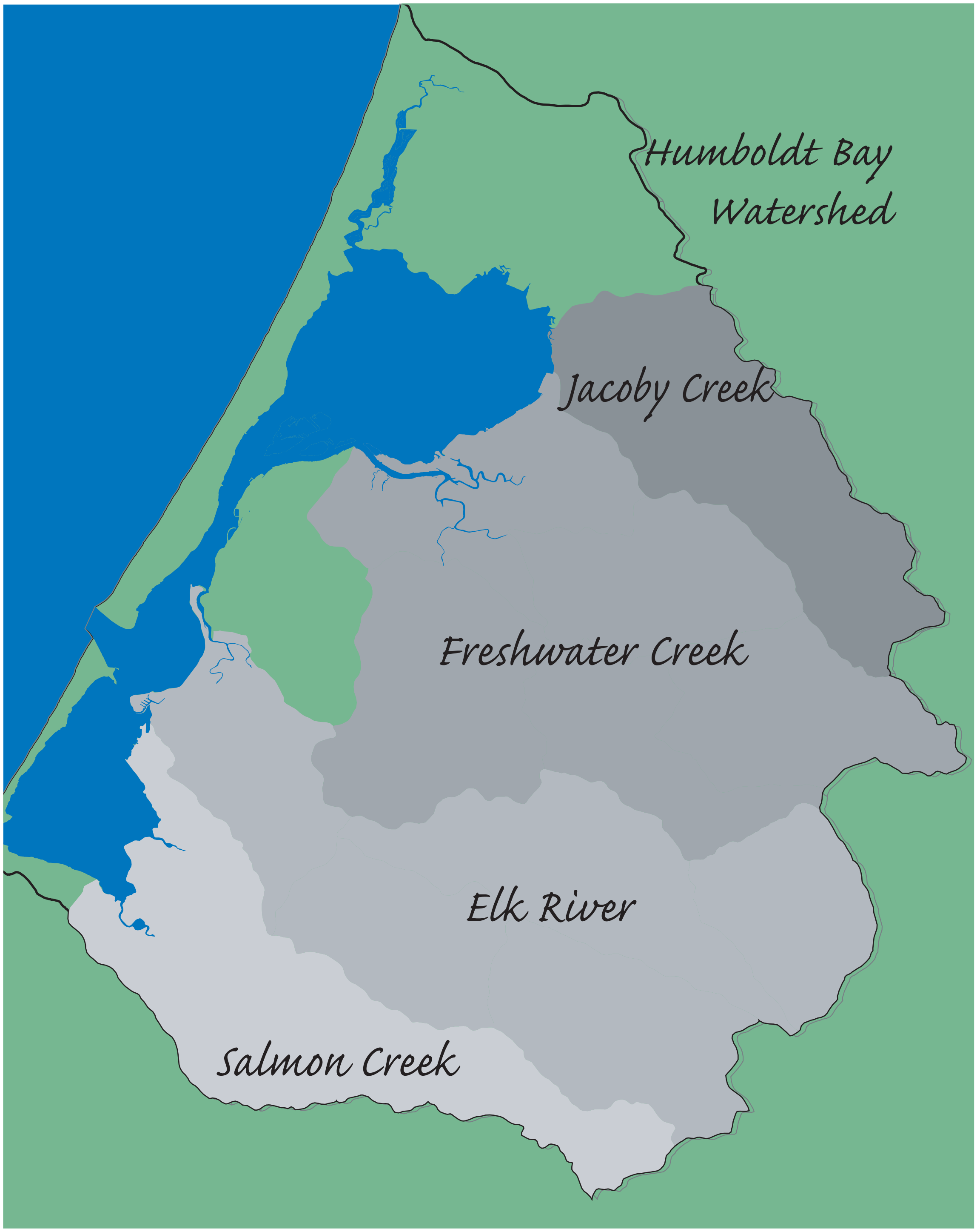
Humboldt Bay Watershed
Salmon and Steelhead Conservation Plan



Prepared for:
California Department of Fish & Game and the
California Coastal Conservancy

Coastal Conservancy

Prepared by:
The Humboldt Bay Watershed Advisory Committee and
The Natural Resources Services Division of
Redwood Community Action Agency

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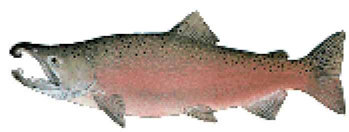

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The mission of the **Department of Fish and Game** is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public.

The **State Coastal Conservancy** acts with others to preserve, protect and restore the resources of the California Coast with a vision of a beautiful, restored, and accessible coastline.

The mission of the **National Marine Fisheries Service**, a branch of the **National Oceanic and Atmospheric Administration**, is to provide stewardship of living marine resources through science-based conservation and management and the promotion of healthy ecosystems.

The mission of the **Humboldt Bay Watershed Advisory Committee** is to improve the watershed's anadromous salmonid populations and related resources while considering regional ecological and socioeconomic needs.

The **Natural Resources Services Division of Redwood Community Action Agency** would like to thank these organizations for their visionary assistance with this document; informational, financial, inspirational, and otherwise.

Endorsement for the Humboldt Bay Watershed Salmon and Steelhead Conservation Plan

We, the undersigned members of the Humboldt Bay Watershed Advisory Committee, have worked together to develop the goals and objectives contained in the Humboldt Bay Watershed Salmon and Steelhead Conservation Plan. The goals and objectives are intended to be used as a framework by agencies and community members either individually or collectively to improve the habitat and management of the Humboldt Bay watershed.

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Preface

The *Humboldt Bay Watershed Salmon and Steelhead Conservation Plan* (*SSCP*) is the result of a long and sometimes arduous process of research and data collection, meetings, lively and sometimes heated discussions, writing, review, revision, and back for more discussion. At times it felt like we, the members of the Humboldt Bay Watershed Advisory Committee (HBWAC), would never finish with this document. However, the process has been as important as completing the final product as we have developed respect for the each other; learned from our differences; developed a greater understanding of opposing view points; and come to agreement on goals and objectives for salmon conservation.

We know that this Plan is not the answer to the ultimate survival of salmon and steelhead in the Humboldt Bay watershed, but is a piece of the puzzle and offers a foundation to base future planning and implementation. Cooperative efforts will not always be the way to ensure that both the human and wildlife communities thrive. There are many other valuable tools available including legal and political avenues, regulations, incentives, personal action, and activism. Discourse, law suits, dissension, regulatory burdens, fear, and anger over how we manage the landscape will continue to be realities within our community. This Plan has evolved from an effort to communicate with people we do not agree with; a willingness to have difficult conversations; and a desire to get out into the watershed and work to protect what we value. This Plan provides some solutions to the threats faced by the salmon populations that the members of HBWAC have agreed upon; whether a timber manager or environmentalist, fisheries advocate or rancher, regulator or private landowner, scientist or farmer. The next step is to take this Plan and ensure that the recommendations it contains are implemented and that new data and information are added to future iterations. The members of HBWAC are eager to help make this happen, and depend upon continued support from past members, technical advisors, funding agencies, and those who have supported this effort to date.

Executive Summary

The *Humboldt Bay Watershed Salmon and Steelhead Conservation Plan* (*SSCP*) is a compilation of watershed information; a report on the evaluation of that information; and a list of high priority goals and objectives aimed at protecting and/or restoring watershed processes in order to preserve and enhance salmon and steelhead habitat. The *SSCP* was developed by the Humboldt Bay Watershed Advisory Committee (HBWAC), a diverse group of watershed stakeholders whose mission is "to improve the Humboldt Bay watershed's anadromous salmonid populations and related resources while considering regional ecological and socioeconomic needs." HBWAC members agreed to work together to find ways to maintain working timber and agricultural lands, accommodate population growth, support sustainable economic development, and protect and restore salmonid populations.

Humboldt Bay watershed contains a mosaic of environments under diverse ownership, jurisdictions, and land use, and no agency or governmental organization has overall responsibility for coordinating watershed protection and/or restoration efforts. It is evident that Humboldt Bay watershed fisheries are in need of recovery. HBWAC did not attempt to set recovery goals, conclusively determine the role of different management activities on cumulative watershed effects (CWE) or recommend specific management restrictions. Instead, the group worked to identify limiting factor trends and design goals and objectives that would assist in the recovery effort.

The *SSCP* was developed to encourage cooperative planning, education, implementation, and evaluation of watershed projects for protecting, maintaining and restoring salmonid habitat and natural watershed processes.

Approach

The *SSCP* focuses on the four main sub-watersheds of Humboldt Bay - from the ridge top to the estuary. From north to south these include Jacoby Creek, Freshwater Creek, Elk River, and Salmon Creek.

Over several years, Redwood Community Action Agency's Natural Resources Services Division (NRS) staff and HBWAC compiled all available existing watershed information for the Humboldt Bay watershed and its tributary sub-watersheds. Sub-committees for each stream provided expert advice, and reviewed and edited draft sub-watershed chapters. Sub-committee products were then brought to the HBWAC for full committee review and approval.

The *SSCP* is comprised of:

- **A summary of information based upon available surveys and reports**
- **Determination of potential limiting factors for salmonids in each sub-watershed (Chapter V)**
- **Goals and objectives that stemmed from that existing information (Chapter VI)**

Historical and current conditions were summarized based on existing information including historical reports, observations, books, newspaper clippings, scientific and technical reports, monitoring data and analysis, fish habitat, sediment and flooding surveys, watershed analysis, letters, memos, and testimonials from landowners. Limiting factors that could potentially affect salmonids were determined for each watershed. Once gaps in research had been identified, priority goals and objectives were developed by the HBWAC.

Overall Conclusions
Because they represent some of the last significant native gene resources in Northern California, the salmonid populations (coho, chinook, steelhead, cutthroat) of Humboldt Bay watershed are critical to conservation and eventual recovery of the species.

Alteration of large-scale watershed processes that create and maintain habitat have impacted salmonid habitat in the Humboldt Bay watershed. HBWAC agreed upon potential and likely limiting factors for salmonids utilizing existing information and data collected from a wide variety of sources. The findings from this research include:

- Concentrations and durations of suspended sediment levels during wet months in Freshwater Creek, and Elk River, and to a lesser extent Jacoby Creek, frequently exceed accepted thresholds for salmonid growth and, at times, survival. Sediment is considered to be the most important limiting factor for salmonids in Freshwater Creek and Elk River.

- The floodplain capacity and function in the Humboldt Bay watershed has been substantially reduced over the past 150 years. Human activity has caused a loss of connectivity between streams and their floodplains reducing overall habitat complexity and availability of backwater and side channel habitat that is important rearing habitat for juvenile salmonids.

- Estuary habitat around Humboldt Bay has been significantly reduced by construction of levees and tidegates, and placement of fill. This habitat is necessary for salmon as it allows them to adapt to salt water and provides significant food resources for growth giving them the best possible chance for survival before they enter the ocean environment.

- The quality and complexity of instream habitat is degraded especially in low gradient reaches that are important for salmonids. There is an overall lack of large wood, deep pools, cover, and clean gravels in all of the watersheds tributary streams.

- Increased sediment inputs from legacy and current timber management activities in the upper watershed, have changed the channel morphology, and reduced channel capacity in the low gradient sections of Jacoby and Freshwater Creeks and Elk River (storage reaches).

- There is a lack of large wood in the middle and lower reaches of Humboldt Bay tributaries. Lack of large wood has reduced available rearing habitat.

- Diminished riparian habitat in Humboldt Bay tributaries has led to increased erosion, bank destabilization, lack of cover and complexity for fish habitat.

Specific Recommendations
HBWAC developed goals to address the above watershed issues concerning salmonids. The goals are very broad and to many may seem so straightforward that they do not even need to be stated. However, with a diverse stakeholder group such as HBWAC, it was critical to come to agreement on the most basic goals. Once agreement was reached the committee members were able to develop more detailed objectives for each goal. From the objectives, riparian projects and descriptions of needed technical studies were developed. This process will be continued. The goals will inform objectives, the objectives

will be refined and actions will be added to ensure implementation. The following is a list of the SSCP Goals for salmon and steelhead conservation in Humboldt Bay watershed:

- Maintain and restore floodplain processes that benefit salmonids.
- Maintain and restore estuary processes that benefit salmonids.
- Maintain and restore balance between delivery of sediment to the channel and sediment transport capacity.
- Establish access to suitable habitat for both adult and juvenile salmonids.
- Maintain and restore channel conditions that support spawning and rearing habitat.
- Protect and maintain instream LWD.
- Increase the amount of instream LWD where appropriate.
- Maintain and restore the long-term supply LWD
- Maintain existing functional riparian habitat.
- Identify and restore degraded riparian habitat where feasible.
- Assess and continue to monitor stream discharge, turbidity, and suspended sediment concentration (SSC).
- Reduce suspended sediment to levels that are suitable to salmonids during all life stages.
- Monitor temperature and dissolved oxygen in Humboldt Bay tributaries.
- Maintain or attain temperature and dissolved oxygen levels beneficial to salmonids during all life stages.
- Maintain and restore suitable high and low flow conditions (flow and velocity) to ensure juvenile summer and winter rearing habitat and adult salmonid migratory access.
- Maintain and restore natural flow regimes and water retention capacity.
- Improve evaluation methods for identifying cumulative watershed effects (CWE) and impacts on salmonids. Provide forums for sharing of information and a climate of mutual cooperation.
- Identify socioeconomic impacts of watershed management and future solutions.
- Work with local resource agencies to provide incentives for landowners who choose to protect and/or restore private lands for fisheries habitat values.

The HBWAC members consider all of the goals in the SSCP to be high priority. The overall prioritization is basic 1) protection of quality habitat; 2) restoration of watershed processes and reconnection of isolated habitat; 3) restoration of instream habitat; and 4) evaluation of restoration techniques and projects. Although there are many good arguments for focusing resources on the most significant limiting factors before working on other restoration opportunities this Plan takes a more holistic view. The entire watershed should be a focus of our stewardship and all of the various tools available should be utilized. Education, outreach, incentives, regulations, acquisition, research, assessment, monitoring, and restoration must all be used in creative ways if we are to protect and ultimately restore healthy runs of native salmon while supporting the local economic and social well being of the community. This document is intended to be updated periodically, dependent on funding availability, progress on project implementation, and need.

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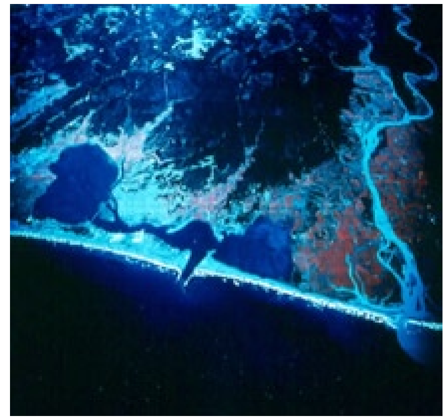
I. Introduction

In Humboldt Bay watershed and elsewhere along the west coast of the United Sates, Pacific salmonids[1] (Oncorhynchus spp.) have experienced dramatic declines in abundance during the past several decades as a result of a multitude of human-induced and natural factors. Wild stocks of salmonids found today in the Humboldt Bay watershed represent remnants of once larger populations that historically thrived in the Bay and it's tributaries.



The 223 square mile Humboldt Bay watershed is important for the spawning, rearing, and migration of anadromous salmonids. The watershed supports four anadromous salmonid species, three of which are considered to be at high risk for extinction.

Three species of salmonids present Humboldt Bay watershed are considered to be at high risk of extinction and are listed as threatened under the Federal Endangered Species Act. They are coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), and steelhead trout (*O. mykiss*). A fourth species found in the watershed, coastal cutthroat trout (*O. clarki clarki*) is not currently listed under the Endangered Species Act (ESA), but was considered for listing in 1999. These remaining salmonid populations in northern California that number in the hundreds are critical to conservation and restoration of the species because they represent the region's **last significant gene resources**. It is essential that existing populations do not deteriorate further, or there will be no basis for recovery. These populations may provide a source of colonists for currently damaged streams as they recover in the future (Higgins 2001).

In order for Pacific salmonid populations to be conserved and restored, a well dispersed network of habitats that retain a high degree of ecological integrity, referred to as **high-quality refugia** must be recovered and preserved to serve as centers for population expansion (Spence et al. 1996). Salmonid populations have historically strayed to avoid habitat degradation, and have re-colonized areas after habitat recovery (Rieman et al. 1993). The last healthy, functioning salmon streams, including those within the Humboldt Bay watershed, constitute refugia (Higgins 2001).

Currently in the Humboldt Bay watershed, coho salmon is the most prevalent of the four species discussed in this document.

While federal and state recovery efforts are underway, this regional document, the *Humboldt Bay Watershed Salmon and Steelhead Conservation Plan* (*SSCP*)*,* was was developed by the Humboldt

[1] The term salmonid refers to members of the family Salmonidae, which includes salmon and trout. Anadromous salmonids migrate between freshwater and the ocean, beginning and ending their lives in freshwater spawning grounds, and spending the majority of their adult lives at sea. Salmon make this migration only once, whereas trout will return to their spawning grounds several times before dying.

Humboldt Bay supported commercial and sports fisheries in the early 1900s. The Humboldt Standard reported

in 1930:
Taking advantage of the large number of silverside salmon that are at present in the bay, local sportsmen are taking some record catches with their trolling tackle... Such a phenomenal run of the small size salmon has not been known on this coast for several years, and throngs of fishermen are trolling Humboldt Bay...

and in 1947:
Salmon fishing on Humboldt Bay is assuming the proportions of a boom, as the big fish keep coming in apparently without let-up... Our Humboldt bay salmon run has become statewide news with all the city papers getting excited about it. Seems little doubt but that the bay has stolen the show from the Klamath and Rogue river mouths.

(Historic articles compiled for HBWAC by watershed resident S. VanKirk)

Bay Watershed Advisory Committee (HBWAC), whose members include watershed stakeholders from a diversity of interest groups. The mission of HBWAC is to improve the Humboldt Bay watershed's anadromous salmonid populations and related resources while considering regional ecological and socioeconomic needs.

The Plan is an assimilation of watershed information, followed by goals and objectives aimed at protecting and/or restoring **watershed processes** in order to preserve and enhance salmon and steelhead habitat in the sub-watersheds of Humboldt Bay. The SSCP offers the foundation for a framework to systematically and cooperatively engage in salmonid habitat enhancement efforts in Humboldt Bay watershed. The long-term purpose of the SSCP is to encourage cooperative planning and implementation for salmonid conservation.

I. A. Scope

The Humboldt Bay watershed is located in the Eureka Plain Hydrologic Unit of the North Coast Hydrologic Region[2]. This document discusses the sub-watersheds that drain into Humboldt Bay and estuarine aquatic habitats, but excludes the bay proper. The *SSCP* focuses on four main sub-watersheds of the Humboldt Bay watershed - from the headwaters to the estuaries. From north to south these include Jacoby Creek, Freshwater Creek, Elk River, and Salmon Creek. See Figure II.1 for location of Humboldt Bay and it's major sub-watersheds.

The focus of the SSCP is on protection and restoration of watershed processes that benefit anadromous salmon and steelhead and their habitat. See Table I.2 for overview of anadromous salmonid species in Humboldt Bay watershed and their characteristics.

This document was developed for use by local, state, and federal governments as well as by landowners, consultants and watershed groups to help these agencies in their efforts to protect and improve watershed processes that support salmonid habitat. This document is intended to be updated periodically, dependent on funding availability, progress on project implementation, and need.

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[2] CALWATER 2.2 watershed designations

I. B. ESA Status of Salmonids in Humboldt Bay Watershed

The National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) is legally responsible for the conservation and recovery of threatened and endangered salmonid populations. The NMFS is responsible for evaluating and listing salmonid ESUs under the Federal ESA and the California Department of Fish and Game (CDFG) is responsible for listing salmonid ESUs under the State ESA.

For more information about ESA listings or to view maps of the ESUs visit the NOAA website

www.nwr.noaa.gov

Salmonid species function as reproductively isolated populations, or Evolutionarily Significant Units (ESUs), which evolve separately and behave like individual species. ESUs have the same protection as species under the Endangered Species Act (ESA).

Excessive water temperatures, high turbidity, sedimentation of habitats, loss of habitat complexity, sport and commercial harvest, pollution, poor hatchery practices, and migration barriers are some of the factors that have contributed to the decline in population abundance of wild salmonid stocks around the globe. Along the north coast surrounding the Humboldt Bay watershed, three species of salmonids are considered to be at high risk of extinction and have been listed as threatened under the Federal ESA. One of those species has been listed as threatened by the State of California. These species and dates of their listing are as follows:

Anadromous Salmonid Species	Federally Listed	State Listed
Coho salmon	1997	2004
Chinook salmon	1999	na
Steelhead trout	2000	na
Coastal Cutthroat Trout	na	na

Table I.1: ESA Status of Anadromous Salmonid Species in Humboldt Bay Watershed

- **Chinook *(Oncorhynchus tshawytscha)***
  Humboldt Bay watershed hosts fall chinook which belong to the California Coast ESU, which includes chinook in coastal streams from Redwood Creek in Humboldt County to the Russian River in Sonoma County. The California Coast ESU was listed as threatened under the ESA in September of 1999, based on loss of habitat and the fact that fall chinook appear to occur in relatively low numbers in northern streams.

- **Coho *(Oncorhynchus kisutch)***
  Humboldt Bay watershed hosts fall and spring coho which belong to the Southern Oregon and Northern California Coast (SONCC) ESU. This ESU includes coho from Cape Blanco in Curry County, Oregon to Punta Gorda in Humboldt County, California. NMFS (currently NOAA Fisheries) listed the SONCC coho ESU as threatened in May of 1997, and defined the ESU as all coho salmon naturally spawning in coastal streams between Cape Blanco and Punta Gorda. The SONCC

Table I.2: Characteristics of Anadromous Salmonids in Humboldt Bay Watershed

Species	Juveniles	Adult	Range	Spawning Time and Location	Spawning Behavior
Chinook *(Oncorhynchus tshawytscha)*	Dorsally blue-green to brown body silvery or light yellow; 6-12 parr marks; adipose fin edged with black.	Largest of the species, averaging 18 to 24 pounds; black lower gumline, olive brown to dark maroon with heavy black spotting on back.	Sacramento-San Joaquin Rivers north to Alaska. In Asia from Japan to Siberia.	Fall run chinook utilize the mainstems of larger river systems, with some utilization of smaller tributaries. Typically 1 to 2% gradient. Typically October to January.	Females lay up to 4,000 eggs; always die after spawning.
Coho *(Oncorhynchus kisutch)*	Adipose fin has dark edge, center is opaque; caudal, anal and adipose fins are pale orange. The leading fin ry of the anal fin is longer than the others and is sickle-shaped.	Black spots on their backs and tail fins; white gums, spawning males have bright red sides, females are paler.	Monterrey Bay to Alaska. In Asia from Northern Japan to Anadyr River in Russia.	Coho utilize all accessible reaches of streams, especially side channels, typically 1-3% gradient. Typically November to January.	Females lay 1000 to 5000 eggs; always die after spawning.
Steelhead *(Oncorhynchus mykiss)*	Dorsally blue or olive grey, silvery on sides and belly; 8 - 13 parr marks, oval almost round; back sides and dorsal fin covered with black spots.	Silvery sides and belly; black spots on back, head, sides, dorsal and caudal fins; mouth lining is white.	Originally found west of the Rockies from Baja to Alaska; introduced throughout the world. Resident forms are known as rainbow trout.	Steelhead typically utilize the tributary channels less than 8% (usually 3-5%) gradient; can use stable side channels to th emainstem. Typically late winter through spring (Dec.-April).	Females lay 200 - 12,000 eggs; some females are capable of spawning up to two or three times throughout their lifespan. If the fish survives spawning it will outmigrate to the ocean and return to spawn again.
Cutthroat *(Oncorhynchus clarki clarki)*	Body evenly spotted above and below lateral line; fins generally plain except for a dark leading edge on dorsal fin; tail usually spotted.	Dark olive green dorsally, sides and belly silvery white; spotting heavy over entire body and fins, especially on front half of body; red or yellow "cutthroat" mark at base of throat.	Humboldt County to Alaska; optionally anadromous	Cuthtoat utilize small streams and headwaters, usually further up than steelhead; use off-channel habitats such as intermittent tributaries and sloughs. Typically late winter through spring.	Females lay 400 - 4000 eggs; some females may spawn up to five times throughout their lifespan.

ESU was listed as state threatened by the State of California in June 2004.

- **Steelhead *(Oncorhynchus mykiss)***
  Humboldt Bay watershed hosts winter and summer steelhead. Humboldt Bay watershed's steelhead belong to the Northern California ESU, which extends from Redwood Creek in Humboldt County to the Gualala River in Sonoma County. The ESU, which includes both winter and summer steelhead, was listed as threatened in June of 2000 based on habitat degradation and the genetic influence of hatchery steelhead on wild stocks.

Chinook salmon

Humboldt Bay watershed's **coastal cutthroat (Oncorhynchus clarki)** belong to the Southern Oregon/California Coast ESU. While some biologists familiar with the region believe, and anecdotal evidence suggests, that major declines in cutthroat populations have occurred since historic times, some populations appear to be stable or increasing (O. W. Johnson et al. 1999). NOAA Fisheries concluded in 1999 that a listing was not warranted at that time. Since then, NOAA Fisheries transferred jurisdiction under the ESA for this species to the U.S. Fish and Wildlife Service (USFWS).

Coho salmon

Regulatory Implications of ESU Listings
Animals or plants listed under the ESA are protected from 'take', which is further defined as 'harm or harassment'. To protect listed fish, any activity that may have an effect on a listed species may be regulated or prohibited. This can include changes or closure of fishing seasons, or regulation of land use practices and development.

Steelhead trout

Part of NOAA Fisheries' regulatory jurisdiction is to designate critical habitat for each listed species. Any actions by the federal government or that has a federal nexus that may affect critical habitat may be regulated and overseen by NOAA Fisheries. Actions on non-federal lands that may have and effect on an ESU may require consultation with NOAA Fisheries. NOAA Fisheries has authority to issue incidental take permits for a listed species if the applicant provides a Habitat Conservation Plan (HCP). For example, Pacific Lumber Company has an HCP and an incidental take permit for coho, chinook, steelhead and coastal cutthroat trout in the Humboldt Bay watershed. Green Diamond Resource Company, the other large commercial timber company in Humboldt Bay watershed currently has an HCP for spotted owls, but is working on an Aquatic HCP that is likely to be approved in Summer 2005.

Coastal cutthroat trout

Chum salmon (Oncorynchus keta) were historically present in the Humboldt Bay watershed, but have not been found in recent years except occasionally in small numbers. Chum salmon Humboldt Bay watershed can be considered in the Pacific Coast Evolutionarily Significant Unit, which was petitioned for federal inclusion to the United States and deemed not warranted.

NOAA Fisheries is currently in the process of developing guidelines for avoiding "take", creating ESU recovery plans, and monitoring recovery for local coho, chinook, and steelhead stocks, as mandated under the ESA. This procedure necessitates cooperation between local, state, and federal governments along with other watershed stakeholders.

I. C. Integration with Regional Planning Efforts and State and Federal Recovery Strategies

The development of the *SSCP* has coincided with both federal and state salmonid recovery planning efforts, and is intended to help synchronize the efforts of groups currently participating in salmonid conservation, not only making them more efficient, but also maximizing the ability of the region to draw state and federal watershed matching grants.

The goals and objectives developed by HBWAC for the *SSCP* were based upon guidelines that have been developed in other watersheds in the Pacific Northwest.

There are numerous water quality, land use, and habitat conservation related planning documents being created by agencies and organizations in Humboldt Bay and around the watershed (Appendix A). Information and goals from the *SSCP* have been incorporated in varying degrees, in to state and federal coho recovery planning and Total Maximum Daily Load (TMDL) process, including the CDFG *Recovery Strategy for California Coho Salmon*, and Elk River and Freshwater Creek's TMDLs. Likewise, applicable information and goals from these documents and processes have been incorporated into the *SSCP*.

Project activities developed in order to achieve the goals and objectives in this document are intended to be cross referenced to protocols in the CDFG *California Salmonid Stream Habitat Restoration Manual.*

Goals and objectives in the *SSCP* are consistent with goals for the State Water Resources Control Board's (SWRCB) *Watershed Management Initiative*, in that this Plan promotes cooperative and collaborative efforts and is designed to focus limited resources on key issues. Protecting and enhancing the anadromous salmonid resources is a broad goal stated by the SWRCB for the Humboldt Watershed Management Area.

Goals and objectives of the *SSCP* are being incorporated into the Humboldt Bay Management Plan (currently being developed by the Humboldt Bay Harbor, Conservation, and Recreation District) and the Humboldt County 2005 General Plan Update.

The mission of HBWAC is to improve the Humboldt Bay watershed's anadromous salmonid populations and related resources while considering regional ecological and socioeconomic needs.

I. D. Goal Development Strategy and General Methods

I. D. 1. The Humboldt Bay Watershed Advisory Committee

The Humboldt Bay Watershed Advisory Committee (HBWAC) was formed in the summer of 1997, primarily in response to the Federal ESA coho listing. The mission of HBWAC is to improve the watershed's anadromous salmonid populations and related resources while considering regional ecological and socioeconomic needs. HBWAC is a cooperative, voluntary association of timberland managers, ranchers, salmon restoration interests, state, federal and local government agencies, environmental groups, citizen groups, and business interests.

HBWAC meets on a monthly basis to conduct watershed planning, including developing outreach and education projects and writing the *Humboldt Bay Watershed Salmon and Steelhead Conservation Plan*. HBWAC provides a forum for communication and cooperation between multiple interest groups, stakeholders, and overlapping jurisdictions within Humboldt Bay watershed. HBWAC has 13 voting members, each with one alternate voting member, representing diverse interest groups (Table I.3). A two-thirds majority is required to pass any committee action. A quorum of seven is necessary to take action on agenda items. The HBWAC meetings are open to the public.

Redwood Community Action Agency's (RCAA) Natural Resources Services Division (NRS) staff and HBWAC have compiled existing information for background of this document which led to creating goals and objectives for each sub-watershed in the Humboldt Bay watershed. Sub-committees for the specific sub-watersheds provided technical and expert advice and reviewed drafts. Before any information was added to the plan, sub-committee work was brought to HBWAC for full committee review. A completed draft of the plan was approved by HBWAC before being released to the public.

Interest Represented	Member Affiliation
Local Government	City of Arcata
State Government	California Coastal Commission California Department of Fish and Game
Federal Government	NOAA - National Marine Fisheries Service
Recreational Fishing	Recreational Fisherman
Watershed Restoration	Fisheries Focus Humboldt Fish Action Council
Environmental Groups	Northcoast Environmental Center Sierra Club
Education/ Outreach	CampFire USA
Science/Technical	McBain and Trush
Landowners/ Agriculture	Rancher Apple Farmer
Industrial Timber	Pacific Lumber Company
Business	Vacant
Watershed Group	Salmon Forever
At Large	Citizen

Table I.3: Humboldt Bay Watershed Advisory Committee - Interests Represented

I. D. 2. *Humboldt Bay Watershed Salmon and Steelhead Conservation Plan* Strategy/Guidelines

I. D. 2.1 Ecological and Biological Goals Framework

An effective strategy to ensure the long-term persistence of salmonids must be grounded in principles of watershed dynamics, ecosystem function, and conservation biology (Spence et al. 1996; Frissel 1993).

Jacoby Creek Watershed gravel bar and representative riparian vegetation

As previously mentioned, considering that Humboldt Bay watershed serves as high quality refugia for Pacific Coast salmonids and that the existing salmonids represent the last significant gene resources, critical habitat needs to be protected and restored. Guidelines for developing the *SSCP* goals and objectives were based on the following ecological and biological goals for salmon and steelhead conservation that were developed by Spence et al. (1996).

- Maintain and restore natural **watershed processes** that create habitat characteristics favorable to salmonids. It is essential that whole, contiguous landscapes be managed to protect natural processes (i.e., the natural rates of delivery of water, sediment, heat, organic materials, nutrients and other dissolved materials), rather than specific states (Reeves et al. 1995). Ecosystems are dynamic, evolving entities that must be managed to retain their capacity to recover from natural disturbances (e.g. climate change, fire, disease, floods).

- Maintain **habitats required by salmonids during all life stages** - from embryos and alevins through adults - and functional corridors linking these habitats. The complex life histories of salmonids demand a wide array of habitat types. Different portions of a watershed may accommodate spawning and rearing, and these habitats vary with species.

- Maintain **connectivity between high-quality habitats** to allow for reinvasion and population expansion. The high degree of landscape fragmentation that has resulted from human activities has left many salmonid populations in relative isolation.

I. D. 2.2 Limiting Factor Determination

Alteration of large-scale watershed processes that create and maintain habitat have impacted salmonid habitat in the Humboldt

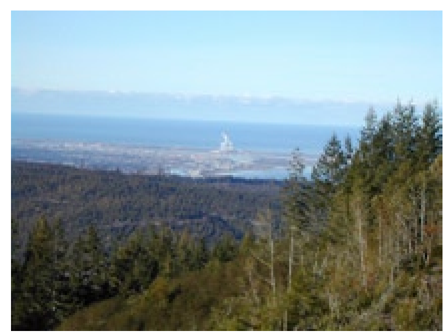
Bay watershed. Stream channels essentially act as transport systems for water, sediment, wood, nutrients and heat which are input into the watershed. In an undisturbed watershed, these products enter streams at natural rates. Land use activities alter the rate of supply of watershed products to the channels, resulting in environmental changes and, potentially, impacts to salmonid populations (Bryant 1996). HBWAC agreed upon *potential and likely* limiting factors utilizing existing information, personal communications, observations, and data collected for other assessments.

II. Setting

Humboldt Bay, a multi-watershed coastal lagoon, is the largest estuary in California north of San Francisco, located 275 miles south. Within the basin are the ancient redwoods of the Headwaters Forest, highly productive industrial timberlands, prime agricultural lands, and functioning streams and wetlands, all of which are connected to the bay and its eel grass beds and tidal marshlands. These natural features support some of the best remaining wild salmon runs in northern California, as well as hundreds of aquatic species, shorebirds, and waterfowl species, and dynamic urban and rural communities of well-informed and actively involved people.

Humboldt Bay is a major shipping center for the north coast and hosts an extensive oyster industry. The most heavily populated urban centers around Humboldt Bay include the City of Arcata (pop. 16,651) and the City of Eureka (pop. 26,128).

The Humboldt Bay watershed is 223 square miles in area. Elevation of the ridges forming the boundary of the watershed to the east is 1,500 feet on average. A narrow band of relatively flat land, consisting of both tidal marshes and stream floodplains, surrounds the bay. Over 90 percent of the bays former tidelands have been converted to agricultural, residential, commercial, or industrial uses. The largest regions of these flatlands include the Arcata bottoms at the north end of the bay and the lower reaches of major streams entering the bay. The remainder of the watershed, at least two-thirds of the total area, is relatively steep and predominately managed for timber production.



Humboldt Bay and the Pacific Ocean - a view from the watershed

From north to south, the four major streams in the Humboldt Bay watershed are Jacoby Creek (draining 17 square miles), Freshwater Creek (draining 31 square miles), Elk River (draining 29 square miles), and Salmon Creek (draining 17 square miles). Jacoby and Freshwater Creeks drain into Arcata Bay to the north, Elk River into Entrance Bay (just south of Eureka), and Salmon Creek into South Bay. Smaller streams flow primarily into the North Bay. See text box on page 12 for more information on smaller urban streams in Arcata. Numerous sloughs exist around the bay that are part of the historic tidal bay ecosystem. Some of these sloughs have limited freshwater input and provide critical nursery habitat for marine species, but relatively little is known about salmonid use of these salt water sloughs.

Humboldt Bay watershed is in the forefront of the controversy about balancing extraction of timber resources and the need to maintain and restore water quality, fish habitat, and reduce hazards

Watershed signage placed by the City of Arcata helps to bring awareness and educate citizens about watersheds in the urban area

to downstream inhabitants. The HBWAC was formed to provide a neutral forum for stakeholders to discuss and problem solve, hopefully leading to improvements within the watershed.

Population centers in the watershed are concentrated in two cities and five smaller communities near Humboldt Bay, with a total population of about 70,000. Scattered farms and residential homes are found upstream of the bay along the streams. Almost the entire upper portion of the watershed is owned by industrial timber companies, Pacific Lumber Company and Green Diamond Resource Company (formerly Simpson Resource Company and before that Simpson Timber Company). The lower reaches of all streams, and the majority of flatlands surrounding the bay, are dominated by agricultural use. Agriculture and residential uses mix in the middle reaches of watershed streams. There is more residential development in Jacoby and Freshwater Creeks than in Elk River or Salmon Creek.

Helicopter logging in Humboldt Bay Watershed

Outside of incorporated municipalities, there is little public ownership of land within the watershed. The few exceptions include: the City of Arcata owns and manages a demonstration forest in the Jacoby Creek watershed; the U. S. Fish and Wildlife Service (USFWS) manages the Humboldt Bay National Wildlife Refuge (HBNWR), with holdings in both the north and south bay areas; Humboldt County manages a small park in Freshwater Creek; and the Bureau of Land Management (BLM) owns Headwaters Forest in upper Elk River and Salmon Creek.

Current land use statistics for the Humboldt Bay (2002) indicate that the majority of existing land use is in timber production (Figures II.1 and II.4).

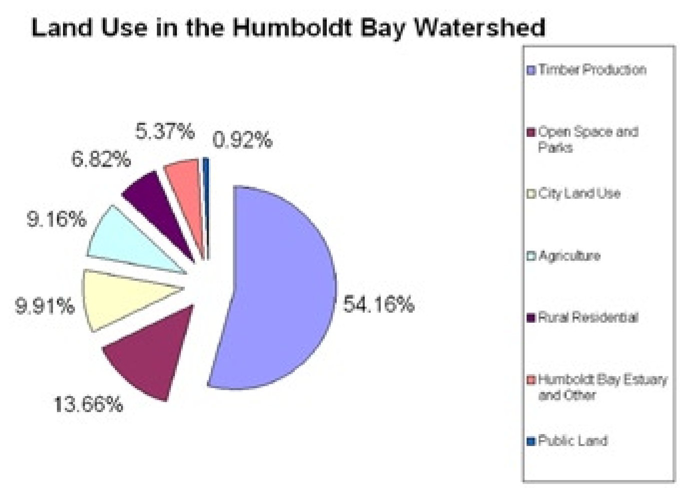
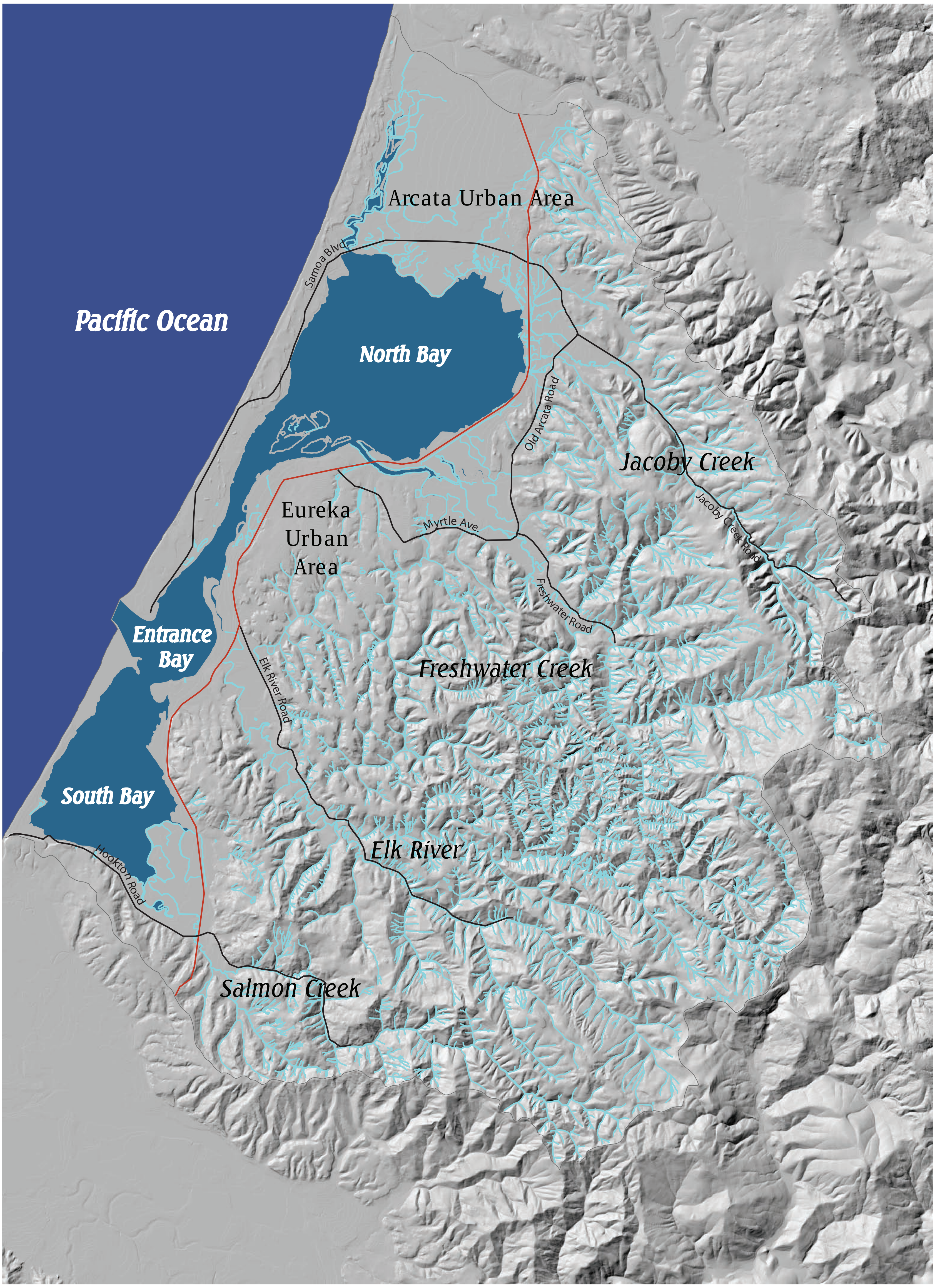


Figure II.1 Land Use in Humboldt Bay Watershed (Statistics from Humboldt County Planning Department 2002).

Figure II.2: Humboldt Bay Watershed



Humboldt Bay Watershed Boundary

Humboldt Bay

Humboldt Bay Streams

Pacific Ocean

Roads

Highway 101

0 4,500 9,000 18,000 Meters

0 15,500 31,000 62,000 Feet

Map Design by
Redwood Community Action Agency Natural Resources Services (NRS) GIS, 2004.
Projection Universal Transverse Mercator (UTM), NAD 27, Zone 10.
10 Meter Digital Elevation Model - Modified Hillshade by NRS.
Streams - Cal. Dept. of Forestry (CDF), 1:24,000, 2000.
Roads - CDF, 1 :24,000, 2000.
Roads data does not account for timber roads, driveways or historic legacy roads.

II. A. Natural History

An understanding of the natural and cultural history of the Humboldt Bay watershed may increase our understanding of how human-caused and naturally occurring watershed processes interact and affect habitat conditions for salmonids as well as other species. Below is a brief description of where salmonid populations are currently found within Humboldt Bay watershed, followed by a short discussion of geology, soils, climate and rainfall, hydrology, and vegetation in the watershed. See Section V for more details on each subwatershed.

II. A. 1. Salmonid Presence

The four main sub-watersheds of Humboldt Bay watershed support native wild populations of salmon and steelhead (Figure II.6). The streams from north to south and the salmonid species each sub-watershed supports are listed in Table II.1 with watershed area and miles of perennial stream.

Tributary	Watershed Area (acres)	Miles of perennial stream	Salmonid Species Present
Jacoby Creek	13,017	26.5	coho, steelhead, cutthroat, resident rainbow trout, and chinook (rarely)
Freshwater Creek	37,100	58	coho, steelhead, resident rainbow trout, cutthroat, and chinook, chum (rarely)
Elk River	37,500	329	coho, chinook, steelhead, and cutthroat
Salmon Creek	16,400	14	coho, steelhead, cutthroat

Table II.1: Salmonid Presence in Humboldt Bay Watershed

II. A. 2. Geology

The Humboldt Bay watershed is located about 30 miles northeast of the junction of the Gorda, Pacific, and North American crustal plates. Tectonic activity in the area is extremely high. The Gorda Plate is undergoing subduction beneath the North American Plate.

Anadromous salmonids in Arcata's Urban Streams

Most of Arcata's urban streams headwaters are situated on the southwest flank of Fickle Hill (1200 feet elevation), a northwest trending ridge that lies east of Arcata. Streams flow from forested headwaters through urban zones, then through agricultural lowlands before discharging to Humboldt Bay.

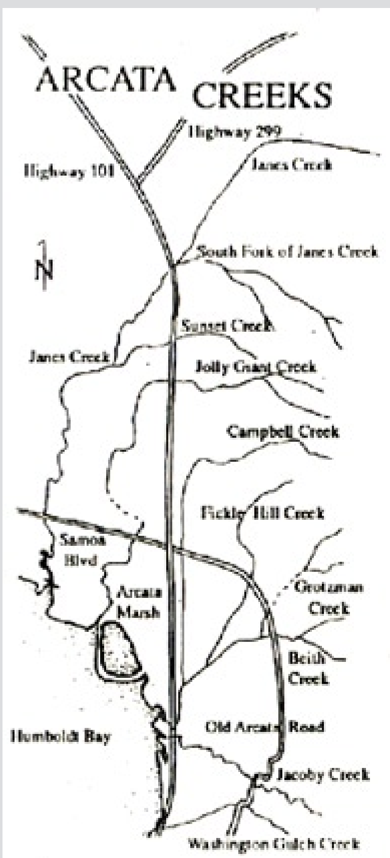
Including Jacoby Creek, there are ten drainage basins within the City, most having a year round stream within the basin boundaries. All of these basins eventually discharge into Humboldt Bay with the exception of the Mad River. The Mad River defines the northern boundary of the City, but only 360 acres of city land (6 percent) drain into that system. Extensive sloughs and wetlands are also part of the natural drainage system (DMP 1997).

Jolly Giant, Janes, Beith, Grotzman, and Campbell Creeks, support salmonid populations in their lower reaches.

Portions of Janes, Jolly Giant, Campbell and Grotzman Creeks are culverted or covered, causing degradation of creek resources. Streams such as Janes Creek have tide gates which are barriers that prevent anadromous salmonids from being able to access critical habitat. Furthermore, recreational use has degraded riparian vegetation along the lower reaches of Arcata's urban creeks.

(Continued on next page).

The City of Arcata's Environmental Services Department is actively working on stream protection and restoration. The City has a Creeks Management Plan and a Creeks and Wetlands Committee that meets monthly. The General Plan Update directly addresses stream issues in the Resource Conservation and Management Element. The policies address natural biological diversity/ ecosystem function, streams conservation and management, water resource management, and forest management among other issues. The City also has a Drainage Master Plan to address each of Arcata's streams from a hydrologic and drainage point of view.



Large-scale tectonic activity has produced a number of northwest-southwest trending faults in the region, which have created most of the watershed streams. Uplifting and folding, the differential motion at the various fault lines, and erosion have resulted in a complex pattern of exposure of rock formations in the watershed (Barnhart, Boyd, and Pequegnat 1992).

Four main geologic formations are exposed in the Humboldt Bay region. (Table II.2 and Figure II.8)The oldest is the Franciscan Formation, consisting of graywacke, sandstone, shale, chert, altered basalt and some limestone. The Franciscan is overlain by the Yager Formation, composed of interbedded shale, graywacke and conglomerate. The Wildcat Group is younger than these formations and consists predominantly of weakly lithified mudstones, along with weakly consolidated siltstone, sandstone, conglomerate, and some interbedded limestone, tuff and lignite. The youngest of the major formations is the Hookton, which consists of continental and shallow marine deposits of variable lithology (Barnhart, Boyd, and Pequegnat 1992).

Watershed	Dominant Formations	Stability
Jacoby Creek	Coastal Terrane	Highly susceptible to erosion and mass wasting
Freshwater Creek	Wildcat Group (western half of watershed) with underlying Yager Formation; Franciscan Central Belt Group (eastern half of watershed)	Wildcat sediments are highly erodible and prone to slope movement. Underlying Yager sediments have rock and sand components and are moderately resistant to erosion. Franciscan sediments are less erodible than Wildcat.
Elk River	Wildcat Group with underlying Yager Formation; Hookton Formation along southern ridgetops	Wildcat sediments are highly erodible, underlying Yager sediments have rock and sand components and are moderately resistant to erosion.
Salmon Creek	Franciscan Melange; Wildcat Group with underlying Yager Formation in the headwaters	Franciscan sediments are more stable and less erodible than Wildcat sediments. Yager sediments have rock and sand components and are moderately resistant to erosion.

Table II.2: Dominant Geology in Humboldt Bay Sub-watersheds

The underlying geology of the sub-watersheds is a major driving force for input of sediments into the stream channel. Geology plays a dominant role in quality of spawning gravels, slope stability, and the intensity of land use that can be tolerated without degrading watershed processes. Because of its relatively young age, high rate of uplift and tectonic activity, the Humboldt Bay watershed exhibits significant instability. The combined effects of high precipitation and unstable geology place North Coast rivers among the highest recorded sediment producers per unit area in the world (Halligan, 1997).

"The Blue Slide" of Franciscan Geology on Jacoby Creek

II. A. 3. Soils

The alluvial deposits around Humboldt Bay are mostly sediments of the Franciscan, Yager, Wildcat, and Hookton formations. Humboldt Bay watershed consists of a variety of soil types that are excellent agricultural and timber soils, and several are considered highly erosive.

II. A. 4. Climate and Rainfall

The Humboldt Bay region has two distinct seasons. The fall and winter season is mild but wet; spring and summer are cool and dry. The mean monthly temperature at Eureka varies by only 10 degrees Fahrenheit throughout the year, with the low mean in January (47 F) and the highest in August (57 F) (Barnhart, Boyd, and Pequegnat 1992).

Elk River watershed's Berta Bridge flooded during a December 2004 rain event. Major flooding is a common occurrence in both Freshwater Creek and Elk River watersheds - its cause a topic of much controversy. More a hazard and nuisance for the landowners but also leaves fish stranded in the fields as flood water receeds.

Eighty-five percent of the precipitation occurs during a seven-month period from mid-October to mid-May. Average annual precipitation ranges from 36 inches at Eureka to over 50 inches per year at the highest elevations in the watershed.

The amount of precipitation varies significantly from year to year. A climactic cycle with periodicity of eight to ten years is evident from long-term rainfall records. Two periods of significant and prolonged droughts occurred from 1975 to 1995. Only five or six years over this period had precipitation equal to or exceeding mean annual precipitation for the correlative period of record.

Precipitation in the Humboldt Bay watershed arises from rain, snow, and fog-drip (fog condensing on vegetation). Snow occurs on the ridgetops occasionally during cold winter storms and rarely over the entire watershed. In the dry season the climate is moderated by summer fog that reduces solar radiation and creates an ideal habitat for a temperate rainforest. Harris (1987) has compiled evidence for the idea that the precipitation from fog drip has probably been considerably reduced by the removal of old-growth forest stands in the watershed.

II. A. 5. Hydrology

Streamflow in Humboldt Bay tributaries are the highest from November through March and the largest floods in the watershed tend to occur during December and January. During the summer and fall, flow varies little and is relatively low. Rain may come late in some years, or persist longer. In 1958, very little rain fell in November and December, while three significant floods had already occurred by the end of the year in 1964.

The magnitude, timing, and number of floods varies considerably from year to year and is not directly related to total annual rainfall, but is more closely tied to the intensity of individual storms. For example, an unusually large flood occurred in Jacoby Creek in 1955, though the total rainfall for the year was average.

Increase in sediment in stream channels has resulted in a reduction of channel capacity that is especially notable in Elk River. In addition vegetation removal, soil compaction, and increase in impervious surfaces through land use practices can result in changes in the timing and intensity of flood events.

Running pine (Lycopodium clavatum) found on the floor of the Redwood Forest

Streamflow has been measured by the U.S. Geologic Survey (USGS) at two locations within the basin. A gauge was operated on Jacoby Creek from 1954 to 1974. Watershed area above the gauge is 5.8 square miles. A gauge was operated on the Elk River near Falk from 1957 to 1967; watershed area above that gauge is 44.2 square miles. Freshwater Creek discharge has been measured since 1990 by Salmon Forever at a location upstream from Freshwater Park.

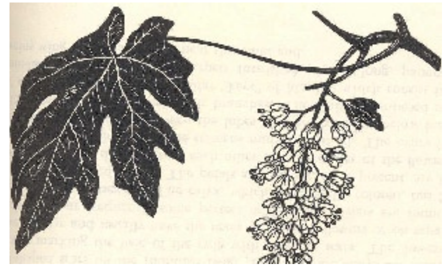
II. A. 6. Vegetation

Below are the five main vegetation communities in the Humboldt Bay watershed (not including dune and tidal marsh).

- **North Coastal Coniferous Forest**. Sitka spruce (*Picea sitchenis*) and grand fir (*Abies grandis*) are members of this community.
- **North Coast Riparian Scrub**. Found along streams, the typical overstory plant is willow (Salix spp.) in the lower parts of watershed streams, near the bay. Further upstream in

the watershed alder (*Alnus oregona*) and bigleaf maple (*Acer macrophyllum*) become common.

- **Redwood Forest**. Dominated by redwood (*Sequoia sempervirens*). The Northern Redwood forest contains Douglas-fir, grand fir, Port orford cedar, Sitka spruce, western red cedar and tan oak. The shrub layer contains huckleberry, rhododendron, salal, and salmonberry. The ground layer is comprised of herbaceous plants and is dominated by the sword fern.
- **Douglas Fir Mixed Hardwood Forest**. Douglas fir (*Pseudotsuga menzesii*) is the major species, found in association with tan oak (*Lithocarpus densiflora*) and other hardwoods.
- **Bald Hills Prairie**. Praries in the Humboldt Bay watershed are grazed and largely converted to introduced European species. Historically, these prairies were likely similar in composition to the prairies of the Bald Hills area in Redwood National Park.



Historic Human Footprint in the Watershed

The Humboldt Bay watershed was and still is inhabited by the Wiyot people. Ethnographic and archaeological evidence suggests the Wiyot came to the region about 900 A.D. while according to their cosmology they have been on the land since the beginning of time. Wiyot villages surrounded Humboldt Bay and were generally located close to streams, the bay shore, or in tidewater areas. At that time the bay was surrounded by salt marshes, wet meadows and forests. Stream zones were clearly the preferred location for habitation based on distribution of the villages. The Wiyot called the area Goal-la-nah, meaning a land a little above the water. The Wiyot, recognizing the life-giving qualities of the bay, were intimately tied to its seasonal and daily cycles for food, transportation and materials. Their lives depended on the productivity of the bay. The Wiyot people managed areas of the watershed to provide hazel, acorns, various basket making materials, fish and wildlife. Despite their presence there for thousands of years, the bay and surrounding lands remained essentially unchanged.

Historic Human Footprint Timeline

- ***Present - 10,000-13,000 years ago***-native American tribes
- ***150-300 years ago -*** European fur trappers
- ***1806 -*** Humboldt Bay region charted by Jonathon Winship
- ***1809 -*** Union Town established
- ***1870 -*** Timber harvest begins in Jacoby Creek
- ***1875 -*** Construction of the first railroad in the watershed
- ***1876 -*** Shingle mill established at Bayside, logs were rafted to mills located in Eureka
- ***1880 -*** Two railroads had been developed in the watershed
- ***1890 -*** First dike built
- ***1880s-1910 -*** Peak of first logging period
- ***1918 -*** Construction begins on Highway 101 stretch between Arcata and Eureka
- ***1920 -*** Apparent exhaustion of the easily accessible timber supply by 1920
- ***1950s -*** Resurgence of logging activity began with harvesting of remaining old growth in the headwaters of the basin, followed by second-growth cuts in the rest of the drainage, which continues to the present.

The Wiyot ate fish throughout the year, and judging from the presence of fish bones in excavated sites people inhabiting the area before the Wiyot also depended primarily on fish in their diet (Loud 1918). Probably the most common fishing technique was to place weirs and traps near the mouths of streams. They used both straight and v-shaped weirs. Different designs were used for chinook and steelhead. Dip nets were often utilized to remove fish from the weirs. Weirs were constructed in late spring or summer, depending on the weather (Benson, Fredrickson, McGrew 1977). The people preserved the salmon by splitting them into three slabs for drying on a rack of green willow poles in the sun, over a small fire and in the houses.

Sir Francis Drake may have been the first European to see the northern California coast, though he recorded nothing of Humboldt Bay. Although Trinidad Bay had been explored by a Spanish expedition in 1775, Humboldt Bay was difficult to observe from the ocean. The bay was not located by sea until 1806 by an American sea captain named Jonathon Winship.

An early picture of the Arcata Warf

Development within the Humboldt Bay watershed began in the mid 1850s in conjunction with the inland Gold Rush, and continued with the exploitation of regional forestry and fisheries resources. An overland expedition from the Trinity gold mines, led by Dr. Josiah Gregg and L. K. Wood, viewed the bay late in 1849. The prospect of a port to supply the mines was very attractive, and the settling and development of the bay began in 1850 (Gates 1983).

As of June, 1850, four separate townships had been claimed on Humboldt Bay: Humboldt City (near Buhne Point), Bucksport, Union (later to become Arcata), and Eureka. The siting of towns was based on the limitation of clear, flat, dry ground. Eureka was one of the few places in the central bay area that met these criteria, and was described as being surrounded by dense spruce forest to the east and marsh to the south (Glatzel 1982).

The area rapidly became a trade depot for inland gold mining operations in 1850 and 1851. Upland forested areas nearest Eureka and Arcata were cleared first, to provide residential areas and agricultural land.

The view out to Humboldt Bay from College Hill, Arcata around 1915

Following the first land claim by European Americans in 1850, the area developed quickly, partly because mining operations in the mountains to the east drew people and provided markets for goods. Agricultural products in particular were in demand; the area was a prime exporter of agricultural products such as potatoes and dairy.

Timber resources were also quickly developed. Carson Mill shipped the first cargo of redwood to Hong Kong in 1855. By the mid-1880s, docks had been built in Eureka and Field's Landing, and numerous railroad spurs were transporting logs from outlying areas such as Jacoby Creek, Freshwater Creek, and Salmon Creek. Jetties were constructed to stabilize the entrance to the bay in the 1890s. By 1914, 8.3 billion board feet of timber had been harvested and shipped from Humboldt Bay (Glatzel 1982).

European development led to the displacement of Wiyot people from their homes, food sources, traveling routes, and hunting and fishing activities. Large numbers of Wiyot people were massacred in 1860 by a small group of settlers, and five years of open warfare ensued (Gates 1983).

By 1947, one hundred years after European settlement, agriculture, timber, and other industries based on the natural resources of the area (commercial fishing, for example) were well-established as the base of the local economy.

Early transportation around the bay skirted the large expanse of tidal marshes. Like many routes used by the European settlers, Old Arcata Road was originally a trail established by the Wiyot; in 1862 it became a wagon trail and was paved around 1925 (Glatzel 1982). Although a major thoroughfare, the road had little impact on the streams and wetlands of the area because it had been sited to avoid the marshes.

Other transportation corridors have had a greater impact. In 1900, construction of the Northwestern Pacific railroad began around the eastern margins of the bay. The railroad functioned like a dike in most locations, with tide gates at almost all slough crossings (Barnhart, Boyd, and Pequegnat 1992). It allowed marshes between the railroad and Old Arcata Road to be converted to agriculture. In 1927, Highway 101 was constructed, and most of the marshes east of the bay were diked and drained.

Higher up in the watershed, railroads were constructed to transport logs to mills around the bay. These railroads penetrated far into Jacoby and Freshwater Creeks and Elk River. A spur also ran a short distance up Salmon Creek (Clark 1969). The development of these railroads was fairly extensive, especially in Freshwater Creek and Elk River. In the Freshwater drainage, rail lines ran up McCready, Cloney and Graham Gulches, as well as Little Freshwater Creek and the South Fork. On the North Fork of the Elk River, the railroad went past the South Branch on the North Fork and up Dunlap and Browns Gulches. On the South Fork of the Elk River, lines went all the way to the Little South Fork (Carranco and Sorenson 1988).

Historic photos of sportfishing in Freshwater Creek. Photos courtesy of Tiffany Rittenhouse.

The development of Humboldt Bay's natural resources provided economic benefits for its new residents and the region thrived through the Civil War, the Depression, and World Wars I and II.

Fisheries

Although there are no early historic fish counts in Humboldt Bay watershed, historic accounts compiled by watershed resident Susie Van Kirk (1998) provide evidence that a healthy population of salmon existed in the stream in the past.

In the early 1900s fish stocks were already in decline, and in response to concerns, the tributaries of Humboldt Bay were stocked with salmon from various rivers in the Pacific Northwest. The Price Creek Hatchery (later replaced by the Fort Seward Hatchery) was on a tributary of the Eel River.

> *Ferndale Enterprise (4 June 1915) - Seventy-thousand steelhead fry, the last shipment for distribution in the streams flowing into Humboldt Bay, were received Monday afternoon from the Price Creek hatchery for distribution in Elk River. This shipment is the last of 420,000 steelhead to be planted this year in Jacoby Creek, Elk River and Freshwater. About 500,000 salmon fry were received and distributed in the three streams earlier in the spring.*

The impact of these non-native stocks on Humboldt Bay watershed's native salmon populations is not known. Hatchery fish can compete for food and shelter with native populations, carry diseases, and affect population genetics.

> *Ferndale Enterprise (28 April 1922) - Stocking Streams of Northern Humboldt--The Humboldt Fish and Game Association has received 200,000 Quinnat salmon from the Fort Seward hatchery*

which will be released for anglers in Freshwater, Salmon Creek, Jacoby Creek, Elk River and Ryans Slough.

An historic harvesting scene in the Arcata Bottoms

Agriculture

Much of the reclaimed marshland around Humboldt Bay was considered the best dairy land in the county. Agriculture developed rapidly around Humboldt Bay between 1865 and 1875. The amount of cultivated land increased from 9,060 acres in 1865 to 19,000 acres in 1875.

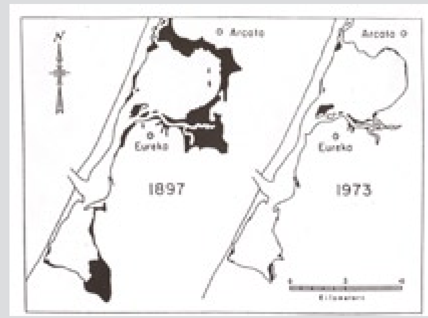


Figure II.3: Decrease in Humboldt Bay marshland distribution from 1897 to 1973 caused by diking (MacDonald 1977).

Early agricultural development took place largely in the floodplains. On much of the northeastern bayside, especially around the Eureka slough, extensive diking occurred in the conversion to agricultural land. Up until 1903, a large expanse of tidal wetlands extended up to and sometimes beyond Old Arcata Road. By 1927, most of the wetlands had been converted to agriculture. Levees were constructed along much of the arable land in the lower stream valleys.

United States Coast Guard (1870) maps of the bay's eastern shoreline from Eureka slough northward reveal a coastal plain absolutely honeycombed with watercourses (streams, rivulets, and sloughs) big and little, all coursing through an extensive marsh affected by daily tides. The simplicity of today's landscape belies its historic complexity. To convert the Humboldt Bay area to agricultural use, marshland was reclaimed, stream channels were straightened, and large woody debris was removed (Van Kirk 2002).

The exportation of agricultural goods became an important part of the local economy. While farms in the hills were worth \$20-\$100 per acre in 1911, rich bottom lands went for \$100-\$500 per acre.

Log train in Freshwater Creek watershed

Timber

Timber harvesting began in the Humboldt Bay watershed in 1850. Early timber harvesting took place mostly for clearing residential areas or farmland in the bottoms, or to provide wood for local construction.

The first successful lumber mill in Humboldt County, formed in 1852 by Ryan and McDuff, was located in Eureka (Gates 1983). In 1867, a mill was built on Indian (Gunther) Island. The mills of Humboldt County sawed 20,375,000 board-feet of timber and 800,000 shingles that year (Coy 1929). Several more mills had been built by 1875, including the John Vance mill on the north side of the Mad River, also known as the 'Big Bonanza', connected to Humboldt Bay by a railroad crossing near the river mouth. A mill was constructed in Salmon Creek, and a railroad was constructed up-creek for accessing timber.

For the first couple of decades of harvest, few machines were used in timber practices. Logs were sawn by hand and moved by teams of oxen. One of the primary forms of log transport from the woods to the mills was by stream, a technique called splash-damming. Logs were piled in the streambed during the summer, upstream of a dam constructed to store higher flow caused by winter rains. When the log ponds upstream of the dams were full and the logs were floating, the splash dams were suddenly destroyed, usually by dynamite, and the logs were transported on the resulting torrent of water to the bay. (Gates 1983).

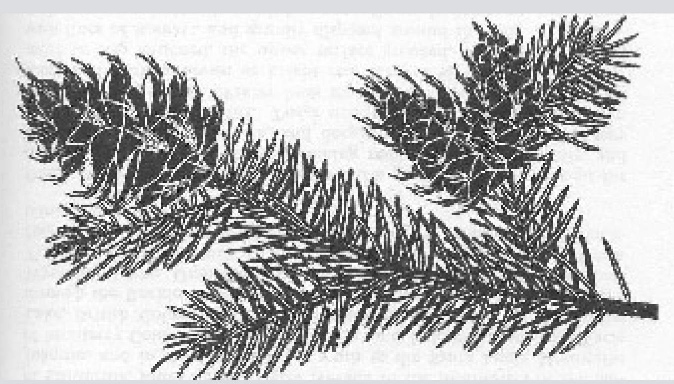
Two men use a "misery whip" saw to fell a giant redwood

In the 1880s, new methods for harvesting and milling significantly increased production. Most companies were building railroads up creeks. A rail line was constructed eight miles up the Elk River valley from Bucksport in 1885 (Gates 1983). The steam donkey, a steam-powered winch on a sled that took over the role of oxen, was invented and came into wide use in forestry practices. By the end of the decade, the band saw was in wide use throughout the county, significantly improving mill productivity. In the late 1880s, county timber production reached 190,000,000 board-feet.

Small Arcata mills began shutting down around 1890 because their timber resources around the bay had been exhausted (Gates 1983), and they lacked resources to access the upper drainages. The Elk River Mill and Lumber Company's land in the McCloud Creek drainage was cleared by 1890.

Timber in the Upper South Fork of the Elk River was accessed by railroad above the mill at Falk, requiring nearly a dozen large wooden trestles (Gates 1983). Railroads were constructed in all of the major Humboldt Bay drainages, opening up the entire Humboldt Bay watershed to timber companies.

With the coming of diesel equipment at the end of World War II, many of the earlier forestry practices changed. Miles of roads were constructed throughout the watershed, often with stream crossings called Humboldt Crossings that did not allow for fish passage and failed during winter rains. Humboldt crossings were built of logging debris (unmarketable logs) covered with dirt. Many of the crossings still exist in the watershed and often fail during storms, pouring sediment into the streams. Timber production reached 1 billion board feet in the 1950s and 1960s.



Photos in this section courtesy of the Ericson Collection in the Humboldt Room at Humboldt State University.

II. B. Recent Trends

The Humboldt Bay area was once a complex ecosystem that supported an amazing abundance of wildlife. From ridge top oaks and old growth redwoods to meandering river estuaries, the Humboldt Bay watershed boasted rich biodiversity. Since European contact, the region's natural environment has severely deteriorated. Old growth redwood forests have been reduced to a mere few thousand acres and the original estuary system is cut off from the bay. Salmon populations are on the verge of extinction and the once-abundant elk population no longer lives in the watershed.

Listening attentively at a Humboldt Bay Stewards (HBS) symposium. The HBS is a collaboration of organizations and individuals working to protect and enhance Humboldt Bay and its resources including the Humboldt Bay estuary which is critical salmonid habitat.

Significant landscape alterations have occurred in land directly adjacent to Humboldt Bay. From 1870 to around 1927, the amount of land in agriculture increased by about five times, and today only one-fifth of historic tidal wetlands remain. The amount of land used for residential and commercial/industrial uses has also increased dramatically, particularly since about 1940. Residential land use tripled between 1940 and 1980 (Shapiro and Associates 1980; Barnhart, Boyd, and Pequegnat 1992). Growth has continued in the watershed with the unincorporated area outside Eureka being one of the fastest growing regions in Humboldt County (Split Rock Ventures 2001). The predominant land uses in the watershed, as well as in Humboldt County, are still agriculture and timber production (Index of Economic Activity 2000).

The City of Arcata acknowledges the landowners who helped to expand the City of Arcata's Community Forest at Jacoby Creek Watershed Day.

In 1972, the State of California passed the Z'berg/Nejedly Forest Practice Act. This act provided the first real regulation of forest harvest practices, including protection for streams and riparian areas. For example, the construction of Humboldt stream crossings became illegal under this act, and riparian areas were given some protection from harvest and road construction.

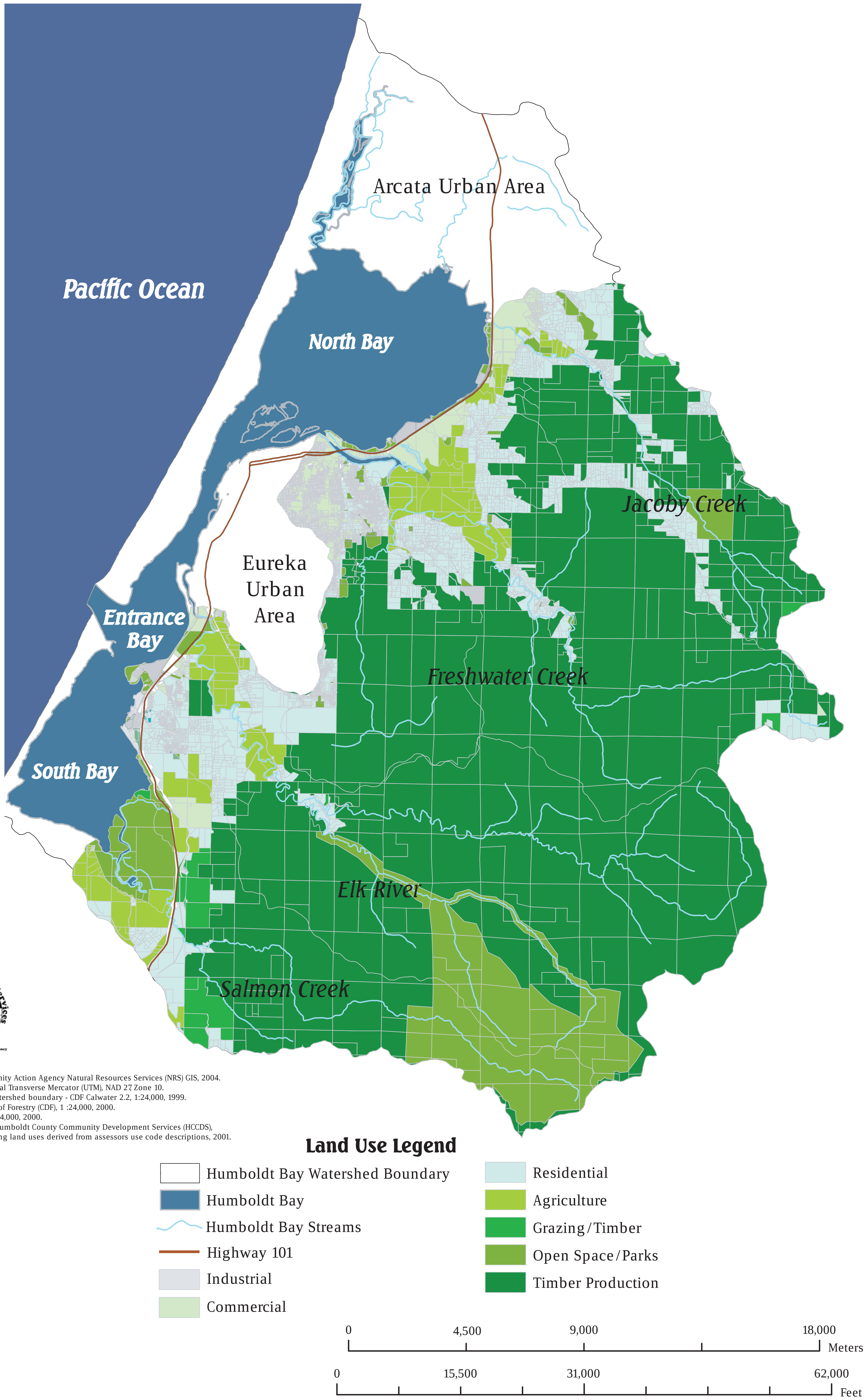
With the exhaustion of timber resources and tighter regulations on forestry practices, production dropped to 500 to 800 million board feet in the 1970s and 1980s. Timber harvest rates increased again in the 1990s when large portions of the upper Humboldt Bay watershed were harvested.

In the 1990s, decreasing salmonid population numbers brought scientists' and policy-makers' awareness to the detrimental effects of forestry practices on salmonid habitats. The state organized the Independent Scientific Review Panel (ISRP) in 1998 to comprehensively review California Forest Practice Rules with regard to their adequacy for protection of salmonids (ISRP 1999). The ISRP recommended many changes to California Forest

Eureka Boat Basin fishing fleet 1955 (above) and today (below).
Photos courtesy of Bill Matson of Eel River Watershed Improvement Group

Practice Rules to enhance protection of salmonids and their habitat. Similarly, timber companies are developing Habitat Conservation Plans (HCPs) for the protection of salmonids and other federally listed species. In Humboldt Bay watershed, Pacific Lumber Company has been operating under a multi-species HCP developed in 1999. The restrictions of the HCP were to remain in place until the company conducted watershed analyses for Freshwater Creek and Elk River to guide future timber harvest. The Freshwater Creek watershed analysis was completed in December 2003, and the Elk River watershed analysis has been publicly released in a draft form. The results of the process have been a source of much controversy and it remains to be seen what changes will result. Green Diamond has voluntarily developed an Aquatic HCP, and currently in 2005, Green Diamond is implementing the plan (the conservation measures and monitoring are being applied) , but the plan has not yet been approved by the regulatory agencies.

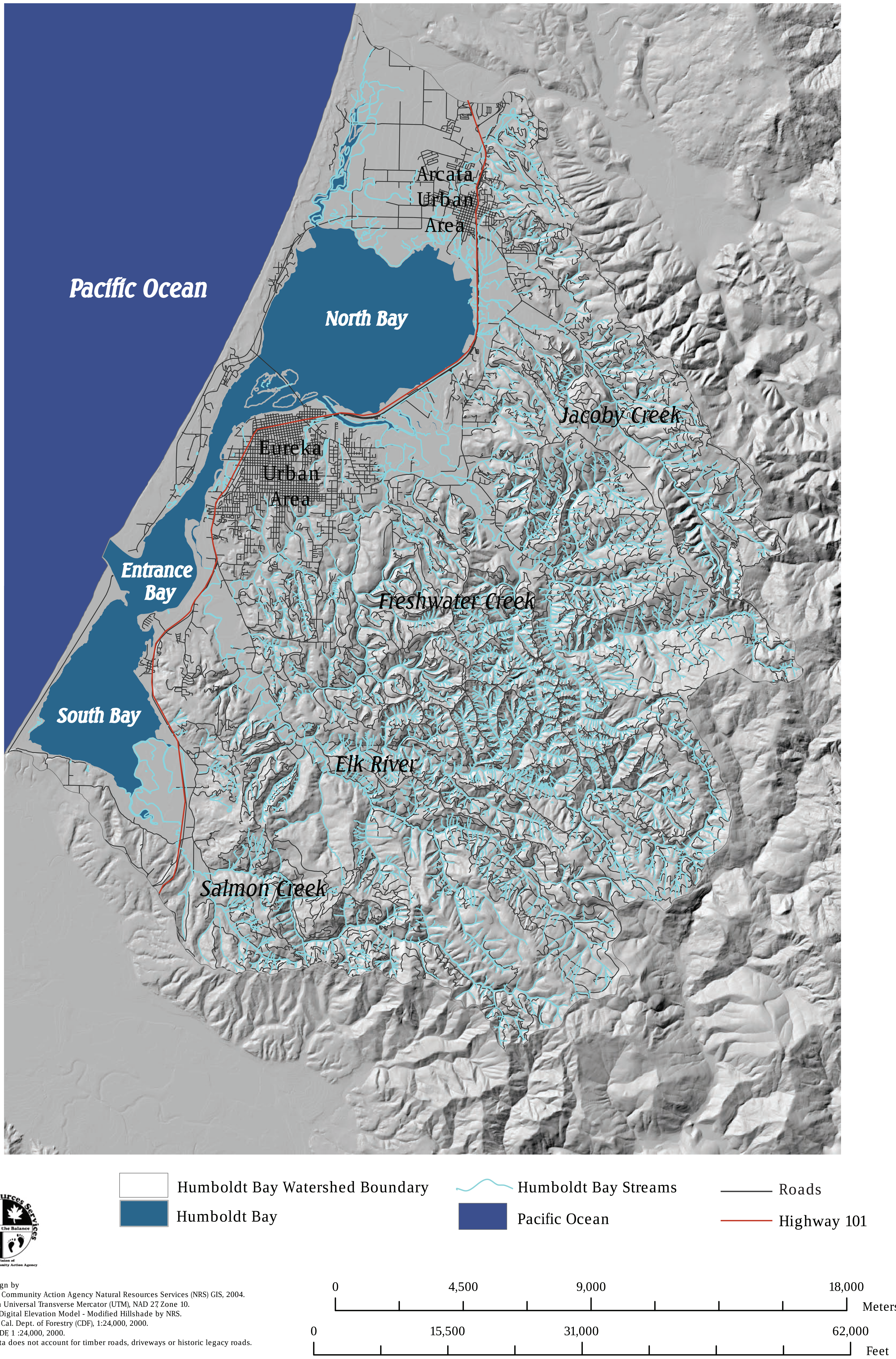
Figure II.4: Land Use
Humboldt Bay Watershed



Map Design by
Redwood Community Action Agency Natural Resources Services (NRS) GIS, 2004.
Projection Universal Transverse Mercator (UTM), NAD 27, Zone 10.
Humboldt Bay Watershed boundary - CDF Calwater 2.2, 1:24,000, 1999.
Roads -Cal. Dept. of Forestry (CDF), 1 :24,000, 2000.
Streams - CDF, 1 :24,000, 2000.
County Parcels - Humboldt County Community Development Services (HCCDS),
generalized existing land uses derived from assessors use code descriptions, 2001.

Figure II.5: Roads

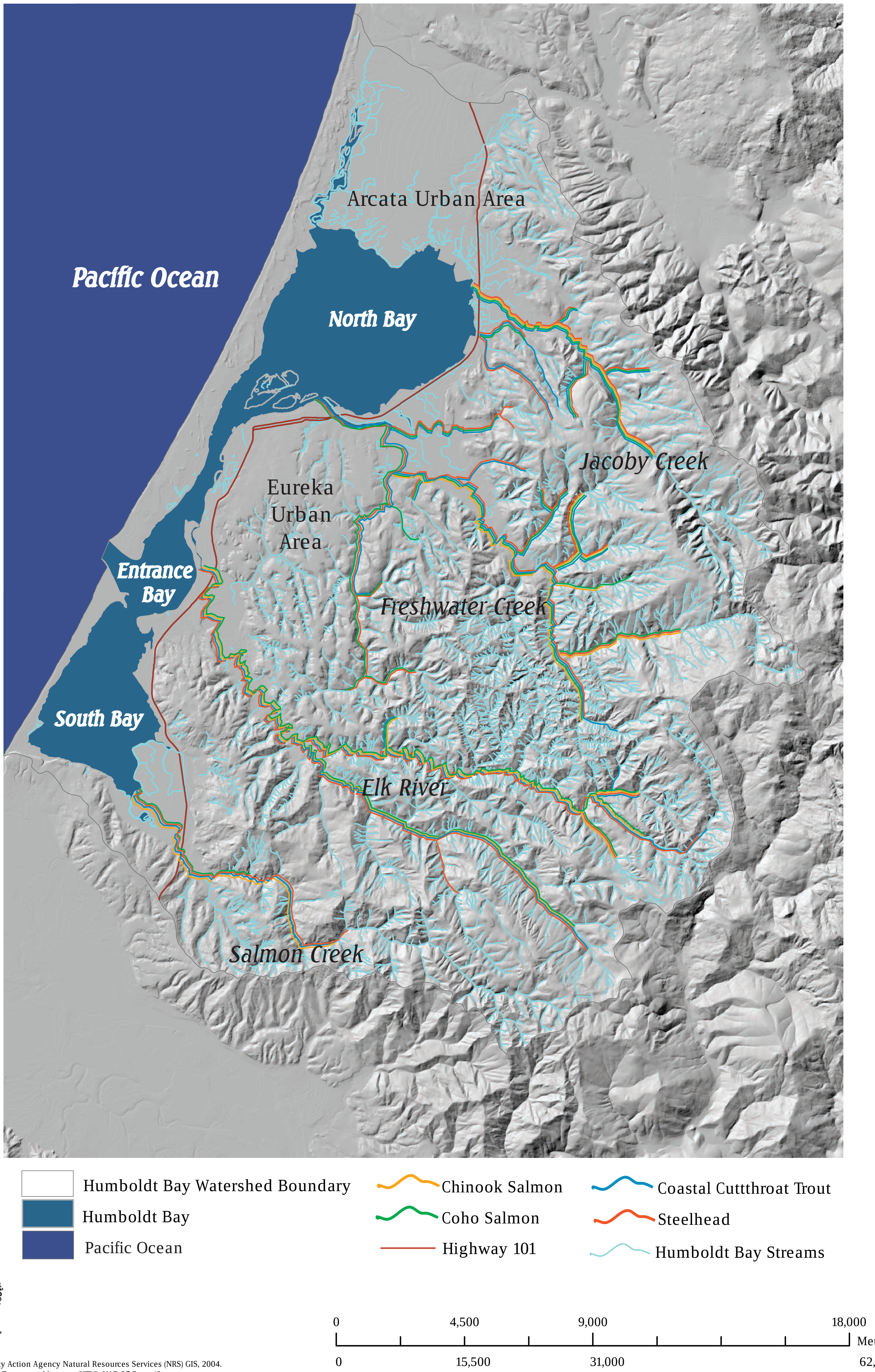
Humboldt Bay Watershed



Map Design by
Redwood Community Action Agency Natural Resources Services (NRS) GIS, 2004.
Projection Universal Transverse Mercator (UTM), NAD 27, Zone 10.
10 Meter Digital Elevation Model - Modified Hillshade by NRS.
Streams - Cal. Dept. of Forestry (CDF), 1:24,000, 2000.
Roads - CDF, 1 :24,000, 2000.
Roads data does not account for timber roads, driveways or historic legacy roads.

Figure II.6: Anadromous Salmonid Distribution

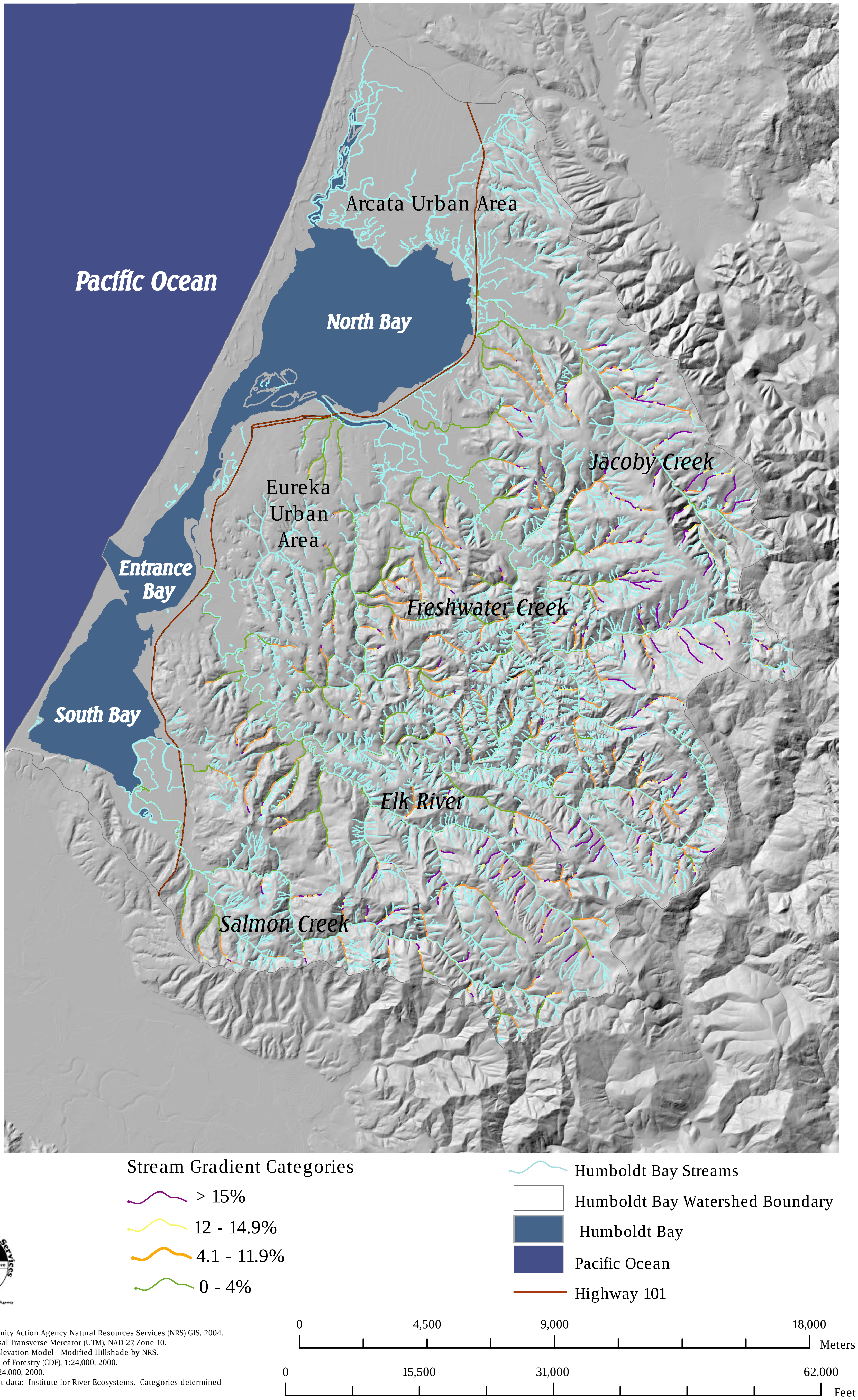
Humboldt Bay Watershed



Map Design by
Redwood Community Action Agency Natural Resources Services (NRS) GIS, 2004.
Projection Universal Transverse Mercator (UTM), NAD 27, Zone 10.
10 Meter Digital Elevation Model - Modified Hillshade by NRS.
Salmonid Distribution data - Cal. Dept. of Fish and Game non-published map
and Pacific Lumber Company Habitat Conservation Plan, 1997.
Streams - Cal. Dept. of Forestry (CDF), 1:24,000, 2000.
Roads - CDF, 1 :24,000, 2000

Figure II.7: Stream Gradient

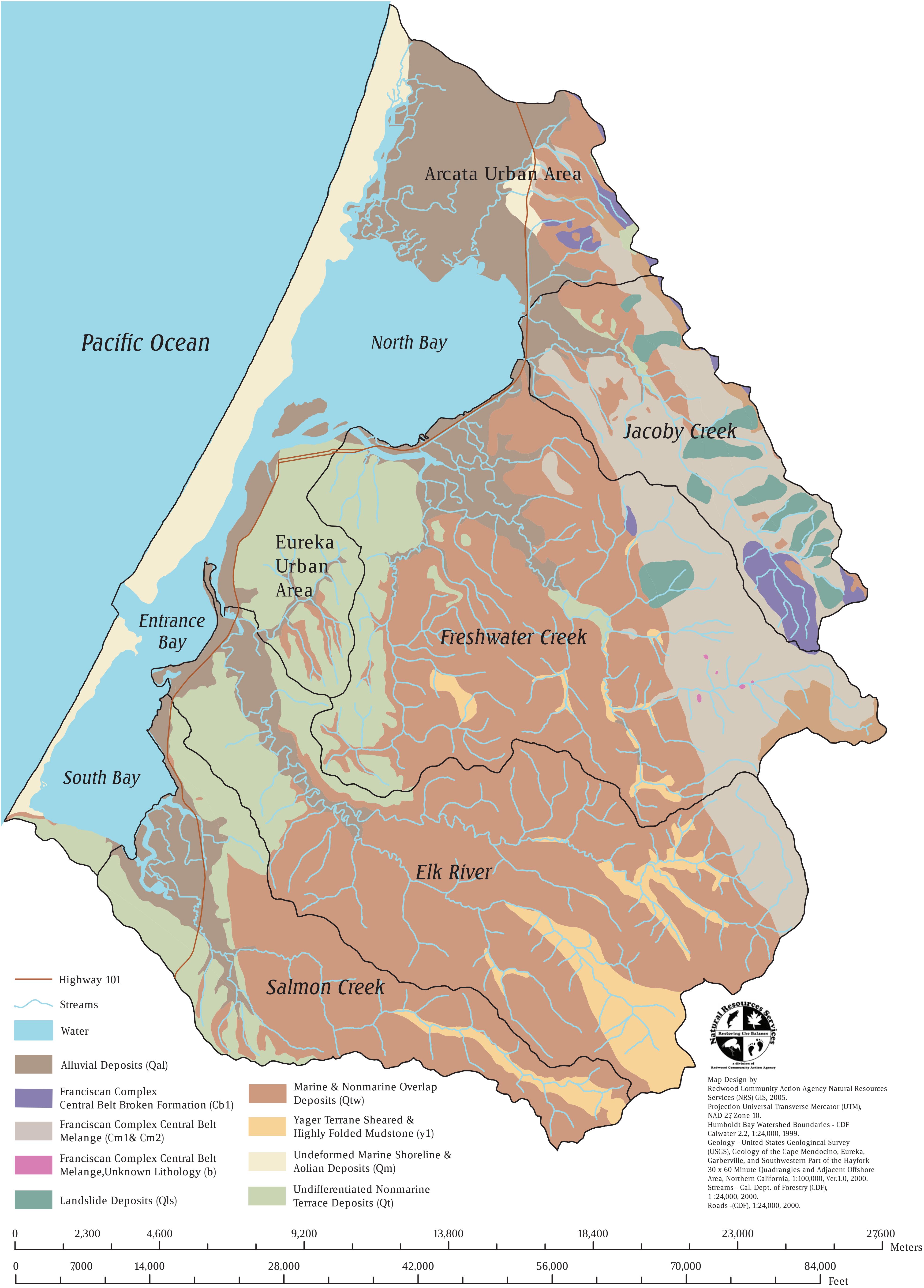
Humboldt Bay Watershed



Map Design by
Redwood Community Action Agency Natural Resources Services (NRS) GIS, 2004.
Projection Universal Transverse Mercator (UTM), NAD 27, Zone 10.
10 Meter Digital Elevation Model - Modified Hillshade by NRS.
Roads - Cal. Dept. of Forestry (CDF), 1:24,000, 2000.
Streams - CDF, 1 :24,000, 2000.
Salmonid gradient data: Institute for River Ecosystems. Categories determined by NRS.

Figure II.8: Geology

Humboldt Bay Watershed



III. Salmonid Habitat Requirements

III. A. Major Life Stages of Anadromous Salmonids

Salmonids in the Humboldt Bay watershed spawn in the fall and winter, and steelhead and cutthroat trout into the spring. All salmonids construct spawning nests, or *redds*, in the gravel bottom of streams, typically located at the tailout of pools (where the water velocity starts to increase at the lower end of a pool) or just above the top of a rifle. The redds are constructed by the female and consist of a series of pockets in the gravel in which fertilized eggs are deposited and buried to a depth of 8 to 20 inches.

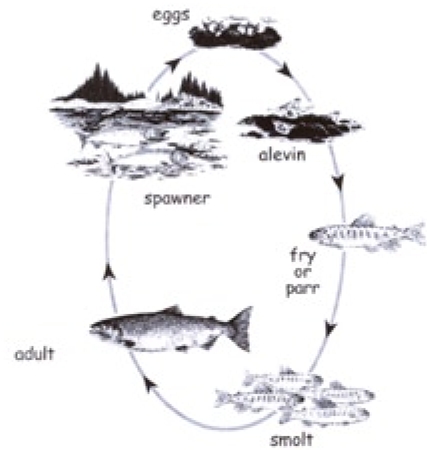


Figure III.1: Salmonid life cycle

The eggs incubate for around 60 days. The hatchling, or *alevin,* continues to develop in the redd as it absorbs the attached yolk sac. The juvenile fish, or *fry,* emerges from the redd between two to nine months after spawning, depending on water temperature.

Length of freshwater residence, or *rearing* time, differs for each species. Chinook spend varying amounts of time in fresh water, depending on the run; coho spend 12-15 months on average in their natal stream; steelhead rear for 1 to 4 years; and cutthroat can reside 1 to 9 years, although a 3 year residence is most common.

Juvenile chinook. Photo courtesy of M. Wallace, DFG

The juveniles migrate seaward throughout spring and early summer. As salmonids make their journey to the ocean, they undergo several physiological and morphological changes preparing them for marine life, a process called *smoltification*. Marine-adapted juveniles, or *smolts*, develop silver skin color and the ability to excrete salt water, among other modifications.

Upon reaching the ocean, they travel various directions and distances depending on species and available food supply. Coho spend 1 to 2 years in the ocean; chinook typically spend 2-4 years (may spend up to seven); steelhead spend one to five years (most California populations only spend 2 years); and cutthroat reside in the ocean less than one year (typically weeks to a couple of months). Adults eventually return to their natal streams to spawn, undergoing dramatic physiological and morphological changes as they re-enter freshwater and prepare for reproduction. Salmon species die after they spawn, while steelhead and cutthroat may return and spawn several times before expiring.

More in-depth info on salmon life history can be found at www.krisweb.com

Healthy freshwater spawning and rearing habitat is crucial to the survival of anadromous salmon and trout. Furthermore, in addition to their intrinsic, biological and economic value, salmonids act as a barometer for overall watershed health. Pacific salmon and steelhead are indicators of properly functioning aquatic ecosystem because they require cool, clean water, complex channel structures and substrates, and low levels of silt.

III. B. Anadromous Salmonid Habitat Requirements Related to Life History Stages

Anadromous salmonids utilize a wide variety of freshwater habitats during their complex life cycles. Individual stocks differ according to periodicity (when they mature and spawn), length of freshwater residence, and spawning and rearing distribution and timing. They have evolved with the fluctuating conditions of a specific watershed or stream not only behaviorally, but biochemically, physiologically, and morphologically (Table III.1).

Rearing populations tend to prefer relatively deep pools with shelter. Pools created by large woody debris and other 'roughness elements' are important for rearing salmonids. For oversummering habitat, coho salmon fry prefer a mixture of different types of pools and riffles with large woody debris, undercut banks, overhanging vegetation, glides, riffles, an average water temperature of 10 to 15 degrees centigrade, and dissolved oxygen near saturation (DFG 1994). Coho tend to utilize estuaries for overwintering habitat.

Chinook salmon. Photo taken by the Yurok tribe.

Life history diversity has been the key to survival for salmonid populations in fluctuating environments and changing habitats. As human-induced changes occur, salmon and trout are confined to increasingly smaller areas of watersheds. The resulting decline in diversity of habitat leaves stocks highly vulnerable to catastrophic environmental events, such as droughts or floods. In order to preserve and recover salmonid species, **habitat diversity** needs to be preserved and restored.

In order to preserve and recover salmonid species, habitat diversity needs to be preserved and restored.

Table III.1: General Habitat Requirements by Salmonid Life Stages

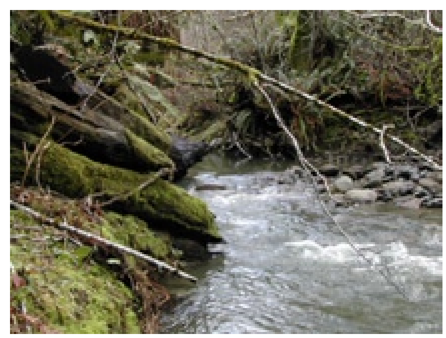
Habitat Needs	Adult Migration and Spawning	Incubation (embryos/ alevins)	Rearing (juveniles and adult residents)	Juvenile Migration
Food Source	Resident species may feed during migration, however most sea-run migratory adults terminate feeding once they enter freshwater	During incubation, the yolk sac of salmon embryos and alevins are digested as a source of nutrients.	Larval and adult aquatic and terrestrial invertebrates are the primary food source for most salmonids (about 95%). Yearling steelhead, coho, and cutthroat trout, and resident adults, may eat salmon fry and eggs when available, and other fish smaller than their gape.	Although diet varies by estuary and seasons, smolts may consume larval and juvenile fish and aquatic and terrestrial invertebrates, including crustaceans. A difference among species is, chinook prefer larger organisms and are opportunistic feeders.
Water Quality	Most adult salmonids migrate at temperature less than 14^0 C; fall chinook migrate when temperatures are substantially warmer. Excess high temperatures may cause outbreaks of disease or low levels of dissolved oxygen (DO). High concentration of suspended sediment may cause spawning salmon runs to be delayed, diverted, or avoided.	Preferred incubation temperatures range from 4.4-14.4^0C; alevin stage is generally less temperature sensitive than the embryonic stages, defects and mortality increase at both higher and lower temperatures.. Dissolved oxygen levels must average greater than 8.0mg/L for embryos and alevins, with mortality and defects occurring at lower levels. DO levels are reduced by excessive fines that enter the substrate interstices, limiting available oxygen.	The preferred temperature range for juveniles and resident salmonids is 10-14^0C. Except for brief periods temperatures should not exceed 23-25^0C . Salmonids should suffer no impairments if DO concentrations remain near 8 mg/L with DO deprivation beginning at about 6 mg/L. Chronically turbid streams (exceeding 70 NTUs) are avoided, however transitory episodes of elevated turbidity have little effect.	Temperature influences the rate of growth and physiological development, also affecting responses to other stimuli. Most migration occurs before stream temperatures reach 11-12^0C. Migration can be influenced by human related alterations of thermal regimes. DO levels should be about 8mg/L.
Habitat Structure	Large woody debris, boulders, and deep pool habitats provide hydrological complexity, facilitate temperature stratification and thermal refugia for resting areas; riparian vegetation and large wood needed in shallow reaches to provide refuge from terrestrial predators. Areas of stable, appropriately sized gravel with minimal fine sediments for spawning.	Salmonids require gravels in the 0.6-10.2 cm size range for their redds, with low concentrations of fine sediments (<13% sediments <0.85mm) and organic material. Bedload and bank stability arising from LWD and intact upslope, floodplain or riparian zones minimize the risk of eggs being deposited within the zone of scour and fill. LWD diversifies flow; better protecting redds from the scouring effects of high flows.	Salmonid fry occupy shallow habitats along the margins of streams, moving into deeper and faster water as they increase in size. Habitat complexity in the form of LWD and associated pool habitats, undercut banks, overhanging vegetation, backwaters, and side channels along unconstrained reaches in alluvial floodplains helps provide cover and refuge from predators and storm events. LWD interacting with large boulders or bedrock create specific micro-habitats.	Migratory salmonids tend to use undercut banks, LWD, boulders, floodplains, and side channels as refugia; providing cover from predators and areas for feeding, holding, and resting. Artificial and natural obstructions may impede migration to estuaries where acclimation to salt water occurs.
Flow and Depth	Streamflow must be sufficient to allow passage over physical barriers (falls, cascades, debris jams). Chinook spawning in mainstem can utilize low flows, whereas coho, steelhead, and cutthroat migrate during periods of high flow to reach headwater spawning grounds. Minimum passage depths are approximately 12 cm for cutthroat, 18 cm for steelhead and coho, and 24 cm for chinook.	Salmonids typically deposit eggs within a range of depths and velocities that minimize the risk of desiccation as water level recedes, and which ensure the exchange of water between surface and substrate interstices is adequate to maintain high oxygen levels and remove metabolic wastes from the redd. Typically most species spawn at depths greater than 15 cm, with the exception of cutthroat, which spawn in shallower water.	Salmonids hold in water adjacent to faster waters to maximize food intake while minimizing energy expenditures, because water velocity is proportional to the amount of food delivered to an area. Smaller-sized fish tend to select shallower and slower moving waters. Newly emerged fry typically select velocities <10.0 cm/s to avoid downstream flow displacement. In summer low-flow periods, streamflow must prevent streams from becoming excessively warm or dry.	Streamflows that maintain normal temperature patterns and have short term increases, are important in facilitating downstream migration of salmonid smolts. Rate of smolt migration is correlated to streamflow, however speed of migration is poorly understood.

IV. Watershed Processes and Potential Risks to Anadromous Salmonid Habitat

Salmon and steelhead are dependent upon a high quality freshwater environment at the beginning and end of their life cycle (NCWAP, Mattole 2002). Habitat conditions for salmonids are dictated by watershed processes. Watershed processes have been affected by past and ongoing human activity, and have impacted habitat elements for salmonids.

V. A. Five Watershed Processes

Watershed processes (i.e. sediment transport, heat transfer, and nutrient, wood and water cycling) and watershed elements (e.g.. channel morphology, riparian structure, water quality) form the core of functioning salmonid habitat. Stream channels essentially act as transport systems for **water, sediment, wood, nutrients and heat** which are input into the watershed. In an undisturbed watershed, these processes occur at natural rates that sustain salmonid populations. Human alterations to the landscape of Humboldt Bay watershed have altered natural watershed processes, resulting in environmental changes that are impacting salmonid populations (Higgins, 2001). Below is a brief discussion of watershed processes followed by each watershed product, potential issues, and potential risks in Humboldt Bay watershed.



IV. A. 1. Water

Land use practices affect both summer and winter streamflows. Redwood forests influence the delivery of water to streams, especially during the dry summer months. In foggy, coastal areas, large trees collect water from the fog through the condensation on their leaves (Harr 1982). The resultant water slowly drips onto the ground, where it infiltrates or is used by the tree for transpiration. Fog drip in Humboldt Bay watershed can increase the amount of water available to the stream in drier seasons. Reduction in summer base flow can limit summer rearing habitat for salmonids. Information regarding summer base flow in Humboldt Bay tributaries is limited and it is not known at this time if this is a problem in the watershed.

Studies conducted in the Casper Creek watershed have found no difference in winter peak flows between logged and unlogged watersheds. However, there were significant differences in annual runoff rates (Ziemer 1998).

Table IV.1: Watershed Processes and Potential Impacts to Anadromous Salmonid Habitat Needs

Watershed Process	Potential Causes	Potential Impacts
Sediment Production	Increase in surface erosion, mass wasting shallow landslides, debris torrents, channel erosion	Excessive sediment fills in estuaries, lagoons, spawning gravels, rearing areas, refugia, and rearing pools. Alters invertebrate composition and densities, effects feeding behavior and overwintering survival. Alteration in channel morphology
Large Woody Debris (LWD)	Riparian zones that do not provide adequate future LWD recruitment. Decrease in amount of existing LWD within stream channel. LWD within channel old or legacy pieces near end of life	Lack of rearing habitat for juveniles, cover for spawning adults, decrease in pool formation and sediment sorting, lack of high flow refugia,
Heat Transfer	Inadequate canopy or narrow, ineffective riparian zones to properly shade streams. Shallow water and turbid water heats faster	High summer temperatures in resting, rearing and refugia pools. Poor juvenile growth and survival. This is less of a problem in Humboldt Bay watershed than inland.
Water Cycle	Alterations of watershed hydrology including changes in peak flows, water quality and summer base flows. Access to floodplains and historic habitat, inadequate circulation	Low or high flows can de-water or degrade stream reaches, impede fish migration and access, alter channel conditions, and jeopardize egg and juvenile survival during summer and overwintering.
Nutrient Cycle	Imbalance in food availability for fish, or a lack of carcasses providing vital nutrient inputs to the stream and riparian ecosystems. Excessive nutrient inputs can cause eutrophication, high biological oxygen demand (BOD), eliminate habitat and/or alter food availability.	Anadromous salmon conduct nutrients both to and from the ocean. Excessive nutrients (live stock or treatment facilities) can kill or reduce rearing populations.

Timber harvest can affect the infiltration and flow of water both through changes in the permeability of the soil and by changes in the drainage network. Changes in ground permeability are caused by compaction in harvest areas, or by compaction in the construction of roads. Areas that have been tractor yarded are especially prone to changes in runoff rates. In highly compacted areas, water is unable to enter the ground and tends to flow much more quickly overland to stream channels (Ziemer 1998).


Sediment accumulation in lower Elk River watershed

Modifications of the drainage network by roads also increase the rate of water delivery to streams. Roads and associated ditch networks capture water and transport it to stream channels much more quickly than natural drainage routes (FEMAT 1994). The longevity of changes due to roads is as permanent as the road itself (FEMAT 1994). In watersheds on the order of 20-200 square miles, increased peak flows have been detected after road building and clearcutting (FEMAT 1994). Similar increases in peak flows have been noted following urbanization of forested and agricultural lands. Studies of Martin Slough watershed, which drains south Eureka, showed an increase in peak runoff due to urbanization of the watershed and a study being conducted by Winzler and Kelly for Martin Slough will estimate potential changes in hydrology from planned development (Redwood Community Action Agency, 2004). An increase in the frequency and magnitude of floods impacts channel morphology, spawning gravels and redds, bank erosion, riparian condition, and sedimentation.

Urbanization within watersheds decreases infiltration rates by adding large areas of impervious surfaces such as parking lots, roofs, driveways, and roads. This increase in impervious surface results in an increase in volume of surface run-off and peak flows. Research conducted in many geographical areas have concluded that stream degradation occurs at approximately 10-20% Total Impervious Area (http://www.krisweb.com/watershd/urban.htm).


Alder trunks buried in sediment in Freshwater Creek watershed
Photo courtesy of the NCRWQCB

Since 1997 residents in Freshwater and Elk Rivers have documented an increase in flood events. A recent assessment (Patenaude 2004) by the Regional Water Quality Control Board showed that the overall channel capacity in Elk River had decreased by 60% since 1965.

IV. A. 2. Sediment

The supply of sediment to stream channels is a natural process, part of the gradual erosion of the landscape (Leopold, Wolman, and Miller 1964). Upland areas supply sediment to streams through slow processes like the erosion of banks of small headwater channels, or more quickly through the mass movement of large quantities of earth in landslides or debris flows (Dunne and Leopold 1978).

Mass wasting event in Elk River watershed. Photo courtesy of PALCO

The removal of vegetation in the watershed can increase the supply of sediment to streams. The amount of bare dirt exposed to rainfall is increased, thus increasing erosion (Ziemer 1998; FEMAT 1994; Spence et al. 1996). Devegetation can also cause an increase in mass movement of sediment (landslides), caused by reduction of root strength binding the soil along with changes in infiltration (Spence et al. 1996). Vegetation removal on small, ephemeral streams may result in increased erosion during storms. Changes in infiltration and drainage patterns from harvesting may alter groundwater flow rates, increasing groundwater discharge and causing erosion of groundwater transport channels (Ziemer 1998). Detailed assessment of landslides, mass wasting, and erosion have been completed in both Freshwater Creek and Elk River by Hart-Crowser for Pacific Lumber Company properties. The data from these studies can be found in the background chapters for Elk River and Freshwater.

Roads can be a major source of increased sediment (FEMAT 1994; Spence et al. 1996). Road networks in many upland areas of the Pacific Northwest are the most important source of management-accelerated delivery of sediment to anadromous fish habitats, which is often much greater than that from all other land management activities combined (FEMAT 1994). The alteration of drainage patterns increases flow velocity and concentrates flow in ditches, where it can cause erosion. Stream crossings are very susceptible to significant erosion, as culverts can become blocked during floods, resulting in crossing failures and erosion (Ziemer 1998). Finally, disruption of drainage networks by roads can result in the concentration of water on unstable slopes, resulting in an increase in the frequency of mass soil movements to the stream channel (Reid and Dunne 1984; Spence et al. 1996).

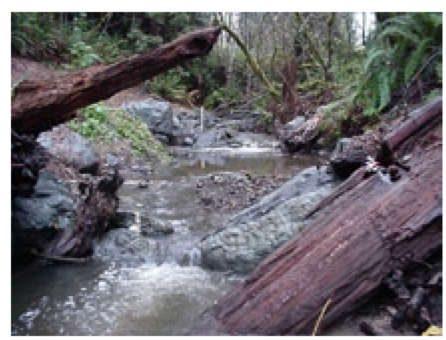
The effects of increased sediment on fish populations have been well-documented (Spence et al. 1996). Increased levels of fine sediment are detrimental to reproduction, smothering eggs in salmon redds, as well as reducing the amount of living space for aquatic insects, the primary food for juvenile salmonids (Furniss, Roelofs, and Yee 1991). Landslides may not only supply significant quantities of fine sediment, but may also result in blockages to fish migration and extensive channel changes, with further erosion (Spence et al. 1996).

The increase in sediment production in Humboldt Bay watershed streams due to land use practices is difficult to quantify, especially given variations in natural rates of sediment inputs. Comparisons between Humboldt Bay tributaries and those in undisturbed watersheds show turbidity levels to be orders of magnitude higher for managed streams. While comparing watersheds with physical differences such as geology, size, and slope is a debated practice, the magnitude of the difference in turbidity levels is cause for concern. Both the Elk River and Freshwater Creek have been listed as water quality impaired due to high sediment production by the SWQCB, and the CDFG considers excess sediment to be the major limiting factor to salmonid production in the watershed.

Large Woody Debris survey on Elk River. Photo Courtesy of PALCO

IV. A. 3. Large Woody Debris

Large trees which fall into coastal streams play a dominant role in forming pools, metering sediment, trapping spawning gravels and creating a more complex stream environment. Redwoods are particularly valuable because a large tree may not decay for several hundred years (Kelly et al. 1995). Fir and spruce trees last for several decades while alder and hardwood species rot within a few years of being recruited into the stream (Cedarholm et al. 1997). In general, the larger the size of the wood, the greater its stability in the stream channel. Heavier pieces require higher flows for mobilization and longer pieces are more likely to be caught by the stream bank and its vegetation (Spence et al., 1996). Reeves et al. (1993) found "that wood is a primary element influencing habitat diversity and complexity in streams. Consequences of decreased amounts of wood include loss of cover and structural complexity, decreased availability and abundance of habitat units, and reduced varieties of current velocities and other hydraulic features" (http://www.krisweb.com/stream/bigwood.htm).



Anchored large woody debris and boulders to enhance complexity in Morrison Gulch a tributary to Jacoby Creek . Photo courtesy of Ross Taylor and Associates

IV. A. 4. Heat

Temperature is an important element in salmon and steelhead habitat. Pacific salmonid species require cold water. Water temperature tolerance varies somewhat between species and also between life stages. Warm temperatures can reduce fecundity, decrease egg survival, retard growth of fry and smolts, reduce rearing densities, increase susceptibility to disease, and decrease the ability of young salmon and trout to compete with other species for food and to avoid predation (Spence et al. 1996; McCullough

1999).

Much of the data on salmonid temperature tolerance is derived from laboratory experiments that may not reflect survival in streams. Lab experiments expose juvenile fish to varying acclimation temperatures, then raise the water temperature at different rates until 50 percent of the fish die. These tests have established lethal values for coho known as critical thermal maxima (CTM) and upper incipient lethal temperatures (UILT). It has not been established how these values relate to fish stress and mortality in nature. Fish in the wild must forage for food and avoid predation, while in laboratory environments the fish are fed and protected from predators. Stress may occur at lower temperatures in the wild as the fish must cope with all the variables of its environment (McCullough 1999). High temperatures, at this time, do not appear to be an issue in Humboldt Bay Watershed (Dana McCanne, personal communication).

CDFG's Natural Stocks Assessment Project is researching juvenile salmonids' use of the estuary. Above, a fyke net was installed by a CDFG crew in "3rd Slough" just upstream of the Highway 101 bridge to determine if juvenile salmonids move into tidal meanders from the mainstem Freshwater Slough. The result: they do!

IV. A. 5. Nutrients

Scientists have found a positive relationship between the amount of nutrients in the water and primary production (i.e., the growth of algae). Algal blooms stimulated by nutrients are followed by an algal die-off when nutrients are depleted. Settling of dead algae stimulates an increase in biological oxygen demand as populations of micro-organisms expand and consume dead algae. The expanding microbial populations thereby reduce oxygen concentration in the water column which can cause fish kills. Ammonium, nitrate, nitrite, and ortho-phosphates may be potential nutrients of concern in Humboldt Bay watershed; however, information on nutrients in Humboldt Bay tributaries is lacking.

The CDFG field crew seining lower Freshwater Slough near the Highway 101 bridge. (Photo courtesy of Mike Wallace of CDFG's NSAP)

IV. B. Potential Risks to Humboldt Bay Watershed Anadromous Salmonids

Land use practices in the Humboldt Bay watershed have been and are currently impacting salmonid habitat. The loss of this crucial habitat calls for restoration and protection actions. Below, three regions of the watershed are examined and assessed for significant land use practices that have historically or are currently impacting each segment. The categories, 'Lower, Middle, and Upper' Reaches are rough estimates related to both slope changes and land use activities.

IV. B. 1. Lower Reach

Selected Elements of Salmonid Habitat...In a Nutshell

Channel Morphology

Natural stream channels transport water and sediment. The channel cross sectional shape, profile and planform (shape when looking at the channel from high above, including the tightness of bends) are all a function of the channels' basic requirement to transport water and sediment most efficiently (Leopold, Wolman, and Miller 1964). These are also the features that create habitat for salmonid spawning and rearing, including the riffles salmonids use for spawning and the pools they use for cover.

A stream in equilibrium is said to be "at grade" but will respond to any changes in flow or sediment supply. A stream loaded in excess of its capacity will deposit the load. When a stream bed fills in as a result of bedload exceeding capacity it is said to be aggraded. Increases in bedload may make a channel much shallower and wider, which in turn reduces the ability to hold high stream flows and increases flood frequency. Conversely, a stream with reduced bedload supply may have a capacity greater than its load and will down cut in order to increase its bedload, which is called degrading (http://www.krisweb.com/hydrol/channel.html).

The spatial distribution of source, transport, and response reaches governs the distribution of potential impacts and recovery times for the stream system. Source reaches are considered to be those with streams with gradients > 20%, transport 4-20%, and response < 4%. (NCWAP Mattole River Basin 2003). In Humboldt Bay watershed the source and transport reaches mainly occur in the forested lands managed for timber production. The response reaches are located in the valley floors which are mainly in rural residential or agricultural production land use.

Natural channels, in response reaches, tend to be dynamic, which means they change location over time. Research indicates that channel migration is important in maintaining natural channel features.

Floodplain

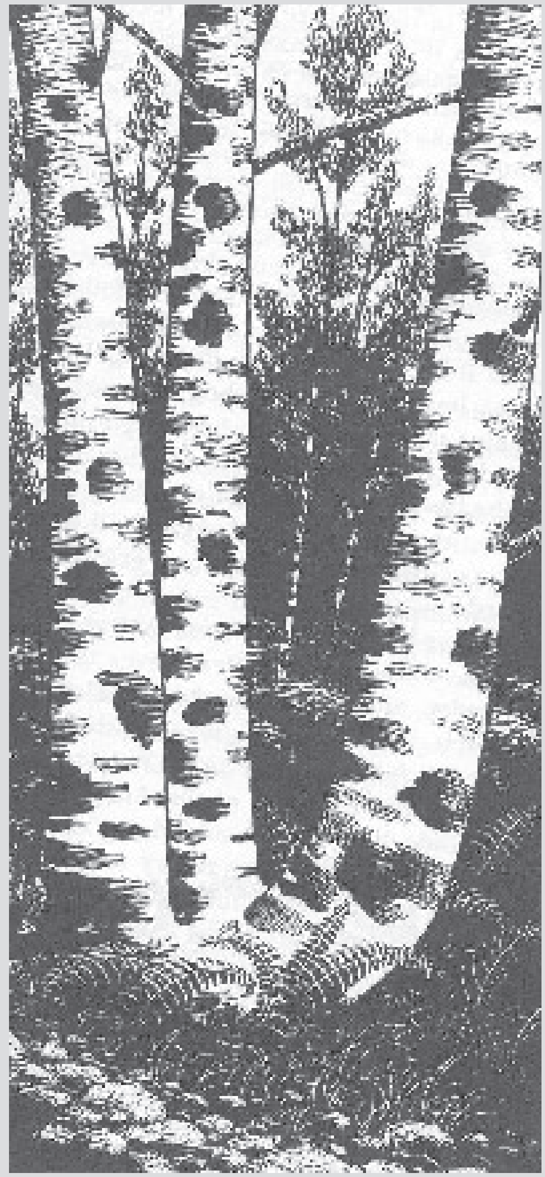
Streams tend to build floodplains which are areas adjacent to the channel that are flooded regularly. In the 1950's, researchers found that the amplitude and frequency of flood events are remarkably consistent among different types and sizes of channels (Leopold, Wolman, and Miller 1964). These floods occur, on average, about every two years. As flow reaches flood stage, water begins to spread out onto the floodplain, reducing velocity within the channel itself. The floodplain thus acts to dissipate energy in the channel during high flow periods.

In altered stream channels, separated from the floodplain, the bed is subject to higher levels of scour and the natural pool and riffle sequence can be disrupted. Constraining channels through rip-rap or straightening disrupts processes that create and maintain the slow migration of the channel across the floodplain and cause degradation of stream habitat (Rosgen 1996). Constraints imposed on stream channels by development in the Humboldt Bay watershed include riprap and bank protection for infrastructure (roads, homes, bridges, railroads, pipelines) and berms and levees for flood protection. The channel of lower Elk River is relatively unconstrained and maintains a natural meander pattern, while a significant section of lower Freshwater Creek has been constricted by levees.

Estuary

Estuaries are important areas where steelhead and salmon acclimate to the shift in salinity and prepare their internal osmotic balance for going to the ocean as juveniles and returning to spawn as adults. Much of the lowland area surrounding Humboldt Bay was once productive estuary, but today only 10 to 15 percent of this habitat remains.

Riparian Zone



The riparian zone is the area which borders a stream. Riparian vegetation plays a key role in the form and function of streams. Prichard (1998) notes the following functions of healthy riparian areas:

- Dissipation of stream energy associated with high waterflow, thereby reducing erosion and improving water quality;
- Filtration of sediment, capture of bedload, and aiding in floodplain development;
- Improvement of floodwater retention and groundwater recharge;
- Stabilization of streambanks through the development of root mass;
- Development of diverse channel characteristics to provide the habitat diversity and water depth, duration, and temperature necessary for fish production.

The vegetation of fully functional riparian ecosystems in the Pacific Northwest generally consists of large conifers or a mixture of large conifers and hardwoods (FEMAT 1993). These riparian forests are a major source of large woody debris in streams (House and Boehne 1987; Bisson et al. 1987; Sullivan et al. 1987). Riparian vegetation also contributes leaves, twigs, and other forms of fine litter that are an important component of the aquatic ecosystem food base (Vannote et al. 1980).

The estuary, or mouth of streams where freshwater meets salt, is important habitat for many salmonids. Historically, Humboldt Bay estuaries were likely very complex, though today, few backwater areas remain in the watershed. A century of diking creeks to make farmland has destroyed estuarine habitat, leaving little safe haven for rearing salmon.

Age Category	Length (inches)
O+ (YOY)	3 or less
1+	3 to 6
2+	6 or greater

Table IV.2: According to accepted fish sampling methods, juvenile salmonids are placed in general age categories according to length. YOY refers to young-of-the year.

Salmonid use of habitat in Humboldt Bay estuaries is not well understood. Chinook salmon juveniles, which migrate at an early age to the ocean, spend time in the estuary before going to the open ocean. A study in a coastal Oregon estuary showed that estuarine residence increases chinook survival in the ocean, probably because fish that stay in the estuary longer are larger on entering the ocean (Riemers 1973). Estuaries may also be important to cutthroat. Giger (1972) reported that some juveniles resided over the summer in the Alsea River estuary in Oregon.

The Anadromous Fisheries Resource Assessment and Monitoring Program (AFRAMP) of CDFG has been monitoring the fish assemblage in Freshwater Creek since 2000. All successful returning steelhead adults examined in Freshwater Creek spent at least two years in the freshwater environment as juveniles. Analysis of the outmigrant population in the spring of 2001 found that 90 percent of juvenile emigrants captured were age 1+ (Ricker 2002). The AFRAMP report presented three possibilities: 1) few to zero age 1+ steelhead smoltified and entered the ocean for the cohort that made up the returning 2000-2001 adult run; 2) age 1+ steelhead that enter the ocean suffer zero or very low survival to adult, or 3) this age class of fish is migrating to the lower river/ estuary and either residing there for a second year or migrating back upstream to rear until age 2+.

McDaniel Slough winding it's way through agricultural land near the mouth of Humboldt Bay. Photo courtesy of Mark Andre, City of Arcata

Estuarine habitat in the Humboldt Bay watershed has been greatly reduced through land use practices. Most of the estuary system lacks significant large woody debris and other habitat complexity elements such as pools, backwaters, or side channels. Reduced habitat diversity has made survival more difficult for juvenile salmonids during downstream migration. The decrease in the size and quality of the estuary affects food supply and shelter necessary for adaptation to the salt water environment during rearing. There is high levels of suspended sediment and a lack of clean spawning gravel in the lower watershed. Spawning adults have ceased using lower reaches of the watershed that were once utilized as recently as the 1960s. Because many of the adults are forced to spawn in the main stem, (often lacking significant habitat complexity) incubating salmonids are often exposed to higher flows, resulting in redds being washed out.

Poor water quality may impair salmonid feeding habits and growth rates. Many toxic pollutants are regularly washed into the Bay from industrial facilities, storm water systems, and ships, including pentachlorophenol (PCPs), petroleum hydrocarbons, furans, dioxin and others. CDFG recently cataloged 177 pollution outfalls that may affect the Bay (Barnhart, Boyd, and Pequegnat 1992). These pollutants can cause serious impacts on human and wildlife that depend on the Bay. Some of the cataloged chemicals are known to accumulate in the tissues of humans, steelhead and shellfish, with the level of compounds carried in a body increasing each time an organism is ingested further along the food chain (known as bioaccumulation). As these chemicals accumulate, a person risks developmental, reproductive, and immunological problems.

IV. B. 2. Middle Reach

The middle reaches of Humboldt Bay watershed streams are the regions most utilized for salmonid rearing habitat. AFRAMP's 2001 downstream migrant trapping for Freshwater Creek results indicated that the majority of salmonid production originated from the mainstem. An estimated 87 percent of the steelhead migrating from Freshwater Creek originated from the main stem section between tributary traps and the lower main stem trap, leaving the remaining 17 percent attributed to tributary production. An estimated 48 percent of all coho salmon smolts migrated from the tributaries (Ricker 2001).

The middle reach is where salmon spend much of their juvenile stage. Rearing habitat is crucial for fish emerging from gravels and moving downstream into the mainstem, especially in summer low flows, when in this watershed the upper reaches become ephemeral and inaccessible. Salmonid juveniles need an abundance of food and cover to sustain fast growth rates, escape predators, and avoid premature displacement downstream to the ocean. These conditions determine the survival of outmigrating fish.

The middle reach of the Humboldt Bay watershed is characterized as mostly residential and has had extensive riparian vegetation removal along its tributaries. Riparian vegetation extraction has greatly diminished salmonid habitat. Riparian cover is important for maintaining low water temperatures, especially in the summer months. Removal of riparian vegetation has resulted in temperature spikes and lack of large woody debris recruitment.

Watershed streams are leveed throughout much of their middle reaches and are now separated from their floodplains. Municipal development has altered channels in both Eureka and Arcata.

There are high concentrations of suspended sediment in the middle reach. Both the high levels of suspended sediment and the lack of clean spawning gravels cause the suffocation of embryos and alevins. Turbidity monitoring in the middle watershed measured high turbidity levels for most of the winter, potentially affecting juvenile salmonids.

Flow has not been found to be a significant problem in Freshwater Creek with regards to rearing habitat. However, low flows may affect migration by creating barriers to fish passage.

Lack of deep pools in the middle reach due to aggradation and limited in-stream structure may decrease the amount of suitable habitat for rearing juveniles and residents. Habitat surveys conducted by PALCO show a decrease in the number of deep pools and depth of remaining pools. Adult fish held in the Humboldt Fish Action Council weir on Freshwater Creek reportedly died due to low dissolved oxygen (DO) levels. Decreased DO levels may be a limiting factor during summer low flow.

IV. B. 3. Upper Reach

Land use in the upper watershed is dominated by industrial timber production. The upper area of the watershed is where the most active logging and road building has taken place and where most sediment in the system is delivered. The upper reaches also contribute most of the large wood into the channel system because the lower reaches no longer produce large woody debris.

Tributaries to the main stem increase in gradient in the upper watershed and limit anadromous migration due to steepness. Rearing and spawning is limited in the steep upper reaches. Suitable rearing habitat exists in the transition zone between the upper and middle reaches. The seasonal intermittent and low flows result in reduction of spawning utilization in the upper tributaries.

The construction of roads in the upper watershed created many fish passage barriers at stream crossings. During early development of roads, fish passage was seldom considered and crossings were constructed right in the streambed. Culverts placed at stream crossings also present a fish passage problem. Typical passage problems created by culverts include excessive drop at outlet (too high of entry jump required); excessive velocities within culvert; lack of depth within culvert; excessive velocity and/or turbulence at culvert inlet; and debris accumulation at culvert inlet and/or within culvert. Even if culverts are eventually negotiated, excess energy expended by fish may result in their death prior to spawning. Migrating fish concentrated in pools and stream reaches below culverts are also more vulnerable to predation by birds, otters, and humans. Culverts which impede adult passage limit the distribution of spawning, often resulting in underseeded headwaters and superimposition of redds in lower stream reaches (Taylor 1999).

IV. C. Cumulative Watershed Effects in Humboldt Bay Watershed

Cumulative impacts are defined as "...the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (CEQ Guidelines, 40CFR 1508.7, issued 23 April 1971.)

"Cumulative watershed effects" was not formally defined by the Council on Environmental Quality (CEQ), but in this document the term refers to cumulative effects that involve watershed processes (specifically, those cumulative impacts that influence or are influenced by the flow of water through a watershed). Such impacts may include: degraded water quality, reduced viability of aquatic and riparian species, nuisance flooding, and damage to recreational and residential properties. Because almost all watershed impacts are influenced by multiple activities, those impacts must be evaluated as cumulative rather than individual (Reid 1999).

Quantification and regulation of CWEs has been a topic of debate for many years in Humboldt Bay watershed. The last five years have seen increasing efforts to quantify and correlate cumulative effects of sediment discharge on channel aggradation, turbidity, and salmon viability, in an attempt to determine appropriate rates and approaches to timber harvest, agriculture, and other land use activities. Other watershed factors, such as traffic on unpaved roads, riparian vegetation changes, residential development, legacy effects, levee construction, separation of the stream from the floodplain, and historic removal of LWD are also important contributors to CWE related to sediment impairment and viability of salmonid populations. Influences beyond the watershed that also contribute to the impacts of concern include results of bay and estuary management, commercial fishing, and hatchery competition.

Factors such as weather patterns, ocean conditions, tidal influences, and the inherent instability of underlying geologies are fundamental, and must always be accounted for in assessing cumulative risks.

Almost all off-site environmental impacts are cumulative impacts. The word “cumulative” indicates that the impact is influenced by multiple activities. Cumulative watershed impacts are of considerable concern because they are responsible for much of the damage to property and to public trust resources that occurs away from the site of a land-use activity (Reid 1999). Because impacts can accumulate through time and space, they may take a long time to become evident, and they may occur a long distance from the activities that generate them (Reid 1999).

Humboldt Bay watershed water quality and fisheries habitat has been and still is impacted by multiple land-use activities that have changed the amounts, delivery rates, and transportation rates of watershed products – sediment, water, and woody debris. Changes in these watershed products are the most common causes for downstream cumulative impacts.

The initial removal of all of the old-growth forest in the watershed resulted in impacts including unprecedented increases in sediment in the stream channels. The canopy of these forests held millions of gallons of water in their foliage, branches, and trunks over the ground layer, creating local microclimates, which buffered the forest floor from temperature extremes. Within the stream zone, large old-growth tree trunks defended streambanks from erosion, defined stream channels, and created deep pools in the stream which protected fish and other aquatic organisms from predators (Murray and Wunner 1988).

Humboldt Bay watershed has been impacted by increased sediment inputs, primarily generated by timber harvest activities on steep, unstable slopes in the upper watershed. Additional land uses such as riparian removal, road and levee construction, residential encroachment, removal of LWD from the stream and herbicide use in the Humboldt Bay watershed contribute to cumulative watershed effects. Other factors contributing to CWE are past over-fishing, poor ocean conditions, erosive geology, hatchery introductions and mixed stock. Cumulative impacts from increase in sediment loads in Humboldt Bay watershed includes modification of the estuary system; reduction of channel conveyance and aggravation of flood hazard; infilling of channel pool habitat; and water quality degradation. Forests influence runoff by intercepting and evaporating rainfall before it hits the ground. Data from Caspar Creek, California (Ziemer 1998, Reid 1999) show that logging of this second-growth redwood forest has increased flood peaks in completely clearcut watersheds by an average of 27 percent, and that the effect is proportional to the amount of forest cover removed in the watershed. Impervious surfaces caused by logging, road building, and urbanization affect runoff rates, which lead to increased stream flow, and quicker responses to storm events (Tuttle, 1985).

Cumulative impacts of water withdrawal can result in lack of summer rearing habitat for juvenile salmonids, especially in drought periods.

Due to the fragile geology of Humboldt Bay watersheds, particularly in Elk River and Freshwater Creek watershed, naturally occurring events need to be considered when determining other land uses, which individually and combined, may contribute to limiting factors affecting salmonid habitat and therefore populations. Cumulative impacts affect watershed processes, which in turn affect fish species differently depending on life stage requirements.