Big River Basin Executive Summary

California Coastal Watershed Planning and Assessment Program

The Big River Basin Assessment began in 2003 as a project of the North Coast Watershed Assessment Program (NCWAP). That program was established by the California Legislature in July 2000 and was managed by the California Resources Agency and the California Environmental Protection Agency. Participating Resource Agency departments included Fish and Game (CDFG), Forestry and Fire Protection (CDF), Conservation/California Geologic Survey (DOC/CGS), and Water Resources (DWR), in conjunction with the North Coast Regional Water Quality Control Board (NCRWQCB) and State Water Resources Control Board.

In July 2003, after conducting large scale assessments on the Mattole and Gualala rivers, and Redwood Creek, the program was eliminated because of reductions in the state budget. However, large-scale watershed assessment efforts are ongoing by the CDFGs Coastal Watershed Planning and Assessment Program (CWPAP), with input from other Resources Agency departments as budgets allow.

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

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. In basins where information was available, these 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. 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 historical land use changes in the watersheds;
- NCRWQCB 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 compiled, collected, and analyzed data related to anadromous fisheries habitat and populations.

Results of assessments conducted by various agency personnel on the Big River team were brought together in an integrated synthesis process. This process describes spatial and temporal relationships between watershed and stream conditions and dynamic watershed processes that have been at work to form them. To assist in this process, the team used Geographic Information System (GIS) based watershed data coverage and an Ecological Management Decision Support (EMDS) model to help evaluate watershed conditions and processes.

Scale of Assessment and Results

The Big River assessment team used the California Watershed Map (CalWater version 2.2.1) to delineate the Big River Basin into three subbasins for assessment and analyses purposes (Figure 1). These study areas were the Coastal, Middle, and Inland subbasins. In general, the CalWater 2.2a Planning Watersheds (PWs) contained within each of these assessment subbasins have common physical, biological, and/or cultural attributes. However, there is enough variance between the three 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 reporting of findings and making recommendations for watershed improvement activities that are generally applicable across a large, relatively homogeneous area. The large Inland Subbasin was also sub-divided into the North Fork, South Fork, and headwaters drainages for some analysis purposes.

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 include:

- A basin level Synthesis Report that includes:
  - Collection of Big 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: www.coastalwatersheds.ca.gov/, and http://imaps.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, important factors include:

- Adequate instream flow during low flow periods to provide juvenile salmonids free forage range, cover from predation, and utilization of localized temperature refugia from seeps, springs, and cool tributaries;
- Good water quality, including appropriate water temperature, water chemistry, turbidity, and sediment load;
- Diverse habitat provided by a combination of deep pools, riffles, and flatwater habitat types;
- Free passage through stream channels;
- A functional riparian zone to control the amount of sunlight reaching the stream, provide vegetative litter and invertebrate fall, contribute to stream bank cohesion, buffer impacts from adjacent uplands, and provide large woody debris and complexity to the stream.

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 floods or major 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 have included 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 like 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).

Figure 1. Big River Subbasins and CalWater2.2a Planning Watersheds.

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 (FRGP). For example, several California counties, with FRGP 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 the 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.

Big River Basin

Named for the giant redwood trees that used to line its banks, the Big River drains a 181.1 square mile watershed located in the northern California Coast Range in western Mendocino County, entering the Pacific Ocean at the town of Mendocino, about 10 miles south of Fort Bragg. The Big River Basin extends 24 miles to the east, to within three miles of Willits and Highway 101. It drains primarily from east to west, sharing ridges with the Noyo River and Caspar Creek basins to the north and the Albion and Navarro river basins to the south. Elevations within the Big River Basin range from sea level at the basin outlet to Irene Peak at 2,836 feet, 5 miles south-southwest of Willits in the east end of the Martin Creek Planning Watershed, Inland Subbasin.

The basin's topography is diverse along its length, varying from flat estuarine environments and uplifted marine terraces to rugged mountains with high relief in the eastern portion. It is characterized by narrow ridgelines separated by deeply incised inner gorges of the major river channels and streams draining the watershed.

The western end of the drainage is distinguished by a long estuary laden with mudflats that become narrow floodplains further upriver and occupy a relatively narrow inner gorge. A sand bar at the mouth partially restricts the connection to the sea during low flow periods in the late summer. Tidal influence extends upward from the mouth three miles in the winter and as far as eight miles during the highest spring tides making the Big River Estuary one of the longest estuaries in northern California (Warrick and Wilcox 1981).

Inland areas of the basin are characterized by second growth forest, with some grasslands in the southeast margins. Logging of the basin started in the 1860s near the mouth and gradually moved eastward. Early logging included heavy use of splash dams, effects of which can still be seen today. Most of the basin is currently owned by large timber companies and managed for timber harvest, though the state owns some sections, and there are smaller ownerships as well.

The Big River is listed on the National Rivers Inventory, a list of potential wild, scenic, and recreational river areas within the United States. The river is listed for five outstandingly remarkable values: scenery, recreation, fish, wildlife, and history (NPS 2004).

The basin supports runs of coho salmon (*Oncorhynchus kisutch)* and steelhead trout (*O. mykiss*). Chinook salmon (*O. tshawytscha*) have been reported occasionally, but there is no significant run. Historical accounts indicate that salmon were plentiful and that salmon fishing was a common activity. However, agency reports starting in the 1950s indicate that salmonid populations were depleted and in decline. In recent years, efforts have been underway to recover salmonid stocks of the Big River Basin. For example, local residents and conservation groups recently organized and purchased a 7,342-acre parcel at the mouth of Big River from a timber company and gave it to California Department of Parks and Recreation to be managed for conservation and recreation.

General Issues, Assessment Sample Base, Assessment Questions, Findings and Conclusions, and Improvement Recommendations

Big River Basin General Issues

Public scoping meetings with Big River Basin residents and constituents and initial analyses of available data by watershed experts developed this working list of general issues and/or concerns:

- Water diversions have the potential to significantly reduce surface water flows of Big River and its tributaries. The potential for land development and increase in demand for water from the basin remains an issue of concern;
- Water temperatures are thought to be unsuitable for salmonids in the mainstem Big River and larger tributaries;
- There is concern that chemical and diesel spills in the basin are impairing stream conditions;
- There is concern that large amounts of sediment generated from road related failures have been and may be delivered to stream channels during major storms;
- Chronic fine sediment levels in many tributaries and the mainstem Big River are thought to be high;
- Estuary conditions are thought to be impaired by sediment;
- Fish habitat, including pool frequency, pool depth, shelter, large woody debris presence, cobble embeddedness, and fish passage are though to be unsuitable for salmonids throughout the basin;
- Timber harvest has been and continues to be the dominant land use in the Big River Basin;
- Landsliding related to roads, timber harvesting, and grassland is a concern;
- Long term effects to stream channels from splash dam logging throughout the basin are of concern;
- It is believed that there have been reductions in salmonid populations from historic levels;
- Sport and commercial fish harvests may have played a role in the reduction of numbers of Big River's salmonid populations;
- There is concern that the decline in the abundance of spawning salmon has likely caused a corresponding decrease in nutrients and organic matter available to streams;
- Graham Mathews and Associates (GMA) (2001) may have over-estimated the bankfull width used in the Sediment Source Analysis (CGS 2004).

Assessment Sample Base

This assessment was based on the following information:

- Geologic maps compiled by CGS, United States Geological Survey, California Department of Forestry, aerial photographic mapping, and field reconnaissance geologic mapping. Geologic features were compiled through the previous work of Durham, 1979, Kilbourne, et al, 1982, 1983, and 1984, Short and Spittler, 2002, stereoscopic evaluation of aerial photos, and limited geologic and geomorphic reconnaissance mapping. Aerial photographs and compilation of existing data represent the primary information sources for this product;
- Additional geologic information was used from the CGS geologic reports about the new Big River State Park Unit for DPR (CGS 2004);
- CDF compiled a history of the basin and analyzed historic land uses and vegetation;
- NCRWQCB utilized information provided by private and agency cooperators on water and substrate quality in various years from 1973 to 2002, with the majority of data from 1995 to 2002;
- Stream flow and precipitation information compiled from the Big River Sediment Source Analysis (GMA 2001a) and DWR;
- CDFG surveyed 55 streams and three sections of the mainstem Big River between 1995 and 2002. Private and agency cooperators also contributed various biological and physical data from 1958 to 2002, including a Watershed Analysis of lands in the basin owned by the Mendocino Redwood Company.

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 and NCRWQCB Appendices contain more specific assessment methods, findings, conclusions, and recommendations for stream and watershed improvements.

Big River Basin

What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Big River Basin?

Findings and Conclusions:

- Both historic and current data are limited. Little data are available on population trends, relative health, or diversity. According to NOAA Fisheries Endangered Species Act listing investigations, the populations of salmonids have likely decreased in the Big River Basin as they have elsewhere along California and the Pacific Coast. Coho salmon in Mendocino County are currently listed as endangered under the California and federal Endangered Species Acts and steelhead trout are listed as threatened under the federal Endangered Species Act;
- Based on limited CDFG, USFWS, Hawthorne Timber Company (HTC), MRC, and the School of Natural Resources at Mendocino High School (SONAR) presence surveys and surveys documented by NMFS, the distributions of coho salmon and steelhead trout do not appear to have changed since the 1960s;
- Steelhead trout were documented in more reaches surveyed by CDFG and MRC since 1990 than coho salmon;
- Thirty tributaries, the mainstem Big River, and the estuary had records of coho salmon and steelhead trout since 1990. Twenty additional tributaries recorded only steelhead trout.

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

Findings and Conclusions:

Flow/Water Quality

- Water temperatures at all seven monitoring sites along the mainstem of the Big River were unsuitable for salmonids;
- Water temperatures in tributaries across the basin showed that temperatures were generally suitable for salmonids in the Coastal and Middle subbasins and mixed in the Inland Subbasin. Temperatures in the larger tributaries in the Inland Subbasin such as the North and South forks Big River were generally unsuitable for salmonids while temperatures in the smaller tributaries were suitable;
- There have been very few water quality samples taken across the basin. Some sites show indications of exceeding NCRWQCB criteria for sodium, copper, specific conductance, total dissolved solids, aluminum, zinc, or boron. However, these findings are based on few sample sites and in some cases may be artifacts of the type of sampling procedure used.

Fish Passage

- Fish passage barriers have been identified in seven surveyed tributaries across the basin and several small tributaries along the estuary are blocked to fish passage by perched culverts;
- Areas of dry channel found during CDFG stream surveys may indicate fish passage problems in some tributaries during periods of low flow.

Erosion/Sediment

- Data collected in four tributaries in the basin indicated excessive amounts of fine sediment in the sub-0.85 mm and/or sub-6.5mm size classes, which would create unsuitable conditions for salmonids. However, much of the basin has not been evaluated for sediment delivery and deposition.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed reaches within the basin except for James Creek and the mainstem Big River. The mainstem Big River has a larger, broader channel and floodplain and is expected to have reduced canopy levels.

Instream Habitat

- A high incidence of shallow pools, and a lack of cover and large woody debris indicate simplification of instream salmonid habitat in surveyed tributary reaches and the estuary.

Gravel/Substrate

- Cobble embeddedness values in many CDFG surveyed reaches were unsuitable for salmonid spawning success. Of surveyed pool tails, only 17.2% had cobble embeddedness less than 26%. In addition, the MRC characterized spawning gravels as fair quality on segments they surveyed;
- Permeability sampling in four locations throughout the basin indicated low to moderate amounts of fine material. This could indicate suitable to somewhat unsuitable conditions for salmonid in these sample sites.

Refugia Areas

- Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin tributaries where they have generally been rated as high potential refugia. Conditions in the Middle and Inland subbasins are mixed and generally rated as medium potential refugia.

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

Findings and Conclusions:

- The geology of the Big River Basin is primarily comprised of Coastal Belt Franciscan Complex. This portion of the Franciscan complex is relatively stable compared to the mélange terrane of the Central Belt, which is found only in the upper parts of the watershed. A small portion of Tertiary age sandstone is found in the Greenough Ridge - Montgomery Woods State Reserve area (EPA, 2001);
- The Coastal and Middle subbasins have much lower relief and longer slopes than the Inland Subbasin, which has a high percentage of area in higher slope classes;
- Redwood and Douglas fir forests have historically and continue to dominate the basin. Additional vegetation includes tan oak, madrone, alder, bishop pine, pygmy cypress, willow, grass, oak, bay laurel, alder oak, and blueblossom. Pre-European forests consisted of mostly large old-growth trees;
- A long history of wildfire has influenced the current vegetation of the Big River Basin, although the specifics of fire practices and history are unknown. However, fire was a natural and frequent occurrence. Prior to European settlement, the Mendocino Coast experienced a fire every 6-20 years during the last 200-400 hundred years (Brown 1999). In 1931, the Comptche fire swept across the eastern part of the basin, burning 10,733 acres, 9% of the basin;
- The basin has experienced a variety of natural disturbances such as earthquakes, flooding, droughts, and decadal climate shifts. Examples include a moderate earthquake that originated about two miles south of the Albion Basin during the mid to late 1800s, another strong earthquake that originated near Fort Bragg in 1898, and the distant San Francisco earthquake in 1906. Earthquakes often trigger landsliding;
- Landsliding has occurred across the entire basin. More landslides and more volume from landslides by area are found in the Inland Subbasin than the other two subbasins;
- Many of the tributaries in the basin are intermittent in their upper reaches and usually have summer and fall flows of less than 1 cfs.

How has land use affected these natural processes?

Findings and Conclusions:

- Historic timber harvest activities reduced riparian canopy, 86% of the basin has experienced one or more timber harvests. However, riparian canopy is currently suitable along most surveyed tributary reaches across the basin;

- As a result of timber harvest, the current landscape is comprised of smaller diameter forest stands than in pre-European times [61% of trees in 75-100 feet wide watercourse buffer zones have diameter at breast height (dbh) less than 24 inches]. The small diameter of near stream trees across the basin limits the recruitment potential of large woody debris to streams and contributes to the lack of instream habitat complexity;
- Splash dam logging involving 27 splash dams across the basin before 1920 likely greatly accelerated erosion and widened stream channels across the basin. However, significant bed lowering along the lowermost reaches of Big River associated with splash dams is unlikely;
- Post splash damming channels are deeply entrenched, cut down to bedrock in many places, lacking functional floodplains, and depleted of LWD and gravel;
- Early splash dam and barrier removal projects, starting in the 1950s, cleared many streams across the basin of timber-related woody debris. The lack of instream complexity seen today likely results from these past practices;
- A lack of LWD throughout the Big River Basin also allows sediment to move more quickly through the stream system and move downstream in greater quantities than pre-disturbance;
- CGS found that channel narrowing, floodplain growth, and encroachment of forest vegetation on marshes seen since 1900 along the estuary is likely the result of a river channel reclaiming itself after the multiple decades of channel clearing, splash dam flooding, and battering by logs in transport;
- Historic sawmill complexes on the Big River flats reduced wetland habitat;
- Construction of near stream railroads in the Coastal and Middle subbasins and North Fork Big River and roads throughout the basin used fill that constricted stream channels and destabilized streambanks;
- From 1937 to 2000 the rate of landsliding across the basin was 664.3 tons/square mile/year (approximately 332 cubic yards or 33 truck loads). Rates were highest in the Inland Subbasin, followed by the Middle and Coastal subbasins, respectively;
- CGS photo mapping of stream channels in 1984 and 2000 found that negative channel features increased in the Mouth of Big River Planning Watershed (PW) and decreased in the North and South forks Big River and Daugherty Creek, as expected between source and depositional reaches. The greatest reductions in negative channel features were seen in Daugherty Creek;
- There has been a significant increase in road building since 1989 across the basin, especially in the Coastal and Middle subbasins. However, new roads have been built to higher standards, on ridge-tops, and are paved; thus creating less of a sediment source;
- Roads and timber harvesting are listed in the NCRWQCB TMDL report as major sources of human-related sediment into the stream system. The effects from these activities are often spatially and temporally removed from their upland sources;
- County culverts located on three tributaries in the Inland Subbasin have been identified as total salmonid passage barriers by a Mendocino County roads study. Additionally, perched culverts have blocked fish passage to small tributaries along the estuary;
- The recent purchase of a large portion of the estuary and transfer to DPR for management as a park also will likely improve temperature and sediment conditions in the Coastal Subbasin as planned management improves roads and riparian zones.

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 the information available for this assessment, it appears that salmonid populations are currently being limited by:

- Low summer stream flows in tributaries in the Inland Subbasin;
- High water temperatures in the mainstem Big River;
- Fish passage barriers;

- Embedded spawning gravels;
- Reduced habitat complexity.

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

- To minimize and reduce the effects of water diversions, take action to ensure compliance with state water laws to address seasonal diversion, off-stream reservoirs, bypass flows protective of coho salmon and other anadromous salmonids and the normal hydrograph, and avoidance of adverse impacts caused by water diversion;
- Discourage instream flow diversions in tributaries with cooler water temperatures for thermal refugia delivered to the warmer North and South Forks and mainstem Big River in the summer;
- Land managers should work to reduce the temperature of water flowing into the Middle and Coastal subbasins. In order to do this, they should maintain and/or establish adequate streamside protection zones to increase shade and reduce heat inputs to Big River and its tributaries throughout the basin;
- Follow the procedures and guidelines outlined by NCRWQCB to protect water quality from ground applications of pesticides.

Fish Passage

- Consider modifying debris accumulations to facilitate fish passage where necessary;
- Adequately fund prioritization and upgrading of culverts to provide fish passage within the range of coho salmon and to pass 100-year flows and the expected debris loads.

Erosion and Sediment Delivery Reduction Activities

- To reduce sediment delivery to Big River, land managers should continue their efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with landuse activities throughout the basin. Thirty-six CDFG stream surveys had road sediment inventory and control as a top tier tributary recommendation;
- Support and encourage existing and active road management programs undertaken by landowners throughout the basin;
- Map unstable soils and use soil mapping to guide land-use decisions, road design, THPs, and other activities that can promote erosion;
- Sediment sources from eroding streambanks and adjacent hillslopes should be identified and treated to reduce sediment generation and delivery to creeks;
- Limit unauthorized and impacting winter use of unsurfaced roads and recreational trails to decrease fine sediment loads;
- Develop erosion control projects similar to the North Fork Ten Mile River erosion control plan (Mendocino Department of Transportation 2001).

Riparian and Instream Habitat Improvement Activities

- Improve instream structure for juvenile ambush escape and cover. Thirty-one CDFG stream surveys and the mainstem Big River have increase escape cover as a top tier tributary recommendation;
- Add LWD to stream channels where appropriate/feasible to develop habitat diversity and to increase shelter complexity. In addition, there is a need to leave large wood on stream banks and in estuarine channels for potential recruitment into stream channels and the estuary;
- Maintain and improve existing riparian cover where needed;
- Encourage growth and retention of near-stream conifers;
- Ensure that any land management activities include protection and preservation of stream and riparian habitats and maintain or improve ecological integrity within the basin;

- Ensure that high quality habitat is protected from degradation. Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin, and mixed in the Middle and Inland subbasins;
- Consider the use of management strategies such as conservation easements to maximize potential benefits to aquatic habitats from near-stream forest protection.

Education, Research, and Monitoring Activities

- State Parks, DFG, MRC, and HTC should continue and expand existing monitoring of anadromous salmonid populations to include some winter and spring fish sampling;
- Support stream gage installations and maintenance to establish a long term record of Big River hydrologic conditions;
- Additional investigations of the physical characteristics of Big River are needed to re-evaluate the Sediment Source Analysis. A regional curve of bankfull dimensions vs. drainage area should be developed for Mendocino County and used to validate CGS (2004) bankfull discharge estimates for Big River;
- Hillslope and in-stream monitoring proposed by the MRC in their Watershed Analysis (2003) should be carried out and additional monitoring programs throughout the basin should be planned with respect to MRC techniques;
- A study examining how sediment plugs moved downstream from historic splash dam locations over time on air photos is recommended;
- Continue water temperature monitoring at current locations and expand these efforts where appropriate;
- Further study of timberland herbicide use is recommended.

Coastal Subbasin

The Coastal Subbasin includes all of the watershed area of the mainstem Big River below its confluence with Peterson Gulch. This encompasses all of the Big River Estuary. Stream elevations across the subbasin range from sea level to 40 feet at the boundary with the Middle Subbasin. The highest point is above Kidwell Gulch on the border with the Middle Subbasin, at 1,235 feet. The subbasin encompasses 32.5 square miles and occupies 17.9% of the total basin area. The Big River estuary is large relative to the size of the Big River drainage, with tidal influence extending approximately 8.3 miles upstream from the ocean. The estuary is the longest undeveloped estuary in California (Warrick and Wilcox 1981). The river joins the Pacific at an opening at the north side of Mendocino Bay. The bay is protected by rocky headlands. This headland minimizes wave-induced longshore sediment transport and allows the mouth to remain open to the sea year round. The town of Mendocino lies just outside of the Big River Basin, north of the river mouth.

Key Findings

Flow/Water Quality

- There are no water temperature data for the Big River Estuary; however, it is expected that the water temperatures in the mainstem Big River quickly cool once they reach the estuary due to the marine influence;
- Water temperatures at monitoring sites on the mainstem of the Big River in this subbasin were fully unsuitable in all years monitored with high diurnal fluctuations (7.9-9.9°F) and high maximum temperatures (75-76°F). This could indicate unsuitable conditions for salmonids in the mainstem upstream of the estuary;
- Most of the Little North Fork Big River and tributary monitoring sites exhibited low diurnal fluctuations suggesting good shading, and/or good flow conditions and/or a tempering marine influence. This indicates suitable conditions for salmonids;
- It is probable that the Little North Fork has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows;
- There are no water chemistry data for the estuary and little data for this subbasin as a whole;
- Water chemistry data available from a small stream near the estuary (R.M. 0.4), but not related to the water chemistry in the estuary itself, indicated that alkalinity and sodium appeared to be below the minimum water quality criteria;

- Basic water chemistry on the mainstem Big River both upstream and downstream of the Little North Fork appear to be within applicable numeric Basin Plan water quality objectives. However, sodium at the mainstem sites upstream and downstream of the Little North Fork confluence exceeds its criteria. Additionally, copper, which is used in many herbicides, exceeds its criteria at sites upstream of the Little North Fork. However, these finding may be artifacts of the type of sampling procedure used;
- Total and fecal coliform was detected on the mainstem at the sites upstream of the Little North Fork confluence. It appears as though the levels detected are not hazardous.

Fish Passage

- Winter access problems for adult fish at a non-existent channel near the mouth of Manly Gulch may be stopping it from being utilized for habitat by salmonids;
- Small tributaries along the estuary are blocked to fish passage by perched culverts;
- Areas of dry channel found during CDFG stream surveys on eight streams may indicate fish passage problems in some tributaries.

Erosion/Sediment

- Pebble counts and V* measurements in one sampled tributary (Berry Gulch) and McNeil core sediment samples in the Little North Fork indicated excessive amounts of fine material in these streams. This could indicate unsuitable conditions for salmonids.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin, but unsuitable on surveyed reaches of the mainstem Big River as expected on a larger order stream with wide channels.

Instream Habitat

- In the estuary, escape and ambush cover are unsuitable for salmonids;
- A high incidence of shallow pools and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in all nine surveyed tributary reaches.

Gravel Substrate

- Cobble embeddedness values in most surveyed reaches were unsuitable for salmonid spawning success.

Refugia Areas

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as high potential refugia;
- The Big River Estuary and the Little North Fork Big River provide the best salmonid refugia in this subbasin;
- The estuary, mainstem Big River, and Little North Fork Big River serve as critical contributing areas, which provide critical ecological functions needed by salmonids such as providing a migration corridor or supplying high quality water.

Key Recommendations

Flow and Water Quality Improvement Activities

- Protect instream flows in Little North Fork Big River, Railroad Gulch, and Laguna Creek to help moderate or cool the warmer mainstem Big River in the summer.

Fish Passage

- Consider modifying fish passage barriers on Manly Gulch and small tributaries along the estuary.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements, and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated that nine out of eleven surveyed tributaries in this subbasin had road sediment inventory and control as a top tier tributary recommendation;

- Continue to support and encourage current and future road management programs undertaken by California State Parks;
- California State Parks should follow the recommendations of CGS (2004) in treating identified sediment sources on roads and road crossings within Big River State Park;
- All roads within Big River State Park and their associated watercourse crossings required for public safety, existing easements, future restoration effort success, and public access must be maintained to high standards (CGS 2004);
- Encourage the use of appropriate Best Management Practices for all land use and development activities to minimize erosion and sediment delivery to streams. For example, low impact yarding systems should be used in any timber harvest operations on steep and unstable slopes to reduce soil compaction, surface disturbance, and resultant sediment yield;
- California Department of Parks should consult with appropriate resource professionals to assist in transitioning industrial timberlands on the Big River State Park to self-sustaining forest (CGS 2004).

Riparian and Instream Habitat Improvement Activities

- Where feasible, add LWD to develop habitat diversity in the main channel and to increase shelter complexity for salmonids. CDFG stream surveys indicated that all nine surveyed tributaries and the mainstem Big River have increase shelter as a top tier tributary recommendation;
- Leave large wood in estuarine channels, on the beach, and on stream banks for potential recruitment into the estuary;
- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the Big River Estuary, mainstem Big River, Little North Fork Big River, Railroad Gulch, East Branch Little North Fork Big River, Berry Gulch Tributary, and Rocky, Thompson, and Berry gulches;
- Create a channel under the main road to connect Manly Gulch to Little North Fork Big River to address winter access problems for adult fish at the non-existent channel at Camp Three.

Education, Research, and Monitoring Activities

- Conduct surveys of ten small tributaries entering the estuary through blocked culverts in the Big River State Park to determine if they provide salmonid habitat;
- Establish monitoring stations to track instream sediment along the estuary;
- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River;
- Assess water temperature and dissolved oxygen in the estuary as there is currently no data on these indicators;
- Establish long-term water chemistry monitoring stations in the lower mainstem Big River. If there are indications of problems, monitoring should be implemented in tributaries as necessary to determine the source of the problem;
- Encourage the involvement of SONAR in fish and habitat monitoring activities.

Middle Subbasin

The Middle Subbasin includes the watershed area of the mainstem Big River just above its confluence with Peterson Gulch to its confluence with the South Fork Big River, not including the North Fork Big River. Stream elevations range from 40 feet at boundary with the Coastal Subbasin to 210 feet at the confluence with the North Fork Big River. The highest point in the subbasin is above Dietz Gulch at approximately 1,560 feet. The Middle Subbasin is the smallest of the three Big River subbasins at 17.9 square miles and occupies 9.9% of the total basin area. Most of the subbasin is owned by Hawthorne Timber Company or Mendocino Redwood Company and is managed for timber production.

Key Findings

Flow/Water Quality

- All of the water temperature monitoring sites on the mainstem Big River had (MWATs) that varied from moderately to fully unsuitable (67-70°F) with maximum daily temperatures (73-77°F) in excess of the lethal limit for salmonids. High diurnal fluctuations were also recorded (7.5-12.8°F), suggesting poor canopy and/or low flows;
- Data from lower Two Log Creek indicated water temperatures were between fully suitable, with a minimum observed MWAT of 58°F, and undetermined with a maximum observed MWAT of 64°F. However, large diurnal temperature fluctuations (6.7-12.0°F) were recorded at both lower Two Log Creek sites, which may indicate poor canopy and/or low flows;
- The only monitored tributary to Two Log Creek, Beaver Pond Gulch, had fully suitable water temperatures, but based on the thermograph, the monitoring device may have been placed in a thermally stratified pool or a site with a significant groundwater component;
- Hatch Gulch had fully suitable water temperatures with minimal diurnal fluctuations. It is likely that Hatch Gulch provides some cooling effect to the mainstem Big River;
- It is also probable that Two Log Creek has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows;
- There is no water chemistry data for this subbasin.

Fish Passage

- Areas of dry channel in Kidwell and Hatch gulches found during CDFG stream surveys may indicate fish passage problems.

Erosion/Sediment

- McNeil core sediment samples in Two Log Creek indicated excessive amounts of fine material in this stream. This could indicate unsuitable conditions for salmonids.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin, but unsuitable on surveyed reaches of the mainstem Big River as expected on a larger order stream.

Instream Habitat

- A high incidence of shallow pools and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in surveyed reaches of Kidwell Gulch, Two Log Creek, and the mainstem Big River between Tramway Gulch and the North Fork Big River.

Gravel Substrate

- Cobble embeddedness values in Hatch Gulch, Saurkraut, and Ayn creeks were unsuitable for salmonid spawning success. In addition, the MRC characterized spawning gravels as fair quality on all seven segments they surveyed;
- Permeability sampling in the Big River below the North Fork Big River indicated low to moderate amounts of fine material. This could indicate suitable to somewhat unsuitable conditions for salmonids.

Refugia Areas

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as medium potential refugia;
- Two Log Creek provides the best salmonid refugia in this subbasin;
- The mainstem Big River serves as critical contributing area.

Key Recommendations

Flow and Water Quality Improvement Activities

- Protect instream flows in Two Log Creek and Hatch Gulch to help moderate or cool the warmer mainstem Big River in the summer.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements, and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated Kidwell Gulch, Two Log Creek, and Saurkraut Creek have road sediment inventory and control as a top tier tributary improvement recommendation.

Riparian and Instream Habitat Improvement Activities

- Where feasible, add LWD to develop habitat diversity in the mainstem channel and to increase shelter complexity for salmonids. CDFG stream surveys indicated Kidwell Gulch, Two Log Creek, and Big River from Tramway Gulch to North Fork Big River have to increase escape cover as a top tier tributary recommendation;
- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the mainstem Big River, Two Log Creek, Ayn Creek, Tramway and Hatch gulches.

Education, Research, and Monitoring Activities

- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River;
- In lower Two Log Creek, both MRC and HTC have temperature monitoring sites in nearly the same location. It may be more effective if one company monitored the site and shared the information with the other while the second monitoring device is deployed at another location.

Inland Subbasin

The Inland Subbasin includes the entire watershed area of the North Fork Big River, South Fork Big River, and the entire watershed area of the mainstem Big River above the confluence with the South Fork Big River. Stream elevations range from 200 feet at the confluence of the mainstem Big River with North Fork Big River to approximately 1,300 feet in the headwaters of the tributaries. The highest point in the subbasin is Irene Peak at 2,836 feet. The subbasin encompasses 130.8 square miles, occupying 72.2% of the total basin area. Most of the subbasin is owned by MRC, Strategic Timber Trust, and Jackson State Demonstration Forest and is managed for timber production. There are also a large number of smaller privately owned parcels near the western border and the small hamlet of Orr Springs lies near the headwaters of the South Fork Big River.

Key Findings

Flow/Water Quality

- Water temperatures at sites on Donkey House, Frykman, Steam Donkey, Goddard, No Name, Water, Johnston, Wildhorse, and Arvola gulches; Chamberlain, James, West Chamberlain, North Fork Ramon, Montgomery, and Martin creeks; Russell Brook; and East Branch North Fork and North Fork Big River are suitable for salmonids;
- Water temperatures at sites on the mainstem Big River, North and South Forks Big River, James, Gates, Martin, Ramon, and Daugherty creeks are unsuitable for salmonids;
- Sites that appear to have strong groundwater influences based on their thermographs include Goddard, Donkey House, No Name, Water, Frykman, Steam Donkey, Goddard Wildhorse, and Johnston gulches;
- Relatively large diurnal fluctuations in virtually all of the monitored sites throughout the South Fork drainage indicate that there is poor canopy and/or low flows. The only exceptions to this are the monitoring sites at Montgomery Woods Reserve, and the sites located in gulches that are apparently dominated by groundwater;

- Montgomery Creek was within the fully suitable range at approximately 60°F during all three years monitored. The maximum diurnal fluctuations varied between 4-5°F. This site is in an undisturbed location in the Montgomery Woods Reserve and is probably a good example of what can be achieved with adequate canopy in the warmer interior portion of the Big River Basin. It should be noted that much of the interior watershed is naturally grasslands, and could not reasonably be expected to achieve these water temperatures;
- It appears as though James Creek has a cooling effect on the North Fork Big River, Gates Creek provides some cooling effect to Daugherty Creek, Russell Brook contributes cooler water to the mainstem Big River, and Water Gulch and West Chamberlain Creek contribute some amount of cooling to Chamberlain Creek;
- On February 27, 2001 a tanker truck containing approximately 7,000 gallons of used motor oil and diesel overturned on Highway 20 and discharged numerous petroleum compounds into James Creek. Because of active cleanup and frequent verification monitoring, this spill is unlikely to have a sustained impact on fish and wildlife;
- A water quality sampling site on the South Fork Big River below the confluence with Daugherty Creek had specific conductance and total dissolved solids measurements that were relatively high compared to Basin Plan water quality objectives;
- Limited water quality data from Chamberlain Creek indicated that specific conductance was at or slightly below Basin Plan standards. Several other water quality parameters, including aluminum, copper, sodium, and zinc exceeded their respective criteria. Given the limited nature of this sampling effort and uncertainties about the method and exact location of sampling, it is suspected that this does not represent actual in-stream water quality but possibly water quality at some point in the drinking water system;
- Sodium was detected at concentrations above the water quality criteria at the North Fork Big River;
- Ammonia samples collected in the North Fork and South Fork Big River indicated that ammonia did not exceed the numeric criteria in either site;
- The two samples of boron and sodium in the South Fork Big River exceeded their numeric criteria. In the case of boron, both samples also equaled or exceeded the DHS action level (1,000 µg/l) and agricultural use criteria (700-750 µg/l).

Fish Passage

- Fish passage barriers exist on Dark Gulch, Johnson Creek, an Unnamed tributary to the South Fork of the Big River, Gulch Sixteen Tributary, and Soda Gulch;
- Areas of dry channel found in 31 surveyed tributaries during CDFG surveys may indicate fish passage problems.

Erosion/Sediment

- McNeil core sediment samples indicated that a significant amount of fine sediment may be entering the North Fork Big River either from James Creek, or between James Creek and Chamberlain Creek. This could indicate unsuitable conditions for salmonids;
- Turbidity and suspended sediment samples in ten locations across the subbasin showed values ranging from 1.6 NTU in James Creek to 811 NTU in South Fork Big River below the confluence with Daugherty Creek.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin except for James Creek.

Instream Habitat

- A high incidence of shallow pools and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in 21 out of 41 surveyed tributaries.

Gravel Substrate

- Cobble embeddedness values in 36 out of 41 CDFG surveyed tributaries were unsuitable for salmonid spawning success. In addition, the MRC characterized spawning gravels as fair quality on 32 segments surveyed and good quality on four;

- Permeability sampling indicated low to moderate amounts of fine material at East Branch North Fork Big River, and significant fine material at Daugherty and Ramon creeks. This could indicate unsuitable conditions for salmonids in Daugherty and Ramon creeks.

Refugia Areas

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as medium potential refugia;
- North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, Water Gulch, West Chamberlain Creek, Arvola Gulch, South Fork Big River, Daugherty Creek and Gates Creek provide the best salmonid refugia in this subbasin;
- The North Fork and South forks Big River and Daugherty Creek serve as critical contributing areas.

Key Recommendations

Flow and Water Quality Improvement Activities

- Protect instream flows in James Creek, Chamberlain Creek, East Branch North Fork Big River, Montgomery Creek, and Russell Brook to help moderate or cool the warmer North and South Forks and mainstem Big River in the summer;
- Ensure that adequate streamside protection measures are used to provide shade canopy and reduce heat inputs to the North and South Forks Big River, mainstem Big River, and Daugherty Creek.

Fish Passage

- Consider modifying fish passage barriers on Dark Gulch, Johnson Creek, an unnamed tributary to the South Fork of the Big River, Gulch Sixteen Tributary, and Soda Gulch.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated that road sediment inventory and control were top tier tributary recommendations in:

Anderson Gulch
Arvola Gulch
Boardman Gulch
Dark Gulch
Gates Creek
Gulch Sixteen
Gulch Sixteen Tributary
James Creek
Martin Creek
Martin Creek Left Bank Tributary
Mettick Creek
Montgomery Creek
North Fork James Creek
North Fork Ramon Creek
Park Gulch
Rice Creek
Russell Brook
Soda Gulch
South Fork Big River
South Fork Big River Tributary #2
Valentine Creek
Water Gulch
Water Gulch Tributary

- Sediment sources from eroding streambanks and adjacent hillslopes should be identified and treated to reduce sediment generation and delivery to creeks in the Chamberlain Creek PW, South Fork drainage, and the headwaters drainage.

Riparian and Instream Habitat Improvement Activities

- Consider adding pool enhancement elements (e.g. LWD) to increase the number of pools or deepen existing pools and add shelter complexity to all surveyed tributaries in the North Fork drainage, Daugherty, Soda, Johnson (tributary to Gates Creek), and Snuffins creeks, and the right bank tributaries of Martin Creek;
- Consider modifying debris accumulations in Horsethief Creek, Dark Gulch, Russell Brook, and Martin Creek to facilitate fish passage;

- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, Water Gulch, West Chamberlain Creek, Arvola Gulch, South Fork Big River, Daugherty Creek and Gates Creek.

Education, Research, and Monitoring Activities

- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River, North and South Forks Big River, James, Gates, Martin, Ramon, and Daugherty creeks;
- Conduct a stream habitat survey of the mainstem Big River upstream from the confluence with North Fork Big River.

Propensity for Improvement in the Big River Basin

Advantages

The Big River Basin has several advantages for planning and implementing successful salmonid habitat improvement activities that include:

- An expanding group of cooperative landowners that includes both public and private landowners from all three subbasins in the Big River that are interested in improving watershed and fishery conditions. Additionally, a technical advisory committee has been formed to aid State Park management decisions. The effect of this is the ability to choose locations for projects where the best result can be achieved in the shortest time period;
- The recent purchase of a large portion of the estuary and transfer to the State of California for management as a park also will likely help improve localized temperature and sediment conditions in that area of the Big River Basin;
- Much of the basin is in the ownership of a few large landowners, making the creation and implementation of a coordinated basin-wide watershed program simpler;
- This assessment provides focus on watershed conditions and processes from the basin scale, through the subbasin scale, and down to the level of specific tributaries. This helps focus project design efforts so that local landowners can pursue the development of site specific improvement projects on an adaptive basis;
- Like most river systems, Big River coho salmon and steelhead trout meta-populations have evolved and adapted to the basin's unique conditions. Although these meta-populations are likely below historic levels, there remain local stocks that can take advantage of improved conditions.

Challenges

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

- Not all landowners are interested in salmonid habitat improvement efforts. Without a watershed wide cooperative land-base, treatment options are limited. In some cases this can remove some key areas from consideration of project development;
- Current levels of coho salmon and steelhead meta-populations could limit the amount of needed straying to rapidly colonize fish into improved or expanded habitat conditions.

Table 1. Summary of Big River subbasins stream and basin conditions and recommended actions.

Identified Conditions	Coastal Subbasin	Middle Subbasin	Inland Subbasin
Instream sediment	~	~	~
Water temperature	~	~	~
Water chemistry	~	~	~
Pools	-	-	-
Flow	+	+	~
Escape cover	-	-	-
Fish passage barriers	~	+	~
Natural sediment sources	~	~	~
Management related sediment sources	-	-	-
Recommended Improvement Activity Focus Areas			
Flow			X
Erosion/Sediment	X	X	X
Riparian/Water temperature	X	X	X
Instream habitat	X	X	X
Gravel/Substrate	X	X	X
Fish passage barriers	X		X

\+ Condition is favorable for anadromous salmonids - Condition is not favorable for anadromous salmonids
~ Condition is mixed or indeterminate for anadromous salmonids X Recommended improvement activity focus areas

The likelihood that any North Coast basin will react in a responsive manner to management improvements and restoration efforts is a function of existing watershed conditions. In addition, the status of watershed delivery processes influencing watershed condition will affect the success of watershed improvement activities. A good knowledge base of these current watershed conditions and processes is essential for successful watershed improvement.

Acquiring this knowledge requires property access to design, implement, monitor, and evaluate suitable improvement projects. Thus, systematic improvement project development is dependent upon the cooperative attitude of resource agencies, watershed groups and individuals, and landowners and managers.

The Big River assessment has considered a great deal of available information regarding watershed conditions and processes in the basin. This long assessment process has identified problems and made recommendations to address them while considering the advantages and challenges of conducting watershed improvement programs in the Big River Basin.

After considering these problems, recommendations, advantages and challenges, the Big River Basin appears to be an excellent candidate for a successful long-term, programmatic watershed improvement effort. According to the current refugia analysis, the Big River has medium potential to become a basin with high quality fishery refugia. 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. Guidelines and resources made available through the California Coho Recovery effort will also provide key aid for reaching the goal of high quality fishery refugia.