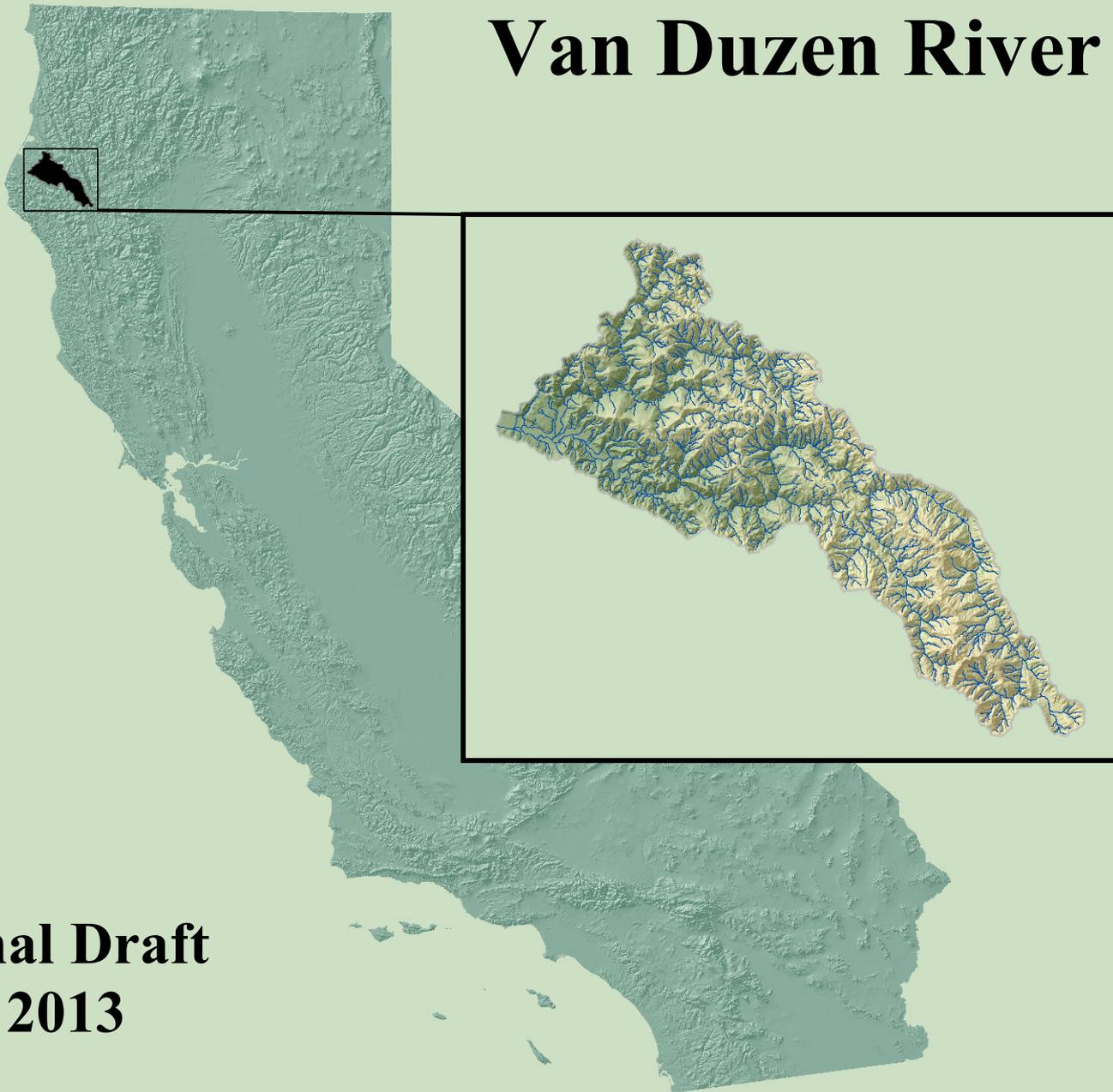


*Coastal Watershed
Planning & Assessment
Program*



Van Duzen River



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Governor, Jerry Brown



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Van Duzen River Watershed Assessment

Prepared through a cooperative effort by

California Department of Fish and Game
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Program*



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California Coastal Watershed Planning and Assessment Program Introduction and Overview

The Coastal Watershed Planning and Assessment Program (CWPAP) is a program of the California Department of Fish and Game (CDFG) based in Fortuna, CA. CDFG's large scale assessment efforts began in 2001 as a component of the North Coast Watershed Assessment Program (NCWAP), an interagency effort between the California Resources Agency and the Environmental Protection Agency. Due to budget constraints, the NCWAP was discontinued in 2003, but CDFG decided to continue large scale watershed assessments along California's coast to facilitate fishery improvement and recovery efforts.

The 430 square mile Van Duzen River Basin is located in the lower Eel River watershed within Humboldt and Trinity counties (Figure 1). This watershed was selected as a CWPAP assessment area because of its high fishery value to anadromous salmonids, including coho salmon that are listed as threatened by both state and federal agencies. This report was guided by following the outlines, methods, and protocols detailed in the NCWAP Methods Manual (Bleier et al., 2003). The program's assessment is intended to provide answers to six guiding assessment questions at the basin, subbasin, and tributary scales.

Program Guiding Questions

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

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

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

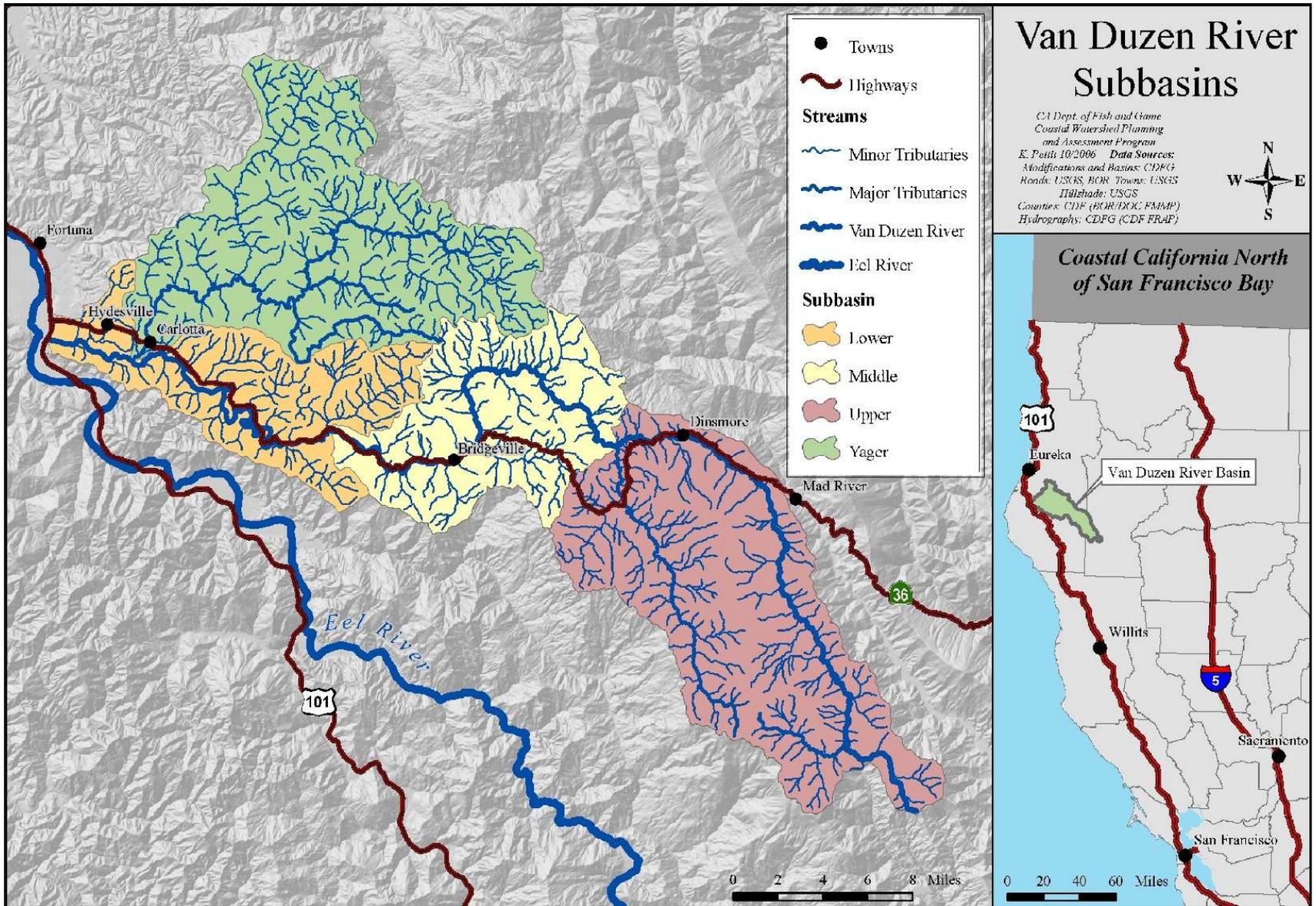


Figure 1. Location of the Van Duzen River Basin and subbasins.

Goals

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

North Coast Salmon, Stream, and Watershed Issues

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

Salmonids thrive or perish during their freshwater phases depending upon the availability of cool, clean water, free access to migrate up and down their natal streams, clean gravel suitable for successful spawning, adequate food supply, and protective cover to escape predators and ambush prey. These life requirements must be provided by diverse and complex instream habitats as the fish move through their life cycles. If any life requirements are missing or in poor condition at the time a fish or stock requires it, fish survival can be impacted. These life requirement conditions can be identified and evaluated on a spatial and temporal basis at the stream reach and watershed levels. They comprise the factors that support or limit salmonid stock production.

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

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

Two important watershed goals are the protection and maintenance of high quality fish habitats. In addition to preservation of high quality habitat, reparation of streams damaged by poor resource management

practices of the past is important for anadromous salmonids. Science-based management has progressed significantly and “enough now is known about the habitat requirements of salmonids and about good management practices that further habitat degradation can be prevented, and habitat rehabilitation and enhancement programs can go forward successfully” (Meehan 1991).

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

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

In general, natural disturbance regimes like landslides and wildfires do not impact larger basins like the 430 square-mile Van Duzen River in their entirety at any given time. Rather, they normally rotate episodically across the entire basin as a mosaic composed of the smaller subbasin, watershed, or sub-watershed units over long periods. This creates a dynamic variety of habitat conditions and quality over the larger basin (Reice 1994).

The rotating nature of these relatively large, isolated events at the regional or basin scale assures that at least some streams in the area will be in suitable condition for salmonid stocks. A dramatic, large-scale example occurred in May 1980 in the Toutle River, Washington, which was inundated in slurry when Mt. St. Helens erupted. The river rapidly became unsuitable for fish. In response, returning salmon runs

avoided the river that year and used other nearby suitable streams on an opportunistic basis, but returned to the Toutle two years later as conditions improved. This return occurred much sooner than had been initially expected (Quinn et al. 1991; Leider 1989).

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

Human disturbance regimes collectively extend across basins and even regional scales and have lingering effects. Examples include water diversions, conversion of near stream areas to urban usage, removal of large mature vegetation, widespread soil disturbance leading to increased erosion rates, construction of levees or armored banks that can disconnect the stream from its floodplain, and the installation of dams and reservoirs that disrupt normal flow regimes and prevent free movement of salmonids and other fish. These disruptions often develop in concert and in an extremely short period of time on the natural, geologic scale.

Human disturbances are often concentrated in time because of newly developed technology or market forces such as the California Gold Rush or the post-WWII logging boom in Northern California. The intense human land use of the last century, combined with the transport energy of two mid-century record floods on the North Coast, created stream habitat impacts at the basin and regional scales. The result of these recent combined disruptions has overlain the pre-European disturbance regime process and conditions.

Consequently, stream habitat quality and quantity are generally depressed across most of the North Coast region. It is within this widely impacted environment that both human and natural disturbances continue to occur, but with vastly fewer habitat refugia lifeboats than were historically available to salmon and steelhead. Thus, a general reduction in salmonid

stocks can at least partially be attributed to this impacted freshwater environment.

Factors Affecting Anadromous Salmonid Production

A main component of the program is the analyses of the freshwater factors in order to identify whether any of these factors are at a level that limits production of anadromous salmonids in North Coast basins. This limiting factors analysis (LFA) provides a means to evaluate the status of a suite of key environmental factors that affect anadromous salmonid life history.¹ These analyses are based on comparing measures of habitat components such as water temperature and pool complexity to a range of reference conditions determined from empirical studies and/or peer reviewed literature. If a component's condition does not fit within the range of reference values, it may be viewed as a limiting factor. This information will be useful to identify underlying causes of stream habitat deficiencies and help reveal if there is a linkage to watershed processes and land use activities.

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

Water Quantity

Stream flow can be a significant limiting factor for salmonids, affecting fish passage, and quantity and quality of spawning, rearing, and refugia areas. For successful salmonid production, stream flows should follow the natural hydrologic regime of the basin. A natural regime minimizes the frequency and magnitude of storm flows and promotes better flows during dry periods of the water year. Salmonids evolved with the natural hydrograph of coastal watersheds, and changes to the timing, magnitude, and duration of low flows and storm flows can disrupt the ability of fish to follow life history cues.

Adequate instream flow during low flow periods is

¹ The concept that fish production is limited by a single factor or by interactions between discrete factors is fundamental to stream habitat management (Meehan 1991). A limiting factor can be anything that constrains, impedes, or limits the growth and survival of a population.

essential for fish passage in the summer time, and is necessary to provide juvenile salmonids free forage range, cover from predation, and utilization of localized temperature refugia from seeps, springs, and cool tributaries.

Water Quality

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

A second important aspect of water quality is turbidity. Fine suspended sediments (turbidity) affect nutrient levels in streams that in turn affect primary productivity of aquatic vegetation and insect life. This eventually reverberates through the food chain and affects salmonid food availability. Additionally, high levels of turbidity interfere with a juvenile salmonids' ability to feed and can lead to reduced growth rates and survival (Bill Trush, Trush & Associates; personal communication).

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

Fish Passage

Free passage describes the absence of barriers to the free instream movement of adult and juvenile salmonids. Free movement in streams allows salmonids to find food, escape from high water temperatures, escape from predation, and migrate to and from their stream of origin as juveniles and adults. Temporary or permanent dams, poorly constructed

road crossings, landslides, debris jams, or other natural and/or man-caused channel disturbances can lead directly to the fragmentation of salmonid habitat and may completely eliminate anadromous salmonids from accessing a stream to spawn.

Instream Habitat Conditions

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

Riparian Zone

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

Riparian zone functions are important to anadromous salmonids for numerous reasons. Riparian vegetation helps keep stream temperatures in the range that is suitable for salmonids by maintaining cool stream temperatures in the summer and insulating streams from heat loss in the winter. Larval and adult macro-invertebrates are important to the salmonid diet and are dependent upon nutrient contributions from the riparian zone. Additionally, stream bank cohesion and maintenance of undercut banks provided by riparian zones in good condition maintain diverse salmonid habitat, and help reduce bank failure and fine sediment yield to the stream. Lastly, the large woody debris provided by riparian zones shapes channel

morphology, helps retain organic matter and provides essential cover for salmonids (Murphy and Meehan 1991).

Therefore, excessive natural or man-caused disturbances to the riparian zone, as well as directly to the stream and/or the basin itself can have serious impacts to the aquatic community, including anadromous salmonids. Generally, this seems to be the case in streams and watersheds in the North Coast of California. This is borne out by the recent decision to list many North Coast Chinook and coho salmon, and steelhead trout stocks under the Endangered Species Act.

Disturbance and Recovery of Stream and Watershed Conditions

Natural and Human Disturbances

The forces shaping streams and watersheds are numerous and complex. Streams and watersheds change through dynamic processes of disturbance and recovery (Madej 1999). In general, disturbance events alter streams away from their equilibrium or average conditions, while recovery occurs as stream conditions return towards equilibrium after disturbance events. Given the program's focus on anadromous salmonids, an important goal is to determine the degree to which current stream and watershed conditions in the region are providing salmonid habitat capable of supporting sustainable populations of anadromous salmonids. To do this, we must consider the habitat requirements for all life stages of salmonids. We must look at the disturbance history and recovery of stream systems, including riparian and upslope areas, which affect the streams through multiple biophysical processes.

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

Natural disturbance and recovery processes, at scales from small to very large, have been at work on north coast watersheds since their formation millions of years ago. Recent major natural disturbance events

have included large flood events such as occurred in 1955 and 1964 (Lisle 1981a) and 1974 (GMA 2001a) ground shaking and related tectonic uplift associated with the 1992 Cape Mendocino earthquake (Carver et al. 1994).

Major human disturbances (e.g., post-European development, dam construction, agricultural and residential conversions, and the methods of timber harvesting practices used particularly before the implementation of the 1973 Z'Berg-Nejedly Forest Practice Act) have occurred over the past 150 years (Ice 2000). Salmonid habitat also was degraded during parts of the last century by well-intentioned but misguided restoration actions such as removing large woody debris from streams (Ice 1990). More recently, efforts at watershed restoration have been made, generally at the local level. For example, in California and the Pacific Northwest, minor dams from some streams have been removed to clear barriers to spawning and juvenile anadromous fish. For a thorough treatment of stream and watershed recovery processes, see the publication by the Federal Interagency Stream Restoration Working Group (FISRWG 1998).

Defining Recovered

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

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

Some types and locations of stream recovery for salmonids can occur more readily than others can. For example, in headwater areas where steeper source reaches predominate, suspended sediment such as that

generated by a streamside landslide or a road fill failure may start clearing immediately, while coarser sediments carried as bedload tend to flush after a few years (Lisle 1981a; Madej and Ozaki 1996). Broadleaf riparian vegetation can return to create shading, stabilize banks, and improve fish habitat within a decade or so. In contrast, in areas lower in the watershed where lower-gradient response reaches predominate, it can take several decades for deposited sediment to be transported out (Madej 1982; Koehler et al. 2001), for widened stream channels to narrow, for aggraded streambeds to return to pre-disturbance level, and for streambanks to fully re-vegetate and stabilize (Lisle 1981b). Lower reach streams will require a similar period for the near-stream trees to attain the girth needed for recruitment into the stream as large woody debris to help create adequate habitat complexity and shelter for fish, or for deep pools to be re-scoured in the larger mainstems (Lisle and Napolitano 1998).

Factors and Rates of Recovery

Over the past quarter-century, several changes have allowed the streams and aquatic ecosystems to move generally towards recovery. The rate of timber harvest on California's north coast has slowed during this period, with declining submissions of timber harvesting plans (THPs) and smaller average THPs (T. Spittler, pers. comm. in Downie 2003). However, in the Van Duzen River Basin, the amount of acreage harvested has increased since 1990 as timber stands matured into merchantable second-growth timber and as selection and other partial harvest silvicultural prescriptions are widely implemented.

Timber-harvesting practices have greatly improved over those of the post-war era, due to increased knowledge of forest ecosystem functions, changing public values, advances in road building and yarding techniques, and regulation changes such as mandated streamside buffers that limit equipment operations and removal of timber. Cafferata and Spittler (1998) found that almost all recent landslides occurring in an area logged in the early 1970s were related to legacy logging roads. In contrast, in a neighboring watershed logged in the late 1980s to early 1990s, landslides to date have occurred with about equal frequency in the logged areas as in unlogged areas.

Further, most north coast streams have not recently experienced another large event on the scale of the 1964 flood. Therefore, we would expect most north coast streams to show signs of recovery (i.e., passive restoration [FISRWG 1998]). However, the rates and

degrees of stream and watershed recovery will likely vary across a given watershed and among different north coast drainages.

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

Continuing Challenges to Recovery

Given improvements in timber harvesting practices in the last 30 years, the time elapsed since the last major flood event, and the implementation of stream and watershed restoration projects, it is not surprising that many north coast streams show indications of trends towards recovery (Madej and Ozaki 1996). Ongoing challenges associated with past activities that are slowing this trend include:

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

Increasing subdivision on several north coast watersheds raises concerns about new stream and watershed disturbances. Private road systems associated with rural development have historically been built and maintained in a fashion that does little to mitigate risks of chronic and catastrophic sediment inputs to streams. While more north coast counties are adopting grading ordinances that will help with this problem, there is a significant legacy of older residential roads that pose an ongoing risk for sediment inputs to streams. Other issues appropriate to north coast streams include potential failures of

roads during catastrophic events, erosion from house pads and impermeable surfaces, removal of water from streams for domestic uses, effluent leakages, and the potential for deliberate dumping of toxic chemicals used in illicit drug labs.

Some areas of the north coast have seen rapidly increasing agricultural activity, particularly conversion of grasslands or woodlands to grapes. Marijuana cultivation has also become locally abundant in some north coast watersheds, including the Van Duzen River. These agricultural activities have typically been subject to little agency review or regulation and can pose significant risk of chronic sediment, chemical, and nutrient inputs to streams.

Associated with development and increased agriculture, some north coast river systems are seeing increasing withdrawal of water, both directly from streams and groundwater sources connected to streams, for human uses. Water withdrawals pose a chronic disturbance to streams and aquatic habitat. Such withdrawals can result in lowered summer stream flows that impede the movement of salmonids and reduce important habitat elements such as pools. Further, the withdrawals can contribute to elevated stream water temperatures that are harmful to salmonids.

Key questions for landowners, agencies, and other stakeholders revolve around whether the trends toward stream recovery will continue at their current rates, and whether those rates will be adequate to allow salmonids to recover their populations in an acceptable time frame. Clearly, the potential exists for new impacts from both human activities and natural disturbance processes to compromise recovery rates to a degree that threatens future salmonid recovery. To predict those cumulative effects will likely require additional site-specific information on sediment generation and delivery rates and additional risk analyses of other major disturbances. Also, our discussion here does not address marine influences on anadromous salmonid populations. While these important influences are outside of the scope of this program, we recognize their importance for sustainable salmonid populations and acknowledge that good quality freshwater habitat alone is not adequate to ensure sustainability.

Policies, Acts, and Listings

Several federal and state statutes have significant implications for watersheds, streams, fisheries, and their management. Here, we present only a brief

listing and description of some of the laws.

Federal Statutes

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

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

The federal Endangered Species Act (ESA) addresses the protection of animal species whose populations are dwindling to critical levels. Two levels of species risk are defined. A threatened species is any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. An endangered species is any species that is in danger of extinction throughout all or a significant portion of its range. In general, the law forbids the take of listed species. Taking is defined as harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting a species or attempting to engage in any such conduct.

Many of California's salmon runs are listed under the ESA, including the Chinook and coho salmon and steelhead trout found in the Van Duzen River Basin (NMFS 2001). The Southern Oregon Northern California Coast (SONCC) Coho Evolutionary Significant Unit (ESU) and California Coastal Chinook ESU were listed as a threatened species in

1997 and 1999, respectively. Steelhead trout were subsequently listed as threatened in 2000.

A take of a species listed as threatened may be allowed where specially permitted through the completion and approval of a Habitat Conservation Plan (HCP). An HCP is a document that describes how an agency or landowner will manage their activities to reduce effects on vulnerable species. An HCP discusses the applicant's proposed activities and describes the steps that will be taken to avoid, minimize, or mitigate the take of species that are covered by the plan.

State Statutes

The state analogue of NEPA is the California Environmental Quality Act (CEQA). CEQA goes beyond NEPA in that it requires the project or plan proponent to select for implementation the least environmentally impacting alternative considered. When the least impacting alternative would still cause significant adverse environmental impacts, a statement of overriding considerations must be prepared.

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

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

The California Endangered Species Act (CESA) ([Fish & Game Code §§ 2050, et seq.](#)) generally parallels the main provisions of the Federal Endangered Species Act and is administered by the California Department of Fish and Game. Coho salmon in the Van Duzen River Basin are listed as endangered under CESA.

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

Assessment Strategy and General Methods

The NCWAP developed a Methods Manual (Bleier et al. 2003) that identified a general approach to conducting a watershed assessment, described or referenced methods for collecting and developing new watershed data, and provided a preliminary explanation of analytical methods for integrating interdisciplinary data to assess watershed conditions.

This chapter provides brief descriptions of data collection and analysis methods used. The reader is referred to the Methods Manual for more detail on methods, data used in the assessment, and assessments of the data.

Watershed Assessment Approach in the Van Duzen River Basin

The steps in large-scale assessment include:

- Conduct scoping and outreach workshops. One public meeting was held to identify issues and promote cooperation;
- Determine logical assessment scales. The Van Duzen Basin assessment delineated the basin into four subbasins (Yager, Lower, Middle, and Upper) for assessment and analyses purposes;
- Discover and organize existing data and information;
- Identify data gaps needed to develop the assessment;
- Collect field data. Stream survey data collection occurred on over 119 miles of stream for this assessment (in addition to previous spawning surveys on streams in the Lower, Middle, and Yager subbasins). Additional data were provided by private and agency cooperators;
- Conduct limiting factors analysis (LFA). The

Ecological Management Decision Support system (EMDS) was used to evaluate factors at the tributary scale. These factors were rated to be either beneficial or restrictive to the well being of fisheries;

- Conduct refugia rating analysis. Watershed, stream, habitat, and fishery information were combined and evaluated in terms of value to salmon and steelhead;
- Develop conclusions and recommendations;
- Facilitate monitoring of conditions.

CWPAP Products and Utility

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

Assessment products include:

- A basin level Report that includes:
 - A collection of the Van Duzen Basin's historical information;
 - A description of historic and current hydrology, geology, land use, and water quality, salmonid distribution, and instream habitat conditions;
 - An evaluation of watershed processes and conditions affecting salmonid habitat;
 - A list of issues developed by landowners, agency staff, and the public;
 - An analysis of the suitability of stream reaches and the watershed for salmonid production and refugia areas;
 - Tributary and watershed recommendations for management, refugia protection, and restoration activities to address limiting factors and improve conditions for salmonid health and productivity;
 - Monitoring recommendations to improve the adaptive management efforts;
- Ecological Management Decision Support system (EMDS) models to help analyze instream conditions;

- Databases of information used and collected;
- A data catalog and bibliography;
- Web based access to the Program’s products:
<http://www.coastalwatersheds.ca.gov/>,
<http://www.calfish.org>, <http://bios.dfg.ca.gov>,
<http://www.dfg.ca.gov/biogeodata/gis/imaps.asp>

Assessment Report Conventions

CalWater 2.2.1 Planning Watersheds and CWPAP Subbasins

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

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

The assessment team subdivided the Lower Eel Basin into four subbasins for assessment and analyses purposes (Figure 2). These are the Estuary, Salt River, Middle, and Upper subbasins. In general, these subbasins have distinguishing attributes common to the CalWater 2.2.1 Planning Watersheds (PWs) contained within them.

Variation among subbasins is a product of natural and human disturbances. Characteristics that can distinguish subbasins within larger basins include differences in elevation, geology, soil types, aspect, climate, vegetation, fauna, human population, land use and other social-economic considerations. Demarcation in this logical manner provides a uniform methodology for conducting large scale assessment. It provides a framework for the reporting

of specific findings as well as assisting in developing recommendations for watershed improvement activities that are generally applicable across the relatively homogeneous subbasin area.

Hydrologic Hierarchy

Watershed terminology often becomes confusing when discussing different scales of watersheds involved in planning and assessment activities. The conventions used in the Van Duzen River Basin assessment follow guidelines established by the Pacific Rivers Council. The descending order of scale is from basin level (e.g., Van Duzen River Basin)–subbasin level (e.g., Lower Subbasin)–watershed level (e.g., Grizzly Creek) (Figure).

The subbasin is the assessment and planning scale used in this report as a summary framework; subbasin findings and recommendations are based upon the more specific watershed and sub-watershed level findings. Therefore, there are usually exceptions at the finer scales to subbasin findings and recommendations. Thus, findings and recommendations at the subbasin level are somewhat more generalized than at the watershed and sub-watershed scales. In like manner, subbasin findings and recommendations are somewhat more specific than the even more generalized, broader scale basin level findings and recommendations that are based upon a group of subbasins.

Terminology

The term watershed is used in both the generic sense, as to describe watershed conditions at any scale and as a particular term to describe the watershed scale introduced above, which contains, and is made up from multiple, smaller sub-watersheds. The watershed scale is often approximately 20–40 square miles in area; its sub-watersheds can be much smaller in area, but for our purposes contain at least one perennial, un-branched stream. Please be aware of this multiple usage of the term watershed, and consider the context of the term’s usage to reduce confusion.

Another important watershed term is “river mile,” indicated as RM. RM is used to assign a specific, measured distance upstream from the mouth of a river or stream to a point or feature on the stream. In this report, RM is used to locate points along the Van Duzen River and/or its tributaries (e.g. Dinsmore Bridge is at RM 45).

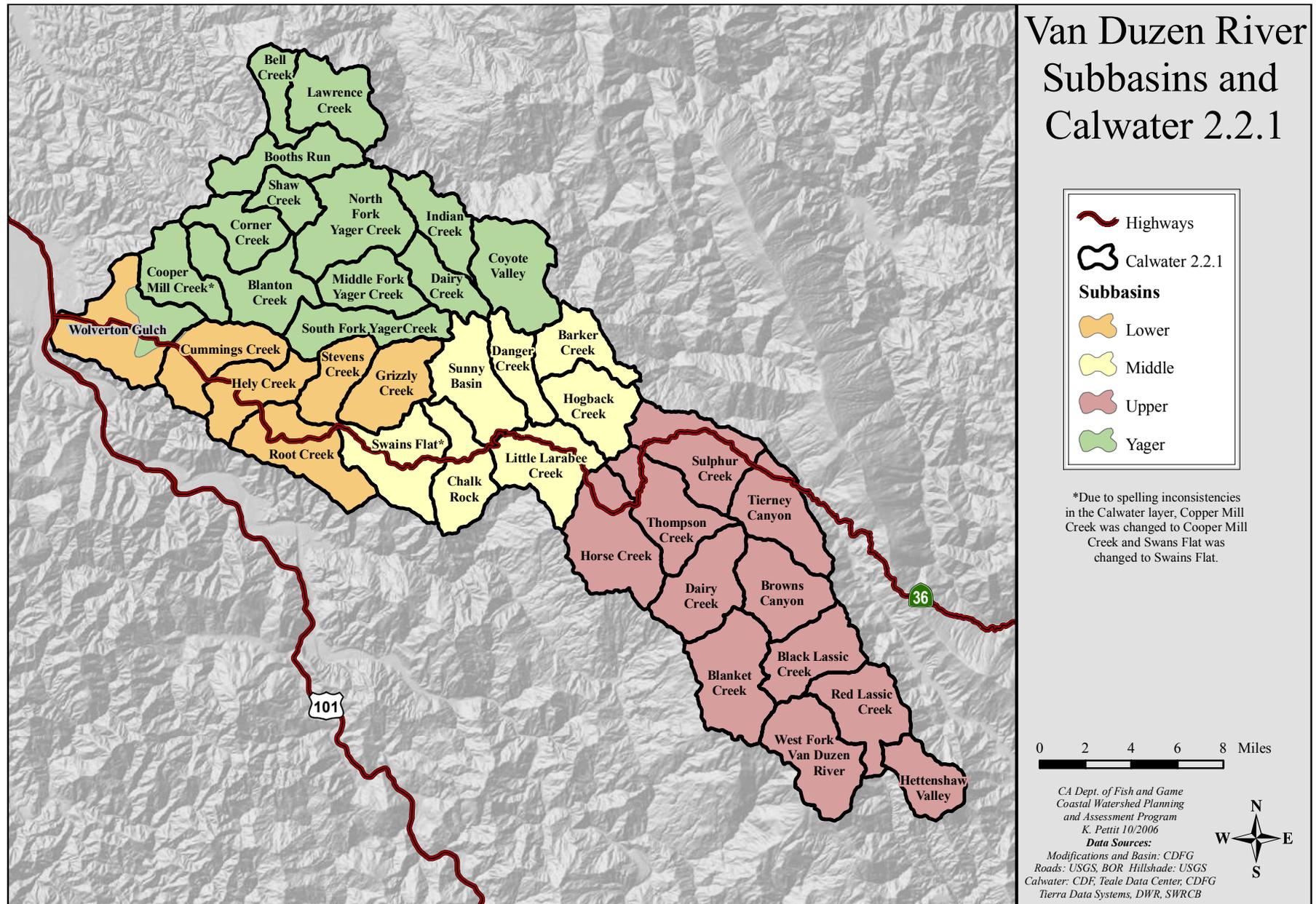
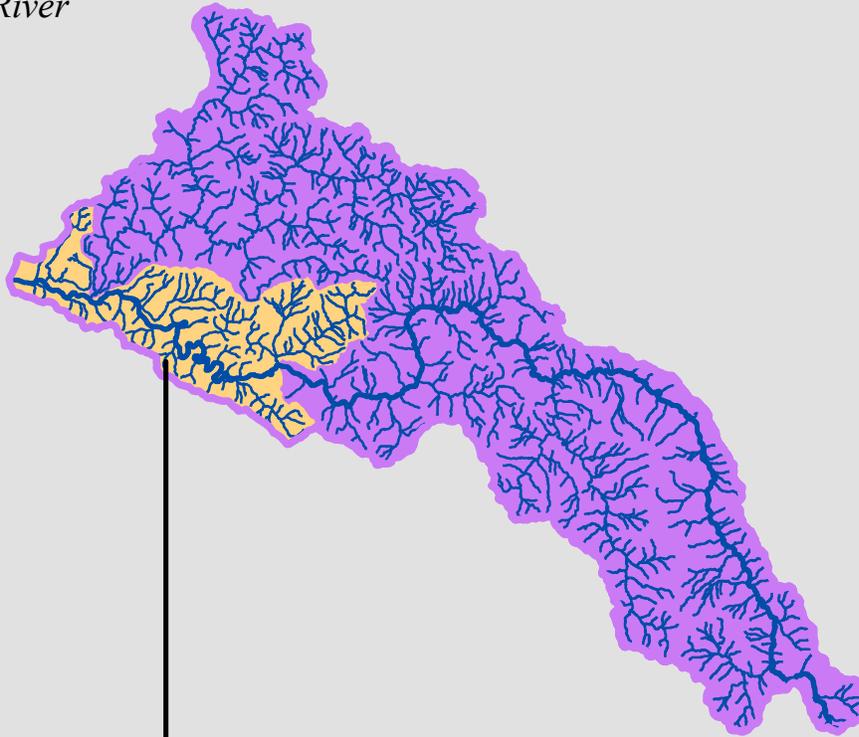


Figure 2. Van Duzen River Basin subbasins and CalWater 2.2.1 planning watersheds.

Hierarchy of Watersheds

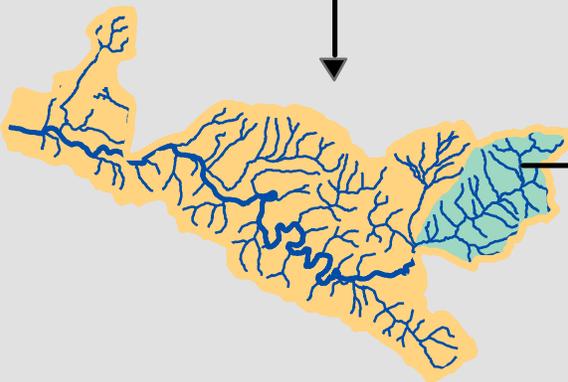
Basin

Van Duzen River Basin



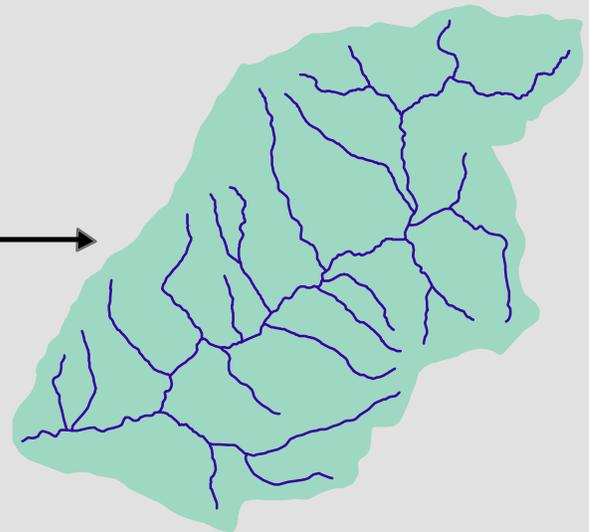
Subbasin

Lower Subbasin



Watershed

Grizzly Creek



CA Dept. of Fish and Game, Coastal Watershed Planning and Assessment Program, K. Pettit 7/2006, Data Sources: CDFG, CDF

Figure 3. Hydrography hierarchy.

Electronic Data Conventions

The program collected or created hundreds of data records for synthesis and analysis purposes and most of these data were either created in a spatial context or converted to a spatial format. Effective use of these data between the four remaining partner departments required establishing standards for data format, storage, management, and dissemination. Early in the assessment process, we held a series of meetings designed to gain consensus on a common format for the often widely disparate data systems within each department. Our objective was to establish standards which could be used easily by each department, that were most useful and powerful for selected analysis, and would be most compatible with standards used by potential private and public sector stakeholders.

As a result, we agreed that spatial data used in the program and base information disseminated to the public through the program would be in the following format (see the data catalog at the end of this report for a complete description of data sources and scale):

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

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

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

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

The metadata available for each spatial data set contain a complete description of how data were collected and attributed for use in the program. Spatial data sets that formed the foundation of most analysis included the 1:24,000 hydrography and the 10-meter scale Digital Elevation Models (DEM). Hydrography data were created by manually digitizing

from a series of 1:24,000 DRG then attributing with direction, routing, and distance information using a dynamic segmentation process (for more information, please see <http://downloads2.esri.com/support/whitepapers/ao/ArcGIS8.1.pdf>)

The resulting routed hydrography allowed for precise alignment and display of stream habitat data and other information along the stream network. The DEM was created by USGS from base contour data for the entire study region.

Source spatial data were often clipped to watershed, planning watershed, and subbasin units prior to use in analysis. Analysis often included creation of summary tables, tabulating areas, intersecting data based on selected attributes, or creation of derivative data based on analytical criteria.

Assessment Methods

Hydrology

In order to help evaluate and categorize streams and rivers, streams are assigned a stream order classification based on the branching pattern of river systems (Strahler 1957). A first order stream is defined as the smallest un-branched tributary to appear on a 7.5-minute USGS quadrangle (1:24,000 scale) (Leopold et al. 1964). This system includes only perennial streams (i.e. those with sufficient flow to develop biota). When two first order streams join, they form a second order stream. When two second order streams join, they result in a third order stream; and as streams of equal order meet they result in a stream of the next higher order (Flosi et al. 1998). Accordingly, the Van Duzer River is classified as a fifth orders stream. Most tributaries in this basin are intermittent or first or second order.

Within the basin there is currently one operating United States Geological Survey (USGS) river gage (USGS ID 11478500). Located near Bridgeville at RM 24, this gage has measured gage height and discharge since 1940. Data recorded from this gage is utilized in this assessment to access seasonal runoff patterns and evaluate linkages between historical flooding and ongoing climatic conditions.

Geology and Fluvial Geomorphology

A general geologic map was compiled for use in this report using published USGS maps and limited, geologic reconnaissance mapping. This map was then simplified combining rock types of similar age,

composition, and geologic history (i.e. the Rohnerville and Hookton formations were combined and generalized to “Quaternary river terraces”). Landslides depicted on the map are derived from McLaughlin et al (2000) and represent only large landslide features as of 2000. Calculations of area occupied by each rock type were based on GIS interpretation.

A limited field reconnaissance as well as a review of aerial photos from years 1948, 1988, and 1996 was conducted to gather specific geologic information relevant to the report.

A review of the available literature, published and non-published, pertinent to the geology of the local area was used to gather information presented in this report.

Vegetation and Land Use

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

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

Year 2000 census data were analyzed to provide population estimates for each Van Duzen subbasin. The 2000 data were available from the CDF’s Fire and Resource Assessment Program (FRAP). The Census Bureau statistics are organized at several levels including: State, County, Census County Division (CCD), Census Tract, Block Group, and Block. The Van Duzen Basin contains sections of census tracts. Census Tracts are made up of blocks. Block

population totals were compiled to determine the estimated population of each Van Duzen subbasin. Blocks that crossed the basin boundary or subbasin boundaries were examined more closely and population values were allocated by estimated fraction of area.

Fish Habitat and Populations

Data Compilation and Collection

CDFG compiled existing available data and gathered anecdotal information pertaining to salmonids and the instream habitat on the Van Duzen River and its tributaries. Anecdotal and historic information was cross-referenced with other existing data whenever possible. Where data gaps were identified, access was sought from landowners to conduct habitat inventory and fisheries surveys. Habitat inventories and biological data were collected following the protocol presented in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). Twenty-one tributaries were surveyed between the years of 1991 and 2004.

Fish Passage Barriers

During their freshwater life phases, salmonids need free access to a variety of stream habitats from the headwaters to the mouth, as both migratory corridors and habitat for rearing and spawning. Barriers lead directly to the fragmentation of salmonid habitat and may completely eliminate anadromous salmonids from accessing a stream to spawn. Barriers may include dams, culverts, diversions, flood control channels, flow dynamics, water quality, and natural features such as waterfalls and bedrock chutes. The assessment utilized the CalFish Passage Assessment Database (PAD) to discuss known barrier locations, and field crews identified and evaluated any additional potential fish passage barriers during stream habitat inventory surveys. Barrier types are categorized as temporary, partial, and total and have varying potential to impact fish passage (Table 1).

Table 1. Definitions of barrier types and their potential impacts to salmonids.

Barrier Category	Definition	Potential Impact
Temporary	Impassable to all fish some of the time.	Delay in movement beyond the barrier for some period of time.
Partial	Impassable to some fish at all times.	Exclusion of certain species and life stages from portions of a watershed.
Total	Impassable to all fish at all times.	Exclusion of all species from portions of a watershed.
Unknown	Fish passage status is unclear	Due to landowner access issues or inadequate funding for sufficient staffing some potential barriers were not examined.

Amended from Taylor 2000

Target Values from Habitat Inventory Surveys

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. In the *California Salmonid Stream Habitat Restoration*

Manual (Flosi et al. 1998) target values were given for each of the individual habitat elements measured (Table 2). When habitat conditions fall below the target values, restoration projects may be proposed in an attempt to meet critical habitat needs for salmonids.

Table 2. Habitat inventory target values.

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

*Primary pools are pools >2 feet deep in 1st and 2nd order streams, >3 feet deep in 3rd order streams, or >4 feet deep in 4th order streams. From the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al 1998).

Canopy Density—Eighty Percent or Greater of the Stream is Covered by Canopy

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

Good Spawning Substrate- Fifty Percent or Greater of the Pool Tails Sampled are Fifty Percent or Less Embedded

Cobble embeddedness is the percentage of an average sized cobble piece, embedded in fine substrate at the pool tail. The best coho salmon and steelhead trout spawning substrate is classified as Category 1 cobble embeddedness or 0-25% embedded. Category 2 is defined by the substrate being 26-50% embedded. Cobble embedded deeper than 51% is not within the range for successful spawning. The target value is for 50% or greater of the pool tails sampled to be 50% or less embedded. Streams with less than 50% of their length greater than 51% embedded do not meet the target value. They do not provide adequate spawning substrate conditions.

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

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

Shelter/Cover- Scores of One Hundred or Better Means that the Stream Provides Sufficient Shelter/Cover

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

Water Temperatures

The maximum weekly average temperature (MWAT) is the maximum value of the seven day moving average temperatures. The MWAT range for “fully suitable conditions” of 50-60°F was developed as an average of the needs of several cold water fish species, including coho salmon and steelhead trout

Table 3). As such, it may not represent fully suitable conditions for the most sensitive cold water species (usually considered to be coho). Temperatures between 61-62°F are considered “moderately suitable,” while a temperature of 63°F is considered “somewhat suitable.” The suitability of a 64°F temperature is considered “undetermined.” Temperatures of 65°F and above are within the ranges considered “unsuitable” for salmonids.

Ecological Management Decision Support System

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

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

Development of the North Coast California EMDS Model.

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

Table 3. Water temperature criteria.

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

The Knowledge Base Network

For California’s north coast watersheds, the assessment team constructed a knowledge base network, the Stream Reach Condition Model. The model was reviewed in April 2002 by an independent nine-member science panel, which provided a number of suggestions for model improvements. According to their suggestions, the team revised the original model.

The Stream Reach Condition model addresses conditions for salmonids on individual stream reaches and is largely based on data collected using CDFG stream survey protocols found in the *California Salmonid Stream Habitat Restoration Manual*, (Flosi et al. 1998).

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

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

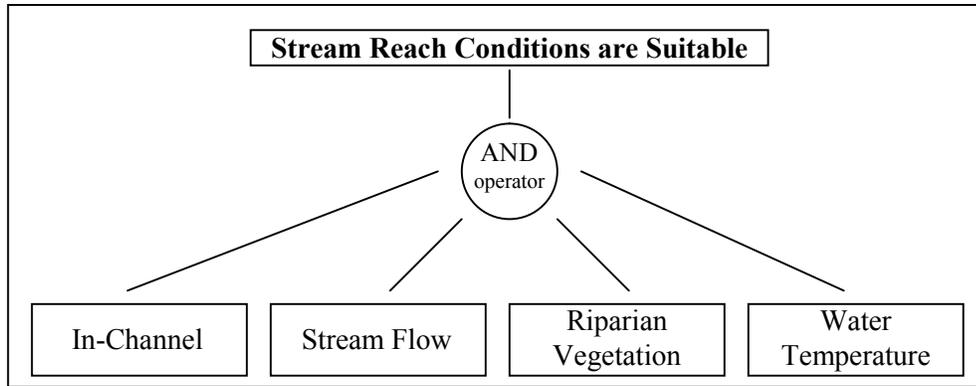


Figure 4: Tier one of the EMDS stream reach knowledge base network.

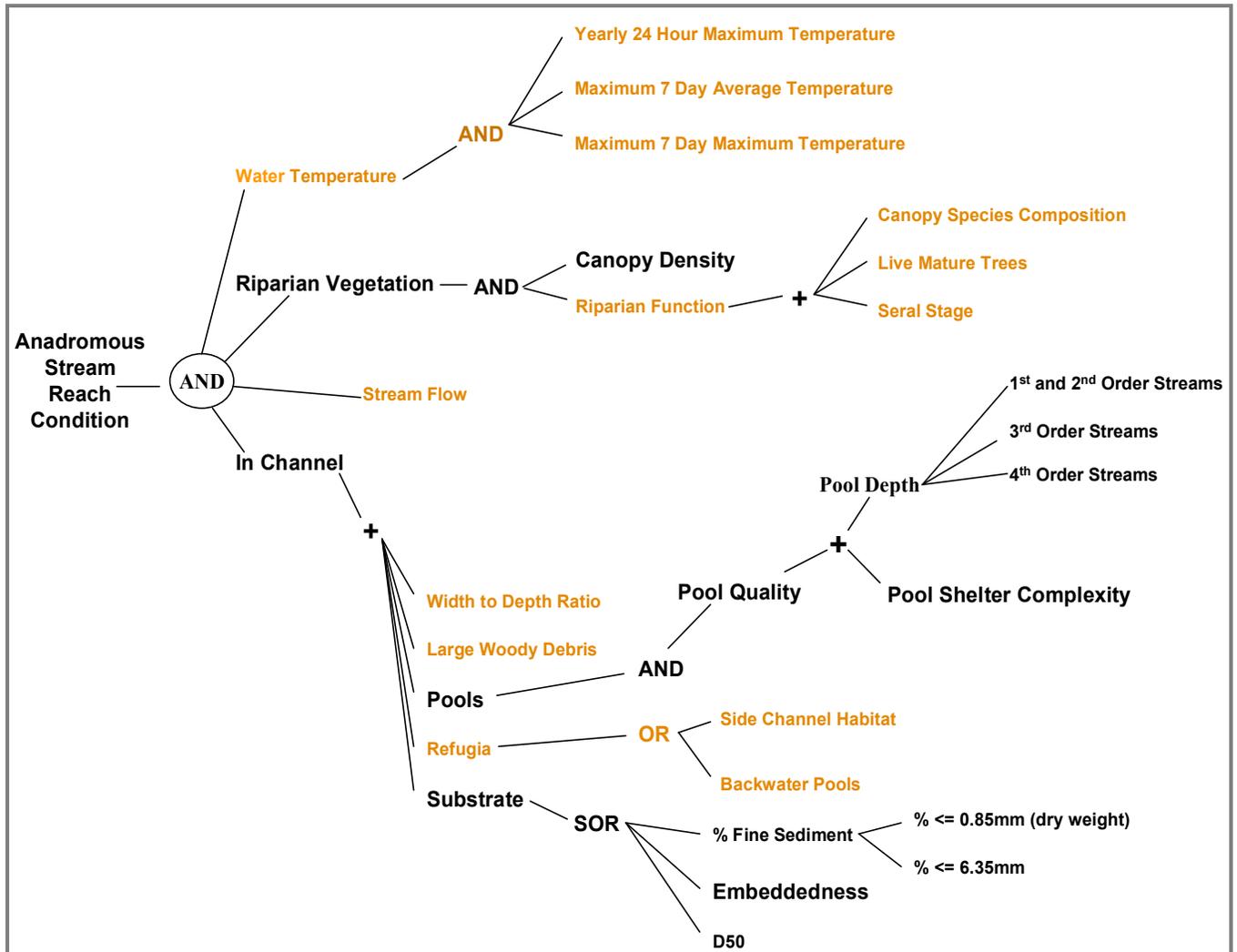


Figure 5. Graphic representation of the Stream Reach Condition model.

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

In Figure 3, the *AND operator* indicates a decision node that means that the lowest, most limiting value of the four general factors determined by the model will be passed on to indicate the potential of the stream reach to sustain salmonid populations. In that

sense, the model mimics nature. For example, if summertime low flow is reduced to a level deleterious to fish survival or well being, regardless of a favorable temperature regime, instream habitat, and/or riparian conditions, the overall stream condition is not suitable to support salmonids.

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

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

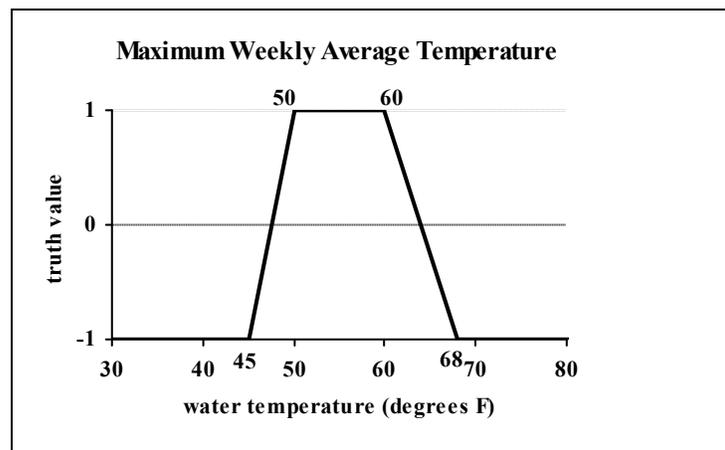


Figure 6. EMDS reference curve for stream temperature.

EMDS uses this type of reference curve in conjunction with data specific to a stream reach. This example reference curve evaluates the proposition that the stream's water temperature is suitable for salmonids. Break points on the curve can be set for specific species, life stage, or season of the year. Curves are dependent on the availability of data to be included in an analysis.

For each evaluated proposition in the EMDS model network, the result is a number between -1 and +1. The number relates to the degree to which the data support or refute the proposition. In all cases a value of +1 means that the proposition is completely true, and -1 implies that it is completely false, while in-between values indicate degrees of truth (i.e. values approaching +1 being closer to true and those approaching -1 converging on completely untrue). A zero value means that the proposition cannot be evaluated based upon the data available. Breakpoints

occur where the slope of the reference curve changes. For example, in Figure breakpoints occur at 45, 50, 60, and 68°F.

EMDS map legends use a seven-class system for depicting the truth-values. Values of +1 are classed as the highest suitability; values of -1 are classed as the lowest suitability; and values of 0 are undetermined. Between 0 and 1 are two classes which, although unlabeled in the legend, indicate intermediate values of better suitability (0 to 0.5, and 0.5 to 1). Symmetrically, between 0 and -1 are two similar classes which are intermediate values of worse suitability (0 to -0.5, and -0.5 to -1). These ranking values are assigned based upon condition findings in relationship to the criteria in the reference curves. The following table summarizes important EMDS Stream Reach Condition model information (Table 4).

Table 4. Reference curve metrics for EMDS stream reach condition model.

Stream Reach Condition Factor	Definition and Reference Curve Metrics
Aquatic / Riparian Conditions	
Summer MWAT	Maximum 7-day average summer water temperature < 45°F fully unsuitable, 50-60°F fully suitable, > 68°F fully unsuitable. Water temperature was not included in current EMDS evaluation.
Riparian Function	Under development.
Canopy Density	Average percent of the thalweg within a stream reach influenced by tree canopy. < 50% fully unsuitable, ≥ 85% fully suitable.
Seral Stage	Seral stage composition of near stream forest. Under development.
Vegetation Type	Forest composition Under development.
Stream Flow	Under development.
In-Channel Conditions	
Pool Depth	Percent of stream reach with pools of a maximum depth of 2.5, 3, and 4 feet deep for first and second, third, and fourth order streams respectively. ≤ 20% fully unsuitable, 30 – 55% fully suitable, ≥ 90% fully unsuitable.
Pool Shelter Complexity	Relative measure of quantity and composition of large woody debris, root wads, boulders, undercut banks, bubble curtain, overhanging and instream vegetation. ≤ 30 fully unsuitable, ≥ 100 - 300 fully suitable.
Pool Frequency	Percent of pools by length in a stream reach. Under development.
Substrate Embeddedness	Pool tail embeddedness is a measure of the percent of small cobbles (2.5" to 5" in diameter) buried in fine sediments. EMDS calculates categorical embeddedness data to produce evaluation scores between -1 and +1. The proposition is fully true if evaluation scores are 0.8 or greater and -0.8 evaluate to fully false.
Percent Fines in Substrate <0.85mm (dry weight)	Percent of fine sized particles <0.85 mm collected from McNeil type samples. < 10% fully suitable, > 15% fully unsuitable. There was not enough of percent fines data to use percent fines in EMDS evaluations
Percent Fines in Substrate <6.4 mm	Percent of fine sized particles < 6.4 mm collected from McNeil type samples. <15% fully suitable, >30% fully unsuitable. There was not enough of percent fines data to use percent fines in EMDS evaluations.
Large Woody Debris (LWD)	The reference values for frequency and volume are derived from Bilby and Ward (1989) and are dependent on channel size. See EMDS Appendix for details. Most watersheds do not have sufficient LWD survey data for use in EMDS.
Winter Refugia Habitat	Winter refugia is composed of backwater pools and side channel habitats and deep pools (> 4 feet deep). Under development.
Pool to Riffle Ratio	Ratio of pools to riffle habitat units. Under development.
Width to Depth Ratio	Ratio of bankfull width to maximum depth at velocity crossovers. Under development.

Advantages Offered by EMDS

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

Using Geographic Information System (GIS) software, EMDS maps the factors affecting fish habitat and shows how they vary across a basin. EMDS models also provide a consistent and repeatable approach to evaluating watershed conditions for fish. In addition, the maps from

supporting levels of the model show the specific factors that, taken together, determine overall watershed conditions. This latter feature can help to identify what is most limiting to salmonids, and thus assist to prioritize restoration projects or modify land use practices.

Limitations of the EMDS Model and Data Input

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

EMDS model using fish population data and other information should be done.

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

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

- Completion of quality control evaluation procedures;
- Adjust the model to better reflect differences between stream mainstems and tributaries, for example, the modification of canopy density standards for wide streams;
- Develop a suite of Stream Reach Model reference curves to better reflect the differences in expected conditions based upon various geographic watershed locations considering geology, vegetation, precipitation, and runoff patterns.

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

Adaptive Application for EMDS and CDFG Stream Habitat Evaluations

CDFG has developed habitat evaluation standards, or target values, to help assess the condition of anadromous salmonid habitat in California streams (Flosi et al. 1998). These standards are based upon

data analyses of over 1,500 tributary surveys, and considerable review of pertinent literature. The EMDS reference curves have similar standards. These have been adapted from CDFG, but following peer review and professional discussion, they have been modified slightly due to more detailed application in EMDS. As such, slight differences occur between values found in Flosi et al. (1998) and those used by EMDS. The reference curves developed for the EMDS are provided in the EMDS Appendix of this report.

Both habitat evaluation systems have similar but slightly different functions. Stream habitat standards developed by CDFG are used to identify habitat conditions and establish priorities among streams considered for improvement projects based upon standard CDFG tributary reports. The EMDS compares select components of the stream habitat survey data to reference curve values and expresses degrees of habitat suitability for fish on a sliding scale. In addition, the EMDS produces a combined estimate of overall stream condition by combining the results from several stream habitat components. In the fish habitat relationship section of this report, we utilize target values found in Flosi et al. (1998), field observations, and results from EMDS reference curve evaluations to help describe and evaluate stream habitat conditions.

Due to the wide range of geology, topography and diverse stream channel characteristics which occur within the North Coast region, there are streams that require more detailed interpretation and explanation of results than can be simply generated by EMDS suitability criteria or tributary survey target values.

For example, pools are an important habitat component and a useful stream attribute to measure. However, some small fish-bearing stream channels may not have the stream power to scour pools of the depth and frequency considered to be high value "primary" pools by CDFG target values, or to be fully suitable according to EMDS. Often, these shallow pool conditions are found in low gradient stream reaches in small watersheds that lack sufficient discharge to deeply scour the channel. They also can exist in moderate to steep gradient reaches with bedrock/boulder dominated substrate highly resistant to scour, which also can result in few deep pools.

Therefore, some streams may not have the inherent ability to attain conditions that meet the suitability

criteria or target values for pool depth. These scenarios result in pool habitat conditions that are not considered highly suitable by either assessment standard. However, these streams may still be very important because of other desirable features that support valuable fishery resources. As such, they receive additional evaluation with our refugia rating system and expert professional judgment. Field validation of any modeling system's results is a necessary component of watershed assessment and reporting.

Limiting Factors Analysis

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

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

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

The LFA assumes that poor habitat quality and reduced quantities of favorable habitat impairs fish

production. Limiting factors analysis is focused mainly on those physical habitat factors within freshwater and estuarine ecosystems that affect spawning and subsequent juvenile life history requirements during low flow seasons.

Two general categories of factors or mechanisms limit salmonid populations:

- Density independent and
- Density dependent mechanisms.

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

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

Restoration Needs/Tributary Recommendations Analysis

CDFG inventoried 36 tributaries and portions of the mainstem Van Duzen River using protocols in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998). The stream surveys were divided into stream reaches, defined as Rosgen (1994) channel types. The stream inventories are a combination of several stream reach surveys: habitat typing, channel typing, biological assessments, and in some reaches LWD and riparian zone recruitment assessments. An experienced Biologist and/or Habitat Specialist conducted quality assurance/quality control (QA/QC) on field crews and collected data, performed data analysis, and determined general areas of habitat deficiency based upon the analysis and synthesis of information.

CDFG biologists selected and ranked recommendations for each of the inventoried

streams, based upon the results of these standard CDFG habitat inventories, and updated the recommendations with the results of the stream reach condition EMDS and the refugia analysis (Table 5). It is important to understand that these selections are made from stream reach conditions that were observed at the times of the surveys and do not include upslope watershed observations other than those that could be made from the streambed. They reflect a single point in time and do not anticipate future conditions. However, these general recommendation categories have proven to be useful as the basis for specific project development, and provide focus for on-the-ground project design and implementation. Bear in mind that stream and watershed conditions change over

time and periodic survey updates and field verification are necessary if watershed improvement projects are being considered.

In general, the recommendations that involve erosion and sediment reduction by treating roads and failing stream banks, and riparian and near stream vegetation improvements precede the instream recommendations in reaches that demonstrate disturbance levels associated with watersheds in current stress. Instream improvement recommendations are usually a high priority in streams that reflect watersheds in recovery or good health. Various project treatment recommendations can be made concurrently if watershed and stream conditions warrant.

Table 5. List of tributary recommendations in stream tributary reports.

Recommendation	Explanation
Temp	Summer water temperatures were measured to be above optimum for salmon and steelhead
Pool	Pools are below CDFG target values in quantity and/or quality
Cover	Escape cover is below CDFG target values
Bank	Stream banks are failing and yielding fine sediment into the stream
Roads	Fine sediment is entering the stream from the road system
Canopy	Shade canopy is below CDFG target values
Spawning Gravel	Spawning gravel is deficient in quality and/or quantity
LDA	Large debris accumulations are retaining large amounts of gravel and could need modification
Livestock	There is evidence that stock is impacting the stream or riparian area and exclusion should be considered
Fish Passage	There are barriers to fish migration in the stream

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

Additional considerations must enter into the decision process before these general recommendations are further developed into improvement activities. In addition to watershed condition considerations as a context for these recommendations, there are certain logistic considerations that enter into a recommendation’s subsequent ranking for project development. These can include work party access limitations based upon lack of private party trespass permission and/or physically difficult or impossible locations of the candidate work sites. Biological

considerations are made based upon the propensity for benefit to multiple or single fishery stocks or species. Cost benefit and project feasibility are also factors in project selection for design and development.

Potential Salmonid Refugia

Establishment and maintenance of salmonid refugia areas containing high quality habitat and sustaining fish populations are activities vital to the conservation of our anadromous salmonid resources (Moyle and Yoshiyama 1992; Li et al. 1995; Reeves et al. 1995). Protecting these areas will prevent the loss of the remaining high quality salmon habitat and salmonid populations. Therefore, a refugia investigation project should focus on identifying areas found to have high salmonid productivity and diversity.

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

- Protection of refugia areas to avoid loss of the last best salmon habitat and populations. The focus should be on protection for areas with high productivity and diversity;

- Refugia area populations which may provide a source for re-colonization of salmonids in nearby watersheds that have experienced local extinctions, or are at risk of local extinction due to small populations;
- Refugia areas provide a hedge against the difficulty in restoring extensive, degraded habitat and recovering imperiled populations in a timely manner (Kaufmann et al. 1997).

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

Potential refugia may exist in areas where the surrounding landscape is marginally suitable for salmonid production or altered to a point that stocks have shown dramatic population declines in traditional salmonid streams. If altered streams or watersheds recover their historic natural productivity, through either restoration efforts or natural processes, the abundant source populations from nearby refugia can potentially re-colonize these areas or help sustain existing salmonid populations in marginal habitat. Protection of refugia areas is noted as an essential component of conservation efforts to ensure long-term survival of viable stocks, and a critical element towards recovery of depressed populations (Sedell 1990; Moyle and Yoshiyama 1992; Frissell 1993, 2000).

Refugia habitat elements include the following:

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

Spatial and Temporal Scales of Refugia

These refugia concepts become more complex in the context of the wide range of spatial and temporal habitat required for viable salmonid populations. Habitat can provide refuge at many scales from a single fish to groups of them, and finally to breeding populations. For example, refugia habitat may range from a piece of wood that provides instream shelter for a single fish, or individual pools that provide cool water for several rearing juveniles during hot summer months, to watersheds where conditions support sustaining populations of salmonid species. Refugia also include areas where critical life stage functions such as migrations and spawning occur. Although fragmented areas of suitable habitat are important, their connectivity is necessary to sustain the fisheries. Today, watershed scale refugia are needed to recover and sustain aquatic species (Moyle and Sato 1991). For the purpose of this discussion, refugia are considered at the fish bearing tributary and subbasin scales. These scales of refugia are generally more resilient to the deleterious effects of landscape and riverine disturbances such as large floods, persistent droughts, and human activities than the smaller, habitat unit level scale (Sedell et al. 1990).

Standards for refugia conditions are based on reference curves from the literature and CDFG data collection at the regional scale. The program uses these values in its EMDS models and stream inventory, improvement recommendation process.

Li et al. (1995) suggested three prioritized steps to use the refugia concept to conserve salmonid resources:

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

Refugia and Meta-population Concept

The concept of anadromous salmonid meta-populations is important when discussing refugia. The classic metapopulation model proposed by Levins (1969) assumes the environment is divided into discrete patches of suitable habitat. These patches include streams or stream reaches that are inhabited by different breeding populations or sub-populations (Barnhart 1994; McElhany et al. 2000). A metapopulation consists of a group of sub-populations

which are geographically located such that over time, there is likely genetic exchange between the sub-populations (Barnhart 1994). Metapopulations are characterized by 1) relatively isolated, segregated breeding populations in a patchy environment that are connected to some degree by migration between them, and 2) a dynamic relationship between extinction and re-colonization of habitat patches.

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

Habitat patches differ in suitability and population strength. In addition to the classic metapopulation model, other theoretical types of spatially structured populations have been proposed (Li et al. 1995; McElhany et al. 2000). For example, the core and satellite (Li et al. 1995) or island-mainland population (McElhany et al. 2000) model depicts a core or mainland population from which dispersal to satellites or islands results in smaller surrounding populations. Most straying occurs from the core or mainland to the satellites or islands. Satellite or island populations are more prone to extinction than the core or mainland populations (Li et al. 1995; McElhany et al. 2000). Another model termed source-sink populations is similar to the core-satellite or mainland-island models, but straying is one way, only from the highly productive source towards the sink subpopulations. Sink populations are not self-sustaining and are highly dependent on migrants from the source population to survive (McElhany et al. 2000). Sink populations may inhabit typically marginal or unsuitable habitat, but when environmental conditions strongly favor salmonid production, sink population areas may serve as important sites to buffer populations from disturbance events (Li et al. 1995) and increase basin population strength. In addition to testing new areas for potential suitable habitat, the source-sink strategy adds to the diversity of behavior patterns salmonids have adapted to maintain or expand into a dynamic aquatic environment.

The metapopulation and other spatially structured population models are important to consider when identifying refugia because in dynamic habitats, the

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

Methods to Identify Refugia

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

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

A second common theme is that over time within the landscape mosaic of habitat patches, good habitat areas will suffer impacts and become less productive, and wink out and other areas will recover and wink in. These processes can occur through either human caused or natural disturbances or succession to new ecological states. Regardless, it is important that a balance be maintained in this alternating, patchwork dynamic to ensure that adequate good quality habitat is available for viable anadromous salmonid

populations (Reeves et al. 1995).

Approach to Identifying Refugia

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

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

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

When identifying anadromous salmonid refugia, the program team took into account that anadromous salmon have several non-substitutable habitat needs for their life cycle.

A minimal list (NMFS 2001) includes:

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

The best refugia areas are large, meet all of these life history needs, and therefore provide complete functionality to salmonid populations. These large, intact systems are scarce today and smaller refugia areas that provide for only some of the requirements have become very important areas, but cannot sustain large numbers of fish. These must operate in concert with other fragmented habitat areas for life history support and refugia connectivity becomes very important for success. Therefore, the refugia team considered relatively small, tributary areas in terms of their ability to provide at least partial refuge values, yet contribute to the aggregated refugia of larger scale areas. Therefore, the team's analyses used the tributary scale as the fundamental refugia unit.

CDFG created a tributary scale refugia-rating worksheet. The worksheet has 21 condition factors that were rated on a sliding scale from high quality to low quality.

Twenty-one factors were grouped into five categories:

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

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

Thirteen factors were grouped into three categories:

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

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

These were identified for further investigation and inclusion in future analysis.

The program has created a hierarchy of refugia categories that contain several general habitat conditions. This descriptive system is used to rank areas by applying results of the analyses of stream and

watershed conditions described above and are used to determine the ecological integrity of the study area. A basic definition of biotic integrity is "the ability [of an ecosystem] to support and maintain a balanced, integrated, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley 1981).

The Report of the Panel on the Ecological Integrity of Canada's National Parks (2000) submitted this definition:

A Definition of Ecological Integrity

The Panel proposes the following definition of ecological integrity: "An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes. In plain language, ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact."

Salmonid Refugia Categories and Criteria:

High Quality Habitat, High Quality Refugia:

- Maintains a high level of watershed ecological integrity (Frissell 2000);
- Contains the range and variability of environmental conditions necessary to maintain community and species diversity and supports natural salmonid production (Moyle and Yoshiyama 1992; Frissell 2000);
- Contains relatively undisturbed and intact riparian corridor;
- All age classes of historically native salmonids present in good numbers, and a viable population of an ESA listed salmonid species is supported (Li et al. 1995);
- Provides population seed sources for dispersion, gene flow and re-colonization of nearby habitats from straying local salmonids;
- Contains a high degree of protection from degradation of its native components.

High Potential Refugia

- Watershed ecological integrity is diminished but remains good (Frissell 2000);
- Instream habitat quality remains suitable for salmonid production and is in the early stages of recovery from past disturbance;
- Riparian corridor is disturbed, but remains in fair to good condition;
- All age classes of historically native salmonids are present including ESA listed species, although in diminished numbers;
- Salmonid populations are reduced from historic levels, but still are likely to provide straying individuals to neighboring streams;
- Currently is managed to protect natural resources and has resilience to degradation, which demonstrates a strong potential to become high quality refugia (Moyle and Yoshiyama 1992; Frissell 2000).

Medium Potential Refugia

- Watershed ecological integrity is degraded or fragmented (Frissell 2000);

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

Low Quality Habitat, Low Potential Refugia

- Watershed ecological integrity is impaired (Frissell 2000);
- Most components of instream habitat are highly impaired;
- Riparian corridor components are degraded;
- Salmonids are poorly represented at all life stages and year classes, but especially in older year classes;
- Low numbers of salmonids make significant straying very unlikely;
- Current management and/or natural events have significantly altered the naturally functioning ecosystem and major changes in either of both are needed to improve conditions.

Other Related Refugia Component Categories:

- Potential Future Refugia (Non-Anadromous);
- Areas where habitat quality remains high but does not currently support anadromous salmonid populations;
- An area of high habitat quality, but anadromous fish passage is blocked by man-made obstructions such as dams or poorly designed culverts at stream crossings etc.

Critical Contributing Areas

- Area contributes a critical ecological function needed by salmonids such as providing a migration corridor, conveying spawning gravels, or supplying high quality water (Li et al. 1995);
- Riparian areas, floodplains, and wetlands that are directly linked to streams (Huntington and Frissell 1997).

Data Limited

- Areas with insufficient data describing fish populations, habitat conditions, watershed conditions, or management practices.