickleback, Sacramento sucker observed
	01/22/1980	CDFG (1980)	Streamside observation					Residents noted large 1979 runs of coho, Chinook, and steelhead. No observations made on this survey
	12/14/1987	Moody (1987)	Streamside observation					Land owner states no salmon run in 12 years
	9/15/1998	CDFG Stream Inventory	Electrofishing			x		Steelhead ranged in size from 50 to 174 mm. Sacramento pikeminnow observed
	10/15/1999	Yoshioka (1999)	Electrofishing	x		x		One coho juvenile, steelhead yoy, 1+ and 2+ observed
	01/19 and 02/01/2001	CDFG (2001)	Spawning survey				x	Unidentified live fish and carcass, redds observed
	07/11,12/2001	CDFG NCCCSI (2005)	Electrofishing				x	Trout, threespine stickleback, lamprey spp., sculpin spp. observed
	08/21/2001	CDFG (2001)	Electrofishing			x		Lamprey spp. observed
	07/22, 23/2002	CDFG NCCCSI (2005)	Electrofishing				x	Trout, threespine stickleback, lamprey spp., sculpin spp., sucker spp. observed
	08/07/2003	CDFG NCCCSI (2005)	Electrofishing				x	Trout, threespine stickleback, Sacramento pikeminnow, lamprey spp., sculpin spp. observed
West Fork Howe Creek	9/15/1998	CDFG Stream Inventory	Electrofishing			x		Steelhead ranged in size from 50 to 120mm FL
Atwell Creek	1975, 1976	Brown (1980)	Electrofishing, direct observation			x		Sculpin spp., threespine stickleback observed
	01/22/1980	CDFG (1980)	Streamside observation					Redds observed
	7/23/1993	CDFG Stream Inventory	Electrofishing			x		Ranged from 30 to 185mm FL. Other species: stickleback, sculpin, Pacific lamprey ammocoetes
	10/14 and 15/1999	CDFG Stream Inventory	Electrofishing			x		0+, 1+, and 2+ steelhead age classes present. Sculpin also present
	07/09 and 11/2001	CDFG NCCCSI (2005)	Electrofishing				x	Trout, threespine stickleback, sculpin spp., lamprey spp. observed
	07/22/2002	CDFG NCCCSI (2005)	Electrofishing	x	x		x	Coho, Chinook, trout, threespine stickleback, sculpin spp. observed
	07/02/2003	CDFG NCCCSI (2005)	Electrofishing	x			x	Coho, trout, Sacramento pikeminnow, sculpin spp., threespine stickleback observed
Nanning Creek	08/16/1973	CDFG (1973)	Electrofishing			x		“resident rainbow trout” in excellent condition
	08/23/1973	CDFG (1973)	Electrofishing, streamside observation			x		Possibly resident rainbow trout.
	1975, 1976	Brown (1980)	Electrofishing, direct observation			x		Sculpin spp. observed
	6/30/1992	CDFG Stream Inventory	Electrofishing			x		Steelhead ranged from 50 to 155 mm FL
	Summer 2001	PALCO (2001)	Electrofishing					No fish observed
Dean Creek	8/25/1992	CDFG Stream Inventory	Electrofishing			x		Steelhead ranged from 82 to 160 mm FL

NCCCSI= North Coast California Coho Salmon Investigation - Bill Jong personal comm.

Habitat Overview

Historic Conditions

Stream surveys were conducted by CDFG as early 1938; however, stream survey efforts were neither specific nor standardized until 1990 when the *California Salmonid Stream Habitat Restoration Manual* was published. Most observations in the historic stream surveys are not quantitative and have limited use in comparative analysis with current habitat inventories. Furthermore, the majority of streams within the subbasin were not surveyed prior to the floods of 1955 and 1964, which greatly exacerbated the detrimental effects of land use practices on these streams; therefore, a clear picture of overall historic stream habitat conditions and salmonid populations is lacking in this subbasin. Nevertheless, data from these stream surveys provide a snapshot of conditions at the time of survey (Table 9).

The earliest stream surveys in this subbasin were conducted in 1938 on five creeks. These surveys generally indicated good spawning and pool conditions, except for fair conditions on Price Creek. Additionally, debris and pollution from logging were noted in Cummings Creek. Surveys were conducted on six creeks from 1949 to 1970. Silty conditions were noted in the lower reaches of Barber Creek (Van Duzen), Fiedler, Cummings, and Price Creeks and Wolverton Gulch.

Three streams were surveyed in the 1970s. Poor habitat in Barber Creek (Eel) was described as impacted by cattle. Spawning conditions in Oil Creek and Nanning Creek were poor. Eight streams were surveyed in the 1980s. Siltation was noted on Wolverton Gulch, Barber (Van Duzen), Cuddeback, Cummings, and Price Creeks.

Additional habitat observations separate from habitat inventories were conducted on six streams in the 1990s and 2000s. PALCO observations of habitat during electrofishing on Cummings Creek noted shallow pools.

Table 9. Habitat observations made in the Upper Subbasin from 1938-2003.

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
Barber Creek (Eel)	02/21/1973	CDFG 1973	Generally lacking in good fish habitat. Substrate is mostly mud and fines, some good spawning gravel. Banks are clear of brush and trees due to agricultural production. Water is degraded by cattle in entire stream except headwaters	Low flow barrier at mouth during summer, 6 ft vertical concrete falls approximately 100 yards from mouth is year –round barrier.
Barber Creek (Van Duzen)	07/15/1965	CDFG 1965	Depths range from 3 in. to 3 ft., substrate composed of silt in the lower reaches and fine rubble to fine gravel upstream, spawning areas, shelter and canopy are abundant	No impassable barriers
	07/02/1984	Franklin and Mitchell (1984)	Average pool depth 8 in., 95% canopy, no spawning gravel, heavily silted substrate due to erosion from livestock grazing, logging	
	01/23/1988	CDFG 1988	Shelter from woody debris and undercut banks, dense riparian overstory. Stream flows through pasture lands	Culvert requires modification for fish passage
Wolverton Gulch	06/12/1963	CDFG 1963	Spawning conditions are poor; substrate is heavily silted, tannin-dyed water, average depth from mouth to headwaters 3 to 2 ft., respectively. Domestic sewage likely draining into stream from outhouse	The many log jams in creek are probably not barriers to fish migration. Three culverts observed obstructed by heavy sediment.
	circa 1965	CDFG	Depths range from 2 in. to 3 ft., bottom of heavily silted coarse gravel, low gradient.	No obstructions observed
	07/02/1984	Franklin and Mitchell (1984)	Erosion causing heavy siltation of stream, average pool depth was 5 in., 80% canopy, pasture land borders stream section	
	10/15/1997	Harris (1997)	Headwaters of creek. Fairly good fish habitat, low to moderate embeddedness, however high volume of fines in channel (fines increase upstream), low LWD abundance (predominantly hardwood), pools mostly less than 3 ft deep, less than 70% canopy (increasing to 95% upstream).	
Cuddeback Creek	06/13/1963	CDFG 1963	In lower 0.75 mile of creek: poor shelter, shallow pools (<3 in), sandy substrate creates poor spawning area. From 0.75 mile from mouth: shelter improves, pools are deeper (4 to 5 in), spawning gravels improve	Low flow barrier during summer, and subsurface flow.
	03/19/1987	CDFG (1987)	Lower reach of stream dries up in summer	
	07/08/1988	CDFG 1988	Stream bottom moderately silted, subsurface flow in areas	
	12/06 and 07/2001	Froland (2001 a/b)	Muddy water, landowner known to cross creek in this area with heavy equipment	
Fiedler Creek	12/15/1964	CDFG (1964)	Little spawning gravel, turbid water	No barriers observed
	05/27/1965	CDFG (1965)	Large quantities of debris: tree branches, cans, bottles, and wood.	
	07/19/1965	CDFG (1965)	Pools varied in depth from 3 to 10 in., heavily silted fine gravel in lower 0.5 mile, coarse gravel and fine rubble from 0.5 to 1 mile from mouth. No flow at mouth	

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
	02/05/1987	CDFG (1987)	Average depth was 0.5 to 1 ft, excellent spawning gravel	
Cummings Creek	08/16/1938	CDFG (1938)	Pool and shelter are good, debris and pollution observed from logging activities	Log jams that divert entire flow
	01/14/1952	CDFG (1952)	Average depth 3 ft., substrate is mostly gravel and rubble, , good spawning areas are numerous, numerous pools	Numerous log jams obstruct stream, no comment on fish passage ability
	06/1961	CDFG (1961)	Good spawning areas, lower reaches of stream go dry in summer, average depths range from 4 to 8 ft., high levels of urban trash in stream, siltation of stream bottom increases from mouth to headwaters	Several log jams and culverts obstruct the stream, no comment on fish passage ability
	01/29/1962	CDFG (1962)	Flows too low to pass through culverts	Four culverts surveyed that were not barriers to fish migration
	12/15/1964	CDFG (1964)	Good spawning gravel available, though some heavily silted	Log jams observed that were not barriers to fish migration
	03/07/1966	CDFG (1966)	Good spawning gravel	Several log jams forming passable, and one impassable barrier
	02/05 and 07/1985	CDFG (1985)	High amounts of sand and silt in creek from erosion of streambanks due to road crossings, cattle, several large log jams. Lower reaches of stream are highly aggraded, and flowing subsurface. Spawning habitat ranged from poor to fair, canopy cover ranged from 10% to 95%. Moving upstream,	Several low flow and probable barriers predominantly composed of LWD observed on Cummings Creek, complete barriers observed on Cummings Creek tributaries
	12/15/1987	CDFG (1987)	Bank erosion contributing fines to stream, log debris accumulation	No observed obstructions defined as fish passage barriers
	12/31/1987	CDFG (1987)	Cattle impacting stream, causing increased sediment and reduction in riparian vegetation	Fences in stream retaining debris, could pose fish migration barrier.
	12/01 and 09/1988 and 01/17/1989	CDFG (1988)	High levels of silt in creek downstream of HWY 36 bridge, most redds observed upstream of this location	Wire fences crossing stream are not impeding salmon migration
	04/19/1989	CDFG (1989)	Bank erosion, low canopy, little shelter and shallow pools in areas detailed for enhancement. Good available spawning gravels	
	01/12 and 25/1990	CDFG (1990)	Spawning habitat considered fair, cows accessing stream	Fences crossing stream may hinder fish passage
	09/03/1991	CDFG (1991)	Good woody debris, and shelter cover	Fish observed upstream of massive log and tire jam
	02/04/1992	CDFG (1992)		Redd observations made above “old tire jam:
	07/07/1993	Preston (1993)	0.5- to 1.5- foot deep pools and scours above HWY 36 culvert	
	10/19/1998	PALCO (1998)	Canopy = 95-100%, shelter rating = 70-90%, average pool depths ≤1 foot	
	09/02/1999	PALCO (1999)	average pool depths < 1 foot	
	09/06/2000	PALCO (2000)	High amounts of LWD on banks, shelter ratings = 20-60%, average pool depths < 1 foot	
	09/13/2001	PALCO (2001)	High amounts of suspended sediment, electrofishing occurred upstream of major LWD. Shelter ratings = 10-75%, average pool depths < 1 foot	
	10/28/2003	PALCO (2003)	Low flow, high gradient, streambanks are highly eroded, fine sediments in pool, large cobble and boulders, shelter coverage ranged from 30% to 70% per surveyed unit	Stream below Hwy 36 is diverted and flat gradient. Often braided with subsurface flows which block fish passage.
Price Creek	08/15/1938	CDFG (1938)	Pools and shelter described as fair.	
	Pre 1951	CDFG	Bottom described as rock and gravel, lower reach of stream goes dry in summer	
	11/23/1964	Rinehart (1964)	Rains made water very muddy and visibility very poor.	
	03/02, 03, 05/1981	Ganz-Haggard (1981)	From mouth to 5.5 miles upstream: Canopy averaged 50 to 80%, channel width averaged 30 to 40 ft., stream bottom heavily silted, gravel 15 to 40%. Due to logging and grazing, high levels of bank erosion.	
	12/10/1986	Froland (1986)	Flows are low probably due to riparian diversions on stream.	
	12/14/1987	Donker (1987)	Numerous slides and other bank erosion observed.	
Sweet Creek	08/15/1938	CDFG (1938)	Survey conducted 100 yards above mouth: spawning area described as good, pools 3.5 feet deep and described as good, pool shelter good.	
	03/06/1981	CDFG (1981)	Very unstable banks, heavily impacted from cattle grazing, canopy averages 50-80%, pool depths ranged from 1.5 to 2 ft., gravel is available at 30-40% average	Several log jams with associated debris accumulations create possible barriers to fish migration
Oil Creek	1938	CDFG (1938)	Survey conducted 100 yards above mouth. Pools = 3 inches deep, good spawning areas	No barriers observed
	06/15/1977	CDFG (1977)	Stream is heavily silted and lacks spawning gravel. Mouth to 200 feet upstream is only available spawning area. Pool shelter (in the form of logging slash) is adequate. Iron pyrite seepage	
	06/08/1990	CDFG (1990)	Good spawning and rearing habitat, canopy averaged 55% over entire survey (from mouth to 1.3 miles upstream)	Several debris accumulations encountered
Howe Creek	08/16/1938	CDFG (1938)	Pools described as good, shelter is good	
	01/22/1980	CDFG (1980)	Shade canopy averaged 20% from mouth to forks, increased to 70% upstream, stable banks, suitable spawning areas	No fish passage barriers encountered

Stream	Date Surveyed	Source	Habitat Comments	Barrier Comments
	12/14/1987	Moody (1987)	Atwell Creek, and unnamed tributary contributing silt to stream	Bridge and concrete platform combination may pose threat to fish passage
	10/15/1999	Yoshioka (1999)	Cover rating =5%, water clarity =excellent.	
Atwell Creek	01/22/1980	CDFG (1980)	Shade canopy averaged 80%, numerous suitable spawning areas, generally stable banks, active slide contributing fines to stream	No barriers to fish passage observed in this 0.5 mile survey
Nanning Creek	08/16/1973	CDFG (1973)	Water depth from 1 inch to 1 foot, stream width 1-2 feet. 5- 6% gradient. Stream bottom: gravel 15%, sand 50%, silt 35%. Shade canopy = 85%. "an excess of slash" in stream and tributaries, "lots of brown algae."	
	08/23/1973	CDFG (1973)	New and old logging slash in creek; log jams, and railroad piers and timbers throughout the drainage. 25% of creek is littered with old logs and debris. Trash on banks	8-10 foot falls 0.25 mile above the mouth serves as a barrier to fish migration.
	12/27/1979	CDFG (1979)	Spawning gravel cemented in sand and silt, stream bottom "extremely unstable," with high levels of fines above and below stream obstructions. Few suitable spawning areas, none in tributaries. Stable streambanks, shade canopy averages 80%, stream gradient averages 2-3%	Many logjams serve as barriers to fish migration, gravel retention behind several. Stream flow obstructed by old logging roads. Removing obstructions would release large amounts of fines.
	Summer 2001	PALCO (2001)		12- to 15- foot fall at mouth.

Current Conditions

In the Upper Subbasin, CDFG fisheries crews conducted stream habitat inventories on fourteen streams totaling 30.3 miles between 1991 and 2002 (Table 10, Figure 5). These streams were chosen based on the known presence of salmonid species. Some of the surveyed area was limited by denied landowner access permission. Three streams, Oil Creek, Atwell Creek and Cummings Creek, each had two habitat inventories completed within a 5 year time frame.

Stream habitat inventory methods were conducted on these tributaries according to methods determined in the *California Salmonid Stream Habitat Restoration Manual* (Flosi, et al. 1998). Analysis of the Upper Subbasin streams' water quality and instream habitat conditions includes the following:

- Canopy density;
- Habitat type categories;
- Pools depth;
- Pool shelter;
- Large woody debris;
- Cobble embeddedness;
- Water quality;
- Water chemistry;
- Wastewater facilities.

Table 10. Upper Subbasin streams surveyed by CDFG.

Stream	Year of Survey	Survey length (miles)	Percent of permanent stream surveyed	Number of Reaches
Wolverton Gulch	1997	2.5	60	1
Wilson Creek	1991	0.5	23	2
Cummings Creek	1991	3.3	100	3
	1996	2.0	61	1
Price Creek	1999	6.9	82	4
Adams Creek	2002	0.8	69	2
Sweet Creek	1999	0.9	45	1
Muddy Creek	2002	0.8	65	2
Oil Creek	1999	0.5	26	1
	2002	0.8	42	2
Howe Creek	1998	4	86	2
Atwell Creek	1993	1.6	41	2
	1998	2.4	61	1
Crystal Creek	2002	0.5	38	1
West Fork Howe Creek	1998	0.4	40	1
Nanning Creek	1992	1.4	60	1
Dean Creek	1992	1	48	1

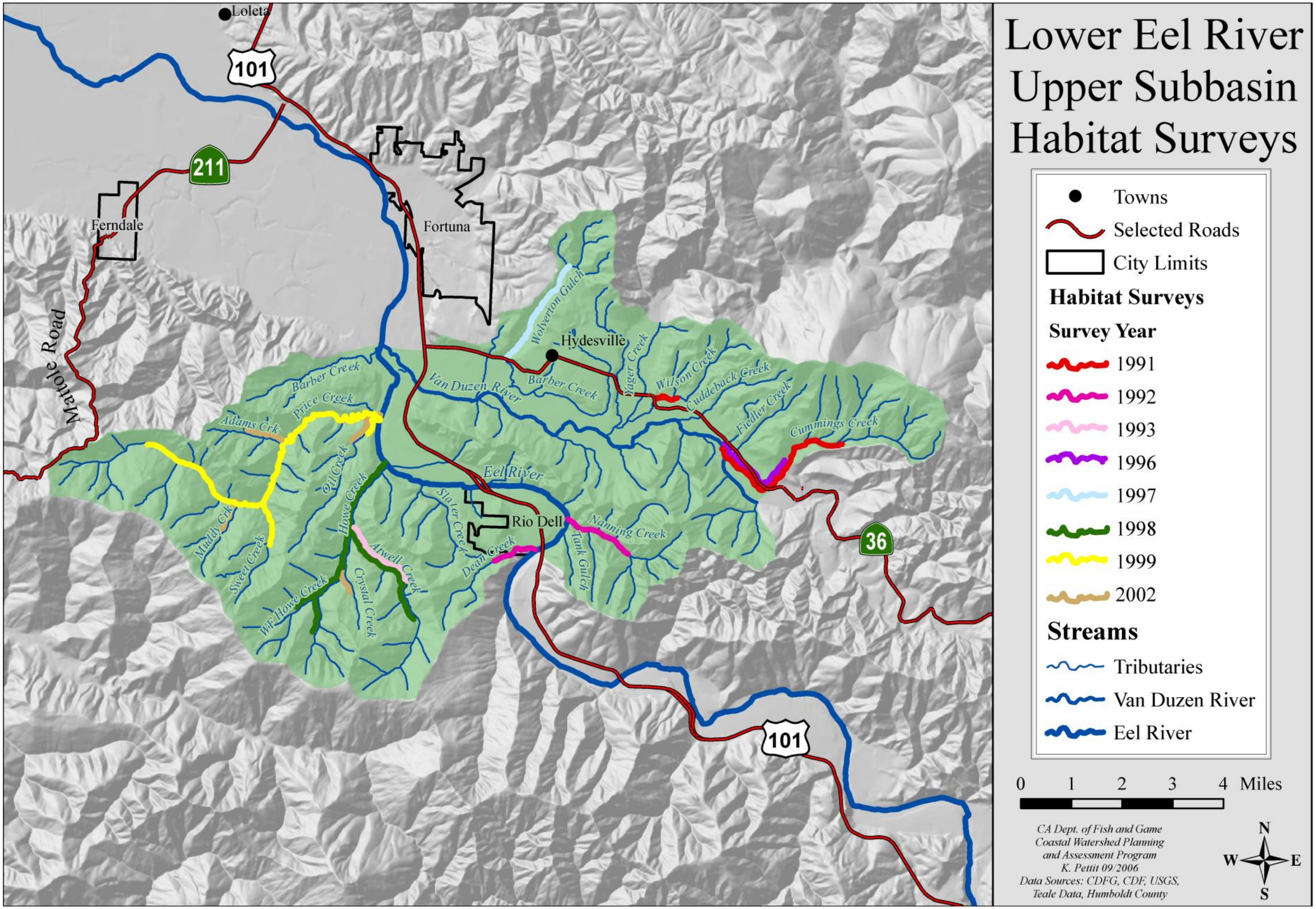

Figure 5. Habitat surveys conducted by CDFG on fourteen tributaries of the Upper Subbasin.

Canopy Density

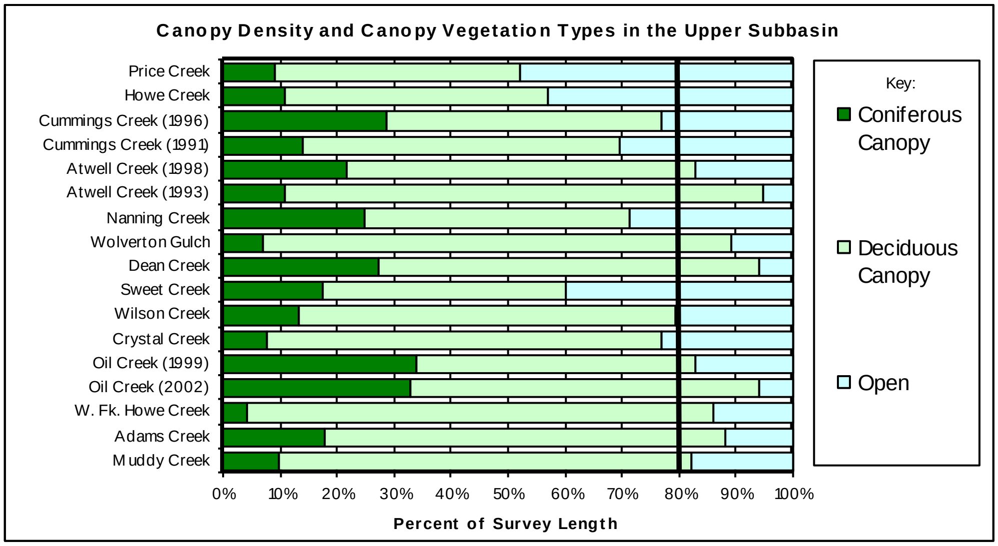

Figure 6. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Upper Subbasin.

Averages are weighted by unit length to give the most accurate representation of the percent of a stream under each type of canopy. Streams are listed in descending order by drainage area (largest at the top).

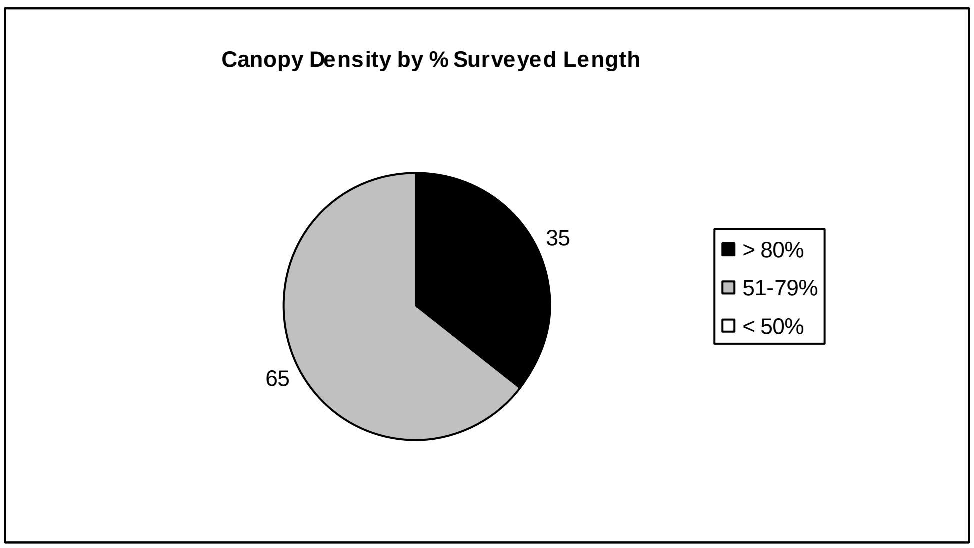

Figure 7. Canopy Density in the Upper Subbasin.

Significance: Streamside canopy density is a measure of the percentage of wetted stream that is shaded by riparian tree canopy. Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Stream water temperature can be an important limiting factor of salmonids. Generally, canopy density less than 50% by survey length is below target values and greater than

Findings: Canopy density measurements on seven of the 14 surveyed streams obtained values below the target value of 80%. On all streams the majority of canopy coverage was provided by deciduous trees. The 1993 Atwell Creek survey had the greatest canopy cover at approximately 95%. The lowest canopy densities of all the Lower Eel River subbasins were obtained in the Upper Subbasin, with three creeks near only 50% coverage. The overall Upper Subbasin EMDS canopy density condition truth score is moderately suitable, however, as poor canopy was found over long survey sections of streams, nearly 11 miles (approximately 1/3 of the total) is considered moderately unsuitable.

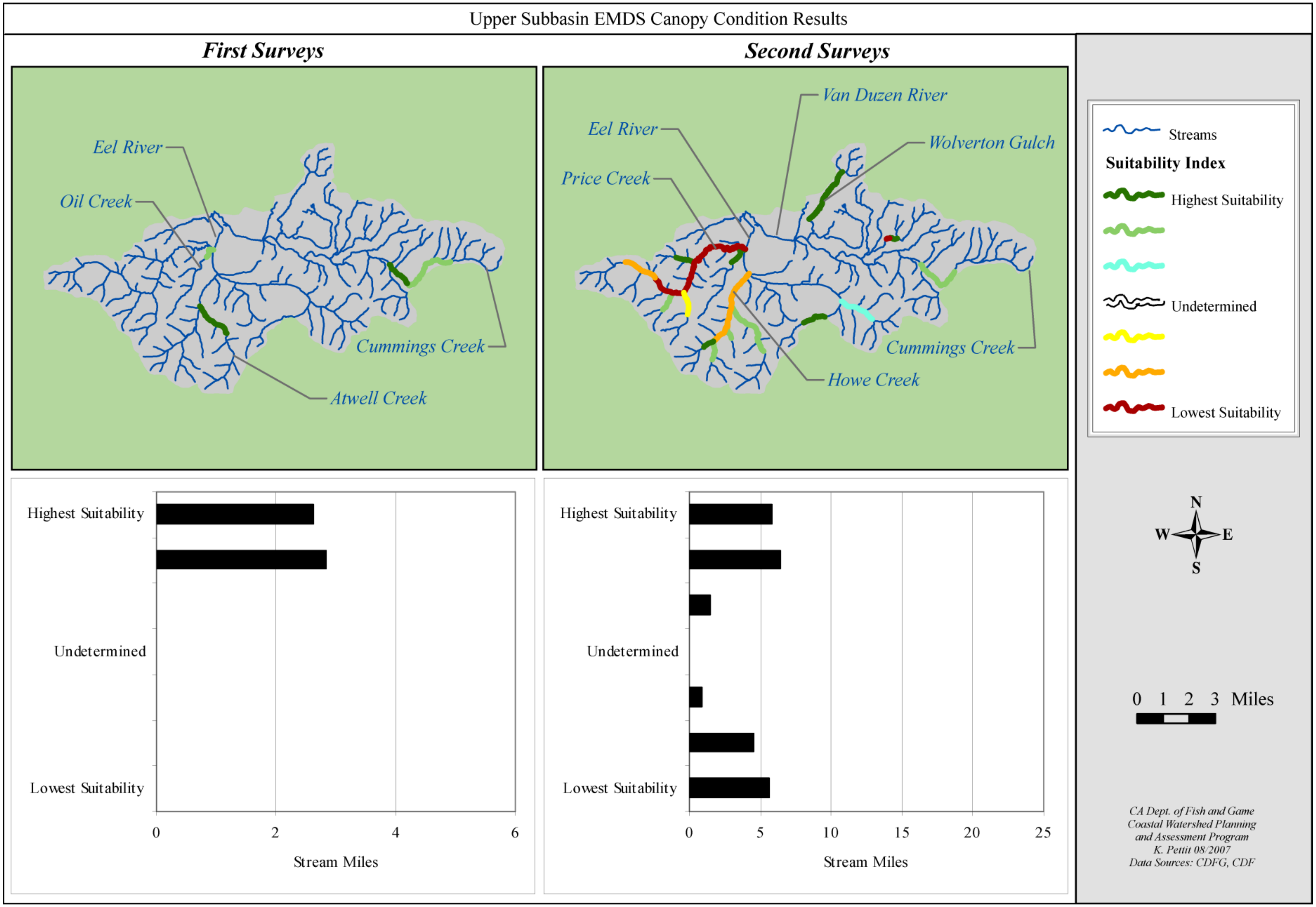

Figure 8. EMDS canopy results for the Upper Subbasin by surveyed stream miles. First surveys of Cummings, Atwell, and Oil Creeks were completed in 1991,199, and 1999, respectively. Second surveys for the same creeks were completed in 1996, 1998, and 2002, respectively.

Habitat Categories

Table 18. Upper Subbasin percent occurrence and percent by length of pool, run, riffle, and dry habitats.

Stream	Stream Order	Survey Length (miles)	Pool, Riffle, Run % Occurrence	Pool: Riffle: Run% total length	Dry % Total Length	Culvert % Total Length
Wolverton Gulch	1	2.5	47:11:40	30:4:64	1	1
Wilson Creek	2	0.5	49:50:31	4:86:10	0	0
Cummings Creek (1991)	1	3.3	34:41:24	11:36:26	27	0
Cummings Creek (1996)	1	2.0	32:34:33	18:24:57	1	0
Price Creek	2	6.9	22:45:33	12:57:30	0	0
Adams Creek	1	0.8	42:29:28	27:35:37	0	1
Sweet Creek	2	0.9	39:49:12	6:90:4	0	0
Muddy Creek	1	0.8	31:44:25	19:47:34	0	0
Oil Creek (2002)	2	0.5	39:34:26	42:28:31	0	0
Oil Creek (1999)	2	0.8	40:35:24	40:32:24	0	5
Howe Creek	2	4	18:46:36	6:65:29	0	0
Crystal Creek	1	0.5	2:48:48	1:74:25	0	1
Atwell Creek (1993)	1	1.6	28:40:31	20:36:42	1	0
Atwell Creek (1998)	1	2.4	28:40:32	18:39:43	0	0
West Fork Howe Creek	1	0.4	24:48:26	7:74:18	0	1
Nanning Creek	1	1.4	38:36:26	26:44:31	0	0
Dean Creek	1	1	28:38:27	19:44:31	5.81	0

Significance: Productive anadromous streams are composed of a balance of pool, riffle and run habitat and each plays an important role as salmonid habitat. Looking cumulatively at pool, riffle, and run relationships helps characterize the status of these habitat types and also provides a measure of stream habitat diversity and suitability for fish. A pool: riffle ratio of approximately 1:1 is suggested as a desirable condition for most wadeable, anadromous, fish bearing streams, but it is not applicable for evaluating salmonid suitability of all stream reaches and channel types (Rosgen 1996). However, pool: riffle relationships showing an over abundance of riffles or runs that may indicate aggraded channel conditions or lack of scour objects needed for pool formation.

Findings: Twelve of the surveyed tributaries had less pools by occurrence than riffles. Additionally, fourteen tributaries had less length in pools than in riffles. West Fork Howe, Crystal, Wilson, Sweet, and Howe Creeks all had less than 10% of their length in pools. Only Oil Creek and Wolverton Gulch had over 30% of their stream length in pools.

Five tributaries had dry habitat units, which obviously indicate poor conditions for fish and are further discussed in the Fish Passage Barriers section. Five tributaries had some of their length in culverts, which are also further discussed in the Fish Passage Barriers section.

Pool Depth

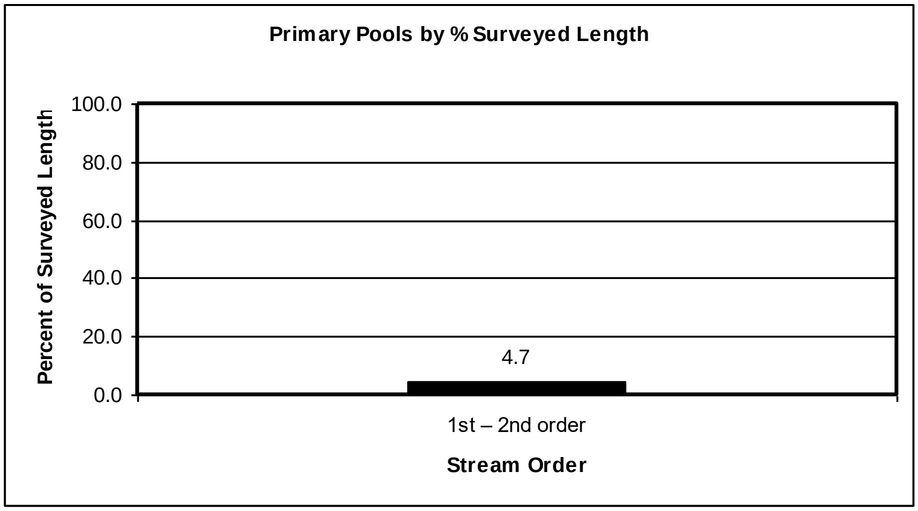

Figure 9. Primary Pools in the Upper Subbasin.

Table 12. Percent length of a survey composed of pools in the Upper Subbasin.

Stream	Stream Order	Percent all measured pools by survey length	Percent pools of depth <2' by survey length	Percent pools of depth 2' - 2.9 by survey length	Percent pools of depth 3' - 4' by survey length	Percent pools of depth > 4' by survey length	Percent pools within target range (>2') by survey length
Wolverton Gulch	1	29.59	22.63	6.71	0	0.25	6.96
Wilson Creek	2	4.23	4.23	0	0	0	0
Cummings Creek (1991)	1	11.48	8.43	3.05	0	0	3.05
Cummings Creek (1996)	1	18.16	14.96	2.82	0.38	0	3.2
Price Creek	2	10.98	7.11	3.21	0.56	0.1	3.87
Adams Creek	1	26.33	26.33	0	0	0	0
Sweet Creek	2	5.82	5.82	0	0	0	0
Muddy Creek	1	16.45	15.42	1.03	0	0	1.03
Oil Creek (2002)	2	41.24	22.55	14.49	3.27	0.93	18.69
Oil Creek (1999)	2	36.03	17.72	4.81	8.28	5.22	18.31
Howe Creek	2	5.88	3.14	2.16	0.41	0.17	2.74
Atwell Creek (1993)	1	20.62	12.36	6.99	1.27	0	8.26
Atwell Creek (1998)	1	17.82	8.08	8.61	1.13	0	9.74
Crystal Creek	1	1.08	1.08	0	0	0	0
West Fork Howe Ck	1	6.32	5.76	0.56	0	0	0.56
Nanning Creek	1	25.4	22.43	2.21	0.76	0	2.97
Dean Creek	1	18.64	15.6	2.59	0.45	0	3.04

Significance: Primary pools provide 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 – 55% of its length in primary pools to be suitable for salmonids. In first and second order streams, primary pools are those of greater than 2 feet deep.

Findings: None of the streams surveyed in the Upper Subbasin met target values for pool depth with only 5% of surveyed reaches being composed of primary pools. Oil Creek had the most primary pools by survey length, for both years with at only 18% However, Oil Creek also had some of the highest percentage of pools less than two feet in depth. On average, only about 7% of the surveyed area was composed of primary pools, which is well below the target values. Most of the pools in all of the surveyed streams were less than 2 feet in depth. Four streams, Adams, Crystal, Williams, and Sweet Creeks, contained no primary pools.

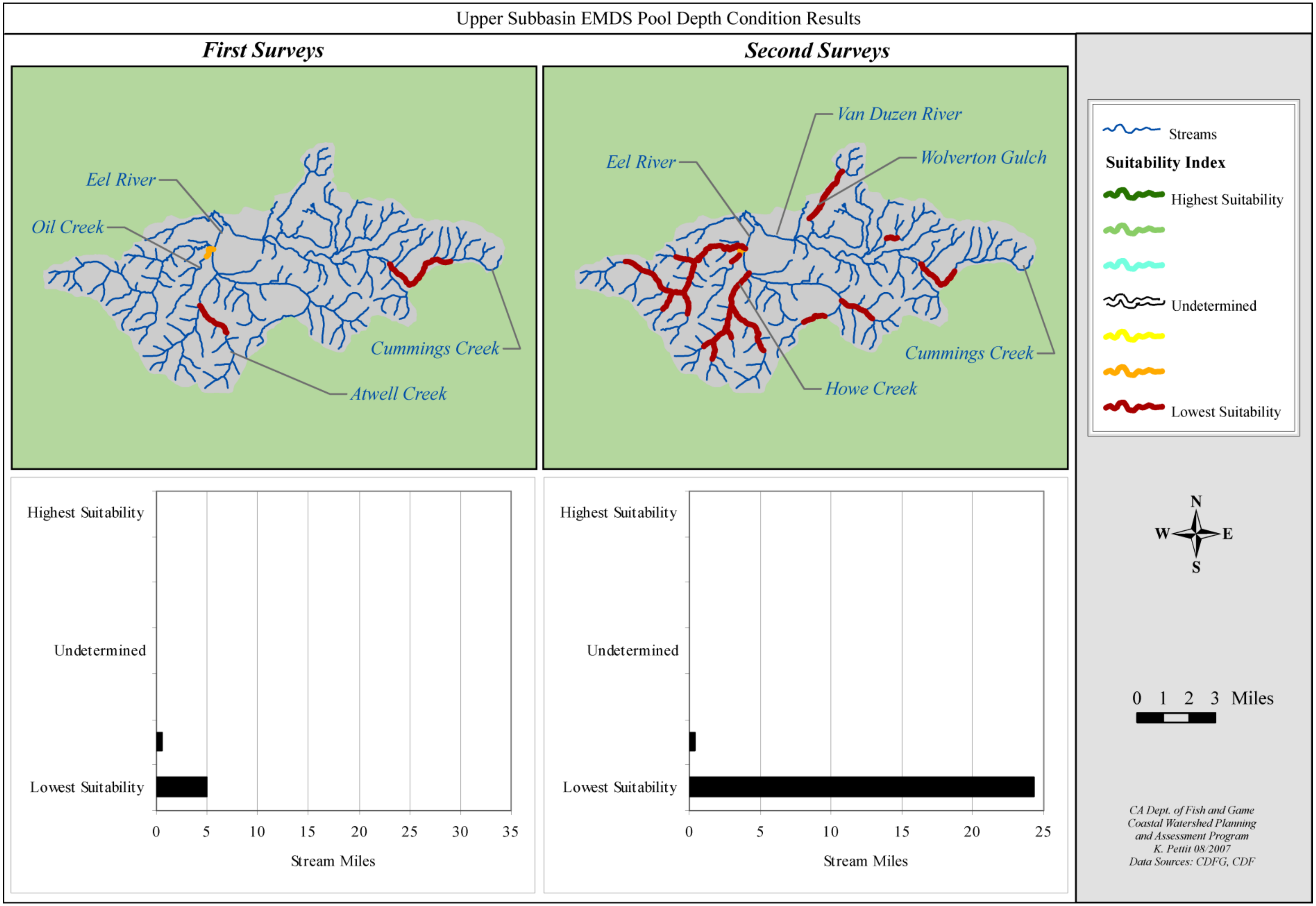

Figure 10. EMDS pool depth results for the Upper Subbasin by surveyed stream miles. First surveys of Cummings, Atwell, and Oil Creeks were completed in 1991,199, and 1999, respectively. Second surveys for the same creeks were completed in 1996, 1998, and 2002, respectively.

Pool Shelter

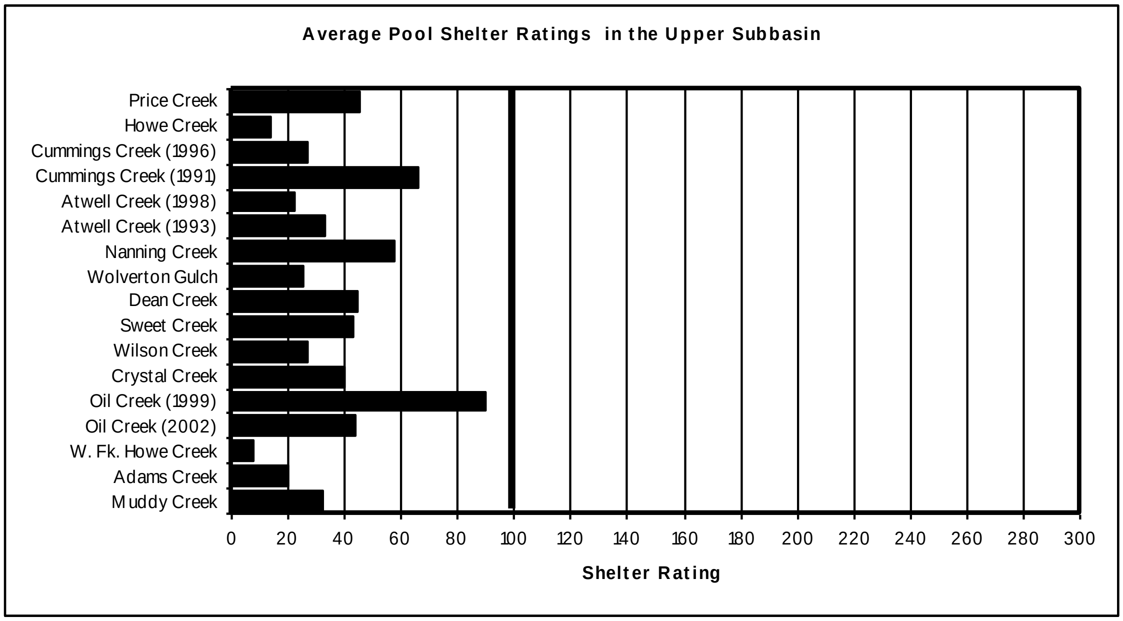

Figure 11. Average pool shelter ratings from CDFG stream surveys in the Upper Subbasin.
Streams are listed in descending order by drainage area (largest at the top).

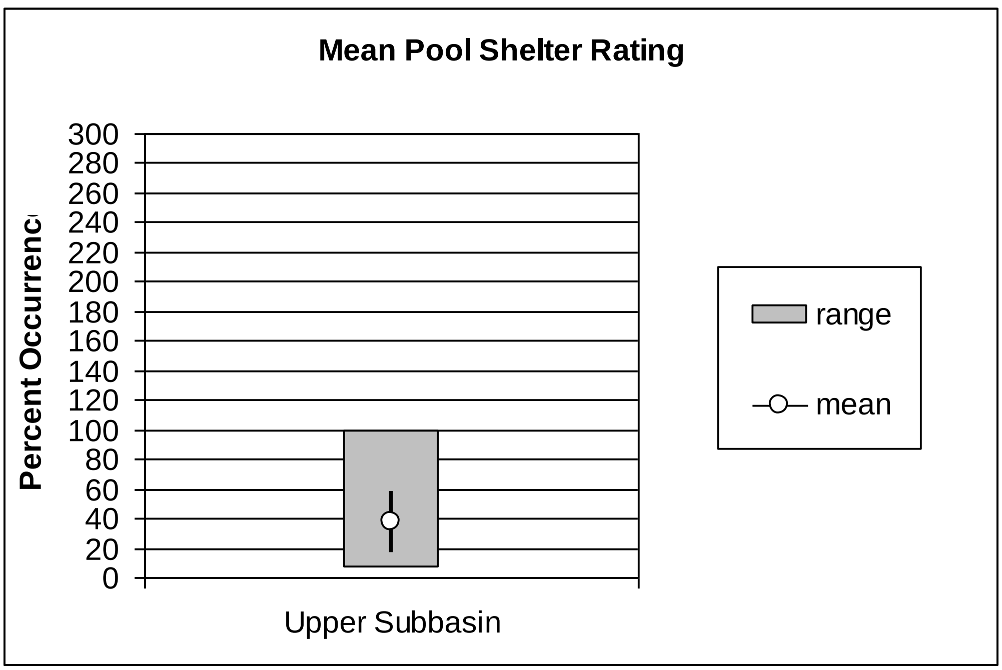

Figure 12. Pool shelter in the Upper Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described and rated in CDFG surveys.

Table 13. Mean percent of shelter cover types in pools for surveyed tributaries in the Upper Subbasin.

Stream	Undercut Banks	Small Woody Debris	Large Woody Debris	Root Mass	Terrestrial Vegetation	Aquatic Vegetation	White Water	Boulders	Bedrock Ledge
Wolverton Gulch	19.8	16.1	8.3	26.3	21.7	2	1.7	3.7	0.4
Wilson Creek	10.3	36.3	8.3	5.7	27	0	0	12.3	0
Cummings Creek (1991)	9.4	20.1	37.3	16.6	2.8	0	0.1	13.5	0
Cummings Creek (1996)	16	24	19	26	6	1	0	7	0
Price Creek	1.3	18.1	12.1	2.9	12.7	7.1	0.8	44	1
Adams Creek	13.8	2.5	7.5	6.25	1.3	0	0	68.7	0
Sweet Creek	1.3	18.8	12.5	12.5	0	0	3.8	51.3	0
Muddy Creek	7.94	5	8.24	0.88	2.06	0	7.94	57.35	10.59
Oil Creek (1999)	10	25.6	38.1	0	0.6	0	3.1	22.5	0
Oil Creek (2002)	8.3	7	69	3.3	0.7	0	1	10	0
Howe Creek	1.1	21.4	12.5	8.9	7.7	0.9	8.9	32.5	0
Atwell Creek (1993)	13	10	36	13	0	0	1	24	3
Atwell Creek (1998)	6.5	31	5	21	3	0	0	26.5	0
Crystal Creek	100	0	0	0	0	0	0	0	0
West Fork Howe Creek	5	0	7.5	0	0	0	23.8	63.8	0
Nanning Creek	4	8	55	3	4	0	2	22	2
Dean Creek	16.7	17.6	40.3	4.9	0.6	0.4	0.4	11.9	7.2

Significance: The pool shelter rating is a relative measure of the quantity and percent composition of small woody debris, root wads, boulders, undercut banks, bubble curtains, and submersed or overhanging vegetation in pool habitats. Pool shelter provides protection from predation and rest areas from high velocity flows for salmonids. Shelter ratings of 100 or less indicate that shelter/cover enhancement should be considered.

Findings: Pool shelter ratings for surveyed streams of the Upper Subbasin were all well below the target value of 100%. Shelter values of ≤30 are considered fully unsuitable. Seven surveyed reaches of Upper Subbasin streams obtained values considered fully unsuitable.

In addition to shelter complexity rating, instream shelter composition is also collected during habitat inventories. There are a total of nine cover types that are cataloged during habitat inventories. Boulders dominated the cover at over 50% in four stream of the Upper Subbasin, and were present in all streams but Crystal Creek. Small woody debris and large woody debris were also present in large quantities in a number of streams.

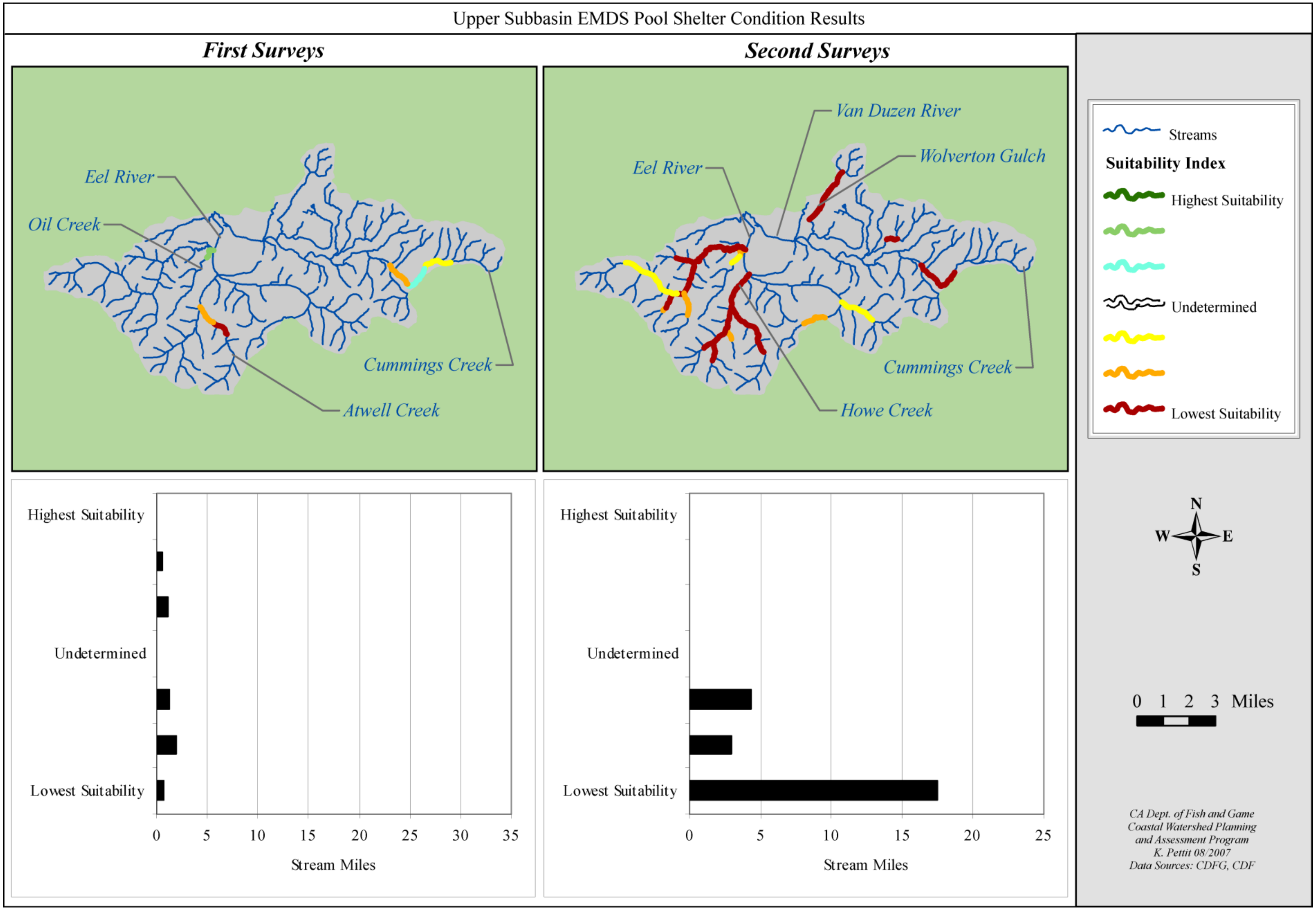

Figure 13. EMDS pool shelter results for the Upper Subbasin by surveyed stream miles. First surveys of Cummings, Atwell, and Oil Creeks were completed in 1991,199, and 1999, respectively. Second surveys for the same creeks were completed in 1996, 1998, and 2002, respectively.

Large Woody Debris

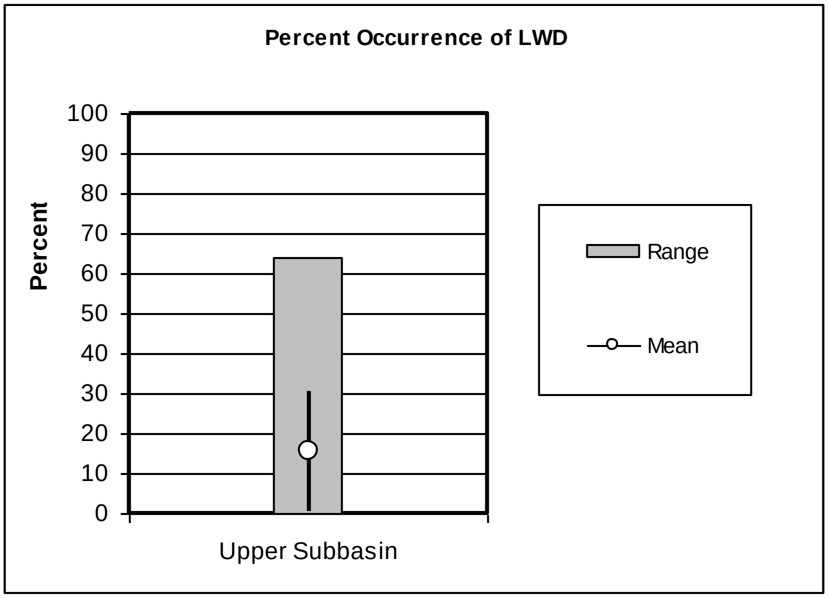

Figure 14. Large Woody Debris (LWD) in the Upper Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, etc.) is described in CDFG surveys. The dominant shelter type is determined and then the percentage of a stream reach in which the dominant shelter type is provided by organic debris is calculated.

Significance: Large woody debris shapes channel morphology, maintains organic matter, and provides essential cover for salmonids. There are currently no target values established for the % occurrence of LWD.

Findings: Large Woody Debris measurements ranged from 0 to 64 in the surveyed streams of the Upper Subbasin. The average percent occurrence of LWD for the Upper Subbasin was 15.5. The dominant shelter type recorded in most stream reaches was boulders.

Cobble Embeddedness

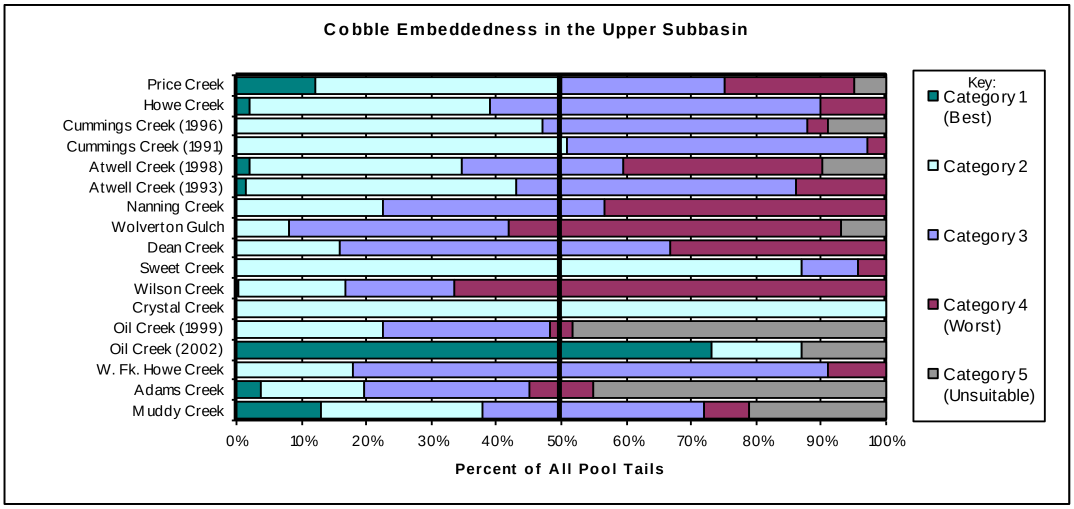

Figure 15. Cobble embeddedness categories as measured at every pool tail crest in surveyed streams in the Upper Subbasin.
Streams are listed in descending order by drainage area (largest at the top).

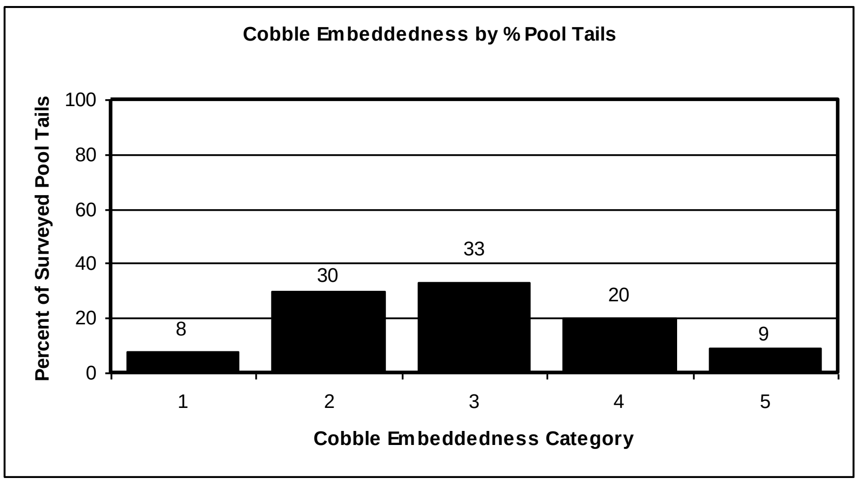

Figure 16. Cobble Embeddedness in the Upper Subbasin.
Cobble Embeddedness will not always sum to 100% because Category 5 (not suitable for spawning) is not included.

Significance: Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments decrease successful spawning and incubation. Cobble embeddedness is t percentage of an average sized cobble piece at a pool tail out that is embedde in fine substrate. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded, and category 4 is 76-100% embedded. Cobble embeddedness categories 3 and 4 are not within the fully supported range for successful us by salmonids.

Findings: Only Oil Creek (2002) met the target value for cobble embeddedness, with measurements reaching 73% in category 1. Embeddedness measurements also indicate suitable conditions in Crystal Creek and Sweet Creek, with 100% and 87% cobble embeddedness in category 2, respectively. Additionally, Price Creek, and Cummings Creek reached approximately 50% embeddedness in categories 1 and 2 in all surveys. The other surveyed streams indicated conditions that were unsuitable for successful salmonid spawning and incubation. For example, Wilson Creek had the highest value in category 4 at nearly 67%; approximately 83% of the surveyed stream was unsuitable for salmonids. Ninety-two percent of Wolverton Gulch carried unsuitable embeddedness measurements for salmonids, with 51% of its surveyed length falling in category 4.

The embeddedness measurements in Oil Creek 2002, which met the target value, are in stark contrast to the 1999 survey, when only 23% of the surveyed stream measured in categories 1 and 2. The other two creeks with multiple years of surveys, Atwell and Cummings Creeks, had similar results in both years.

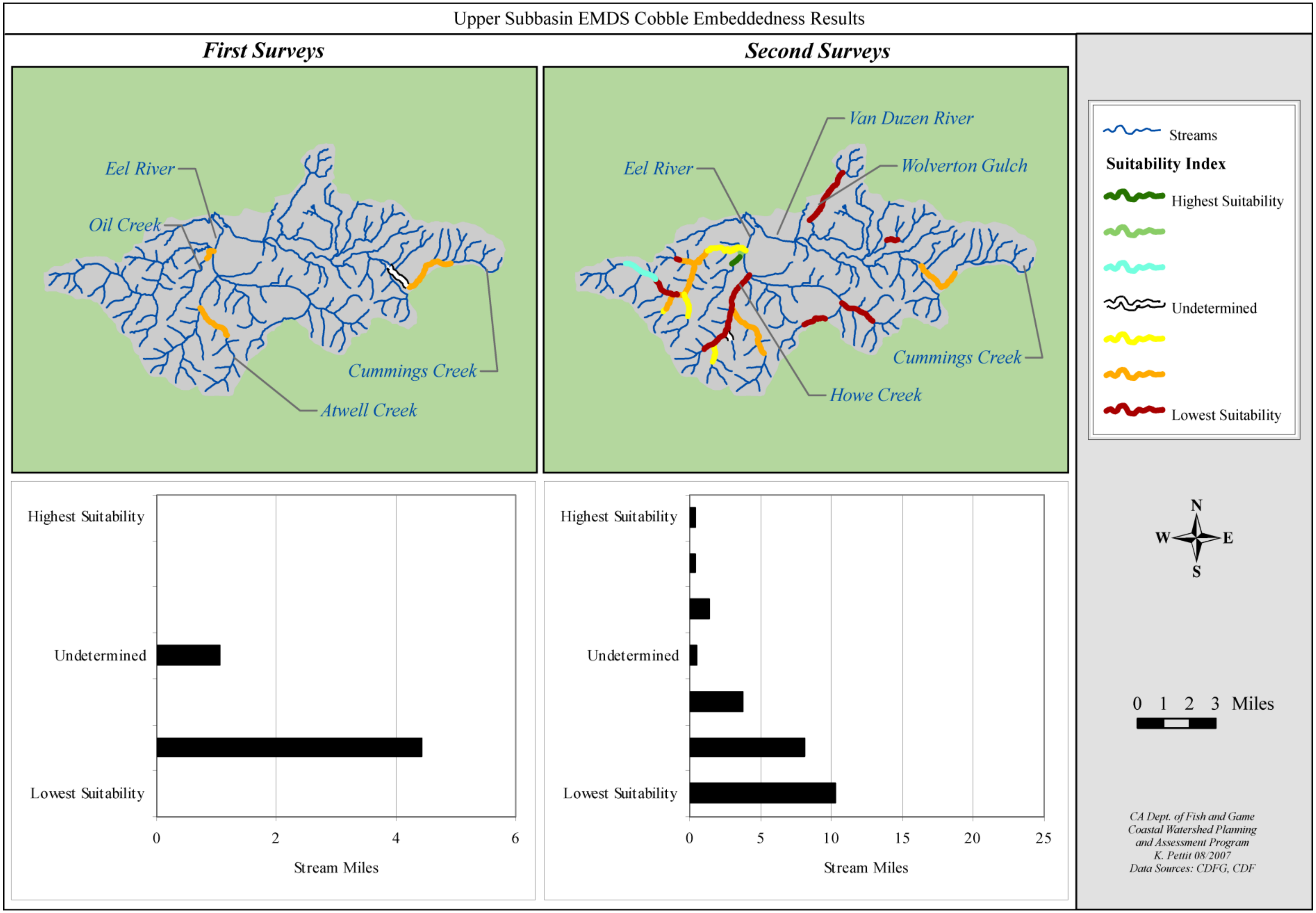

Figure 17. EMDS cobble embeddedness results for the Upper Subbasin by surveyed stream miles. First surveys of Cummings, Atwell, and Oil Creeks were completed in 1991,199, and 1999, respectively. Second surveys for the same creeks were completed in 1996, 1998, and 2002, respectively.

Water Quality

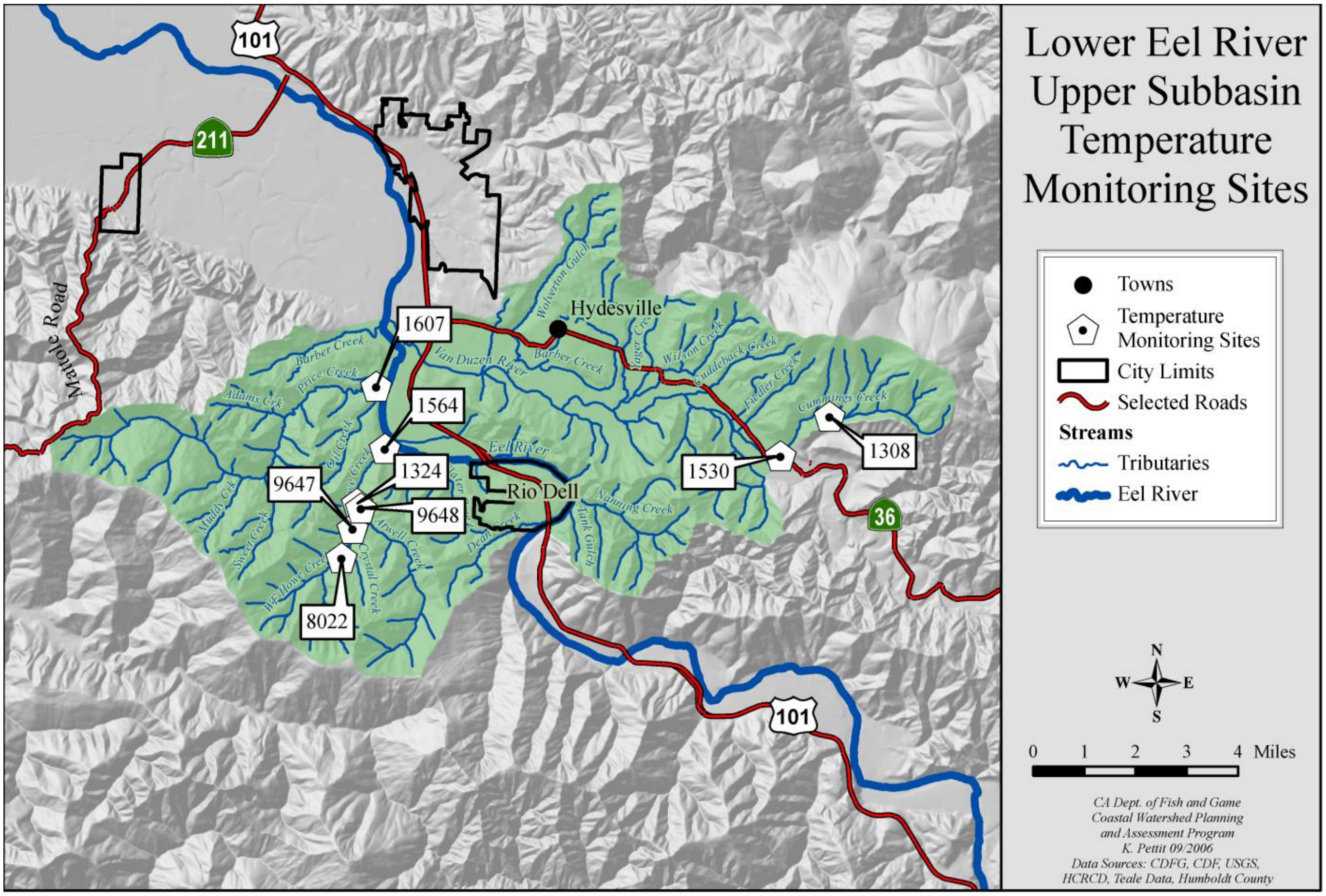

Figure 18. Locations of temperature monitoring sites in the Upper Subbasin.

Table 94. Maximum weekly average temperatures and maximum daily average temperatures collected in the Upper Subbasin.

Creek	Site	Max MWAT (°F)	MWAT Range (°F)	Max Daily Average (°F)	Years of Data
Fully Suitable (50-60°F)					
Cummings Creek	1530	60	59-60	61	4
Cummings Creek	1308	60	58-60	61	3
Howe Creek	8022	60	--	61	1
Somewhat Unsuitable (65°F)					
Howe Creek	9647	65	64-65	65	2
Moderately Unsuitable (66-67°F)					
Price Creek	1607	66	65-66	68	4
Howe Creek	1324	66	63-66	67	3
Howe Creek	1564	67	64-67	67	7

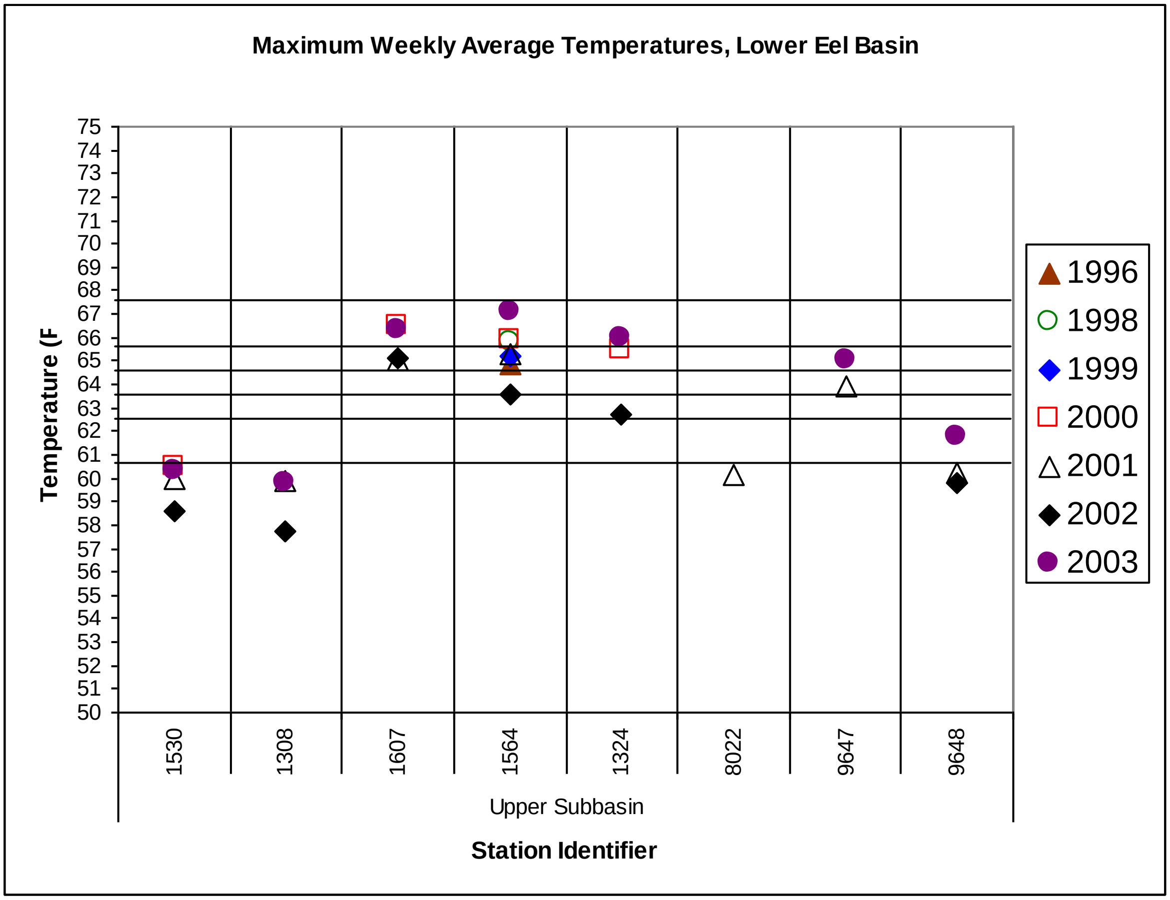

Figure 19. Maximum weekly average temperatures recorded at sites in the Upper Subbasin.

Significance: CWPAP considers suitability ratings for MWATs as: fully suitable at 50-60°F, moderately suitable at 61-62°F, somewhat suitable at 63°F, undetermined at 64°F, somewhat unsuitable at 65°F, moderately unsuitable at 66-67°F, and fully unsuitable at ≥68°F.

Findings: Eight locations within the Upper Subbasin were continuously monitored for water temperature (Figure 18). All temperature monitoring sites were located in tributaries, and no location recorded MWATs higher than 68°F, or seasonal maximum of over 75°F (Table 9, Figure 19). This subbasin had the highest number of locations with repeat sampling, at seven out of the eight sites. Additionally, the Howe Creek watershed had a total of 5 locations: four located on Howe Creek, and one on Atwell Creek.

Water temperatures were measured in Howe Creek over the longest period of record (one station recorded 7 years of data). Temperature monitors in this creek recorded MWATs that fell in several of the suitability categories. The only Howe Creek temperature monitor that measured MWATs considered fully suitable was deployed for one season only. This monitor was located the furthest upstream of any of the other three, which can explain its collection of cooler temperatures. The CDFG habitat inventory of Howe Creek confirms that canopy density increased in the upper reach of survey. The other Howe Creek monitoring sites (9647, 1324, and 1564 in order from upstream to downstream) recorded increasingly warmer temperatures, respectively. In general all sites were measured over the same months (June/July to September/October), which could support the view that these temperature differences are due to location along the stream from mouth to headwaters. However, as the sampling methodology of each location from year to year is not fully known, this comparison is difficult to confirm.

The Price Creek temperature monitor was also located close to the mouth of the stream, and logged MWATs that are considered moderately unsuitable.

Water Chemistry

Table 15. NCRWQCB water quality objectives for the Eel and Van Duzen Rivers (NCRWQCB 2006d, EPA 1999).

Parameter	Standard	
	Eel River	Van Duzen River
Dissolved Oxygen	Above 7.0 mg/L 100% of the time Above 7.5 mg/L 90% of the time Above 10.0 mg/L 50 % of the time);	Above 7.0 mg/L 100% of the time Above 7.5 mg/L 90% of the time Above 10.0 mg/L 50 % of the time)
Conductivity	Below 375 micromhos 90% of the time Below 225 micromhos 50% of the time	Below 375 micromhos 90% of the time Below 175 micromhos 50% of the time
Total Dissolved Solids	Below 275 mg/L 90% of the time Below 140 mg/L 50% of the time	Below 200 mg/L 90% of the time Below 100 mg/L 50% of the time
pH	Between 6.5 and 8.5	pH (between 6.5 and 8.5) (NCRWQCB 2006d)
Turbidity	Not applicable	Recommended at no greater than 20% above background levels (TMDL)

Significance: Water chemistry interacts with basic trophic levels affecting the production and availability of food for aquatic organisms. Nutrients are often limiting factors in the biological capacity of a stream yet a proper balance is needed to prevent eutrophication. Pollutants are a concern where they interfere with the biological function of aquatic organisms, or can be a threat to those that consume them. Large sources of nutrients and pollutants are commonly municipal and industrial wastewater facilities, storm runoff, and agricultural operations. Naturally occurring nutrients and heavy metals are often found in much smaller concentrations.

Findings:

Water Chemistry Studies:

The HCRCD studied water quality conditions in the Eel River in 1996 and 1997, including temperature and macro-invertebrate surveys. Macro-invertebrate communities are closely linked to water quality and are used to determine if a water body has been impacted and to what degree. Surveys were done once in the spring and once in the fall of 1996 on Price, Howe, and Cummings Creeks. Conditions of the macro-invertebrate communities generally improved on the fall survey due to seasonal changes. However, Price Creek had a high percentage of dominant taxa, a low Simpson Index rating, and a high Modified Hilsenhoff rating in both spring and fall, all of which put it in the “highly impacted” category.

Findings:

Wastewater Facilities:

While the Fortuna wastewater treatment facility discharges the highest volume of effluent in the Lower Eel River Basin, the cumulative discharge volume of the adjacent Rio Dell and Scotia wastewater treatment facilities in the Upper Subbasin is substantial. These facilities discharge into the Eel River between October 1st and May 14th, and during the summer they discharge effluent into gravel bar percolation ponds. Both have recently been re-permitted with stipulated alterations and upgrades.

The wastewater treatment facility in Scotia, owned by Humboldt Redwood Company (formerly Pacific Lumber), is permitted to discharge up to 0.7 mgd of effluent into the Eel River during winter months. The treatment system consists of screening, grinding, and grit removal, a primary clarifier, a redwood trickling filter, a secondary clarifier, a chlorine contact chamber, three treatment/polishing ponds, and a sludge digester. A Cease and Desist order was issued in 2006 for not removing 85% of suspended solids and biological oxygen demand (BOD) from influent. The influent had become dilute, making removal of 85% of suspended solids and BOD difficult. Under its new permit, the Scotia facility is required to conduct a "special study" to determine if effluent is moving from the percolation ponds on the Eel River gravel bar to the Eel River itself, and if so, the permit requires alternative action. This has already been shown to occur just downstream at the Rio Dell facility, so, in all likelihood, Scotia will need to find a new discharge site for its summer time effluent. Humboldt Redwood Company will have until 2010 to resolve the issues addressed in their new permit (NCRWQCB 2006a, 2006b).

In their Eel River Watershed Management Area document, the Water Board states that Scotia has "a municipal runoff problem and Humboldt Redwood Company has a permitted ash dump where Regional Water Board staff is currently taking action. There are also upland and in-stream quarries near Scotia that need investigation" (NCRWQCB 2005b).

The Rio Dell wastewater treatment facility serves the City of Rio Dell and is located at 475 Hilltop Drive in Rio Dell on the banks of the Eel River, and east of Highway 101. This facility is permitted to discharge up to 0.9mgd of effluent to the Eel River during winter months. The facility provides collection, sedimentation, biological treatment using rotating biological contactors, disinfection, and dechlorination of wastewater. Between May 15th and September 30th, the facility discharges effluent into a percolation pond, approximately 100 feet wide by 300 feet long on a thin gravel bar underlain by clayey soils. This design has allowed effluent to surface on the gravel bar and discharge directly into the river (NCRWQCB 2005a). Stipulations of the new permit require compliance with priority pollutant limitations for effluent. There are 126 priority pollutants recognized as having heightened detrimental effects on humans and aquatic organisms, four of these are a concern at this facility – copper, cyanide, dichlorobromomethane, and MtBE (a gasoline additive) (NCRWQCB 2007, Lisa Bernard personal comm.). According to the The City of Rio Dell website (http://www.riodellcity.com/home.html) the city has completed all the required environmental documents and are continuing to move forward with improvement projects to address all issues concerning the NCRWQCB's Cease and Order by achieving priority pollutant compliance.

Fish Passage Barriers

Potential fish passage barriers, specifically stream crossings were surveyed in the Upper Subbasin as a part of the coastal Humboldt County culvert inventory and fish passage evaluation conducted by Ross Taylor and Associates (2001) (Table 10). Criteria for priority ranking included salmonid species diversity, extent of barrier present, culvert risk of failure, current culvert condition, salmonid habitat quantity, salmonid habitat quality, and a total salmonid habitat score.

As a part of this inventory five stream crossing were evaluated in the Upper Subbasin. Two of these crossings are in the Barber Creek (Eel River) drainage: one at Grizzly Bluff Road and the other at Price Creek School Road. These both ranked in low-priority (#56, and 57 out of 67) for restoration work. The Grizzly Bluff Road culvert has a high jump from the culvert through the inlet and may be have velocity barriers within the culvert. The Price Creek School Road culvert is in poor condition and inadequately sized. This crossing is upstream of the box culvert and is a nearly complete barrier to juvenile fish due to velocity. There is also a six foot tall vertical concrete falls 100 yards upstream from the mouth of Barber

Creek (Eel) that poses a barrier to fish passage (CDFG 1973). However, the channel does have small steps in it that should allow adult salmonids access (CDFG 2007).

The other three crossings evaluated in the inventory are in the Wolverton Gulch draingage: two on River Bar Road and one on Rohnerville Road. All ranked low in priority (#48, 49, and 67 out of 67) for restoration work (CDFG 2005). The two most downstream culverts on Wolverton Gulch are most likely not barriers for migrating adult salmon; however the most downstream culvert is probably a barrier to juvenile salmonids. The most upstream culvert is not a barrier for adult salmon, but this culvert along with the upper downstream culvert is temporary barriers to juveniles due to velocity.

Additional fish passage problems on Upper Subbasin streams have been identified. Price Creek has several temporary small rock dams that have been constructed to facilitate water diversion (CDFG 1999). These dams block upstream and downstream migration by juvenile salmonids at observed flows. Furthermore, if the material forming the dams is too large, then it may impede salmonid spawning by covering pool tail-outs with particles that are either too large to be used as spawning substrate or are too large to be removed by typical autumn stream flows prior to the upstream migration by adult salmon.

The mouths of Dean, Cummings, and Fiedler Creeks have poor access for migrating adult salmon (CDFG 1992, 1996). There is a bedrock chute at the mouth of Dean Creek that poses a partial salmonid barrier (CDFG 2005).

A concrete box culvert where Blue Slide Road crosses Oil Creek may pose a fish passage barrier. Biological sampling conducted during the inventory of 2002 found coho salmon below but not above this culvert. Blue Slide Road also crosses Slater Creek, and this culvert is a total salmonid barrier (CDFG 2005). Other suspected passage problems occur at a culvert at stream mile 0.6 of Adams Creek (CDFG 2002).

Highway 36 crosses Barber, Fischer, and Wilson Creeks and an unnamed tributary to the Van Duzen River. All of these culverts were found to be partial barriers to salmonids (CDFG 2005).

Sometimes, large debris accumulations in streams can cause fish passage barriers. These are noted in CDFG stream inventories. Stream inventories in the Upper Subbasin found possible problems of this sort on Adams, Atwell, West Fork Howe, Dean, Nanning and Cummings Creeks and Wolverton Gulch.

Table 16. Culverts surveyed for barrier status in the Upper Subbasin (Taylor 2001).

Stream Name	Road Name	Priority Rank	Barrier Status	Upstream Habitat
Barber Creek (Eel)	Grizzly Bluff Road	56	Very high jump, lack of depth and possible velocity barriers within culvert.	Approximately 2.8 miles of poor salmonid habitat.
	Price Creek School Road	57	Not a barrier for adults. Nearly a complete barrier for juveniles due to excessive velocities over a wide range of migration flows.	Approximately 1.8 miles of likely poor salmonid habitat.
Wolverton Gulch	River Bar Road	48	Probably not a barrier for adults. Probably a barrier to juveniles due to excessive velocities at a range of migration flows.	Approximately 3.8 miles of poor salmonid habitat.
	River Bar Road	49	Probably not a barrier for adults. Temporary barrier to juveniles due to excessive velocities at the upper range of migration flows.	Approximately 3.8 miles of poor salmonid habitat.
	Rohnerville Road	67	Not a barrier for adults. Probably a temporary barrier to juveniles due to excessive velocities at the upper range of migration flows.	Approximately 2.7 miles of fair salmonid habitat.

Habitat Conclusions

Streams surveyed before 1990 and habitat inventories from 1991 to 2002 were compared to indicate changes between historic and current conditions. Data from older stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair, and poor are based on the judgment of the biologist or scientific aid who conducted the survey. The results of historic stream surveys are qualitative and cannot be used in comparative analyses with quantitative data provided by habitat inventory surveys with any degree of accuracy. However, the two data sets can be compared to show general trends.

Where habitat data were available from both older stream surveys and recent stream inventories it appeared that habitat conditions degraded in five of the eight streams (Table 17). Spawning habitat, pool habitat, and shelter decreased in Cummings and Sweet creeks while pool habitat and shelter decreased in Howe Creek. Pool habitat decreased in Wolverton Gulch and spawning habitat decreased in Atwell Creek.

Instream habitat conditions were generally poor in this subbasin at the time of more recent CDFG surveys (late 1990s and early 2000s). Surveyed reaches fell below target values and were evaluated as unsuitable for salmonids by EMDS for nearly all habitat characteristics, except canopy density (Table 18). The only exception occurring in Oil Creek, where embeddedness achieved a suitable rating in 2002 (pool shelter was rated suitable in 1999 but not during the 2002 survey). Pool quality and pool depth values were calculated to be the lowest suitability in 15 of the 17 surveys. Moreover, the majority of streams contained the lowest or next to lowest suitability rating for pool shelter and embeddedness.

These habitat factors are likely limiting factors to the salmonid populations in nearly all the surveyed streams within the subbasin. High sediment loads in these streams results in decreased pool size, shallow pool depths and highly embedded spawning areas.

Canopy density was suitable on all surveyed streams except for Sweet, Howe, and Price Creeks. Accordingly, water temperatures were found to be unsuitable for salmonids in Howe, Price Creeks, and Cummings Creek. Water temperature is likely a limiting factor for salmonids at these locations. It is important to note that current canopy density measurements do not take into account differences between smaller, younger riparian vegetation versus the larger microclimate controls that are provided by old and second growth forest canopy conditions.

Oil, Atwell, and Cummings Creeks have two years of survey data. Because these surveys are not replicates, they cannot be used to quantitatively compare values between years. However, these surveys do have some overlap in area. Comparison of these survey data can, therefore, provide some description of changes in habitat between years. For example, pool shelter for Oil Creek in 1999 is considered suitable, however, in 2002 these values fall to unsuitable levels. Embeddedness values in this same stream were unsuitable in 1999 and suitable in 2002.

Although macroinvertebrate data indicate that Price Creek is a highly impacted system, there is not enough data to determine whether water chemistry is a limiting factor in tributaries in this subbasin. Additionally, the NCRWQCB has identified several concerns at the Scotia and Rio Dell wastewater treatment plants, but no specific data exists to determine if water chemistry is impacting salmonids in the mainstem Eel River.

Table 17. Comparison between historic habitat conditions with current habitat inventory surveys in the Upper Subbasin.

Stream	Canopy Cover		Spawning Conditions		Pool Depth/Frequency		Shelter/Cover		Summary of Changes from Historic to Current
	Historic	Current	Historic	Current	Historic	Current	Historic	Current	
Wolverton Gulch	ND	Fully suitable	Poor	Fully unsuitable	2 to 3 feet deep	Fully unsuitable	ND	Fully unsuitable	Pool habitat decreased
Cummings Creek	ND	Suitable	Good	Unsuitable	Good	Fully unsuitable	Good	Fully unsuitable	Spawning habitat, pool habitat, and shelter decreased
Price Creek	ND	Unsuitable	ND	Unsuitable	Fair	Fully unsuitable	Fair	Fully Unsuitable	Pool habitat and shelter remained similar
Sweet Creek	ND	Unsuitable	Good	Unsuitable	Good	Fully unsuitable	Good	Fully Unsuitable	Spawning habitat, pool habitat, and shelter decreased
Oil Creek	ND	Fully suitable	Good	Suitable	3 inches deep	Unsuitable	ND	Fully Unsuitable	Habitat remained similar
Howe Creek	ND	Unsuitable	ND	Unsuitable	Good	Fully unsuitable	Good	Fully unsuitable	Pool habitat and shelter decreased
Atwell Creek	Averaged 80%	Suitable	Numerous	Unsuitable	ND	Fully unsuitable	ND	Fully unsuitable	Spawning habitat decreased
Nanning Creek	85% canopy	Suitable	15% gravel substrate	Fully unsuitable	1 inch to 1 feet deep	Fully unsuitable	ND	Fully Unsuitable	Habitat remained similar

*ND is no data available
Where multiple years of historic streams surveys were available, the oldest surveys were used.

Table 18. EMDS reach condition results for the Upper Subbasin.

Stream	Year	Canopy	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Muddy Creek	2002	++	---	---	--	-
Adams Creek	2002	+++	---	---	---	--
West Fork Howe Creek	1998	+++	---	---	---	---
Oil Creek	1999	++	--	--	++	--
	2002	+++	--	--	--	++
Crystal Creek	2002	++	---	---	--	U
Wilson Creek	1991	+	---	---	---	---
Sweet Creek	1999	-	---	---	--	-
Dean Creek	1992	+++	---	---	--	---
Wolverton Gulch	1997	+++	---	---	---	---
Nanning Creek	1992	+	---	---	-	---
Atwell Creek	1993	+++	---	---	--	--
	1998	++	---	---	---	--
Cummings Creek	1991	++	---	---	-	-
	1996	++	---	---	---	--
Howe Creek	1998	--	---	---	---	--
Price Creek	1999	--	---	---	--	--
Upper Subbasin		+	---	---	--	--

Key: +++ = Highest Suitability U = Insufficient Data or Undetermined - - - = Lowest Suitability

Restoration Projects

Far more restoration activity has been done in the Upper Subbasin than the other subbasins in the Lower Eel Basin. To date, 117 projects have been completed and another sixty are on-going. The three most common types of restoration projects are road and stream crossing upgrades, bank stabilization and livestock riparian exclusion, followed closely by installation of instream structures for the creation of complex habitat. Projects have been spread relatively evenly over the subbasin with a concentration in the Howe and Price Creeks basins largely related to the Howe Creek Ranch acquisition and conservation project. Specific projects are listed below along with an approximate number of that type of project (many projects have more than one component so these numbers may be an underestimate).

- Sediment and temperature improvement projects on the Van Duzen River conducted by the HCRCD;
- Erosion assessment on Carlotta tract of the Van Duzen River;
- Water quality control via animal waste improvement projects;
- Temperature and macro-invertebrate monitoring by HCRCD;
- The lower 10.5 miles of the Van Duzen River were flown to assess restoration potential and identify watershed problems;
- Barber Creek riparian planting;
- Yager Creek bank stabilization projects including boulder weir and willow mattresses (6 projects);
- Boulder and bio-engineered bank stabilization on the Van Duzen River (5 projects);
- Erosion assessment on Simpson Timber Company land in the Fiedler, Cuddeback, and Wilson Creek watersheds;
- “Salmon in the Classroom” curriculum at Hydesville, Cuddeback, and Rio Dell elementary schools.

<u>Wolverton Gulch:</u>

- Upslope management with tree planting and back stabilization;
- Barber Creek riparian vegetation restoration and livestock crossing upgrades (1,700ft on Wolverton Gulch and 300ft on Barber Creek);
- Fish passage improvement.

<u>Cummings Creek:</u>

- Instream structures and bank stabilization;
- Interpretive information and trail;
- Basin wide upstream erosion and prevention assessment and watershed planning;
- Road decommissioning and relocation;

- Road decommission monitoring;
- Stream crossing upgrades.

Price Creek watershed (including Grouse, Muddy, and Sweet Creeks):

- Livestock exclusionary fencing (9 projects) and riparian planting (3 projects);
- Off stream watering sites (8 projects);
- Storm proofing roads including an inner gorge roadway and road decommissioning and stream crossing upgrade or decommissioning (30 projects);
- Ortho-imaging for watershed planning;
- Salmon Limiting Factors assessment and restoration priorities for two ranches;
- Bank stabilization and instream structures (10 projects);
- Baffles installed on a culvert on Oil Creek;
- Stream crossing decommissioning on Sweet Creek.

Howe Creek watershed (including Crystal and Refuge Creeks):

- Bank stabilization (7 projects) and instream structures and maintenance (12 projects);
- Land acquisition for resource conservation;
- Livestock exclusionary fencing (15 projects) and tree planting (6 projects);
- Off stream watering sites (4 projects);
- Improve temporary stream crossings and culverts (7 projects) and storm proofing roads, stream crossings (14 projects);
- Culvert inventory;
- Livestock trail hardening (3 projects);
- Fish passage improvement.

More information such as date and specific location can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis.edu/nrpi/).

Two large scale restoration efforts have been conducted, one in Cummings Creek watershed and the other on Howe Creek Ranch which encompasses portions of both Howe Creek and Price Creek. The Cummings Creek Watershed Recovery Plan developed in 1996 out of a situation where a primary access road next to the creek had failed. In the interest of the residents' safety and the health of Cummings Creek, a watershed assessment was conducted to look at old logging roads and other sediment sources. Appropriate solutions were implemented through the Cummings Creek Watershed Advisory Council. In addition to the components in the list above, the creek was surveyed by CDFG for salmonid habitat twice and for spawning activity over several years. In 2000, turbidity and temperature stations were installed as well as permanent photo points and cross sections for monitoring purposes (Matson 2000).

The Howe Creek Ranch was bought from the Hackett family by a land trust, with the help of CDFG and the State Coastal Conservancy, with a permanent conservation easement in place. This allowed this 4,400 acre ranch to adopt Best Management Practices and create conservation enclaves. The goals of the easement include aquatic habitat restoration, upslope and riparian erosion control, and riparian protection via livestock exclusionary fencing and timber harvest buffers, while still maintaining a ranching and timber harvest economy. This experimental and progressive approach will hopefully become established throughout the region as a way to ensure future protection of aquatic resources.

Integrated Analysis

Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFG stream inventories provide a list of recommendations that address those conditions that did not reach target values (see the Fish Habitat section of this subbasin). A CDFG biologist selected and ranked habitat improvement recommendations for 17 surveys in the Upper Subbasin (Table 19). The tributary recommendation process is described in more detail in the Synthesis section of the Basin Profile.

In order to compare tributary recommendations within the subbasin, the recommendations of each stream were collapsed into five target issue categories (Table 20). The top three recommendations of each stream are considered to be the most important, and are useful as a standard example of the stream. When examining recommendation categories by number of tributaries, the most important target issue in the Upper Subbasin is Erosion/Sediment.

However, comparing recommendation categories in the subbasin by number of tributaries can be confounded by the differences in the length of survey for each tributary. Therefore, the number of stream miles within the Upper Subbasin assigned to various recommendation categories was calculated (Figure 20). By examining recommendation categories by number of stream miles, the most important target issue remains Erosion/Sediment. Instream Habitat and Riparian/Water Temp are also in the top tier of recommended improvement activities. Because of the high number of recommendations dealing with these target issues, high priority should be given to restoration projects that emphasize sediment reduction, riparian vegetation planting, pools, and cover.

Table 19. Occurrence of stream habitat inventory recommendations for streams of the Upper Subbasin.

Stream	Survey Length (mile)	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Muddy Creek	0.8		3			1	2				
Adams Creek	0.8	3	4			1	2	5	6		7
West Fork Howe Creek	0.4	4	5			3	2	1			
Oil Creek (1999)	0.5	1	2			4			3		
Oil Creek (2002)	0.8						2				1
Crystal Creek	0.5			2	1						
Wilson Creek	0.5	2			1	3	4				5
Sweet Creek	0.9	1		2		3	4				
Dean Creek	1.0	3	4			1	2		5		6
Wolverton Gulch	2.5	1	2			4	3	5	6	7	
Nanning Creek	1.4					2	1		3		
Atwell Creek (1993)	1.6	1				3	4		2		
Atwell Creek (1998)	2.4	1	2	5		3	4		6		
Cummings Creek (1991)	3.4	2	3			1	4		5		
Cummings Creek (1996)	2.0	2	1	5		4			3		
Howe Creek	4.0	1	2	5		3	4		6	7	
Price Creek	6.9	3	4	1		5	6			2	7

Table 110. Top three ranking recommendation categories by number of tributaries in the Upper Subbasin.

Upper Subbasin Target Issue	Related Table Categories	Count
Erosion / Sediment	Bank / Roads	19
Riparian / Water Temp	Canopy / Temp	5
Instream Habitat	Pool / Cover	18
Gravel / Substrate	Spawning Gravel / LDA	5
Other	Livestock / Barrier	2

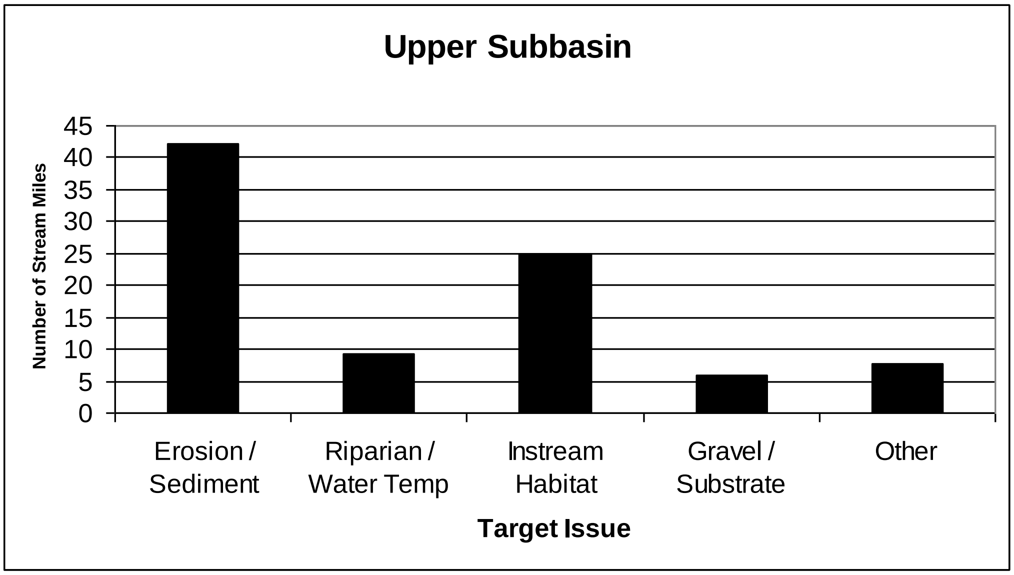

Figure 20. Recommendation target issues by stream miles for the Upper Subbasin.

Refugia Areas

The interdisciplinary team identified and characterized refugia habitat in the Upper Subbasin by using professional judgment and criteria developed for north coast watersheds (Table 27). The criteria included measures of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. The team also used results from information processed by the EMDS at the stream reach scale.

The most complete data available in the Upper Subbasin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered. Salmonid habitat conditions in the Upper Subbasin on surveyed streams are generally rated as medium potential refugia.

In the Van Duzen River tributaries, no stream received a refugia ranking high than medium potential. Four streams received this ranking and two streams were rated as low quality refugia. Half of the streams were considered data limited.

In the Eel River tributaries, Oil Creek was the only stream that ranked as high potential refugia and is considered the best salmonid habitat in this subbasin. The remaining streams were split between the medium potential and low quality refugia categories. The Howe Creek watershed contained all streams with medium potential, while the Price Creek watershed contained all streams with a low quality rating. Nearly all the Eel River tributaries that were evaluated were also considered data limited. The following refugia area rating table summarizes subbasin salmonid refugia conditions.

Table 21. Tributary salmonid refugia ratings in the Upper Subbasin.

Stream	Refugia Categories				Other Categories		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area	Data Limited
Van Duzen Tributaries							
Barber Creek				x			x
Wolverton Gulch			x				
Wilson Creek			x				
Cuddeback Creek				x			x
Fiedler Creek			x				x
Cummings Creek			x				
Eel River Tributaries							
Barber Creek				x			x
Price Creek				x			
Unnamed tributary (Adams Creek)				x			x
Sweet Creek				x			x
Muddy Creek				x			x
Oil Creek		x					x
Howe Creek			x				Needs resurvey
Atwell Creek			x				
Unnamed tributary (Crystal Creek)			x				x
West Fork Howe Creek			x				x
Nanning Creek			x				x
Dean Creek			x				x

Key Subbasin Issues

- Sediment level in streams is high and creates a multitude of problems for fish habitat;
- Gravel mining practices have created a seasonal fish passage barrier at the mouth of the Van Duzen River that requires mitigation to prevent stranding of adult fish during fall migration;
- Accessibility to habitat is potentially blocked at various points in the subbasin;
- Urban and agricultural wastewater disposal poses a problem to aquatic ecosystems in the Mainstem Eel River;
- Water temperatures are stressful to salmonids in Mainstem Van Duzen and Eel Rivers and are unsuitable in some tributaries;

Responses to Assessment Questions

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

Findings and Conclusions:

- The Upper Subbasin has more tributaries and more streams sampled than the other Lower Eel subbasins. Stream inventories conducted by the CDFG on fourteen tributaries between 1991 and 2002, as well as other fish sampling data have documented the presence of Chinook, coho, and steelhead. Historical recorded data show that these salmonid species were being collected in fish rescue operations in the early 1940s;
- Prior to 1990, coho salmon were found in Wolverton Gulch, Cuddeback, Fiedler, Cummings, and Howe creeks. Since 1990, they have been detected in Cummings, Oil, Howe, and Atwell Creeks;
- Chinook spawning has been observed in Wilson, Cuddeback, Fiedler, Cummings, Price, and Atwell Creeks in recent years;
- Steelhead trout were historically found in 13 creeks. In recent years, steelhead and have been detected in ten streams: Wolverton Gulch, Wilson, Cummings, Price, Oil, Howe, West Howe, Atwell, Nanning, and Dean Creeks.
- Sacramento pikeminnow, which were first reported in the mainstem Van Duzen in 1988, have been observed in tributaries throughout the subbasin since the late 1980s (Brown and Moyle 1988);

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

Findings and Conclusions:

Flow and Water Quality:

- Water quality is being impacted by cattle that have direct access to streams;
- The cumulative discharge volume of the Rio Dell and Scotia wastewater treatment facilities is substantial. These facilities discharge into the Eel River between October 1st and May 14th, and during the summer they discharge effluent into gravel bar percolation ponds. Both have recently been re-permitted with stipulated alterations and upgrades;
- Low summer flows may be stressful to salmonids, and dry or intermittent reaches on the Van Duzen River seasonally prevent connection to the Eel River;
- Turbidity levels are high during winter rains, which correspond to salmon spawning season.

Erosion/Sediment:

- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing, and feeding habitat for salmonids. High sediment levels are confirmed by embeddedness measurements in surveyed reaches;
- The Van Duzen River is usually isolated from the Eel River in late summer and early fall due in part to increased bedload deposition at the confluence;
- Livestock have unrestricted access to many tributaries, resulting in stream bank erosion;
- Soils (and bedrock) in streams of the Upper Subbasin are prone to erosion, and slides and streambank failures have been observed to contribute fines to the streams.

Riparian Condition/Water Temperature:

- Canopy cover is poor throughout the basin, and does not meet the target value of 80% coverage in eight of the 17 surveys of the subbasin. What canopy is available over streams is primarily made up of deciduous vegetation, as opposed to historically present coniferous vegetation;
- A 1998 study done by Humboldt County RCD showed maximum weekly temperatures above 20 degrees Celsius (68 degrees Fahrenheit) in the Eel River at the confluence with the Van Duzen River from July 1st through mid September, 1996, as well as in the Van Duzen River at the 101 bridge during that same timeframe;
- Sites monitored in Howe and Price Creeks in were found unsuitable, recording maximum weekly temperatures above 65 degrees Fahrenheit in June through October over several years.

Instream Habitat:

- High quality salmonid habitat is lacking in all surveyed reaches of the Upper Subbasin streams, and is evidenced by the low percentage of overall pool habitat by surveyed stream length, the high percentage of shallow pools and low levels of pool shelter cover;
- None of the surveyed streams met target values of pool depth. More shallow pools by survey length were encountered in this subbasin than in the Middle Subbasin;
- Lack of adequate pool shelter is a widespread issue in the subbasin. Every stream surveyed in this subbasin with the exception of Oil Creek has pool shelter values that were below suitable and none met target values. Sedimentation of coarse material can affect recruitment of large woody debris, and both fine and coarse sediment can fill in hiding places around shelter components such as boulders and logs;
- Limited historic stream surveys, prior to the impacts of extensive land use activities and the floods of 1955 and 1964, generally indicated good spawning and pool conditions, except for fair conditions on Price Creek.

Gravel/Substrate:

- Substrate embeddedness was very high on Wolverton Gulch, Wilson Creek, Dean Creek, Nanning Creek, and Westfork Howe Creek. With the exception of Oil Creek, all streams surveyed were poorly suited for spawning.

Refugia Areas:

- Salmonid habitat conditions on surveyed streams are generally rated as medium potential refugia. Oil Creek provides the best salmonid habitat of Eel River tributaries and was the only stream in the subbasin that received a high potential rating;
- Medium potential refugia areas that drain into the Eel River include Howe Creek and its tributaries, Nanning Creek and Dean Creek;
- Four out of the six tributaries of the Van Duzen River received a medium potential refugia category

rating. In general, the tributaries located in the eastern portion Van Duzen study area provided the best potential refugia of the Van Duzen tributaries.

Barriers and Other Habitat Issues:

- The mouth of the Van Duzen River, if left alone, creates a barrier to adult fish passage due to its broad, braided and shallow low flow channel. Cooperation between the CDFG and local gravel mining companies has led to the seasonal installation of high gradient “barrier” culverts which prevents adult salmon from entering the Van Duzen River and getting stranded in low flow conditions until higher flows supersedes the need for the culverts;
- Log debris accumulations occur on Cummings, Dean, Atwell, West Fork Howe, Adams, and Nanning Creeks, and Wolverton Gulch;
- Culverts on Adams and Oil Creeks may be barriers to fish passage;
- Barber Creek and Wolverton Gulch each contain several road crossings that are not problematic for adult fish, however, they are barriers for juvenile salmonid passage;
- Rock dams occur on Price Creek and may pose as barriers to fish passage;
- The mouth of Dean Creek is a perched sediment delta and potentially acts as a barrier to fish passage;
- Connectivity at the mouths and lower reaches of Feidler and Cummings Creeks and Wolverton Gulch may be an issue due to sedimentation.

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

Findings and Conclusions:

- Soils and bedrock of the Upper Subbasin are easily eroded;
- The two most common geologic formations in this subbasin are the Wildcat Formation, which is comprised of uniformly fine sediment and is highly erosive, and the Coastal Belt Melange Formation, which is even more erosive but contains a wide range of sediment sizes from boulders to silt;
- Soils of the Upper Subbasin are susceptible to erosion, and slides from the stream banks and roads have been observed to contribute fines to the stream;
- Filling of pools by sediment is an issue in every creek surveyed in this subbasin. The majority of streams were of the lowest suitability in terms of pool depth and frequency;
- Uplift has increased the erosion potential of the area;
- Rapid incision rates of the mainstem and its tributaries have left very steep, high banks which increase its likelihood for rockfalls and landslides;
- Frequent landslides especially during heavy storm events and/or seismic events contribute a significant amount of fine sediments to the stream;
- Several faults cut through this basin weakening bedrock and increasing the potential for seismic triggering of landslides;
- Stream banks become saturated during seasonal heavy precipitation, and are extremely vulnerable to sliding during prevalent earthquakes;
- Kelsey (1977) posits that the Van Duzen River has aggraded significantly since the 1964 flood upstream of, but likely applying to this study area;
- Climatic models predict warmer summers and milder winters, which would have an effect on stream flows (less summer flows), stream water temperatures (higher water temperatures), and water quality (reduced water quality). Any combinations of these factors would be detrimental to portions of the

salmonid life cycle.

How has land use affected these natural processes?

Findings and Conclusions:

- Seasonal flooding is increasingly common throughout this subbasin. Disturbance of the basin's already unstable soils by land use activities has altered runoff rates;
- In 2003, Rio Dell's wastewater treatment facility received a 'cease and desist' order from the Regional Water Quality Control Board for problems arising from sludge removal and summer discharge into the Eel River through gravel bar percolation. The city has completed all the required environmental documents (2009) and is continuing to move forward with improvement projects to address all issues concerning the NCRWQCB's Cease and Order by achieving priority pollutant compliance.
- Livestock grazing operations occur in 11% of subbasin. Wastes from the beef and dairy cattle industry have affected the water quality of many of the subbasin's streams;
- Bar skimming had been the preferred method of gravel extraction on the Lower Van Duzen River up until 1996. This method has been shown to widen channels thus creating a shallow, braided reach;
- In 2001, 136 adult migrating Chinook salmon were stranded at the mouth of the Van Duzen River likely exacerbated by years of widening of the low flow channel from gravel mining and aggradation;
- Since 2003, the lower four miles of the Van Duzen River are purposefully blocked to salmonids by three temporary culverts. A single threaded channel is also dug through the lower stranding reach. This ensures that migrating adult salmonids do not get stranded in the shallow water conditions that exist until rains have created sufficient flows for upstream passage;
- The building of roads throughout the subbasin has created fish passage barriers in some of the tributaries of the Van Duzen River and Eel River (see Barriers and Other Habitat Issues);
- Logging has occurred (1989-2005) in both the Wildcat Formation and the Coastal Belt Melange Formation. Some areas have been entered more than once, and different yarding and harvesting methods have been used across the subbasin; these methods influence the impact logging can make on a watershed;
- Riparian vegetation has been cleared through past timber harvest activities. Canopy cover over surveyed streams of this basin was predominantly composed of deciduous vegetation. Smaller trees adjacent to streams result in a reduction in the recruitment potential of large woody debris.

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

Findings and Conclusions:

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

- Low summer flows;
- Fish passage barriers;
- High levels of fine sediments in streams;
- Loss of habitat area and complexity;
- A shortage of areas with suitable spawning gravel in tributaries;
- High summer water temperatures;
- Competition with Sacramento pikeminnow.

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

Barriers to Fish Passage:

Table 22. Recommended actions for correcting barriers to fish passage.

Streams	Recommended Actions XXX: Highest Priority			
	Continue efforts to identify and alleviate fish passage impediments at culverts or other road crossings.	Improve fish passage by modifying debris accumulations.	Improve fish passage by building fishways at sediment deltas that may impair anadromous fish migrations.	Monitor and, if necessary, remove rock dams to improve fish passage
Price Creek				X
Adams Creek	X	X		
Oil Creek	X			
Atwell Creek		X		
West Fork Howe Creek		X		
Dean Creek		X	X	
Nanning Creek		X		
Van Duzen River			XXX	
Wolverton Gulch	XXX	X	X	
Fiedler Creek	XX		X	
Cummings Creek		X	X	

Flow and Water Quality:

Table 23. Recommended actions to improve flow and water quality.

Streams	Recommended Actions XXX: Highest Priority			
	Insure that water diversions used for domestic or irrigation purposes bypass sufficient flows to maintain all needs of fishery resources.	Reduce water temperatures	Plant willows, redwoods, alder or fir trees to help reduce water temperature in areas with insufficient shade.	Remove excessive contributions of wastewater to aquatic ecosystems
Eel River		XX		XX
Price Creek	XX	X	XX	
Howe Creek	X	X	X	
Van Duzen River	XXX	XX		
Cuddeback Creek	XX			
Fiedler Creek	XX			
Cummings Creek		XX	X	

Erosion and Sediment Reduction:

Table 24. Recommended actions to correct erosion and sedimentation.

Streams	Recommended Actions XXX: Highest Priority				
	Continue to identify and reduce sources of sediment delivery to stream channels from road systems.	Re-vegetate exposed stream banks and/or install structures to increase bank stability.	Modify debris accumulations to prevent further erosion of stream banks.	Build livestock exclusionary fencing along creeks and create offsite watering areas	Install instream structures that enhance natural sorting of spawning gravels
Price Creek	XX	X		XX	
Adams Creek	XX		X		X
Sweet Creek	XX	X			
Muddy Creek	XX				
Howe Creek	XX	X		X	
West Fork Howe Creek	XX		X		X
Atwell Creek	XX		X		
Crystal Creek	XX				
Dean Creek	XX		X		
Nanning Creek	XX		X		
Van Duzen River		XX			
Wilson Creek	XX				
Wolverton Gulch	XXX	XX	X	X	
Cuddeback Creek	XX	XX			
Fiedler Creek	XX	XX			
Cummings Creek	XX	XX	X		

Riparian and Instream Habitat:

Table 25. Recommended actions to correct riparian and instream habitats.

Streams	Recommended Actions XXX: Highest Priority				
	Increase depth, area or shelter complexity in pools, by adding LWD or combinations of boulders and LWD.	To increase the number of pools, design and install pool forming structures.	Increase shelter complexity in flat water units by adding LWD.	Consider thinning hardwoods to increase growth of conifers where riparian forest is strongly dominated by hardwoods and shade canopy will not be adversely affected.	Consider planting barren nearstream areas with alder, willow, redwood, or fir trees to increase streamside shade canopy and allow for LWD recruitment.
Price Creek	X	X		X	X
Adams Creek	XX				
Sweet Creek	X	XX			X
Muddy Creek	XX	X		X	
Howe Creek	XX	XX			X
West Fork Howe Creek	XX	XX		X	
Atwell Creek	XX	X			
Crystal Creek	X	XX		X	
Dean Creek	XX	X			
Nanning Creek	X				
Van Duzen River	X				X
Wolverton Gulch	XX	X	X	X	XX
Wilson Creek	XX	XX			
Cummings Creek	XX	XX	X	X	X

Education, Research, and Monitoring:

Table 26. Recommendations for education, research, and monitoring.

Streams	Recommended Actions XXX: Highest Priority	
	Conduct retrospective surveys of habitat improvement structure effectiveness to assess need for project maintenance.	Water quality and temperature monitoring should be conducted over several years to characterize conditions in streams
Eel River		XX
Price Creek	X	XX
Howe Creek	X	XX
Van Duzen River		XX
Cuddeback Creek		XX
Fiedler Creek		XX
Cummings Creek	XX	

Subbasin Conclusions

More biological and habitat surveys were conducted on streams of the Upper Subbasin than in the other subbasins in this Lower Eel assessment due to the higher number of streams containing salmonids within the subbasin. These studies describe deterioration in habitat due, in part, to the introduction of high levels of sediment. Soils in this subbasin are highly susceptible to erosion and have entered the streams through land used activities and many road related and stream bank slides.

The geologic composition and climatic environment of the area aggravate these erosive conditions with soils entering streams during periods of heavy saturation. Salmon spawning areas have become heavily silted and are therefore unproductive in many of the studied streams. While not conclusive, measured water temperatures in some streams neared stressful conditions when compared to suitable salmonid habitat criteria. Additionally, there are several possible barriers to fish passage on streams in the form of culverts and dry reaches. These barriers have limited the movement of adult and juvenile fish and decreased the overall amount of habitat available to salmonids in the subbasin.

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