Executive Summary

The North Coast Watershed Assessment Program (NCWAP) was an interagency effort between the California Resources Agency and the California Environmental Protection Agency (CalEPA) established to provide a consistent body of information on North Coast watersheds for use by landowners, stakeholders, collaborative watershed groups, and agencies. The NCWAP was initiated in response to specific requests from landowners and watershed groups that the State take a leadership role in conducting scientifically credible, interdisciplinary assessments that could be used for multiple purposes. The need for comprehensive watershed information grew in importance with listings of salmonids as threatened or endangered species, the Total Maximum Daily Load (TMDL) consent decree, and the increased availability of assistance grants for protecting and restoring watersheds.

NCWAP participating State agency departments include:

- Forestry and Fire Protection (CDF);
- Fish and Game (CDFG);
- Conservation/California Geologic Survey (CGS);
- Water Resources (DWR), in conjunction with the North Coast Regional Water Quality Control Board (RWQCB);
- State Water Resources Control Board (SWRCB).

Due to California's General Fund reductions in 2003, the NCWAP program was cut from the state budget before the Redwood Creek Basin assessment report was complete. This report was completed by the CDFG's Coastal Watershed Planning and Assessment Program (CWPA) with inputs from other Resources Agency Departments as budgets and time constraints allowed. This assessment was guided by the following assessment questions at the basin and subbasin scales:

Assessment Guiding Questions

- 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 relationships of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions?
- How has land use affected these natural processes and stream 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:

Strategic Goals

- Organize and provide existing information and develop 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 information 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

Each of the program's participating departments developed data collection and analysis methods used in their basin assessments. The departments also jointly developed a number of tools for interdisciplinary synthesis of information. These tools included models, maps, and matrices for integrating information on basin, subbasin, and stream reach scales to explore linkages among watershed processes, current conditions, and land use. The tools provided a framework for identifying refugia areas and factors limiting salmonid productivity, as well as providing a basis for understanding the potential for cumulative impacts from natural and man caused impacts. The NCWAP team identified relationships or root causes contributing to the habitat deficiencies and made recommendations to improve habitat conditions. This information is useful for developing restoration, management, and conservation recommendations.

The general steps in our large-scale assessments include:

- Form multi-disciplinary team;
- Conduct scoping and outreach workshops;
- Determine logical assessment scales;
- Discover and organize existing data and information according to discipline;
- Identify data gaps needed to develop the assessment;
- Collect field data;
- 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.

The roles of the five original participating NCWAP agencies in these efforts included these activities:

- DOC/CGS compiled, developed, and analyzed data related to the production and transport of sediment;
- CDF compiled, developed, and analyzed data related to vegetation and land use in the watersheds;
- RWQCB compiled, developed, and analyzed water quality data for the assessment;
- DWR installed and maintained stream monitoring gages where needed to develop and analyze stream flow information;
- CDFG collected and analyzed data related to anadromous salmonid populations and their habitat.

Results of assessments conducted by various agency personnel on the Redwood Creek team were brought together in an integrated synthesis process. This process recognizes the dynamic spatial and temporal relationships between watershed and stream conditions and watershed processes. To assist in this process, the team used Geographic Information System (GIS) based watershed data coverage and the Ecosystem Management Decision Support (EMDS) model to help evaluate watershed and stream conditions.

Assessment Products

Assessment products include:

- A basin level geologic evaluation that includes:
  - Map of landslides and geomorphic features related to landsliding with accompanying text;
  - Relative landslide potential map with accompanying text;
- A basin level Synthesis Report that includes:
  - Collection of Redwood Creek historical and sociological information;
  - Description of historic and current vegetation cover and change, land use, geology and fluvial geomorphology, water quality, aquatic habitat conditions, and distribution and status of anadromous salmonids;
  - Evaluation of watershed conditions and land use affecting stream habitat;
  - An interdisciplinary analysis to detect relationships between watershed conditions, watershed processes and stream habitat conditions, salmonid distribution, and refugia areas;
  - Tributary and watershed recommendations for management, refugia protection, and restoration activities to address limiting factors and improve conditions for salmonid production;
  - Monitoring recommendations to improve the adaptive management efforts;
  - Compilation of reference materials.
- Web based access to the Program's products: http://ncwatershed.ca.gov/, and http://imaps.dfg.ca.gov/.

Redwood Creek Assessment Subbasins

The Redwood Creek assessment team used the California Watershed Map (CalWater version 2.2a) to delineate the Redwood Creek Basin into five subbasins for assessment and analysis purposes. These study areas were the Estuary, Prairie Creek, Lower, Middle, and Upper subbasins (Table ES-1and Figure ES-1). In general, the CalWater 2.2a Planning Watersheds (PWs) contained within each of these assessment subbasins have common physical, biological, and/or cultural attributes. Delineation in this manner provides a large, yet common scale for conducting assessments. It also allows for reporting of findings and making recommendations for watershed improvement activities that are generally applicable across a large, relatively homogeneous area. The Subbasins are:

Estuary Subbasin: The Estuary Subbasin includes Redwood Creek below the confluence with Prairie Creek, including Strawberry Creek, Sand Cache Creek and Dorrance Creek.

Prairie Creek Subbasin: The Prairie Creek Subbasin contains all of Prairie Creek watershed except for a small portion of Skunk Cabbage Creek that is in the Estuary Subbasin.

Lower Subbasin: The Lower Redwood Creek Subbasin includes the area above the confluence of Redwood and Prairie Creeks to the confluence of Redwood and Devil's Creeks including Devil's Creek.

Middle Subbasin: Middle Redwood Creek Subbasin includes the area above the confluence of Redwood and Devil's Creeks and extends just upstream of State Highway 299 crossing to the confluence of Redwood and Lupton Creeks, including Lupton Creek.

Upper Subbasin: The Upper Redwood Creek Subbasin includes the area above Lupton Creek and covers the same area as the CalWater 2.2 Lake Prairie Hydrologic Area.

Table ES1. Redwood Creek subbasin attribute summary.

	Estuary Subbasin	**Prairie Creek Subbasin**	**Lower Subbasin**	**Middle Subbasin**	**Upper Subbasin**	**Total**
Square Miles	5.4	39.6	69.5	100.1	67.7	282
Total Acres	3,429	25,339	44,488	64,088	43,344	180,690
Private Acres	2,007	463	275	58,040	40,970	101,280
Federal Acres	1,422	18,247	44,213	6,048	2,375	71,960
State Acres	0	6,629	0	0	0	6,630
Principal Communities	Orick			Redwood Valley		
Predominant Land Use	Livestock Grazing	Park Land	Park Land	Timber Production	Timber Production	
Predominant Vegetation Type	Pasture Land	Redwood Forest	Redwood Forest	Douglas-fir Forest	Hardwood Douglas-fir Forest	
Anadromous Fish Stream Miles	5	24	28	42	23	122
Lowest Elevation	0	26	26	325	866	
Highest Elevation	1,243	2,270	1,286	4,091	5,322	

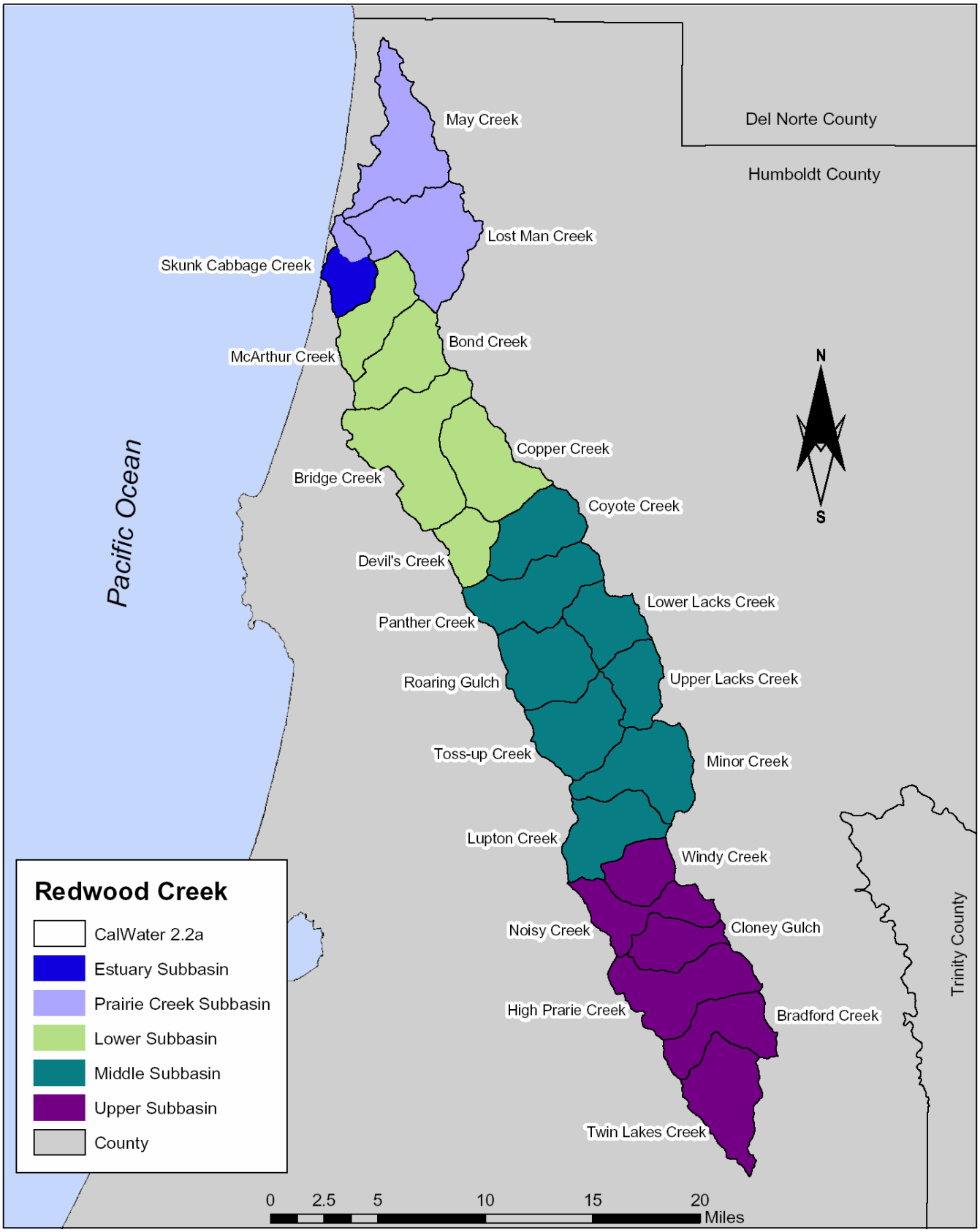

Figure ES- 1. Redwood Creek Subbasins and CalWater2.2a Planning Watersheds.

Redwood Creek Basin Profile

Redwood Creek flows into the Pacific Ocean near the town of Orick, approximately 35 miles north of Eureka, in northern Humboldt County, California. The basin contains approximately 285 square miles (about 180,000 acres) of mostly forested and mountainous terrain. The elongate shaped basin extends in a NE/SW direction for approximately 65 miles and averages only about 6 miles wide (Figure ES-2). Elevation ranges from sea level near the town of Orick up to 5,200 feet at the headwaters near Board Camp Mountain, located at the south-east end of the basin.

Geology

The Redwood Creek basin has large areas with highly unstable terrain. The basin is situated in a tectonically active and geologically complex area, with some of the highest rates of uplift, and seismic activity in North America (Cashman et al. 1995; Merritts 1996). The basin's elongate shape is largely controlled by the Grogan Fault which the Redwood Creek channel follows for most of its length. Distinct bedrock units meet at the Grogan Fault, predominantly, Redwood Creek schist to the west and coherent sandstone and incoherent sandstone-mudstone units to the east. These bedrock units are relatively weak, easily weathered, and when saturated by heavy rainfall, become susceptible to landsliding. Inner gorge areas appear to be particularly unstable because the steep slopes combine with emergent groundwater (Fetter 1980; Freeze and Cherry 1979) to reduce overall slope stability within the hillsides (Bell 1998; Rahn 1996; Griggs and Gilchrist 1977; Duncan 1996; Sowers and Royster 1978). As a result of geologic instability, approximately 72% of the basin shows signs of very high or high landslide potential. The areas considered high or very high landslide potential are vulnerable to ground disturbance that can initiate erosion. Any land use that weakens the structural integrity of hillslopes can significantly add to erosion rates.

The Upper and Middle subbasins have the greatest percent of area covered (80 and 73 percent respectively) by active and dormant landslides, disrupted ground, and debris slides. The Prairie Creek Subbasin has the smallest area (56%) in these features that are sources of sediment delivery to streams. Recent findings indicate that the Upper Subbasin is contributing the most sediment to streams and the Prairie Creek Subbasin contributes the least sediment.

Climate

The climate of the Redwood Creek Basin varies from moderate seasons along the coastal area to the more extreme seasons inland. The majority of precipitation occurs November through March and ranges from 32 inches at lower elevations to 98 inches at the headwaters with frequent snow above 2,000 feet. Winter storms often bring heavy rainfall.

Fog and moist marine air are climatic features near the coast. Fog often occurs daily in the summer and frequently throughout the year. Air temperatures near the coast average from 47 ^{o} F in January to 59 ^{o} F in June. Higher elevations and the inland region tend to be relatively fog free. Iinland temperatures range from below freezing in winter to above 100° F in summer months.

Recent flood events (1955, 1965, 1972, 1975, and 1997) played important roles in shaping the stream channel and aquatic habitat conditions of the Redwood Creek Basin. The flood of December 1964 had the most significant and long-lasting adverse impacts to salmonid habitat in Redwood Creek. Although peak discharge was not much different than the flood of 1955, the amount of disturbance to channel features from the 1964 flood was much greater. A difference between the two storms was that rigorous logging activity occurred between 1955 and 1964, which left the basin's terrain in a disturbed condition and extremely vulnerable to erosion from the heavy rain on snow event. Less drastic, but significant erosion occurred during storms in 1972, 1975 and 1997 (Madej 2001).

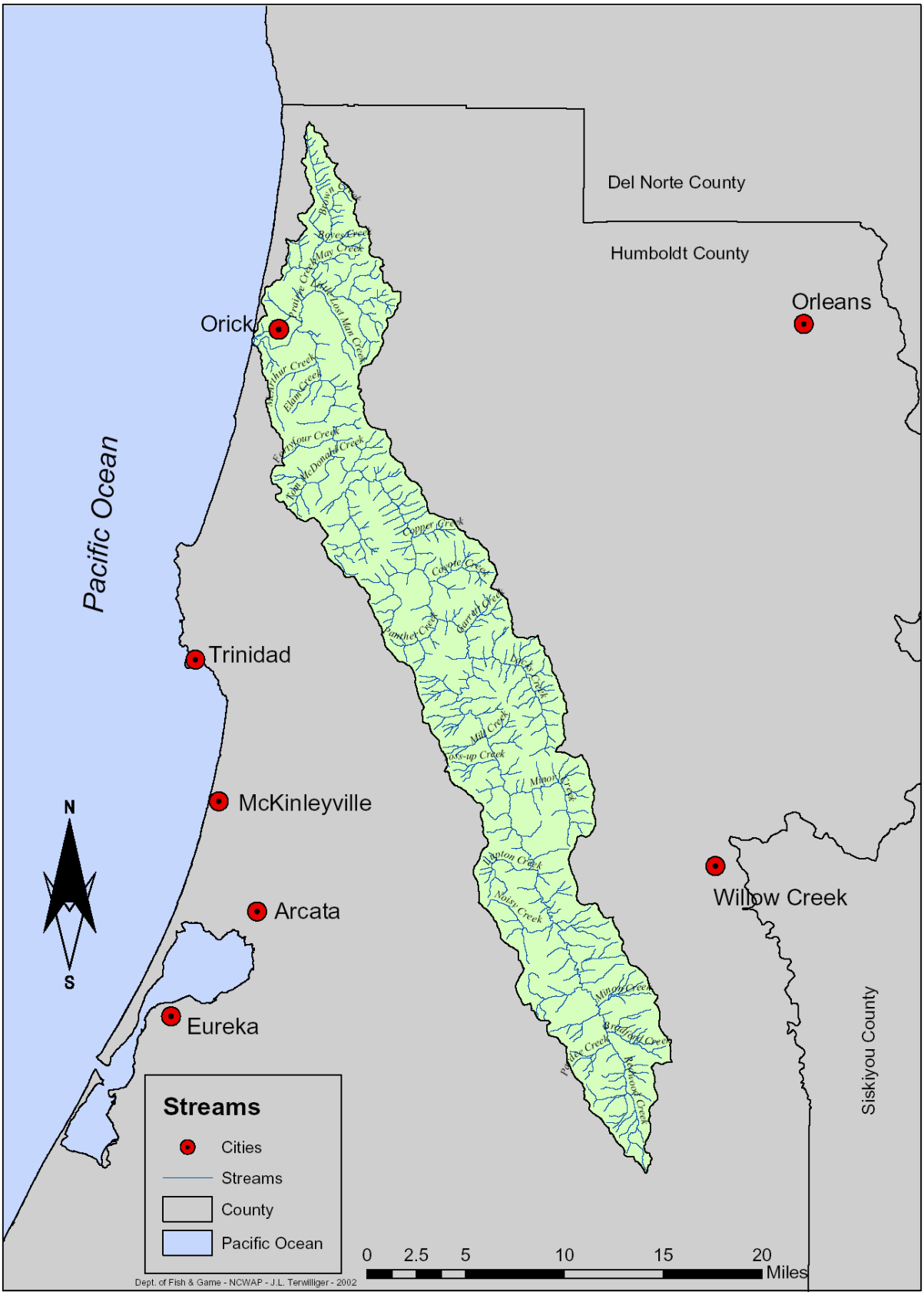

Figure ES- 2. Redwood Creek.

Vegetation

Five vegetation types account for 90 percent of the vegetation in Redwood Creek. Redwood and redwood-Douglas-fir vegetation types cover about 61,000 acres, accounting for 34 percent of the watershed area. Most of the Redwoods grow in the Estuary, Prairie Creek and Lower subbasins. Douglas fir stands cover 71,652 acres, or 40 percent of the watershed mostly within the Middle and Upper subbasins. The other major vegetation types are annual grass/forbs, Oregon white oak, tanoak, and red alder. Areas of grasslands are found along the main ridge tops and south facing slopes of the watershed. Stands of ponderosa and Jeffery pine are found at the upper elevations.

The Redwood Creek Basin in 2004 has about 24,000 acres, 13 percent of the basin area in old growth coniferous forests. Most of this is in park lands where ancient redwood groves are famous and include some of the world's tallest trees. Prior to timber harvesting efforts, 82 percent (150,000 acres) of the basin supported mature coniferous forests.

Land Use

Land use in the Estuary Subbasin includes the town of Orick, agricultural lands, livestock grazing, park lands, and land managed for timber production. Park lands (RNSP) are located in the Prairie Creek and Lower Subbasins. Private forestland, managed for timber harvesting are in the Middle and Upper subbasins. Eight large land owners own approximately 90% of the private lands in the Middle and Upper subbasins. Small private developments are a found in the Estuary, Middle and Upper subbasins.

Approximately 65,000 acres in the Prairie Creek and Lower subbasins are managed by RNSP. RNSP also manages 1,400 acres in the Estuary Subbasin. The RNSP land management strategies include: 1) perpetuation of the redwood forest and associated ecosystems as prime resources; 2) perpetuate ongoing natural influences on the basis of natural values and visitor use; and 3) protect threatened and endangered species and species of special concern (USDOI 1999).

Large scale timber harvesting began in the basin during the early 1950s, although harvests and land clearing occurred in the late 1800's and early 1900's in the Estuary and Prairie Creek subbasins. Over the last century, timber operations provided jobs and produced large quantities of timber products. By 1966, fifty-five percent of the basin's coniferous timber was cut and by 1992, over 80 percent (123,000 acres) of the basin's timber lands were harvested at least once. Large scale even age silviculture prescriptions (clear cuts) and tractor yarding were the most commonly used timber harvest methods in the past. The first timber harvest rules were implemented in 1972 and these rules continue to evolve to help meet growing concerns over watershed conditions. Most of the basins timberlands are now restocked, and should continue to be a productive source of future lumber products.

The vast majority of road construction occurred during the initial timber harvest period of the 1950s-1970s. These roads were built without the present knowledge of road construction methods to minimize erosion. Consequently poorly designed roads are major sources of sediment delivery to streams.

Beginning in 1978, road improvement projects within the RNSP (mostly in the Lower Subbasin) have removed or treated 215 miles of roads. Road assessment for the entire Redwood Creek Basin is nearing completion (Bundros et al. 2004). With the funding of the road assessment program, roughly 90% of the private lands in the Redwood Creek Basin will be inventoried and prioritized for road treatments. At present, road assessments and implementation projects are a focus of RNSP and private landowners of the basin.

Water Quality

Thirty years of water chemistry data collected 1958-1988 by USGS and USEPA characterizes Redwood Creek as a moderately hard water, moderately oligotrophic stream. Most water chemistry parameters were within optimal ranges for human consumption. However, due to excessive sediment inputs to stream channels and a reduction in shade canopy, the basin's streams are listed as sediment and temperature impaired under Section 303(d) of the federal Clean Water Act, and hence falls under jurisdiction of the state and federal TMDL programs. High water temperature and excessive sediment loads have adversely altered the stream habitat creating undesirable conditions for anadromous salmonids in portions of the basin, especially in the mainstem of Redwood Creek. In addition, high turbidity levels in Redwood Creek are believed to occur more frequently and persist longer than in the past.

The coolest water temperatures are found in the Prairie Creek Subbasin, the headwaters area of Redwood Creek, and in tributary streams. At present, tributary contributions are unable to reduce the high temperature along the mainstem. However, localized patches of cool water refugia may form at the confluences of tributaries along the mainstem Redwood Creek. Temperature refuge sites in the mainstem are also located in thermally stratified pools, near springs, or sites where cool intergravel flows accumulate to maintain cool bottom water (Ozaki 1988).

Salmonid Fishery Resources

The Redwood Creek Basin supports populations of Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and other valuable fisheries resources. Due to declining populations in California's northern coastal streams, Chinook, coho and steelhead are listed as threatened under the endangered species act. Coastal cutthroat trout are a California Special Concern Species. Redwood Creek's anadromous salmonid stocks are critically valuable natural resources and increasing the abundance, diversity and distribution of these stocks are vital steps towards the restoration of viable salmonid populations to California.

A review of the past fisheries studies, anecdotal information and data collected for this assessment indicates that the present anadromous salmonid populations are less abundant and less widely distributed compared to their historic presence in the Redwood Creek Basin. Impairments to freshwater and estuarine habitat have been identified as leading factors in the decline. Summer steelhead, sea run coastal cutthroat, coho and Chinook salmon have likely suffered widespread declines due to their sensitivity to degradation of specific habitat factors necessary to complete the freshwater and/or estuarine phase of their life cycle. Winter run steelhead tolerate a wider range of habitat conditions than the other anadromous species, and they are still widely distributed in the basin, but their abundance is likely below historic numbers. Steelhead have persisted in streams where other species have declined or are now rarely observed.

There are several habitat factors necessary for the successful completion of an anadromous salmonid's life history. Good estuarine conditions, good instream habitat, and benefits from nearstream forests and riparian vegetation are essential for healthy populations. Good stream condition includes several factors: clean and adequate stream flow, appropriate water temperature, clean gravels, and channel diversity. Adequate instream flow and free passage is essential to provide salmonids access to spawning grounds, free forage range, cover from predation, and utilization of localized temperature refugia. Instream shelter provided by LWD, vegetation, boulders and undercut banks are also essential. A bottleneck to salmonid production or limiting factor may emerge when any of these habitat factors are missing or deficient in function.

Redwood Creek Basin Key Issues and Summary Findings

Salmonid populations have declined from historic levels, prompting listings under the state and federal ESA's:

- Redwood Creek's anadromous salmonid stocks are critically valuable natural resources;
- Present anadromous salmonid populations are less abundant and less widely distributed compared to their historic presence in the Redwood Creek Basin;
- Increasing the abundance, diversity and distribution of Redwood Creek's salmonid stocks are vital steps towards the restoration of viable salmonid populations to California;
- Sport and commercial fish harvests have played a role in the reduction of Redwood Creek's salmonid populations, but persistent impairments to critical habitat are likely most responsible for their decline;
- Given improving aquatic habitat conditions, it will likely take several generations before salmonid populations rebound to viable levels;
- The presence of salmonid stocks does not mean that efforts to protect them and their habitat should be relaxed;
- The capacity for salmonids to increase in abundance and distribution is in part limited by the reproductive potential of existing stocks;

Impairments to freshwater and estuarine habitat needed to complete salmonid freshwater life cycles have been identified as a leading factors in the decline of Redwood Creek's anadromous salmonids:

- A significant factor affecting salmonid production is the large reduction in area and habitat quality of the estuary/lagoon;
- The present habitat problems observed in most streams of the basin are often related to excessive sediment in stream channels and/or the lack of a large conifer contributions in riparian and nearstream forests;
- Warm water temperature in mainstem Redwood Creek limits salmonid production in most of the Upper Subbasin and all of the Middle and Lower subbasins;
- Many tributaries across the basin have cool water temperatures but often lack the combination of structural components that create the habitat diversity and complexity needed to support viable salmonids populations;
- Excessive sediments inputs can result in several adverse and long lasting impacts to salmonid habitat including impaired spawning habitat, a decrease in channel diversity, a reduction in the numbers and depths of pools, stream bank erosion, widened channels, and loss of shade;

- As a result of timber harvests and stream bank erosion, there is a loss of shade provided by large conifers and a low potential for near term LWD input to several anadromous reaches in the basin;

- The negative impacts from excessive sediments are in some cases exacerbated by the general lack of instream large wood debris (LWD);

- More LWD is needed in many stream channels to help with channel maintenance processes including formation of pools and sediment routing, providing shelter for fish, and to provide nutrient inputs;

Natural geologic instability contributes to sediment inputs to the basin's stream network:

- The Redwood Creek Basin is situated in a tectonically active and geologically complex area. Most of the bedrock is relatively weak, easily weathered and naturally susceptible to erosion;

- The region experiences a high level of seismic activity and major earthquakes have occurred along the Cascadia subduction zone as well as within the individual tectonic plates and along well-defined faults;

- The inner gorge of the Redwood Creek channel is particularly prone to yielding sediment from stream side landslides;

- High rates of regional uplift provide a continual source of sediment to the basin.

Much of the naturally occurring erosion resulting from slope instability has been compounded by human activities:

- The combination of naturally unstable terrain, intensive land use and severe storms (such as the one that occurred in December 1964) can trigger major episodes of erosion;

- Much of the erosion in the basin is linked to legacy impacts from past land uses;

- There are high road densities in much of the basin and large amounts of sediment is generated from road related failures, especially from roads located on steep, unstable slopes;

- Large scale removal of timber accelerates storm runoff and contributes to an increase in erosion;

- Fine sediment accumulations in stream channels are typically more abundant where land use activities such as roads or land clearing expose soil to erosional processes;

- High turbidity levels in Redwood Creek are believed to occur more frequently and persist longer than observed in the past;

- Many of the effects from land use activities on upland sediment sources are spatially and temporally displaced from response reaches;

- Past fluvial erosion was accelerated by land use and this erosion could have been minimized with better erosion-control and road-maintenance measures.

Riparian and near stream forests functions have been altered by timber harvests and bank erosion:

- Timber harvests in riparian and nearstream forest areas contribute to a reduction in both overstory shade canopy and LWD input potential;

- Shade over the water from willow and alder riparian vegetation alone is not enough to keep water cold;

- Micro-climate benefits provided by near stream forests and overstory shade are important to help provide cool air near streams that helps maintain cool water temperature;

- Retention and recruitment of large coniferous trees are needed along streams, especially along mainstem Redwood Creek;

- As trees grow and become subject to harvest, how will management protect valuable aquatic and fishery resources from similar impacts as occurred in past years?

The Redwood Creek basin is an excellent candidate for a successful long-term, programmatic watershed improvement effort:

- Management strategies should take a basin-wide perspective;

- It is important to note that without management strategies that promote restoring integrity to watershed ecosystem process by addressing root causes of problems, instream improvement projects will likely be short-lived patches on the environment;

- Stream condition improvement and increasing anadromous salmonid populations largely depends on achieving a balance between the socio-economic needs for timber resources and management needed to maintain or improve basin conditions that sustain viable fish populations;

- Most of the basin has a high potential to improve fish habitat conditions. Reaching that goal is dependent upon the formation of a well organized and thoughtful improvement program founded on broad based community support for the effort.

Basin Scale Recommendations

Barriers to Fish Passage

- Fish barriers were found at culverts, perched sediment deltas, or boulder and/or debris accumulations.
- Facilitate fish passage at sites that may impede upstream fish passage into tributary streams for spawning or downstream movements.

Flow and Water Quality Improvement Activities:

- Water flow does not appear to be and issue at this time over most of the basin. However, fish habitat requirements and channel maintenance flows should be considered prior to any water development projects including riparian diversions and small domestic water use;
- In order to help reduce water temperature in tributaries and the mainstem, ensure that near stream forest management encourages growth and retention of conifers sufficient for providing shade and cool micro climate benefits to stream and riparian zones;
- Consider using willow baffles, tree planting or other applicable methods to promote effective shading and to reduce the channel width along reaches of Redwood Creek;
- Timber harvests or other land use should be conducted in a manner that does not accelerate runoff rates, increase sediment delivery to stream channels, or impede recovery of riparian and nearstream forest functions needed to improve aquatic habitat conditions;

Erosion and Sediment Delivery Reduction Activities:

- Existing sediment production problem sites that have potential to deliver sediments to streams should be evaluated and mitigated;
- Since timber harvesting and other land use can cause disturbances that may contribute to slope instability, management on slopes with high landslide potential and/or on lands adjacent to streams should first involve a risk assessment or be avoided. Determination of appropriate practices should be made through the use of the CGS landslide and landslide potential maps, in conjunction with site-based geological examinations by licensed and appropriately trained geologists;
- For timber management on steep and/or potentially unstable slopes (in many cases, slopes greater than 35%) we recommend use of lower impact silvicultural prescriptions to maintain vegetative cover and the use of cable or helicopter yarding to reduce the potential for erosion and sediment production, which can result in sediment accumulation in Redwood Creek;
- Landowners should continue road erosion hazard surveys throughout the basin and use this information to set priorities for road removals and upgrades, and implement these improvements as rapidly as private and public funding allow. Roads located on unstable slopes and roads near streams should receive high priority for survey and upgrades and decommissioning projects;
- Consider avoidance or mitigation for risks of excessive erosion when planning, building or removing roads in or near deep-seated landslides and earthflows;
- Reduce road density across the basin especially in the Middle and Upper subbasins;
- If new roads need to be constructed, they should be designed to prevent erosion and not be located near the valley bottom where they may pose a high risk of generating sediment delivery to streams. Consider locating roads along ridge tops where feasible;
- The use of fire for site preparation purposes should be minimized on schist soils during warm, dry periods (late summer and fall).

Riparian and Stream Habitat Improvement Activities:

- To increase shade canopy, promote growth and retention of large conifers in the nearstream corridor along mainstem Redwood Creek;

- Where current near stream forest canopy is strongly dominated by hardwoods and site conditions are appropriate, land managers should consider cautious thinning of hardwoods from below to hasten the development of denser and more extensive coniferous canopy component;
- To address the lack of large woody debris in many tributary channels and along the Redwood Creek mainstem, management should promote growth of near stream conifers and allow natural recruitment of trees and LWD to stream channels;
- Where near stream conifers are not large enough to function as naturally occurring scour elements, consider importing LWD from nearby hillslopes for placement in locations and orientations where it will provide beneficial habitat elements and will not accelerate adverse bank erosion;
- Add combinations of boulders and LWD to increase shelter complexity to cool water patches located in Redwood Creek. The cool patches may be located in temperature stratified pools or adjacent cool water inputs from springs, seeps and tributary flows;
- For timber harvest plans in the Upper and Middle subbasins, consider additional measures to increase function of watercourse protection zones when justified by lack of large conifers to provide shade and microclimate, lack of instream LWD, and low LWD loading potential;
- Consider the use of conservation easements or other management strategies to maximize potential benefits to aquatic habitats from near stream forest protection along the middle and upper reaches of Redwood Creek;
- Consider limiting cattle access in streams where their presence has caused significant bank erosion and impaired growth of vegetation;
- Prescribed fire use within the Redwood Creek basin could reduce adverse impacts to watercourses and wet areas. Regular use of prescribed fire could reduce fuels so that catastrophic fires are less likely to occur.

Monitoring, Education and Research Activities:

- Utilize CalVeg GIS layers to locate areas where coniferous trees are too small to provide beneficial functions of LWD loading. These areas should be considered for LWD addition to stream channels if needed to retain and promote desirable pool characteristics, sediment routing and other channel maintenance processes;
- Temperature monitoring by land owners and responsible agencies should continue at current and additional sites to extend trend lines and track changes that may impact salmonids or that may indicate a status change. The establishment of trend lines from these data will aid in future studies, validate improvements from forest and stream recovery and will be helpful for habitat improvement project effectiveness monitoring;
- Monitoring suspended and in-channel stored sediments by sampling sediment size distribution, turbidity, V*, photo points, etc. should be continued, and tracking of streambed levels with stream channel cross sections should be continued by responsible agencies and landowners;
- A long-term, concerted monitoring effort among the land owners, interested parties and responsible agencies is needed to determine the status and trends of anadromous salmonid populations of Redwood Creek. Efforts should include annual counts of adults and juveniles to develop stock recruitment and habitat relationships;

- Biological monitoring, particularly for aquatic insects and aquatic food web dynamics, will be an important addition to monitoring efforts in the Redwood Creek basin;
- Ensure that CEQA-compliant environmental assessment is conducted prior to issuance of the Fish and Game Code 1600 series streambed alteration permits and Corps of Engineers or NOAA Fisheries permitting requirements are complete for significant projects on streams of Redwood Creek;
- It is unclear whether modern timberland management practices will allow full restoration and recovery of desirable watershed ecosystem function. Conservation easements that provide wider buffers along water courses or additional management measures may be needed to provide the protection needed to promote watershed and aquatic ecosystem recovery;
- CDFG stream habitat surveys provide information only for reaches accessible to anadromous salmonids. Additional surveys above the limits to anadromy are necessary to identify upstream conditions that affect anadromous reaches such as riparian canopy status or additional sediment delivery sites that may benefit from erosion control treatments.

The Subbasins

Estuary Subbasin

The Redwood Creek estuary/lagoon plays a vital role as habitat for juvenile and adult anadromous salmonids. The estuary/lagoon once had all of the characteristics of excellent anadromous salmonid habitat, but its present value as fisheries habitat is greatly reduced compared to the historic condition. Over the past 125 years, the estuary area was altered by conversion of forest, riparian and wetland areas to pasture land, channel modifications, and levee construction. These changes combined with sediment accumulations have impaired the physical and biologic function and capacity of the estuary/lagoon to support salmonids. The present estuary condition limits salmonid production.

The Redwood Creek estuary is an excellent candidate area for channel and riparian improvement projects that benefit anadromous salmonids. RNSP and others have developed management alternatives to improve the estuarine habitat while offering flood control protection to the town of Orick and pasturelands surrounding the estuary. The recent project alternatives involve levee removal, relocation, and re-configuration. A restoration project should benefit fish production by increasing the depth and area of the lower embayment while increasing instream shelter, connectivity, and circulation between the main channel and slough channels. Projects that increase the estuary/lagoon's juvenile salmonid carrying capacity and survival rate during the summer months should receive high priority. Restoration efforts that move conditions and processes towards historic status also will benefit other fish and wildlife resources of Redwood Creek.

Estuary Subbasin Issues and Summary Findings

Key salmonid fishery issues of concern identified for the Redwood Creek estuary include:

Juvenile salmonid rearing success is impaired by estuarine habitat conditions;

- Survivorship is very low (estimates of 7-15%) for juvenile Chinook and steelhead that rear in the lagoon through the summer;

- The estuary/lagoon once supported an abundant, year round population of coastal cutthroat trout. At present, only a few coastal cutthroat are found during fish surveys;
- A few juvenile coho typically reside in the lagoon, but these may not survive until fall;
- The fish rearing area of the Redwood Creek estuary/lagoon has been reduced by 50 to 75 percent;
- The estuarine channels are shallower and less diverse compared to historic conditions;
- Habitat shelter complexity is low due to a lack of riparian vegetation and LWD;
- Dissolved oxygen levels can be at stressful or lethal levels in the slough channels;

Channel modifications from the flood control levee system have likely had the most impacts to the physical form and alterations of natural processes that drive the estuarine ecosystem:

- The affects of levees exacerbate sediment accumulations and a contribute to the loss of estuarine habitat area and diversity, loss of tidal connectivity to slough channels, and a reduction in tidal prism;
- Benefits from riparian forests are lost by removal of riparian trees for pasture development and levee construction;
- Riparian vegetation is periodically removed from the estuary channel as part of a levee maintenance procedure.

The estuary is particularly susceptible to watershed cumulative effects:

- Much of the water quality and sediment characteristics of the estuary are related to upstream watershed conditions;
- The low gradient, depositional reach of Redwood Creek in the Estuary Subbasin accumulates sediment delivered from upstream reaches;
- Water flowing into the estuary during summer months is above desirable temperatures for salmonids;

Estuary habitat improvement projects have been proposed:

- A large amount of work has been done by RNSP, private landowners, public agencies, and interested parties to develop alternatives to improve habitat conditions in the estuary/lagoon, while protecting Highway 101 and the Town of Orick. These include various levee setback alternatives and shortening the extent of the levees to exclude the lowermost channel reach;
- A properly functioning riparian zone is needed to improve the estuarine ecosystem and increase the estuary's value as salmonid habitat.

Estuary Subbasin Recommendations

- A great amount of work has been done by RNSP, private landowners, public agencies, and interested parties to develop alternatives to improve habitat conditions in the estuary/lagoon, while protecting Highway 101 and the Town of Orick. These include

widening the levees and shortening the extent of the levees to exclude the lowermost channel reach;

Flow and Water Quality Improvement Activities:

- Increase tidal prism by restoring tidal and riverine flow and connectivity between the main channel and slough channels;
- Increase depth and tidal exchange at the confluence of North Slough channel;
- Increase circulation between the lagoon, Strawberry Creek, and sloughs to help mix water and increase dissolved oxygen levels;
- Prevent or reduce cattle waste from entering stream and slough channels;
- Land managers should work to maintain and/or establish adequate overstory shade canopy along Redwood Creek and its tributaries throughout basin to reduce water warming from solar radiation and high air temperatures;
- The goal of any controlled breech project must be to maintain the volume in the lagoon to best support the anadromous fisheries;
- Digging of any artificial channel through the beach sand berm that would result in an uncontrolled breech should be discouraged;
- Any controlled breech should be performed as an option and in coordination with the expert judgment of RNSP staff and CDFG to preserve natural resources.

Erosion and Sediment Delivery Reduction Activities:

- Reduce inputs of sands by tidal currents to the embayment and North Slough by modifying levee configuration or removing levees altogether;
- Use levee set back, reconfiguration or removal strategies to achieve more natural flood plain characteristics;
- Land managers should continue their efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with all land use activities throughout the basin to reduce sediment delivery to the estuary.

Riparian and Instream Habitat Improvement Activities:

- A properly functioning riparian zone is needed to improve the estuarine ecosystem and increase the estuary's value as salmonid habitat;
- Where feasible, develop or improve riparian vegetation function along the banks of Redwood Creek, Strawberry Creek, and slough channels;
- Use levee set backs, reconfiguration, or levee removal strategies to develop a wider flood plain to restore natural sinuosity, improve connectivity with sloughs and adjacent wetlands, and promote the development of an effective zone of riparian vegetation;
- Work to restore natural drainage patterns within adjacent wetlands and the subbasin;
- Increase off-channel and rearing habitat by improving conditions of sloughs and tributaries (Strawberry, Dorrance and Sand Cache creeks);
- Increase depth and complexity in the main channel and slough channels;
- Where feasible add LWD to increase instream shelter complexity;

- Leave large wood in estuarine channels, on the beach, and on stream banks for potential recruitment as complex shelter elements;
- Relocate drift logs that block tidal connectivity between the embayment and the North Slough channels;
- Re-establish a corridor of riparian vegetation to lower Strawberry Creek and restore riparian function in areas where vegetation removal or significant cattle impacts have been noted. This may require temporary fencing the riparian zone to prevent cattle and deer from grazing on seedlings and trampling growing trees.

Education, Research, and Monitoring Activities:

- Work should continue by Redwood National and State Parks (RNSP), private landowners, agencies, and interested parties to improve habitat conditions of the estuary by modifying the levees system while protecting Highway 101 and the town of Orick;
- RNSP, DFG, RWQCB should continue existing monitoring of anadromous salmonid populations and expand to include some winter and early spring sampling;
- Water temperature and dissolved oxygen monitoring in the lagoon and sloughs should continue. Some dissolved oxygen measurements should be collected just before sunrise to capture lowest diurnal levels;
- Monitoring water quality in the lagoon should be expanded to include nutrient levels (ammonia, nitrates, nitrates) that may be elevated from runoff from cattle pastures;
- Work with USACE, Redwood National and State Parks, and Humboldt County Department of Public Works to modify levees and levee maintenance manuals to be consistent with habitat requirements of salmonids and a properly functioning estuarine ecosystem.

Prairie Creek Subbasin

The Prairie Creek Subbasin supports self sustaining populations of Chinook and coho salmon, steelhead and coastal cutthroat trout. It is believed that the Prairie Creek Subbasin supports more coho than all other subbasins in Redwood Creek. Under RNSP management, protection is given to natural resources and refugia habitat that are important to the recovery and expansion of anadromous salmonid populations of the Redwood Creek Basin. Based on integrated analysis, it is apparent that timber harvest activities, road and highway construction, and road density have long lasting adverse impacts to anadromous salmonid stream habitat in the subbasin. Physical factors including debris jams that impede fish passage and sediment inputs that impair anadromous salmonid habitats are linked to these past land use activities. In contrast, undisturbed areas of the subbasin generally maintain desirable conditions for anadromous salmonids. Overall, the best stream habitat of the subbasin was found in areas that received the least amount of land disturbance.

The Prairie Creek Subbasin provides an excellent opportunity to maintain and improve stream habitat conditions and to strengthen anadromous stocks of Redwood Creek. Road removal and road improvement projects in the Lost Man Creek Planning Watershed should help alleviate sediment sources to Lost Man Creek. The Prairie Creek Subbasin offers opportunities for conducting effectiveness monitoring of stream and riparian habitat improvement activities, and further research into watershed dynamics that may be applied to similar north coast streams. In addition, the Prairie Creek Subbasin is an excellent location to study watershed science and to observe responses of fish populations in disturbed versus undisturbed watersheds. These streams

offer the opportunity to compare and contrast natural stream recovery with habitat improvement projects aimed at increasing aquatic habitat quality and fish abundance and diversity.

Prairie Creek Subbasin Issues and Summary Findings

The Prairie Creek Subbasin is predominantly managed by RNSP:

- RNSP management goals include the protection of natural resource values including anadromous salmonids and their habitat;
- The RNSP is a World Heritage Site and is part of the California Coast Range Biosphere Reserve, designations that reflect worldwide recognition of the parks' natural resources as irreplaceable.
- The RNSP has done a significant amount of work to survey road systems, identify problems, and implement road removals and upgrades that should result in reducing erosion and sediment inputs into stream channels;
- Much of the upper watershed of Prairie Creek and Little Lost Man Creek watersheds are relatively undisturbed areas. These areas retain old growth forest characteristics and provide some of the highest quality fisheries habitat within the Redwood Creek basin.

Before RNSP was expanded, approximately half of the subbasin was logged using timber harvest practices that resulted in disturbance to salmonid habitat:

- Impacts from past timber harvest still effect some riparian and stream habitat;
- Debris accumulations on Lost Man Creek may impede anadromous fish passage to upstream spawning grounds;
- Lost Man Creek watershed still has a relatively high density road network;
- It appears that land use has exacerbated landsliding in the Lost Man Creek Planning Watershed and the landscape has not fully recovered from past disturbances.

Impacts from Prairie Creek Hatchery operations:

- Steelhead/rainbow trout from other basins were introduced through the hatchery.

Sediment impacts from the Highway 101 bypass are a concern:

- Surface and drainage alterations associated with the construction of the Highway 101 bypass resulted in the generation and delivery of large quantities of fine sediments into headwaters of tributary streams. Salmonid spawning and rearing habitat of Prairie, Brown, Boyes, and May Creeks were affected by the event.

Prairie Creek Subbasin Recommendations

Barriers

- Modify large debris accumulation on Lost Man Creek to improve passage of spawning adults;

Flow and Water Quality Improvement Activities:

- Ensure that adequate streamside protection measures are used to maintain shade canopy in order to reduce moderate inputs to the lower reach of Prairie Creek and to maintain good water temperature in Lost Man Creek and other tributary streams;
- Water flow or water quality does not appear to be and issue at this time, but fish habitat requirements and channel maintenance flows should be considered prior to any water development projects.

Erosion and Sediment Delivery Reduction Activities:

- Continue road assessments and upgrades or removal of roads, especially in the Lost Man Creek planning watershed;
- Work with CalTrans to reduce sediment input potential to streams from HWY 101 activities;
- Consider bank stabilization projects in the Lost Man Creek watershed.

Riparian and Instream Habitat Improvement Activities:

- Restore riparian function in areas where vegetation removal or significant cattle impacts have been noted in lower Prairie Creek;
- Consider adding pool enhancement structures to increase the number of pools or deepen existing pools in Lost Man Creek, May Creek, and Boyes Creek.

Supplemental Fish Rescue and Rearing Activities:

- The use of Prairie Creek hatchery can be considered to supplement fishery resources of Redwood Creek if populations fail to respond to current management strategies.

Education, Research, and Monitoring Activities:

- The wide range of habitat conditions within the watershed provides an opportunity to monitor channel and salmonid habitat recovery rates under various habitat improvement treatments within a variety of channel types and conditions;
- Humboldt State University and RNSP should continue and expand their salmonid population and continuous temperature monitoring tasks in the Prairie Creek subbasin. This includes the use of fish counting weirs, spawner and redd surveys and juvenile population studies;
- A long term, concerted monitoring effort between the land owners, interested parties and responsible agencies is needed to determine the status and trends of anadromous fish populations in the Prairie Creek Subbasin;
- Water temperature monitoring should occur at the confluence of Prairie Creek and the mainstem to determine the effects of colder Prairie Creek water on the mainstem and estuary;
- Nutrients contributed to streams from eggs and decaying carcasses has declined. Studies should be conducted to discern relationships between nutrient contributions from carcasses, stream productivity, and salmonid production;
- Ensure that any land management activities include protection and preservation of stream and riparian habitats;
- CalTrans should continue to monitor and reduce sediment delivery from the Highway 101 bypass.

Lower Subbasin

The Lower Subbasin supports populations of all anadromous salmonid species of Redwood Creek. The lower mainstem of Redwood Creek is an important migratory route for all species and provides spawning area for Chinook salmon. Lower Subbasin tributary streams provide important salmonid spawning and year round rearing habitat for all salmonid species.

Elevated summer water temperature and lack of channel complexity are factors most limiting juvenile anadromous salmonid production in lower mainstem Redwood Creek. These limiting factors are products of channel aggradation and associated impacts such as a widened channel, lack of shade over the water, and lack of LWD. Watershed erosion, excessive sediment inputs to streams and loss of large conifers from nearstream areas in the Upper, Middle and Lower subbasins are root causes for limiting factors.

Water temperature is generally suitable in the tributaries year round. However, in the tributary streams fish habitat lacks sufficient area in deep, complex pools. Spawning gravels were moderately to highly embedded in fine sediments, which is considered unfavorable for successful incubation salmonid eggs.

Based on the survey sample sites, stream habitat improvement activities for Lower Subbasin streams include reducing sediment inputs by stabilizing stream bank and hillslope erosion, increasing depth and complexity to existing pool habitats, promoting nearstream conifer growth, and adding shelter complexity to cool water refuge sites. Further surveys are needed to assess conditions of other Lower Subbasin tributaries.

The Lower Subbasin offers opportunities for implementing projects, conducting effectiveness monitoring of stream and riparian habitat improvement activities, and further research into watershed dynamics that may be applied to similar north coast streams. In addition, the Lower Subbasin is an excellent location to study watershed science and to observe responses of fish populations in disturbed versus undisturbed watersheds. These streams offer the opportunity to compare and contrast natural stream recovery with habitat improvement projects aimed at increasing aquatic habitat quality and fish abundance and diversity.

Lower Subbasin Issues and Summary Findings

Impairments to freshwater habitat needed to complete salmonid freshwater life cycles have been identified as a leading factors in the decline of Lower Subbasin anadromous salmonids:

- Mainstem Redwood Creek summer water temperatures generally exceed favorable limits for salmonid production;
- Anecdotal accounts by long time residents and CDFG reports indicate that water temperature was once much colder in Redwood Creek;
- Lower Subbasin tributaries provide water temperature that supports salmonids;
- A lack of instream large woody debris (LWD) contributes to poor aquatic habitat structure including a low number of deep, complex pools;
- LWD recruitment potential to Lower Subbasin appears low at many locations;
- Stream habitat conditions in the Lower Subbasin can be improved.

Lands within the Lower Subbasin are managed by RNSP:

- RNSP management goals include the protection of natural resource values including anadromous salmonids and their habitat;
- The Lower Subbasin was made part of the Redwood National and State Park system in 1978.
- Prior to 1978, approximately 68% of the landscape was harvested for timber resources.
- Adverse impacts from legacy timber harvests are still affecting mainstem and tributary stream habitat.

The lower reach of Redwood Creek is a low gradient, depositional reach which accumulates excessive sediments derived from upstream sources:

- The aggraded channel condition contributes to elevated water temperatures, a widened channel, and an overall lack of channel diversity and complexity in Redwood Creek;
- During the summer months of recent low rain years (2001 and 2002) the lowermost reach of Redwood Creek became intermittent or dry from the Highway 101 bridge up to the confluence with Hayes Creek, loosing connection with the estuary. In a recent newspaper article in the McKinleyville Press (2002), it was noted by a local resident since 1945 that Redwood Creek has never been so low.

Lower Subbasin Recommendations

Barriers to Fish Passage

- Modify or remove potential barriers such as deltas or boulder and/or debris accumulations that may impede upstream fish passage into tributary streams for spawning.

Flow and Water Quality Improvement Activities:

- Promote near stream conifer growth to reduce solar radiation and to moderate air temperatures along stream corridors. This will reduce heat inputs to Redwood Creek and its tributaries and help to keep water cool.

Erosion and Sediment Delivery Reduction Activities:

- Any reduction of sediment from upstream sources will benefit the lower mainstem Redwood Creek;
- In order to reduce sediment delivery to Redwood Creek and its tributaries RNSP should continue efforts such as road improvements (e.g., upgrading crossings, rocking native surface roads, outsloping, ensuring surface drainage does not flow directly into watercourses, etc.) and decommissioning (e.g., removing unstable fills, removing drainage structures and fills, restoring natural contours, blocking vehicle access, etc.) throughout the Redwood Creek Basin;
- To address accumulations of fine sediments observed in Elam, Bridge, and Forty-four creeks, Sediment sources from eroding stream banks and adjacent hillslopes should be identified and treated.

Riparian and Stream Habitat Improvement Activities:

- Where appropriate, land managers should use tree planting, thinning from below, and other vegetation management techniques to promote the development of large near stream conifers along mainstem Redwood Creek, Bridge Creek or other steam reaches with a low coniferous component in the riparian zone. Thinning to encourage conifer growth should be done with consideration of maintaining adequate shade canopy over stream channels;
- Strategically add wood into pools and flatwater units to increase pool depth and overall shelter complexity in Bridge, and Elam, Forty-four creeks and other streams within the subbasin that lack deep complex pools;
- Consider adding shelter complexity with wood to existing cool temperature refuge sites on Redwood Creek, and lower reaches of tributary sites. This could be done even on a temporary basis using small woody debris to provide escape cover for juvenile salmonids during summer season. The cool patches may be located in temperature stratified pools or adjacent to cool water inputs from tributary flows at Bridge Creek or near springs, and seeps.

Education, Research, and Monitoring Activities:

- The range of habitat conditions within the Lower Subbasin provides an opportunity to monitor channel and salmonid habitat recovery rates using habitat improvement treatments within a variety of channel types and conditions;
- Perform stream habitat surveys in tributaries throughout the Lower Subbasin to identify excessive erosion areas, assess salmonid stream habitat, identify deltas or boulder and/or debris accumulations that may impede passage for spawning, and to identify potential sites for improving habitat with restoration techniques;
- Monitoring in-channel sediment by measuring sediment size distribution, turbidity, V*, photo points should be increased; tracking of streambed levels with stream channel cross sections should be continued along the mainstem reach of lower Redwood Creek;
- A long term, concerted monitoring effort between the land owners, interested parties and responsible agencies is needed to determine the status and trends of anadromous fish populations in Lower Subbasin streams. Studies should include annual counts of adults and juveniles to develop stock recruitment relationships;
- Land managers and responsible agencies should increase continuous temperature monitoring efforts along the mainstem and at additional tributary locations to determine the impact of cold-water inputs from tributary and ground water sources;
- Although there were no formal stream reach surveys for LWD; observations of crews and findings regarding pool complexity indicate that there is limited instream LWD. Formal surveys for LWD loadings could be done to verify these observations.

Middle Subbasin

Streams of the Middle Subbasin play important roles as anadromous salmonid habitat. Coho salmon, once noted as abundant in some streams were not detected in 2001 surveys. Potential access problems and lack of sheltered pools may be limiting coho in these streams.

Elevated summer water temperature, lack of channel complexity, and low amounts of instream shelter elements are factors most limiting juvenile anadromous salmonid production in mainstem

Redwood Creek. These limiting factors are products of channel aggradation and associated impacts such as a widened channel, lack of shade over the water, and lack of LWD. Watershed erosion, excessive sediment inputs to streams and loss of large conifers from nearstream areas in the Upper, Middle subbasins are root causes for limiting factors.

Water temperature is generally suitable in the tributaries year round. However, the tributary streams lack sufficient habitat area in deep, well sheltered pools and most tributaries have less than a desirable amount of good spawning habitat.

After 30 years of relatively moderate winters and droughts, the mainstem has self-adjusted from a near featureless channel, overwhelmed by sediment, to a channel providing structural diversity and formation of regularly spaced pools, runs, and riffles. Except for a setback in 1997 due to a 12 year flood event that initiated several landslides, associated sediment delivery and a rise in bed elevations, the channel remains on a recovery trajectory (M. Madej RNSP, Personnel Communication). The problem of deficient amounts of instream shelter still persists.

The Middle Subbasin offers opportunities for developing and implementing watershed, stream and riparian habitat improvement activities. Watershed management strategies aimed at reducing erosion and developing functional near stream forests will help address landscape issues affecting stream habitat. The near stream forest corridor should be managed to encourage growth and retention of large coniferous trees. Stream habitat improvement activities should focus on increasing depth and complexity to existing pool habitats, and adding shelter complexity to cool water refuge sites. This will help to reduce water temperature, increase bank stability, provide a source of LWD and reduce sediment inputs to stream channels.

Middle Subbasin Issues and Summary Findings

Salmonid populations have declined from historic levels, prompting listings under the state and federal ESA's:

- There is a decline in abundance and distribution of coho salmon and coastal cutthroat trout in the Middle Subbasin;
- Coho salmon were not observed in 2001 fish surveys;
- The summer steelhead population has declined to critically low levels of abundance;
- Chinook salmon show variable spawning success among years.

Impairments to freshwater habitat needed to complete salmonid freshwater life cycles have been identified as a leading factors in the decline of Redwood Creek's anadromous salmonids:

- Mixed conditions for salmonid spawning and rearing success exist in the subbasin;
- There is a lack of shade canopy along mainstem Redwood Creek;
- High summer water temperature along the mainstem Redwood Creek and lower reaches of Lacks and Minor creek impairs juvenile rearing habitat and adult holding habitat for summer steelhead;
- There is a lack of deep and complex pools in tributary streams and mainstem Redwood Creek;
- A lack of instream large woody debris (LWD) contributes to poor aquatic habitat structure including a low number of deep, complex pools;

- LWD recruitment potential to Lower Subbasin appears low at many locations;
- Stream habitat conditions in the Middle Subbasin can be improved.

<u>The Middle Subbasin terrain is highly susceptible to erosion:</u>

- High potential exists for large sediment inputs from disturbed and unstable hillslopes;
- High levels of sediment are stored in mainstem and some tributary channels;
- Historically active landslide features cover 4,200 acres (6.5%) of the subbasin. These features are critical sources of sediment inputs to stream channels.

- **Land uses can increase erosion rates:**
  - Land use has made the Middle Subbasin's terrain more susceptible to erosion;
  - High road density of both abandoned and useable roads adds to sediment delivery potential;
  - Debris slides and debris flows are often initiated by management activities (such as road construction) that take place on existing earthflows or rockslides.

<u>Riparian and near stream forests have been altered by timber harvests and bank erosion:</u>

- Timber harvests have caused significant levels of disturbance to riparian and near stream forest areas causing a reduction in both overstory shade canopy and LWD input potential;
- In response to aggraded channels, stream banks erode, channels widen, and riparian vegetation becomes less affective to provide shade over the water;

<u>What are the impacts from Chezem dam on Redwood Creek and salmonids?</u>

Middle Subbasin Recommendations

Barriers to fish passage

- Investigate improving fish passage through 500 foot long culvert under HWY 299 on Lupton Creek;
- Modify sediment deltas or boulder accumulations that impede upstream migration into tributaries. A sediment delta formed by boulder accumulations is located within the lowermost reach of Panther Creek and possibly other tributaries;
- Modify large debris accumulations that may impede fish passage on Panther Creek and other tributaries (completed by Green Diamond and the California Conservation Corps in 2004).

Flow and Water Quality Improvement Activities:

- Reducing water temperature is essential to improve anadromous salmonid habitat in the Middle Subbasin. A long term goal should be to reduce water temperature in the middle reach of Redwood Creek and the lower reaches of tributary streams including Panther, Coyote, Minor and Lacks creeks;

- A reduction in temperature will likely occur as the result of increasing pool frequency and depth, controlling erosion, increasing the coniferous component of the riparian zone and allowing near stream conifers to obtain large size for development of microclimate benefits;
- Functional nearstream conifer forests need to be developed and/or maintained along Redwood Creek in the Middle Subbasin. Large near stream conifers are needed to help increase shade canopy, moderate air temperatures, and to promote LWD loading. This may require more than the minimum protection provided by present Forest Practice Rules;
- Increase shelter complexity in existing cool water refuge sites;
- Managers should explore methods to develop cool water refuge sites on Redwood Creek and the lower reaches of Panther, Lacks, and Minor and other creeks. Methods should include using pool scour elements, and increasing connectivity to cool ground water sources.

Erosion and Sediment Delivery Reduction Activities:

- In streams where the majority of pool tail spawning substrate is highly embedded with fine sediment, sediment sources should be located, rated according to their potential sediment yields, and treated;
- Upgrade or decommission roads in accordance with existing or future road assessment surveys. This work should be done especially on older roads built below current standards on unstable slopes and roads near streams in Upper and Lower Lacks, Minor, Lupton, Panther, and Coyote and Roaring Gulch planning watersheds;
- For timber management in Lacks, Minor, Coyote and other planning watersheds, with active landslides or on steep and/or potentially unstable slopes (slopes ≥ 35%) we recommend the use of lower impact silvicultural prescriptions to maintain vegetative cover, root strength, and the use of cable systems or helicopter yarding to reduce the potential for mass wasting and sediment production;
- Land management activities adjacent to all streams, particularly in the inner gorge, head walls, and on slopes 35% (19 degrees) or greater, must be carefully evaluated and designed to avoid generation and delivery of sediment to stream systems;
- Timberland managers should decrease the use of tractor or ground lead yarding on all slopes steeper than 35% (19 degrees); and use fully suspended (skyline) cable or helicopter yarding on steep and unstable slopes;
- RNSP and private landowners should continue efforts such as road improvements (e.g., upgrading crossings, rocking native surface roads, outsloping, ensuring surface drainage does not flow directly into watercourses, etc.) and decommissioning (e.g., removing unstable fills, removing drainage structures and fills, restoring natural contours, blocking vehicle access, etc.) throughout the Redwood Creek basin to reduce sediment delivery to Redwood Creek and its tributaries;
- A qualified, licensed geologist or engineer should be consulted before initiating any project that involves road construction, timber harvest, or building. The NCWAP Landslide Potential maps should be reviewed before modifying hillslopes to avoid creating, or contributing to, hillslope instability and excessive, human-induced erosion through mass wasting or creation of gullies.

Riparian and Stream Habitat Improvement Activities:

- To increase overstory shade and to promote input of large woody debris, encourage near stream conifers to grow to large sizes and retain them along Redwood Creek and all tributary streams in the subbasin;
- Where there is adequate shade canopy along Lacks, Minor, Molasses, and Coyote Creeks, land managers should consider thinning hardwoods from below in riparian areas to hasten the development of large near stream conifers;
- Trees large enough to function as LWD need to be allowed to grow and recruit to stream channels from riparian and near stream forest areas.
- Consider adding pool forming structures to increase the number of pools in Redwood, Lacks, Minor, Lupton, Molasses, Panther, Mill, and Beaver creeks;
- Deepen and increase the size of existing pools in Dolly Varden, Toss Up, Garret, Lupton creeks and in lower reach of Coyote Creek;
- Add wood into pools and flatwater units to increase shelter complexity especially where the average size of near stream conifers is less than 2 feet DBH in Redwood, Lacks, Minor, Lupton, Panther, Coyote and Molasses creeks;
- Consider adding shelter complexity to existing temperature refuge sites on Redwood Creek.

Education, Research, and Monitoring Activities:

- Water temperature monitoring should continue at the current locations to observe changes in temperature as effects from aggradation, degradation, channel widening, and riparian condition adjust over time;
- Identify potential perched sediment deltas and/or debris accumulations that may impede passage for spawning into Panther Creek and other Middle Subbasin tributaries;
- A long term, concerted monitoring effort between land owners, interested parties and responsible agencies is needed to determine the status, abundance and trends of anadromous fish populations of the Middle Subbasin streams;
- Investigate impacts from fine sediments on salmonid spawning success and aquatic insect community structure;
- Formal stream reach surveys were not done for LWD; however observations of crews and findings regarding pool complexity indicate that there is limited instream LWD. Formal survey for LWD loadings could be done to verify these observations;
- Monitoring in-channel sediment routing and storage(e.g., sediment size distribution, turbidity, V*, photo points, etc.) should be increased and tracking of streambed levels (i.e., stream channel cross sections) should be continued;
- Summer steelhead dive counts should be conducted on an annual basis on the middle reach of mainstem Redwood Creek and in the lower reach of Lacks and Minor creeks;
- Continue monitoring juvenile fish population trends such as downstream migrant trapping operations on mainstem Redwood Creek;
- Investigate possible improvements to cool water refugia and potential to increase such areas;
- Further study of the effects of Chezem summer dam on fish and fish habitat is warranted;

- Ensure that CEQA-compliant environmental assessment is conducted prior to issuance of the Fish and Game Code 1603 streambed alteration permits and Corps of Engineers or NOOA Fisheries permitting requirements are complete for any summer dams on Redwood Creek.

Upper Subbasin

The Upper Subbasin streams provide important habitat for anadromous salmonids. The mainstem of Redwood Creek is an important migratory route for all species and provides spawning area for Chinook salmon. Tributary streams provide important salmonid spawning and year round rearing habitat for steelhead.

Streams of the Upper Subbasin were severely affected by the combination of unstable geology, intensive land use, the flood of 1964, and other recent flood events. Land use activities, combined with natural geologic slope instability of the subbasin, and high precipitation regimes continue to generate large quantities of sediment inputs into streams. Watershed management strategies aimed at reducing sediment inputs by reducing erosion will help address landscape issues that contribute to impairment of aquatic habitat.

Stream habitat improvement projects should also focus on preserving cool water flowing from the headwaters reach of Redwood Creek by re-establishing riparian shade and reducing the channel width along mainstem Redwood Creek. Restoration projects such as tree planting and adding LWD and shelter complexity to stream channels may increase the rate of stream recovery. Adding shelter complexity to cool water refuge sites will provide summer steelhead protective cover needed during their summer holding stage. In tributary watersheds, stream habitat improvement activities should focus on increasing frequency, depth and complexity to pool habitats, adding instream shelter complexity, and promoting nearstream coniferous forest growth retention.

Upper Subbasin Issues and Summary Findings

Impairments to freshwater habitat needed to complete salmonid freshwater life cycles have been identified as a leading factors in the decline of the Upper Subbasin's anadromous salmonids:

- Mixed conditions for salmonid spawning and rearing success exist in the subbasin;
- There is a lack of shade canopy along mainstem Redwood Creek;
- High summer water temperature along the mainstem Redwood Creek impairs juvenile rearing habitat and adult holding habitat for summer steelhead;
- The water temperatures increase quickly to above desirable levels in the upper mainstem Redwood Creek due to the widened stream channel and lack of riparian shade canopy;
- There is a lack of deep and complex pools in tributary streams and mainstem Redwood Creek;
- A lack of instream large woody debris (LWD) contributes to poor aquatic habitat structure including a low number of deep, complex pools;
- LWD recruitment potential to Lower Subbasin appears low at many locations;
- Stream habitat conditions in the Upper Subbasin can be improved.

The Upper Subbasin is highly susceptible to erosion:

- Seventy-two percent of the subbasin has high or very high land slide potential
- Land use such as timber harvest activities exacerbate erosion potential;
- Recently the Upper Subbasin has produced more sediment than the Middle and Lower Subbasins combined;
- The Upper Subbasin generates and exports sediments that contribute to aggradation and persistent impairment of salmonid habitat in the Lower and Estuary subbasins.

Land management can influence watershed processes:

- Land uses, such as timber harvest activities, increase erosion potential over much of the Upper Subbasin;
- High road density of both abandoned and useable roads adds to instream sediment delivery potential;
- Debris slides and debris flows are often initiated by management activities (such as road construction) that take place on existing earthflows or rockslides.

Riparian and near stream forests have been altered by timber harvests and bank erosion:

- Timber harvests have caused significant levels of disturbance to riparian and near stream forest areas causing a reduction in both overstory shade canopy and LWD input potential;
- In response to aggraded channels, stream banks erode, channels widen, and riparian vegetation becomes less affective to provide shade over the water;

Upper Subbasin Recommendations

Barriers to Fish Passage

- Modify sediment deltas or boulder and/or debris accumulations that impede upstream migration into tributaries. A barrier is located at the confluence of Lake Prairie Creek. Consider modifying debris accumulation and building step pools in the lower reaches where sediment accumulations may restrict or delay access to migrating salmonids.

Flow and Water Quality Improvement Activities:

- Maintaining and improving good water temperatures in tributaries and in the upper reach of Redwood Creek is essential to improve of salmonid habitat condition in the Upper Subbasin and also will provide benefits to downstream reaches;
- A high priority should be placed on re-establishing riparian shade and reducing the channel width along portions of the upper reach of Redwood Creek. This will help extend the benefits of cool water flowing from the headwaters reach.

Riparian and Instream Improvement Activities:

- In appropriate locations along the upper reach of mainstem Redwood Creek, consider installing live willow baffles or other habitat structure to help establish shade over water and to encourage channel width reduction;
- The riparian corridor and near stream forest along the upper reach of Redwood Creek should be managed to encourage growth and retention of coniferous trees. The shade provided by large trees will help maintain cool water temperatures, their stems will provide large woody debris and provide nutrient inputs to the stream, and roots will add stability to banks and buffer against sediment delivery. This may require more than the minimum protection provided by Forest Practice Rules;
- In tributaries with an abundance of shade, consider cautious thinning from below in riparian areas to hasten the development of large near stream conifers;
- Design and engineer pool enhancement structures to increase the number of pools or increase the size, deepen, or add shelter complexity to existing pools in Redwood Creek and Fern Prairie Creek and Minon Creek and other tributaries;
- Consider adding shelter complexity with wood and large boulders to existing cool temperature refuge sites on upper Redwood Creek. This could be done on a seasonal basis using small woody debris to provide escape cover for adult summer steelhead and juvenile salmonids during summer season. The cool patches may be located in temperature stratified pools or adjacent cool water inputs from tributary flows, springs, and seeps;
- To address the lack of complex pools add, large woody debris in Redwood and Minon and Fern Prairie creeks, consider direct placement of large woody debris in existing pool habitat, especially where the average size of near stream conifers is less than 2 feet DBH;
- Consider the use of conservation easements along the upper reach of Redwood Creek to protect valuable riparian and near stream forest from development or timber harvests.

Erosion and Sediment Delivery Reduction Activities:

- In streams where the majority of pool tail spawning substrate is highly embedded with fine sediment, sediment sources should be located, rated according to their potential sediment yields, and treated;
- Upgrade or decommission roads in accordance with existing or future road assessment surveys, especially roads located on unstable slopes and roads near streams. These are found throughout the subbasin but are most frequent in Windy Creek, Twin Lakes Creek, Bradford Creek, and High Prairie Creek Planning Watersheds;
- Consider bank stabilization projects in tributary streams throughout the Upper Subbasin;
- Throughout the Upper Subbasin, timberland managers should avoid the use of tractor yarding on slopes steeper than 35% (19 degrees) and instead use full suspension cable or helicopter yarding on steep and/or highly unstable slopes.

Education, Research, and Monitoring Activities:

- Conduct stream surveys in tributaries and mainstem reaches not addressed in this report;
- Continue temperature monitoring at the current locations to observe changes in temperature as effects from mainstem fluvial conditions, such as aggradation, degradation, channel widening, and riparian function adjust through time;

- Monitoring for in-channel sediment (e.g., sediment size distribution, turbidity, V*, photo points, etc.) should be continued and tracking of streambed levels (i.e., stream channel cross sections) should be continued at upper Redwood Creek study sites;
- A long term, concerted monitoring effort between the land owners, interested parties and responsible agencies is needed to determine the abundance and trends of anadromous fish populations of Upper Subbasin streams;
- Summer steelhead dive counts should be conducted on an annual basis along the upper reach of mainstem Redwood Creek.

Improvement in the Redwood Creek Basin

Advantages

Redwood Creek Basin has several advantages for planning and implementing successful salmonid habitat improvement activities that include:

- Approximately one third of the basin in managed by RNSP to persevere natural resource values;
- An interdisciplinary team of watershed scientists from the Redwood Creek Land Owners Association are working together to solve watershed problems;
- A basin wide effort is underway to perform road assessment and road implementation projects;
- Several in basin studies have shown relationships between land use, geology, climate, and stream conditions;

Challenges

The Redwood Creek Basin also has some challenges confronting efforts to improve watershed and fish habitat conditions, and increase anadromous fish populations:

- Land use on the basin's unstable geology will require careful planning and mitigation to prevent large scale sediment generating floods like seen in the past;
- A watershed wide cooperative land-base needs to be maintained, so treatment options can be implemented at a basin scale. Without basin wide participation, some key areas may be removed from consideration of project development;
- The present reduced levels of coho salmon and summer steelhead populations limit re-colonization potential into improved or expanded habitat conditions.