11 Executive Summary: Part II

Considerable effort is currently being devoted to the conservation and restoration of salmonids in the Pacific Northwest. Aquatic conservation strategies have been developed for all Federal lands in the region; however, no comparable strategies exist for protecting and restoring salmonid habitats on private lands. Nonfederal lands constitutes more than 50% of the total land area in the region, and many of the most historically productive streams and rivers flow through private lands; thus, these lands have a critical role to play in the recovery of salmonids.

Part II of this document presents an ecosystem-oriented approach to the planning and monitoring of salmonid habitat conservation efforts on nonfederal lands in the Pacific Northwest. We focus on the effects of land- and water-use practices on salmonids and their habitats and on how these impacts can be minimized through improved planning and management, but we recognize that other human activities significantly influence salmonid populations and must be addressed if salmonids are to persist over the long term. Thus, the recommendations contained herein should be considered as one part of a larger, comprehensive strategy to restore salmonids.

This document provides a conceptual framework for organizing a regional conservation strategy, guidelines for monitoring habitat conservation plans (HCPs) and other conservation efforts, and criteria by which the Agencies can evaluate habitat conservation activities. Recommendations made in this document are intended as guidelines for conservation planning, not formal requirements. Each planning situation is likely to be unique, and not all planning elements may be warranted in each case.

We propose a hierarchical approach to the development and evaluation of HCPs and other conservation efforts, stressing the need for site- or watershed-level conservation efforts to be developed and evaluated within the larger context of basin and regional conservation goals. We outline critical issues that should be addressed during HCP planning at the scales of region and basin, watersheds, and individual sites as well as specific elements that should be contained in HCPs and criteria for evaluating the potential effectiveness of HCP provisions where such criteria are supported by current scientific information. Strategies are proposed for monitoring the compliance and the effectiveness of conservation plans at levels ranging from specific sites to regions. Finally, issues related to the implementation of this conservation strategy are discussed.

11.1 Ecological Goals of Salmonid Conservation

A restoration strategy to ensure the long-term persistence of salmonids will be most effective if it is grounded in principles of watershed dynamics, ecosystem function, and conservation biology (reviewed in Part I). We believe that five fundamental ecological goals should underlie salmonid conservation activities at all levels, from site-specific management prescriptions to watershed plans to regional recovery efforts. These goals include

- Maintain and restore natural watershed processes that create habitat characteristics favorable to salmonids.

- Maintain habitats required by salmonids during all life stages—from embryos and alevins through adults—and maintain functional corridors linking these habitats.

- Maintain a well-dispersed network of high-quality refugia to serve as centers of population expansion.

- Maintain connectivity between high-quality habitats to allow for reinvasion and population expansion as degraded systems recover.

- Maintain genetic diversity and integrity within and among salmonid stocks and species.

Activities that maintain and restore natural watershed and ecological processes, facilitate the expansion of refugia, enhance connectivity between refugia or from headwaters to the ocean, and allow full expression of the genetic potential of the species should be encouraged; those activities that do otherwise should be discouraged.

11.2 Planning Elements

Ecosystem-oriented approaches to land and resource management are being recommended by scientists and the management agencies that oversee activities on public and private lands. Although the term "ecosystem management" has been defined a number of different ways in the literature, the goal of preserving ecosystem integrity while deriving sustained benefits for human populations is common to most definitions. For Habitat Conservation Plans or other conservation agreements to succeed, it is important that they be developed and evaluated within the context of larger ecosystem restoration strategies. In this regard, a broad spectrum of issues should be addressed: site-specific impacts: cumulative effects of multiple activities (in space and time) throughout a watershed; the distribution and status of salmonid species or population segments at region, basin, watershed, and site levels; and the status of other biota and resource values.

Implementation of ecosysteni-oriented approaches to land management requires a hierarchy of planning scales, including regions, basins or provinces, watersheds, and individual sites. Watershed analyses and site prescriptions that are the most likely components of conservation plans should be imbedded within analyses at larger spatial scales. This is critical for salmonid conservation efforts because 1) the distribution and environmental requirements of salmonids typically extend beyond watershed boundaries and 2) the spatial context within which a particular watershed lies is an important factor for evaluating the potential ecological effects of land management activities. In the remainder of this section, we identify what we believe to be key planning elements at various levels in the planning hierarchy that should be involved in the preparation and evaluation of HCPs or other conservation efforts.

11.2.1 Region and Basin (or Province) Levels

A number of important issues and goals transcend watershed boundaries and thus cannot be satisfactorily addressed without basin-level and regional assessments. These include protecting aquatic biodiversity or ecosystems with unique physical or biological attributes; identifying and protecting threatened, endangered, or other at-risk species or stocks that may be adversely affected by the proposed activities; determining the role of the affected stream or watershed in fostering connectivity between existing refugia (e.g., Federal key watersheds, salmon core or source areas, aquatic diversity areas); maintaining proper function of migration corridors used by anadromous salmonids and enabling dispersion of resident species; assessing the current and historic potential of the affected area to produce salmonids and the potential for restoration if degraded; identifying the primary natural and anthropogenic stressors presently occurring and projected to occur within the basin and determining if these will be exacerbated by the proposed activities: and assessing the potential for the proposed activities to affect estuarine environments into which anadromous salmonids enter.

Three initial steps by the managing Agencies would facilitate attainment of these broader goals: 1) establishing a network of key watersheds on private lands to complement Federal key watersheds; 2) adopting riparian protection standards for all riparian areas across the four-State area: and **3)** delineating evolutionarily significant units (ESUs) for all species of anadromous and resident salmonids. The establishment of key watersheds is needed to ensure that regional conservation goals are not adversely affected by site- and watershed-level decisions on nonfederal lands. Protection of the riparian zone is essential for maintaining many stream processes, moderating the influence of upland management on aquatic systems, re-establishing connectivity between fragmented habitats and biotic refugia, and maintaining ecologically functional migration corridors linking headwater streams to the ocean. The delineation of ESUs is needed to clarify biodiversity objectives, which in turn should be considered when designating key watersheds.

11.2.2 Watershed Level

Watersheds with areas of approximately 20–200 square miles are generally the most practical for planning and analysis: it is at this level that linkages between physical and biological processes can be addressed most effectively. Watershed analysis serves several important functions: 1) it offers a means of addressing cumulative effects of multiple activities within a watershed on ecological processes and aquatic habitats; 2) it provides an assessment of current conditions within the watershed, which allows existing resource problems to be identified and future activities to be planned in a more ecologically sound manner; 3) it helps to identify specific portions of the watershed highly sensitive to human disturbances and allows prescriptions to be developed appropriately for the level of sensitivity; and 4) it provides information that helps to refine our understanding of physical and biological processes and how these vary across the landscape—information that can then be used to develop ecoregion- or basin-level standards or criteria. Watershed analysis can also help identify and prioritize habitat-restoration opportunities.

We recommend that watershed analysis be a key component of conservation planning on nonfederal

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lands. Conservation plans should, at a minimum, incorporate evaluations of how proposed activities will potentially affect hydrology (total water yield, peak flow, base flow, and seasonal timing), sediment transport (mass wasting and surface erosion), riparian functions (LWD recruitment, small organic litter inputs, stream shading, bank stabilization, and nutrient cycling), channel condition (bed morphology, substrate type, and physical structure), and water quality (temperatures, dissolved oxygen, and pollutants). Watershed-level analyses should also be conducted to assess biological conditions in the watershed, including fish distributions, status, and habitat conditions. Although specific resource issues are discussed individually, conservation plans should strive to integrate various analyses because of the strong linkages among processes.

Specifically, we recommend HCPs and other conservation agreements should contain the elements listed below.

- **Conservation plans should iiiclude a strategy for preventing cumulative hydrologic effects within the watershed or watersheds.** Land- and water-uses can substantially influence the amount and timing of water delivered to the stream channel, resulting in changes in total water yield, peak flows, summer base flows; and seasonal timing of flows. Conservation plans should specifically address each of these issues by minimizing the areal extent of vegetation disturbance, the area in hydrologically "immature" condition, and the areal extent of roads and other impervious surfaces. Provisions should be included for protecting summer-low flows and seasonal flushing flows, and for reducing irrigation withdrawals where inadequate flows are of concern.

- **Conservation plans should iiiclude a long-term plan for minimizing cumulative sediment delivery to streams.** Land-use activities substantially alter the rate at which sediment is delivered to streams via both mass wasting and surface-erosion processes. Conservation plans should contain provisions to minimize or avoid land-use activities in areas susceptible to mass wasting and surface erosion as well as in riparian zones; minimize total road density within the watershed, including limited entry to roadless areas; develop a road maintenance schedule to prevent and mitigate effects of sediment; and actively rehabilitate roads no longer in use, particularly those in riparian areas. Plans for minimizing impacts of sediment should be based on a thorough assessment of existing and potential erosion and mass wasting problems within the watershed, with the goal of identify areas within the watershed that are at high risk for erosion.

- **Conservation plans should include a comprehensive strategy for protecting riparian areas along all streams.** Riparian vegetation provides shade and moderates stream temperatures, contributes Iarge woody debris to streams, adds small organic matter to streams, stabilizes streambanks, controls sediment inputs from surface erosion, and regulates nutrient and pollutant inputs to streanis. Removal of riparian vegetation diminishes each of these critical functions. All HCPs should establish riparian buffers designed to maintain the full array of ecological processes needed to create and maintain favorable conditions through time.

- **Conservation plans should include a comprehensive strategy for maintaining water quality.** High water quality is required by salmonids during all life stages and can be degraded by land-use and water-use activities. The goal of the water-quality plan should be to maintain temperature, dissolved, nutrients, and other dissolved materials (including toxic substances, where applicable) within the natural range of variability for the particular body of water and time of year. A thorough assessment of current conditions within the watershed is needed to develop this strategy. This assessment should seek to identify acute water quality problems within the watershed, identify specific factors that contribute to these problems, and compare current temperature regimes with reference conditions.

- **Conservation plans should contain a watershed-level strategy for minimizing the impact of roads on aquatic ecosystems.** Roads frequently are the dominant liuman-caused source of sediments delivered to streams, and they influence the routing of water from uplands to the stream channel. In addition, when placed near streams, roads often simplify channels, alter hydraulic processes, and prevent natural channel adjustments. The road strategy should include the development of a long-term transportation plan, regularly scheduled maintenance, replacement of inadequate road culverts, and removal and rehabilitation of roads that are unneeded or that degrade salmonid habitats.

- **Conservation plans should include an assessment of salmonid distributions and status.** The ultimate goal of habitat conservation plans is to protect habitats required by salmonids during all life stages. Identifying important salmonid habitats is critical to the development of specific management strategies and prescriptions. Goals of this assessment should be to 1) identify all habitats accessible (existing or potential) to salmonids, 2) document the distribution and abundance of wild salmonids by species and life stage, 3) identify areas of high productivity or importance for specific life stages, 4) determine trends in salmonid abundance within the watershed, and 5) document past and present indtroductions from hatcheries to waters within the watershed,

- **Conservation plans should include an assessment of current channel conditions and physical habitat.** Channel conditions and physical habitats of salmonids have been altered directly through channelization, revetments, stream cleaning, and dam construction, and indirectly through changes in hydrology, sediment loading, and recruitment of large woody debris. The goals of the habitat assessment should be to characterize channel forms and geomorphic processes affecting channels in the watershed; to identify reaches that are sensitive to large variation in runoff, sediment supply, and large woody debris; to identify reaches that have been subject to human-caused and natural disturbances; and to evaluate the effects these disturbances have had on sensitive reaches and to assess the degree of recovery.

11.2.3 Site Level

The landscape- and watershed-level analyses proposed in this document provide the context from which site-level prescriptions can be made that will effectively protect salmonids. Knowledge of existing watershed conditions and resource problems, as well as the potential sensitivity of different areas of the basin or watershed to land use activities, will enable owners of nonfederal lands to avoid undesirable effects on salmonids and their ecosystems.

Conservation plans should incorporate site-specific prescriptions that accurately reflect the resource concerns identified for the affected area. Uniform prescriptions are generally inappropriate; nevertheless, certain practices are inherently less disruptive to ecosystems than others and should be employed to the degree possible. These best-management practices are discussed by land-use type in the main body of the document, but for brevity are presented here under categories of land alteration, roads, riparian buffers, channel modifications, water use, and water quality.

Land Alteration

Emphasis should be given to minimizing the areal extent and intensity of disturbance to vegetation and soils. Logging-rotation schedules, grazing, farming, mining, and urbanization should be adjusted to minimize the total area in a disturbed state at any given time to minimize cumulative hydrologic effects. Logging should be avoided on areas identified as high risk for mass failures, such as those with steep (> 30°) or unstable slopes. Similarly ranching, agriculture, urbanization, and mining should be precluded from erosive and floodprone areas. Selective tree harvest is recommended for areas identified as moderately sensitive, while ground-based logging equipment is advised only in low-risk areas. We recommend against the burning of logging slash, favoring its retention to control surface erosion except where it increases fire risk. Where range conditions are not good-to-excellent, we recommend suspension of grazing until vegetation has recovered. Once conditions have improved, grazing strategies should be adjusted to preclude deterioration. Where surface erosion is evident, mulching is recommended until vegetative cover is restored. Areas identified as highly erosive should be retired from agriculture. Mining lands denuded of vegetation should be revegetated quickly to reduce erosion. Where chemical constituents of mine spoils inhibit recovery, spoils should be treated to ensure successful re-establishment of vegetation. The most effective means for minimizing urban impacts is through strict State, county, and city land-use planning. Construction should be avoided on steep hillslopes and seasonal wetlands.

Roads

Regardless of land-use type, we reconmend placing roads away from streams, riparian areas, or wetlands; avoiding unstable hillslopes or areas where risk of sediment delivery to streams is high; avoiding stream crossings; installing culverts adequate to allow year-round passage of fish; reseeding and stabilizing areas disturbed during construction; ensuring adequate drainage from road surfaces to minimize erosion; and regularly maintaining drainage ditches and culverts. We also encourage obliteration and revegetation of problem roads and removal or replacement of inadequate culverts. Alternative forms of urban transportation should be promoted to reduce the need for additional roads.

Riparian Buffers

Regardless of land-use type, riparian buffers are reconmended on all streams; their dimensions will depend on the setting and level of protection desired. An evaluation of appropriate buffer widths for protecting critical riparian functions and a review of State and Federal forest-practice rules is presented in the main text. Similar buffers are needed for nonforest lands, and niay require planting native riparian vegetation in highly disturbed agricultural, range, mining, and urban areas. Only those activities that can be performed without adversely affecting natural riparian functions or values should be allowed in buffers. We recommend that grazing be excluded through fencing or removal of livestock in all riparian areas where function of riparian vegetation is impaired. Once recovery has occurred, riparian grazing should be limited in duration and intensity to ensure these functions are maintained. Facilities for watering livestock should be located away from the stream channel and riparian zone, where possible. Where riparian areas are fenced, small access areas for livestock may be appropriate if unlikely to degrade the stream. Conservation can be further enhanced by retiring converted wetlands from agriculture. Urban riparian areas and wetlands that have not been developed should be preserved and no new development allowed. Where feasible, impervious surfaces should be removed and vegetation restored.

Channel Modifications

Where feasible, we recommend removal of dams and rip-rap structures, as well as reintroduction of beaver. In general, we recommend against instream manipulations, such as placement and cabling of logs or other artificial structures, because of high cost per mile and high likelihood of failure or adverse consequences. These structures should only be viewed as stopgap efforts in special situations, not as mitigation for poor management practices. Reconnecting streams to off-channel areas has greater potential for restoring salmonid abundance, but natural riparian recovery through revegetation is emphasized.

Water Use

New water allocations should be approached with great caution, while increased instream water rights are needed for fisheries. All water diversions from salmonid streams should be screened to prevent entrainment. For streanis with diminished water quality or quantity, a watershed conservation strategy should be developed to reduce the volume of water needed for agriculture. Drainage structures should not be used unless combined with irrigation from deep groundwater. Water for mining purposes should not be withdrawn from streams supporting at-risk salmonids or habitats identified as critical for salmonid production. A conservation strategy for mining water should be developed, including treatment and recycling of wastewaters and reductions in groundwater pumping where streaniflow niay be affected. Where urban water withdrawals are degrading salmonid habitats, water conservation and recycling should be promoted.

Water Quality

Regardless of land-use type, chemical treatments should be applied only outside riparian zones (including those of headwater streams), and aerial spraying should be conducted to prevent drift into the riparian zone. Where drainage ditches and tiles exist, intensive use of fertilizers or pesticides should be avoided. Organic farming and integrated pest management should be encouraged where water quality has been degraded by agricultural chemicals. We recommend against mineral or aggregate mining in streams or riparian areas of streams containing salmonids or that drain into salmonid habitats. Mining should be avoided where tailings and wastewater have the possibility of entering aquatic systems. Wastewaters should be treated and recycled on site, and waters not clean enough for re-use should not be discharged into streams. Control structures should be used to retain toxic materials and should be built to withstand extreme precipitation and geological events. Spoils containing toxic materials should be buried below the plant-rooting zone so that these materials are not absorbed by plants or carried by ground water and subsequently released into the environment. In urban areas, stormwater should be routed through waste treatment facilities, and the use of chemical pesticides and fertilizers should be discouraged.

11.3 The Role of Monitoring in Salmonid Conservation Activities

'Monitoring of salmonid conservation activities is critical for ensuring that provisions of conservation agreements are being met (implementation monitoring), that implementation of conservation plans is having the desired effect on aquatic ecosystems (assessment monitoring), and that there is an adequate information base for modifying plans if necessary to protect salmonids and their habitats (adaptive management). In this document, we propose a monitoring strategy designed to assess the condition and detect statistical trends in aquatic ecosystems at spatial scales from site to region. Sampling designs and indicators are recommended to track trends in physical, chemical, and biological conditions in uplands as well as in riparian areas and streams so that critical planning elements are monitored at appropriate spatial and temporal scales.

Long-term monitoring of salmonid conservation activities is essential to document the decadal trends in ecosystem conditions that occur in response to natural and anthropogenic disturbances and to allow separation of the effects of human activity from natural variation. Multiscale monitoring is important to assess the effects of management activities at the scales of the site or the reach as well as to address cumulative effects at the level of catchments, basins, ecoregions, and multi-State regions. Interdisciplinary monitoring is needed because ecosystems are complex aggregations of biotic and abiotic components. Monitoring should be inter-institutional because lands are held by many different institutions, both public and private, and because many agencies have regulatory and management missions that directly or indirectly relate to salmonid conservation.

An effective monitoring program will require a computerized database-management system conducive to data entry, storage, retrieval, analysis, and reporting. Organizing a successful monitoring program of such complexity requires considerable Federal coordination and leadership but also must involve close coordination with State, tribal, and local governments, as well as private interests; this is essential both to ensure consistency of information and to take advantage of existing programs and information resources. The Research and Monitoring Committee for the President's Forest Plan is currently examining how to implement such a program on Federal lands; extending this effort to nonfederal lands in the Pacific Northwest would greatly enhance salmonid conservation planning.

11.3.1 General Monitoring Framework

Eight activities provide a framework for monitoring salmonid conservation efforts: 1) develop a set of assessment questions or objectives that the monitoring should address; 2) determine the indicators that will be used to assess biotic and abiotic conditions as well as ensure that these indicators can be related to the ecological values, the natural and anthropogenic stressors, or both; 3) use the index concept in selecting the sampling period, sampling sites (e.g., streams) and sampling locations at the sites as well as in data analysis (i.e., focus data collection and analysis on particular times, places, and indices.); 4) develop a sampling design that is appropriate for answering assessment questions (item 1 above); 5) establish reference conditions against which conservation efforts may be measured; 6) apply the data to answer resource management questions or to develop new assessment questions; 7) evaluate the effectiveness of the strategy and its results; and 8) identify ecosystem elements and processes requiring additional research.

77.3.2 Monitoring Implementation and Effectiveness of Conservation Plans

All HCPs and other conservation agreements should include an approved and consistent implementation monitoring program, by which the Agencies can determine if landowners are complying with provisions of the. conservation plan. Most HCPs prepared using this guidance will involve monitoring the implementation of land-use controls to reduce hydrological modifications, sediment transport, and riparian disturbance, and many will contain provisions to improve water quality and physical habitat structure. Indicators should be measured through remote sensing and site visits (e.g., range condition, riparian tree-retention requirements). To be most effective, baseline data should be collected before conservation activities begin, and all data should be entered into a database to facilitate tracking of progress.

All conservation plans should involve monitoring to assess the effectiveness of land-use controls in restoring and protecting salmon and salmonid habitats. The focus of the monitoring should be on the aquatic and riparian ecosystems and should include physical, chemical, and biological indicators. As with implementation monitoring, consistent design and indicators should be used to the degree possible. Both remote sensing and site visits are needed. as is a large database management system.

I1.3.3 Sampling Design for Monitoring Implementation and Assessment of Conservation Plans

For monitoring habitat conservation activities, we recommend a multi-State, regional, sample survey. This survey design is recommended for several reasons. 1) There are ecoregional patterns in biotic and abiotic factors, and it takes a regional approach to assess this variability. 2) Summarizing segment-level information in an organized manner facilitates making landscape-level statements, which are important for regionally distributed organisms like salmon. 3) It will be extremely expensive to inventory or census all nonfederal lands and stream miles in the region with the quantitative indicators needed to accurately and precisely assess status and trends. 4) Regional assessments of status-and-trends should be conducted in a statistically consistent and unbiased manner. 5) Fragmentary monitoring fosters fragmentary ecosystem management and social systems. 6) Previous site- and catchment-specific assessments are a key reason that it took so long to determine the extent of deteriorating stocks.

A regional sample survey or census is also important for placing individual conservation activities into an ecoregional and basin context. Such a survey can help establish reference conditions for determining desired directions and outcomes for restoration, for setting quantitative criteria for evaluating progress, and for assessing the effectiveness of conservation plans. A regional sampling effort is also needed to determine if trends in assessed variables result from the effects of the HCP or from changes in climate, fish passage, harvest, and hatcheries. Furthermore, a regional assessment provides a basis for determining the relative condition of various watershed and stream reaches in HCPs. Regional-scale monitoring can generate important data to establish standards for specific habitat attributes. And finally, a regional approach would help standardize sampling designs and methods among the managing agencies, allowing for greater efficiency in sampling and analysis.

We propose that the Agencies adopt something like EPA's EMAP sampling design. This design is easily intensified if detailed information is needed for a single HCP or basin, yet it offers great cost savings by not requiring intensive inventorying of entire drainages. In addition, the EMAP design facilitates accurate and precise inference about resources throughout the region of concern. Equally important, EMAP's randomized design and its monitoring frequency offer rapid assessment of regional status and trends, which would be exceedingly costly or time consuming via an inventory approach.

11.3.4 Physical, Chemical, and Biological Indicators

Quantitative indicators are needed to ensure that ecological signals are discriminated from spatial, temporal, and methodological variances, thereby aiding rapid detection of trends and accurate estimates of status. Linkages between major planning elements and the recommended indicators should facilitate adaptive management and modifications in conservation plans when results deviate from expectations.

Several indicators or indicator groups have been found to be precise and responsive to stressors, especially when data are composited and metrics are integrated into multinietric or multivariate indices. Indicators that should be monitored at all assessment monitoring sites include measures of landscape condition, physical and chemical habitat variables in streams and riparian areas, benthic macroinvertebrates, and aquatic vertebrates. Monitoring of microbial respiration is recommended for urban and mining streams, and sampling of periphyton is recommended for streams on agricultural and range lands. Monitoring of salmonid genetics, spawning, and rearing should be conducted in random subsets of streams. Multiple indicators should be sampled at as many sites as possible.

11.3.5 Other Monitoring Issues

An important goal of a regional monitoring program is to identify and protect streams and catchments that are in very good condition or highly productive of salmonids. These areas are important as reference sites, biological refugia, sources of high quality water, or locations for studying natural rates of ecological processes. In addition, information obtained from reference sites may prove useful in refining criteria or standards to more accurately reflect variability across the landscape.

Several programmatic concerns should be incorporated into an effective monitoring program. Although not all of the indicators discussed above need to be monitored at all sites, it is critical that indicators and monitoring protocols be consistent among conservation plans to allow integration and analysis at broader spatial scales. To this end, all monitoring personnel should receive consistent training, and repeat sampling should be conducted at a subset of locations by other persons to ensure among-watershed comparability and to assess sampling variance. To evaluate ecoregional and basin patterns, watershed-scale data must be aggregated to the larger spatial scales; this will require coordination by the Agencies. Finally, procedures will be needed for disseminating the results of monitoring to other agencies and to the public.

Additional monitoring and assessment are desirable to attain salmonid conservation goals. These include 1) consistent probability-based survey designs and sampling methods (across all States) to more accurately estimate salmon spawning or escapement; 2) monitoring of smolt production at randomly located traps; 3) rigorous stock assessment (through genetic and morphometric analyses) of salmonids in all sub-basins of the Pacific Northwest to aid in delineating ESUs and to address biodiversity issues: 4) assessment of the influence of salmonid diseases within basins (also important in defining ESUs); 5) delineation of aquatic diversity areas and key spawning areas throughout the Pacific Northwest region to help prioritize restoration efforts; 6) continued monitoring of adults and smolts at dams and hatcheries to track trends in abundance; 7) continued monitoring of salmon harvest to document its effects on salmonid populations; 8) development of a central fish database of historical information. Monitoring of these variables also requires integration with the monitoring discussed above.

11.4 Implementation Strategy

Successful conservation and restoration of salmonid habitat in the Pacific Northwest will require that individual conservation efforts, such as HCPs, be integrated into a comprehensive regional program. An important part of such a program will be identifying who is responsible for developing habitat conservation plans, monitoring the implementation and effects of those plans, and evaluating the overall effectiveness of the program. Most of this chapter focuses on these issues. Additional issues that will likely arise during conservation planning are briefly discussed.

11.4.1 Development of HCPs and a Regional Conservation Strategy

It is clearly the responsibility of landowners and land managers, with Agency guidance, to develop conservation plans at the site or watershed scale. For watersheds with single ownership, this process is relatively straightforward; however, where conservation efforts involve multiple ownerships or mixed private and government ownerships, the process becomes more complex. In such cases, two strategies are recommended. Where there are dominant or codominant owners, we recommend that they take the lead in HCP preparation, with contributions from fellow landowners proportionate to ownership. Where ownership patterns are more heterogeneous, watershed councils or cooperatives should be formed to either produce a plan using existing county or municipal staff or private contractors.

A regional plan or program is similarly problematic, but involves a much larger spatial scale (region versus watershed). We believe that the conservation strategy for nonfederal lands proposed in this document will be most effective if it is integrated with Federal aquatic conservation strategies including the Northwest Forest Plan, PACFISH, and INFISH. All of these programs would be enhanced if they were linked with one another and with other Federal, State, and Tribal entities into a comprehensive regional salmonid conservation program.

We believe a salmonid conservation program for nonfederal lands will be most effective if it combines both voluntary and regulatory components. To the degree possible, the Agencies should work closely with landowners to mutually identify issues of concern, identify options or guidelines, and provide individual landowners sufficient information to employ protective actions voluntarily. However, given the current status of many salmonids in the Pacific Northwest and past failure of voluntary programs, a regulatory component will be necessary. The establishment of science-based criteria and best-management practices directed at minimizing ecological impacts are important aspects of such an approach.

11.4.2 Monitoring Conservation Efforts Locally and Regionally

The question of who should monitor salmonid conservation activities involves several issues. Individual conservation plans niust be reviewed for adequacy prior to implementation. Once an HCP has been implemented, it must be monitored to ensure that all required provisions have been followed and that it is having the desired effect on salmonid ecosystems. In addition, the process of developing HCPs must be monitored to assure quality and regional consistency.

Review of individual conservation plans should be conducted by Agency staff, technically trained in the disciplines of geology, hydrology, soil science, aquatic ecology, fisheries ecology, and if appropriate, toxicology and engineering. If the watershed or watersheds affected by the HCP contain only nonfederal lands, we recommend at least bi-agency review. If the affected watershed drains contiguous Federal lands, the appropriate Federal land-management agency should be included in the review process. A goal of these reviews should be the development of consistent plans, at least within ecoregions, and regardless of ownership. For HCPs prepared pursuant to the Endangered Species Act, a formal public comment period is required before approval. We also recommend that the overall conservation program itself undergo periodic peer review, with reviewers representing other agencies, academia, and the private sector.

Implementation monitoring for HCPs should mostly be conducted by Agency staff (or by contractors) because HCPs are a contract with the Federal Government. Ideally, persons conducting the HCP reviews will also perform some of the implementation monitoring, especially site inspections. Where remote sensing is involved, staff should include geographers and landscape ecologists with skills in GIS analysis and interpretation of aerial photographs.

Development of a regional assessment monitoring system for salmonid ecosystems is also clearly an Agency responsibility, although with appropriate coordination it could include other Federal, State, Tribal, and private entities. The same is true for monitoring individual HCPs. All three types of monitoring information should be entered into an Agency computer database to facilitate rapid, quantitative analysis.

11.4.3 Additional Issues in Implementing a Salmon Conservation Strategy

We see a clear need for a cooperative Federal, State, and Tribal effort in developing a computer database (with GIS capabilities) to support salmonid conservation planning. Database managers, computer programmers, and statisticians will be needed to ensure effective and responsive operation. Inforination must be readily available to all interested agencies, landowners, and concerned public.

Several issues relating to equitable treatment of landowners also warrant discussion. In attempting to develop a sound ecosystem approach to conservation on nonfederal lands, the potential exists that landowners who have been good stewards may be asked to restrict activities in certain areas to protect critical salmonid habitats—habitats that are important precisely because the land was well managed—whereas landowners who have intensively and extensively exploited resources may avoid such restrictions. Similarly, where many landowners are involved in a conservation agreement, the actions of one landowner may adversely affect all landowners within the basin. This is an especially important issue in comparing restrictions applied to forest lands with those for urban, agricultural, and range lands. These issues will be difficult to resolve. Alternative conservation trade-offs, land exchanges, tax breaks, or other incentives may provide means for rewarding good stewardship. Conversely, removal of Federal subsidies or other disincentives may be required *to* penalize poor stewards. Finally, we believe it is important that a regional habitat conservation strategy for salmonids consider other factors directly influencing salmonid populations (hatcheries, salmonid harvest, dam operations), as well as the root causes of environmental deterioration (i.e., population growth, resource consumption).

These recommendations acknowledge that ecosystem management will be accomplished through many individual and independent actions. But they also acknowledge that if ecosystem management and salmon conservation are to succeed, each independent action must be integrated into a comprehensive program with a regional conservation objective. The science underlying landscape management and salmonid conservation constantly progresses: thus, implementing an effective strategy requires adapting to new information as it is developed. It is our belief that the planning elements contained in this document provide a foundation from which to build a successful strategy by applying what we already know about ecosystem function as well as by facilitating the collection of information that will allow us to improve planning efforts in the future.

12 Purpose

Much as the loss of Pacific Northwest salmon has come from "multiple compounding human acts of commission and omission," their restoration will come from multiple sources and solutions; single-minded pursuit of one or two strategies will ensure failure.

Ellen W. Chu and James R. Karr
Editors' Note in *Illahee,* 1994

Without question, the complexity of social and ecological issues encompassed by the current salmonid crisis exceeds that for any other resource issue in the history of the Pacific Northwest. The widespread decline of salmonids in the region, as Chu and Karr note, is the result of numerous human activities, including land management (logging, grazing, agriculture, mining, and urbanization), water use (hydroelectric operations, irrigation withdrawals, domestic consumption, dilution of industrial and domestic effluent, and river transportation of commodities), and fishery management (harvest, hatchery supplementation, and introduction of non-native species). The direct and indirect linkages between the health of salmonid populations (and aquatic ecosystems in general) and these many industries and activities have important implications. Restoration of salmonids will affect virtually everyone who resides in the Pacific Northwest through 1) costs of water, food, electricity, and other commodities; 2) the availability of jobs in the fishery, forest, agricultural, and mineral industries; 3) restrictions on use of private lands; and many other avenues. Furthermore, the development of successful restoration strategies will require an unprecedented level of cooperation among managing agencies and between the public and private sectors.

Recent listings of anadromous salmonid stocks in Washington, Oregon, and California under the Endangered Species Act (ESA) have prompted a number of private and other nonfederal landowners to prepare habitat conservation plans (HCPs) pursuant to Section 10 of ESA. ESA allows for incidental take of threatened or endangered species (see Section 9.3 in Part I for a definition of "take") or modification of their habitats provided that a habitat conservation plan is developed by the applicant and subsequently approved by the Secretaries of Commerce (anadromous species) or Interior (resident species). In addition, a number of watershed councils have formed in the Northwest for the purpose of developing conservation strategies for salmonids on nonfederal lands or lands of mixed Federal, State, Tribal, and private ownership. The National Marine Fisheries Service, Fish and Wildlife Service, and U. S. Environmental Protection Agency (the Agencies) seek to develop a coordinated program for evaluating habitat conservation plans, prelisting agreements, and other conservation efforts on nonfederal lands to assure compliance with **ESA,** the Clean Water Act, and other relevant legislation.

In the remainder of Part II, we develop an ecosystem-oriented approach to the planning and monitoring of salmonid habitat conservation efforts on nonfederal lands in the Pacific Northwest. We focus on the effects of land- and water-use practices on salmonids and their habitats and on how these impacts can be minimized through improved planning and management. Although habitat degradation is clearly a major cause of salmonid declines across much of the Pacific Northwest, many salmonid populations will likely continue to decline regardless of how well the landscape is managed unless steps are taken to reduce other human impacts (e.g., overharvest, hatcheries). Thus, the recommendations contained herein should be considered only part of a larger, comprehensive salmonid restoration strategy.

We intend for this document to provide 1) a conceptual framework from which the Agencies can organize a regional conservation strategy, 2) practical information for nonfederal entities to assist them in preparing HCPs and other salmonid conservation plans, 3) guidelines for monitoring HCPs and other conservation efforts, and 4) criteria by which the Agencies can evaluate habitat conservation activities. These four elements are presented together because it is essential that landowners or watershed councils preparing HCPs or other conservation plans have a thorough understanding of the Agencies' management

AR053243

goals (and the reasoning behind those goals) if watershed- and site-level conservation efforts are to succeed. In addition, information in this document may assist county and local governments in developing zoning regulations, land-use ordinances, development standards, and other regulations or guidelines that are compatible with salmonid conservation objectives.

Chapter 13 presents several broad ecological goals that should guide regional salmonid conservation efforts, emphasizing the role of nonfederal lands in achieving these regional goals. Chapter 14 outlines specific planning elements that should be incorporated into habitat conservation plans for nonfederal lands. "Planning elements," as used in this document, comprise three parts: 1) identification of issues and concerns at site, watershed, basin (or provincial), and regional levels; 2) specific evaluations needed to determine if proposed activities are likely to disrupt watershed processes, aquatic ecosystems, salmonid species, or other biota; and 3) data or information needed to perform these evaluations. Incorporated into this section is an evaluation of the effectiveness of current Federal and State forest practice rules for Washington, Oregon, California, and Idaho in protecting riparian functions. Chapter 15 proposes a monitoring strategy to ensure that habitat conservation plans are both implemented and produce the desired outcome. In Chapter 16, we suggest a framework for implementing this conservation strategy. The volume concludes with an Appendix listing sources of data and information that landowners and agencies may find useful in developing and evaluating HCPs and other conservation efforts.

The recommendations made in this document are intended as guidelines for conservation planning, not formal requirements. Each planning situation is likely to be unique, and not all planning elements may be warranted in each case. Nevertheless, a conservation strategy for nonfederal lands will be most successful if it fosters consistency among conservation planning efforts, builds on or complements existing programs that promote ecosystem management, and integrates into a broader regional recovery program for both Federal and nonfederal lands. Succeeding in this effort will require close coordination and cooperation among Federal, State, Tribal, and local governments, and the private landowners or watershed councils who engage in salmonid conservation efforts.

AR053244

13 Goals of Salmonid *Consewation*

An effective restoration strategy to ensure the long-term persistence of salmonids must be grounded in principles of watershed dynamics, ecosystem function, and conservation biology (Frissell 1993). Part I of this document was intended to provide the technical foundation from which such a strategy could be developed. We presented a detailed discussion of physical, chemical, and biological processes operating upon the landscape, within riparian areas, and within aquatic ecosystems that influence the ability of these ecosystems to support salmonids. We also discussed how land-use activities alter salmonid habitats by disrupting these natural processes, particularly the rate of delivery of water, sediment, fine and coarse organic debris, and dissolved substances to streams, rivers, lakes, and estuaries.

From this review of the literature, we have identified five ecological and biological goals as central to salmonid conservation:

- Maintain and restore natural watershed processes that create habitat characteristics favorable to salmonids. It is essential that whole, contiguous landscapes be managed to protect natural *processes* (i.e., the natural rates of delivery of water, sediment, heat, organic materials, nutrients, and other dissolved materials), rather than specific *states* (Reeves et al. 1995). Ecosystems are dynamic, evolving entities that must be managed to retain their capacity to recover from natural disturbances (e.g., climate change, fire, disease, floods). Active, in-channel habitat restoration is recommended only for severely degraded systems where failure to act may cause irreparable harm to the aquatic system; such restoration should be an interim measure, not a measure to mitigate damage to streams and riparian areas or to exempt them from protection (FEMAT 1993).

  In stating that an important goal of salmonid conservation is to maintain and restore natural processes, we recognize that an expectation of returning ecosystems to pristine conditions is unrealistic, particularly on private lands, given the current degree of human disturbance to the landscape and the continued demand for other natural resources. Nevertheless, substantial progress toward the goal of naturally functioning aquatic ecosystems and salmonid habitats can be made by identifying portions of the landscape where the signatures of key processes are strongest and employing management practices that are appropriate for the level of sensitivity. Important in this approach is considering how multiple activities, in space and time, interact to influence salmonid habitats.

- Maintain habitats required by salmonids during all life stages—from embryos and alevins through adults—and functional corridors linking these habitats. The complex life histories of salmonids frequently demand a wide array of habitat types. Different portions of a watershed may accommodate spawning and rearing, and these habitats vary with species. Large lowland rivers are rearing habitats for some species and serve as important migration corridors through which anadromous fish pass on their way to and from the sea. These migration routes must be ecologically healthy with high water quality, the physical attributes required for holding, feeding, or hiding, as well as the biological elements favorable to salmonids during these physiologically demanding transition periods.

- Maintain a well-dispersed network of high-quality refugia to serve as centers of population expansion. Conservation biologists suggest that the most fundamental goal of species (and ecosystem) protection is to preserve those habitats that retain a high degree of ecological integrity. Populations within these "healthy" habitats have the greatest probability of surviving natural disturbance events or long-term shifts in environmental conditions.

- Maintain connectivity between high-quality habitats to allow for reinvasion and population expansion. The high degree of landscape fragmentation that has resulted from human activities has left many salmonid populations in relative isolation. Long-term persistence of salmonid metapopulations depends on developing connectivity between subpopulations through restoration and maintenance of corridors, so that these populations can interact in a natural fashion.

- Maintain genetic diversity and integrity within and among salmonid stocks and species. Preserving natural genetic diversity at the level of

AR053245

individuals, stocks, and species enhances the ability of salmonids to respond to and survive natural environmental change, as well as human-caused perturbations. The loss of life-history types or stocks diminishes the ability of salmonids to persist over the long term. Wild salmonid stocks are subtly adapted to local environmental conditions; alteration of the genetic integrity of these stocks through planting of hatchery fish, exploitation, construction of barriers, or other means renders them less adapted to their environments,

We believe that these ecological goals for attaining regional recovery of salnionids should underlie conservation efforts at all levels, from site-specific prescriptions to watershed, basin, and regional plans. Activities that maintain natural watershed and ecological processes, facilitate the expansion of refugia, enhance connectivity between refugia or from headwaters to the ocean, and allow full expression of the genetic potential of the species should be encouraged; those activities that do otherwise should be discouraged.

The National Marine Fisheries Service has indicated that Federal lands and Federal activities shall bear as much of the burden as possible for conserving listed salmonid populations and the ecosystems upon which they depend (NMFS 1995a, b). Yet nonfederal lands account for more than 50% of the total land area in the Pacific Northwest and they include some of the most productive waters; consequently, conservation on nonfederal lands must be an integral part of a regional salmon recovery program. The goals listed above cannot be met entirely on Federal lands for a number of reasons. First, the wide range of habitats demanded by the complex life histories of anadromous salnionids cannot be provided on Federal lands alone. Second, persistence of salmonids requires preservation of genetic and life-history diversity of salnionid stocks across the landscape; loss of salmonid stocks on private lands diminishes the overall capacity of the species to persist in the face of natural environmental change (e.g., climatic shifts). Third, connectivity between relatively intact refugia on Federal lands can be maintained or restored only by conserving ecologically healthy corridors on nonfederal lands. And fourth, many of the most productive salmonid habitats once occurred in low-gradient river reaches and estuaries, areas that are largely in private or municipal ownership; consequently, recovery of salmonids to healthy or fishable levels will require restoration of these biologically important waters.

In addition to the ecological goals discussed above, habitat conservation on private lands should consider important societal goals as well. The harvest of salnionids is an integral part of many cultures in the Pacific Northwest. Salmonids have significant ceremonial and economic importance to Native American cultures of the region. Furthermore, anadromous salmonids have until recently supported tens of thousands of commercial fishers along the coasts of California, Oregon, and Washington. Sport fishing provides an important source of recreation and food as well as diversifying local economies in the region. The loss of salmonid stocks in Pacific Northwest rivers diminishes the rich cultural heritage unique to this region. In addition, the local economies of many small communities in the Northwest are based on the use or extraction of natural resources. Conservation activities may affect the ability of private landowners to continue to extract commodities to sustain their livelihoods. Support for conservation programs by private landowners is essential for attaining the ecological goals outlined above.

Because many private landowners and niunicipalities have been or are likely to be affected by ESA listings, this document focuses on HCPs; however, the recommendations are equally appropriate for other habitat conservation activities intended to allow owners of nonfederal lands to proceed with land-use or water-use activities while satisfying endangered species, clean water, or other legal mandates. As noted above, many ecological and social issues related to salmonid conservation involve region- or basin-level considerations. Private landowners, municipalities, States, or other nonfederal landowners should be made aware of these considerations, but cannot reasonably be expected to technically address all of these concerns within a conservation plan. Thus, the recommendations provided in this document are intended to aid both owners of nonfederal lands engaged in conservation planning and the Federal agencies responsible for administering HCPs and broader conservation programs.

Finally, we emphasize that the process of developing and approving habitat conservation plans should be an evolving one. Limits to scientific knowledge have precluded us from making specific recommendations on many aspects of conservation planning. Furthermore, specific criteria proposed in this document may not be appropriate in all circumstances, owing to the inherent variation in aquatic ecosystems across the landscape and at any one location through time. Consequently, these criteria should be viewed as indicators of ecosystem or habitat condition, not rigid standards. New information, some of which may be gained through the extensive monitoring strategy suggested herein, should be incorporated into the process as these data become available. The specific planning and monitoring elements proposed in this document represent our best professional judgement. Review and revision of this document among the Agencies, the scientific community, and the public is essential to further develop credible restoration strategies.

14 Planning Elements

Ecosystem-oriented approaches to land and resource management are being recommended by scientists and the management agencies that oversee activities on public and private lands (FEMAT 1993; FS and BLM 1994a, 1994c). Although the term "ecosystem management" has been defined a number of different ways in the literature, the goal of preserving ecosystem integrity while deriving sustained benefits for human populations is common to most definitions (Montgomery et al. 1995). Ecosystem management represents a substantial departure from historical management approaches that 1) attempted to maximize the efficiency with which a limited number of commodity values were extracted or developed, 2) focused on single species rather than on biological communities or assemblages, and 3) were based on administrative units or areas of single ownership rather than on more ecologically meaningful units, such as watersheds, basins, and ecoregions.

As a society, our thinking about applied ecosystem management is in the early stages. Not only is our scientific understanding of ecosystem processes incomplete, but our current institutional structure—with responsibilities for resource protection and production fragmented among various Federal, State, and local agencies—can make regional ecosystem planning difficult. Although there are encouraging signs of greater interdisciplinary research and interagency cooperation, the development of regional strategies for salmonid conservation will be an ongoing and evolving activity for decades. Nevertheless, society can begin working immediately toward larger ecosystem goals by implementing sound management practices at the scales of watersheds and local sites. Habitat conservation ecosystem-oriented approaches to land management plans (HCPs) offer an opportunity to begin to integrate habitat conservation efforts on nonfederal lands with similar efforts on Federal lands.

Section 10 of the Endangered Species Act (ESA), which specifies conditions permitting the incidental take of species, contains several key provisions that are designed to ensure that the intent of the Act is realized and that reasonable alternatives to the proposed activities are considered. Specifically, ESA requires that HCPs address

1) the impact that will likely result from the taking (of a species or its habitat),
2) the steps that the applicant will take to minimize and mitigate such impacts and the funding that will be available to implement such steps,
3) the alternative actions to such taking that the applicant considered and the reasons why such alternatives are not being utilized,
4) such other measures that the Secretary may require as being necessary or appropriate for purposes of the plan.

To satisfy the intent of ESA, it is important that HCPs be developed and evaluated within the context of larger ecosystem restoration strategies. In this regard, a broad spectrum of issues should be addressed in HCPs: site-specific impacts; cumulative effects of multiple activities (in space and time) throughout a watershed; the distribution and status of salmonid species or population segments at region, basin, watershed, and site levels; and the status of other biota and resource values. Montgomery et al. (1995) and the *Federal Ecosystem Analysis Guide* (REO 1995)[1] suggest that implementation requires a hierarchy of planning scales, including regions,

[1] The Federal watershed analysis protocols were first published by the Regional Ecosystem Office (REO) under the title *Federal Agency Guide for Pilot Watershed Analysis* (REO 1994), which we hereafter refer to as the *Pilot Watershed Analysis Guide.* A revised version, *Ecosystem Analysis at the Watershed Scale: The Revised Federal Guide for Watershed Analysis, version 2.1* (REO 1995), contains additional analytical modules as well as revised protocols for existing modules. In this document, we cite the revised guide under the shortened name *Federal Ecosystem Analysis Guide;* however, because the revised version is supplemental to the original, the reader should obtain both of these documents.

basins or provinces (i.e., groups of smaller basins with similar characteristics, such as small coastal streams in Oregon, Washington, or California), watersheds, and individual sites (Figure 14-1). Watershed analyses and site prescriptions that are the most likely components of conservation plans should be imbedded within analyses at larger spatial scales. As suggested earlier, most planning activities at the regional and provincial levels are beyond what can reasonably be expected of private landowners developing HCPs; thus responsibility will fall primarily on State and Federal management agencies for ensuring that HCPs for sites or watersheds satisfy larger ecosystem restoration goals.

The hierarchical approach for conservation planning on public lands suggested by Montgomery et al. (1995), FEMAT (1993), and the *Federal Ecosystem Analysis Guide* (REO 1995) is both necessary and appropriate for protection of salmonids on private lands as well.

> *Each of these scales of analysis and planning are necessary for implementing ecosystem management because: (1) the distribution and environmental requirements of a number of species are not organized on a watershed basis, and thus need to be considered across levels of the analysis and planning hierarchy; and (2) the spatial context within which the watershed lies is an important factor in evaluating the ecological significance of land management alternatives.*
> (Montgomery et al. 1995)

In the remainder of this chapter, we identify what we believe to be key planning elements at various levels in the planning hierarchy that should be involved in the preparation and evaluation of HCPs or other conservation efforts. Again we note that this list of planning elements is purposely broad to cover a wide range of activities and conservation issues; the specific elements to be considered in an HCP or other conservation plan will vary depending on the specific activity proposed and relevant ecological issues.

14.1 Region and Basin Levels

14.1.1 Key Issues

This chapter identifies issues and analyses to be conducted at the scale of regions and basins (or provinces) to determine whether watershed- and site-level conservation efforts will facilitate attainment of regional conservation goals outlined in Chapter 13 of this document. As stated earlier, analyses at these scales will be conducted by Federal, State, and Tribal agencies. Typically, basins and provinces encompass areas of thousands to tens of thousands of square miles, e.g., the Willamette, Deschutes, Yakima, Clearwater, and other major sub-basins of the Columbia River system, and the Smith and Eel Rivers of northern California. Several biological and ecological issues are relevant at these large spatial scales. Biodiversity, species or stocks at risk, cumulative effects, habitat fragmentation and connectivity, metapopulation dynamics, and total salmonid production are all issues that transcend watershed boundaries and thus cannot be satisfactorily addressed without basin-level and regional assessments. Similarly, issues related to the estuarine and marine environments into which anadromous salmonids enter also need to be addressed at this level (e.g., pollutants, sediment loading, fish harvest management) because the perpetuation of populations within a watershed or basin depends on maintaining these habitats and limiting mortality from fishing.

We believe three initial steps by the managing agencies are essential to address these issues: 1) establish a network of key watersheds on private lands that complements Federal key watersheds designated in FEMAT (1993) for westside ecosystems and those currently being developed for eastside systems (FS and BLM 1994b); 2) adopt riparian protection standards for all riparian areas across the four-State area (we do not imply that uniform standards would be appropriate); and 3) delineate evolutionarily significant units (ESUs) for all species of anadromous and resident salmonids. FEMAT (1993) recommends that key watersheds should include watersheds that currently contain habitats or water of high quality, that in the future could provide high-quality habitats, or that are currently habitats for at-risk stocks. We suggest additional criteria: include watersheds with high biodiversity (fish and nonfish species), watersheds that have unique attributes that favor salmonids (e.g., biological "hot spots"), and watersheds or corridors that are important for linking existing refugia, as proposed by the Oregon Chapter of the American Fisheries Society (Henjum et al. 1994). Minimum riparian-protection standards are desired because human activities within the riparian zone have the most direct and damaging effects on salmonids. Protection of the riparian zone is essential for protecting many stream processes, moderating the influence of upland management on aquatic systems, re-establishing connectivity between habitat fragments and biotic refugia, and maintaining ecologically functional migration corridors from headwater streams to the ocean. The delineation of ESUs is needed to clarify biodiversity objectives that in turn should be considered in the establishment of key watersheds. NMFS is in the process of defining

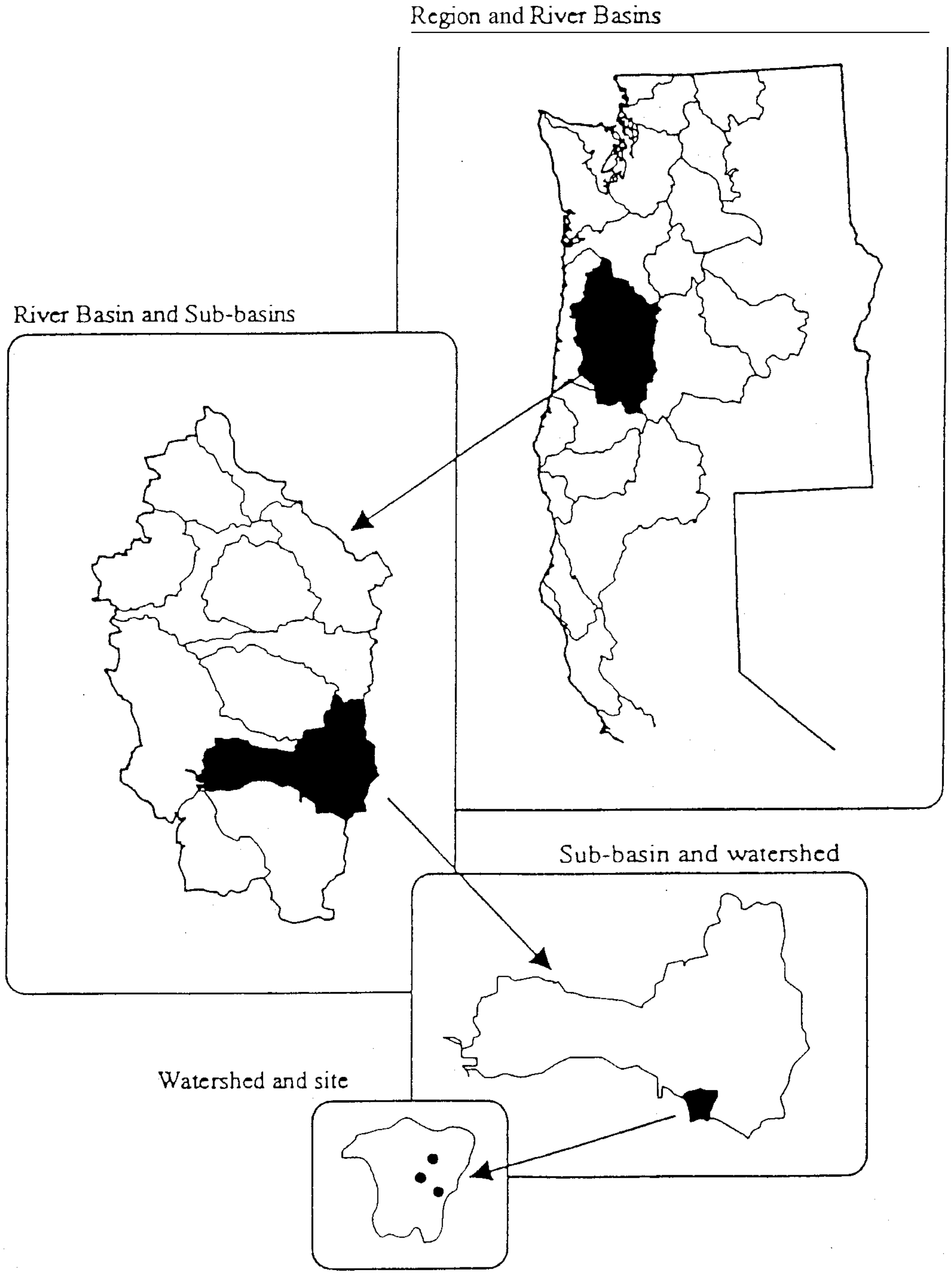

Figure 14-1. A spatial hierarchy for salmonid conservation planning. From REO (1994).

AR053249

ESUs for all of the anadromous salmon and for steelhead and sea-run cutthroat trout, as part of region-wide status reviews (NMFS 1994). Similar analyses are needed for resident salmonid species, particularly bull trout.

14.1.2 Evaluations

In evaluating habitat conservation plans, the Agencies need to address a series of questions at the region and basin scales that relate to the conservation goals suggested earlier. These are listed by issue below.

Biodiversity

- Is the basin or province an area of high diversity for fish species or stocks, other aquatic species, or terrestrial biota?
- Does the basin possess unique physical attributes that would suggest corresponding unique biological attributes that may not have been identified?
- Does the basin contain narrow endemic populations, or populations with unique genetic or life history attributes?
- Do hatchery populations of salmonids threaten the integrity of wild stocks?

Stocks or Species At Risk

- Are there threatened, endangered, or other at-risk species or stocks in the basin that would be affected by the proposed activities?
- If at-risk stocks are not present in the watershed but present in the basin, could the proposed activity limit the expansion or recovery of at-risk stocks?

Connectivity and Metapopulations

- What is the watershed's location relative to key watersheds on Federal lands? Is it immediately adjacent to or linked to key watersheds on Federal lands?
- Is the area or part of the area covered under the conservation plan used as a migration corridor by anadromous stocks?
- Is the area a potential dispersion corridor for resident stocks?
- Are existing salmonid populations likely "seed sources" for recolonization of degraded habitats?
- Are there physical, chemical, or biological barriers that prevent or inhibit movement of fish to and from the basin?

Salmonid Production

- What is the current importance of the stream or watershed in the overall production of wild salmonids in the basin and region?
- What was the historical importance of the stream in the overall production of salmonids?
- Does the basin have high or low restoration potential?
- Does the area affected by the proposed activity contain any biological "hot spots" (i.e., reaches that support a disproportionate number of fish relative to surrounding reaches)?

Cumulative Effects and Fragmentation

- What are the primary stressors in the watershed? Are these stressors of natural origin or a consequence of human activities?
- Are the proposed activities addressed by the conservation plan likely to exacerbate or mitigate these stressors?
- Would the proposed activities result in further fragmentation of aquatic habitats, thereby diminishing prospects for recovery?
- What are the anticipated future developments (e.g., urbanization and water development) in the basin and region?

Estuarine and Marine Environments

- What are the primary stressors affecting salmonids in the estuarine and marine environments?
- Would the activities proposed in the conservation plan exacerbate or alleviate those stressors?
- What role is fish harvest playing in the health of the affected populations?

We fully recognize that information constraints may prevent many of the above questions from being answered satisfactorily. Frequently, the data for performing these analyses may not exist. (One objective of the regional monitoring program proposed in Chapter 15 of this document is to address these gaps in our information base.) For other issues, data may exist but are not readily available to the managing agencies (see Appendix **A**). The time and cost of acquiring and interpreting these data for analysis of individual conservation plans is almost certain to be prohibitive. Therefore, it is essential that a centralized database be developed containing information relevant to salmonid conservation at the basin or regional level in useful forms, such as maps of species distributions, land-use patterns, water withdrawals, and barriers to migration (physical, chemical, and biological). Development of a regional database management system in support of salmonid conservation planning must be a cooperative effort with other Federal, State, and Tribal agencies. These issues are discussed at length in Chapters 15 and 16.

AR053250

14.2 Watershed Level

Watersheds with areas of approximately 20-200 square miles are generally the most practical for planning and analysis (FEMAT 1993; Montgomery et al. 1995). It is at this level that linkages between physical and biological processes can be addressed most effectively. In Part I of this document, we identified numerous physical arid chemical processes that affect salmonids and their habitats, as well as biological processes that may be altered by changes in physical-chemical habitat characteristics. Important physical-chemical processes include morphological development of stream channels, sediment transport, hydrology, heat transfer in streanis, nutrient cycling, and various functions provided by standing or downed riparian vegetation (e.g., bank stabilization, sediment control, shading, coarse and fine organic inputs, microclimate, physical structure, etc.). Important biological considerations include the physiological and biological requirements of individual fish (e.g., food, space, migration routes), population-level processes (e.g., local adaptation, life-history patterns and diversity), and community-level interactions (e.g., predator-prey, competitor, and disease-host relationships). As reflected in the ecological goals outlined in Chapter 13, maintaining these processes within the natural range of variability should be a primary goal of watershed-level planning.

The concept of "watershed analysis" evolved out of concern that site-by-site planning of land-use activities has generally failed to adequately address tlie cumulative effects on these complex processes of multiple human activities occurring throughout a watershed. Thus, an important goal of watershed analysis is to assess the potential effects of site-level activities, given tlie historical and projected future patterns of land use, development, and ecological function. In addition to addressing cumulative effects, watershed analysis serves other important functions. It provides an assessment of current conditions within the watershed, which allows existing resource problems to be identified and future activities to be planned in a more ecologically sound manner. Watershed analysis also helps identify specific portions of the watershed that are highly sensitive to human disturbances, such as areas prone to mass-wasting or surface erosion. Climate, soils, geology, topography, vegetation, and many other factors influence how materials and energy are delivered from tlie hillslope to tlie stream channel. Each watershed is unique and will respond differently to land-use practices; thus, no simple prescriptions can be applied uniformly across the landscape to ensure salmonids and their habitats are protected. Watershed analysis allows prescriptions to be developed that account for this inherent variability. Finally, watershed analysis can provide information that helps to refine our understanding of physical and biological processes and how these vary across the landscape. This information can then be used to develop ecoregion- or basin-level standards that more accurately reflect the spatial and temporal variability in ecological processes.

We recommend that watershed analysis be a key component of conservation planning on nonfederal lands. Specifically, we suggest that HCPs and other conservation efforts incorporate evaluations of how proposed activities will potentially affect hydrology (total water yield, peak flow, base flow, and seasonal timing), sediment transport (mass wasting and surface erosion), riparian functions (LWD recruitment, sniall organic litter inputs, stream shading, bank stabilization, and nutrient cycling), channel condition (bed morphology, substrate type, and physical structure), and water quality (stream temperatures and pollutants). Watershed-level analyses should also be conducted to assess biological conditions in the watershed, including fish distributions, habitat condition, and population viability. For HCPs covering other aquatic and terrestrial biota, additional analyses beyond those recommended here would be warranted. The evolving watershed analysis protocols outlined in the *Federal Ecosystem Analysis Guide* (REO 1995) and tlie State of Washington (WFPB 1994) address many critical watershed, riparian, and aquatic processes. The reader is referred to these guides for specific protocols and resulting products.

In each of the sections that follows, we discuss a specific process that may be disrupted by human activities. Each discussion begins with a summary of key issues that we believe should be addressed in HCPs based on our review of the literature (Part I of this document). We then provide recommendations regarding the elements that should be included in the HCP. The intent is to offer general guidelines, not the specific protocols for performing those analyses. The Agencies, and other State, Tribal, and private interests will ultimately need to develop standardized protocols for field sampling and data analyses to ensure consistency among conservation plans to the extent possible. We then present recommendations regarding numeric or narrative criteria that may be used *to* evaluate whether HCPs or other conservation activities are likely to adequately address resource concerns. These recommendations are made only where they can be supported with existing scientific information, Where such data are deficient, we discuss factors that are likely to influence the responses to land management activities so that management agencies have some technical basis for evaluating the adequacy of HCP provisions. We also note that, because of inherent variability in ecological

AR053251

conditions across tlie landscape and at any one location through time, establishing fixed numeric standards for habitat parameters (e.g., temperature, pool frequency, large woody debris, etc.) may fail to accomniodate this variability and lead to inadequate protections or unwarranted constraints on management activities. Nevertheless, without quantitative ambient criteria, conservation objectives will prove difficult to achieve. Thus we emphasize that where numeric criteria are presented in this report, they are intended to serve as benchmarks or targets. If analysis demonstrates such criteria are inappropriate for the particular region or situation, then these standards should be modified.

An assumption underlying recommendations made in the following sections is that the aquatic habitats affected by the proposed activities support salmonid populations (or influence downstream areas that support salmonids) that are listed, or likely to become listed if not protected, as threatened or endangered under ESA. Consequently, the recommendations are generally conservative in nature and each recommendation may not be appropriate in all circumstances. We also note that because the focus is on salmonids, the recommendations contained herein do not ensure protection of other resource values and in fact may contribute to their degradation. For example, hydrologic effects of timber harvest may be minimized by dispersing numerous small clearcuts over a wide area; however, this may result in a highly fragmented landscape, to the detriment of various wildlife species that would be better protected by employing a few large clearcuts.

14.2.1 Hydrology

Key issues

Land- and water-uses can substantially influence the amount and timing of water delivered to the stream channel. Our review of the literature identified four principal ways in which human activities may influence stream discharge patterns: 1) changes in total water yield; *2)* increases in peak flows (particularly during rain-on-snow events); 3) increases or decreases in summer base flows; and 4) altered seasonal timing of flows. In most instances, land-use activities result in an increase in total water yield due to decreases in evapotranspiration demand following the removal of vegetation (Bosch and Hewlett 1982; Satterlund and Adams 1992). However, in one study in the Cascade Range of Oregon, total water yield decreased slightly after vegetation removal, apparently through loss of fog drip (Harr 1982). Increases in peak flows can be caused by tlie reduced evapotranspiration demands (primarily in the fall), changes in the distribution and melting rate of snow, increased efficiency with which water is routed to the stream channel, or any combination of these mechanisms. Summer low flows may increase in response to reduced evapotranspiration demands, but may also decrease in areas where 1) soil compaction reduces infiltration and, hence, subsurface storage, 2) channel incision causes a lowering of the water table (Rhodes et al. 1994), **3)** natural vegetation is replaced with species having greater evapotranspiration demand (Hicks et al. 1991b), and 4) sediment accuniulations in the channel force the stream to flow subsurface. Seasonal timing of flows is affected by many of the above mechanisms, as well as through storage and withdrawal of water for irrigation and hydropower generation.

Stream discharge strongly influences the amount of habitat available to salmonids and the physical characteristics of those habitats; thus hydrologic changes influence salmonids in a variety of ways. Increases in peak flows can scour spawning gravels, change substrate size, redistribute large woody debris within the channel, facilitate channel incision or widening, and accelerate bank erosion. Reduced summer low flows can dewater stream reaches, prevent or inhibit fish migration, and produce higher summer temperatures. Changes in the seasonal timing of flows may disrupt the migration of salmonid juveniles and adults, and may increase the frequency with which disturbances occur during specific life stages (e.g., the incidence of spawning gravel scouring during early fall). In addition, natural flood and drought cycles are important for normal establishment of riparian vegetation. Hydrologic changes in watersheds may indirectly affect salmonid habitats by altering soil moisture content and stability, which affect the rate of sediment delivery to streams via mass failures and surface erosion.

Recommendations

We recommend that HCPs and other conservation plans contain a strategy for preventing cumulative hydrologic effects within the watershed or watersheds. Ideally, the conservation plan should specifically address each of four 'hydrologic issues identified above: total water yield, peak flows, summer low flows, and seasonal timing. For forest, agricultural, and range lands, the following provisions may be appropriate in an HCP: minimizing the areal extent of vegetation disturbance; minimizing the area in hydrologically "immature" condition and deferring further activities until hydrologic recovery has occurred (particularly in areas prone to rain-on-snow events); and minimizing tlie areal extent of roads and skid trails. For urban areas, provisions for minimizing impervious surfaces would be desirable. Where water storage or withdrawals for irrigation or mining occur, provisions should be included for protecting summer low flows, flows needed for migration, and seasonal flushing flows (flows resembling natural peak flows for scouring substrates), as well as for reducing irrigation withdrawals where inadequate flows are of concern. In most instances, this will involve reducing summer usage and winter storage.

Developing a thorough and defensible management strategy for minimizing hydrologic effects will require a thorough assessment of current watershed conditions. For all land uses, basic information on climate, soils, geology, topography and vegetation will be needed. For forested lands, the analysis should include mapping and assessment of current hydrologic maturity of stands within the watershed; mapping of existing roads, skid trails, landings, and other areas where ground disturbance has occurred; and identifying hydrologically sensitive zones, including areas where rain-on-snow events are likely to occur. Protocols for evaluating potential changes in peak flow niay be found in the Federal *Pilot Watershed Analysis Guide* (REO 1994) and in the Washington watershed analysis guide (WFPB 1994) though modification of the WFPB protocol is under consideration. In California, Sustained Yield Plans may also provide information on potential hydrologic effects in forested systems. For agricultural lands, rangelands, and urban areas, assessment of the current areal extent of disturbance (vegetation, roads, other inipervious surfaces) is also important. The Natural Resource Conservation Service (formerly Soil Conservation Service) has developed hydrologic models that can be used to estimate effects of changes in land use (agriculture, range, and urban) on peak flows in streams (SCS 1982, 1986).

Regardless of land-use type, HCPs should also identify areas where evidence of human-caused hydrologic disturbance exists (e.g., channel incision or widening, dewatering of stream reaches, gullying of incoming drainage channels) and include provisions for mitigating those impacts and reversing the processes that create them to the maximum extent possible. For irrigated agricultural lands, information regarding total withdrawals for the watershed should be presented.

Evaluation Criteria

Our review of the literature found no widely accepted method for determining thresholds for minimizing cumulative hydrologic effects. The probability of significant hydrologic changes resulting from land-use activities generally increases with the percentage of the watershed that has been disturbed (Bosch and Hewlett 1982); however, numerous factors, including climate, vegetation type, soils, geology, land surface form, elevation, and type of disturbance all influence the hydrologic response and confound the ability to predict change. The most frequently used method for assessing cumulative hydrologic impacts is the equivalent clearcut area (ECA) method, the application of which is limited to forested ecosystems. The ECA method involves developing coefficients that express the effects of various forest practices in terms of the equivalent clearcut area that would yield a comparable hydrologic response. The model accounts for site characteristics such as vegetation type, elevation, type of disturbance, and time elapsed since the management activity occurred.

Several recent reviews have found the ECA method to be deficient in many respects (Beschta et al. 1995; Rhodes et al. 1994; Murphy 1995). Rhodes et al. (1994) recommend against using the ECA method because it fails to account for many factors that influence the amount of degradation caused by the disturbance, including proximity to the stream or riparian zone, geomorphic sensitivity, and cumulative affects of other activities, such as grazing and mining. Their objections pertain primarily to using the ECA method alone to determine all cumulative effects (e.g., sedimentation, shade, LWD recruitment), not just hydrologic effects. Beschta et al. (1995) address hydrologic aspects of the ECA approach more directly. They note that although increases in water yield in response to logging are well documented, the assumed correlation between increases in water yield and increases in channel-modifying peak flows has not been firmly established. They also suggest that simple coefficients are inadequate to represent the different mechanisms by which peak flows may be generated (e.g., rain, rain-on-snow, and snowmelt systems), though they acknowledge that because coefficients vary with elevation, these effects may be incorporated into the procedure. In addition to these problems, the hydrologic response to clearcutting depends on the size and distribution of the harvest areas; a few large patch cuts are likely to produce greater increases in yield than many small cuts of equivalent total area. Finally, clearcuts of similar size may exhibit different hydrologic responses depending on the specific harvest and yarding practices and the resulting degree of soil compaction.

Despite these limitations, the ECA method may be useful as a coarse-level indicator of potential hydrologic problems within forested watersheds. Bosch and Hewlett (1982) and Satterlund and Adams (1992) both conducted extensive literature reviews regarding changes in water yield associated with logging and other forest treatments in coniferous forests and found that in most instances, water yield increased if 15%-30%or more of the watershed was disturbed. It should be noted that these reviews uncovered few studies in which less than 20% of the watershed was disturbed, so changes in yield may occur with less extensive disturbance as well. McCammon (1993 in Murphy 1995) concluded that the level of risk was low in coniferous stands where ECA levels were less than 15% of forest stands less than 30 years in age, but increased at higher ECA levels. His assessment considered several processes in addition to hydrology, and assumed that hydrologic recovery occurs in 15-30 years, Together these observations suggest that no more than 15%-20%of the watershed should be in a hydrologically immature state at any given time. Given the uncertainties associated with the ECA approach, this threshold value should be used only as a general guidepost, not as an absolute measure of cumulative effect. For example, if significant portions of the watershed lie in the transient snow zone, or if past harvest has occurred in hydrologic source areas, more conservative ECA threshold values may be appropriate. Similarly, more conservative measures would be appropriate where channel condition has already been degraded by hydrologic changes, or in watersheds where lack of large wood increases the potential for damage during high flows. In two recent evaluations, the ECA model underestimated changes in total water yield observed in the field (King 1989; Belt 1980 in Reid 1993), underscoring the need to exercise caution in using this method as anything other than a general indicator.

Little information exists regarding possible thresholds of liydrologic disturbance on range and agricultural lands. Although the potential for increased water yields is generally less where precipitation is lower, the greater likelihood for overland flow and rapid routing of water to the stream channel suggest these landscapes may be just as likely to produce channel-modifying peak flows in response to human disturbaiices. Methods analogous to tlie ECA method are difficult to apply for range and agricultural lands because the nature of the land disturbance. On forested landscapes, particularly where clearcutting is the primary harvest method, it is relatively easy to define discrete areas of disturbance. On rangelands, the intensity of disturbance is generally lower than for logging, except perhaps in the riparian zone; however, the areal extent of disturbance is usually high and the alteration persists as long as grazing continues. In agricultural areas, both the intensity and areal extent of disturbance are high and the hydrologic response is confounded by the effects of irrigation withdrawals and storage, as well as differences in evapotranspiration demand of crops compared with natural vegetation. Because of the lack of scientific information, we cannot make specific recommendations regarding thresholds of disturbance for these land uses.

In urban areas, tlie magnitude of peak flows and frequency of high flow events generally increases as a function of the percent area with impervious surfaces (e.g., rooftops, roads, sidewalks, parking lots, etc.). Two studies in urban areas of the Pacific Northwest suggest that increased frequency of peak flows resulting in significant changes in stream channel stability can occur when the percent imperviousness exceeds 10% (Booth 1991; Booth and Reinelt 1993). Other studies have shown decreases in macroinvertebrate diversity (Klein 1979; Steedman 1988; Schueler and Galli 1992; Shaver et al. 1995), fish diversity (Scliieler and Galli 1992), and degradation of fish habitat or declines in abundance (Steward 1983; Shaver et al. 1995) when percent imperviousness exceeds 7%-12%. These changes are not entirely due to hydrologic stress, because pollutants and other factors may also contribute to degradation. Nevertheless, these studies suggest that HCPs developed for urban areas should seek to minimize percent impervious area, preferably below the apparent 7%-10% threshold.

We found no established methodologies for addressing cumulative watershed effects on summer low flows or changes in seasonal timing of stream discharge and therefore cannot recommend watershed-level numeric criteria related to these issues. Landowners should strive to minimize changes relative to natural flow regimes in the drainage. In systems where reduction in summer flow and the resultant higher temperatures may adversely reduce salmonid production or prevent existence, construction of dams or increases in water withdrawals should be avoided.

14.2.2 *Sediment Transport*

Key issues

Land-use activities substantially alter the rate at which sediment is delivered to streams via both mass wasting and surface erosion processes (reviewed in Chapter 6). Acceleration of mass wasting and surface erosion occurs in response to removal of vegetation or groundcover, disturbance to soils, and disruption of hydrologic processes (primarily changes in soil moisture content and water routing). In disturbed forested systems, mass wasting events (e.g., landslides, debris avalanches, earthflows, bank failures) are the most important source of sediment inputs to streams and most often occur in association with roads, because of failure of cut and fill slopes, stream crossings, and culverts (Furniss et al. 1991). Surface erosion is generally less important on forested lands because of tlie high infiltration capacity of forest soils; however, significant surface erosion may occur in certain geologic types and on

AR053254

road surfaces, skid trails, landings, and burned or scarified areas where soils are exposed or compacted and where a lack of adequate drainage structures results in channelized surface flows. In grazed and row-crop agricultural systems, the degree of soil disturbance and vegetation removal is typically more extensive than occurs during timber harvest; consequently, the potential for surface erosion is generally greater than on forest lands. In these systems, surface erosion is likely to be a more important source of sediment inputs than mass failures, except on steep terrain or along stream banks.

Increases in sediment delivery to streams can influence salmonids and their habitats in numerous ways. Increased inputs of sediments can result in increased fractions of fine sediments in spawning gravels that niay both reduce intragravel flow of oxygen to developing embryos and entomb alevins. Increased fine sediments may also reduce interstitial spaces in cobble that juvenile salmonids use as winter cover. Large amounts of sediment delivered to streams can effectively reduce pool volume, decreasing rearing habitat for juvenile and resting pools for migrating adults. Elevated sediment loads also increase the frequency of channel scour and fill events, increase channel width through aggradation, and decrease stability of large woody debris. Sedimentation of bottom substrates interferes with the production and diversity of macrobenthos by eliminating rearing space and preventing hyporheic movement. Finally, increases in turbidity and suspended sediments can interfere with normal feeding by salmonids and cause gill damage.

Recommendations

We recommend that HCPs and other conservation plans develop a long-term plan for minimizing cumulative sediment delivery to streams. Important provisions of a conservation plan should include minimizing or avoiding land-use activities (logging, yarding, grazing, farming, mining, road construction) in areas susceptible to mass wasting and surface erosion and in riparian zones; minimizing total road density within tlie watershed, including limited entry to roadless areas; developing a road maintenance schedule to prevent, identify, and mitigate sediment impacts; and active restoration of roads and skid trails no longer in use, particularly those in riparian areas.

Plans for minimizing sediment impacts should be based on a thorough assessment of existing erosion and mass wasting problems within the watershed and their association with specific site conditions and land-use activities. Each watershed contains unique vegetative, soil, geologic, and climatic attributes. Consequently, recognizing specific combinations of characteristics that have led to mass failures or surface erosion in the past provides the best means for identifying areas where risk of future erosion is high. Information on past mass wasting events and surface erosion can be obtained from on-the-ground surveys, aerial photographs, and historical reports. Mapping these areas can assist in developing long-term roading and harvest plans. Analytical approaches for assessing potential for landslides, debris torrents, gully erosion, sheet and rill erosion, bank erosion, and for estimating total sediment yield can be found in the *Pilot Watershed Analysis Guide* (REO 1994) and the Washington watershed analysis guide (WFPB 1994). Additional methods for assessing erosion on forested lands can be found in EPA (1980a) and in Knighton and Soloman (1989). Methods also exist for modeling sediment yields from small watersheds in agricultural and urban areas (Wischmeier and Smith 1978). The goals of these analyses are to estimate the spatial extent of these erosional processes within the watershed, to relate their occurrence to land-use type or watershed characteristics, to assess the resulting delivery of sediment to streams, and to identify areas within the watershed that are high risk for specific types of erosion.

Evaluation Criteria

Because complex interactions among many factors determine the rates of surface erosion and mass failure, it is difficult to develop specific guidelines for determining the adequacy of HCPs or other conservation efforts in relation to erosion. We found little information in the literature that would support the development of numeric criteria for the purposes of preventing cumulative sediment impacts at the watershed level. Nevertheless, tlie relative risk of erosion from an area may be assessed based on qualitative and quantitative descriptions of climate, geology, soils, topography, and vegetation. In addition, historical information on landslides in unmanaged or old-growth basins niay offer additional insights into appropriate criteria. In tlie paragraphs below, we discuss specific attributes that have been identified in the literature as important in determining mass soil movement and surface erosion risk.

Mass Wasting. The factors most often associated with mass failures are slope steepness exceeding the angle of internal friction, wet soils, geology and soil texture susceptible to failure, and removal of vegetation.

Slope. Slope gradient is generally the most important determinant of mass failure risk, although critical thresholds for slope vary with the type of mass soil movement. For debris avalanches and

AR053255

flows (rapid-shallow mass soil movements), Swanston et al. (1980) suggest that risk is high on slopes greater than 34°, medium on slopes between 29 and 34°, and low on slopes less than 29°. Satterlund and Adams (1992) suggest that a critical slope threshold for mass failures under a variety of conditions lies around 30". Based on an extensive review of the literature, Sidle et al. (1985) conclude that most slopes greater than 35" are subject to rapid mass soil movements (i.e., debris avalanches, landslides) and many slopes greater than 25° are susceptible to failure, particularly if the soil niantle is poorly bound to the underlying rock.

Slower mass soil movements, including rotational slumps, earthflows, and soil creep, may occur on more gentle terrain. Swanston et al. (1980) conclude that risks of slumps and earthflows are high on slopes > 30°, medium on slopes from 15–30°, and low on slopes < 15". Sidle et al. (1985) suggest that lower limits for initiation of mass failures are 7–18" for rotational slumps, 4–20" for earthflows, and 1.3–25° for soil creep. They also note that extensive mass soil movements have been observed on gradients of 12–25° in northern California and that these slower movement processes niay contribute more sediments to these streams than rapid failures on steeper slopes.

The above reviews suggest that for all types of mass soil movements, the risk of mass soil movements is high on slopes > 30"; we therefore recommend that activities be minimized or avoided on slopes exceeding this gradient except where a slope stability assessment conducted as part of a watershed analysis indicates the risks of mass wasting and delivery of material to stream channels is low. For lesser slopes, risks of mass failure niay also be high and final decisions regarding appropriate land management practices should be based on site-specific analyses of precipitation and hydrologic characteristics, soil type, geology, and other site conditions discussed below. In general, increasingly conservative standards should be adopted with increasing likelihood that sediments generated by mass failures will enter the stream channel.

Soil Moisture. The risk of mass failure typically increases as soil moisture increases. **As** soils become saturated, positive pore water pressure exerts force that can allow shear stress to overcome resistant forces of cohesion, friction, and binding strength of roots. Consequently, the probability of mass failures increases with intensity of precipitation. Satterlund and Adams (1992) suggest that landslide hazard increases substantially when storm precipitation exceeds 12.5 cm (4.9 in), but note that less intense storms can trigger landslides when soils are already wet from previous precipitation events. Swanston (1991) suggests that critical rainfall intensities for debris avalanches lie between 7.6 and 15.2 cm (3–6 in) in a 24-hour period. Other types of mass failures, including slumps and earthflows, depend more on long-term water accumulation (seasonal and annual) than on individual storm events. Swanston et al. (1980) concluded that risks of debris avalanches and debris torrents are high for areas receiving more than 203 cm per year (80 inches per year) total precipitation or 102 cm per year (40 inches per year) distributed over a clearly defined rainy season, moderate for areas receiving between 51 and 102 cm per year (20–40 inches per year), and low for areas with less than 51 cm per year (20 inches per year). Thus, both the potential for high-intensity rainfall events (or rain-on-snow events) and total annual precipitation should be weighed when evaluating mass failure risk.

Landform and subsurface drainage characteristics also influence the relationship between soil moisture and the likelihood of mass failure. Convex slopes tend to disperse water, whereas concave slopes concentrate water into smaller areas, facilitating rapid, localized increases in soil moisture during storms (Sidle et al. 1985). In addition, because water tends to drain both downward and laterally towards the stream channel, soil moisture tends to be highest towards the base of slopes and near the stream channel. Landslide risks are also high where the density of drainage depressions is great. Risk also increases where bedrock or other impervious materials underlie a shallow soil mantle (Swanston et al. 1980), which causes subsurface waters to concentrate. The presence of permeable low-density zones above impervious layers indicates saturated flow parallel to the slope, which confers a higher risk of hillslope failure. Springs on hillslopes are also indicative of near-surface flow. More conservative land management is warranted on slopes exhibiting on or more of these characteristics.

Geology and Soil Type. The geologic factors that tend to predispose hillslopes to various kinds of mass failures are generally well known (Sidle 1985). Shallow, rapid mass soil movements (e.g., debris avalanches and torrents) are typically associated with one or more of the following conditions: shallow soils overlying hard, impermeable surfaces; parallelism between the slope and underlying planar rock structures (bedding planes, fractures, joints, and faults); and unconsolidated or weakly consolidated soils. Earthflows, slumps, and soil creep occur most frequently where soft, clay-rich rocks form a thick, plastic soil mantle (Swanston et al. 1980; Sidle et al 1985; Satterlund and Adams 1992). Like debris avalanches, these slower moving failures are also

AR053256

more likely where underlying planar structures run parallel to the hillslope.

Specific soil textures that influence susceptibility of hillslopes to debris avalanches and torrents have been summarized by Swanston et al. (1980). They conclude that risk of debris avalanches is high for unconsolidated, noncohesive soils and colluvial debris, including sands and gravels, rock fragments, weathered granites, pumice, and noncompacted glacial tills with low silt content (< 10%) and no clay. They suggest that the risk of failure is intermediate for unconsolidated, noncohesive soils and colluvial debris that have moderate silt content (10%-20%) and low (< 10%) clay content, Fine-grained, cohesive soils with greater than 20% clay or mica content are considered low risk soils for rapid mass failures. Soil texture depends on interactions between parent rock type and climatic conditions. Siltstones, shales, mudstones, pyroclastics (volcanoclastics), and serpentines generally weather rapidly into clays; consequently, soils derived from these materials may be less prone to sliding. In contrast, soils derived from granites and sandstones are typically shallow and cohesionless and, therefore, more susceptible to landslides and debris avalanches (Satterlund and Adams 1992)

Soil texture is also a critical factor in regulating earthflows and slumps, although the characteristics that result in slumps and earthflows differ from those typically associated with rapid mass soil movements. Swanston et al. (1980) summarize the relative risks of slumps and earthflows in relation to soil texture as follows. They suggest that fine-grained, cohesive soils derived from sedimentary rocks, volcanics, aeolian and alluvial silts, and glaciolacustrine silts and clays are prone to slower earth movements. In addition, soils with high clay content (>20%) or with clay minerals that swell upon wetting (e.g., the smectite group) also are at relatively high risk of earthflows and slumps, as are the amorphous clays (Satterlund and Adams 1992); thus, soil types associated with slumping may differ from those that lead to more rapid mass movements. Soils of variable texture with both fine and coarse grained components arranged in layers or lenses, and soils with clay fractions derived from illite and kaolinite groups are at medium risk of slower mass movements. Soils with variable texture and low or widely dispersed clay fractions generally have low risk of failure.

<u>Vegetation Removal</u>. The removal of vegetation influences mass failure processes in two ways. First, the reduction in evapotranspiration demand increases the amount of water within the soil, which may elevate soil water tables (Chamberlain et al. 1991). Second, the root network of vegetation niay help stabilize soils by creating a laterally strong matrix of roots and soil, by anchoring the soil mantle to more stable underlying rock or soil, and by providing local reinforcement in the immediate vicinity of trees (Sidle et al. 1985). As roots decompose following logging, these stabilizing effects diminish. It is unclear which of these mechanisms is most important in stabilizing soils (Sidle et al. 1985) and, consequently, it is difficult to make recommendations regarding management practices related to vegetation removal. Nevertheless, in areas with shallow soils and steep slopes, retention of both large conifers and deciduous understory is advised. Procedures for assessing root strength influence on landslide risk are available (see Sidle et al. 1985).

Swanston et al. (1980) note that the size and location of timber harvest units, as well as subsequent land treatments, can greatly influence the incidence of debris avalanches and torrents, as well as earthflows and slumps. They suggest that large clearcuts that create continuous downslope openings have higher risk of failure than smaller patch cuts (< 20 acres) or partial cuts because of the combined effects of increased soil moisture and, for shallow slides, reduced root strength. They also suggest that failure risk can be reduced by avoiding post-harvest broadcast burning on sites with slopes > 34".

Surface Erosion. The vulnerability of areas to surface erosion depends on several site characteristics including slope, soil type (infiltration rate and degree of compaction), drainage characteristics, and the presence of vegetation or organic litter.

Slope. The erosive force of water increases with the velocity of runoff; consequently, the rate of surface erosion increases with both the gradient and length of the slope. EPA (1980a) reported that soil loss increases approximately as the 1.4 power of percent slope for slopes less than 20% (11°) and as a power of slope length that increases with gradient. On rangelands, Heady and Child (1994) state that a doubling of the slope doubles the erosive power of water and increases the amount of material eroded by a factor of 16. Consequently, incremental increases in slope gradient result in a disproportionately greater risk of surface erosion. We found no published reference to critical slope thresholds for minimizing surface erosion. However, Henjum et al. (1994) concluded that in order to control sediments on eastside forests, no logging should be conducted on slopes with gradients steeper than 17" on pumice soils (highly erosive) and 31° on other soil types. They also recommended that on slopes between 17" and 31°, 40% of the basal area should be retained with half of this area consisting of trees larger than the mean diameter. These recommendations also offer a basis for agricultural, range, and urban lands to limit erosion, although the greater frequency and areal extent of disturbance on these lands may call for more protective measures.

Soils. Soil structure and composition are also important factors in erosion. Although there are a large number of soils within the range of Pacific salmon, typical soil types offer little instructive information. EPA (1980a) describes erosive soils as those with low organic matter, high amounts of silt or fine sand (e.g., loess), a blocky structure (e.g., clay), and low permeability (e.g., calichi). In contrast, the least erosive soils contain high levels of organic matter, are low in silt or fine sand, have a fine granular or crumbly structure, and are highly permeable. Thus soil type should be incorporated into the assessment of surface erosion risk.

Drainage Characteristics. The two types of soil erosion of concern in this subsection are rill or gully erosion and splash or sheet erosion. The former is more impressive and more easily observed, but the latter may be equally damaging, especially on rangelands and farmlands; however, it is more difficult to assess. It is best to prevent both types by proper land management. Where gullies exist they can be mitigated by sets of check dams and revegetation with stem-sprouting vegetation. Splash erosion is best controlled by revegetation and mulching. Because roads are vulnerable to both sheet and gully erosion, we recommend that information describing road density and mitigation be included in conservation plans (see Section 14.2.5).

Vegetative Cover and Organic Litter. Rainfall, slope, and soil texture and structure can be controlled relatively little; however, vegetation can be managed and proper management of plant cover also improves surficial soil texture and structure. For example, Packer and Laycock (1969, in Heady and Child 1994) report that plant and litter cover account for 50%–80% of the variance in erosion studies on rangelands. For the erosive granitic soils of southwest Idaho, Packer (1951, in Heady and Child 1994) recommends 70% cover with vegetation and litter where perennial grasses dominate and 90% in landscapes dominated by annual grasses. This translates to bare soil patches an average of < 10 cm in diameter in the former case and < 5 cm in the latter. Ground cover of 70% is also recommended for the sagebrush-wheatgrass assemblage of western Wyoming to reduce soil compaction and bulk density (Packer 1963, in Heady and Child 1994). On more humid grasslands, Ellison (1950, in Heady and Child 1994) reported a yield of 1.2 tons per hectare of splash erosion when there was 7 tons per hectare of herbage and litter, but 170 tons per hectare from bare soil. Clearly, increases in the amount of bare ground, soil bulk density, and devegetation—whether by over grazing, agriculture, or deforestation—produces increased runoff and soil erosion. Over sufficient time and at sufficient intensities, these uses have led to desertification in arid and semiarid environments.

14.2.3 Riparian Buffers

Riparian Functions in Relation to Buffer Width

Key Issues. Our review of the literature (Section 3.9) revealed six specific functions of riparian zones that are essential to the development and maintenance of aquatic habitats favorable to salmonids. Riparian vegetation provides shade to stream channels, contributes large woody debris to streams, adds small organic matter to streams, stabilizes streambanks, controls sediment inputs from surface erosion, and regulates nutrient and pollutant inputs to streams. In addition to these functions that directly influence aquatic habitats, riparian areas are critical habitats for a variety of terrestrial and semi-aquatic organisms and serve as migration or dispersion corridors for wildlife species (FEMAT 1993). Many of these benefits derive from the availability of water and unique microclimates in these zones. Long-term conservation of salmonids requires protecting not only the immediate functions that riparian vegetation provides, but the ecological conditions within the riparian zone needed to maintain natural vegetation communities (e.g., soil productivity, microclimate) as well. Although riparian buffers alone are insufficient to ensure healthy salmonid habitats, there is consensus in the scientific community that protection of riparian ecosystems should be central to all salmonid conservation efforts on both public and private lands (FEMAT 1993; Cederholm 1994; Cumins et al. 1994; Rhodes et al. 1994; Murphy 1995; and others).

Removal of riparian vegetation through logging, grazing, agriculture, or other means can diminish each of the important functions listed above (see review in Chapter 6). The removal of overhead cover results in more extreme temperatures during both the summer and winter through greater radiative heating and cooling. The lack of recruitment and active removal of large woody debris has left many streams in the Pacific Northwest depleted of large wood that is essential in creating pool and off-channel habitats, retaining sediments and organic materials (including salmon carcasses), creating hydraulic and physical complexity, and providing overhead cover for salmonids. The loss of root matrices of riparian trees and shrubs destabilizes streambanks, allowing banks to slough and collapse during high flow events.

AR053258

Reductions in understory vegetation and disturbance to the organic litter layer permits raindrops to directly hit the soil, facilitating detachment and transport of soil to the stream channel. Alteration of riparian vegetation can also increase nutrient loadings to streams and allow chemical (e.g., pesticides, fertilizers) and biological (e.g., bacteria) contaminants associated with land-use practices to enter the stream.

Fish-bearing streams are influenced not only by the condition of adjacent riparian areas, but conditions of upstream reaches as well, including ephemeral and perennial nonfish-bearing streams. Sediments generated from unprotected upstream reaches are transported and deposited downstream, filling pools and decreasing channel stability. Removal of large trees from headwater areas may reduce recruitment of wood to downstream areas. Temperature increases caused by canopy removal in small streams can also affect downstream reaches. Because these influences of land management propagate downstream, protection of riparian zones along nonfish-bearing streams and ephemeral channels is also needed to maintain salmonid habitats.

Recommendations. We recommend that habitat conservation plans and other conservation agreements include a comprehensive plan for protecting riparian areas along all fish-bearing and nonfish-bearing streams, including ephemeral channels. Riparian buffers should be established for all land-use types and should be designed to maintain the full array of ecological processes (i.e., shading, organic debris inputs, bank stability, sediment control, and nutrient regulation) needed to create and maintain favorable conditions through time. Consideration should also be given to protecting microclimatic conditions (temperature, humidity, wind speed, soil moisture, etc.) to ensure the persistence of natural vegetation communities and, where applicable, other riparian-dependent terrestrial and semi-aquatic species.

Conservation plans should include an assessment of current and historical riparian conditions for the entire watershed (or in the case of very large watersheds, the portion reasonably affected by the HCP) with the objectives of determining the degree to which riparian functions have been altered (if at all) by past land-use practices, projecting recovery periods for various riparian functions, and identifying strategies for accelerating recovery. This analysis should include an overall assessment of cumulative effects and maps of current riparian conditions. The Federal Agencies are currently in the process of developing analytic modules that specifically address riparian functions. Washington State has developed a riparian function module that addresses current riparian conditions, long-term recruitment of large woody debris, and canopy closure/stream temperatures. The functions of nutrient cycling, litter inputs, sediment control, bank stabilization, and microclimate protection are not explicitly addressed in the riparian modules of either the Federal or State of Washington guides.

Evaluation Criteria. The establishment of riparian buffer zones is generally accepted as the most effective way of protecting aquatic and riparian habitats (Cumins et al. 1994). We define buffer zones as areas adjacent to the stream channel or floodplain in which land-use activities are prohibited or substantially restricted. In most instances, riparian management can be divided into two components: delineation of appropriate riparian buffer widths and determination of allowable activities within the riparian buffer zone. Both of these components can be addressed by considering the functional roles of the riparian zone, and particularly those of riparian vegetation.

A functional approach to riparian protection requires a consistent definition of riparian ecosystems based on "zones of influence" for specific riparian processes. In constrained reaches, the active stream channel remains relatively stable through time and riparian zones of influence may be defined based on site-potential tree heights and distance from the active channel. In unconstrained reaches with braided or shifting channels and broad floodplains, the riparian area of influence is more difficult to define. In these reaches, it is more appropriate to define the riparian zone based on the extent of the floodplain, rather than the active channel, because movement of the active channel across the floodplain through time may render buffer strips ineffective. Consequently, it is reasonable to propose buffers of varying absolute widths based on specific reach-level characteristics. Riparian Reserves for Federal lands (FEMAT 1993; FS and BLM 1994c) incorporate these ideas by defining riparian reserves based on multiple criteria. For example, the boundaries for Riparian Reserves surrounding fish-bearing streams are defined by five potential criteria: 91 m (300 ft) slope distance on each side of the channel, two site-potential trees, the outer edges of the 100 year floodplain, the distance from the active channel to the top of the inner gorge, or to the outer edges of riparian vegetation, whichever is greatest.

The effectiveness of riparian buffers can be best evaluated within the context of specific protection goals. For example, riparian standards designed to protect only salmonid habitats would differ substantially from standards to protect other riparian-dependent species, including amphibians, birds, mammals, and reptiles. Consequently, it is reasonable to expect more conservative riparian protection strategies for a multi-species HCP than for one designed for protecting only salmonids. In the sections below, we review literature pertaining to the buffer widths required to provide full protection to specific riparian functions identified as critical in the technical foundation (Section 3.9). For some functions, these relationships are not entirely clear and these uncertainties are noted.

Stream Shading. The ability of riparian forests to provide shade to stream chaiinels is a function of numerous site-specific factors including vegetation composition, stand height, stand density, latitude (which determines solar angle), topography, and orientation of the stream channel. These factors influence how much incident solar radiation reaches the forest canopy and what fraction passes through to the water surface. The shading influence of an individual tree can be expressed geometrically as a function of tree height, slope, and solar angle. For example, Broderson (1973) notes that in mid-July at 45°N latitude, a 61 m (200 ft) high tree on level terrain provides shade 27 m from its base. The same tree provides shade a slope distance of 41.6 m from its base (i.e., 36.6 m measured horizontally from the stream edge) on a 31° slope and 68.8 m (48.9 m horizontal) from its base on a 45" slope. These values represent the *maximum* potential zone of influence for a tree of this height at this latitude and time of year. In natural forests, stand density and composition may moderate the shading influence of trees within this zone with trees closer to the stream channel and understory shrubs providing the majority of stream shade.

The most thorough studies of the effectiveness of riparian buffer strips have been conducted in the Cascade and Coast Ranges of western Oregon. Brazier and Brown (1973) found that angular canopy densities comparable to old-growth stands (i.e., 80%–90%)could be attained with buffers of approximately 22–30 m for coniferous forests in the southern Cascades and Oregon Coast Range. Data from Steinblums et al. (1984) suggests buffers greater than 38 m are needed to retain 100% of natural shading in coniferous forests of the western Cascades (610–1220 m elevation). Based largely on these data, several authors have coiicluded that buffers of 30 m or more provide adequate shade to stream systems (Murphy 1995; Johnson and Ryba 1992; Beschta et al. 1987). The generalized curves presented by FEMAT (1993) suggest that cumulative effectiveness for shading approaches 100% at a distance of approximately 0.75 tree heights from the stream channel (see Figure 3-2). This translates to 25.1 m and 38.9 m for forests with average tree heights of 33.5 m (110 ft) and 51.8 m (170 ft), respectively.

The apparent consensus that buffers exceeding 30 in are needed for stream shading has been based largely on studies in the Cascade and Coast Ranges. There is little published information regarding buffer widths needed to provide natural levels of shade for streams in eastside forest, rangeland, and agricultural systems. Eastside forests, particularly old-growth ponderosa pine forests, have lower stem densities and crown-closure than westside Douglas-fir-dominated systems and frequently lack the dense understory vegetation typical of many westside riparian areas. Consequently, the width of buffers needed to maintain full shading may differ. For hardwood-dominated riparian forests that were once common along streams east of the Cascades, appropriate buffer widths for shade are even less certain, in part because examples of intact riparian ecosystems are extremely rare. More research on riparian influences on shading for all ecosystems east of the Cascades is needed before specific criteria can be recommended; however, in most instances, buffer widths designed to protect other riparian functions (e.g., LWD recruitment) are likely to be adequate to protect stream shading.

LWD Recruitment. Large wood enters stream channels by a variety of mechanisms, including toppling of dead trees, windthrow, debris avalanches, deep-seated mass soil movements, undercutting of streanibanks, and redistribution from upstream (Swanson and Lienkamper 1978). Most assessments of buffer widths required for maintaining natural levels of large wood have considered only wood delivered by toppling, windthrow, and bank undercutting. Yet in some systems, wood delivered from upslope areas (via mass wasting) or upstream reaches (via floods or debris torrents) may constitute a significant fraction of the total wood present in a stream reach. In attempting to identify sources of large wood pieces in 39 stream reaches, McDade et al. (1990) failed to account for more than 47% of the woody debris pieces, suggesting that upslope and upstream sources potentially may be quite important. These mechanisms of delivery are more difficult to model, thus the discussion below focuses on recruitment from the immediate riparian zone. Nevertheless, in evaluating habitat conservation plans, consideration should be given to potential recruitment of wood from upslope areas and nonfish-bearing channels.

The potential for a tree or portions of a tree to enter the stream channel by toppling, windthrow, or undercutting is primarily a function of slope distance from the stream channel in relation to tree height and slope angle. Consequently, the zone of influence for large wood recruitment is defined by the particular stand characteristics rather than an absolute distance from the stream channel or floodplain. Other factors, including slope and prevailing wind direction, niay influence the proportion of trees that fall in the direction of the stream channel (Steinblums et al. 1984; Robison and Beschta 1990b; McDade et al. 1990); however, if the goal is to maintain full recruitment of large wood to the channel, then protection of all trees within the zone of influence is desirable.

FEMAT (1993) concluded that the probability of wood entering the active stream channel from greater than one tree height is generally low (see Figure 3-2). Exceptions occur in alluvial valleys, where stream channels may shift in response to sediment deposition and high flow events. Two models of large wood recruitment also assume that large wood from outside of one tree height seldom reaches the stream channel (Van Sickle and Gregory 1990; Robison and Beschta 1990). Murphy and Koski (1989) found that 99% of all identified sources of LWD were within 30 m of the stream channel in hemlock and Sitka spruce forests of southeastern Alaska with site potential tree heights of approximately 40 m (131 ft) (M. Murphy, personal communication). Their study defined LWD as pieces greater than 3 m length and 10 cm diameter and thus excluded smaller fractions classified as large wood in other studies. In addition, because trees far from the stream channel generally contribute smaller individual pieces (i.e., the tops of trees) that are more easily transported downstream, the authors' abilities to identify sources likely decreased with increasing distance from the channel. Consequently, protecting all LWD recruitment may require slightly larger buffer zones. McDade et al. (1990) examined LWD recruitment to streams at 37 sites in the Cascade and Coast Ranges of Oregon and Washington and found that source distances were as far as 55 m in old-growth (> 200 years) coniferous forests and 50 m in unmanaged, mature (80-200 year old) conifer stands. Tree heights averaged 57.6 m in old-growth stands and 48 m in mature stands; thus, source distances were approximately equal to one site-potential tree height. In this study, woody debris was defined as pieces greater than 1 m length and 0.1 m diameter at the small end. Cederholm (1994) reviewed the literature regarding recommendations of buffer widths for maintaining recruitment of LWD to streams and found most authors recommended buffers of 30-60 m for maintaining this function. In summary, most recent studies suggest buffers approaching one site-potential tree height are needed to maintain natural levels of recruitment of LWD.

An additional consideration in determining appropriate activities in riparian zones relative *to* large wood recruitment is the potential size distribution of LWD. Murphy (1995) notes that larger pieces of wood form key structural elements in streams, serving to retain smaller debris that would otherwise be transported downstream during high flow events. Bisson et al. (1987) suggest that the size of these key pieces is approximately 30 cm or more in diameter and 5 m in length for streams less than 5 m in width and 60 cm or more in diameter and 12 m in length for streams greater than 20 m in width.

For making Endangered Species Act determinations of effect, NMFS (1985c) uses large-size fractions of wood to define properly function habitats. These key pieces are defined as greater than 60 cm in diameter and 15 m in length for westside systems and greater than 30 cm in diameter and 11 m in length for eastside systems. Consequently, riparian protection plans need to ensure not only an appropriate amount or total volume of wood, but pieces of sufficient size to serve as "key pieces" (Murphy 1995).

Fine Organic Litter. Smaller pieces of organic litter (leaves, needles, branches, tree tops, and other wood) enter the stream primarily by direct leaf or debris fall, although organic material may also enter the stream channel by overland flow of water, mass soil movements, or shifting of stream channels in unconstrained reaches. Little research has been done relating litter contributions to streams as a function of distance from the stream channel; however, it is assumed that most fine organic litter originates within 30 m, or approximately 0.5 tree heights from the channel (FEMAT 1993). In deciduous woodlands, windborne leaf litter may travel farther from source trees than needles or twigs from coniferous vegetation; consequently, riparian buffers may need to be wider than suggested above to protect natural levels of organic inputs. Nevertheless, in most cases buffers designed to protect 100% of LWD recruitment will likely provide close to 100% of small organic litter as well.

Bank Stabilization. Roots of riparian vegetation help to bind soil particles together, making streambanks less susceptible *to* erosion. In addition, riparian vegetation provides hydraulic roughness elements that dissipate stream energy during high or overbank flows, further reducing bank erosion. In most instances, vegetation immediately adjacent to the stream channel is most important in maintaining bank integrity (FEMAT 1993); however, in wide valleys with shifting stream channels, vegetation throughout the floodplain may be important over longer time periods, Although data quantifying the effective zone of influence relative to root strength is scarce, FEMAT (1993) concluded that most of the

AR053261

stabilizing influence of riparian root structure is probably provided by trees within 0.5 potential tree heights of the stream channel. Consequently, buffer widths for protecting other riparian functions (e.g., LWD recruitment, shading) are likely adequate to maintain bank stability. In addition, consideration should be given to the composition of riparian species within the area of influence because of differences in the root morphology of conifers, deciduous trees, and shrubs varies. Specific relationships between root types and bank stabilization have not been documented; however, if the purpose of riparian protection is to restore natural bank characteristics, then retaining natural species composition is a reasonable target for maintaining bank stabilization function of riparian vegetation.

Sediment Control. The ability of riparian buffers to control sediment inputs from surface erosion depends on several site characteristics including the presence of vegetation or organic litter, slope, soil type, and drainage characteristics. These factors influence the ability of buffers to trap sediments by determining the infiltration rate of water and the velocity (and hence the erosive energy) of overland flow. Several recent reviews have examined the relationship between buffer width and sediment retention (Belt et al. 1992; Castelle et al. 1992; Johnson and Ryba 1992) and tlie information below is taken primarily from these sources.

Several studies have examined effectiveness of buffers in controlling sediments from forested lands. Broderson (1973) concluded that buffer widths of 15 ni controlled most sediments on slopes less than 50% (26°) and that buffers of 61 m were effective on extremely steep slopes in watersheds of western Washington. Corbett and Lynch (1985) recommended buffers of 20-30 m for controlling sediments. In Pennsylvania, Lynch et al. (1985) concluded that buffers of 30 m removed 75%-80% of suspended sediments in stormwater draining areas that had been clearcut and burned, but that greater sedimentation occurred in areas that were logged and subsequently treated with herbicides. FEMAT (1993), citing these same studies, concluded that buffers of approximately one site potential tree were probably adequate to control sediments from overland flow.

Belt et al. 1992 provide a thorough review of studies examining sediment transport below roaded areas on forested soils and drew four conclusions related to riparian buffers strip design: 1) riparian buffers should be greater where slopes are steep, 2) riparian buffers are ineffective in controlling sediments resulting from channelized flows that originate outside of the riparian buffer, 3) sediments rarely travel more than 91 m, unless flows are channelized, and 4) removal of natural obstructions to flow—vegetation, woody debris, rocks, etc.—within the buffer increases the travel distance of sediments, Johnson and Ryba (1992) reviewed three studies of buffer effectiveness in reducing sediments in runoff from agricultural lands and found recommendations ranging from 3 m for sandy soils up to 122 m for clay soils (Wilson 1967). Gilliam and Skaggs (1988) reported 50% deposition of sediments within the first 88 m of a vegetated buffer adjacent to agricultural fields. Recommendations of the Soil Conservation Service (SCS 1982) call for buffers in agricultural lands of 8-46 m depending upon slope. Belt et al. (1992) concluded that while studies support tlie use of buffer strips as a means of filtering sediment from agricultural lands, they provide no definitive means for determining appropriate buffer widths.

Because of the high degree of variability in the effectiveness of buffers, we cannot draw any definitive conclusions regarding buffer widths required for sediment control. On gentle slopes, buffers of 30 m may be sufficient to filter sediments, whereas on steeper slopes, buffers of 90 m or more may be needed. In addition, riparian buffers are most effective in controlling sediments from sheet erosion and have less influence on sediments that reach the stream channel via channelized flow (Broderson 1973; O'Laughlin and Belt 1994; Murphy 1995), although Megahan and Ketcheson (1996) reported that obstructions (logs, trees, and rocks) significantly reduced the travel distance of granitic sediments in concentrated flows below forest roads on Idaho. We suggest that, except on steep slopes, buffers designed to protect other riparian functions will generally control sediments to the degree that they can be controlled by riparian vegetation. It is essential, however, that riparian protection be compleniented with practices for minimizing sediment contributions from outside the riparian area, particularly those from roads and associated drainage structures, where large quantities of sediment are often produced. In addition, activities within the riparian zone that disturb or compact soils, destroy organic litter, remove large down wood, or otherwise reduce the effectiveness of riparian buffers as sediment filters should be avoided.

Nutrients and Other Dissolved Materials. Riparian vegetation takes up nutrients and other dissolved materials as they are transported through the riparian zone by surface or near-surface water movement. However, the relationship between buffer width and filtering capacity is less well understood than other riparian functions. Those studies that have been published indicate substantial variability in the effectiveness of buffer strips in controlling nutrient inputs (reviewed in Castelle 1992; Johnson and Ryba

1992). The required buffer width for filtering nutrients and other dissolved materials depends on the specific type and intensity of land use, type of vegetation, quantity of organic litter, infiltration rate of soils, slopes, and other site-specific characteristics.

Lynch et al. (1985) observed significant increases in levels of nitrate-nitrogen following logging of a mixed-deciduous forest in Pennsylvania where 30 m buffers were retained; however, they concluded that these levels were not detrimental to stream biota. In the northern Rockies, increases in numerous chemical parameters (pH, bicarbonate, nitrate, sulfate, potassium, calcium, and magnesium) were recorded in surface waters adjacent to three areas that were clearcut and burned, but where undisturbed buffers measuring 30-61 m were retained (Snyder et al. 1975). These results suggest that even fairly wide buffer strips may not prevent elevation of some chemicals following logging, particularly if water is routed to the stream via channelized flow, rather than overland flow through the riparian buffer strip.

Several studies have examined the potential effectiveness of vegetated filter strips in retaining nutrients from agricultural systems. Dillaha et al. (1989) reported that 9.1 m vegetated filter strips removed 79% of phosphorous and 73% of nitrogen on experimental plots in Virginia. Madison et al. (1992; cited in Castelle 1994) reported that 9.1 m grass buffer strips removed approximately 96.0%-99.9% of phosphate phosphorous, nitrate-nitrogen, and ammonium-nitrogen. Xu et al. (1992; cited in Castelle 1994) reported greater than 99% reduction in nitrate-nitrogen in soils in a 10 m mixed herbaceous and forested buffer strip in North Carolina. Nutrient and bacteria levels in runoff from poultry and dairy farms or direct manure applicatioiis may be substantially higher than from other agricultural lands; consequently, buffers may need to be wider. Vanderholm and Dickey (1978) monitored natural runoff from feedlots and found that buffer widths of 91 m on a 0.5% slope and 262 m on a 4.0% slope removed 80% of nutrients, suspended solids, and oxygen demanding substances from surface runoff (cited in Johnson and Ryba 1992). Shisler et al. (1987) reported that wooded riparian buffers in Maryland removed 89% of excess nitrogen and 80% of excess phosphorous from animal wastes with most of the removal being achieved within 19 m. Doyle et al. (1977) found that forest and grass buffer strips of approximately 4 m reduced nitrogen, phosphorous, potassium and fecal bacteria levels in runoff from manure applications, but they did not indicate the percent reduction in these materials. Young et al. (1980; cited in Johnson and Ryba 1992) recommended buffer widths of 36 m for controlling nutrients in runoff from feedlots. Two studies have proposed that buffer strip width should be a function of the total area affected by animal wastes. A 1:1 buffer area to waste area ratio has been suggested as sufficient to reduce nutrients from poultry manure to background levels (Bingham et al. 1980). Similarly, Overcash et al. 1981 reported that a 1:1 buffer area to waste area reduced animal waste concentrations by 90%-100%.

Little information exists regarding the effectiveness of buffers in filtering runoff in urban areas. One exception is the study of Phillips (1989), who modeled pollutant removal efficiencies from residential areas. He found that buffers of 22.9 m required for estuarine shorelines in North Carolina were inadequate for reducing nitrogen, phosphorous, and BOD of runoff from residential areas.

Because of the variability observed in the effectiveness of buffers in controlling input of nutrients and other dissolved materials, it is difficult to recommend specific criteria for buffer widths for this function. Belt et al. (1992) concluded that although the utility of buffer strips in reducing nutrient loading has been demonstrated for forested and agricultural systems, existing studies do not provide an adequate basis for determining effective buffer widths. The studies of Snyder et al. (1975) and Lynch et al. (1985) cited above indicate that nutrient increases from logging and burning may occur even with fairly large buffers (30-60 m), however, these nutrient increases represent whole-watershed responses to logging and larger buffers may have little value in further reducing nutrient loads. Based on the above review, we suggest that for most forest lands, buffers designed to protect other riparian functions (e.g., LWD recruitment, shading) are probably adequate for controlling nutrient inputs to the degree that such increases can be controlled by buffers. Exceptions may occur when fertilizer or other chemical applications result in high concentrations of nutrients in surface runoff.

For rangelands, agricultural systems, and urban areas, we believe current understanding is insufficient to make specific buffer recommendations. The review of Johnson and Ryba (1992) suggests that effective buffers for nutrient control on forest and grasslands range from approximately 4-42 m, but that substantially wider buffers are needed to control nutrients and bacteria (fecal coliform) from feedlot runoff. We recommend that buffer widths for nutrient and pollution control on these lands be tailored to specific site conditions, including slope, degree of soil compaction, vegetation characteristics, and intensity of land use. In many instances, buffer widths designed to protect LWD recruitment and shading may be adequate to prevent excessive nutrient or pollution concentrations. However, where land use activity is especially intense, buffers for protecting nutrient and pollutant inputs may need to be wider than those designed to protect other riparian functions, particularly when land-use activities may exacerbate existing water quality problems. Buffers need to be accompanied by other protective measures when drainage structures (e.g., irrigation canals, drain tiles) bypass the riparian zone.

Riparian Microclimate and Productivity. Changes in microclimatic conditions within the riparian zone resulting from removal of adjacent vegetation can influence a variety of ecological processes that may affect the long-term integrity of riparian ecosystems. However, the relationship between buffer width and riparian microclimate has not been documented in the literature. FEMAT (1993) presented generalized curves relating protection of microclimatic variables relative to distance from stand edges into forests (see Figure 3-3). These curves suggest that buffers need to be extended an additional one-to-two tree heights outside of the riparian zone to maintain natural levels of soil moisture, solar radiation, and soil temperature within the riparian zone and even larger buffers (up to three tree heights) to maintain natural air temperature, wind speeds, and humidity. The recommendations of FEMAT (1993) were based on studies in upland forests in the Cascades (Chen 1991), and their applicability to riparian zones is uncertain (O'Laughlin and Belt 1994). Therefore, additional research is needed before we can confidently suggest buffer widths that are likely to protect riparian microclimate.

The long-term productivity of riparian habitats may also be affected by management in adjacent upland forests. Decaying logs in the riparian zone may be important sites for germination of many types of vegetation because they retain moisture and tend to shed leaf litter that can bury seedlings (reviewed in Harmon et al. 1986). In particular, rotting logs in forests of western hemlock and sitka spruce appear to be key sites for germination. McKee et al. (1982) found that 94%-98%of all seedlings in forests of hemlock and spruce on the Olympic Peninsula were growing on LWD that constituted only 6%-11% of the forest floor. Christy and Mack (1984) found that 98% of all western hemlock seedlings were associated with rotting large wood in a mixed old-growth forest of hemlock and Douglas-fir. In this study, only 6% of the total forest floor area was covered with LWD. Harmon et al. (1986) urge some caution in interpreting these results because the relationship between seedling establishment and long-term survival is not known.

Large wood is also an important source of nutrients and organic matter in riparian forests. In an old-growth, Douglas-fir forest in the western Cascades, Sollins et al. (1980; cited in Maser et al. 1988) found that stems of fallen trees contained 46%, 30%, and 12% of the total nitrogen, potassium, and phosphorous, respectively, found on the forest floor. Means et al. (unpublished data; cited in Maser et al. 1988) found that about 30% of all soil organic matter in two old-growth Douglas-fir forests was contained in downed trees of 500 years age or older. Sollins et al. (1980) found that proportion of soil organic matter from LWD was four-fold higher than in other forms of forest litter. These studies suggest that long-term integrity of riparian areas may be dependent on adequate recruitment of large wood to the forest floor from within the riparian zone and adjacent uplands. They also suggest that the practice of removing down logs from within the riparian zone and placing them in channels may affect long-term riparian productivity. Maintaining recruitment of wood to the riparian zone (not just the stream channel) would require extending buffer zones beyond the edge of the defined riparian zone.

Wildlife Habitat. The importance of riparian areas to many wildlife species is well documented (see review Section 3.9.8). However, generic recommendations for riparian buffers to protect wildlife are not justifiable because each species has unique habitat requirements. Johnson and Ryba (1992) reviewed the literature related to buffer widths for wildlife protection and found recommended buffer widths to be highly variable, ranging from 10-200 m. Suggested buffer widths by taxa included: 30-100 m for beaver, 67-93 m for small mammals, 100 m for large mammals, and 75-200 m for birds. Requirements for amphibians and reptiles were not included in their review; however, most amphibians require cool, moist habitats throughout their life cycles and many species are commonly found associated with large woody debris (FEMAT 1993). Consequently, maintaining microclimatic conditions and recruitment of LWD within the riparian zone may be essential for protecting amphibians. FEMAT (1993) also conducted a review and found studies recommending buffers from 30-183 m in width for wildlife protection; they did not, however, base riparian reserve widths on wildlife needs. Cumins et al. (1994) also noted the importance of riparian zones for wildlife but did not incorporate wildlife needs into their buffer width recommendations.

Buffers and Windthrow. Trees within riparian buffers that are immediately adjacent to clearcuts have a greater tendency to topple during windstorms than trees in undisturbed forests. Extensive blowdown can potentially affect aquatic ecosystems in a number of ways, both positive and negative. In stream systems that lack wood because of past management practices, blowdown may immediately

AR053264

benefit salmonids by providing structure to the channel. Over the long-term, however, blowdown of smaller trees may hinder the recruitment of large wood pieces that are key to maintaining channel stability and that provide habitats for vegetation and wildlife within the riparian zone. In addition, soil exposed at the root wads of fallen trees may be transported to the stream channel, increasing sedimentation. Other riparian functions, including shading, bank stabilization, and maintenance of riparian microclimates may also be affected. Rhodes et al. (1994) suggest that buffers need to extend to a distance of two site-potential tree heights (or > 91 m) to protect riparian buffers from windthrow; however, local site conditions dictate vulnerability of stands to windthrow and appropriate buffer widths would vary accordingly.

Effectiveness of Federal and State Forest Practices in Maintaining Riparian Functions

The review in the preceding section provides a framework for assessing the relative protection afforded specific riparian processes by riparian management guidelines currently in effect on Federal and nonfederal lands. Riparian management guidelines have been most completely developed for forested lands on both public and private lands. Riparian management guidelines for Federal lands within the range of the northern spotted owl are detailed in the Record of Decision (ROD) for the President's Forest Plan (FS and BLM 1994c); these guidelines apply to much of the region in western Oregon, Washington, and California. Interim riparian protection measures for managing anadromous fish-producing waters on Federal lands outside the range of the northern spotted owl (i.e., eastern Washington, Oregon, and California, and all salmon-bearing steams in Idaho) are contained in PACFISH (FS and BLM 1994a). Interim riparian protection measures for streams with resident (nonanadronious) native fish in eastern Oregon, eastern Washington, Idaho, western Montana, and portions of Nevada are detailed in INFISH (FS 1995). Forest practices in riparian areas on nonfederal lands are regulated by forest practices rules specific to each State. At present, no coniparable protections exist for range, agricultural, and urban lands.

ROD, PACFISH, INFISH, and the States each define the width of riparian management zones and allowable activities within the riparian zone based on water-type classifications. Streams on Federal lands are classified based on presence or absence of fish, whether the stream is intermittent, and whether the stream is in a key or nonkey watershed (Table 14-1). Ponds, lakes, and wetlands are classified based on size and whether they are natural or constructed. Water classification systems for Idaho, Washington, Oregon, and California are more variable. All of these States use presence or absence of fish to classify streams, but additional classification variables are used, including other beneficial uses (e.g., domestic water supplies: all States) stream width (ID, WA), mean annual flow (OR), substrate type (WA), bank side-slope angle (CA), and whether the stream is capable of downstream sediment transport (CA) (Table 14-1).

Federal riparian reserves (ROD) or riparian habitat conservation areas (PACFISH, INFISH) differ from the riparian management zones of the States both in terms of how riparian zone widths are defined and the level of activity allowed within the riparian zone. ROD, PACFISH, and INFISH define riparian reserve widths based on site-potential tree heights, whereas all of the State forest practice rules have fixed-width riparian management zones, though in some states these widths may be increased on steep slopes or highly erodible soils (ID, CA, WA). The Federal strategies allow timber harvest and other activities within riparian reserves (ROD) or riparian habitat conservation areas (PACFISH, INFISH) only if such activities will not compromise Aquatic Conservation Strategy (ROD) or Riparian Management (PACFISH, INFISH) objectives or if such activities are needed to attain these objectives. In contrast, all four States generally allow greater activity within the riparian management zone. State forest practice rules seek to protect riparian shading and LWD recruitment through retention of 1) a percentage of overstory and understory vegetation (all States), 2) a specified basal area of conifers per length of stream or per acre (OR), **3)** a specified number of trees per length of stream (ID, CA, WA, OR), or 4) a specified number of trees of various dimensions per length of stream (ID). The width of the riparian zone and the degree of human disturbance allowed within the zone for each stream class varies by State (Table 14-1). In addition, some States have different buffer widths or leave tree requirements depending on the district or region (WA, OR) or the type of harvest (clearcut vs. partial cut or thinning, OR) or yarding method (CA). In Washington State, watershed analysis can be used to justify smaller or larger buffers and more or less harvest within riparian zones as long as riparian functions are not impaired. Similarly, California allows increases or decreases in riparian management zone width and canopy retention requirements based on site characteristics or proposed forestry practices, provided they do not degrade beneficial uses. These changes must be approved by a Registered Professional Forester or the Director of Forestry and Fire Protection.

Because of the different classification schemes and inconsistent leave-tree requirements, it is not possible to quantitatively compare the effectiveness of the State forest practice rules in protecting riparian

Table 14-1. Riparian management regulationsfor Federal, State, and private forest lands in Idaho, Oregon, Washington, and California. SPT = site potential tree, SPZ = stream protection zone, RMA = riparian management area, WLPZ = water course and lake protection zone, RR = riparian reserve, RHCA = riparian habitat conservation area. Modified from Stephen Phillips, Pacific States Marine Fisheries Commission.

Regulating Authority	REQUIREMENTS: STREAM SHADE	REQUIREMENTS: TREE RETENTION				
IDAHO Idaho Code Title 38, Chap. 13 Rules 1-8	*Class I Streams* Leave 75% of current stream shade. *Class II Streams* No specific shade requirements. Leave undisturbed soils to a minimum of 5' width.		Stream Class/Width			
			Class IA	Class IB	Class IC	Class II [1]
			Over 20' fish-bearing [2]	10'–20' fish-bearing [2]	Under 10' fish-bearing [2]	headwater, few if any fish
		Tree Diameter (DBH)	Minimum Number of Standing Trees per 1000' (each side)			
		0–7.9"	200	200	200	--
		8–11.9"	42	42	42	--
		12–19.9"	21	21	--	--
		20+"	4	--	--	--
		SPZ Width [3,4]	75'	75'	75'	5'
OREGON OAR 629-24 OAR 629-57	For all fish-bearing and and large and medium nonfish-bearing streams retain all understory vegetation within 10 ft of the high water level and all trees within 20 ft of the high water level		Stream Type/Width/Flow			
			Type FI	Type FII	Type FIII	Type N-D [5]
			Large, fish-bearing >25' width	Medium, fish-bearing 8'–25' width	Small, fish-bearing <8' width	Small, non-fish-bearing <8' width
			>10 cfs avg. annual flow	2–10 cfs avg. annual flow	<2 cfs avg. annual flow	<2 cfs avg. annual flow
		Tree Retention [6]	Square Feet of Conifer Basal Area per 1,000' of Stream (each side) [7]			
		Coast Range	170–230	90–120	20–40	n.a.
		W. Cascades/Interior	200–270	110–140	20–40	n.a.
		Siskiyou	170–220	90–110	20–40	n.a.
		Eastside	130–170	70–90	50 [8]	n.a.
		RMA Width	100'	70'	50'	0–70'
WASHINGTON WAC 222-30 WAC 222-16-30	Applies only if there is harvest planned within RMZ. once stream temperature and elevation are determined, a nomograph is used to derive minimum canopy cover Additional requirements if >25% of canopy removed and temperature model indicates stream temperature increase >2.8°C		Stream Type/Width			
			Type 1 & 2 Water	Type 1 & 2 Water	Type 3 Water	Type 4 Water
			>75' width	<75' width	<5' width	>2' width
			State shorelines or substantial fish numbers [9]	State shorelines or substantial fish numbers [9]	Significant fish numbers [9]	Nonfish-bearing perennial or intermittent
		Substrate Type	Trees per 1,000' of stream (westside)/Trees >4"DBH per acre (eastside) [10]			
		Gravel/Cobble	50 / 135	100 / 135	25 / 135	When needed to protect resource
		Boulder/Bedrock	25 / 75	50 / 75	25 / 75	
		RMZ Width [11] West	25'-100'	25'-75'	25'	25'
		RMZ Width [11] East	50' avg.	50' avg.	50' avg.	--
CALIFORNIA 14 CCR 916 (936, 956)	*Class I Streams* Retain at least 50% overstory & understory canopy covering ground and 25% overstory conifers. *Class II Streams* Retain 50% total canopy covering ground, retain 25% of overstory conifers. *Class III Streams* 50% of total understoty vegetation shall be left.			Stream Class [12]		
				Class I [13]	Class II [14]	Class III
				Fish always or seasonally present; fish spawning or migration habitat	Fish always or seasonally present within 1,000 feet downstream	Nonfish-bearing capable of sediment transport
			Side Slope Class	Minimum no. conifers >16" DBH & >50' height per acre		
				≥2	≥2	--
		WLPZ Width [15]	<30%	75'	50'	Determined on site-specific basis
		WLPZ Width [15]	30%–50%	100'	75'	
		WLPZ Width [15]	>50%	150'	100'	

AR053266

Table 14-1. Riparian management regulations for Federal, State, and private forest lands in Idaho, Oregon, Washington, and California. SPT = site potential tree, SPZ = stream protection zone, RMA = riparian management area, WLPZ = water course and lake protection zone, RR = riparian reserve, RHCA = riparian habitat conservation area. Modified from Stephen Phillips, Pacific States Marine Fisheries Commission.

Regulating Authority	REQUIREMENTS: STREAM SHADE	REQUIREMENTS: TREE RETENTION					
ROD (FS & BLM 1994c)	No specific shade requirements; shade protected through large riparian reserves. No harvest permitted in riparian reserves when riparian conservation objectives are adversely affected, as determined by watershed analysis.	Western OR, WA, and CA within range of northern spotted owl.		*Stream or Lake Type* [16]			
				Type I	Type II	Type III	Type IV
				Fish-bearing	Permanent nonfish-bearing	Lakes/natural ponds	Intermittent streams, wetlands <1 ac.
		RR Width [17]		300'/2 SPT	150'/1 SPT	300'/2 SPT	100'/<1
PACFISH Alternative 4 (FS & BLM 1994a)	No specific shade requirements; shade protection through riparian reserves. No harvest in RHCAs except if natural disturbance and riparian conservation objectives not compromised.	East. OR, east. WA, ID, and portions of CA w/anadromous salmonids outside range of spotted owl.		Stream or Lake Type			
				Type I	Type II	Type III	Type IV
				Permanent, fish-bearing	Permanent, nonfish-bearing	Lakes, ponds, reservoirs, wetlands >1 ac.	Intermittent stream, wetlands <1 ac.
		RHCA Width	key	300'/2 SPT	150'/1 SPT	150'/1 SPT	100'/1 SPT
			non-key	300'/2 SPT	150'/1 SPT	150'/1 SPT	50'/0.5 SPT
INFISH (FS 1995)	No specific shade requirements; shade protected through large riparian reserves. No harvest permitted in riparian reserves when riparian conservation objectives are adversely affected, as determined by watershed analysis.	East. OR, east. WA, ID, west. MT, and portion of NV with resident native fish outside range of anadromous fish.		Stream or Lake Type			
				Type I	Type II	Type III	Type IV
				Fish-bearing	Permanent nonfish-bearing	Lakes, ponds, reservoirs, wetlands >1 ac.	Intermittent streams, wetlands <1 ac.
		RHCA Width	priority	300'/2 SPT	150'/1 SPT	150'/1 SPT	100'/1 SPT
			non-priority	300'/2 SPT	150'/1 SPT	150'/1 SPT	50'/0.5 SPT

[1] Idaho is currently considering changing Class II SPZ width to 30', with tree retention of 140 trees in 0-7.9" diameter class per 1,000' of stream.
[2] ID class I streams also includes those used for domestic water supplies.
[3] Widths for ID, OR, CA, ROD, PACFISH, and INFISH are based on slope distances. WA uses horizontal widths. All widths apply *to* each side of stream channel.
[4] ID may require wider SPZ when stream is adjacent *to* steep slopes or erodible soils.
[5] OR distinguishes between large, medium, and small streams for N and D type streams, Data shown above are for small streams.
[6] Tree retention requirements shown are for clearcut harvest in areas with good conifer stocking; basal area requirements are higher for partial cuts and thinning. In addition to basal area requirements, OR also has leave tree requirements of 40 live conifers per 1,000 ft of stream for large Type F streams and 30 live conifers per 1,000 ft of stream for medium Type F streams.
[7] Higher value represents "standard management target" for basal area; lower value represents "active management target." Operators may place conifer logs or downed trees in Type F streams and receive basal area credit toward meeting tree retention requirements as long as active management target is achieved.
[8] In eastside systems, snags, dead and dying trees, and hardwoods may be counted towards basal area requirements.
[9] "Substantial" and "Significant" for spawning, rearing, or migration are not defined.
[10] WA expresses leave tree requirements as trees per 1,000 ft of stream for westside systems and trees ≥4" dbh for eastside systems. For westside streams, ratio of conifer to deciduous RMZ leave trees: Type 1 & 2 waters, representative of stand; Type 3 waters <5' stream width, 1 to 1 with 6 minimum size or next largest available. For eastside streams, operator must leave all conifers ≤12" dbh plus 16 live conifers per acre from 12-20 dbh and 3 live conifers per acre > 20".
[11] RMZ width for eastside streams must average 50', with 30' minimum and 300' maximum for clearcuts. For partial cuts, minimum and maximum RMZ widths are 30' and 50', respectively.
[12] CA also delineates class IV streams: man-made water courses, usually downstream, established domestic, agricultural, hydroelectric supply, or other beneficial uses.
[13] CA class I streams also include: domestic water supplies on site and/or within 100' downstream of operation
[14] CA class II streams include those providing aquatic habitat for nonfish aquatic species.
[15] Values represent general WLPZ widths. Widths may be decreased (to a minimum of 50 ft for class I and II streams) or increased based on soil, slopes, geology, hydrology, and proposed management practices with approval from the Registered Professional Forester and the Director, provided downstream beneficial uses are not degraded.
[16] ROD has an additional class "constructed ponds, reservoirs, and wetlands" not included in this table.
[17] Riparian Reserve or RHCA width may be extended to top of inner gorge, outer edge of 100-yr floodplain, or outer edge of riparian vegetation if these distances are greater than prescribed slope distance or SPT height.

functions. Nevertheless, a qualitative sense of the level of protection afforded to specific processes can be gained based on riparian buffer width and the allowable level of activity. Figures 14-2 and 14-3 illustrate the differing buffer widths and protection levels for each class of water on Federal and nonfederal lands for eastside and westside systems. To facilitate comparison between Federal and State regulations, we converted fixed buffer widths into site-potential tree heights. We assumed a site-potential tree height of 170 feet for westside forests (Figure 14-2) and 110 feet for eastside forests (Figure 14-3) based on FEMAT (1993) designations. However, forests in the Olympics of Washington, the Siuslaw National Forest of Oregon, and the redwood zone of California contain site-potential trees in excess of 200 ft; consequently, the riparian zones of influence extend farther from the stream channel in these systems. Below we evaluate Federal and State riparian zones for Oregon, California, Idaho and Washington in terms of the protection they provide to shading, LWD recruitment, organic litter inputs, bank stability, sediment control, and nutrient control. Riparian buffer widths required to maintain 100% of each function are shown on the top of each figure and were based on the review in the preceding section. Assessing the degree of protection based on site-potential tree heights poses some difficulties. For certain functions (LWD recruitment, shading, organic litter inputs), site potential tree height is the best yardstick for assessing protection because tree height directly influences these functions. However, for other functions (e.g., bank stabilization and perhaps sediment control and nutrient regulation) absolute width of the buffer may be more important than width relative to site-potential tree height. Thus comparing westside and eastside systems directly should be done with caution for these latter functions. Furthermore, the bars shown in Figures 14-2 and 14-3 should not be construed as representing the percent of function maintained. For example, most LWD is recruited within 30 m of the stream channel; consequently, in a westside system an unharvested buffer measuring one-half site potential tree may provide substantially more than 50% function with respect to wood inputs.

Stream Shading. Leaf Litter Inputs, Nutrient Regulation. Based on the review in the previous section, we conclude that buffer widths of approximately 0.75 site-potential tree heights are needed to provide full protection of stream shading, litter inputs, and nutrient regulation. FEMAT, PACFISH, and INFISH require riparian buffers along both fish-bearing and nonfish-bearing streams that are sufficient to protect these functions with the exception of intermittent and nonkey (PACFISH) and nonpriority (INFISH) watersheds in eastside systems. Eastside streams in nonforested areas may also be an exception because PACFISH and INFISH define buffer widths based on the 100-year floodplain; thus, the level of protection depends on whether the reach is constrained or unconstrained,

State forest practice rules generally provide less complete protection of shading, litter inputs, and nutrient control than do Federal standards and guidelines. In addition to having narrower buffers, the State forest practice rules allow activity within the riparian zone that may diminish riparian functions. For westside systems in California, buffer widths are sufficient to provide full protection of these functions only for fish-bearing streams (Class I) with side slopes exceeding 50%; buffer widths for all other States and stream classes are inadequate for maintaining full protection (Figure 14-2). For eastside systems in California, buffers are generally wide enough to maintain full function along fish-bearing streams with slope > 30% and steep (side slopes > 50%) nonfish-bearing tributaries that drain into fish-bearing streams, but not for streams on lesser slopes in each class (Figure 14-3). In addition, California allows substantial reduction in overstory conifers *(75%* removal), which may alter the composition of leaf litter as well as nutrient dynamics. Buffer widths for both fish-bearing and nonfish-bearing streams in western Oregon and Washington do not assure full shading, organic litter, and nutrient control functions, both because buffers are insufficiently wide and because removal of trees is allowed within the riparian zone (Figure 14-2). For eastside systems, however, these fixed-width buffers provide greater relative protection since site-potential tree heights are smaller compared to those in westside systems, Larger fish-bearing streams in Oregon (Type FI) appear to be fully protected, whereas medium-sized fish-bearing streams (OR FII) are marginally protected and small fish-bearing streams are less so. Idaho's forest practice rules provide buffers for fish-bearing streams that approach the fully protective width; however, 25% of existing shade may be removed. Washington's riparian buffers fur eastside fish-bearing stream are generally the narrowest of the four States, although they may be extended to 300 feet where riparian vegetation reaches that far from the active channel (Table 14-1). As with Idaho, 25% (or more if expected temperature increase is < 2.8°C) of canopy can be removed. Nonfish-bearing streams in Washington and Idaho receive little protection.

Bank Stabilization. Retention of riparian vegetation within 0.5 site-potential tree heights of the active stream channel appears necessary to maintain streambank stability. Buffers required by FEMAT,

AR053268

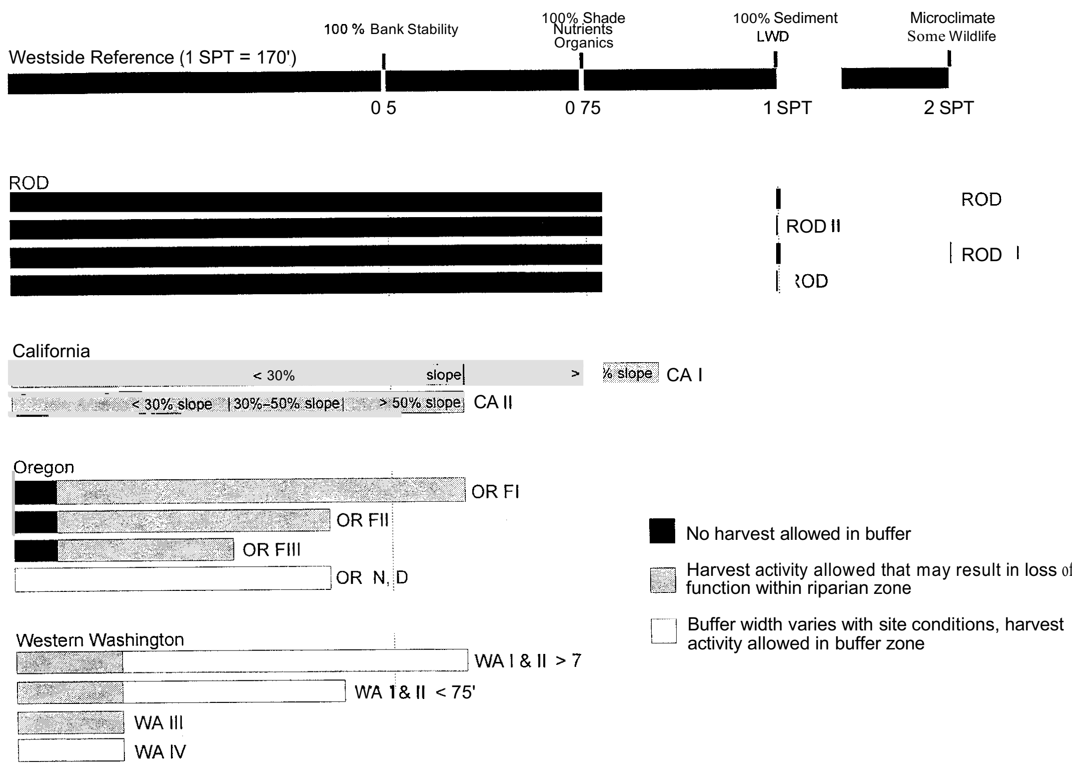

Figure 14-2. Riparian buffer widths by stream class for ROD and State forest practice rules for westside forests. Reference bar at top indicates approximate widths required for full protection of riparian functions.

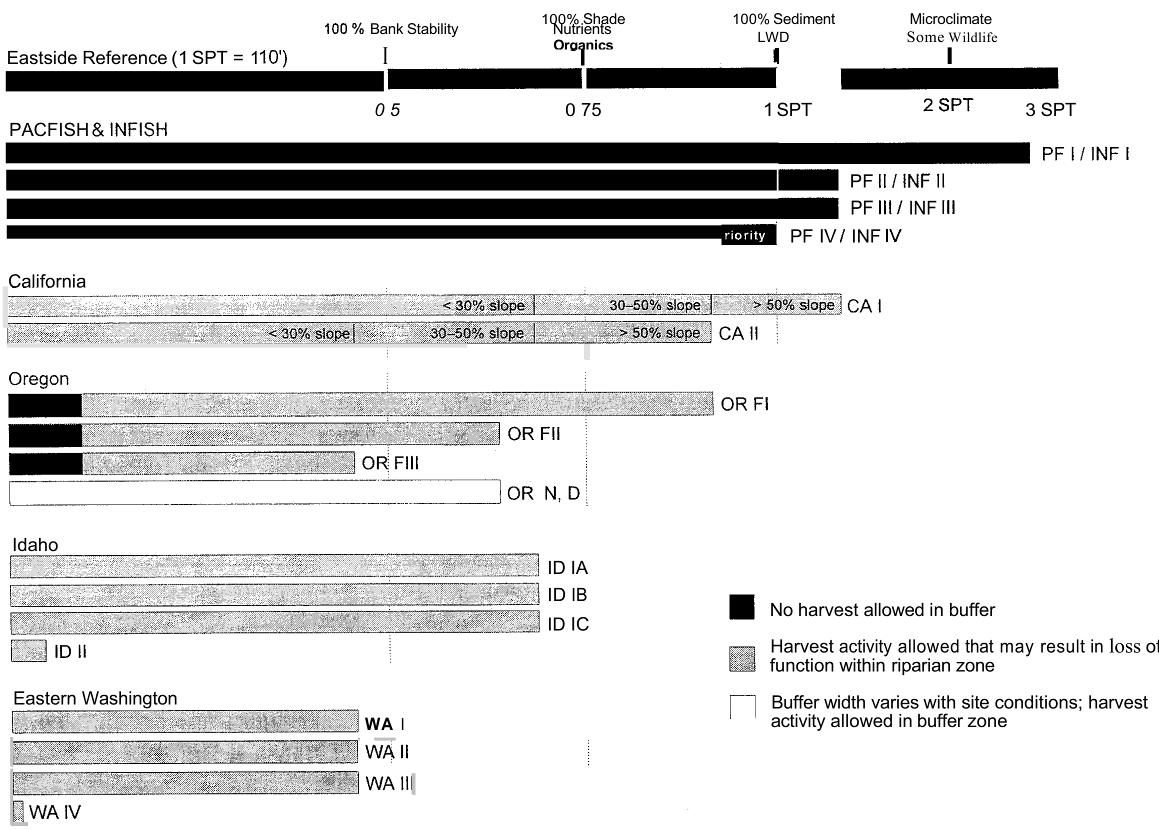

Figure 14-3. Riparian buffer widths by stream class for PACFISH and State forest practice rules for eastside forest. Reference bar at top indicates approximate widths required for full protection of riparian functions.

PACFISH, and INFISH for Federal lands generally provide full protection for this function along all fish-bearing and nonfish-bearing streams (Figures 14-2 and 14-3). Riparian buffers required by State forest practice rules are generally wide enough to protect bank stability along most fish-bearing waters in eastside systems. Little protection is provided for Idaho Class II and Washington Class IV waters. For westside systems, forest practice rules provide less coniplete protection of streanibanks, though we again note that absolute distance may be a more appropriate metric for evaluating effectiveness of riparian buffers in maintaining bank stability. Only Oregon's large fish-bearing streams and California's steep-sided (> 30% Class I, > 50% Class II), fish-bearing streams are well protected if buffers of 0.5 site potential trees are assumed to provide full protection. Because all States allow some harvest within the riparian zone, bank stability may be further compromised, although Oregon provides a 20-foot, no-harvest zone immediately adjacent to fish-bearing channels, which provides an additional measure of protection to bank integrity.

LWD Recruitment. Full recruitment of LWD by toppling, windthrow, or stream undercutting will generally occur if no-harvest riparian buffers of one site-potential tree height are retained. (Exceptions may occur in second growth stands where hardwoods have excluded regeneration of coniferous trees, leading to depletion of large size classes of debris). Riparian reserves provided by ROD, PACFISH, and INFISH are generally adequate to ensure close to 100% recruitment of LWD from riparian sources to both fish-bearing and permanent non-fish bearing streams on Federal lands, with the exception of intermittent streams in non-key watersheds of eastside systems (Figures 14-2 and 14-3). For nonforested streams on the eastside, the adequacy of riparian buffers for maintaining wood inputs varies depending upon valley and channel type, since riparian buffers are defined based on the 100-yr floodplain.

In contrast, buffers on private lands are generally inadequate to maintain full LWD recruitment to the stream channel, both because buffers are insufficient in width and because removal of conifers is allowed within the buffer zone (Figures 14-2 and 14-3). Only California Type I and II streams (side slopes > 30%) and Oregon Type FI streams require buffer widths approaching the dimensions needed for full recruitment and then only for eastside systems; however, long-term recruitment may be diminished by removal of conifers within the riparian zone. Murphy (1995) analyzed the effectiveness of State riparian buffers based on buffer widths and leave tree requirements along fish-bearing streams and concluded that the percent of LWD source trees remaining in the riparian zone after harvest in the four States are approximately 23% for California (Class I), 49% for Idaho (Class IB), 58% for western Oregon (Type FI), and 32% for western Washington (Type 1 & 2, < 75 feet width), if minimum standards are followed. These values indicate a substantial reduction in long-term ability of the riparian zone to provide wood to the stream channel under State forest practice rules. Botkin et al. (1994a) concluded that Oregon's Forest Practice Rules protect all riparian functions except that of supplying LWD, particularly large-sized pieces. Differences in each State's management allowances further influence the quality and quantity of conifer recruitment to streams. Oregon and California specify that leave trees must be conifers while Idaho and Washington permit hardwoods as well as conifers to qualify as leave trees. The lack of conifer retention will generally reduce the size and longevity of LWD that is recruited to the stream channel. Little protection is provided for recruitment of wood into nonfish-bearing channels. This wood is important in retaining sediments produced in headwater reaches (see below) and may be an important source of debris for downstream reaches if transported by high flows or debris torrents.

Sediment Control. Because mass wasting and channelized erosion are responsible for much sediment delivered to streams, management practices in upslope areas may be just as important as those used in the riparian zone. Considering only sediments generated by surface erosion within the riparian zone, buffers of approximately one site-potential tree would likely be effective in trapping most sediments, provided that slopes are not excessively steep (see above review). Under ROD, PACFISH, and INFISH, sediment retention is probably adequate for most streams except intermittent streams in non-key watersheds in eastside systems (Figure 14-2 and 14-3). State-required buffers are substantially narrower than those for Federal streams and as a consequence have a lower probability of providing full protection, although for gentle slopes buffers narrower than one site-potential tree may be sufficient to remove the majority of sediments. California is the only State that has explicit rules for increasing buffer widths based on slope steepness; forest practice rules for Idaho indicate buffers should be wider where slopes are steeper but provide no specific dimensions for steeper areas. Effectiveness of State riparian buffers for sediment control is also influenced by specific requirements for retaining groundcover or downed wood, both of which can reduce the impact of management activities on sediment retention capability. California requires retaining a minimum of 75% surface cover within the riparian zone and

AR053271

treatment (mulching, seeding, rip-rapping , chemical stabilizers) of large bare patches created by forest practices. Oregon requires all vegetation within 10 feet and all trees within 20 feet of the stream channel be retained (except as allowed for road construction, yarding corridors, or stream crossings); in addition, Oregon requires operators to leave all downed wood within the riparian management zone along fish-bearing streams. Idaho forest practice rules state that logging and yarding within the stream protection zone of Class I streams should be conducted in a way to "minimize stream bank vegetation and channel disturbance" and to ensure "[sediment] filtering effects are not destroyed" but does not provide specific criteria for meeting these objectives. Similarly, Washington requires that logging and cable yarding within the riparian zone be conducted with "reasonable care" so as to minimize disturbing soils; use of tractor and wheeled skidding systems within the riparian zone must be approved by the Department of Natural Resources.

Based on site-potential tree heights, State forest practice rules would appear to provide somewhat greater protection for eastside streams than westside streams; however, this is probably not the case. The ability of riparian buffers to retain sediments is likely more a function of absolute distance (and slope) than distance relative to site-potential tree heights. Furthermore, overland flow likely occurs more frequently in eastside systems because forests are more open and the amount of organic duff and vegetative groundcover is typically less. State forest practice rules generally provide minimal protection for intermittent and nonfish-bearing streams. Yet these streams are extremely important in controlling sediment delivery because of their greater density (over 50% of the total length of stream channels in a watershed, Reid and Ziemer 1994, in Murphy 1995).

Other Riparian Functions. Riparian buffers required on Federal lands by ROD and PACFISH provide some protection of other riparian characteristics, including riparian microclimate, site productivity, and some riparian-dependent wildlife species, although degree of protection for these functions is uncertain. The level of protection is greatest for ROD Class I and III waters, PACFISH Type I streams, and INFISH Type I streams, which require buffers a minimum of two site-potential trees in width. No State regulations have fixed widths to address these additional functions. However, all States indicate that wildlife resources must be considered in planning timber harvest activities, particularly where sensitive species are potentially affected. California's forest practices rules specifically list microclimate modification as one potential wildlife concern to be evaluated. In addition, some States have snag (ID), downed wood (OR), or wildlife reserve tree (WA) retention requirements designed to protect certain wildlife needs. Oregon encourages retention of vegetation along small streams (including non-fish bearing) to protect amphibians that may inhabit these reaches, and Washington requires maintaining conifer/hardwood ratios similar to natural vegetation communities along fish-bearing streams, in part to protect wildlife values.

Summary and Conclusions

As noted above, specific recommendations for riparian buffer widths can only be made with a clear definition of riparian management goals. If the goal is to maintain *instream* processes over a relatively short time frame (years to decades), then fully protected riparian buffers of approximately one site potential tree (30–45 m in most Pacific Northwest forests) are likely adequate to maintain 90%–100% of most key functions, including shading, LWD recruitment (excluding wood recruited from upslope and upchannel areas), small organic litter inputs, nutrient regulation, and sediment control (for surface erosion in the riparian zone only). If the goal is to maintain natural microclimatic conditions within the riparian zone as well as large wood for nurse logs and nutrient contributions—conditions that may be essential for long-term (decades to centuries) maintenance of natural species composition and production of riparian vegetation as well as a number of wildlife species—then buffers need to be substantially wider. Similarly, prevention of blowdown within the riparian zone requires buffers of greater width. Cederholm (1994) has suggested that if the goal of management is to protect riparian ecosystems, there is a need to first define riparian areas from a functional perspective, and then maintain buffers around these ecosystems.

Based on the above review and analysis, we conclude that Federal riparian reserves outlined in ROD (FS and BLM 1994c), PACFISH (FS and BLM 1994a), and INFISH (FS 1995) in general provide adequate protection to riparian processes critical to maintaining salmonids in most instances. In addition, these riparian reserves provide some protection to microclimatic conditions within the riparian zone, help maintain recruitment of wood into the riparian zone, and provide greater protection for other riparian-dependent wildlife species along fish-bearing streams than do State forest practice rules. Protection for these latter functions is less along nonfish-bearing streams. In contrast, State forest practice rules **do** not ensure 100% protection for most critical riparian functions. Buffer widths are in most instances sufficient to protect bank stabilization and leaf litter inputs, but insufficient to provide 100% of LWD recruitment, shading, and perhaps sediment control. In addition, the allowance of timber harvest within the riparian zone further diminishes the capacity of the riparian zone to provide all of these functions,

Because of the critical condition of many wild salmonid populations, we recommend that management activities be avoided within the riparian buffer zone under HCPs or other conservation agreements, particularly in old-growth and late-successional forests. Riparian forests that have not been disturbed by land-use activities provide the greatest level of protection for aquatic habitats and should generally not be disturbed until a significant percentage of riparian areas across the landscape has been restored. In second growth forests, particularly where natural vegetation has been replaced with hardwood trees and shrubs, management in the form of hardwood removal, thinning of small-diameter conifers in crowded condition, and planting of conifers may help accelerate the recovery of riparian forests, particularly with respect to recruitment of large wood (Berg 1995). These activities should be performed carefully so as not to diminish other riparian functions, including shading, sediment control, and bank stabilization. The overall goal should be to restore the riparian zone to a "natural" condition, not to maintain timber production within the riparian zone over the long term. For other land uses, including grazing and agriculture, riparian conditions likely bear little resemblance to natural conditions. In these areas, activities that are contributing to riparian degradation should be curtailed or avoided to allow these systems to recover. Where possible, efforts should be made to restore and reclaim wetland and floodplain areas that have been separated from riverine systems.

Although protection of riparian areas is essential to the conservation of salmonids, it is important to reiterate those functions for which riparian buffers have limited utility. These include hydrologic changes caused by alteration of upland vegetation and soil conditions in the catchment; sediment inputs from mass wasting and channelized erosion; nutrient or pollutant inputs that result from catchment modification or that reach the stream by channelized flow; and recruitment of large wood via processes other than toppling and windthrow. Consequently, riparian buffers should be viewed as one element of an overall watershed management plan. These buffers will only be effective if steps are taken to minimize cumulative impacts from upland areas as outlined elsewhere in this document.

14.2.4 Water Quality

Key Issues

High water quality is important not only for protecting salmonids and other aquatic organisms, but for preserving other beneficial uses as well, including recreational values, and agricultural, industrial, and domestic water supplies. Deterioration of water quality due to land use activities diminishes each of these values.

Water temperature influences all aspects of salmonid physiology, behavior, and ecology. Temperatures approaching or exceeding the physiologically tolerable range can cause direct mortality or acute stress in salmonids. In addition, relatively small increases in stream temperature at any time of year can adversely affect salmonids by changing metabolic requirements, behavior, rate of development of embryos and alevins, migration timing, competitive interactions, predator-prey interactions, disease-host relationships, and other important ecological functions (reviewed in Sections 4–6). Changes in both physiological and ecological processes may also occur with increases in diel temperature fluctuations. These adverse effects may occur even when temperatures are well within the physiologically tolerable range for the particular species. Because salmonids are adapted to the specific thermal regimes encountered throughout their life histories, maintaining natural temperature regimes is critical for their protection.

Salmonids require high levels of dissolved oxygen (DO) throughout most of their life stages with early life stages being most sensitive to reduced DO levels (reviewed in Section 5.2). Dissolved oxygen may be lowered in streams and rivers as a result of industrial and municipal discharges, nutrient-induced algal blooms, temperature increases, and increased siltation, which hinders exchange of water between surface and intragravel waters. Low DO levels influence developing eggs and alevins in a number of ways including reduced survival, retarded or abnormal development, delays in time to hatching and emergence, and reduced size of fry. In juveniles and adults, low DO impairs swimming performance, reduces growth, and inhibits migration.

Salmonids can also be adversely affected by a variety of toxic pollutants. These contaminants can enter streams as chronic inputs, such as industrial effluent or runoff from agricultural and mining areas, or as episodic inputs, such as chemical spills during transportation or failure of containment structures. Effects vary depending upon the chemicals, exposure, and interactions with other chemical, but can range from direct mortality and behavioral or morphological abnormalities to bioaccumulation of substances in tissues, making fish unfit for human consumption.

Recommendations

We recommend that HCPs and other conservation efforts include a strategy for maintaining levels of temperature, DO, nutrients, and other dissolved materials within the natural range of variability for the particular body of water and time of year. Development of such a strategy will be most effective if it is preceded by a thorough assessment of current conditions within the watershed. This assessment should have three goals: to identify acute water quality problems within the watershed (e.g., areas where temperatures or DO levels violate State criteria or the tolerable range for extant salmonids during a particular life stage), to identify specific factors that contribute to these problems, and to compare current temperature regimes with reference conditions derived either from either historical data or data from relatively undisturbed watersheds within the region. In some watersheds, data for establishing appropriate reference standards for water quality parameters will be lacking. In these instances, reference standards may have to be inferred based on knowledge of presettlement conditions compared with current land and water uses. Current conditions should not be used except in undisturbed watersheds. The regional monitoring strategy outlined in Chapter 15 would, over time, assist in developing reference standards.

Maps identifying water-body types and uses can be compiled from State agencies with responsibility for water quality and fishery resources. Water quality data are available from Federal, State, and Tribal records, as well as from ambient monitoring by the applicant, and then related to land uses in the watershed. Specific water quality attributes that should be examined include temperature, dissolved oxygen, nutrients, turbidity, acidity, alkalinity, heavy metals, and other toxicants if there is reason to expect they may be entering aquatic ecosystems. Detailed analytic procedures for temperature, dissolved oxygen, turbidity, and nutrients are given in the *Federal Ecosystem Analysis Guide* (REO 1995). The Federal guidelines for temperature generally address only summer maximum temperatures. We recommend that analysis of diel temperature fluctuations and winter temperatures/ice formation also be conducted using historical records, comparisons of sites in perturbed versus unperturbed systems, and local knowledge. Where salmonid spawning occurs, monitoring of intragravel oxygen dissolved oxygen during the incubation period can help identify water quality problems, though sedimentation and bedload movement may also lead to low dissolved oxygen on salmonid redds.

Evaluation Criteria

The primary objective of the Clean Water Act (CWA) is to "restore and maintain the chemical, physical, and biological integrity of the Nations' waters." To this end, CWA directs States to establish water quality standards that describe beneficial uses of water in each drainage basin, numeric and narrative criteria necessary to protect these uses, and various policies to be implemented when managing State water quality (REO 1995). The Endangered Species Act (ESA) requires that any activities authorized by Federal agencies (including HCPs and other agreements) cannot jeopardize listed species.

We recommend that HCPs and other conservation efforts consider how new activities may adversely affect water quality in water bodies containing threatened or endangered species. In areas where existing water quality problems are impairing ecological function, conservation plans should seek to alleviate the causes of water quality degradation and maintain all water quality parameters within the range required for specific species and life stages. Conservation measures will be most effective if they are designed not only to ensure compliance with State water quality criteria but to maintain or restore water quality parameters to natural background levels.

Temperature. We believe that it is important *to* consider three fundamental questions in evaluating potential effects of temperature alterations on salmonids: Do temperatures exceed the maximum tolerable level for the particular species? Are temperatures within the preferred temperature range during each specific life stage? And do temperatures depart significantly from the natural range of variability for the particular body of water? This latter question is critically important because of local adaptation of individual salmonid stocks to the specific thermal regimes in their spawning and rearing streams. The importance of local adaptation to thermal regimes was highlighted by The Technical Advisory Committee of the Oregon Department of Environmental Quality (ODEQ 1995), who concluded that "It is not desirable to homogenize the temperature regimes of Oregon rivers if we want to preserve [life-history] diversity."

State water quality criteria generally consist of two components: an absolute numeric criterion for maximum summer temperatures (usually defined as the average daily maximum temperature over some defined time period) and maximum allowable increases (or decreases) for individual point sources or nonpoint source activities. Some States have maximum thresholds that vary depending on the presence or absence of particular species, with lower criterion in waters used by salmonids for spawning and rearing. In addition, maximum criteria in some States (OR, CA) vary with drainage basin or region in order *to* account for natural differences in temperature regimes. For example, under the proposed Oregon criteria, the lower Willamette and Columbia Rivers would be 20°C, 2.2°C higher than for the rest of the State (see below). Similarly, some

States have varying criteria for allowable increases, depending on a classification of the water body. For example, Washington water quality standards allow greater temperature increases in high-elevation waters. State water quality criteria, therefore, primarily target the first two questions listed above. Although minimizing the incremental change associated with a given activity somewhat addresses the need to maintain natural temperature regimes, it fails to prevent cumulative effects of multiple activities that may raise temperatures several degrees above natural levels, to the detriment of salmonids.

The available evidence suggests that most salmonids stocks are adversely affected by temperatures above 15.6–17.8°C; although fish may survive these warm temperatures, populations typically do not thrive under such conditions. The ODEQ (1995) recommended an absolute maximum criterion of 15.6°C for all waters, measured as the 7 day average daily maximum; a maximum threshold of 12.8°C for waters used by salmonid species for spawning and rearing; and a maximum threshold of 10°C for waters serving as habitat for bull trout. Based on an extensive literature review, Rhodes et al. (1994) recommended that no new activities that would increase water temperatures should be allowed on Federal lands where summer maximum temperatures exceed 15.6°C in waters that presently or historically supported spawning and rearing salmonids listed as threatened or endangered. We suggest that in evaluating HCPs for listed species or stocks, waters with maximum summer temperatures above 12.8–15.6°C should be considered potentially degraded, and that assessment of potential causes of degradation should be performed. Streams in certain regions (e.g., low-elevation, nonforested areas) may naturally experience temperatures exceeding these levels and thus are not necessarily impaired; however, temperatures above this range warrant a close look at potential human impacts.

Temperature tolerances of various salmonid species during each life stage have been fairly well-documented in the literature (reviewed in Tables 5-3 and 5-6). Figures 14-4, 14-5, and 14-6 summarize the temperature requirements of spring chinook salmon, coho salmon, and bull trout. We reconmend that these published ranges be used as a coarse screen for identifying temperature-related problems. If temperatures are above or below the preferred range, further assessment of potential anthropogenic causes is warranted.

Evaluating temperatures in relation to natural temperature regimes for the water body is more problematic. Ideally, reference standards should be established for each basin and water quality should be evaluated relative to those standards. Departures from reference conditions, even if State standards are not exceeded, would indicate potential impairment of aquatic ecosystem function. For example, if maximum stream temperatures exceed by more than 1–3°C those in a stream of similar size, elevation, and aspect in an unmanaged system, it may indicate the potential for indirect effects on salmonids. The difficulty lies in establishing appropriate reference standards, since few watersheds remain in undisturbed condition. Even streams in wilderness areas are subjected to grazing and may not be reliable indicators of natural temperature regimes. Therefore selection of reference sites and establishment of temperature standards should be a rigorous process. Sampled reaches must be randomly selected to ensure their representativeness and knowledge of all land uses upstream is needed. The ODEQ (1995) concluded that there is insufficient information to establish specific temperature requirements for the different stocks of salmonids and other cold-water fish in Oregon. The monitoring program outlined in Chapter 15 would aid in developing such standards.

In addition *to* the above temperature standards, we recommend that for all waters containing threatened or endangered stocks, no new activities be initiated that would result in measurable increases in stream temperature. This recommendation is consistent with the threatened and endangered provisions of the Oregon's proposed water quality standards recommended by the Technical Advisory Committee (ODEQ 1995). In addition, because of local adaptation of salmonids and the value of high-quality cold streams as habitats, we recommend against temperature criteria that allow greater anthropogenic warming in colder, high-elevation waters. Finally, we support the ODEQ (1995) recommendation that special protection be provided for coldwater refugia.

Dissolved Oxygen. Next to temperature, dissolved oxygen (DO) is the most frequently limiting water quality variable for aquatic life. State and Federal water quality criteria for salmonids vary with designated use, life stage, measurement, and statistic. For example, the criterion for intergravel DO needed in egg incubation varies from a minimum of 5 $mg \cdot L^{-1}$ and a 7-day mean of 6 $mg \cdot L^{-1}$ in Idaho to a minimum of 6 $mg \cdot L^{-1}$ and a 7-day mean of 11 $mg \cdot L^{-1}$ in the water column for Oregon. The EPA criterion is a minimum of 8 $mg \cdot L^{-1}$ and a 7-day mean of 9.5, both measured in the water column. Washington does not distinguish between incubation and other uses. Idaho requires 6 $mg \cdot L^{-1}$ or 90% saturation for all other uses. Oregon mandates a 30-day mean of 8 $mg \cdot L^{-1}$, a 7-day minimum of 6.5 $mg \cdot L^{-1}$, and a minimum of 6 $mg \cdot L^{-1}$ for cold water communities. In Washington, waters are classified by their minimum DO as fair (4 $mg \cdot L^{-1}$), good (6.5 $mg \cdot L^{-1}$), excellent (8 $mg \cdot L^{-1}$), or extraordinary (9.5 $mg \cdot L^{-1}$).

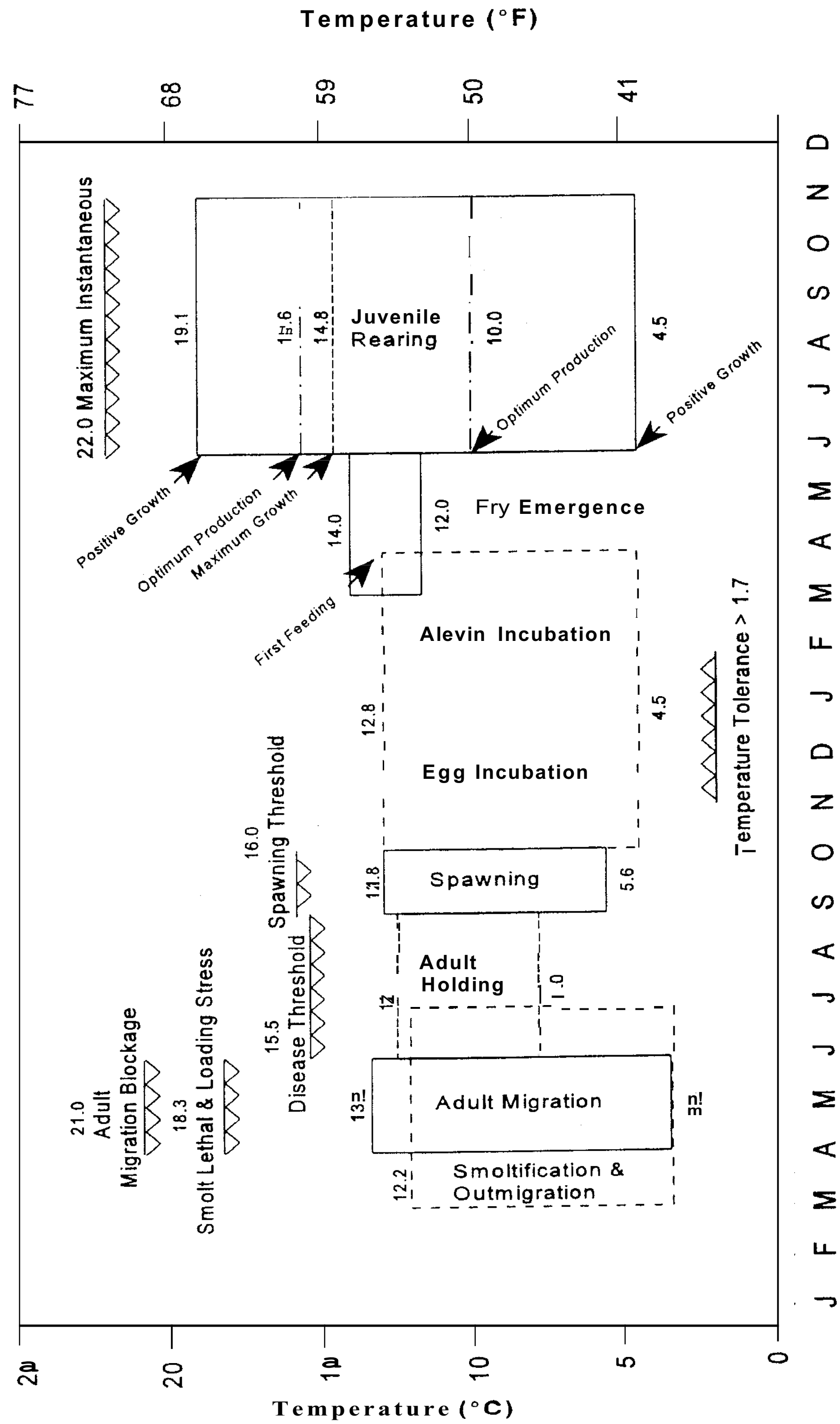

Figure 14-4. Spring chinook salmon temperature requirements by life stage. From D. McCullough (ODEQ 1995).

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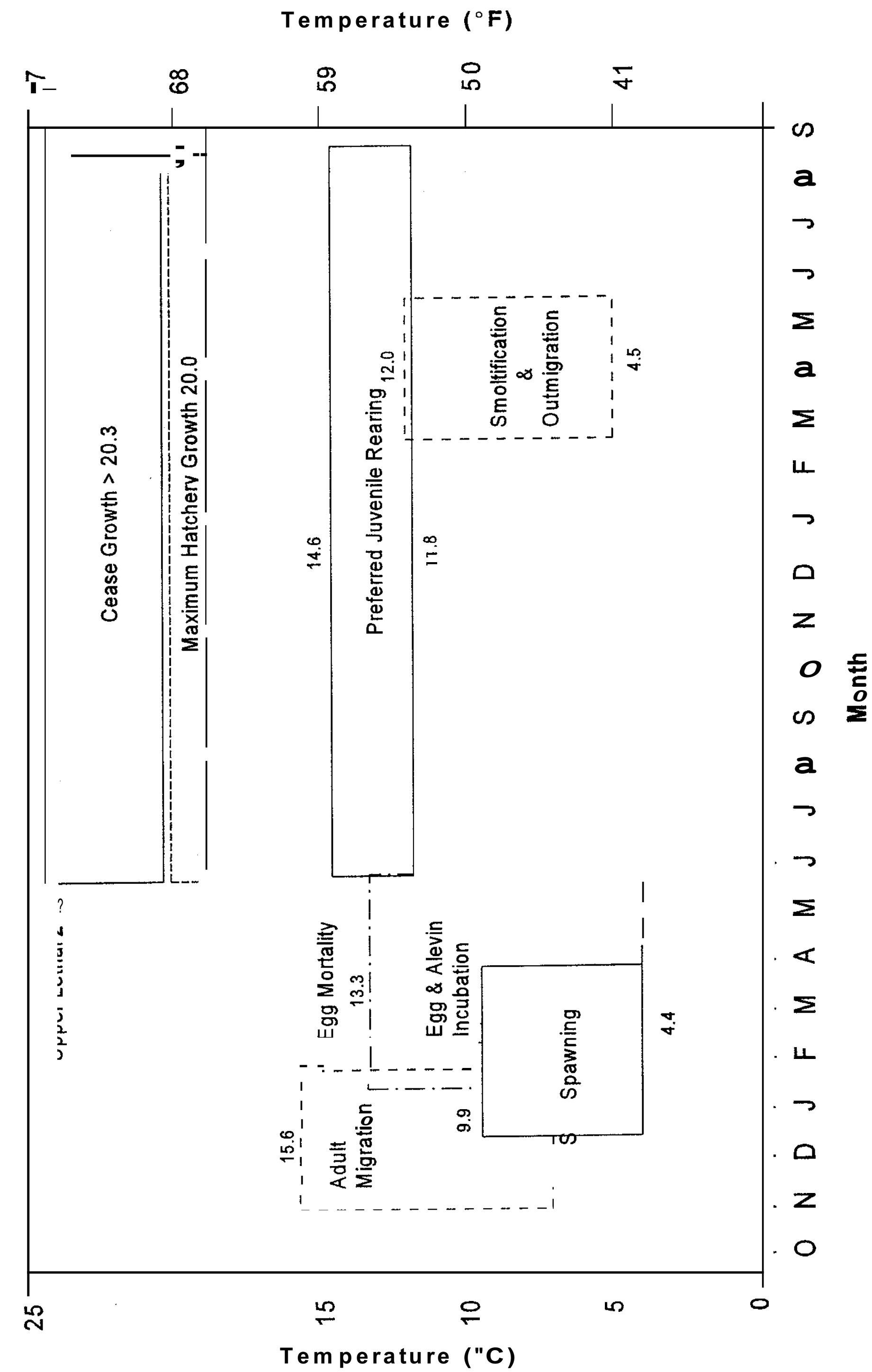

Figure 14-5. Coho salmon temperature requirements by life stage. Modified from ODEQ (1995).

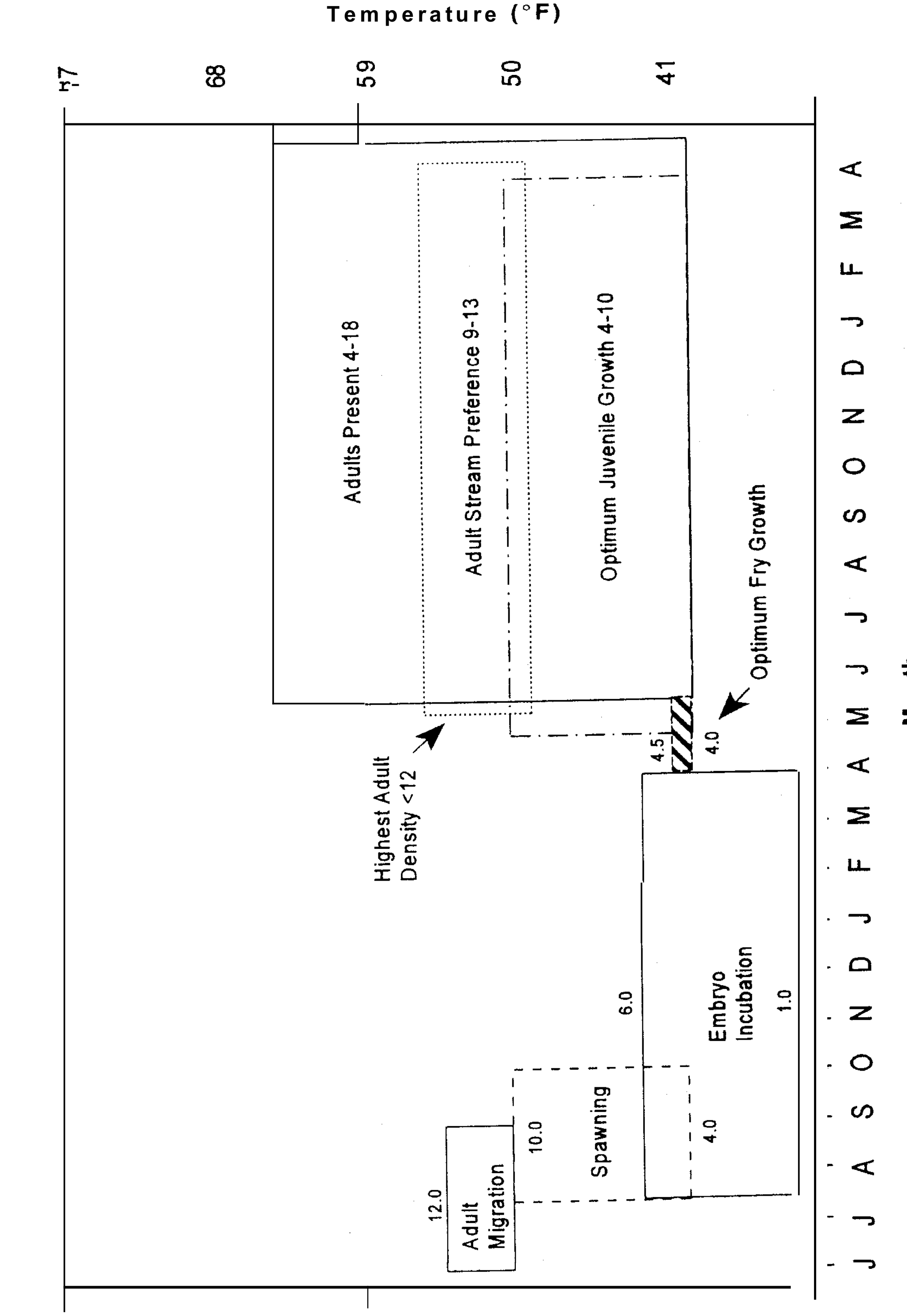

Figure 14-6. Bull trout temperature requirements by life stage. From D. Buchanan (ODFW) in ODEQ (1995).

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Laboratory and field studies indicate that intergravel DO concentrations $< 8\ mg \cdot L^{-1}$ reduce survival and size at emergence of fry, and that embryo survival is negligible below $6\ mg \cdot L^{-1}$. Salmonid rearing, the next most sensitive life stage, is affected at DO levels $< 8\ mg \cdot L^{-1}$, which decrease swimming speed and growth and alter insect emergence timing (affecting a critical food source). DO concentrations $\leq 6\ mg \cdot L^{-1}$ result in avoidance, reduced metabolic efficiency, mortality of sensitive invertebrates, and decreased salmonid harvest rates.

As with temperature, any change from natural DO concentrations places salmonids at greater risk. In addition, most of the studies upon which these results are based were derived from short-term laboratory research where cumulative effects from many other stressors were purposely eliminated. For both reasons, plus the fact that threatened and endangered species require extra protection, we recommend an intergravel DO concentration of $8\ mg \cdot L^{-1}$ measured as a spatial median minimum in egg pockets during incubation, For salmonid rearing, we recommend a 30-day mean of $8\ mg \cdot L^{-1}$, and a 7-day mean of 6.5 $mg \cdot L^{-1}$, both measured by continuous monitors with a 30 min. recording interval.

Nutrients. The principal problem with nutrients (nitrogen and phosphorus) in most salmonid waters is their role in promoting excessive algal growths in streams and lakes. The result in both cases is reduced DO when the plants respire in the dark, or when they die and decompose. Nutrient enrichment may result from municipal and industrial point sources, livestock wastes, and agricultural wastes. Excessive loading of dissolved or fine particulate carbon can also deplete DO. In all these cases, oxygen and temperature criteria should suffice in place of separate nutrient criteria. Two possible exceptions to this are the protection of estuaries and lakes from eutrophication and avoidance of ammonia toxicity. Although nutrient enrichment may be of minimal concern in streams, when the nutrients eventually reach ponded rivers, lakes, and estuaries these systems may become overloaded and depleted of sufficient oxygen for salmonids or other uses. This is another reason for basin-scale planning and waste load allocation, but here again low DO concentrations are among the early indicators of concern. Ammonia toxicity is another matter. Any measurable concentrations of ammonia are indicators of potential chronic or acute toxicity. Because ammonia toxicity varies considerably with temperature, DO, and pH (primarily), we cannot recommend a single value; instead we advise referring to the EPA criteria document (EPA 1986). We do recommend that applicants with agricultural, municipal, and industrial discharges provide data on ammonia.

Toxicants. There are hundreds of toxic organic chemicals, and even more with unknown toxicities, as well as many metals and metalloids that are toxic. However, with a few exceptions, these are unlikely to occur in most salmonid waters. Metals are likely to be a problem only in the vicinity of mines and municipal and industrial point and nonpoint discharges. Toxic organics are likely to occur in the same discharges, as well as runoff from agricultural lands. Where toxic substances are believed to be a problem, we recommend that HCPs or other conservation efforts include sampling of fish for analysis of toxic effect (See Chapter 15 and Table 15-2). Chemical concentration data from composite whole fish samples are appropriate. Simple ICP scans should suffice for metals; GC scans for particular organic toxics should be based on usage and discharge rates in a particular crop or industry instead of an entire scan. Because many pesticides now in use are short lived, the best indicators of potential problems are use rates and direct bioassessments (see Chapter 15).

14.2.5 Roads

Key Issues

Roads can contribute to aquatic habitat degradation in several ways. Roads are frequently the dominant human-caused source of sediments delivered to streams due to mass failures of cut and fill slopes and channelized surface erosion. In addition, both paved and unpaved roads result in more rapid routing of water to the stream channel, potentially increasing the magnitude and frequency of peak flow events, which in turn can result in downstream transport of LWD, scouring of the stream bed and banks, and other structural modification of the stream channel. Placement of roads near streams frequently necessitates construction of revetments, which simplify channels, alter hydraulic processes, and prevent natural channel adjustments. Finally, runoff from roads in urban areas can contain significant concentrations of substances that are toxic to fish.

Recommendations

For HCPs or other conservation efforts that encompass whole watersheds or significant portions of watersheds, we recommend that a watershed-level strategy for minimizing impact of roads on aquatic ecosystems be developed. (Such a plan would likely be excessive for small landowners; however, the Agencies may wish to consider road density in evaluating conservation plans.) The strategy should include a long-term transportation plan for the watershed, a maintenance schedule for all existing roads, replacement of road culverts that are inadequate to allow adult and juvenile fish passage during both high- and low-flow events, and removal and rehabilitation of roads that are no longer needed or that are contributing to the degradation of sensitive salmonid habitats. Issues germane to road design, construction, and maintenance at the site level are discussed in Section 14.3.1.

Preparation of a strategy for minimizing impacts of roads will require information on the current distribution and use of roads within the watershed, identification of existing drainage and erosion problems, and identification of all stream crossings and culverts. Road distribution information can be obtained through aerial photographs, whereas identification of erosion problems or inadequate culverts will require field surveys. Maps showing all roads and any associated resource problems within the area covered by the conservation plan should be generated.

Evaluation Criteria

Evaluation of the effects of roads on aquatic systems is confounded by the fact that roading virtually always accompanies other land uses, making it difficult to distinguish between causal agents. Nevertheless, some studies linking aquatic habitat conditions to cumulative effects of roading have been published. Cederholm et al. (1981) reported increased sediments in salmonid spawning gravels in watersheds where roads exceeded 3% of the total land area. Dose and Roper (1994) examined historical and current description of stream channels in nineteen watersheds in southern Oregon and found significant changes in channel morphology (widening and shallowing) in most streams where road density exceeded 0.84 $km{\cdot}km^2$. In contrast, changes in morphology were not significant in unroaded wilderness areas and drainages with lower road density. In both of these studies, logging was the predominate land use and was likely an important contributor to the observed degradation. Although these studies are insufficient for developing specific targets for road density or percent roaded area, they suggest that roads may serve as a general indicator of human disturbance and habitat quality.

14.2.6 Salmonid Distributions and Status

Key Issues

The ultimate goal of habitat conservation plans is to ensure the long-term persistence and health of salmonid populations through protection of their habitats. This entails protecting habitats required for all life stages, including adult migrations, spawning, incubation, winter and summer and rearing for juvenile and resident fish, and juvenile migrations. Effective conservation planning at the watershed level depends on knowledge of the distribution of salmonids within the watershed, the capacity of different portions of the watershed to sustain salmonids during various life stages, and the relative health of these populations. Identifying areas important to salmonid production is critical to the development of specific management strategies and prescriptions.

Recommendations

We recommend that HCPs and other conservation plans include a thorough assessment of salmonid distributions and status within the planning area. The goals of this assessment should be 1) to identify all habitats accessible (existing or potential) to salmonids, 2) to document the distribution and abundance of wild salmonids by species and life stage (including threatened and endangered stocks), 3) to identify areas of high productivity or importance for specific life stages (i.e., "hot spots"), 4) to determine trends in salmonid abundance within the watershed, and 5) to document past and present hatchery introductions to waters within the watershed. This information, together with information generated from the analysis of channel conditions and physical habitat (see Section 14.2.7), can then be used to develop specific management prescriptions that protect relatively undisturbed habitats, avoid sensitive or biologically important reaches, and restore degraded reaches.

Information on the present and historical distribution and abundance of salmonids within the watershed may be obtained from State and Tribal agencies, past stream surveys, historical records, and local residents. Because utilization of many streams by salmonids is poorly documented, field sampling may be needed to confirm recorded data. Field sampling may be especially important to document spawning habitats, particularly those in small and ephemeral streams. Information on the use of particular stream reaches by salmonids and their relative productivity is most likely to be obtained from local biologists, although such information may not be readily available. In these instances, field surveys may be needed. Historical records (e.g., biological surveys, migrant trapping data) may be useful in determining the cause of salmonid declines, such as the loss of specific life-history types within a population (see e.g., Lichatowich et al. 1995). In general, estimates of population size are unlikely to be available. The most likely source of data for population trends is counts from State-operated traps or surveys (e.g., juvenile migrants, escapement estimates, redd counts) or counts at fish passage facilities at major dams.

Specific products of the analysis should include maps of species presence and distribution within the watershed, maps of habitat use by species and life history stage, descriptions of the current status of

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populations in the watershed, descriptions of trends in abundance (when possible), identification of habitats used by threatened and endangered species or stocks, and narrative summaries of stocking history.

Evaluation Criteria

Because the purpose of this analysis is primarily to gather information, no evaluation criteria are proposed. Assessments of habitat condition are discussed in the following section.

14.2.7 Channel Condifionand Physical Habitat

Key Issues

Channel conditions and physical habitats of salmonids have been substantially degraded by land-use practices throughout much of the Pacific Northwest. Stream channels have been altered directly through channelization, revetments, stream cleaning, and dam construction, and indirectly through changes in hydrology, sediment loading, and large woody debris recruitment (reviewed in Chapter 6). In many instances, cumulative effects of numerous land-use practices have resulted in streams that lack structural and hydraulic complexity, pool and off-channel habitats used for rearing and refugia, and high-quality spawning gravels. Artificial constraints on stream channels, changes in hydrology and sediment loading, and the loss of large woody debris together have destabilized stream channels, making them more susceptible to scouring during high flows, further altering substrate composition. These changes in turn influence spawning and rearing habitats of salmonids, as well as production of invertebrates that salmonids require for food.

Recommendations

Because the physical habitat degradation most often results from changes in other watershed processes, measures designed to minimize changes in watershed hydrology, sediment loading, and recruitment of large wood are likely to result in improved physical habitat for salmonids. However, where channel conditions have already been degraded it may be necessary to apply more conservative measures to facilitate recovery and prevent further damage. Therefore, we recommend that HCPs include a watershed-wide assessment of channel and habitat conditions. The purpose of this assessment should be several fold: to characterize channel forms and geomorphic processes directly affecting channels in the watershed; to identify reaches that are sensitive to large variation in runoff, sediment supply, and large woody debris; to identify reaches that have been subject to human-caused and natural disturbances (e.g., land use, flow diversions, stream cleaning, splash dams, channel incision, channelization, floods, and wildfires) and, where relevant, the land use practices associated with those disturbances; and to evaluate the effects these disturbances have had on sensitive reaches and how long it takes sensitive reaches to recover from disturbances (REO 1994).

Characterizing channel forms and geomorphic processes involves mapping of hillslope and valley features in the watershed, including floodplains, terraces, estuaries, alluvial fans, streamside slides, earthflows, and debris-flow termini, lakes, dams, and glacial moraines. The identification of sensitive reaches entails identifying and evaluating the condition of alluvial valleys or other reach types that are typically important to salmonid production. To evaluate past disturbance events, data on streamflows, landslides, vegetation cover, and land use can be obtained. Agency records and interviews with local residents provide information about past human disturbances, including timber harvesting, splash damming, mining, grazing, water diversions, stream channelization, and other activities that have likely modified channel attributes. Field sampling should be conducted *to* characterize specific habitat attributes including channel width and depth, bank condition, substrate composition, LWD abundance and size, pool frequency and size, and presence of beaver ponds and off-channel rearing habitats. Procedures for performing channel assessments can be found in the channel condition and physical habitat modules in the *Federal Ecosystem Analysis Guide* (REO 1995) and the stream channel assessment module of the Washington watershed analysis manual (WFPB 1994).

In assessing habitat conditions, a number of habitat concerns related to specific life stages should be considered (Table 14-2). For adult migration, key objectives include identifying barriers to migration, assessing frequency and condition of holding pools, and identifying important cold-water refugia, particular for species such as spring chinook that oversummer within streams. For spawning and incubation, HCPs should address the availability and condition of spawning gravels (including intergravel dissolved oxygen), as well as evidence of erosion, scouring, and dewatering of spawning redds. Summer and winter rearing habitats for juveniles and resident fishes should be identified and their conditions documented; habitat concerns include diminished frequency, size, and depth of pools, loss of off-channel habitats, reduced structural and hydraulic complexity (e.g., LWD), elimination of beaver ponds, and loss of both summer and winter cover. Habitat issues related to juvenile migration include water quality and quantity, instream cover,

Table 14-2. Habitat concerns, by salmonid life stage, that should guide conservation efforts.

Life stage	Habitat concerns
Adult migration	Impassible or poorly designed culverts Impassible dams or diversions Impassible because of water quality (high temperatures, pollutants) Reduced frequency of holding pools Lack of cover in holding pools Reduced cold-water refugia
Spawning and incubation	Availability of spawning gravel Siltation of spawning gravels Erosion of spawning gravels Evidence of redd scour Evidence of redd dewatering
Juvenile rearing	Evidence of diminished pool frequency, area, or depth Reduced cover for summer rearing habitats Poor water quality (high temperatures, pollutants, low DO) Dewatering of stream reaches Reduced hydraulic heterogeneity Reduced invertebrate production Reduced pool frequency (winter refugia) Reduced off-channel rearing areas Loss of winter cover in substrate interstices (increased cobble embeddedness)
Juvenile migration	Poor water quality (high temperatures, gas supersaturation) Lack of instream cover Impassible barriers (physical, chemical, biological)

and migration barriers. Each of these habitat concerns should be discussed relative to historical and current conditions. The *Federal Ecosystem Analysis Guide* (REO 1995) includes a module for assessing physical stream habitats, with emphasis on needs of salmonids.

Evaluation Criteria

Evaluation of salmonid habitats is complicated by the fact that there is substantial natural variability in habitat attributes. This variability arises from differences in the rates of watershed processes (water, sediment, and wood delivery) as well as differences in channel morphological features that control the fate of those materials once in the channel, including stream gradient, channel width, degree of constrainment, and bed material. We believe that, for most habitat attributes, existing data are insufficient *to* justify numeric criteria for various habitat elements, partly because there are so few unmanaged systems remaining in the Pacific Northwest (especially nonforested systems) to provide appropriate reference points, and partly because methods of measuring and reporting habitat characteristics have rarely been consistent between studies. Nevertheless, published data on habitat attributes in unmanaged systems may provide coarse-level metrics for assessing whether specific stream segments may be in degraded condition.

Channel Type. Channel type is an important variable for stratifying data related to physical habitat (e.g., pools, LWD frequency), channel conditions, channel sensitivity, and salmonid distribution information. Channel segments should be classified as erosional or depositional, constrained or unconstrained, and by stream gradient. No specific criteria are relevant since these attributes are determined entirely by landform.

Large Woody Debris. The frequency and volume of large woody debris within stream channels is influenced by a number of factors including stream size and gradient and the age and structure of riparian vegetation, which determine loading rates of large wood. Figure 14-7 illustrates the high degree of variability in the frequency of large wood pieces in relation to stream width for unmanaged systems in the Pacific Northwest. Bilby and Ward (1989) reported that the mean size (measured as diameter, length, and volume) of individual wood pieces increased with increasing stream width, but that the frequency of LWD pieces decreased with increasing stream size. They attributed these trends to the

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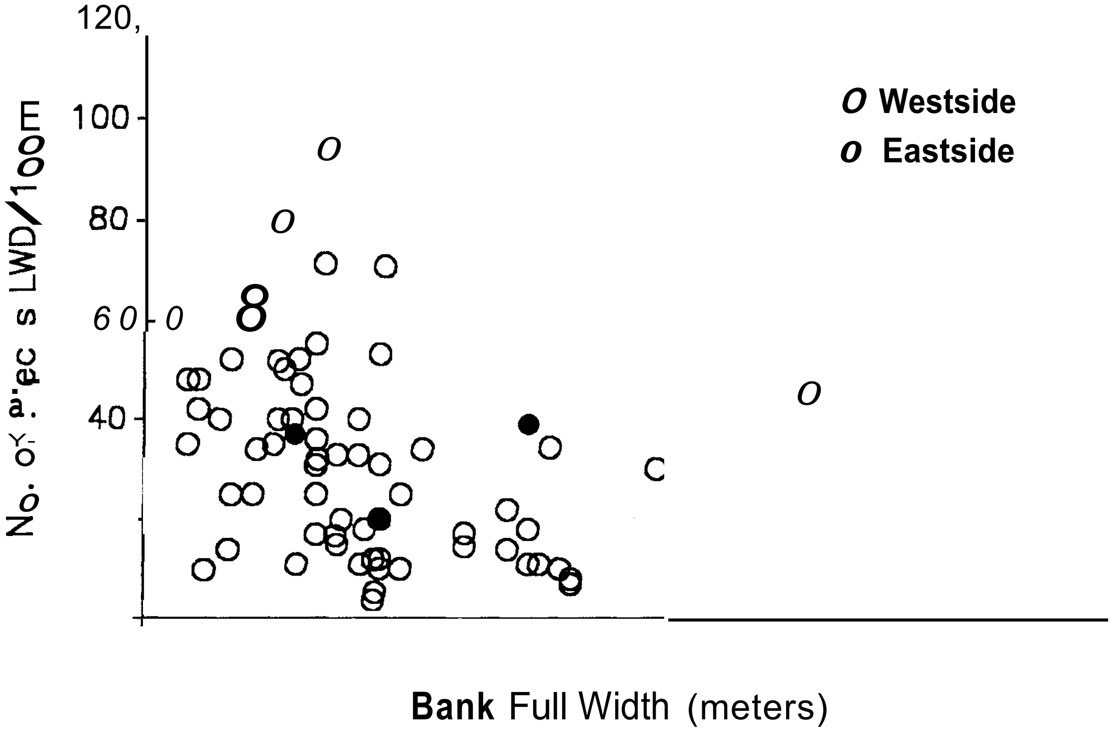

Figure 14-7. Abundance of large woody debris in relation to channel width for streams in the Pacific Northwest and Alaska. Data compiled from Robison and Beschta (1990), Cederholm et al. (1989), Murphy and Koski (1989), Fox (1992), Bilby and Ward (1991), Leinkamper and Swanson (1987), Long (1987), Fausch and Northcote (1991), Ralph et al (1991), Ralph et al. (unpublished data), and Dincola (1979).

greater stability of smaller size fractions in narrower streams, Other studies have indicated higher frequencies of wood in larger streams (e.g., Robison and Beschta 1990; Murphy and Koski 1989) or no trend in wood frequency with stream size (Ralph et al. 1991). Studies relating LWD frequency to stream gradient have been similarly variable. Murphy and Koski (1989) and Robison and Beschta (1990) found that LWD counts were highest in low-gradient (0.5%) reaches, but that at gradients of 1%–2.5% there was no consistent trend. Similarly, data from Sullivan et al. (1987) suggest no obvious trend in LWD frequency for gradients ranging from 3%–5%.

Peterson et al. (1992) stressed the need to establish target conditions for LWD in streams as a means of determining habitat condition. We concur that establishing targets is an important goal; however, in most instances data for developing such targets are generally not available. Peterson et al. (1992) recommended using regression equations developed by Bilby and Ward (1991) relating frequency and volume of LWD to stream width to set targets for LWD. These equations represent the most complete data available that we know of for Pacific Northwest streams; however, we suggest that they only be applied to the types of streams for which they were derived, namely forested streams in western Washington with widths of 4–19m and gradients from 1%–18%, and even then with considerable caution because of the high natural variation within this data set.

In addition, LWD counts alone may be poor indicators of habitat condition and effects of management. Ralph et al. (1991) found no difference in the number of LWD pieces between streams in managed and unmanaged forests, but that the average size of LWD pieces was significantly smaller in harvested systems. They therefore concluded that counts of LWD pieces alone are not useful as management objectives because they fail to account for important differences in the size (and therefore stability) of wood pieces. Bilby and Ward (1991) reported significantly higher frequencies of LWD in streams in old-growth forests than in second-growth or recently clearcut stands. As noted earlier, larger sized "key pieces" perform a critical function in retaining smaller debris. NMFS (1995) has developed provisional criteria for larger pieces of LWD for streams in the Coast Range and east of the Cascades. They concluded that streams in the Coast Range should be considered "properly functioning" when they exceed 80 pieces/mile of wood larger than 61 cm (24 in) in diameter by 15.2 m (50 ft) in length, and where adequate sources for woody debris recruitment are present in the adjacent riparian zone. East-side streams are considered properly functioning where LWD exceeds 20 pieces/mile of wood greater than 30.5 cm (12 in) and 10.7 m (35 ft) in length and where adequate sources of recruitment exist.

The regression equations of Bilby and Ward (1989) indicating increasing average volume of individual debris pieces with increasing stream size reflects the greater ability of larger systems to transport smaller wood. This trend should not be construed to mean that larger pieces are unimportant in small streams or that large diameter trees could be removed without impairing ecological function. Pool area and sediment retention are both related to the size of wood pieces (Bilby and Ward 1989). In addition, small streams, even those without fish, may be important sources of LWD for downstream, fish-bearing reaches.

In developing LWD criteria, we therefore suggest that stream reaches need to be stratified by width, gradient, and ecoregion (or other indicators of vegetation type), and that both counts by size class and volumetric measures be employed. Rhodes et al. (1994) recommend against establishing specific numeric standards for in-channel LWD and instead recommend full protection of LWD recruitment from the riparian zone. We concur with the recommendation of Peterson et al. (1992) that a common definition of large woody debris be adopted throughout the region so that, over time, comparability of studies will be enhanced, allowing more meaningful targets to be defined. They recommended wood greater than 10 cm diameter by 2 m length be classified as LWD because the majority of studies have used this definition. We recommend that this definition be used to define minimum piece size for LWD but believe it is important to sytematically quantify larger-size fractions as well. The frequency distribution of different size classes is likely to be more important than total number (or total biomass) of all pieces exceeding some minimum length.

Pool Frequency and *Qualify.* Pool habitats are required by most salmonids at one or more life stages (reviewed in Chapter 5). The loss and reduction in quality of pool habitats has been identified as a major source of habitat degradation through large portions of the Pacific Northwest (McIntosh et al. 1994a). These alterations have resulted from removal and lack of recruitment of large woody debris, combined with increased sediment delivery to streams.

Pool formation depends on a wide variety of factors, including gradient, channel width, and LWD or other physical obstructions. Consequently, there is a high degree of natural variability in pool frequency and volume, even in unmanaged systems. Furthermore, methods for defining pool habitats have varied substantially among studies, making comparisons difficult. The most frequently used metric of pool habitats is the percent of total surface area in pools. Other indices include pool frequency, volume, and residual depth, the latter two of which may provide a better indication of pool quality than percent pool area or frequency. Pool frequencies for managed and unmanaged streams in Washington are shown in Figure 14-8 (see review in Peterson et al. 1992). In eastern Oregon and Washington, frequencies of deep pools (> 1.6 m) in unmanaged systems ranged from 2.7 to 14.3 per kilometer of stream (B. McIntosh, USDA Forest Service, Pacific Northwest Station, personal communication).

Based on an extensive review of the literature, Peterson et al. (1992) recommended a target condition for percentage area of the stream surface area comprised of pools of 50% for Washington streams with gradients < 3%. MacDonald et al. (1991) concluded that total area, depth, or frequency of pools may not always be a reliable indictor of anthropogenic effects. Because of the high degree of natural variation, we conclude that available data are inadequate to recommend specific criteria for pool frequencies that would be indicative of stream condition. The 50% target recommended by Peterson et al. (1992) may be useful as a first indicator of potential degradation, but should not be widely applied outside of the region. NMFS (1995) has adopted provisional guidelines for pool frequency based on channel width. These are shown in Table 14-3. Again, we suggest that these values be used as general indicators, rather than absolute measures of habitat condition. The monitoring strategy suggested in Chapter 15 would produce consistent and reliable data from which regional targets could be derived.

Bank Stability. Erosion and slumping of streambanks can be an important cause of sedimentation and channel degradation in streams. Thus, bank stability can be a useful indicator of channel condition. However, we found no published information that would support establishment of specific numeric criteria for bank condition. Some bank instability is likely even in unmanaged systems. In wide alluvial valleys, lateral migration of the stream occurs through bank erosion and point bar accretion (MacDonald et al. 1991). In constrained reaches, temporary bank instability may follow the

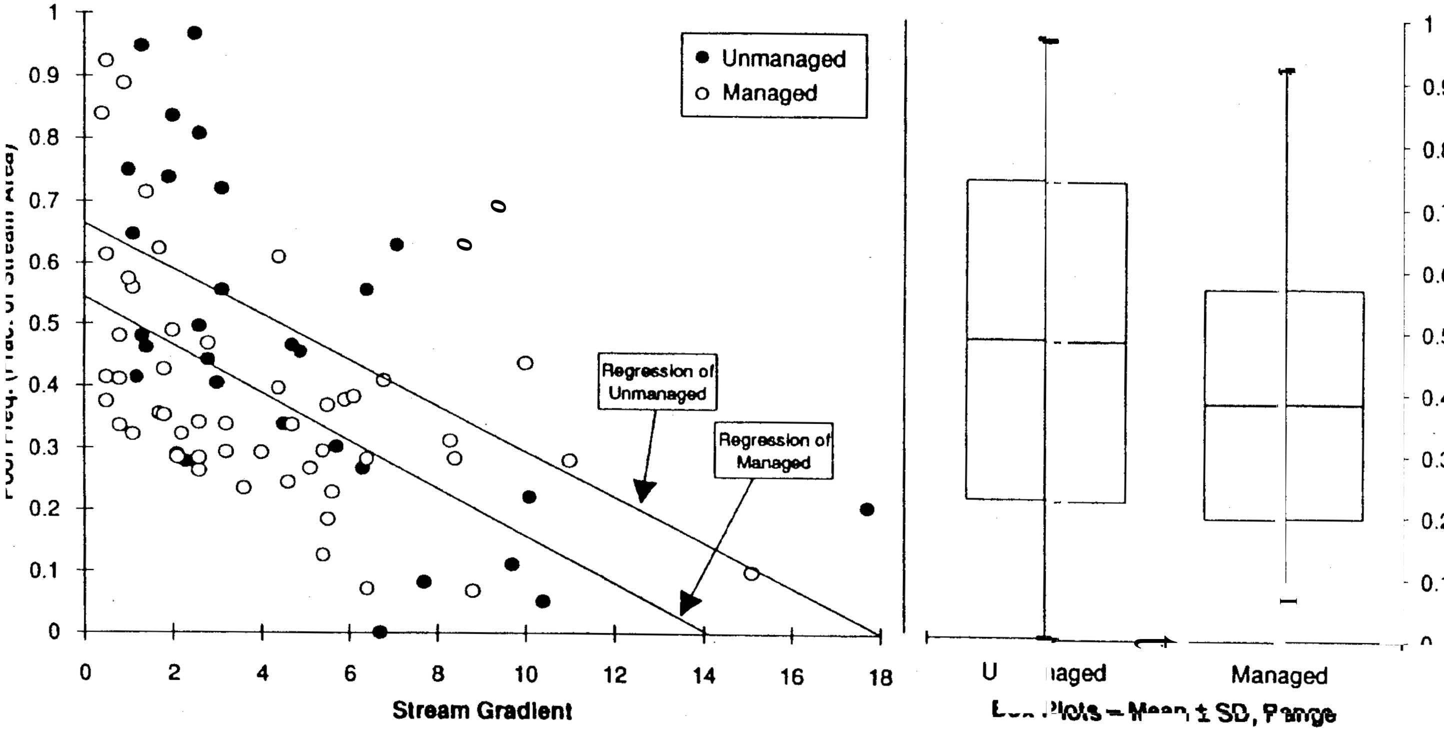

Figure 14-8. Relationship between fraction of the stream area comprised of pools and gradient for streams in managed and unmanaged forests in Washington. After factoring out the effect of gradient, pools area was significantly higher in unmanaged systems. From Ralph et al. (1991) in Peterson et al. (1992). Reprinted with per…

Table 14-3. Provisional minimum pool-frequency standards for determining properly functioning salmonid habitats. Proposed by NMFS (1995a).

Channel width (feet)	# Pools/mile
5	184
10	96
15	70
20	56
25	47
50	26
75	23
100	18

input of LWD that redirects hydraulic energy. Rhodes et al. (1994) and NMFS (1995) recommend that watersheds containing threatened and endangered species be managed so that 90% of streambanks are stable, although they provide no quantitative information to support this target. They suggest that for areas where this standard is not met, activities that would decrease stability of forestall recovery should not be permitted until the standard is reached or a trend of improvement is statistically demonstrated. We found no additional published information recommending criteria for bank stability, nor did MacDonald et al. (1991).

Substrate Composition. Excessive concentrations of fine sediments in spawning and rearing habitats can reduce survival of embryos and alevins by entombing embryos and reducing flow of dissolved oxygen, decrease the availability of interstitial hiding places, alter production of macroinvertebrates, and reduce total pool volume. A nuniber of different methods have been proposed for quantifying substrate composition and assessing the degree of sedimentation on substrate composition. For spawning gravels, fine sediments are commonly expressed as the percentage of sediments by weight or volume smaller than a particular particle size, usually < 0.85 mm or < 6.4 mm, two standard dimensions of substrate sieves. The effect of fine sediments of a particular fraction on incubating embryos and alevins depends on percentages of other size fractions (reviewed in Peterson et al. 1992), consequently, there can be substantial difference in results between studies. Bjornn and Reiser (1991) reviewed data from four laboratory studies and found that percent emergence of swim-up fry begins to decrease when percent fine sediment smaller than 2-6.4 mm (definition differed among studies) exceeded 15%. They also presented data for five salmonids indicating that embryo survival begins to decrease when percentage fines exceed 10%-25% (particle size < 6.4 mm), with rainbow and cutthroat trout being more sensitive than steelhead trout, kokanee, and chinook salmon (Figure 4.9 in Bjornn and Reiser 1991). Rhodes et al. (1994) concluded that survival to emergence for chinook salmon in the Snake River Basin is probably substantially reduced when fine sediment concentrations (< 6.4 mm in size) in spawning gravel exceed 20%. They recommended suspension of ongoing activities and prohibition of new activities where this standard is exceeded. Peterson et al. (1992) reviewed eleven laboratory and field studies of survival to emergence and concluded that in most instances an increase in percent fine sediment (< 0.85 mm in size) from 11% to 16% would result in a reduction in survival to emergence. Reported values were estimated by eye from figures and summary data from these studies.

Natural levels of fine sediment in spawning gravels vary with gradient and underlying geology. In western Washington, percent fine sediments (< 0.85 mm in size) in spawning gravels in unmanaged basins have been reported to range from 6.4% to 14.5% (reviewed in Peterson et al. 1992). Based on this review, Peterson et al. (1992) proposed a target of 11% fine sediments in spawning gravels for low-to-moderate gradient streams in Washington. They noted that this target should not be indiscriminately applied across geologic boundaries and that higher levels do not necessarily indicate degraded conditions. Rather, they suggest that where sediment levels exceed this target, the potential causes of sedimentation should be thoroughly examined. We concur with these recommendations.

Cobble embeddedness has frequently been used as an indicator of the quality of over-wintering habitat for juvenile salmonids, which hide in coarse substrate interstices during periods of low temperature and are adversely affect if these spaces become filled with sediment. MacDonald et al. (1991) provide a review of methods for measuring embeddedness in streams and difficulties associated with these methodologies. The State of Idaho is currently proposing embeddedness standards for protecting salmonid fry over-wintering habitat (MacDonald et al. 1991). These standards would call for cobble embeddedness not to exceed natural baseline levels at the 95% confidence level, where baseline levels are determined for unmanaged watershed with similar characteristics. Rhodes et al. (1994) recommended that watersheds should be managed so that cobble embeddedness averages less than 30% in winter rearing habitats; however, they provided no empirical support for this particular threshold value. Peterson et al. (1992) suggested that an interstitial space index (ISI) developed by Vadenboncouer (1988) is more sensitive to change and bears a closer relationship to juvenile habitat requirements than cobble embeddedness; however, they concluded that data on interstitial space in Washington was lacking and therefore made no recommendations regarding appropriate standards. Because of the lack of available information, we make no specific recommendations regarding targets for interstitial space in rearing habitats. Nevertheless, monitoring of cobble embeddedness or interstitial space may allow detection of trends at a particular site (see Chapter 15).

14.2.8 Summary and Conclusions

Watershed-level planning has four important goals: 1) to address cumulative effects through time and space of multiple human activities and natural variation on aquatic habitats, 2) to assess current conditions within the watershed and identify existing resource problems, *3)* to relate existing resource problems to site conditions and land management practices, and 4) to use the knowledge gained to avoid future activities in areas that are sensitive to perturbations. Watershed analyses can also help identify and prioritize habitat restoration opportunities. In the preceding sections, we have reviewed specific processes that have been identified as important in affecting salmonids and their habitats. For ease of discussion, these processes were reviewed individually; however, it is important to recognize that upland, riparian, and aquatic processes interact in complex ways and that, consequently, conservation plans need to address all processes in a comprehensive and integrated manner. For example, improvements in large woody debris recruitment resulting from riparian buffers may be negated if peak flows or debris torrents increase in frequency in response to poor upland management. In addition, many factors may act synergistically to the detriment of salmonids. Lower stream flows, higher light levels (and photosynthesis), and warmer temperatures may combine to reduce oxygen levels in streams to levels that would not be reached by each factor alone. Similarly, the resistance of salmonids to disease is influenced by many water quality attributes (e.g., temperature, pollutants, oxygen levels). These examples represent only a few of the many possible ways in which multiple stressors may interact to produce effects greater than would be anticipated based on any single factor.

14.3 Site Level

The regional/basin and watershed-level analyses proposed in Sections 14.1 through 14.2 are designed to provide the context from which site-level prescriptions can be made that will effectively protect salmonids and, if desired, other resource values. Knowledge of existing watershed conditions and resource problems, as well as the potential sensitivity of different areas of the basin or watershed to land use activities, will enable owners of nonfederal lands to better avoid undesirable effects on aquatic ecosystems and the salmonids they support. Nevertheless, it is the cumulative effect of activities occurring at the site level that ultimately determine the health of aquatic and terrestrial ecosystems.

In this section, we briefly review specific management practices applied at the site level that afford the greatest protection to salmonids and their habitats. By site level, we mean the specific portions of the landscape upon which land-use activities are carried out by a landowner, such as harvest units, grazing units, agricultural fields, mining sites, and areas of urban development. We begin with a discussion of practices that are common to more than one land-use type and conclude by identifying practices specific to logging, grazing, agriculture, urbanization, and mining. We reiterate that the recommendations contained in the following sections assume that the affected watersheds support salmonids that are either listed or likely to become listed as threatened or endangered under ESA. Recommendations for protection of other species or resource values would likely differ. As specified in Section 10 of ESA, approval of an HCP requires that landowners discuss alternatives to a "taking" of a species that were considered and why these alternatives were not implemented.

14.3.I General Practices

Riparian Buffers

Riparian buffers along all streams should be maintained, regardless of the type of land use. Specific dimensions of riparian buffers and management prescriptions will likely vary with site conditions and conservation objectives. **A** detailed discussion of riparian buffers can be found in Section 14.2.3. Aspects of riparian management relevant to specific land uses are discussed in subsequent sections.

Road Design, Construction, and Rehabilitation

Roads frequently constitute the dominant source of sediments delivered to streams. As discussed in Section 14.2.2, a long-term transportation plan for the watershed is desirable to minimize total disturbed area. Thus cumulative effects need to be considered when planning site-level 'activities.

It is beyond the scope of this document to recommend specific engineering standards for roads, however, we recommend the following general guidelines for road construction regardless of land

AR053287

use type. Roads should be located away from streams, riparian areas, wetlands or other moist areas, and unstable hillslopes. Stream crossings should be avoided across or above reaches identified by watershed analysis as critical habitats for salmonid spawning. If crossings are unavoidable, they should be constructed in locations where the least amount of change in channel structure is needed and where potential for upslope impacts is minimal. Long-span skylines can be used to transport logs across steep-walled canyons, eliminating the need for creek crossings altogether, while minimizing construction costs. Culverts should be installed at angles and heights that allow passage during both high- and low-flow conditions. They should be placed below the original stream bed and have gradients less than 1%. Capacity should be sufficient to withstand 100-yr floods and care should be taken to ensure that water velocities in culverts are not excessive for fish passage.

New road construction should be minimized or avoided in areas where sediment-related degradation of salmonid habitats is identified in watershed analysis until the sources of that degradation have been alleviated. However, there may be instances where construction of new roads may reduce total sediment loads if it allows other, erosion prone roads to be retired and reclaimed. Construction methods for roads should seek to minimize the areal extent of soil disturbance. Landowners should adhere to minimum standards for width and gradient to reduce the amount of site disturbance. The height of cut slopes should be minimized to reduce the risk of failure, and materials should be end hauled rather than side cast where risks of slope failure are high. Areas disturbed during construction should be stabilized and reseeded following completion. Water needed for construction should not be withdrawn from streams bearing or upstream of habitats of threatened or endangered salmonids. Fuel should be stored away from streams and riparian areas, where the risk of contamination from spills is negligible. On slopes and soils where erosion potential is high, roads should be built only during the dry season.

Adequate drainage from road surfaces is critical to minimizing the erosive energy of water. Drainage control for new road construction should seek to 1) disperse, rather than concentrate, runoff: this can be accomplished using outsloped roads, cross drainage structures, and frequent relieving of drainage ditchlines; 2) avoid altering natural drainage patterns or discharging of water into non-drainage areas or fill slopes; 3) design drainage structures to withstand 100-yr-interval floods; 4) control scouring at culvert outlets using energy dissipators. All drainage ditches and culverts should be routinely maintained to prevent clogging with debris and sediments. Where drainage structures along existing roads are inadequate and causing erosion problems, these roads should be reconstructed with appropriate drainage or removed and reclaimed. A more complete list of recommendations for minimizing impacts of roads on aquatic systems is given in Table 8-1.

Active Restoration

Most of the recommendations in this document are designed to reduce or eliminate anthropogenic stressors that disrupt natural watershed processes and result in aquatic habitat degradation. These "passive restoration" techniques include such practices as 1) riparian buffers that preclude logging, grazing, agriculture and urban development; 2) cessation of irrigation withdrawals; 3) elimination of chemical use in farming, logging, and agriculture; and other practices that require no direct human intervention, other than alleviating the stress on the ecosystem. There are occasions, however, where direct mechanical, chemical, or biological intervention may be needed to accelerate the recovery of salmonid habitats or prevent further degradation. These "active restoration" techniques include such things as obliteration and revegetation of roads, removal or replacement of inadequate culverts or other barriers to migration, addition of logs or other structures to streams, removal of dams or rip-rap structures, gravel cleaning, vegetation manipulations (e.g., juniper removal, thinning, herbicide applications), use of prescribed fire, reintroduction of native species, and application of piscicides.

Kauffman et al. (1993) note that the greatest failure of many active restoration techniques occurs when these methods are implemented before the primary anthropogenic stressors have been eliminated. Furthermore, active restoration techniques frequently fail because factors limiting salmonid production are incorrectly identified. In each of these instances, costly restoration practices may fail to provide the presumed benefits to salmonids, or worse, may result in additional damage to stream ecosystems. Finally, many instream manipulations fail because the geomorphic context of a particular site is not considered.

Instream structural additions, in particular, have been widely employed throughout the west as a means of restoring structure to streams that have been degraded by past logging, splash damming, stream cleaning, mining, and grazing practices. Large sums of money have been devoted to instream restoration techniques, despite the frequent failure of structures to achieve desired biological outcomes or to withstand high flow events (Beschta et al. 1991; Frissell and Nawa 1992). Moreover, artificial structures can have significant negative effects on fish habitats. Hard structures can prevent natural channel adjustments, facilitate changes in channel morphology through changes in channel hydraulics (e.g., channel incision or widening), and exacerbate bank erosion and sediment inputs (Beschta et al.

1991). **A** common refrain in the literature related to active restoration, and instream manipulations in particular, is that these methods should be interim measures until natural functions can be restored; they should not be viewed as substitutes for or exemptions from habitat protection (Reeves et al. 1991; FEMAT 1993; Rhodes et al. 1994; Murphy 1995). We concur with this assessment. Placement of structures in streams should occur only as an emergency measure for preventing additional degradation, and then only after activities responsible for the degradation have ceased. Other active channel restoration techniques, such as reconnecting streams to off-channel areas, have greater potential for restoring salmonid abundance. These activities should be carefully planned and should not be considered substitutes for sound riparian management. Upland restoration techniques, such as erosion control programs, stabilization and revegetation of unused roads, and replacement of dysfunctional culverts have a higher likelihood of success with minimal risk to aquatic habitats.

74.3.2 Forest Practices

The impacts of forest practices can be reduced through a variety of practices (reviewed in Section 8.3). Emphasis should be given to minimizing the areal extent and intensity of disturbance to vegetation and soils. The site prescriptions discussed below provide high levels of protection for aquatic ecosystems.

Riparian Buffer Zones

Riparian buffers on all pernianent and ephemeral streams are recommended for protecting salmonid habitats. The specific dimensions of riparian buffers should depend on the specific ecological functions for which protection is desired (reviewed in Section 14.2.3). Once appropriate buffer widths are determined, we recommend that no forestry activities be allowed within these buffers in old-growth or late-successional forests. In second-growth forests, limited harvest, thinning, planting, or other manipulations may be appropriate in order to facilitate recovery and protection of key functions that have been identified through watershed analysis. These activities may be particularly appropriate in coastal forests where natural coniferous vegetation has been replaced by dense stands of alder and salmonberry, leaving little opportunity for conifer regeneration (Berg 1995). These activities should only be allowed when they can be performed without adversely impacting other riparian functions or values; use of ground-based equipment within the riparian zone should be avoided or minimized.

Silvicultural System

Rotation schedule in upland forests can be adjusted to minimize the total area in a disturbed state at any given time to minimize cumulative hydrologic effects (see Section 14.2.1). Sedimentation and soil compaction can be minimized if timber harvest, road construction, and site preparation activities are conducted during seasons of the year when potential for erosion is lowest. In most areas this will be the dry season; however, harvesting on snowpack may be effective in minimizing soil disturbance.

Harvest methods should be determined based on site-specific conditions. Logging should be avoided on areas identified in the watershed analysis as high risk for mass failures. In general, high risk areas will be those with steep slopes ($> 30°$) and unstable soil where there is a high probability that material will be delivered to the stream (see Section 14.2.2). Selective harvest, rather than clearcutting, is recommended for areas identified as moderately sensitive. Clearcutting *is* recommended only in areas of low sensitivity (i.e., low slopes, stable soils, far from streams).

Harvest System

Harvest systems should be determined based on site-specific conditions. On highly sensitive sites, helicopter logging minimizes disturbance to soils. Cable systems that partially or fully suspend logs off the ground (e.g., skyline) cause less disruption to soils than those where logs are not suspended (e.g., skidding). Use of ground-based equipment is advised only in low-risk areas.

For ground-based logging operations, designated skid trails can be established to minimize total area subject to compaction. Beschta et al. (1995) suggest that the percent compacted area can be reduced to 5% with careful planning. Careful planning of skid trails not only reduces soil disturbance but helps maintain high site productivity.

Site Preparation

Site preparation involves treatment of slash from logging operations and management of vegetation prior to planting. Appropriate treatment of slash depends on the specific resource concerns at the site. Where sediment delivery to streams, compaction of soils (by equipment used), and retention of nutrients on site are concerns, we recommend against burning of slash. Instead, we recommend scattering, mechanically chopping, or windrowing slash to control surface erosion. In some instances, such activities may be inappropriate if build-up of fuels would increase the risk of fires. Vegetation management entails removal of shrubs or trees by mechanical, chemical, and fire treatments. Mechanical treatments involving heavy equipment and scarification of soil should be avoided where sediment delivery and hydrologic alterations are of concern. Chemical treatments should be applied only outside of riparian buffer areas, including those of headwater streams; for aerial spraying of herbicides and fertilizers, applications should be conducted to prevent drift into the riparian zone (apply parallel to riparian zone and under low wind conditions). Mixing of chemicals and washing of equipment should be conducted only where contamination of waters will not occur. Low-intensity prescribed fires may be appropriate in eastside forests for vegetation management.

Reforestation

To minimize the duration of hydrologic and erosion impacts, replanting of harvested areas should occur within two years of harvesting. Where reforestation occurs in the riparian zone, the goal should be to maintain natural vegetative assemblages in order to restore natural quantities, compositions, and seasonality of leaf litter inputs.

14.3.3 Grazing

Grazing impacts can be minimized by controlling livestock distribution, animal numbers, timing of forage use, kind and class of livestock, and total forage use, as well as by allowing complete rest from grazing (Platts 1991). The effectiveness of grazing strategies in protecting salmonids depends on the potential vegetation at the site; consequently, grazing strategies need to be tailored to the site and specific habitat concerns identified in the watershed analysis,

Riparian Buffer Zones

Riparian buffers are recommended for all permanent streams that support salmonids, as well as ephemeral streams that influence salmonid habitats downstream. The specific dimensions of riparian buffers should depend on the specific ecological functions for which protection is desired (reviewed in Section 14.2.3). We recommend that grazing be excluded in all riparian areas where function of riparian vegetation (shading, LWD, leaf litter inputs, sediment and nutrient control, bank stabilization) is currently impaired until such time as these functions are restored. This can best be accomplished by removing livestock or fencing of riparian areas. Once recovery has occurred, riparian grazing should be limited in duration and intensity to ensure these functions are maintained. Specific grazing strategies and their relative effectiveness in protecting aquatic habitats are shown Table 8-2. Only those with good-to-excellent ratings for all functions should be eniployed. Where riparian vegetation has been lost or reduced by livestock grazing, planting of native shrubs and trees is recommended to accelerate recovery.

Watering Facilities

Watering facilities should be located away from the stream channel and riparian zone, where possible. Where riparian areas are fenced, small access areas that allow livestock to take water directly from the stream may be appropriate where such access is not likely to degrade the stream.

Upland Grazing Strategies

Upland grazing should be managed to minimize surface erosion and disruption of hydrologic processes. Watershed analysis should identify portions of the range in poor, fair, good and excellent condition. Where range conditions are in other than good-to-excellent condition, we recommend temporary suspension of grazing until vegetation has recovered. Once conditions have improved, grazing strategies should be adjusted to ensure that conditions do not deteriorate again. This may be done by controlling grazing intensity by reducing the number or changing the class of livestock, reducing duration of grazing, or limiting total forage utilization (i.e., residual biomass).

Sediment Control

In areas where sediments are reaching the stream channel by surface erosion, steps should be taken to reduce surface erosion. Restoring vegetative cover (through control of grazing) should be given the highest priority. Where surface erosion is evident, mulching is recommended until vegetative cover is restored. Retentive structures may be appropriate for controlling rill and gullying erosion; however, design of these structures is critical, since poorly constructed dams or other devices may accelerate rather than alleviate erosion.

Chemical Applications

Application of chemical fertilizers and pesticides should be conducted to prevent contamination of waterways. No spraying should be conducted within the riparian zone or over surface waters. Aerial spraying should be conducted to prevent drift into the riparian zone (apply parallel to riparian zone and under low wind conditions). Mixing of chemicals and washing of equipment should be conducted only where contamination of waters is unlikely.

Channel Restoration

Where channel conditions have been degraded by grazing, replanting of riparian vegetation is recommended in order to accelerate recovery.

14.3.4 Agricultural Practices

Although specific methods for conserving salmonid habitats on agricultural lands are not as well developed, the principles for protecting streams on agricultural lands are similar to those for forest and grazing practices. Habitat conservation plans should emphasize protecting riparian zones, reducing sedimentation, minimizing fertilizer and pesticide inputs, and minimizing disruption of hydrologic processes.

Riparian Buffer Zones

Riparian buffers are recommended for all permanent streams on agricultural lands that support salmonids, as well as ephemeral streams that influence salmonid habitats downstream. The dimensions of riparian buffers should depend on the specific ecological functions for which protection is desired (reviewed in Section 14.2.3). Use of agricultural machinery within the riparian zone or disturbance to vegetation or soils within the riparian zone should be avoided. Where channels have been degraded, by agricultural activities, planting of riparian vegetation native to the region is recommended. Conservation can be further enhanced by retiring converted wetlands from agriculture.

Sedimentation Control

Watershed analysis should be used to identify areas that are susceptible to surface erosion. Areas identified as highly erosive, with high probability of delivering sediments to streams, should be retired from agriculture. For moderately susceptible areas, various practices can be employed to reduce soil loss, including minimizing the area or frequency of tillage, mulching, use of cover crops during the rainy season, and terracing of hillslopes. Construction of settling basins in drainages susceptible to channelized erosion may further reduce sediment inputs.

Water Use

In circumstances where water has been over allocated or water quality issues identified, new water allocations should be approached with caution. This is particularly applicable where threatened or endangered stocks are present. All diversions of water from streams used by salmonids for spawning, rearing, or migration should be screened to prevent entrainment. For streams where water quality or quantity have been diminished by agricultural practices, a watershed conservation strategy should be developed to reduce the volume of water needed for agriculture, thereby increasing the amount available for aquatic resources. Components of this strategy should include one or more of the following: replacement of water-intensive crops with drought-resistant crops or crops appropriate for the precipitation regime within the region; elimination of water diversions; use of drip irrigation instead of high spray systems; lining of irrigation ditches; and maintenance of instream flows during critical stress periods (i.e., low flows, high temperatures). Where drainage ditches and tiles exist, intensive use of fertilizers or pesticides should be avoided because these structures are direct conduits to streams. In addition, drainage structures reduce summer water availability by routing water rapidly from the system and therefore should not be used unless combined with irrigation from deep groundwater.

Chemical Applications and Pest Control

Application of chemicals and pesticides should be conducted in a manner that minimizes contamination of aquatic systems. No chemicals should be applied within the riparian zone or over surface waters, and aerial applications should be conducted parallel to the riparian zone and under low-wind conditions to prevent drift into the riparian zone. Where water quality has been degraded by agricultural chemicals, organic farming and integrated pest management are recommended.

14.3.5 Mining Practices

Habitat protection measures for mining operations vary depending on the type of mining (e.g., surface mining, pit mining, underground mining, instream or floodplain aggregate mining). The goals of conservation practices at mining sites are similar to those of other activities (i.e., minimizing disturbance to soils and vegetation); however, the issue of potential contamination from toxic runoff and site reclamation also deserve special attention. The discussion below encompasses all types of mining, though not all HCPs will necessarily need to address each specific element.

Riparian Buffer Zones

We recommend that mineral or aggregate mining be avoided in streams or riparian areas of streams containing salmonids or that drain into salmonid habitats. Riparian buffers alone are likely inadequate to prevent chemical contamination of streams from untreated waste waters and runoff, thus, wastewaters should be treated before being released into streams (see below). Where channels have been degraded by past activities, active restoration including planting of riparian vegetation should be conducted.

Water Use

Water for mining purposes should not be withdrawn from streams supporting at-risk salmonids or habitats identified during watershed analysis as critical for salmonid production. Elsewhere, a water conservation strategy should be developed, including treatment and recycling of wastewaters and reductions in groundwater pumping where streamflow may be affected.

Sediment Control

Disturbance of soils is unavoidable during mining operations, however, care should be taken to minimize the aerial extent of ground disturbance. Lands that are denuded of vegetation should be stabilized as quickly as possible to reduce erosion, and methods such as contouring, mulching, and construction of settling ponds should be employed to minimize detachment and transport of soils. Disturbed sites should be revegetated as quickly as possible, and topsoil should be overlaid on mining sites to assure successful regeneration. Where chemical constituents of mine spoils (e.g., pH, salinity, toxic metals) are likely to inhibit recovery of vegetation, spoils should be treated to ensure successful reestablishment of vegetation.

Water Quality

Mining should be avoided where tailings and wastewater have the possibility of entering aquatic systems. Wastewaters should be treated (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycled on site to minimize discharge to streams. Waters that are not clean enough to be re-used should not be discharged into streams. Pumping of groundwater should be avoided where lowering of the water table may facilitate transport of toxic materials. Control structures (barriers, ponds) should be constructed to retain toxic materials and should be built to withstand extreme precipitation events. Spoils containing toxic materials should be buried below the rooting zone of plants so that these materials are not taken up by plants and subsequently released into the environnient.

14.3.6 Urban Land Use

Urban land use poses the most difficult challenge to salmonid conservation planning, both because ownership is distributed among many individuals and because in most instances the landscape alteration approaches permanence. The most effective means for minimizing impacts is through county and city land-use planning.

Riparian Buffer Zones

Riparian buffers are perhaps even more critical in urban areas than in agricultural, range and forest lands because of the intensity of disturbance in surrounding uplands. Those riparian areas and wetlands that have not been paved or otherwise developed should be preserved and no new development allowed. Where feasible, impervious surfaces, such as parking lots and abandoned buildings, should be removed and vegetation restored.

Hydrology

Recommendations for minimizing the percent of landscape with impervious services is equally germane at the site and watershed levels (see Section 14.2.1). A program for reducing inipervious surfaces is currently being developed for Olympia, Washington, and should serve as a model for other urban environments (PWD 1995). Similarly, alternative forms of transportation (cycling, mass transit) should be promoted to reduce tlie need for additional roads. Where urban water withdrawals are degrading salmonid habitats, water conservation and recycling should be promoted. Further channelization of degraded streams should be avoided and wetlands should be maintained or restored.

Sediment Control

New construction of roads and buildings should be avoided on steep hillslopes that are susceptible to surface erosion and mass wasting. Sediment control measures, including matting, mulching, seeding, and construction of sediment traps should be employed at all new construction sites. Erosion can also be avoided by performing new construction during the dry season.

Water Quality

It is assumed that urban runoff is a major potential source of contaminants for salmonid-bearing streams, lakes, and estuaries. In such cases, urban stormwater should be routed through waste treatment facilities. In addition, use of chemical pesticides and fertilizers should be discouraged.

14.4 Data Needs

To perform the analyses outlined in the preceding sections, a substantial amount of information is needed, including data on ecoregion, climate, hydrology, geology, soils, stream channel networks, vegetation, disturbances (natural and anthropogenic), land use, and water use. Aerial photographs are particularly important in assessing historical and current watershed conditions. Potential data needs for watershed-level analyses related to physical and chemical processes are indicated in Table 14-4. In some instances, data are readily available in useable form from Federal or State agencies. Other data can be derived from existing data (e.g., slope stability will be based on topography, soil type, vegetation, etc.). Additional data are likely to be obtained only through field surveys and historical archives.

Data potentially needed for analyses of biological processes at the regional, basin, and watershed levels are listed in Table 14-5. Some of this information will already have been gathered for analyses of physical and chemical habitat attributes. Biological data needs include historical and current information on salmonid production; species distribution maps for salmonids, as well as other aquatic and terrestrial biota; distribution maps for threatened and endangered species of fishes and other taxa; species diversity maps; and genetic analyses. Some of this information can be obtained from Federal and State agencies, although in some regions, biological information may be sparse. Other data, including key watershed designations for private lands and ESU delineation for salmonids, are currently not widely available and it will be tlie responsibility of the agencies to develop this information for HCPs and other conservation efforts. A listing of sources for physical and biological data and how this information may be obtained can be found in Appendix A.

AR053292

Table 14-4. Potential data needs for performing analyses of relationships between land-use practices and physical-chemical processes in watersheds, riparian zones, and streams. Data availability codes: 1 = maps or data usually available, 2 = poor coverage in some regions, 3 = maps or data generally derived from other data or field surveys.

		Hydrology			Sediment transport		Riparian functions					Channel condition			Water quality	
Data type	Data avail.	Peak flow	Base flow	Season. timing	Mass wast.	Surf eros.	LWD	Org. litter	Stream shade	Bank stabil.	Nutr. cycl.	Bed morph.	Substr. type	Phys. struct.	Stream temp.	Pollu-tants
General maps																
Ecoregion maps	1	x	x	x	x	x									x	
WAU maps (WA)	2	x	x	x	x	x										
Topographic maps	1	x	x	x	x	x			x			x			x	
Aerial photographs																
Current	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Historical	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Climate																
Rainfall map	2	x	x	x	x	x										
Rainfall records	2	x	x	x	x	x										
Snowfall records	2	x	x	x	x	x										
Rain/snow zone maps	3	x	x	x	x	x										
Temperature records	2	x	x	x											x	
Hydrology																
Peak flow timing	1	x		x												
Streamflow records	2	x	x	x												x
Geology																
Bedrock map	1		x		x	x						x	x	x		
Structural geol. map	2		x		x	x						x		x		
Soils																
Soil type	2		x		x	x					x		x			
Soil descriptions	3				x	x							x			
Slope stability	3				x							x	x			
Stream channels																
Channel network	3	x	x	x	x	x										
Stream classification	2		x				x	x	x	x	x					
Vegetation																
Current veg. (type/age)	2,3	x	x	x	x	x	x	x	x	x	x			x	x	
Historic veg. (type/age)	2,3	x	x	x	x	x	x	x	x	x	x			x	x	
Potential vegetation	3	x	x	x	x	x	x	x	x	x	x			x	x	
Disturbances																
Wildfire	3	x	x	x	x	x	x	x	x	x	x		x	x		
Landslides	3				x		x					x	x	x		
Debris torrents	3				x		x					x	x	x		
Land uses																
Road maps (by age)	2,3	x	x	x	x	x						x	x	x	x	
Logging history maps	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Prescribed burns	?	x	x	x	x	x	x	x	x	x	x		x	x	x	
Grazing history	3	x	x	x		x	x	x	x	x	x	x	x	x	x	
Agricultural history	3	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Mining history	3				x	x	x	x	x	x	x	x	x	x	x	x
Landfills	1					x							x			x
Urban area	1	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Current land use	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Water uses																
Dams	1	x	x	x								x	x	x	x	
Irrigation diversions	3		x	x								x	x	x	x	x
Point source discharges	3															x
Stream temp. records	2														x	

AR053293

indicates agencies will most likely be responsible for data preparation

		Salmonid Habitat					Population Level					Community Level			Other Biota	
Data type	Data avail	Spawn	Incub	Sum rear	Wint rear	Migrat barriers	Pop viab	Life hist div	Meta pop	ESUs	Connec tivity	Comp	Pred	Disease & paras	Bio divers	Species at risk
General maps																
Key watershed maps	2						x		x		x					
Topographic maps	1 I	x		x	x	x										
Aerial photographs																
Current	1 I	x		x	x	x										
Historical	1 I	x		x	x	x										
Hydrology																
Streamflow records	2	x		x	x											
Stream channels																
Channel network	3										x					
Pool/riffle ratios	3	x	x	x	x							x	x			
Salmonid production																
Adult migrants	2						x		x							
Downstream migrants	2						x		x							
Population estimates (res)	3						x		x							
Historical records	3	x		x	x	x	x	x	x							
Species distribution																
Salmonids current	2								x	x	x	x	x			
Salmonids historic	2								x	x	x	x	x	x		
Native fishes	1											x	x			
Nonnative fishes	1											x	x			
Hatchery locations	1									x		x	x	x		
T&E fishes	1														x	x
Other aquatic T&E biota	1														x	x
T&E terrestrial biota	1														x	x
Biological surveys																
Fishes	2 3	x	x	x	x	x	x	x	x			x	x	x	x	x
Other biota	2,3											x	x	x	x	x
Species diversity																
ESU maps*	3														x	x
Genetic info (salmonids)	2						x		x	x						
Fishes*	3														x	
Other biota*	3														x	
Water quality																
Stream temperatures	2 I	x	x	x	x	x	x	x			x	x	x	x		
Dissolved oxygen	2,3	x	x	x	x	x	x							x		
Intergravel DO	3	x	x													
Turbidity	2,3	x	x	x	x	x										
Bacteria/pathogens†	3															
Acidity	2 3	x	x	x	x	x										
Alkalinity	2 3	x	x	x	x											
Toxic contaminants	2 3	x	x	x	x	x										
Land uses																
Road maps	2 3	x	x	x	x	x	x	x								x
Logging history maps	1 I	x	x	x	x	x	x	x								x
Grazing history maps	3	x	x	x	x	x	x	x								x
Agricultural history maps	3	x	x	x	x	x	x	x								x
Mining history	3	x	x	x	x	x	x	x								x
Urban area maps	1 I	x	x	x	x	x	x	x								x
Current land use	1 I	x	x	x	x	x	x	x								x
Water uses																
Dams	1 I	x	x	x	x	x	x	x			x	x	x	x		x
Irrigation	3	x	x	x	x	x	x	x			x			x		x
Domestic/agricultural wells	1			x												

† Bacteria/pathogen data for human health concerns and general indicator of water quality

15 Monitoring Salmonid Conservation Activities

Monitoring plays a critical role in all commercial, ecological, and social activities. It is the process that researchers use to obtain data and develop procedures through which a society assesses how well it is achieving its objectives. Ignorance of those objectives, or failure to adequately measure progress toward goals, guarantees they will not be met and increases the probability of undesirable consequences. This chapter presents monitoring elements that enable assessment of condition and detection of statistical trends in aquatic ecosystems at spatial scales from site to region. Sampling designs and indicators are proposed to track trends in physical, chemical, and biological conditions in uplands as well as riparian areas and streams so that critical planning elements can be monitored at appropriate spatial scales and temporal frequencies. Although there are many types of monitoring to obtain inforniation for many purposes, we focus on two major types: implementation monitoring and assessment monitoring (sensu FS et al. 1994). Planners and managers use implementation monitoring to determine compliance with the term of HCPs and other conservation agreements, and they, like scientists, use assessment monitoring to determine the effectiveness of activities in protecting or restoring salmonids and their habitats. Assessment and iniplementation monitoring are proposed both for individual HCPs and for providing the regional context to evaluate the overall effectiveness of salmonid conservation activities. Section 15.1 offers general guidelines for both types of monitoring programs. Specific issues for implementation and assessment monitoring are described in Sections 15.2.1 and 15.2.2, respectively. Sections 15.2.3 and 15.2.4 discuss the recommended sampling design and indicators.

15.1 General Guidelines for Monitoring Ecosystems & Salmonids for Conservation Planning

Because the Pacific Northwest now lacks an integrated approach for monitoring salmonids and aquatic ecosystems, we have difficulty determining whether changes in characteristics reflect fundamental changes in ecosystem function and structure, identifying the stressors associated with the changes, and quantifying the degree to which ecological problems are increasing regionally (Messer et al. 1991; Botkin et al. 1994). An effective program for monitoring salmonid conservation activities, as suggested in Chapter 10, would be long-term, multiscale, interdisciplinary, and interinstitutional. In addition to the above concerns, we offer four general guidelines based on our own experience and that of other monitoring programs.

15.1.1 Long-Term Monitoring

Monitoring over the long term documents trends in ecosystem conditions that occur in response to natural and anthropogenic disturbances, and it allows separation of the effects of human activity from natural variation. Over short time periods, natural variation in climatic conditions can produce strong signals that may mask anthropogenic effects. Furthermore, the effects of many human activities manifest themselves long after an activity has ceased, often in response to extreme environmental events (e.g., mass wasting associated with major storm events).

We recommend developing a common set of quantitative indicators for the Pacific Northwest and standardized methods of data collection. Annual monitoring (though not necessarily at the same sites each year) is best conducted by technically trained crews and ideally should continue for centuries. Issues important to successful implementation of a long-term monitoring program include ensuring adequate funding, scheduling of monitoring activities, archiving and retrieval of monitoring data, periodic reporting of monitoring results, and application of monitoring results to management situations (e.g., adaptive management). These issues are discussed in greater detail elsewhere in this chapter.

15.1.2 Multiscale Monitoring

Monitoring across many scales measures the effects of site- or reach-scale management activities as well as cumulative effects at the level of watersheds, basins, ecoregions, and multi-State regions. Monitoring crosses disciplines because ecosystems are complex aggregations of biotic and abiotic components, and those involved represent those areas of ecological expertise. Statistical sampling designs used at both the population and site levels facilitate the conduct of monitoring at appropriate spatial and temporal scales. Conipliance can also be evaluated at local and regional scales to ensure that planned practices are implemented as outlined in conservation agreements across the region. When management practices are also monitored at local and Pacific Northwest scales, certain results can be determined: 1) the site-specific effects on salmon of conservation activities, 2) trends in regional distribution of salmon species and populations, and 3) the effects of salmon conservation on human society. A subset of indicators applied at the site, stream section, catchment, and region scales would facilitate data integration and analysis. If multiscale monitoring is allied with long-term monitoring over many decades or centuries, integrated observations about trends would amplify today's piecemeal knowledge about salmon populations, ecosystem conditions, land use, and the productivity of the lands for commercial resources.

Although this region presently lacks the program implementation and assessment monitoring suggested above, it does have many of the necessary pieces in place at the private, State, and Federal levels—at least for indicators. Differences in the perceived acceptability of qualitative versus quantitative indicators seem resolvable; however, fundamental differences in sampling designs hinder comparisons across institutions. As suggested by FS et al. (1994), a proposal to test instream and riparian indicators and designs could bring the Federal agencies and their cooperating State agencies closer together (Mulder et al. 1995).

15.1.3 Interinstitutional Monitoring

Monitoring becomes interinstitutional because lands are held by many different institutions, both public and private, and because many agencies have regulatory and management missions that directly or indirectly relate to salmonid conservation. Given the roughly 200,000 stream miles and 400,000 square miles of land eventually involved, at least three scenarios can be described for implementation and assessment monitoring.

First, employ a cadre of field and laboratory staff to periodically census the whole resource; this approach would be expensive and funded probably over a short term, if at all. Alternatively, self-monitoring and reporting by all landowners could be instituted. Self-monitoring is conducted by many States for point-source discharges, but may result in poorly implemented programs of questionable integrity (Chapter 10). Self-monitoring programs typically generate additional compliance monitoring because agencies would need to confirm or spot-check reports. Finally, a survey with sampling of selected sites could be started to infer results across the population. Whatever the choice, it will require close cooperation among many Federal and State agencies, as well as nongovernment organizations, district conservationists, and landowners.

The Research and Monitoring Committee of the Regional Ecosystem Office in Portland (REO) has the authority and provides the foundation for integrating Federal monitoring efforts in this region. Given the regional scale of the salmonid issues, the extensive Federal holdings in the region, current funding levels, and the previous leadership in monitoring protocols shown by Federal research laboratories, the Federal agencies appear to be a logical choice for coordinating this effort. However, it is essential that states, Tribal and other governmental parties be involved in developing the core monitoring strategy to ensure comprehensiveness and support for implementation. Once agreement is reached on a sampling design, indicators, and database management, there should be periodic reviews by, and consultations with, nonfederal technical staff from the agencies, as well as universities, industries, and environmental groups. This might best be accomplished through technical working groups such as described by Hayslip (1993).

Critical Agency concerns include what should be monitored and how (including by whom, where, and when), and whether individual and aggregate conservation plans are protecting and restoring salmonids. The where and when of monitoring are discussed under monitoring design in Section 15.2.3; the what of monitoring is outlined in Section 15.2.4, which focuses on indicators and sampling. Recommendations on whom should conduct monitoring in various instances are covered in the implementation portion of this document (Chapter 16).

15.1.4 Cooperative Support

A useful monitoring program needs the support of a computerized-database management system for timely data entry, storage, retrieval, analysis, and reporting. Such a system will be more responsive if it links Federal and nonfederal lands and draws support from both Federal and nonfederal institutions. Given the scope and complexity of the potential data, it is essential that data be converted quickly and accurately into relevant information (MSG 1993; Paulsen et al. 1991). Moreover, digital databases (including geographic information systems) ought to be easily retrievable by all interested parties.

Organizing a successful monitoring program of such coniplexity requires considerable Federal coordination and leadership. Such organization ensures that the collected data will have utility and

AR053296

more knowledge than we have now will accrue concerning our effects on these systems.

Owners of private lands and managers of public lands will need to cooperate in conservation planning and monitoring activities because they will be the important users of the monitoring information. For example, biological integrity and sustainable levels of natural resource production (Figure 15-1, Paulsen and Linthurst 1994) are ecological and social goals that now concern to some degree the community of landowners, managers, and scientists. Common objectives can be attained with cooperative monitoring activities and practical ecosystem management. We recommend that a coordinated private-State-Federal monitoring and assessment program be implemented in the PNW on both Federal and nonfederal lands. Henjum et al. (1994) and McCullough and Espinosa (1996) have made similar calls for rigorous monitoring programs. The Research and Monitoring Committee for the President's Forest Plan is currently examining how to implement such a program on Federal lands; extending this effort to nonfederal lands in the Pacific Northwest would greatly enhance salmonid conservation planning.

15.2 Recommended Strategy for Monitoring Salmonid Conservation Activities

In the remainder of Chapter 15 we propose a strategy with eight activities for monitoring salmonid conservation. This monitoring strategy is based on the discussion of existing monitoring programs in Chapter 10 and the preceding general guidelines.

1. Develop a set of assessment questions or objectives that the monitoring should address. MacDonald et al. (1991) consider this the most critical step in monitoring. For example, determine the proportion of stream miles in the region (or a particular basin) that support summer salmonid populations (or salmonid spawning); determine the relationship of riparian buffer width (or condition) and various measures of stream condition (e.g., sedimentation, temperature, LWD, channel coniplexity); assess whether prohibited activities are occurring and with what frequency (e.g., harvest activities in riparian buffers).

2. Determine the indicators that will be used to assess biotic and abiotic conditions: ensure that these indicators can be related to the ecological values, the natural and anthropogenic stressors, or both. Include biological, habitat, and stressor indicators to assess biological condition, diagnose the site's environmental conditions, and evaluate the management and landscape conditions that affect the more proximal indicators (Karr and Dudley 1981; Karr et al. 1986; Messer 1990; Hughes et al. 1992; Fore et al. 1996). If hydrology and sediment transport are critical planning elements, implementation and assessment monitoring should include land-use types and extents within the watershed. If biodiversity is a concern, indicators should focus on ecosystem structure and function from the genetic to the landscape levels versus focusing on an indicator species (Noss 1990; Landres 1992; NRC 1992). If early detection of stress and recovery are concerns, changes in species composition of r-selected species and disappearance of sensitive species may be the most useful indicators (Schindler 1987). MacDonald et al. (1991), Rapport (1992), and Cairns et al. (1993) stated that good indicators are sensitive to multiple stressors and responsive to general disturbances yet have relatively low sampling error. They should also be easily measurable, interpretable, and cost-effective. In addition, useful indicators are biologically and socially relevant, anticipatory of future changes, and diagnostic of particular stressors. Such indicators are integrative of a number of different stressors. Hughes (1993) demonstrates how stream indicators were evaluated through use of these characteristics.

3. Use the index concept in selecting the sampling period, sampling sites (e.g., streams) and sampling locations at the sites, as well as in data analysis. Indexing is the process by which data collection and analysis are logically focused on particular times, places, and indices (Hughes et al. 1992).

- Index Period. Although aquatic systems change markedly with seasons, many variables generally look the same from year to year during the same season, unless perturbed. Thus aquatic systems can be sampled when they are 1) least varying, 2) most likely to be stressed by perturbations of concern, and 3) safely and economically sampled. This period (an index period) will be the summer or early fall for most Pacific Northwest streams, but may be other seasons if spawning or sediment loading are concerns (Plafkin et al. 1989).

- Index Sites. In the same manner, a subset of all stream miles or lakes can be sampled to avoid taking a census of them all (see the following guideline). These sites should include reaches on rivers as well as streams, especially when dealing with anadromous and potamodromous fishes. A set of these sample data can be statistically assembled to represent the total stream or lake population. (Note that here and in subsequent cases the term "population" is used in a

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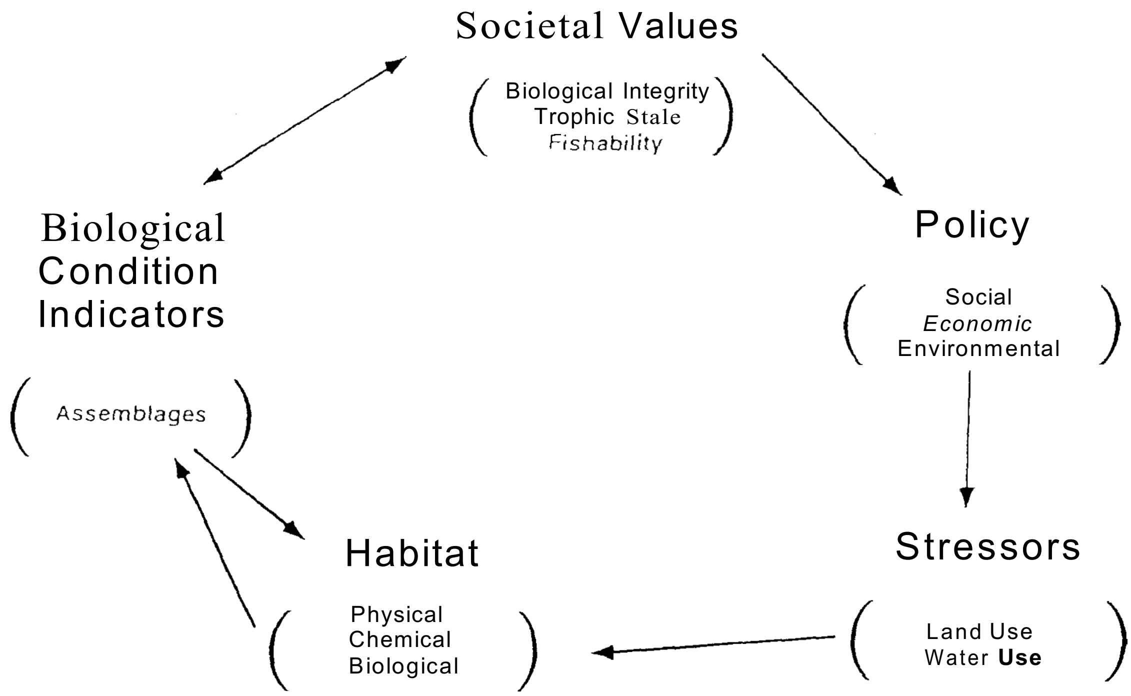

Figure 15-1. Relationships between societal values, policy, and stressor, abiotic condition (habitat), and biological condition indicators. Biological condition indicators are linked to societal values and biological condition assessments influence policy only through societal values, Also, biological condition indicators determine our choice of habitat indicators, which are the proximate determinants of biological condition. From Paulsen and Linthurst (1994)

statistical sense and refers to all stream miles or lakes of interest in the region.) This process has been very successful in assessing human opinions through political polls and market surveys, but has received remarkably little attention in ecological monitoring.

- Index Stations. At a single stream site, reach, lake, or watershed there are numerous macro- and microhabitat characteristics that could be evaluated. If a single sample inadequately captures the complexity of a site, as is the case with most biological and physical habitat indicators, it is useful and cost effective to index the site by randomized systematic samples of different variables. These may be composited by habitat type to represent the site. The rationale for this sanipling protocol is to assess the complexity of the site while limiting the cost of sampling and processing. On the other hand, because stream water is usually well mixed, a single index sample may suffice for estimating water quality for an entire reach.

- Numerical Indexes. The large amounts of data that may be generated from each site are often most useful if they can be converted or reduced into readily understood, summarized information. This is the role of numerical indexes. A numerical index, like a composite sample, synthesizes large amounts of information so that it can be easily displayed and understood. It is intended for nonspecialists more than for specialists, but it can offer considerable ecological insight when examined from the perspective of many sites through time. Examples are indexes of biological integrity (Karr et al. 1986; Kerans and Karr 1994; Fore et al. 1996) and *an* index of landscape stressors (Hughes et al. 1993). The

AR053298

ecological merit of an index is a function of the quality and type of variables used to generate it (Barbour et al. 1995, Karr et al. 1986).

4. *Develop a sampling design that is appropriate for answering assessment questions (item 1 above).* If the ecosystem or region is the appropriate level for management or reporting, the monitoring and assessment also must be at these levels (Landres 1992; Paulsen et al. 1991; FS and BLM 1994a). Assessing whether HCP conditions are being met or if aquatic ecosystem conditions are improving or degrading across large regions requires data sampled at long temporal and large spatial scales (Hughes et al. 1992; Barrett et al. 1993; FS and BLM 1994a). Populations of sites, rather than individual sites, must be emphasized. Status-and-trend estimates must demonstrate a strong statistical foundation so uncertainty can be explicitly represented in confidence terms (Stevens 1994). These requirements support use of a probability sample of streams, which would be clearly representative and free of subjectivity in comparison with hand-picked sites. Populations should be stratified after sampling; this allows multiple interpretations of the data, permits detection of unanticipated issues, and improves precision if the misclassification rate of streams in various possible strata approaches 20% (Stevens 1994). Hall et al. (1978) also support an extensive poststratified design because it provides the greatest temporal and spatial perspective and takes the least time for evaluating condition and assessing cause-effect relationships. According to the REO (1995) and Botkin et al. (1994), the monitoring design should offer efficiencies of scale across large areas, distribute sites to reveal significant spatial variability, and include enough sites to determine statistical reliability.

5. *Establish reference conditions (e.g., historical or natural, relatively undisturbed watersheds and stream segments) as standards against which conservation efforts may be measured.* The goal of conservation need not be to achieve the reference condition. Frequently, the goal will be to reverse trends in resource condition so that they begin heading towards natural conditions. Because of the great diversity and multiple scales of the landscape and salmonid conservation issues, as well as variation in natural rates of disturbance, reference conditions will likely be derived from a variety of methods, including regional reference sites with minimal human disturbance, historical conditions, and models developed from such information (Platts et al. 1987; EPA 1990; Messer 1992; NRC 1992; Barrett et al. 1993; Hughes 1995). In general, naturalness can be estimated from the presettlement species complement, from the predicted degree that the system would change if humans were removed, or from the amount of cultural energy needed to retain the current system (Anderson 1991).

Natural disturbances of the landscape (e.g., fire, floods, drought, mass wasting) and variable oceanic and atmospheric conditions (El Niño, coastal upwelling intensity, climate) complicate the use of reference sites for establishing salmonid habitat or ecosystem standards. Even in undisturbed systems, streams may attain a variety of states in response to periodic disturbances and subsequent recovery (Reeves et al. 1995). Consequently, reference conditions should be defined to include the natural range of conditions occurring across the region or basin. Defining reference conditions to include the range of natural variation protects us from attempting to make all watersheds and rivers behave in the same manner. It also offers a disturbance gradient and spatio-temporal framework against which the extent of anthropogenic disturbances can be compared and with which the relationship between watershed conditions and salmonid responses can be modeled. This does not mean that because watersheds experience natural disturbances that human disturbances are insignificant. It simply provides a reference for evaluating the various degrees of the two sources of disturbance, as well as the conditions occurring in the absence of disturbance. Given the extent of human disturbance in the region, locating reference sites may be difficult with a probability sampling design so it will likely need to be amplified with subjectively chosen sites. A principal goal of the regional monitoring program outlined below is to produce a database from which the Agencies can better develop reference conditions for HCPs.

6. *Apply the data in answering resource management questions, or in developing new assessment questions.* Although this seems obvious, data are frequently collected but left unused. Certainly, data can be used to identify watersheds or stream sections where habitat has improved, remained the same, or degraded, and to determine the association of such changes with stressors. The focus here should be informational rather than punitive, assuming that management guidelines were followed. Monitoring information is also useful in assessing the successes and failures of the conservation program and validating or invalidating the principles incorporated in the planning efforts. These assessments will probably take decades for many issues. On the other hand, implementation monitoring can and should produce rapid alterations in land use if prohibited activities are violated, detected, and corrected.

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Finally, the information is useful for demonstrating increased or decreased biological integrity and salmonid populations and comparing such changes to changes in habitat. Here again, tlie focus is more on research (e.g., validation of conservation principles) than compliance as long as approved conservation practices are implemented. The Watershed Analysis Coordination Team (WACT 1995) states that "existing data [are] adequate to accurately determine the current and historical status and distribution of aquatic biota" for low intensity analyses. However, current databases and distributional information for salmonids are spotty and based largely on presence information or subjective assessments. Data for other biota are even less reliable. Reliance on salmonids alone to assess biological integrity ignores many of the indicator concepts discussed above.

7. *Evaluate the effectiveness of the strategy and its results.* Using the results of monitoring, we recommend that the Agencies produce brief annual reports for public review and periodic research synthesis papers that are prepared by scientists trained in statistics and ecology. Regular program peer-and-participant reviews and recommendations for modifications are another essential part of monitoring. Because the implementation and assessment monitoring constitute the necessary data-acquisition phases for ecosystem research and management, evaluating the level of effort periodically becomes crucial: stable funding is needed to support the program with competent and dedicated staff.

8. *Identify ecosystem elements and processes requiring additional research.* Although this is not a major objective of monitoring on nonfederal lands, it is an activity that validates the inipleniented scientific and management practices; hence, it is recommended that suggestions for future research be part of a monitoring program and the issues identified be passed on to research institutions if not funded by the program.

15.2.I Monitoring Implementation of HCPs and other Conservation Activities

HCPs and other salmonid conservation plans will probably contain a variety of provisions because of differences in current and attainable conditions among ecoregions and basins. We expect that virtually all HCPs prepared using this guidance will involve monitoring the implementation of land-use controls to reduce hydrological modifications, sediment transport, and riparian disturbance. Many will also require implementing activities that improve water quality and physical habitat structure. Some HCPs may involve removal of non-native fish species or introduction of beaver and LWD.

HCPs should include an approved and consistent implementation monitoring program; implementation monitoring is the process by which the Agencies determine if landowners are complying with provisions in their HCPs. To be most effective, baseline data should be collected before conservation activities begin. All data should be GIS compatible and entered into the database along with an indication of its sources (landowner, agency) to facilitate tracking of progress. Implementation monitoring is needed to ensure that prohibited activities do not occur and that permitted activities follow specific guidelines in the plan. Table 15-1 recommends a number of indicators potentially needed for an iniplenientation monitoring program. Not all indicators will need to be monitored in every instance, but others may need to be added to suit specific conditions and objectives. Most reconnended indicators are based on land use and land cover, resource extraction practices, pollution controls, and physical habitat structure. Indicators are discussed in more detail in Section 15.2.4.

15.2.2 Monitoring Effectiveness of HCPs and other Conservation Activities

The objectives of assessment monitoring will vary somewhat because of differences in land use and attainable conditions throughout the region, although there should be consistency in design and indicators to the greatest degree possible. If all HCPs involve monitoring to assess the effectiveness of their land-use controls, then ultimately we can determine the degree to which salmonids and their habitat have been restored or protected. To accomplish this goal, the focus of the monitoring should be on the aquatic and riparian ecosystems and include physical, chemical, and biological indicators. In addition, assessment of watershed conditions, which is a focus of implementation monitoring, will also provide information for adaptive management.

Because rapid detection of trends depends on early and precise assessments of condition, HCPs should encourage assessment monitoring that is started as soon as a consistent and rigorous program is developed by the Agencies. As with implementation monitoring, a large database will be produced requiring a large database-management system. These data will be useful for quantifying the relationships between various land uses and the response of salmonids and their habitats. Thus, both remote sensing and site visits are complementary in assessment monitoring. For example, to determine tlie extent and duration of riparian protection from farming, grazing, and logging, remote imagery aggregated over the drainage and site can be

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Table 15-1. Recommended indicators for implementation monitoring.*

Assessed	Indicator
HCP description	Latitude, longitude, or UTM coordinates, area affected, initiation and completion dates [R]
Hydrology	% catchment with old uneven growth, closed and open canopy, nonforest, barren (forestland) [R] % catchment forested, shrubland, grassed, row-cropped (cropland) [R] % catchment grassland, shrubland, barren (rangeland) [R] % catchment forested, grassed, barren, impervious (urban, mining) [R] % stream miles channelized, ditched, piped (urban, cropland, mining) [R] %wetland [R] Wetland condition [S] Range condition [S] Water withdrawals [R,S]
Sediment transport	% catchment with mass wasting [R] % eroding stream banks (if specified in HCP) [R,S] Road density and proximity to streams [R] Harvest, roading, and restoration techniques [S] Tillage techniques [S] Mine site location and reclamation [R,S] Construction site sediment retention [R] Range condition [S]
Energy transfer and temperature	% channels with riparian forest within 10, 100, and 1000 m [R]
Water quality: nutrients and toxics	Lagoon capacity and integrity (confined livestock facilities, point source discharges, mines) [S] Effluent chemistry (point sources, irrigation return flows, storm drains) [S] Random, multispecies, whole effluent bioassays (point source discharges, mines, irrigation return flows) [S] Chemical applications [S] Irrigation techniques [S]
Physical habitat structure	% riparian zone within 100 m with natural riparian woody plants [R] % road crossings with inadequate culverts [S] % unscreened diversions [S] % impassable dams [R, S] Size, number, and location of LWD (if required in HCP) [S, R in large rivers] Frequency of off-channel habitats and LWD in riparian zone [R,S] Livestock density and timing [S] Livestock watering locations [S] Riparian fencing and forage condition [S]
Stream and riparian biota	Nonnative species and stocks (if required by HCP) [S] Beaver sign (if in HCP) [S] Fish stocking levels [A] Aquatic vertebrate species presence [S]

* A = Agency data, R = remote sensing, S = site inspection

employed; then, site visits are needed to assess the intensity of those land uses as well as their impact on aquatic life and physical and chemical habitat. Table 15-2 recommends a number of indicators for an assessment monitoring program; others will likely be added and some may be found inaccurate or imprecise in some ecoregions. As with implementation monitoring, we recommend several indicators representing each of the six monitoring categories listed in the table. Indicators are discussed in greater detail in Section 15.2.4.

15.2.3 Sampling Design for Monitoring Implementation and Assessment of HCPs and other Conservation Activities

Because of continued declines in widely ranging salmonids, a substantial proportion of the hundreds of thousands of stream miles and square miles of watersheds in the Pacific Northwest may eventually be covered under HCPs or other types of salmonid conservation agreements. To contain costs for agencies and landowners, technical innovations and training are employed. For example, a combination

Table 15-2. Recommended indicators for assessment monitoring.' Assumes indicators as described in Table 15-1 are provided.

Assessed	Indicator
Hydrology	Quantity and timing of peak and low flows (calibrated staff gage) Channel scour (scour chains) Discharge (measure) Valley type (map) [R]
Sediment transport	% fines (Wohlman pebble count at 100 intervals) Substrate size (Wohlman pebble count at 5 locations along 11 transects) % eroding bank (visual count at ends of 11 transects)
Energy transfer and temperature	% channel with riparian forest at 10, 100, and 1000 m [R] Extent and type of riparian vegetation in canopy, mid-layer, and ground cover (visually estimate classes at ends of 11 transects) % canopy cover (densiometer at ends of 11 transects) % channel and banks with anthropogenic disturbance (visual count at ends of 11 transects) Intensity of anthropogenic disturbances along channel and banks (visual count at ends of 11 transects) Extent of open channel with algal or macrophyte blooms (5 locations on 11 transects)
Water quality	Temperature (recording thermograph, summer low flow, 7-day, 0.5 hour recording frequency) Nutrients (N & P forms, lab analysis) Dissolved oxygen (recording thermograph, summer low flow, 7-day, 0.5 hour recording frequency) Turbidity & chloride (lab analysis) Toxics (whole-fish tissue contamination; for mines, point sources and irrigation return flows only; focus on suspected heavy metals and organics) Conductivity (meter) Intergravel dissolved oxygen (subset of sites only where FPOM is prevalent; stratified random sample of egg pockets during incubation, syringe sampling)
Physical habitat structure	Channel sinuosity and aspect (bearing compass at centers of 11 transects) Off-channel habitats (visual and measurements at ends of 11 transects) Residual pool volume (thalweg profile: depth measurements at 100 intervals along entire site) Channel cross section dimensions (measure width and depth at 5 points along each of 11 transects) Substrate size and complexity (Wohlman pebble count and % fines < 1 mm at 5 points along each of 11 transects) Bank undercutting, height, erosion, slope (measure with clinometer and **rod** at ends of 11 transects) LWD (record size, placement in bankful channel, number of pieces via running tally) Cover (include off-channel pools, undercut banks, LWD, overhanging and instream vegetation at 5 points along each of 11 transects) Gradient (clinometer, at centers of 11 transects) Riparian vegetation structure (species composition, DBH measurements across transects or plots within riparian zone of influence)
Stream and riparian biota	Microbial respiration (only where toxics and organic enrichment expected; sediment dissolved oxygen consumption with field respirometer) Periphyton (enriched streams only; quantitative sample from 11 transects; species composition and abundance) Benthic macroinvertebrates (quantitative samples from 11 transects; species composition and abundance) Fish and amphibians (systematic sample of a reach length that is 40–50 times the wetted stream width) Riparian birds (only for multispecies HCPs; systematic sample of 1 km reach at 11 sites during breeding season; species composition and abundance)

* R = remote sensing, all others require site inspection.

of remote sensing, using both aerial photography and satellite imagery, with site visits for selected indicators would facilitate moniitoring. The use of such technology could save hundreds of work years and millions of taxpayer dollars. Similarly, data gathered by trained field staff following a sampling design are more reliable, less costly, and less disruptive for the landowners. These examples reveal again the necessity for cooperation.

Initially, one might logically focus monitoring on an individual drainage or set of reaches covered in an HCP. Conimonly, the drainage or reaches are subjectively selected to be representative or typical, but rarely is the assumption that such sites are representative tested through statistical evaluation. Subjective site selection is a common approach for persons concerned with a particular place. However, because of the variability in streams in the Pacific Northwest one must either census all stream reaches in an HCP or region, or have a large sample size. A rule of thumb in survey sampling designs advises a minimum of 20–50 sites to adequately represent a population. If that population contains streams of markedly different sizes, gradients, and substrates, a sufficient number of sites is needed so that each class contains 20–50 sites. Note that this does not mean 20-50 samples are needed within each reach.

A regional sample survey or census is also iniportant for placing individual conservation activities into an ecoregional and basin context. Because of widespread deterioration in salmonid habitats, it will frequently be necessary to establish reference conditions from information acquired from outside the area covered by the HCP. Reference conditions are essential for determining desired directions and outcomes for restoration, for setting quantitative criteria for evaluating progress, and for assessing the effectiveness of the HCP. Minimally disturbed reference sites offer a means for determining if trends in assessed variables result from the effects of the HCP or from changes in climate, passage, harvest, and hatcheries. Although establishment of reference conditions is desirable, reference sites are likely to be scarce or absent from extensively disturbed regions. In these instances, reference conditions may be established by other means, including historical data, quantitative models, and professional judgement (Hughes 1995).

Even if few HCPs are implemented for nonfederal lands, it will be useful to determine regional conditions and trends via a regional sample survey or census. Both landowners and the Agencies will need to know whether various watersheds and reaches in HCPs are in markedly better or worse condition than others in the basin and ecoregion. Such information is also useful for developing planning elements of the initial HCP. An ecosystem approach to salmonid conservation involves tailoring management prescriptions to the specific capacities of particular systems. Unfortunately, as the preceding sections have shown, we often lack the information to develop ecoregional standards, let alone watershed- or site-specific standards. Regional-scale monitoring can provide data for establishing these standards before conservation activities in such places are developed.

Another argument for regional HCP monitoring is that salmonid conservation and biodiversity are fundamentally regional issues. Whether conservation planning becomes commonplace, the responsible State and Federal agencies are beginning to recognize that their current assessment and compliance monitoring programs are inadequate. The various programs have differing assessment questions, indicators, reference standards, and database management systems. Consequently, their sampling designs, sampling methods, and reported results appear contradictory or biased. **A** good deal of the responsibility for the "salmon problem" rests with the management agencies responsible for the salmon and their habitats, and the inadequacies of their monitoring and reporting. Correcting these shortcomings requires developing a more rigorous and consistent regional monitoring program.

We recommend a multi-State regional sample survey for several reasons. 1) There are ecoregional patterns in biotic and abiotic factors at both multi-State and basin scales (Hughes et al. 1994) and it takes a regional approach to assess them. 2) Summarizing segment level information in an organized manner facilitates making landscape-level statements (Conquest et al. 1994; Yoder and Rankin 1995). Landscape-level statements are needed for regionally distributed organisms like salmon. 3) It would be prohibitively expensive to inventory or census all nonfederal lands and stream miles in the region with the quantitative indicators needed to accurately and precisely assess status and trends. 4) Regional assessments of status and trends should be conducted in a statistically consistent and unbiased manner to instill public confidence and to avoid not identifying a problem when one exists (Type II error; Rhodes et al 1994). *5)* Fragmentary monitoring fosters fragmentary ecosystem management and social systems (Karr 1994). **6)** Previous emphasis on site- and watershed-specific assessments is a key reason that it took so long to determine the regional extent of deteriorating salmon stocks, although many would argue that signs have been evident for decades. 7) **A** multi-state and multi-agency survey elevates monitoring to a regional concern and makes results less easy to ignore.

There are several advantages of a randomized sample survey over other sampling designs. If we infer aquatic conditions from nonrandomly picked sites, we cannot estimate the uncertainty of our assessments or the biases of our inferences (Larsen et al. 1995). A randomized sample survey is necessary to determine population characteristics (Larsen et al. 1994) and to allow unbiased condition and trend estimates. A randomized survey sample also allows data assessment by basin, ecoregion, political unit, ownership class, or any other regional phenomenon.

We propose that the Agencies adopt something like EPA's EMAP sampling design. The EMAP design is easily intensified (Serveiss 1995; Stevens 1994) if detailed information is needed for a single HCP or basin, yet it offers great cost savings by not requiring intensive inventorying of entire drainages. In addition, the EMAP design facilitates accurate and precise inference about resources throughout the region of concern, something that the currently popular stream inventories or subjectively chosen fixed sites cannot offer. Equally important, EMAP's randomized design and nionitoring frequency offer rapid assessment of regional status and trends, which would be exceedingly costly or time consuming via an inventory approach.

EMAP pilots support using several sampling design features. 1) Use a randomized grid (e.g., Overton et al. 1990) to select approximately 200 stream points from digitized versions of GS 1:100,000 scale topographic maps. 2) Use a classification or weighting process to ensure that all channels of interest are represented and that the smallest and most numerous ones are not over represented. 3) Check maps and conduct field visits to ensure that the streams are target systems. 4) Determine ownership and obtain access permission. 5) Record reasons for non-targets and inaccessibility, and draw a replacement from the stream population.

For implementation monitoring, it may be possible to census all watersheds with HCPs or other conservation agreements as long as the nuniber or areal extent remains small. As the areas in conservation agreements increase, a randomized sample of watersheds should be obtained through use of a grid design (Stevens 1994). These are sampled without replacement to ensure that the maximum number of watersheds are eventually monitored. Digitized watershed boundaries are overlain by classified land-use and land-cover data, such as that from thematic mapper with a 30 meter pixel size, from 1:40,000 scale color infrared air photos, or both. Site visits should include focused inspections at points of particular concern (e.g. feed lots, treatment facilities, extraction practices) as well as random inspections of extensive activities (stream crossings, riparian fencing, road construction). By maximizing the sample size, this sampling design is oriented towards assessing condition and it facilitates assessments of subpopulations of waters.

For assessment monitoring, representative samples may be obtained by sampling a stream section equivalent to 40 channel widths long that is centered on the stream point designated by the computer; locations can be confirmed with maps and a GPS unit. At the site, we recommend using a randomized systematic sample design to collect quantitative data on physical, chemical, and biological variables at multiple stations. We also suggest compositing of multiple biological samples for each assemblage by major habitat type, although there remains disagreement in the scientific community regarding the benefits of compositing samples (see e.g., Fore et al. 1996). During the index period(s) of interest, sampling variances (temporal, crew, measurement) can be evaluated by resampling 10-15 randomly selected sites. Land use and land cover within watersheds should be assessed via remote sensing data as described above. For the following three years, repeat this process at approximately 200 new stream points selected each year, including the resampling. In year five, resample all sites sampled in year one, in year six all those sampled in year two, and so on. This sampling design balances our ability to assess status, the precision of which is increased by increased sample size, and to detect trends, the sensitivity of which is improved by sampling the same waters annually (Larsen et al. 1995). More detailed sampling designs than are possible to develop herein must be developed by the Agencies following consultation with other nonfederal and Federal partners.

15.2.4 Physical, Chemical, and Biological Indicators

Quantitative indicators like those proposed by EMAP (Hughes 1993) and McCullough and Espinosa (1996) are needed to ensure that ecological signals are discriminated from spatial, temporal, and methodological variances, thereby aiding rapid detection of trends and accurate estimates of status.

A set of variables is recommended to measure the iniplenientation and effects of conservation activities on the attributes and processes identified as critical (Tables 15-1 & 15-2). These variables include several representing each of the major planning elements discussed in Chapter 14. In addition, they were chosen to assess how well the conservation activities produce the desired changes in physical and chemical habitat. Not all variables need to be monitored in all situations; instead appropriate variables depend on the type of impact and conservation efforts proposed (see parenthetical comments in Tables 15-1 and 15-2). A set of

AR053304

biological variables is included because the biota are the fundamental indicators of concern. Also, monitoring landscape, habitat and biota will enable the Agencies to validate whether the activities are having the desired effects. Linkages between major planning elements and the recommended indicators should facilitate adaptive management and HCP modifications when results are contrary *to* expectations.

Based on EMAP pilots (Hayslip et al. 199.5; Klemm and Lazorchak 1995), such data could be collected with about 6000 work hours per year (3 persons × 10 hours per site × 200 sites per summer). A similar number of hours is needed annually for geographers to conduct the land-use and land-cover investigations. Additional resources would be required for air photos, gear, travel, and sample processing. Additional indicators (riparian birds, salmonid spawning, salmonid genetics) or additional sites would add to the costs. A substantial investment is also needed for database management, data analysis, and reporting, but these additional costs are common to all current monitoring programs. This could be a very cost-effective investment compared with the cost of current Federal programs (e.g., EMAP, NAWQA).

The following discussion supports assessment of particular indicators or indicator groups, All are commonly nionitored by various institutions, though not in the same ways. In pilot variance studies in various parts of the country and in the hands of specialists, they have all been found to be precise and responsive *to* stressors, especially when data are composited and metrics are integrated into multimetric or multivariate indices, Although field methods have been widely tested (Baker et al. 1994; Hayslip et al. 199.5; Klemm and Lazorchak 1995), the results of these studies are mostly in preparation for submission to journals. The data demonstrate that different indicators respond differently to different stressors, revealing the need for multiple indicators of different types. **At** a minimum, we recommend consistent, quantitative monitoring of the landscape, physical and chemical habitat variables, benthic niacroinvertebrates, and aquatic vertebrates at all assessment monitoring sites. In addition, we reconmend monitoring microbial respiration in urban and mining streams; periphyton in agricultural and rangeland streams; and riparian birds and salmon genetics, spawning, and rearing in random subsets of streams. Monitoring multiple indicators at as many sites as possible is recommended.

Stressors. Human uses of the landscape and riparian zone in large part govern the condition of the water body. This information is available from digitized land-use and land-cover data for each watershed and available remote imagery for each drainage (Rhodes, et al. 1994; Paulsen, et al. 1991). It is used to assess the type, condition, and extent of woody riparian vegetation, both for the site and for a random sample of upstream stream sections. Types, intensity, and extent of watershed, basin, or regional land use and land cover are used to estimate areal disturbance, road density, stream crossings, stream proximity, and migration barriers. Fish stocking and harvest rates, livestock stocking rates, water withdrawals, and historical information about resource exploitation are also useful, but often more difficult to acquire. We recommend monitoring land use, land cover, and historical and present resource extraction rates through use of remote and print data. In addition, site inspections are needed for ground truthing and for the indicators listed in Table 15-1, which vary with land use.

Physical Habitat Structure. There is considerable agreement among State and Federal agencies in the need to monitor many structural components of streams and riparian ecosystems. Riparian indicators include valley type, riparian vegetation structure, human disturbance, and canopy cover. Channel indicators include sinuosity, aspect, gradient, bank erosion or channel incision, bank height, bank undercutting, thalweg profile, depth, and width. An additional set of indicators of habitat complexity include large woody debris, fish cover, and a number of substrate variables (size, complexity, percentage of fines). Because they typically determine the basic capacity and current character of the site, we recommend quantitative measurements of these indicators wherever possible. Current research on the relationships between these variables and fish populations promise to make them even more useful in the future.

Water Qualify. The chemical condition of the water offers a useful means to classify streams by their mineral type and nutrient status, and water quality is a powerful signal for landscape scale stressors. Highly mobile indicators like chloride and nutrients are among the first signals of landscape level perturbations and they are useful measures of landscape revegetation and nutrient retention. Although water chemistry may be of less importance in many forested watersheds, it is critical where land uses include human settlements, agriculture, and livestock grazing. At a minimum, we recommend monitoring temperature, nutrients, turbidity, conductivity, chloride, and dissolved oxygen. If salmonid spawning is of concern, then intergravel dissolved oxygen should also be monitored at a subset of sites during the incubation season. Continuous monitoring of dissolved oxygen and temperature may be recommended in areas likely to experience reduced concentration or supersaturation during late summer. In the vicinity of mines and

AR053305

point sources, monitoring for toxics contained in fish tissue is advised.

Microbial Respiration. This is an assemblage and community-level measure of the reach's carbon processing rate that can be rapidly and inexpensively evaluated on site with simple techniques. It is especially sensitive to the amount of fine particulate organic matter in the system, as well as to the presence of toxics that are likely to result from past or present mining and urban activities. Because most carbon processing in streams results from microbes, this is a useful assemblage to evaluate. It also offers a direct, quantitative measure of a biological ecosystem function. We recommend monitoring microbial respiration for distinguishing chronically toxic or organically enriched waters from a population of streams.

Periphyton. Periphyton assemblages are key primary producers in stream ecosystems, and streams with high rates of primary production are typically our most productive salmonid waters. On the other hand, excessive levels of periphyton signal nutrient enrichment. Composition of periphyton assemblages is also an excellent indicator of low-level or chronic sedimentation in streams, which is determined from the relative abundances of motile and nonmotile diatoms. We recommend monitoring periphyton where fish are absent or in regions where nutrient enrichment is likely.

Benthic Macroinvertebrates. Benthic assemblages are a popular and easily monitored set of stream organisms. They occupy a key position between the algal and detrital food base and fish. Also they are species rich and numerous enough to occupy a large array of habitats and niches. This diversity in structure and function facilitates their use in assessing the effects of numerous perturbations, from water quality changes to sedimentation. Benthos, like periphyton, are especially useful for assessing aquatic biological integrity in fishless waters. They should be monitored in all streams.

Aquatic Vertebrates. Aquatic vertebrates are typically the top carnivores in PNW streams. Forested streams support 0-5 fish species and 0-3 amphibian species, all of which can be effectively sampled with the same gear and methods. Although headwater streams occasionally contain no vertebrates, most larger coastal streams support 2-3 lamprey species, 2-3 sculpin species, and at lower elevations and inland 1-3 minnow species, in addition to salmonids. Each species provides information about the biological integrity of the reach and each is susceptible *to* different types of anthropogenic stressors. Protocols focusing only on salmonids miss key information about other anadromous species and resident vertebrates. Aquatic vertebrate monitoring is recommended for all streams.

Salmon Spawning and Rearing. **A** primary concern of this document is restoration and protection of salmon populations in the PNW. The most appropriate methods to determine achievement of that objective is to monitor spawner abundance or redds and smolt production. The former can be accomplished by aerial surveys, traps, or stream walks, depending on stream size, and the latter is best monitored through use of outmigrant traps. In cooperation with the State fishery agencies, a randomized subset of streams should be monitored for salmon rearing and spawning.

Riparian Birds. Birds provide an easily sampled indicator of how a terrestrial vertebrate assemblage responds to riparian conditions as well as to conditions in the stream and watershed. They are best sampled by competent ornithologists during the breeding season, when populations are most stable and censuses easily taken through sightings and songs. Birds are of great interest to the public and are monitored by Federal agencies through the Partners in Flight Program, the National Breeding Birds Survey, and Christmas bird counts. We recommend monitoring birds wherever multi-species HCPs are developed and at a subset of sites as an indicator of riparian integrity.

Several steps facilitate data collection, analysis, and reporting. At the site, portable data recorders or standardized field sheets facilitate data entry in the database management system. Verification and validation checks on the data are needed for quality control. Measurement data converted to numerical indicators are useful for comparing resample variance with population variance. By running exploratory analyses (scatter plots, principal components analysis, regression analysis, correlations) indicator patterns and behaviors can be easily assessed. To express status and track trends, we recommend selecting ecologically meaningful indicators that possess relatively little sampling variance but considerable responsiveness to stressors. Such indicators should be plotted as histograms, cumulative frequency distributions, maps, or pie graphs for interpretation by interested persons. These indicators are also used to demonstrate regional patterns, temporal patterns, and proportions of the stream population that exceed or fail to meet various criteria. Criteria and reference conditions should be developed from regional reference sites, historical information, models, and expert judgement (Rhodes et al. 1994; Hughes 1995). The ecological acceptability of conditions and trends is a value judgement (Kay and Schneider 1992), but marked changes from reference conditions can be considered marginal or severely impaired (Barbour et al. 1995; Hughes 1995). A regional landscape-aquatic database also facilitates examination of the effects of natural variability among ecoregions and basins as well as the effects of floods, droughts, fire, and ocean conditions.

15.2.5 *Other Monitoring Issues*

A similar sampling and analysis design is recommended if the Agencies choose to sample only at the watershed scale. In such cases the stream population is necessarily smaller and less variable, so a smaller random sample can be obtained. For statistical consistency and reliability, a general rule is a minimum of 30 sites for each class of interest. Because of greater site proximity, there may be advantages in dropping some indicators so that crews can sample more than one site per day. Note, however, that it only takes seven watershed-specific monitoring programs to result in the 200 sites recommended for monitoring in a regional program, but without the regional applicability. Clearly, if regional information is desired it is most cost effective to design a regional survey as proposed. If the interest is both regional and watershed-specific, then the grid can simply be intensified where needed to provide both. Whatever the landscape scale, a probability sampling design is essential for reliably assessing status and trends, unless the entire resource can be rapidly and quantitatively censused.

Regardless of whether the monitoring is conducted at the watershed or regional scale most indicators and monitoring protocols should be the same so that results can be integrated. It is essential to include stressor information in implementation and assessment monitoring. Riparian and instream biological, physical, and chemical indicators are needed if the monitoring objectives involve ecological assessment.

Streams and watersheds that are found to be in very good condition or highly productive of salmonids deserve protection as reference sites, biological refugia, sources of high quality water, or locations for studying natural process rates. Conservation activities that connect these refugia with others are more likely to be successful in protecting and restoring salmonids and biodiversity in general.

Several programmatic concerns should be incorporated into an effective monitoring program. All monitoring personnel must receive consistent training and repeat sampling should be conducted at a subset of locations by other persons to ensure among-watershed comparability and to assess sampling variance. To evaluate ecoregional and basin patterns, watershed-scale data must be aggregated to the larger spatial scales. This requires common indicators among watersheds and Agency coordination to analyze and integrate the data. Regional results should be regularly reported through workshops, the media, and informational brochures.

A successful monitoring program depends on adequate, long-term funding. Contributions from both Federal and nonfederal sources, including landowners and the general public, might consist of money, staff, or equipment. We encourage the maximum amount of cooperation possible in the collection, analysis, and reporting of the data because of the great value of salmonid ecosystems and the importance of high quality information for making rational decisions about natural resources. Two issues, identifying funding sources for long-term monitoring and designating a lead agency (or agencies) for database management and reporting, need to be resolved if salmonid conservation activities are to be accurately evaluated and if monitoring information is to be used effectively both to adaptively manage and to guide future planning efforts.

In addition to the monitoring discussed above, other forms of monitoring and assessment are desirable. 1) There is a substantial need for rigorous stock assessment through use of genetic and morphometric analyses of salmonids in all sub-basins of the Pacific Northwest; this data will aid in delineating ESUs and addressing biodiversity issues. Also, it could be coupled with the other forms of fish monitoring. 2) We need to assess salmonid diseases within basins and at distribution breaks. Disease is a poorly studied limiting factor, and information on disease may also assist in defining ESUs. 3) In addition to those in Oregon, aquatic diversity areas and spawning "hot spots" should be located in the other States and in other regions of Oregon. These areas serve as foci for protection and restoration, and they are useful for setting recovery expectations for disturbed sites. 4) Continued monitoring of adults and smolts is needed at dams and hatcheries, especially the effects of these perturbations on the timing and abundance of salmonid migrations. As dams are removed and hatchery practices modified, pre- and post-modification monitoring will provide useful information on their effects. 5) Monitoring of salmon harvest is needed to document the successes and failures of the various options. 6) A central fish database of historical information is needed. Such a database was developed from museum data for Oregon (Hughes et al. 1987), but it needs amplification with other forms of less rigorous data on fish species and abundances (e.g., collections without museum specimens, probable distributions). To our knowledge, the other States in the region lack even the museum database, despite the importance of knowing the fish species to expect in any watershed of the region, as well as the range and probable abundance of a species. Clearly, the monitoring of these more regional components of the salmonid

AR053307

environment requires integration with the monitoring program discussed in the preceding subsections,

15.3 Summary

Considerable information exists about the successes and failures of compliance monitoring and the benefits and shortcomings of various assessment monitoring designs (reviewed in Chapter 10). In addition, there are sufficient examples of the advantages of quantitative indicators and indicators of biological condition, in particular. These are all only briefly examined in this volume.

To evaluate compliance and assess the effectiveness of management practices at both local and regional scales, a comprehensive interagency, Federal-nonfederal monitoring program is strongly recommended. It should be entered into only after a thorough examination of long-term objectives and goals. We need rigorous sampling designs and quantitative data (from physical, chemical, and biological indicators) to make informed decisions about those goals and objectives and to practice adaptive management in a rational manner. Unfortunately, if we continue to develop ecological and economic policies without monitoring strategies to measure their effects, it is likely that we will ultimately guarantee ecological and economic failure. Perhaps these shortcomings partially explain why Karr (1995), McCullough and Espinosa (1996), and Henjum et al. (1996) feel our current regulatory agencies do not respond to degradation in an effective and timely manner. We have the potential and the tools to do much better; we recommend committing the monitoring and management resources necessary *to* do so.

AR053308

16 Implementation Strategy

"My grandfather taught me how to mend net, to close a gaping hole one knot at a time, measuring each mesh **Fishing** *was all small acts, practiced with the devotion of the religious. .We owe following generations no less than restoration of the Northwest's wild salmon runs. Ours must De small acts practiced with the same devotion of my grandfather mending web "*

James B. Petit
Solid Faith in Small Acts *in Illahee*, 1994

Conservation and restoration of salmonid habitat in the Pacific Northwest will require that a series of small acts be integrated into a comprehensive program. A successful conservation program aims to restore the natural function of landscapes—at least sufficiently to restore the processes and habitats supporting Salmonids. Each action can be viewed in the context of how well it protects or enhances salmonids and their habitats. Similarly, the conservation activities of individual landowners can be made most effective if they are woven into a regional habitat and salmon conservation program.

An implementation strategy involves the large temporal and spatial scale issues in salmonid conservation. In preceding sections of this document we have presented niuch information about why, where, and how we need to restore and protect salmonids and their habitats. We have also recommended why, where, and how monitoring should be implemented. In this chapter we discuss who needs to do what and when they need to do it. In Section 16.1 we recommend how a regional conservation plan should be developed. Section 16.2 discusses the implementation of site and regional monitoring programs. Finally, Section 16.3 summarizes additional issues that need to be considered when implementing a successful conservation strategy.

16.1 Development of HCPs and a Regional Salmon Conservation Strategy

The "what" portion of an implementation strategy includes developing HCPs and other conservation practices, monitoring the implementation and effects of those practices, and developing and evaluating the overall conservation program. Clearly, it is the responsibility of landowners and land managers, with Agency guidance, to develop conservation plans at the site or catchment scale. To date, HCPs for salmon have been developed primarily by large corporations, municipalities, or Federal agencies. If more salmonid stocks are listed under ESA, the need will increase to develop conservation plans for watersheds with multiple ownerships, including watersheds with many small private landowners that share ownership, as well as watersheds with mixed private, State, Federal, and Tribal ownership. In these instances, conservation planning becomes increasingly complex. Federal-nonfederal land exchanges could facilitate planning and land management in some of these cases, especially within the checkerboard ownership patterns that resulted from the last century's railroad lands. The scientific principles guiding conservation of aquatic and riparian habitats should not differ between Federal and nonfederal lands; however, conservation standards may be more conservative on Federal lands. Because of the desired size of the planning units, 20-200 square mile watersheds, we expect that most HCPs will eventually involve multiple landowners. The strategy in such cases is likely to take one of two courses. Where there are dominant or codominant owners, we recommend that they take the lead in HCP preparation, with contributions from fellow landowners proportionate to ownership. Where ownership patterns are more heterogeneous, watershed councils or cooperatives can be formed to either produce a plan via existing county or municipal staff or contract for one, as many of the large landowners do now. A growing number of watershed councils appear to be following this tack.

A regional plan or program is similarly problematic, but it involves a much larger spatial scale (region versus watershed). The Federal land management agencies through the Record of Decision (ROD) for the President's Forest Plan (FS and BLM 1994c) have established a program for Forest Service and Bureau of Land Management lands west of the Cascades. PACFISH (FS and BLM 1994a) proposes interim planning guidelines for anadromous salmonids on Federal lands east of the Cascades and INFISH (FS 1996) provides similar guidelines for resident salmonids on Federal lands in the interior portion of the Northwest. *An Ecosystem Approach to Salinoizid Conservation* covers nonfederal, salnionid-bearing streams throughout major portions of California, Idaho, Oregon, and Washington. All of these reports document programs that would be enhanced if they were linked with one another and with other Federal, State, and Tribal entities into a comprehensive regional salmonid conservation program. Such a program should include listed species, at risk but currently unlisted species, and their ecosystems. In other words, the Agencies should work to ensure that this program and individual conservation plans incorporate an overall conservation strategy for Federal, as well as nonfederal, lands in tlie four-State region.

A strategy to implement a salmon conservation program on nonfederal lands requires a new perspective for Federal fisheries agencies. Many private landowners have demonstrated a willingness to change management practices. For example, many improvements in agricultural practices, range management, forestry management, and mining have occurred in the past 50-100 years, but these changes occurred slowly. As innovations proved effective and profitable, they were disseminated through the affected community. The Natural Resources Conservation Service (NCRS), formerly the Soil Conservation Service (SCS), practices a method that serves as one model for resource conservation planning on nonfederal lands. It is based on mutually identifying and discussing issues, identifying options or guidelines, and providing individual landowners sufficient information to change their actions voluntarily. The EPA practices an alternative model. EPA develops science-based criteria and best treatment practices that States can accept or modify with sufficient scientific support. The States list desired uses for water bodies and apply the necessary criteria to protect those uses. EPA and the States regulate tlie dischargers through permits, monitoring, and if necessary, fines. This process has been successful at markedly reducing point source pollution by private and public dischargers over the past 25 years. Both approaches involve substantial Federal investments either in field staff in the case of tlie SCS or in matching funds for municipal waste treatment in tlie case of EPA.

We recommend an implementation strategy that combines the best of both models. It should be science based and include a regulatory component because of the urgent need to change current practices in order to restore salmonids. In addition, there should be sufficient field staff to aid landowners in developing and implementing HCPs because of the fundamental philosophical and technical changes needed. Because salmonids are resources of national concern, Federal aid for planning, implementation, and monitoring is merited.

16.2 Monitoring Conservation Efforts Locally and Regionally

As discussed in Chapter 15, conservation planning must be monitored at both the site and regional levels. In addition to implementation and assessment monitoring, tlie process of developing HCPs must also be monitored to assure quality and regional consistency. But who should do the monitoring, and who should pay for it? Chapter 10 discusses some of tlie failures of well known monitoring programs. Given concerns with losing wild salmonids from the Pacific Northwest for their own sake, as well as for the enormous economic consequences that entails, we must strive to do a much better job of monitoring and enforcement.

16.2.1 Program Monitoring

At the level of program implementation and development of HCPs and other conservation agreements, we recommend two different activities. First, the HCPs themselves should be largely reviewed by Agency staff. We recommend at least bi-agency review if the HCP waters do not drain contiguous Federal land. **If** they do drain contiguous Federal land, the appropriate Federal land management agency should review the HCP and the Agencies should review the Federal conservation plan. These reviews should be conducted by staff that are professionally trained in the disciplines of geology, hydrology, soil science, aquatic ecology, riparian forest ecology, fisheries ecology, and where necessary, toxicology and engineering. Consistent plans should be the goal, at least within ecoregions and regardless of ownership. In addition, HCPs should complement existing State conservation programs, and the most complete analyses should be considered adequate for both purposes. Second, public comment, as required by Section 10 of ESA, should be requested before HCP approval. The comments and recommendations, along with the Agency responses, should be entered and tracked in the computer database. We also recommend that the overall conservation program itself undergo periodic peer review, similar to those already conducted by tlie Science Advisory Board for EPA, with reviewers representing other agencies, academia, and the private sector. This is common practice for ensuring the integrity of science and will add to the credibility of tlie Agency's conservation efforts.

16.2.2 HCP Implementation Monitoring

Implementation monitoring should mostly be conducted by Agency staff. This monitoring could be accomplished by contract or by State employees, with results entered directly into the Agencies central database. Although some State agencies have a better record than the Federal government in enforcing laid-use and pollution laws, this creates interstate inconsistency, an unnecessary additional layer of bureaucracy, and added overhead costs. In addition, an HCP is a contract with the Agencies, not with a State, although States may be integrally involved in other conservation efforts. Ideally, persons conducting the HCP reviews will also perform some of the implementation monitoring, especially site inspections. Because of the array of expertise involved, site visits are expected to require more than one staff member. The remote sensing portion of the implementation reviews require geographers and landscape ecologists with skills in GIS analysis and airphoto interpretation, but they too should be expected to conduct some ground truthing. Results and comments should be entered into the centralized computer database.

16.2.3 HCP and Regional Assessment Monitoring

Development of a regional assessment monitoring system for salmonid ecosystems is clearly an Agency responsibility, although if properly coordinated, it could include other Federal, State, Tribal, and private crew members. The same is true of crews monitoring HCPs, although in this case private landowners are likely to show more interest in the monitoring. Whatever the scale of the monitoring and whomever the employer, the crews should be trained consistently, use the same sampling methods and quality assurance protocols, and be dispersed randomly in the region to the greatest degree possible. Along with the assurance of repeat sampling by different crews, this will minimize biased results. If State crews are prohibited by their employers from crossing State lines to sample, if other Federal crews cannot sample on nonfederal lands, or if private crews can only sample on their own lands, mixed crews are not recommended. As with the other two types of monitoring, data should be stored in the centralized computer database.

16.3 Additional Issues in Implementing a Salmon Conservation Strategy

As discussed above in the nionitoring subsections, there is a clear need for a cooperative Federal, State, and Tribal effort in developing the computer database as well as support for the necessary database managers, computer programmers, and statisticians to ensure effective and responsive operation. The Agencies and others will also need to support a substantial database containing digitized remote sensing data as well as a periodically updated library of topographic maps and air photos, together with a librarian to coordinate them. Much of this information will also be useful to other persons interested in developing future HCPs.

Although the proposed program incorporates some of the highest technology and planning in landscape ecology and conservation biology, the results of the planning and monitoring should not be reported only to scientists. The public must remain actively engaged in this process. This may be best accomplished by preparing annual reports in an easily read and understood format for public consumption.

The databases, including the HCP implementation and monitoring results, should be used to improve our ability to develop ecoregion-specific management programs. A critical aspect of this entire strategy is to position ourselves to learn from and correct past and future mistakes. We recommend that conservation measures be reviewed and revised if monitoring or new research suggests inadequacies; the frequency of review would depend on specific concerns or issues, but adaptive management requires strong linkages between monitoring and the modification of conservation strategies.

We also see three issues relating to equitable treatment of landowners that are likely to be concerns in successful conservation planning. 1) Landowners that have previously managed their lands to conserve ecological integrity or biological diversity may be expected to restrict future resource exploitation more than those who have intensively and extensively exploited resources, particularly if these lands contain habitats critical to the persistence of salmonid stocks. This also is an issue in comparing forestland restrictions with urban, agricultural, and rangeland restrictions. No single land use should shoulder a disproportionate share of the burden in restoring salmonid habitats. We have attempted to make consistent recommendations for all land uses but suspect situations will arise where comparable restrictions are impractical. Alternative conservation trade-offs, land exchanges, tax breaks, or other incentives may provide means for rewarding good stewardship. 2) In contrast, multi-owner conservation efforts will occasionally include individual landowners that have been poor stewards and whose actions may limit salmon and ecosystem recovery throughout a planning area. Strategies (e.g., education, removal of Federal subsidies) will be needed to deal with these instances. 3) Violations of the antidegradation clause of the Clean Water Act, as well as listed species, occur on Federal lands. This is another reason we recommend implementation and assessment monitoring of both Federal and nonfederal lands.

Salmon conservation and the enforcement of ESA come at a time when choices are increasingly limited. Marsh (1965[1864]) predicted this very condition for Pacific salmon over 100 years ago. Now we have the choice of driving more stocks and species toward threatened and endangered status or of managing our lands to avoid that situation. Given some present trends in the Pacific Northwest, salmonids not currently listed as threatened or endangered under the Endangered Species Act are at risk of listing in the future. Conservation efforts are far more likely to succeed if we conserve remaining relatively healthy salmonids—rather than drive them to listing and then attempt to restore them. For this reason, we strongly recommend development of HCPs or other forms of conservation planning and monitoring throughout the region, regardless of whether a particular stock or species is listed. Agency staff are mandated by other laws than ESA (e.g., Clean Water Act, National Environmental Policy Act), as well as by their knowledge of conservation biology, to manage proactively and to seek to prevent species from becoming threatened or endangered.

We also have two broader strategic concerns. First, a focus on the immediate physical and chemical habitat of salmonids and the land uses that affect them is insufficient to conserve salmon. Other activities, including hatchery and harvest practices, as well as water withdrawals and the operation of dams, need to be included in a successful conservation strategy. Even if conservation efforts eventually restore habitats throughout the region, salmonids may still decline unless we modify hatchery operations, promote terminal instead of mixed-stock fisheries, limit water withdrawals from thermally and low-flow stressed rivers, and modify or remove dams that impede upstream and downstream migration. Second, continuation of current growth rates in human population and resource consumption in the Pacific Northwest indicate that demands for resources—and the incumbent effects on salmonids—are likely to intensify. Ultimately, these root causes of environmental deterioration will need to be addressed as part of our conservation planning efforts.

These recommendations acknowledge that ecosystem management will be accomplished through many individual and independent actions. But they also acknowledge that if ecosystem management and salmon conservation are to succeed, each independent action must be integrated into a comprehensive program with a regional conservation objective. The science underlying landscape management and salmonid conservation is constantly changing; thus, implementing an effective strategy requires adapting to new information as it is developed. It is our belief that the planning elements contained in this document provide a foundation from which to build a successful strategy by applying what we already know about ecosystem function, as well as facilitating the collection of information that will allow us to improve planning efforts in the future.

AR053312

Appendix: Information Sources

A.1 Introduction

This appendix supports Part II, "Planning Elements and Monitoring Strategies," which itself builds on Part I, "Technical Foundation" of *An Ecosystem Approach to Salmonid Conservation*. Within Section A.2, we identify selected sources of information that may assist resource managers, regulators, and landowners in obtaining the necessary background data to develop comprehensive habitat conservation plans or to critically evaluate such plans. We have not compiled an exhaustive list of all sources, but we have provided examples of sources that individuals may use directly or may use as a guide for seeking other sources to meet their particular data needs. For each type of data, information is listed in a tabular format: tlie data coverage (i.e., regional or state) appears in the left column with the form of available data (e.g., maps, documents, information, GIS coverages, and other electronic databases); the data source appears to the right, along with a brief description of the data *(in italics)*, if available. Following this description is an alphabetical list of all addresses and Internet addresses of sources included in this appendix.

Users are cautioned about the changeability of electronic access to information. Because electronic information changes frequently, access to tlie World Wide Web universal resource locators (URLs), email addresses, and telephone area codes with numbers below may have changed since publication of this document. Consequently, as many access points as possible via many media have been provided. One strategy to recapture access is to enter an address using one less segment of it in tlie hopes of entering a server at one or two levels of specificity above the location of the sought information.

In Section A.3 we provide brief sketches of relevant Federal and State laws and regulations that may be of concern or use to landowners involved in conservation planning for salmonids and their habitats. This is not an exhaustive list, but we sought relevant information in the areas of land use, forestry, agriculture and pesticides, range, mining, water quality, instream flows, and channel alteration for the four States in the Pacific Northwest. Persons needing further information are encouraged to visit a university law library or appropriate web sites. Section A.4 presents a list of mailing addresses, phone numbers, FAX numbers, and internet addresses for various Federal and State government offices in the Pacific Northwest.

A.2 Regional Versus State-Specific Data and Sources

Data or data sources that apply to more than one of the States of California, Idaho, Oregon, and Washington are listed first under "Regional." If there are any State-specific sources (e.g., State offices of Federal agencies) or exclusively State-specific data (e.g., State of Washington Watershed Analysis Units Map), those entries follow. State-specific data that are available from one source for multiple States are included under "Regional," as are sources that apply generally to all locations regardless of the specificity of the data itself. Just because there are no "State-specific" entries does not mean there are no State-specific data from a source that also has data for other States in the region (and is thus listed under "Regional").

Data sources by category are illustrated in Table A. Data may be available in different forms (e.g., GIS layers, maps, digital, print) and sources may use different criteria for determining land or regional characteristics (e.g., Bailey's ecoregions versus Omernik's ecoregions). In addition, the same data may be available in various forms from different sources (e.g., 1:250,000 hydrology maps are available in hard copy from the Geological Survey's Map Distribution Center or in digital form from the Geological Survey's Node of the Geospatial Data Clearinghouse on the Internet). Finally, some data may be available from multiple vendors (e.g., hard-copy GS 7.5 minute topographic maps). In some cases, sources are addresses (postal or Internet) of sources that distribute data. In other cases, sources are citations to literature; documents must be obtained from a library or the publisher. Some data are identified with an asterisk (*) indicating that data are known to exist, but a specific data source, data availability (whether it is published or is available for public release), or the content of the data (whether the data source contains the data type) is not known.

Users are cautioned to evaluate the applicability of any data source relative to their specific needs.

This appendix is not nieant to be a comprehensive list of all available sources; other sources of applicable data may be available. The user may identify these when beginning with the provided examples and starting points. It is likely that once some of these sources of information are contacted by a user with data needs for a specific location or application, other, more specific data forms will be suggested. It is highly recommended that the user consult with identified local and State agencies and offices or local field offices of Federal agencies prior to acquiring data; less expensive or more site-specific data and information may be available at the local or State level given a specific data requirement for a specific location.

This appendix presents one table for each of fifteen types of data that may be useful for developing and evaluating habitat conservation plans: 1) Ecoregion, 2) Hydrologic Unit, *3)* Topography, 4) Geology, 5) Soils, 6) Current Vegetation, 7) Historical Vegetation, 8) Aerial Photographs, 9) Land Use History, 10) Precipitation, 11) Streamflow, 12) Stream and Surface Water Type, 13) Water Quality, 14) Fish Species Distribution, and 14) Threatened and Endangered Species.

Table A. Data source overview.

Data Type	States			
	CA	ID	OR	WA
1. Ecoregion	R	R	R,S	R
2. Hydrologic unit	R,S	R,S	R,S	R,S
3. Topography (and aspect*)	R	R	R	R
4. Geology	R	R	R	R
5. Soils	R,S	R	R	R,S
6. Vegetation (current)	R,S	R,S	R,S	R,S
7. Vegetation (historical)	R	R	R,S	R
8. Aerial photographs (current)	R,S	R,S	R,S	R,S
9. Land-use (or environmental†) history	R	R	R,S	R
10. Precipitation	R	R	R,S	R,S
11. Streamflow	R,S	R	R	R,S
12. Stream and surface water type	S	R‡	S	S
13. Water quality	R,S	R,S	R,S	R,S
14. Species distribution—fish	R,S	*S*	R,S	R
15. Endangered/threatened species	R,S	R,S	R,S	R

* Aspect can be derived from topographic map data.
† Environmental history may be derived from land-use history and historical vegetation.
‡ Surface water type for Idaho may be available from regional sources under "Streamflow."
R Regional. State affiliates or offices of Federal agencies or data sources are included with regional sources.
S State-specific.

AR053314

Table A-1. Sources for ecoregion data

Data coverage	Data form	Source
Regional	Map	Bailey, R. G. 1978. Description of the ecoregions of the United States. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, 324 25th St., Ogden, UT 84401-2310, (801) 625-5437. Developed initially to provide a spatial *framework* for the *U.S.* Department of the Interior, Fish and Wildlife Service (FWS), National Wetlands Inventory.
	Map	FS (Forest Service). 1993. National hierarchical framework of ecological units, ECOMAP. U.S. Department of Agriculture, Forest Service, Washington, D.C. Developed to provide a consistent framework for *the* implementation of ecosystem management by the Forest Service at the national, regional, and forest planning levels. The map units are differentiated by multiple factors including climate, physiography, geology, soils, water, and potential natural communities.
	Map/GIS Digital	Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118–125. Electronic copy available (no fee) on the Intemet (World Wide Web) through the Geological Survey's node of the National Geospatial Data Clearinghouse as an *ARC/INFO* export tile: *http://nsdi.usgs.gov/nsdi/wais/water/ecoregion.html*. Initially developed to classify streams for water resource management, derived from those factors considered most important in controlling water quality in a given area, including land surface form, land use, soils, and natural vegetation.
	Map	Thiele, S. A., C. W. Kilsgaard, and J. M. Omernik. 1993. The subdivision of the Coast Range Ecoregion of Oregon and Washington. On file at U.S. Environmental Protection Agency, 200 SW 35th St., Corvallis, OR 97331.
State		
Oregon	Maps	Clarke, S. E., D. White, and A. L. Schaedel. 1991. Oregon, USA, ecological regions and subregions for water quality management. Environmental Management 15:847–856. Bryce, S. A, and S. E. Clark. 1996. Landscape-level ecological regions: linking state-level ecoregion frameworks with stream habitat classifications. Environmental Management 20:297–311.

Table A-2. Sources for hydrologic unit data.

Data coverage	Data form	Source
Regional	Map	GS (Geological Survey). 1994a. Hydrology map of the 48 conterminous United States. Map scale 1:250,000. U.S. Department of the Interior, Geological Survey, Washington, D.C. This map is available (no fee) on the Internet (World Wide Web [WWW]) through the GS node of the National Geospatial Data Clearinghouse, http://nsdi.usgs.gov/nsdi/wais/water/huc25O.html, as an ARC/INFO export file. See also GS-Info./Maps below. GS (Geological Survey). 1994b. Hydrologic unit map of the United States. Map scale 1:7,500,000. U.S. Department of the Interior, Geological Survey, Washington, D.C. *Hydrologic units are watersheds defined by topographic drainage divides.*
State		
California	Map	GS (Geological Survey). 1978. Hydrologic unit map, 1978, State of California. Map scale 1:500,000. U.S. Department of the Interior, Geological Survey, Reston, Virginia.
Idaho	Map	GS (Geological Survey). 1982. Hydrologic unit map, 1981, State of Idaho. Map scale 1:500,000. U.S. Department of the Interior, Geological Survey, Reston, Virginia.
Oregon	Map	GS (Geological Survey). 1976. Hydrologic unit map, 1974, State of Oregon. Map scale 1:500,000. U.S. Department of the Interior, Geological Survey, Reston, Virginia.
Washington	Map	GS (Geological Survey). 1976. Hydrologic unit map, 1974, State of California. Map scale 1:500,000. U.S. Department of the Interior, Geological Survey, Reston, Virginia.
	Map	WDNR (Washington Department of Natural Resources). N.y. Watershed Analysis Unit (WAU) map. Map scale 1:100,000. Washington Department of Natural Resources, Photo & Map Sales, P.O. Box 47013, Olympia, WA 98504-7013, (360) 902-1234.

Table A-3. Sources for topography data.

Data coverage	Data form	Source
Regional	Maps	U.S. Department of the Interior, Geological Survey, Map Distribution Section, Map Sales, Federal Center, Box 25286, Denver, CO 80225, (303) 236-7477. *The Geological Survey produces 1:24,000 (7.5 minute) topographic quadrangles for all areas within the conterminous United States. Topographic maps may be ordered from the Map Distribution Section at the above address or from local vendors; the Map Distribution Section can provide a list of local and regional vendors.*
	GIS-Info./ Maps	U.S. Department of the Interior, Geological Survey, Public Inquiries Office (PIO), Building 3, Room 3128, Mail Stop 522, 345 Middlefield Road, Menlo Park, CA 94025, (415) 329-4390. *PIO assists the public in selecting and ordering of all GS products and provides counter service for GS topographic, geologic, and water-resources maps and reports. The Menlo Park office covers the States of California, Idaho, Oregon, and Washington.*
	Maps/GIS Digital	GS node of the National Geospatial Data Clearinghouse, WWW address at http://nsdi.usgs.gov/nsdi/. *Metadata that describe geology, water, and mapping sets available on the World Wide Web. Many data sets are available on-line, including digital elevation model, land use/land cover, and water resources. An interactive search can be performed using States or latitude and longitude of a specific location. The program will search for all GS spatial data available for that location.*

Table A-4. Sources for geology data.

Data coverage	Data form	Source
Regional	Info/maps	U.S. Department of the Interior, Geological Survey, Geological Inquiries Group (GIG), 907 National Center, Reston, VA 22092, (703) 648-4383. GIG provides information and answers inquiries concerning all aspects of geology, such as the geology of specific areas, energy and mineral resources, earthquakes, volcanos, geochemistry, geophysics, and geologic map coverage. GIG produces Geologic Map Indexes, by State. Geologic maps show the underlying geology of a specific area and often include other information such as the presence of rock outcrops, unstable soils (sometimes determined by bumpy, uneven ground surface using aerial photographs), etc.
	GS-info /maps	U.S. Department of the Interior, Geological Survey, Public Inquiries Office (PIO), Building 3, Room 3128, Mail Stop 522, 345 Middlefield Road, Menlo Park, CA 94025, (415) 329-4390. PIO assists the public in the selection and ordering of all GS products, and provides counter service for GS topographic, geologic, and water-resources maps and reports. The Menlo Park office covers the States of California, Idaho, Oregon, and Washington).
	Maps/ GIS Digital	GS node of the National Geospatial Data Clearinghouse. WWW address at http://nsdi.usgs.gov/nsdi/. Metadata that describe geology, wafer, and mapping sets are available on the World Wide Web. Many data sets are available on-line, including digital elevation model, land use/land cover, and water resources.

Table A-5. Sources for soils data.

Data coverage	Data form	Source
Regional	*Soil surveys (books)*	*U.S. Department* of *Agriculture, National Resource Conservation Service (NRCS) (formerly Soil Conservation Service* [SCS]), *West Regional Office, Sacramento, CA. Additional soil information for specific States or counties can be obtained through the NRCS State Conservationist* or *Resource Inventory Specialist at the appropriate NRCS State office, or through local NRCS field offices. Addresses and phone numbers* for *State offices are as follows: California,* 2121-C *2nd Street, Davis, CA* 95616, (916) 757-8200; *Idaho,* 3244 *Elder Street, Room* 124, *Boise,* ID 83705-4711, (208) 378-5700; *Oregon,* 1220 S. *W. Third Avenue, Room* 1640, *Portland, OR* 97204-2881, (503) 414-3028; *Washington, Rock Pointe Tower* II, *Suite* 450 *W.* 316 *Boone Avenue, Spokane, WA* 99201-2348, (509) 353-2337. *Provides Soil Surveys in book form by County, primarily covering agricultural areas, which include aerial photographs and soil maps. Soil type descriptions include slope, permeability, and other useful information, Contact the Regional or State office and request the phone number of the field office for your County. Field offices generally distribute the Soil Surveys for that County free of charge. Inquire as to whether the survey covers your area of interest before requesting the survey book itself. Staff may also assist you in determining the soil type for your location.*
	Data base	*National Soil Characterization Database. The database* of *the Soil Survey Laboratory* (SSL), *National Soil Survey Center, currently contains analytical data* for *more than* 20,000 *pedons* of *U.S. soils. The data are available on one standard CD-ROM disk.* To *obtain technical information about these data, contact Steven L. Baird, USDA, Natural Resources Conservation Service, National Soil Survey Center, Soil Survey Laboratory, Federal Building, Room* 152, *MS* 41, 100 *Centennial Mall North, Lincoln,* NE 68508-3866, (402) 437-5363. To *order the data, contact the USDA, Natural Resources Conservation Service, National Cartography and Geospatial Center,* 501 *Felix* St., *Bldg.* 23 *(P.O. Mail* 6567), *Fort Worth, TX* 761 15, (800) 672-5559. *Current Price:* $50.00 for *single CD-ROM disk.* *The National Soil Characterization Database is composed of the SSL working computer files. It includes data that may or may not represent the central concept of a soil series or map unit and pedons sampled to bracket a range of soil properties within a series or a landscape; all such data are retained in the database. Users unfamiliar with a given soil may want to consult a knowledgeable soil scientist to determine how well the data represents a soil series; the database has not been edited to remove all of the erroneous or sometimes misleading data. Users are responsible for assessing the accuracy and applicability of the data. The characterization data are stored in a fixed length, column positional, tab-delimited file structure, with a two-record freeform header, in master and State data sets, ASCII format.*

Table A-5. Sources for soils data.

Data coverage	Data form	Source
	GIS Digital	USDA Natural Resources Conservation Service (NRCS), National Cartography and Geospatial Center (NCGC), Fort Worth, TX 76115-0567, (800) 672-5559. For information on the availability of GIS coverages of soil information for specific States, contact the NRCS State Conservationist or Resource Inventory Specialist at the appropriate NRCS State office. (Addresses and phone numbers are listed under "Soil surveys" above.) *The NRCS maintains three soil spatial (GIS) databases including the Soil Survey Geographic Data Base (SSURGO), the State Soil Geographic Data Base (STATSGO), and the National Soil Geographic Data Base (NATSGO). Components of map units in each database are generally phases of soil series. Information such as particle size distribution, bulk density, available water capacity, soil reaction, salinity, and organic matter is included for each major layer in the soil profile. Also included are data on flooding, water table, bedrock, subsidence characteristics of the soil, and interpretations for erosion potential, engineering, building and recreational development, and cropland, woodland, wildlife habitat, and rangeland management.* *SSURGO provides the most detailed level of information and is used primarily for farm and ranch conservation planning; range and timber management; and county and parish, township, and watershed resource planning and management. These data are digitized from original soil survey maps (see Soil Survey Reports above). Data are collected and archived in 7.5 minute topographic quadrangle units (scale 1:15,840 to 1:31,680). Digital coverage for many areas in the United States is currently limited.* *STATSGO is used primarily for river basin, State, and multicounty resource planning. Soil maps for STATSGO are made by generalizing more detailed soil survey maps or, where detailed maps are not available, by integrating data on geology, topography, vegetation, and climate, as well as Landsat images. The GS 1:250,000-scale topographic quadrangle series is used as a map base; data are collected and archived in one degree by two degree topographic quadrangles.* *NATSGO is used primarily for national, regional, and multistate resource appraisal, planning, and monitoring. The NATSGO map was digitized at a scale of 1:7,500,000 and is distributed as a single data unit for the conterminous United States coverage.* *The NCGC operates both a Geographic Resource Analysis Support System (GRASS) and an ARC/INFO GIS. Other formats may be available.*

AR053320

Table A-5. Sources for soils data.

Data coverage	*Data form*	*Source*
	Database inventory	*The National Resources Inventory (NRI) is a database form of the inventory of land cover and use, soil erosion, prime farmland, wetlands, and other natural resource characteristics on nonfederal rural land in the United States. For more information on data-collection methods and results for specific States or regions, contact the NRCS State Conservationist or Resource Inventory Specialist at the appropriate NRCS State office. (Addresses and phone numbers are listed under "Soil Surveys" above.) Data can be ordered off the World Wide Web at* http://www.ncg.nrcs.usda.govlnri.html. To *obtain the data analysis software or for additional information on* the *NRI program, contact USDA-Natural Resources Conservation Service, Resources Inventory and Geographic Information Systems Division,* P.O. Box 2890, *Washington, D.C.* 20013, (202) 720-4530. *To order data write the USDA-Natural Resources Conservation Service, National Cartography and Geospatial Center, Fort Worth Federal Center, Bldg.* 23, *Room* 60, P.O. Box 6567, Fort *Worth, TX* 76115-0567, (800) 672-5559. *Inventories are conducted at 5-year intervals by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), to determine the conditions and trends in the use of soil, water, and related resources nationwide and statewide. The NRI is linked to NRCS's extensive Soil Interpretations Records database to provide additional soils information. Data elements consistent within the NRI database among the last three (1982, 1987, and 1992) NRIs: I) farmstead, urban, and built-up areas; 2) streams less than 1/8 mile wide and water bodies less than 40 acres; 3) type of land ownership; 4) soils information—soil classification, soil properties, and soil interpretations such as prime farmland; 5) land cover/use—cropland, pasture land, rangeland, forest land, barren land, rural land, urban and built-up areas; 6) copping history; 7) irrigation—type and source of water; 8) erosion data—wind and water; 9) wetlands—classification of wetlands and deep-water habitats in the U.S. (1982 and 1992 only); IO) conservation practices and treatment needed; 11) potential conversion to cropland.* *The 1992 NRI is the most extensive inventory yet conducted, covering 800,000 sample sites, representing the Nation's nonfederal land—some 75% of the Nation's land area. Data collected in the 1992 NRI provide a basis for analysis of 5- and IO-year trends in resource conditions. New data elements added for the 1992 NRI include 1) streams greater than 1/8 mile wide and water bodies by kind and size greater than 40 acres; 2) Conservation Reserve Program land under contract: type of earth cover—crop, tree, shrub, grass-herbaceous, barren, artificial, water; 3) forest type group; 4) primary and secondary use of land and water; 5) wildlife habitat diversity; 6) irrigation water delivery system; 7) Food Security Act (FSA) wetland classification.* *For a more detailed understanding of the data element characteristics, request a copy of the "Instructions for Collecting 1992 NRI Sample Data." Many data items in the 1992 NRI are consistent with previous inventories.*

Table A-5. Sources for soils data.

Data coverage	Data form	Source
		Database Availability: The NRI database is available to the public on four CD-ROMs (ISO 9660 format) at $50 per disk. Each disk contains data for a collection of States that form a contiguous region (CD #1 includes Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming). Each disk includes separate files containing the Soils Interpretations Records and spatial data sets for mapping NRI data (see "Spatial Data Sets," below). All files are flat ASCII files. Data can be downloaded on a State-by-State basis if disk storage space is limited. Database documentation is provided. *Spatial Data Sets: Spatial data sets of boundaries of Major Land Resource Areas, 8-digit hydrologic units, and counties are provided on each CD for the region corresponding to the NRI data with and without Federal lands. These data sets contain the same spatial identifiers used in the NRI database allowing NRI users to create interpretive maps. The data are provided in Geological Survey, DLG-3 formatted files on the four data CDs for the appropriate region. GRASS-GIS vector formatted files are included on the data analysis software. Documentation on spatial databases is provided.*
State		
California	Info/ *Database*	*National Resource Conservation Service (NRCS): USDA, Natural Resources Conservation Service,* 2121-C *Second Street, Suite* 102, *Davis, CA* 95616, (916) 757-8262. *NRI Information via email: nri@ca.nrcs.usda.gov.* *In California, over 8,000 sample sites were used. Nonfederal land represents 94% of the State's land base. At each sample point, information is available for three years: 1982, 1987, and 1992. From this time series, changes and trends in land use and resource characteristics can be estimated and analyzed for a IO-year period.*
	GIS Digital	*Natural Resources Conservation Service (NRCS) SSURGO and STATSGO spatial databases. See entry under "Regional" above.*
Idaho	*GIS Digital*	*Natural Resources Conservation Service (NRCS) SSURGO and STATSGO spatial databases. See entry under "Regional" above.*
Oregon	*GIS Digital*	*Natural Resources Conservation Service (NRCS) SSURGO and STATSGO spatial databases. See entry under "Regional" above.*
Washington	Map	Soil *Erosion Potential Map for WAU, Washington Department of Natural Resources, Photo* & *Map Sales, P.O.* Box 47013, *Olympia, WA* 98504-7013, (360) 902-1234.
	GIS Digital	*Natural Resources Conservation Service (NRCS) SSURGO and STATSGO spatial databases. See entry under "Regional" above.*

Table A-6. Sources for data on current vegetation.

Data coverage	Data form	Source
Regional	Land-cover maps	U.S. Department of the Interior, Geological Survey, National Cartographic Information Center Cover (NCIC), Western Mapping Center, 345 Middlefield Road, Menlo Park, CA 94025, **(415) 328-**4309. NCIC offices accept orders for aerial photographs and satellite imagery and sell custom cartographic products such as GS digital data, color and feature map separates, orthophotoquads, and land-use and land-cover maps.
	Maps/GIS digital	Geological Survey (GS) node of the National Geospatial Data Clearinghouse at http://nsdi.usgs.gov/nsdi/. Metadata that describe geology, water, and mapping sets are available on the World Wide Web. Many data sets are available on-line, including digital elevation model, land *use/land* cover, and water resources. The Land Use and Land Cover (LULC) data files describe the vegetation, water, natural surface, and cultural features on the land surface. GS provides these data sets and associated maps as a part *of* its National Mapping Program.
	Database inventory	The National Resources Inventory (NRI) is an inventory of land cover and use, soil erosion, prime farmland, wetlands, and other natural resource characteristics on nonfederal rural land in the United States. See NRI annotafions in Table ***A-5*** for description and source.
	Database survey, biological	National Biological Service (NBS), Gap Analysis Program (GAP). These data are meant to be used at a scale of 1:100,000 or smaller (such as 1:250,000 or 1:500,000) to assess the conservation status of vertebrate species and vegetation cover types over large geographic regions. The data may or may not have been assessed for statistical accuracy. Data evaluation and improvement are ongoing. NBS makes no claim as to the data's suitability for other purposes. Contact Michael D. Jennings, Coordinator, GAP Analysis Project, National Biological Service, Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Idaho. GAP Data Sets are available on-line on the Internet via the World Wide Web at http:l/www.nr.usu.edulgaplimaplpreus.html. See also: NBS homepage at http:l/www.its.nbs.govlnbs and the National Biological Information Infrastructure, Directory of Biological Data and Information at http:llwww.its.nbs.gov/nbiildirectory/html.

Table A-6. Sources for data on current vegetation

Data coverage	Data form	Source
		*NBS is part of the USGS, and it began GAP to map species diversity and identify priority areas containing species currently not represented in areas managed for their natural values. The basic GAP data layers are 1) land cover, 2) vertebrate species distributions, 3) land ownership, and **4)** land management. Vegetation maps are constructed from Landsat imagery. For each species of terrestrial vertebrates in an area, a habitat association model is used to identify polygons on the vegetation map considered suitable habitat. Known occurrences of each species are compiled by county from published literature and museum records.* *Range maps for the species are then estimated as those polygons with vegetational classes considered suitable habitat that occur in counties with known species occurrence. GAP is primarily organized at the State level, as a cooperative effort of the NBS with other public and private organizations. This and other data may be available through the Information Transfer Center, Mr. Rich Gregory, Director, 1201 Oak Ridge Drive, Suite 200, Fort Collins, CO 80525, (970) 226-9401 or (970) 223-9709, FAX (970) 226-9455 or the Technology Transfer Center, Mr. Phil Wondra, Director, P.O. Box 25287, Denver, CO 80225-0287, (303) 969-2590, FAX (303) 969-2160, email Phil_Wondra@nbs.gov. These offices form the core of the Information and Technology Services branch of the National Biological Service at http://www.its. nbs.gov.* *The Information Transfer Center responds to the information needs of the natural resource community in three major ways: by providing references to the scientific literature on a topic of interest; by functioning as a research liaison between scientists and anyone needing assistance with a challenging natural resource problem; and by editing, publishing, and distributing manuscripts written by NBS scientists. A critical information transfer tool is the compilation of references to the scientific literature. This service is the responsibility of the Bibliographic Information Branch of the Information Transfer Center. More than 300,000 citations are contained in the databases, indexed and distributed as Wildlife Review and Fisheries Review. Some 24,000 citations are added to the database each year.* *Wildlife Review and Fisheries Review is available by subscription through the U.S. Government Printing Office. The databases are also available in CD-ROM format from a private vendor. Libraries and other information sources now have the capability of conveniently conducting their own literature searches using the databases on CD-ROM. The Biological Assistance Branch provides technical assistance to agency personnel throughout the United States.* *See also Table A-8, Aerial Photographs (current).*
State		

Table A-6. Sources for data on current vegetation.

Data coverage	Data form	Source
California	Maps	NCIC State Affiliate: Map and Imagery Laboratory Library, University of California, Santa Barbara, CA 93106, (805) 961-2779.
	Data sets	National Biological Service (NBS), Gap Analysis Program (GAP) See entry under "Regional" above. GAP Data Sets are available on-line on the Internet via the World Wide Web at http://www.nr.usu.edu/gap/imap/preus.html for the following California ecoregions: Cascade Ecoregion, Central West Ecoregion, East Sierra Nevada Ecoregion, Great Valley Ecoregion, Modoc Plateau Ecoregion, Mojave Ecoregion, North West Ecoregion, Sierra Nevada Ecoregion, Sonoran Ecoregion, and South West Ecoregion.
Idaho	Info	NCIC State Affiliate: Idaho State Historical Library, 610 N. Julia Davis Dr., Boise, ID 83702, (208) 334-3356.
	Data sets	National Biological Service (NBS), Gap Analysis Program (GAP). See entry under "Regional" above. GAP Data Sets are available on-line for the State of Idaho on the Internet via the World Wide Web at http://www.nr.usu.edu/gap/imap/preus.html.
Oregon	Info	NCIC State Affiliate: Oregon State Library, Public Services, Salem, OR 97310, (503) 378-4368 .
	Data sets	National Biological Service (NBS), Gap Analysis Program (GAP). See entry under "Regional" above. Oregon GAP Vegetation GIS coverage. In Oregon, the NBS, through the Idaho Cooperative Wildlife Unit, is working with the Oregon Department of Fish and Wildlife, The Nature Conservancy, and Defenders of Wildlife. GAP Data Sets are available on-line on the Internet via the World Wide Web http://www.nr.usu.edu/gap/imap/preus.html for the State of Oregon.
Washington	Info	NCIC State Affiliate: Washington State Library, Information Services Division, Olympia, WA 98504, (360) 753-4027.
	Map	Forest stand age map in IO-year increments; hydrologic maturity map, Washington Department of Natural Resources, Photo & Map Sales, P.O. Box 47013, Olympia, WA 98504-7013, (360) 902-1234.
	Data sets	National Biological Service (NBS), Gap Analysis Program (GAP). See entry under "Regional" above. GAP Data Sets are available on-line for the State of Washington on the Internet via the World Wide Web at http://www.nr.usu.edu/gap/imap/preus.html.

Table A-7. Sources for data on historical vegetation.

Data coverage	Data form	Source
Regional	Aerial photographs	U.S. Department of the Interior, Geological Survey, Photographic Library (LIB-P), Mail Stop 914, Building 20, Box 25046, Federal Center, Denver, CO 80225, (303) 236-1010. *The Photographic Library contains a collection of over 250,000 photographs (predominantly black-and-white) taken during GS studies. A few photographs taken before the founding of the GS (1879) are included in the collection. Library staff will prepare lists of selected photographs in response to specific requests. Photographs are indexed by subject and location.*
	Scientific literature	Franklin, J. F., and C. T. Dyrness 1973. Natural vegetation of Oregon and Washington. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Oregon State University Press, Corvallis, Oregon. *This book describes the natural vegetation communities (plant associations) in the Pacific Northwest, and could be used to identify the indigenous plant communities likely to have inhabited a given general area. Consult your State Library or State University Library for availability. It is no longer printed by the Federal government.* *Shultz, S. T. 1990. The Northwest coast: a natural history. Timber Press, Portland, Oregon. **Data are known to exist but a specific source for the data is not known, the availability is not known, or the content of the data is not known.*
State		
Oregon	Map	*Historical maps from OSU Map Library, Valley Library, Oregon State University, Corvallis, OR 97331, (541) 737-3331.
	Map	* Historic vegetation maps of Oregon counties, digitized by FS.
	Scientific literature	Teensma, P. D., J. T. Rienstra, and M. A. Yeiter. 1991. Preliminary reconstruction and analysis of change in forest stand age classes of the Oregon Coast Range from 1850 to 1940. Technical Note OR-9. U.S. Department of the Interior, Bureau of Land Management, 825 NE Multnomah Street; P.O. Box 2965; Portland, OR 97208 (503) 231-6274.

Table A-8. Sources for aerial photographs

Data coverage	Data form	Source
Regional	Photographs	WAC Corporation (Aerial Photography), 520 Conger Street, Eugene, OR 97402-2795, (800) 845-8088 or (541) 342-5169. *WAC can provide coverage of westem Oregon, westem Washington, and norfhern California.*
	Maps/GIS digital	U.S. Department of the Interior, Geological Survey, National Cartographic Information Center (NCIC), Western Mapping Center, 345 Middlefield Road, Menlo Park, CA 94025, (415) 328-4309. *NCIC offices accept orders for aerial photographs and satellite imagery, and sell custom cartographic products such as GS digital data, color and feature map separates, orthophotoquads, and land-use and land-cover maps.*
	Landsat data	U.S. Department of the Interior, Geological Survey, EROS Data Center (EDC), Sioux Falls, SD 57198, (605) 594-6151 (Aerial Photographs); and EOSAT, Landsat Customer Service c/o EROS Data Center (EDC), Sioux Falls, SD 57198, (605) 594-2291 (Landsat Data). *EDC sells high- and low-altitude photographs; and also reproduces and distributes Landsat data through a cooperative agreement with NOAA (National Oceanic and Atmospheric Administration) and EOSAT (Earth Observation Satellite Company).*
State		
California	Maps	NCIC State Affiliate: Map and Imagery Laboratory Library, University of California, Santa Barbara, CA 93106, (805) 961-2779.
Idaho	Maps	NCIC State Affiliate: Idaho State Historical Library, 610 N. Julia Davis Dr., Boise, ID 83702, (208) 334-3356.
Oregon	Maps	NCIC State Affiliate: Oregon State Library, Public Services, Salem, OR 97310, (503) 378-4368.
Washington	Maps	NCIC State Affiliate: Washington State Library, Information Services Division, Olympia, WA 98504, (360) 753-4027.

Table A-9. Sources for data on land-use history.

Data coverage	Data form	Source
Regional	Land-use maps	U.S. Department of the Interior, Geological Survey, National Cartographic Information Center (NCIC), Western Mapping Center, 345 Middlefield Road, Menlo Park, CA 94025, (415) 328-4309. *NCIC offices accept orders for aerial photographs and satellite imagery, and they sell custom cartographic products such as GS digital data, color and feature map separates, orthophotoquads, and land-use and land-cover maps.*
	County zoning mapslinfo	County planning and development departments. *These local departments may have zoning or land-use maps available. Zoning regulates acceptable uses for land and often is based generally on land-use history. These departments may also have current or historical aerial photographs, as well as geologic maps showing underlying geology and areas of unstable soils, GS topographic maps, and many other types of maps of that specific county. Contact your county's planning, zoning, or development department.*
	Maps/GIS digital	GS node of the National Geospatial Data Clearinghouse at http:llnsdi.usgs.govlnsdil. *Metadata that describe geology, water, and mapping sets are available on the World Wide Web. Many data sets are available on-line, including digital elevation model, land use/land cover, and water resources. The Land Use and Land Cover (LULC) data files describe the vegetation, water, natural surface, and cultural features on the land surface. The Geological Survey provides these data sets and associated maps as apart of its National Mapping Program.*
	National Resources Inventory	The National Resources Inventory (NRI) is an inventory, or catalog, of land-cover and use, soil erosion, prime farmland, wetlands, and other natural resource characteristics on nonfederal rural land in the United States. *See NRI annotations in Table **A-5,** Soils.* See also entries in Table A-7, Vegetation—historical.
State		
California	Maps	NCIC State Affiliate: Map and Imagery Laboratory Library, University of California, Santa Barbara, CA 93106, (805) 961-2779.
Idaho	Info	NCIC State Affiliate: Idaho State Historical Library, 610 N. Julia Davis Dr., Boise, ID 83702, (208) 334-3356.

Table A-9. Sources for data on land-use history.

Data coverage	Data form	Source
Oregon	*Info*	NCIC *State Affiliate: Oregon State Library, Public Services, Salem,* OR *97310, (503) 378-4368.* *The State of Oregon, through the Land Conservation and Development Commission (LCDC) set land-use zoning criteria for the entire State; each County developed a plan or code to comply with the LCDC guidelines. County Planning or Development Departments in Oregon can indicate how land is zoned. State of Oregon Land Conservation and Development Department, 1175 NE Court St., Salem, OR 97310, (503) 373-0050.*
Washington	*Info*	NCIC *State Affiliate: Washington State Library, Information Services Division, Olympia, WA 98504, (360) 753-4027.*

Table A-10. Sources for precipitation data

Data coverage	Data form	Source
Regional	Maps/info	Oregon Climate Service, Strand Agricultural Hall, Room 316, Oregon State University, Corvallis OR, 97331-2209, (541) 737-5705, FAX (541) 737-2540, email to oregon@ats.orst.edu. George Taylor, State Climatologist. *Can provide hard-copy Annual Precipitation Map for the Western United States and States of Oregon, Washington, Idaho, Nevada, Montana, and Utah ($5.00 fee for 11" x 17" color-coded State map), and can provide other climatology information regarding a specific location. Phone responses and simple mailings have no fees. FAXs, diskettes, letters with data interpretation and GIS layers have fees. Data can be requested by phone, mail, or email. Access also provided to the NOAA atlas of precipitation frequency. World Wide Web homepage is on the Internet at http://ocs.ats.orst.edu, and from this page annual precipitation maps of Oregon and the Pacific Northwest can be downloaded. These maps were generated by the PRISM model by Chris Daly and are color coded in 100 mm increments.*
	Maps	New PRISM maps for the United States are now available via ftp. *These are 1961-1990 monthly mean precipitation grids, modeled at 2.5-min (~5 km) spatial resolution. Spatial domain is the lower 48 States. All but a few State maps are highly preliminary, but the peer-review and revision process is progressing. The maps will be updated periodically to reflect recent changes. To download the maps: (1) ftp fsl.orst.edu, (2) anonymous, (3) <your email address>, (4) cd pub/daly/prism, (5) binary, (6) get prism_us.Z (about 10 MB), (7) get prism_us.doc, (8) quit. Use the 'uncompress' command to extract the prism_us file. The file will expand to nearly 70 MB, so make sure you have disk space! Read the documentation carefully. It will indicate the status of the various State and regional sections of the maps, and provide important geographic information. The PRISM file is in a generic ASCII format that should be accessible by everyone.*
State		
Oregon	Maps	Oregon Climate Service, Strand Agricultural Hall, Room 316, Oregon State University, Corvallis OR, 97331-2209, (541) 737-5705, FAX (541) 737-2540, email to oregon@ats.orst.edu. (see above). *For Oregon, annual precipitation maps are available for each County.*
Washington	Maps	Washington Department of Natural Resources, Photo & Map Sales, P.O. Box 47013, Olympia, WA 98504-7013, (360) 902-1234. *Can provide Annual Precipitation Map for the State of Washington (fee).*

Table A-11. Sources for streamflow data.

Data coverage	Data form	Source
Regional USWEST	Digital	GS Gaging Station Records. Available on CD-ROM from USWEST Optical Publishing, Boulder, CO. Also available on the Internet via the World Wide Web at http://wwwdwatcm.wr.usgs.gov/historical.html for WA, OR, and ID.
	Info	GS National Water Data Storage and Retrieval System (WATSTORE). *All types of water data are accessed through WATSTORE, including an index of sites, daily water values with more than 240,000 daily parameters (e.g., streamflow, water temperatures, ground-water levels), peak flow file, water quality file, and ground-water site inventory file. Information on specific types of data, acquisition of data or products, and user charges can be obtained from the Wafer Resources Division District Offices (see State entries, below).*
	Maps/GIS digital	GS node of the National Geospatial Data Clearinghouse at http://nsdi.usgs.gov/nsdi. *Metadata that describe geology, water, and mapping sets are available on the World Wide Web. Many data sets are available on-line, including digital elevation model, land use/land cover, and water resources.*
State California	Info	GS Water Resources Division District Office, Federal Building, Room W-2235, 2800 Cottage Way, Sacramento, CA 95825, (916) 978-4633. *WATSTORE.*
	Info	California Department of Water Resources (DWR) World Wide Web site at http://wwwdtw.water.ca.gov. Division of Local Assistance (DLA) District Offices. Division of Local Assistance-Headquarters, Department of Water Resources, P.O. Box 942836, Sacramento, CA 94236-0001 or 1020-9th Street, Sacramento, CA 95814; Ray Hart, Division Chief (916) 327-1646. Northern District, 2440 Main Street, Red Bluff, CA 96080-2398; Linton A. Brown, District Chief (916) 529-7342. Central District, 3251 S Street, Sacramento, CA 95816-7017; Dennis Letl, District Chief (916) 445-5631. *Since 1988, when the Division was formed, staff has provided technical and financial assistance to State, Federal and particularly local agencies for developing, managing, and improving water resources in California. A variety of programs is offered through the headquarters office in Sacramento and the Northern, Central, San Joaquin, and Southern Districts located in Red Bluff, Sacramento, Fresno, and Glendale, respectively. The*

AR053331

Table A-11. Sources for streamflow data.

Data coverage	Data form	Source
		Division has over 300 people working around the State who are skilled in various disciplines and who can answer questions on water quality, water rights, surface and ground water, geohydrology, desalination, reclamation and reuse of water, water conservation, land and water use, recreation planning, floodplain management, environmental review, agricultural drainage, water transfers, and long-range water supply and demand. The Division also administers loan and grant programs designed to restore urban streams and to make more efficient use of surface and ground water resources.
Idaho	Info	GS Water Resources Division District Office, 230 Collins Road, Boise, ID 83702, (208) 334-1750. *WATSTORE.*
	Info	Geological Survey (DOI) Idaho District homepage is the World Wide Web source for Idaho water information at http://wwwidaho.wr.usgs.gov. *Links to the Idaho District Water Data Page at http://wwwidaho.wr.usgs.gov/public/h2odata.html, which contains information on surface-water data, water-use data, the National Water Summary, national hydrologic conditions, and other resources. Includes an on-line Idaho District Data Requesf Form.*
	Info	The Idaho Department of Water Resources (IDWR) has its main office at 1301 North Orchard Road, Boise, ID, (208) 327-7900, FAX (208) 327-7866. IDWR has four full-service regional offices that can assist with water and adjudication matters. For help, contact *the* regional office in your area. Northern Region: 1910 Northwest Blvd., Suite 210, Coeur d'Alene, ID 83814-2615, (208) 769-1450, FAX (208) 769-1454; Western Region: 2735 Airport Way, Boise, ID 83705-5082, (208) 334-2190, FAX (208) 334-2348; Southern Region: 222 Shoshone St. East, Twin Falls, ID 83301-6105, (208) 736-3033, FAX (208) 736-3037; and Eastern Region: 900 North Skyline Drive, Idaho Falls, ID 83402-6105, (208) 525-7161, FAX (208) 525-7177. Also can be accessed via the World Wide Web at http://www.state.id.us/idwr/idwrhome.html. *The Idaho Department of Water Resources (IDWR) is responsible for the administration and allocation of water rights and permit and licensing systems to control beneficial use of Idaho waters. IDWR is also concerned with conservation and development of waters through planning, and it can provide information regarding endangered species, minimum streamflows, river flow information, floodplain management, stream channel alteration permits, etc.*
Oregon	Info	GS Water Resources Division District Office, 847 NE 19th Avenue, Suite 300, Portland, OR 97232, (503) 231-2009. *WATSTORE.*

Table A-11. Sources for streamflow data

Data coverage	Data form	Source
Washington	Info	GS Water Resources Division District Office, 1201 Pacific Avenue, Suite 600, Tacoma, WA 98402, (206) 593-6510. WATSTORE.
	Info	GS Water Resources Inventory. Public inquiries can be made of the GS regarding water resources of Washington State via the World Wide Web at http://wwwdwatcm.wr.usgs.gov/inquiries/html or via email (all Internet mail sent to pubinfo@maildwatcm.wr.usgs.gov will be delivered directly to the Public Information Officer). The on-line form allows messages to be sent to the Public Information Officer; questions and comments may also be sent to other GS contacts. Historical water resources data available and services provided by the Public Information Officer (PIO) include: • Loan copies of open-file reports, water-resources investigations, and water-supply bulletins for studies conducted in the State of Washington. • Limited loan copies are available on selected professional papers, water-supply papers, geohydrologic monographs, circulars, teachers' educational packets, techniques of water-resources investigations, miscellaneous field investigations, and hydrologic atlases. • Field measurement notes of streamflow for continuous, partial, and crest stage gage stations operated by the Tacoma Field Office. • Summary of field measurements of streamflow (mostly posf-1983 for Tacoma Field Office. For surface water unit values (transmission via satellite every 15, 30, or 60 minute values) of streamflow, gage height, reservoir elevation, or temperature preceding the current Water Year: all available data needs to be restored into the computer data base. A fee will be assessed based on the amount of restoration and review process needed. • Plots of streamflow peaks of interest. • Limited statistical analyses of flow duration, high- and low-flow frequency as well as peak flow frequencies. There is a fee for custom analyses. • Station description, quality of records, location of instrumentation, datum of gage, and remarks from old water supply papers. • Card catalogue information of old water quality data showing probable sources of unpublished data or data published in interpretive reports but not in dafa bases.

Table A-I1. *Sources* for *streamflow data.*

Data coverage	Data form	Source
		• *Source programs of groundwater or surface models developed by the Washington District personnel. Information for all other GS modeling programs available to the public through Reston Headquarters or private companies.* • *Temperature records of selected gaging stations operated for State of Washington, Deparfment of Ecology.* • *Field data, notes, correspondence and other pertinent project records from Federal archives or the National Archives in response to on-going research studies, consulting services, and Freedom of Information Act requests.* • *Cross-sectional survey notes from streams and rivers where sediment studies have been done.* • *Forwards requests to GS Regional Office for certification of all types of records for official use in court testimonies. As NA WDEX (National Water Data Exchange) Assistance Center, responsibilities are limited to accessing GS data bases in the State of Washington. Requests for information contained in other State databases or related to other States are forwarded to the headquarters office of NA WDEX in Reston, Virginia.* • *Miscellaneous field measurements of streamflow in the State of Washington since 1890. There may be a charge for some requests, depending on the size and urgency.*

Table A-12. Sources for data on stream and surface-water type.

Data coverage	Data form	Source
Regional		See entries under "Streamflow" above.
	Data	*FS Stream Survey Database. **Data are known to exist, but a specific source for the data is not known, the availability is not known, or the content of the data is not known.*
State California	Info	CA Department of Water Resources (DWR) World Wide Web site at http://wwwdrw.water.ca.gov. Division of Local Assistance (DLA) District offices. Division of Local Assistance-Headquarters, Department of Water Resources, P.O. Box 942836, Sacramento, CA 94236-0001 or 1020-9th Street, Sacramento, CA 95814; Ray Hart, Division Chief (916) 327-1646. Northern District, 2440 Main Street, Red Bluff, CA 96080-2398; Linton A. Brown, District Chief (916) 529-7342. Central District 3251 S Street, Sacramento, CA 95816-7017; Dennis Letl, District Chief (916) 445-5631. *See annotations above.*
Idaho	Info	Geological Survey (DOI) Idaho District homepage. World Wide Web Source for Idaho water information at http://wwwidaho.wr.usgs.gov. *Links to the Idaho District Water Data Page at http://wwwidaho. wr.usgs.gov/public/h2odata.html, which contains information on surface water data, water use data, the National Water Summary, national hydrologic conditions, and other resources. Includes an on-line Idaho District Data Request Form.*
	Info	Idaho Department of Water Resources (IDWR). IDWR has it's main office located at: 1301 North Orchard Road, Boise, ID, (208) 327-7900, FAX (208) 327-7866. IDWR has four full-service regional offices to assist with water and adjudication matters. For help, contact the regional office in your area. Northern Region: 1910 Northwest Blvd., Suite 210, Coeur d'Alene, ID 83814-2615, (208) 769-1450, FAX (208) 769-1454; Western Region: 2735 Airport Way, Boise, ID 83705-5082, (208) 334-2190, FAX (208) 334-2348; Southern Region: 222 Shoshone St. East, Twin Falls, ID 83301-6105, (208) 736-3033, FAX (208) 736-3037; and Eastern Region: 900 North Skyline Drive, Idaho Falls, ID 83402-6105, (208) 525-7161, FAX (208) 525-7177. Also can be accessed via the World Wide Web site at http:/lwww.state.id.uslidwr/idwr.home. html. *See annotations above.*

Table A-12. Sources for data on stream and surface-water type

Data coverage	Data form	Source
Oregon	Info	Oregon Department of Forestry, 2600 State Street, Salem, OR 97310, (503) 945-7200; Jim Brown, State Forester, (503) 945-7211; Mike Beyerle, Deputy State Forester, (503) 945-7202; Fred Robinson, Assistant State Forester, (503) 945-7205. • NORTHWEST OREGON AREA, Lee Oman, Area Director, Area Office, 801 Gales Creek Road, Forest Grove, Oregon 97116-1199, (503) 357-2191, FAX (503) 357-4548. District Headquarters: Forest Grove District, Dave Johnson, District Forester, 801 Gales Creek Road, Forest Grove, Oregon 97116-1199, (503) 357-2191, FAX (503) 357-4548); Tillamook District, Mark Labhart, District Forester, 4907 E. Third Street, Tillamook, Oregon 97141-2999, (503) 842-2545, FAX (503) 842-3143; Astoria District, Stan Medema, District Forester, Route 1, Box 950, Astoria, Oregon 97103, (503) 325-5451, FAX (503) 325-2756; Clackamas-Marion District, Dan Christensen, District Forester, 14995 S. Hwy. 211, Molalla, Oregon 97038, (503) 829-2216, FAX (503) 829-4736; West Oregon District, Mike Templeton, District Forester, 24533 Alsea Hwy., Philomath, Oregon 97370, (541) 929-3266, FAX (541) 929-5549; South Ford District, Fred Stallard, Administrative Supervisor, 48300 Wilson River Hwy., Tillamook, Oregon 97141, (503) 842-8439, FAX (503) 842-6572. • SOUTHERN OREGON AREA, Craig Royce, Area Director, Area Office, 1758 N.E. Airport Road, Roseburg, Oregon 97470-1499, (541) 440-3412, FAX (541) 440-3424. District Headquarters: Southwest Oregon District, Cliff Liedtke, District Forester, 5286 Table Rock Road, Central Point, Oregon 97502, (541) 664-3328, FAX (541) 776-6260; Coos District, Rick Rogers, District Forester, 300 Fifth Street, Bay Park, Coos Bay, Oregon 97420, (541) 267-4136, FAX (541) 269-2027; Western Lane District, Darrel Spiesschaert, District Forester, P.O. Box 157, Veneta, Oregon 97487-0157, (541) 935-2283, FAX (541) 935-0731; Eastern Lane District, Dan Shults, District Forester, 3150 Main Street, Springfield, Oregon 97478, (541) 726-3588, FAX (541) 726-2501; Linn District, Dan Shults, District Forester, 4690 Highway 20, Sweet Home, Oregon 97386, (541) 367-6108, FAX (541) 367-5613. • EASTERN OREGON AREA, Jeff Schwanke, Acting Area Director, Area Office, 3501 E. 3rd. Street, Prineville, Oregon 97754, (541) 447-5658, FAX (541) 447-1469. District Headquarters: Northeast Oregon District, Gary Rudisill, District Forester, 611 20th Street, La Grande, Oregon 97850, (541) 963-3168, FAX (541) 963-4832; Central Oregon District, Mike Howard, District Forester, 220710 Ochoco Hwy., Prineville, Oregon 97754, (541) 447-5658, FAX (541) 447-1469; Klamath-Lake District, Roy Woo, District Forester, 3400 Greensprings Drive, Klamath Falls, Oregon 97601, (541) 883-5681, FAX (541) 883-5555.

Table A-12. *Sources for data on stream and surface-water type.*

Data coverage	Data form	Source
		The Oregon Department of Forestry, authorized by Oregon Revised Statute 526.008 and established in 1911, is under the direction of the State Forester, who is appointed by the Oregon Board of Forestry. The statutes direct the State Forester to act on all matters pertaining to forestry in the protection of forest lands and the conservation of forest resources. The department administers the Oregon Forest Practices Act, Log Patrol Act, Log Brand Act, Small Tract Optional Tax Law, forest land classification, forestry assistance to Oregon's 24,000 non-industrial private woodland owners, forest resource planning, and community and urban forestry assistance. Staff can access data which identifies the type of surface water which may be present on a specific parcel of land. * *ODFW stream surveys of private land.* **Data is known to exist, but a specific source for the data is not known, the availability is not known, or the content of the data is not known.*
Washington	Map	*Washington Department of Natural Resources, Photo & Map Sales, P.O.* Box 47013, *Olympia,* WA 98504-7013, (360) 902-1234. *DNR Water Type Map.*
	Info	*Public inquiries of the Water Resources Inventory can be made to the GS about water resources of Washington State via the World Wide Web at* http://wwwdwatcm.wr.usgs.gov/inquiries/html *or via email (all Internet mail sent* to pubinfo@maildwatcm.wr.usgs.gov *will be delivered directly* to *the Public Information Officer).* *The on-line form allows messages to be sent to the Public Information Officer; questions and comments may also be sent to other GS contacts. See annotations above.*

Table A-13. Sources for water-quality data.

Data coverage	Data form	Source
Regional	Electronic	U.S. Department of Agriculture, National Resource Conservation Service, National Resources Inventory (NRI) at http://www.ncg.nrcs.usda.gov/nri.html.
State		
California		California Department of Water Resources (DWR), Division of Local Assistance (DLA) District Offices. Division of Local Assistance-Headquarters, Department of Water Resources, P.O. Box 942836, Sacramento, CA 94236-0001; or 1020-9th Street, Sacramento, CA 95814; Ray Hart, Division Chief (916) 327-1646. Northern District, 2440 Main Street, Red Bluff, CA 96080-2398; Linton A. Brown, District Chief (916) 529-7342. Central District 3251 S Street, Sacramento, CA 95816-7017; Dennis Letl, District Chief (916) 445-5631.
		U.S. Department of the Interior, Geological Survey, Water Resources Division District Office, Federal Building, Room W-2235, 2800 Cottage Way, Sacramento, CA 95825, (916) 978-4633.
		California Department of Water Resources (DWR) at http://wwwdrw.water.ca.gov.
Idaho		Idaho Department of Water Resources (IDWR). IDWR main office: 1301 North Orchard Road, Boise, ID, (208) 327-7900, FAX (208) 327-7866. IDWR has four regional offices: Northern Region: 1910 Northwest Blvd., Suite 210, Coeur d'Alene, ID 83814-2615, (208) 769-1450, FAX (208) 769-1454; Western Region: 2735 Airport Way, Boise, ID 83705-5082, (208) 334-2190, FAX (208) 334-2348; Southern Region: 222 Shoshone St. East, Twin Falls, ID 83301-6105, (208) 736-3033, FAX (208) 736-3037; and Eastern Region: 900 North Skyline Drive, Idaho Falls, ID 83402-6105, (208) 525-7161, FAX (208) 525-7177.
		U.S. Department of the Interior, Geological Survey, Water Resources Division District Office, 230 Collins Road, Boise, ID 83702, (208) 334-1750.
		Idaho Department of Water Resources at http://www.state.id.us/idwr/idwrhome.html.
Oregon		U.S. Department of the Interior, Geological Survey, Water Resources Division District Office, 847 NE 19th Avenue, Suite 300, Portland, OR 97232, (503) 231-2009.
		Oregon Rivers Information System (ORIS), Northwest Environmental Database, Brent O. Forsberg, Coordinator at forsberg@dfw.or.gov. ORIS can be accessed through the Oregon Department of Fish and Wildlife (ODFW), homepage at http://www.dfw.state.or.us.
Washington		Washington Department of Natural Resources, Photo & Map Sales, P.O. Box 47013, Olympia, WA 98504-7013, (360) 902-1234.U.S. Department of the Interior, Geological Survey, Water Resources Division District Office, 1201 Pacific Avenue, Suite 600, Tacoma, WA 98402, (206) 593-6510.
		U.S. Department of the Interior, Geological Survey, Water Resources Division District Office, 1201 Pacific Avenue, Suite 600, Tacoma, WA 98402, (206) 593-6510.
		———Geological Survey, Water Resources Inventory; Water Resources of Washington State at http://wwwdwatcm.wr.usgs.gov/inquiries/html.

AR053338

Table A-14. Sources for data on fish species distributions.

Data coverage	Data form	Source
Regional	GIS	*EPA *River Reach Database.* **Data is known to exist, but a specific source for the data is not known, the availability is not known, or fhe content of the data is not known.*
	Maps	U.S. *Department of the Interior, Geological Survey (GS).* *GS markets four series of maps depicting the distribution of certain fish and wildlife species and other ecological elements along the coastal areas of the conterminous 48 States. Produced by the Fish and Wildlife Service (FWS) from GS base data, the maps are designed fo help in making location and design decisions about development along the coasts. The maps cover broad geographic areas with limited topographic detail and depict the habitats of fish and wildlife. Of particular interest are the coastal habitats of endangered species, migratory waterfowl, and commercially important fish. The maps also show certain land-use designations, such as national wildlife refuges, State waterfowl management areas, and parks. The five-color maps are printed on 24- by 35-inch sheets, each covering 2 degrees of longitude by 1 degree of latitude. The Pacific Coast maps are the first comprehensive series of natural resource maps of the West Coast. The maps depict fish and wildlife and their habitats and major land-use designations. The 30-map series covers the entire 40,150 square-mile Pacific coastal zone from Mexico to Canada, including Puget Sound. The 159-page narrative report provides detailed explanations and additional technical information about the ecological data displayed on each map. The ecological data plotted on the maps is derived from FWS ecological inventories. These maps can be obtained from any of the GS map sources listed under "Topography," above.*
State		
California	*GIS*	*California Department* of *Fish and Game.* For *further information about the Geographic Information System contact* John *Ellison,* 1730 I *Street, Suite* 100 *Sacramento, CA* 95814, (916) 323-1477, *email* to *jellison@dfg.ca.gov.*
Idaho	*Info*	*Idaho Department* of Fish *and Game. Headquarters,* 600 *S. Walnut, P.O. Box 25, Boise, ID* 83707, (208) 334-3700; *Panhandle Region,* 2750 *Kathleen Avenue, Coeur* d'Alene, ID 83814, (208) 769-1414; *Clearwater Region,* 1540 *Warner Avenue, Lewiston,* ID 83501, (208) 799-5010; *Southwest Region,* 3101 *S. Powerline Road, Nampa, ID* 83686, (208) 465-8465 *(From Boise, call:* 887-6729); *McCall, 555 Deinhard Lane, McCall,* ID 83638, (208) 634-8137; *Magic Valley Region,* 868 *East Main Street,* P.O. *Box* 428, *Jerome, ID* 83338, (208) 324-4350; *Southeast Region,* 1345 *Barton Road, Pocatello, ID* 83204, (208) 232-4703; *Upper Snake Region,* 1515 *Lincoln Road, Idaho Falls, ID* 83401, (208) 525-7290, Salmon Region, 1214 **Hwy** *93 N.,* P.O. Box 1336, *Salmon, ID* 83467, (208) 756-2271. Also *available is a homepage on the World Wide Web at* http://www.state.id.uslfishgame/fkhgame.html.

Table A-14. *Sources for data on fish species distributions.*

Data coverage	*Data form*	*Source*
Oregon	*Data*	*Oregon Rivers Information System (ORIS)—Northwest Environmental Database. Coordinator: Brent O. Forsberg; email to forsberg@dfw.or.gov.* ORIS *can be accessed on-line on the World Wide Web through the ODFW homepage at* http://www.dfw.state.or.us). *The Oregon Rivers Information System is a comprehensive collection of data on the rivers in the State of Oregon. The data is part of a four-State collection effort by the Bonneville Power Administration called the Northwest Environmental Database. These other States include Washington, Idaho, and Montana. The search program allows the user to view data on the following Oregon river resources: anadromous fish, resident fish, wildlife, natural features, recreation, cultural features, institutional constraints, and other associated resources. The user will be presented with a series of menus allowing searches by a specific river, a drainage basin, or a county of interest; a specific resource type in any drainage basin or county; a specific township and range for resources; and a specific river reach by Environmental Protection Agency reach number. By selecting one of the on-line options, you may read the Operation Manual; down load the search program and data files; or use the ORIS program to search data on-line.*
	Data	**Oregon Department* of *Fish and Wildlife (ODFW), Oregon Species Information Database. ODFW, Northwest Region, Corvallis, OR,* (541) 757-4186. *Contact: Wanda* McKenzie. **Data is known to exist, but a specific source for the data is not known, the availability is not known, or the content of the data is not known.*
	Data	*Oregon State University Museum of Ichthyology. Corvallis, OR. Contact Dr. Doug Markle,* (541) 737-1970.

Table A-15. Sources for data on threatened and endangered species (fish and other biota).

Data coverage	Data form	Source
Regional	Lists	U.S. Department of the Interior, Fish and Wildlife Service, Portland, OR (503) 231-6118. FWS also maintains a homepage on the World Wide Web with a sub-directory for lists of endangered species in Region 1 (includes Pacific Northwest) at http://www.fws.gov/statl.rl.html. *Lists are maintained by the FWS; they include endangered and threatened species under FWS jurisdiction, and species listed (added) under a memorandum of understanding between FWS the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS).* *Species or stocks under the sole jurisdiction of NMFS are not listed. For freshwater habitats in the Pacific Northwest, those species/stocks are Sacramento R. winter run chinook salmon; Snake R. spring/summer run chinook salmon; Snake R. fall run chinook salmon; Snake R., (ID, stock) sockeye salmon: Shortnose sturgeon* (Acipenser brevirostrum).
State		
California	Lists	California Department of Fish and Game, Natural Diversity Data Base (NDDB). The NDDB can be accessed through the World Wide Web at http://spock.dfg.ca.gov/Endangered/endangered.html, and it provides lists of endangered and threatened species. *The NDDB is constantly being updated and expanded. All locational data entered into the NDDB are based on actual field sightings. There is an on-line disclaimer "The absence of a listed species from the county accounts does not necessarily mean it is absent from the county, only that no occurrence data are currently entered into the NDDB. Data from the Data Base does not constitute an official response from a State agency, will not in itself meet the requirements of the California Environmental Quality Act and does not replace the need for conducting field work." There are several categories of endangered species. Both Federal and State categories are defined and listed.*
Idaho	Info	Idaho Department of Fish and Game. Headquarters, 600 S. Walnut, P.O. Box 25, Boise, ID 83707, (208) 334-3700; Panhandle Region, 2750 Kathleen Avenue, Coeur d'Alene, ID 83814, (208) 769-1414; Clearwater Region, 1540 Warner Avenue, Lewiston, ID 83501, (208) 799-5010; Southwest Region, 3101 S. Powerline Road, Nampa, ID 83686, (208) 465-8465 (from Boise call 887-6729); McCall, 555 Deinhard Lane, McCall, ID 83638, (208) 634-8137; Magic Valley Region, 868 East Main Street, P.O. Box 428, Jerome, ID 83338, (208) 324-4350; Southeast Region, 1345 Barton Road, Pocatello, ID 83204, (208) 232-4703; Upper Snake Region, 1515 Lincoln Road, Idaho Falls, ID 83401, (208) 525-7290; Salmon Region, 1214 Hwy 93 N., P.O. Box 1336, Salmon, ID 83467, (208) 756-2271. *Also* has a homepage *on* the World Wide Web at http://www.state.id.us/fishgame/fishgame.html.

AR053341

Table A-15. Sources for data on threatened and endangered species (fish and other biota).

Data coverage	Data form	Source
	Info	Idaho Department of Water Resources. Main office: 1301 North Orchard Road, Boise, ID, (208) 327-7900, FAX (208) 327-7866. IDWR has four full-service regional offices to assist with all of water and adjudication matters. For, contact the regional office in your area. Northern Region: 1910 Northwest Blvd., Suite 210, Coeur d'Alene, ID 83814-2615, (208) 769-1450, FAX (208) 769-1454; Western Region: 2735 Airport Way, Boise, ID 83705-5082, (208) 334-2190, FAX (208) 334-2348; Southern Region: 222 Shoshone St. East, Twin Falls, ID 83301-6105, (208) 736-3033, FAX (208) 736-3037; and Eastern Region: 900 North Skyline Drive, Idaho Falls, ID 83402-6105, (208) 525-7161, FAX (208) 525-7177. Also, IDWR can be accessed via the World Wide Web at http://www.state.id.us/idwr/idwrhome.html. *The Idaho Department of Water Resources (IDWR) is responsible for the administration and allocation of water rights and permit and licensing systems to control beneficial use of Idaho waters. IDWR is also concerned with conservation and development of waters through planning, and can provide information regarding endangered species, minimum streamflows, river flow information, floodplain management, stream channel alteration permits, etc.*
Oregon	Info	Oregon Department of Fish and Wildlife (ODFW), 2501 SW First Ave., P.O. Box 59; Portland, OR 97207. General Phone Number: (503) 229-5406; General Information: (503) 229-5222; Habitat Conservation Division: (503) 229-6967; Wildlife Division: (503) 229-5454. ODFW Regional Offices: Northwest Region, Corvallis, (541) 757-4186; Southwest Region, Roseburg, (541) 440-3353; Central Region, Bend, (503) 388-6363; Northeast Region, LaGrande, (541) 963-2138; Southeast Region, Ontario, (541) 573-6582; Marine Region, Newport (541) 867-4741; Columbia Region, Clackamas, (503) 657-2000. ODFW can be accessed through the World Wide Web at http://www.dfw.state.or.us. The Executive Summary of the *Biennial Report on the Status of Wild Fish in Oregon* is available and can be downloaded from this source. *This summary provides an overview of selected anadromous and game fish species of concern and their locations, as well as a table of Oregon endangered, threatened, and sensitive nongame fishes. The executive summary addressed the status of selected species while the full report includes information on all wild freshwater and estuarine fish species in Oregon. Most of the information in the report comes from ODFW files, particularly annual reports filed by ODFW district biologists or from State research projects For more information about this report contact Kathryn Kostow at ODFW, email to kostowk@dfw.or.gov.*

A.3 Laws and Regulations

By means of laws and regulations, cooperative leadership and funding are provided to States and local landowners to acconiplish stated goals of the laws and their programs. These laws, regulations, and programs, in turn, need scientific information to accomplish their objectives. Moreover, many of the laws incorporate clauses that emphasize the importance of citizens and recognize that environments diverse and safe for other living things provide healthy physical and economic environments for people.

Four sets of rules need to be examined to understand the effect of laws and regulations on salmonid habitat: tlie U.S. Code (which include the public laws and the statutes), Federal regulations (pursuant to the USC, laws, and statutes), state codes (statues), and state regulations.

Federal legislation is developed when Congress passes bills; after signing by the President (or tlie override of a veto), the bill becomes law. First published in "slip" form (usually saddle-stapled sheets), it is called a Public Law and is given a number that designates the session of Congress and then the sequential order in which the bill was signed into law. *Statutes At Large* are bound collections of Public Laws ordered sequentially; the *U.S. Code* (USC) integrates laws and their amendments with related laws by subject into bound volumes (called titles) that are periodically updated. Unfortunately, the sections of each particular law are numbered differently from one form to the next; also, all public laws do not ultimately become published in tlie USC. Laws transfer power ("authorize") and they designate levels of funding ("appropriate"); often one law authorizes certain action and suggests a level of support while another law actually appropriates funds—the root cause of so-called "unfunded mandates." Laws may be adjudicated in civil or criminal courts.

Federal regulations originate in the Executive branch as a response by the department or agency authorized to implement a particular public law; these regulations are usually published first in the *Federal Register* for public comment. Regulations are revised, republished as final, and ultimately codified—collected, bound, and published—in the *Code* of *Federal Regulations* (CFR). Regulations make laws operative, they have the force of law, and their purposes are administrative or related to enforcement. In addition to civil and criminal courts, regulations may also be adjudicated in the Federal administrative court system.

Forms and function of State laws and regulations follow those of the Federal government: State laws originate in legislatures and are collected into books of statutes; regulations are then promulgated by State executive agencies to iniplement the laws. Access to the law largely depends on understanding its structure, purpose, and function.

In many ways, laws and regulations prescribe ideals. Courts, however, play a pivotal role in applying law to actual situations: court cases and decisions shape the interpretation and direct the meaning a law assumes over time. Regardless of legislative intent and executive management goals, law can come to mean what the courts say it means, a result of selected information, situational evidence, savvy argument, and persuasion. These meanings are socially derived, and they have come to be one documented expression of social values tied to a particular time and place. Unlike the law, court cases clarify how people will act (not how they should act) with respect to property, land, other people, other species, and so on. As a result, an accurate analysis of how law and regulations effect salmon habitat niust ultimately review decisions of the civil, criminal, and administrative courts of both State and Federal systems.

This section lists and describes briefly Federal and State laws related to salmon habitat restoration both implicitly and explicitly. References to regulations have been collected only when they were encountered; further research and analysis in this literature would yield prescribed practices. Finally, court case literature would yield information on whether practices in laws and regulations were accepted and applied or were challenged and changed. We do not review case law herein.

A.3.1 Federal Laws

The pre-eminent Federal laws used to protect salmonids and their habitats include the Endangered Species Act (ESA), tlie Clean Water Act (CWA), the National Environmental Policy Act (NEPA), and the Food Securities Act (FSA). ESA was created to conserve the ecosystems upon which threatened and endangered species depend and to provide a program to conserve listed species and their ecosystems. Various sections of ESA obligate Federal agencies to minimize putting listed species in further jeopardy, and it outlines permit conditions including take. CWA is intended to restore and maintain the chemical, physical, and biological integrity of the Nation's waters by eliminating the discharge of pollutants into waters and by attaining water quality suitable for fish and wildlife. EPA has developed guidelines that decree protection from discharges from agriculture, forestry, mining, construction and hydrologic modifications. NEPA has a policy section that identifies the rights and responsibilities of each person to enjoy, preserve, and enhance the environment. The Federal government is responsible for coordinating Federal programs to help people preserve a diverse environment aiid act as trustees for future generations. FSA provides incentives for farmers and ranchers to conserve riparian areas and wetlands in order to continue receiving Federal subsidies. Each of these four laws is discussed in greater detail in Part I, Chapter 9 of this document.

Other Federal laws explicitly extended to private landowners include the Forest Stewardship Act (PL 102-574, 16 USC 1600 et seq.), which amends the Federal Forest and Rangeland Renewable Resources Planning Act (PL 102-574, 16 USC 2101), and the Coastal Zone Management Program (CZMP). The Forest Stewardship Act allows local foresters to develop a program for management of nonfederal lands, and the CZMP was developed to protect beneficial public uses including biological resources and water quality, but it does not apply to streams with flow less than 20 cfs. Three other relevant Federal programs are tlie Conservation and Wetland Reserve Programs, which compensate farmers who protect sensitive lands by removing them from production, and the Surface Mining Control aiid Reclamation Act (PL 98-409), which regulates open pit mining.

A.3.2 State Laws

Numerous State laws and programs have been enacted that directly or indirectly relate to the protection of salmonids (and other fishes) and their habitats or other beneficial uses of streams and rivers. The following section briefly describes laws and regulations related to general land use, forestry, agriculture and pesticides, range, mining, water quality, instream flows, and channel alteration.

California

The sources for most of our legal information for California was West's Annotated California Codes (WACC).

General Land Use. One of the most far reaching laws is the California Coastal Act (CCA, Public Resources Sections 30,000-31,405), which creates state-local partnerships for comprehensive land-use planning. The CCA requires protection of public access to the shore, conservation of environmentally sensitive habitats, and preservation of scenic beauty through development restrictions.

Forestry. Forest Practices in California are mandated by tlie Z-Berg-Nejedly Forest Practices Act (1973). California's Forest Practice Rules (Title 14, Subchapters 4-6, California Code of Regulations) covers silvicultural methods (Article 3), harvest practices and erosion control (Article 4), site preparation (Article 5), water course and lake protection (including riparian protection zones; Article 6), and roads (including water crossings; Article 12).

Agriculture. Pesticide uses are restricted by Food and Agriculture Sections 12971-12979, while pesticide monitoring is covered in Section 13148. Screens at diversions are also required (Fish & Game 5900-6028).

Mining. Permits are required for suction dredging (Fish and Game Section 5653), placer mining requires pollution controls (Public Resources Section 2555), and protection and reclamation of mined land is ensured (Public Resources Section 2710).

Endangered Species. State endangered and threatened species are protected (Public Resources Code Section 2050) and public funds (separate from fish and game or nongame funds) are authorized for native species conservation and enhancement (Fish and Game Section 1750).

Water Quality. Water quality laws are outlined in two areas. Fish and Game Section 5650 makes it "unlawful to deposit in, permit to pass into, or place where it can enter waters, any material deleterious to fish, plant, or bird life." The Water Quality Control Act (Water Section 13,000 et seq.) authorizes standards for point and diffuse pollution, combines quality and quantity issues, requires permits for dischargers, including dredging and filling (Section 13,376). Unpermitted discharges are subject to civil penalties (Section 13,385), while intentional or negligent violations are subject to criminal penalties (Section 13,387). Section 13,050 defines a waste as any waste substance associated with human habitation or of human or animal origin. Pollution includes wastes that unreasonably affect beneficial uses, while beneficial uses include recreation, esthetic enjoyment, and preservation or enhancement of fish, wildlife, or other aquatic resources. This Act is available on the internet: http ://agency. resource. ca.gov/wetlands /permitting/tbl_cntnts_porter.html.

Instream Flows. California Fish and Game sets minimum flows to assure continued viability of stream fish and wildlife (Public Resources Code Section 10001).

Channel Alterations. Devices that prevent or impede fish passage, or tend to do so, are prohibited (Fish and Game Sections 5901 and 12015). Additional protections against channelization and other disturbances of the bed, bank, and channel are covered in Public Resources Code Section 1600 et seq.

Idaho

Relevant laws for Idaho were gleaned from tlie Idaho Code.

Forest Practices. Rules and regulations pertaining to the Idaho Forest Practices Act, Title 38, Chapter 13, Idaho Code are given in Idaho Administrative Rules IDAPA 20.15 -- Department of State Lands. Rule 2 includes general rules. Rule 3 regulates timber harvest activities, including those in riparian areas. Rule 4 prescribes restrictions for stream crossings. If stream beneficial uses are not fully protected aiid the activity is deemed a substantial threat, the activity can be halted (Section 38-1314).

Agriculture. Pesticide restrictions are outlined in Section 22-3420. Fish screens are required on irrigation diversions (Section 36-906).

Mining. Surface mining is regulated under tlie Idaho Surface Mining Act (Title 47, Chapter 15, Idaho Code). Tlie purpose of the Act is to protect tlie public health, safety, and welfare by requiring reclamation of all lands disturbed by mineral exploration and surface mining operations (Section 47-1501). It requires the operator to, among other things, provide maps and diagrams of tlie mining site identifying access and haul roads, nearby creeks or other water bodies, mining pits, mineral stockpiles, and tailings, as well as to develop a reclamation plan (Section 47-1506). Dredge and placer mining must also be conducted in a manner that protects stream and watercourses for the enjoyment , use, and benefit of all people (Section 47-13 12)

Water Pollution. Existing instream beneficial uses of each water body and the level of water quality necessary to protect those uses must be maintained aiid protected (Section 39-3601 to 3603). Water pollution is defined as alteration of tlie physical, thermal, chemical, or biological properties of State waters that will (or is likely to) render waters detrimental to recreational and esthetic uses or to fish or aquatic life (Section 39-103). Tlie State has tlie authority to enter private property to conduct monitoring.

Instream flows. Minimum flow is considered a beneficial use to protect fish, wildlife habitat, aquatic life, water quality, esthetics, or recreation. Minimum flows are the amounts of water needed to protect such uses (Section 42-1501).

Channel Alterations. No person may construct or maintain a dam or other obstruction without installing a proper fishway (Section 36-906). Fish screens are required on all canals aiid conduits (Section 36-906). Unpermitted channel alterations are prohibited (Section 42-3801-3813) and they are also restricted by the general nuisance law (Section 52-101-111).

Oregon

Laws and regulations for Oregon were taken from the Oregon Revised Statutes (ORS), the Oregon Administrative Rules (OAR), and Butterwortli's *Oregon Revised Statutes Annotated.*

General Land Use. All land in Oregon is zoned by counties to meet land use criteria set by the Land Conservation and Development Commission. Zoning is designed to protect forest and agricultural land from residential developments and tlie Oregon coast from recreational home developments that preclude easy public access to the State's beaches and estuaries. OAR 603-70 and 72 grant funds to surface water, flood, and municipal districts for erosion control, water conservation, water quality enhancement, stream bank stabilization, and riparian management projects. Substantial damage to wildlife, flora, aquatic or marine life, or habitat is considered an environmental crime (ORS 468.920).

Forestry. Oregon's Forest Practices Act (44 ORS 527-610–770) mandates protection of fishery resources during forestry activities. Rules for channel alterations, riparian conditions, chemical application, harvest, road construction and maintenance, and forested wetlands are described in OAR 629. OAR 629-57-2000–2660 specifically address water protection. The Board of Forestry directed that monitoring of water quality and fish habitat receive high priority and adequate funding (OAR 629-57-2005). Forest practices rules require that stream crossing structures provide passage for adult and juvenile fish, both up- and downstream (OAR 629-24-522).

Agriculture. Pesticide restrictions are outlined in OAR 603-57. Basins designated as total maximum daily load (TMDL) waters are subject to water quality management plans (ORS 568.900-.933). These plans are designed to prevent and control water pollution from agriculture by restricting land clearing and cropping practices. Confined animal operations are regulated under OAR 340-51, which prohibits animal wastes from waters without a permit and requires manure to be collected, stored, and distributed so as to prevent pollution. Civil penalties are assessed for failure to submit plans, violation of permit compliance schedules, failure to provide access, placing wastes where they are likely to enter waters, unpermitted discharges, water pollution, standards violations, or use impairment. OAR 603-90 protects water uses required by State and Federal law. Adversely affected water uses are listed, the necessary pollution control measures are described, and a strategy and schedule for iniplenientation are developed. Violations are the same as for confined animal operations and each day's violation is considered a separate offense. Fish screens are covered in 41 ORS 498.705-750.

Rangelands. This regulation is designed to restore properly functioning ecosystems and ecosystem processes on State lands by maintaining, restoring, or enhancing water quality and rangeland health (OAR 141-110). Health is defined as soil integrity and sustainable ecological processes. Rangelands vulnerable to adverse transitions are to be monitored.

Mining. A permit is required for chemical process mining (OAR 690-78). It must depict the duration, location, diversions, and measures to avoid damaging aquatic life or public water uses.

Water Quality. ORS 468B defines pollution as the alteration of physical, chemical, or biological properties of waters, including temperature and turbidity that renders such waters detrimental to fish, aquatic life, or their habitat. It also prohibits pollution, placing wastes where they are likely to be carried to waters, and discharge of wastes if they reduce water quality standards. Water quality violations include causing major harm or risk to the environment and failure to provide access when required (OAR 340-12-055). Detrimental change in biological communities is prohibited (OAR 340-41-027). Miscellaneous provisions on water rights, uses, and protection are treated in 45 ORS 541.605.990, chapter 541.

Instream Flows. OAR 340-56 allows the Department of Environmental Quality (DEQ) to apply for instream water rights for pollution abatement, while OAR 690-77 allows DEQ, the Department of Fish and Wildlife, and the Parks Department to obtain instream rights for aquatic life, recreation, wildlife, ecological values, and pollution abatement. Water control structures and water diversions are not required to obtain these rights.

Channel Alterations. Removal and fill for all waters and wetlands of the State requires a permit and plan (OAR 141-85). The plan must describe the public value of the project, its duration, hydrological and fish impacts, and potential effects on rare, threatened or endangered species. Wetland fill and removal requires mitigation that exceeds or equals the value of the wetland.

Washington

Laws for this State are summarized primarily from *West's Revised Code of Washington, Annotated.*

General Land Use. The State Growth Management Act (WAC 365-195) requires counties with human populations of 50,000 or more to develop plans for urban growth following standards. Urban growth areas can also be designated in rural areas. The Shoreline Management Act (90.58 RCW) protects State over local interests, long- versus short-term issues, shoreline ecology, increased public access, and recreational values through land-use planning.

Forestry. Timber harvesting regulations, including riparian protections, are detailed in WAC 222-30. WAC 222-24 describes requirements for road construction and maintenance, including stream crossings (WAC-24-040). Use of forest chemicals is covered in WAC 222-38. Sections 76.42.030 RCW and 76.42.060 RCW, respectively, authorize wood debris removal and prohibit its deposition in channels. A program to reduce hazards from mass earth movements by identifying sensitive sites and restricting uses is described in 76.09.300-320 RCW. Tlie Department of Ecology can modify forest practice regulations (90.48.420 RCW) that result in pollution. The Departments of Forestry and Ecology have right of entry at any reasonable time (76.09.150, 160 RCW).

Agriculture. Pesticide uses and users are restricted (15.58 RCW). Tlie Department of Ecology can issue pollution violation notices for agricultural activities (90.48.450 RCW).

Mining. Section 78.56 RCW requires an environmental impact statement before mining. The Departments of Ecology and Fish and Wildlife incorporate mitigation measures in the permit to reduce impacts on fish and wildlife. Mine and mill tailings and effluents must be reduced by stabilization, removal, or reuse. Quarterly inspections are required and citizen reviews and suits are allowed. Aggregate mining is covered under WAC-220-1 10-130.

Water Quality. The State Water Protection Act (WAC 173-20) requires that beneficial uses of water be maintained and allows no further degradation of these uses. Pollution is defined as alteration of the physical, chemical, or biological environment, including temperature, turbidity or any substance likely to be detrimental to fish and aquatic life (90.48.020 RCW). Pollution is unlawful (90.48.080 RCW), including that from fish hatcheries (90.48.210 RCW), and entry rights are provided (90.48.090 RCW). A coastal protection fund is authorized (90.48.390-400 RCW).

Instream Flows. The Department of Ecology may establish minimum flows to protect fish, esthetics, recreation, and water quality (90.22.010 RCW). Water flows are also covered in 75.20.50 RCW.

Channel Alterations. The Hydraulics Code provides guidelines for bank protection (WAC 220-110-050), dredging (WAC 220-110-130), treatment of large woody material (WAC 220-110-150), and

AR053346

culvert installation (WAC-220-1 10-070). Channel obstructions are prohibited on waters that are boatable or that can float logs or posts (88.28.050 RCW) and fishways are required around dams or obstructions (72.20.060 RCW). Section 86.16 RCW regulates construction and operations in floodplains that adversely influence flow regimes or health and property. Practices on aquatic lands must preserve and enhance water dependent uses, giving nonwater dependent uses low priority (79.90.450-545 RCW). Wildlife habitat and spawning values must be considered before leasing.

A.4 Federal and State Government Offices

Below are addresses, phone numbers, FAX numbers, and internet addresses for Federal and State Agencies that may be able to provide assistance or data related to conservation planning. Because electronic information changes frequently, access to the World Wide Web (URLs), email addresses, and telephone area codes with nunibers below inay have changed.

A.4. I Federal Offices

U.S. Departmenf of Agriculture.

———Forest Service, 316 E. Myrtle, Boise, ID 83702, (208) 364-4340.

———Forest Service, 630 Sansome St., San Francisco, CA 94111 (415) 556-8551.

———Forest Service, 319 SW Pine, Portland, OR 97208 (503) 221-3418.

———Natural Resources Conservation Service, National Cartography and Geospatial Center, 501 Felix St., Bldg. 23 (P.O. Mail 6567), Fort Worth, TX 761 15, (800) 672-5559.

———Natural Resources Conservation Service, National Soil Survey Center, Soil Survey Laboratory, Federal Building, Room 152, MS 41. 100 Centennial Mall North, Lincoln, NE 68508-3866, (402) 437-5363.

———Natural Resources Conservation Service, 101 SW Main Suite 1300, Portland, OR 97204 (503) 414-3094.

———National Resource Conservation Service (California), 2121-C Second Street, Suite 102, Davis, CA 95616 (916) 757-8262

———Natural Resources Conservation Service, Resources Inventory and Geographic Information Systems Division, P.O. Box 2890. Washington, D.C. 20013, (202) 720-4530.

U.S. Departmenf of Commerce.

———National Marine Fisheries Service, 3773 Martin Way E., Building C, Olympia, WA 98501, (360) 534-9330.

———National Marine Fisheries Service, 525 NE Oregon St., Portland, OR 97232-2737, (503) 230-5400.

———National Marine Fisheries Service NW Regional Office, 7600 Sand Point Way, N.E.BIN C15700, Bldg. 1, Seattle, WA 981 15-0070, (206) 526-6150.

———National Marine Fisheries Service, Boise Field Office, 1387 S. Vinnel Way, Ste 377, Boise, Idaho, 83709, (208) 378-5696.

———National Marine Fisheries Service, SW Region, 501 West Ocean Blvd., Ste 4200, Long Beach, CA 90802-42 13, (3 10) 980-4001

———National Marine Fisheries Service, Santa Rosa Field Office, 777 Sonoma Ave., Rm 325, Santa Rosa, CA 95404-6515, (707) 575-6050

U.S. Department of the Inferior.

———Bureau of Land Management, 825 N. E. Multnomah, Portland, OR 97208, (503) 952-6002 (OR & WA).

———Bureau of Land Management, 316 E. Myrtle, Boise, ID 83702, (208) 364-4340.

———Bureau of Land Management, Federal Office Building Room E-2841, 2800 Cottage Way, Sacramento, CA 95825, (916) 484-4676.

———Fish and Wildlife Service, 500 NE Multnomah Suite 1692, Portland, OR 97232, (503) 231-6118 (CA, ID, OR, WA).

———Fish and Wildlife Service, Klamath River Office (California), 1215 S Main, Suite 212, Yreka, CA 96097-1006, (916) 842-5763.

———Fish and Wildlife Service, Coastal Office (California), 1125 16th St., Room 209, Arcata, CA 95521-7201, (707) 822-7201.

———Fish and Wildlife Service, Idaho State Office, 4696 Overland Rd., Room 576, Boise, ID 83705, (208) 334-1931.

———Fish and Wildlife Service, Oregon State Office, 2600 SE 98th Ave., Suite 100, Portland, OR 97266, (503) 231-6179.

———Fish and Wildlife Service, HCP-Forest Resources (Oregon), 333 SW 1st Ave., Portland, OR 97208-3623, (503) 326-62 18.

———Fish and Wildlife Service, Consultation & Conservation Planning (Oregon), 911 NE 11th Ave. Portland, OR 97232-4181, (503) 231-6241..

———Fish and Wildlife Service, HCP Program, 3704 Griffin Lane, Suite 102, Olympia, WA 98501, (360) 753-4474.

———Fish and Wildlife Service, Upper Columbia River, 11103 E. Montgomery Dr., Suite 2, Spokane, WA 99206, (509) 891-6839.

———Geological Survey, EROS Data Center (EDC), Sioux Falls, SD 57198, (605) 594-6151 (Aerial Photographs); and EOSAT, Landsat Customer Service c/o EROS Data Center (EDC), Sioux Falls, SD 57198, (605) 594-2291 (Landsat Data).

———Geological Survey, Geological Inquiries Group (GIG), 907 National Center, Reston, VA 22092, (703) 648-4383.

———Geological Survey, Map Distribution Section (MDS), Map Sales, Federal Center, Box 25286, Denver, CO 80225, (303) 236-7477.

———Geological Survey, National Cartographic Information Center (NCIC),Western Mapping Center, 345 Middlefield Road, Menlo Park, CA 94025, (415) 328-4309.

———Geological Survey, Photographic Library (LIB-P), Mail Stop 914, Building 20, Box 25046, Federal Center, Denver. CO 80225, (303) 236-1010.

———Geological Survey, Public Inquiries Office (PIO), Building 3, Room 3128, Mail Stop 522, 345 Middlefield Road, Menlo Park, CA 94025, (415) 329-4390.

———Geological Survey, National Cartographic Inforination Center (NCIC) California State Affiliate: Map and Imagery Laboratory Library, University of California, Santa Barbara, CA 93106, (805) 961-2779.

———Geological Survey, National Cartographic Information Center (NCIC) Idaho State Affiliate: Idaho State Historical Library. 610 N. Julia Davis Dr., Boise, ID 83702, (208) 334-3356.

———Geological Survey, National Cartographic Information Center (NCIC) Oregon State Affiliate: Oregon State Library, Public Services, Salem, OR 97310 (503) 378-4368.

———Geological Survey, National Cartographic Information Center (NCIC) Washington State Affiliate: Washington State Library, Information Services Division, Olympia, WA 98504, (206) 753-4027.

———Geological Survey, Water Resources Division District Office (California), Federal Building, Room W-2235, 2800 Cottage Way, Sacramento, CA 95825, (916) 978-4633.

———Geological Survey, Water Resources Division District Office (Idaho), 230 Collins Road, Boise, ID 83702, (208) 334-1750.

———Geological Survey, Water Resources Division District Office (Oregon), 847 NE 19th Avenue, Suite 300, Portland, OR 97232, (503) 231-2009.

———Geological Survey, Water Resources Division District Office (Washington), 1201 Pacific Avenue, Suite 600, Tacoma, WA 98402, (206) 593-6510.

U.S. Environmental Protection Agency.

———Region IX, 75 Hawthorne St., San Francisco, CA (415) 744-1305.

———Region X, 1200 Sixth Ave., Seattle, WA 98101, (206) 553-1200.

———Idaho Office, 1435 N. Orchard St., Boise, ID 83706 (208) 378-5746.

———Oregon Office, 811 SW Sixth Ave, Portland, OR 97204 (503) 326 3250.

———Washington Office, 300 Desmond Dr. SE, Lacey, WA (360) 753-9437.

A.4.2 State Offices

California

California Department of Fish and Game.

———Headquarters. 1416 Ninth St. Sacramento, CA 95814, (916) 653-7664. For further information about the Geographic Inforination System contact: John Ellison, 1730 I Street, Suite 100 Sacramento, CA 95814, (916) 323-1477, email to jellison@dfg.ca.gov.

———Region 1, Northern California–North Coast, 601 Locust St., Redding, CA 96001, (916) 225-2300.

———Region 2, Sacrainento Valley–Central Sierra, 1701 Nimbus Dr., Rancho Cordova, CA 95670, (916) 358-2900.

———Region 3, Central Coast, P.O. Box 47, Yountville, CA 94599, (707) 944-5500

———Region 4, San Joaquin Valley–Southern Sierra, 1234 Shaw Ave., Fresno, CA 93710, (209) 222-3761.

———Region 5, Southern California–Eastern Sierra, 330 Golden Shore, Suite 50, Long Beach, CA 90802, (310) 590-5132.

California Department of Forestry.

———Administrative Unit, 1416 Ninth St., Sacramento, CA 94244-2460, (916) 653-5121.

____Coast-Cascade Region, 135 Ridgway Ave, Santa Rosa, CA 95402, (707) 576-2275.

____Sierra-South Region, 1234 East Shaw Ave., Fresno, CA 93710, (209) 222-3714.

California Department of Water Resources.

___Headquarters, P.O. Box 942836, Sacramento, CA 94236-0001; or 1020-9th Street, Sacramento, CA 95814; Division Chief (916) 327-1646.

____Division of Local Assistance, Northern District, 2440 Main Street, Red Bluff, CA 96080-2398; District Chief (916) 529-7342.

____Division of Local Assistance, Central District 325 1 S Street, Sacramento. CA 95816-7017; District Chief (916) 445-5631.

California Regional Water Quality Control Board.

___North Coast Region (1), 5550 Skyline Blvd., Suite A, Santa Rosa, CA 95403, (707) 576-2220, FAX (707) 523-0135.

____San Francisco Bay Region (2), 2102 Webster St., Suite 500, Oakland, CA 94612, (510) 286-1255, FAX (510) 286-1380.

____Central Coast Region (3). 81 Higuera St., Suite 200, San Luis Obispo, CA 93401-5427, (805) 549-3147, FAX (805) 543-0397.

____Central Valley Region (5S), 3443 Routier Rd., Suite A, Sacramento, CA 95827-3098, (916) 255-3000, FAX (916) 255-3015.

___Central Valley Region (5F), 3614 East Ashlan Ave., Fresno, CA 93726, (209) 445-5116, FAX (209) 445-5910.

____Central Valley Region-Redding Office (5R), 415 Knollcrest Dr., Redding, CA 96002, (916) 224-4845, FAX (916) 224-4857.

___Lahontan Region (6SLT), 2092 South Lake Talioe Blvd., Suite 2, South Lake, Talioe, CA 96150. (916) 542-5400, FAX (916) 544-2271.

Idaho

Idaho Department of Fish and Game.

____Headquarters, 600 S. Walnut, P.O. Box 25, Boise, ID 83707, (208) 334-3700.

___Panhandle Region, 2750 Kathleen Avenue, Coeur d'Alene, ID 83814. (208) 769-1414.

____Clearwater Region, 1540 Warner Avenue, Lewiston, ID 83501, (208) 799-5010.

___Southwest Region, 3101 S. Powerline Road, Nampa, ID 83686, (208) 465-8465 (from Boise call 887-6729).

___McCall Region, 555 Deinhard Lane, McCall, ID 83638, (208) 634-8137.

___Magic Valley Region, 868 East Main Street, P.O. Box 428, Jerome, ID 83338, (208) 324-4350.

___Southeast Region, 1345 Barton Road, Pocatello, ID 83204, (208) 232-4703.

___Upper Snake Region, 1515 Lincoln Road, Idaho Falls, ID 83401, (208) 525-7290.

___Salmon Region, 1214 Hwy 93 N., P.O. Box 1336, Salmon, ID 83467, (208) 756-2271.

Idaho Department of Lands.

___Coeur d'Alene Staff Headquarters, 701 River Ave., P.O. Box 670, Coeur d'Alene, ID 83816, (208) 769-1525.

___Priest Lake Area Office, Cavanaugh Bay #132, Coolin ID 83821, (208) 443-2516.

____Pend Preille Lake Area Office, P.O. Box 909, Sandpoint, ID 83864, (208) 263-5104.

___St. Joe Area Office, 1806 Main Ave., St. Maries, ID 83861, (208) 245-4551.

___Clearwater Area Office, 10230 Highway 12, Orofino, ID 83544, (208) 476-4587.

___Payette Lakes Area Office, 555 Deinhard Lane, McCall, ID 83638.

___Southwest Idaho Area Office, 8355 W. State St. Boise, ID 83703, (208) 334-3488.

___South Central Idaho Area Office, P.O. Box 149, Gooding, ID 83330, (208) 934-5606.

___Eastern Idaho Area Office, 3563 Ririe Highway, Idaho Falls, ID 83401, (208) 523-5398.

Idaho Department of Water Resources.

___Main office, 1301 North Orchard Road, Boise, ID, (208) 327-7900, FAX (208) 327-7866.

___Northern Region, 1910 Northwest Blvd., Suite 210, Coeur d'Alene, ID 83814-2615, (208) 769-1450, FAX (208) 769-1454.

____Western Region, 2735 Airport Way, Boise, ID 83705-5082, (208) 334-2190, FAX (208) 334-2348.

____Southern Region: 222 Shoshone St. East, Twin Falls, ID 83301-6105, (208) 736-3033, FAX (208) 736-3037.

___Eastern Region: 900 North Skyline Drive, Idaho Falls, ID 83402-6105, (208) 525-7161, FAX (208) 525-7177.

Idaho Division of Environmental Quality.

___Main office, 1410 Hilton, Boise, ID 83702, (208) 334-4250.

Oregon

Oregon Climate Service.

___Strand Ag Hall, Room 316, Oregon State University, Corvallis OR, 97331-2209. (541) 737-5705, FAX (541) 737-2540, email oregon@ats.orst.edu.

Oregon Department of Environmental Quality.

___Main office, 811 SW Sixth Ave, Portland, OR 97204, (503) 229-6121.

Oregon Department of Fish and Wildlife.

___Main office, 2501 SW First Ave., PO Box 59; Portland, OR 97207; General Phone Number, (503) 229-5406; General Information, (503) 229-5222; Habitat Conservation Division, (503) 229-6967; Wildlife Division, (503) 229-5454.

___Northwest Region, 71 18 Vandenberg Ave., Corvallis, OR 97330, (541) 757-4186.

___Southwest Region, 4192 N Umpqua Hwy., Roseburg, OR 97470, (541) 440-3353.

___Central Region, 61374 Parrell Rd., Bend, OR 97702. (503) 388-6363.

___Northeast Region, 107 20th Street, LaGrande, OR, 97850. (503) 963-2138.

___Southeast Region, 237 S. Hines Blvd., P.O. Box 8, Hines. OR 97738, (503) 573-6582.

___Marine Region, Marine Science Drive, Bldg. 3, Newport, OR 97365, (541) 867-4741.

___Columbia Region, 17330 SE Evelyn St., Clackamas, OR 97015, (503) 657-2000.

Oregon Department of Forestry.

___Main office, 2600 State Street, Salem, OR 97310, (503) 945-7200; State Forester (503) 945-7211; Deputy State Forester (503) 945-7202; Assistant State Forester (503) 945-7205.

___Northwest Oregon Area Office, Area Director, 801 Gales Creek Road, Forest Grove, Oregon 971 16-1 199, (503) 357-2191, FAX (503) 357-4548.

___Northwest Oregon Area, Forest Grove District, District Forester, 801 Gales Creek Road, Forest Grove, Oregon 97116-1199, (503) 357-2191, FAX (503) 357-4548.

___Northwest Oregon Area, Tillainook District, District Forester, 4907 E. Third Street, Tillamook, Oregon 97141-2999, (503) 842-2545, FAX (503) 842-3143.

___Northwest Oregon Area, Astoria District, District Forester, Route 1, Box 950, Astoria, Oregon 97103, (503) 325-5451, FAX (503) 325-2756.

___Northwest Oregon Area, Clackamas-Marion District, District Forester, 14995 S. Hwy. 211, Molalla, Oregon 97038, (503) 829-2216, FAX (503) 829-4736.

___Northwest Oregon Area, West Oregon District, District Forester, 24533 Alsea Hwy., Philomath, Oregon 97370, (541) 929-3266, FAX (541) 929-5549.

___Northwest Oregon Area, South Ford District, Administrative Supervisor, 48300 Wilson River Hwy., Tillainook, Oregon 97141, (503) 842-8439, FAX (503) 842-6572.

___Southern Oregon Area Office, Area Director, 1758 N.E. Airport Road, Roseburg, Oregon 97470-1499, (541) 440-3412, FAX (541) 440-3424.

___Southern Oregon Area, Southwest Oregon District, District Forester, 5286 Table Rock Road, Central Point, Oregon 97502, (541) 664-3328, FAX (541) 776-6260.

___Southern Oregon Area, Coos District, District Forester, 300 Fifth Street, Bay Park, Coos Bay, Oregon 97420, (541) 267-4136, FAX (541) 269-2027.

___Southern Oregon Area, Western Lane District, District Forester, P.O. **Box** 157, Veneta, Oregon 97487-0157, (541) 935-2283, FAX (541) 935-0731.

___Southern Oregon Area, Eastern Lane District, District Forester, 3150 Main Street, Springfield, Oregon 97478, (541) 726-3588, FAX (541) 726-2501.

___Southern Oregon Area, Linn District, District Forester, 4690 Highway 20, Sweet Home, Oregon 97386, (541) 367-6108, FAX (541) 367-5613.

___Eastern Oregon Area Office, Area Director, 3501 E. 3rd. Street, Prineville, Oregon 97754, (503) 447-5658, FAX (503) 447-1469.

___Eastern Oregon Area, Northeast Oregon District, District Forester, 611 20th Street, La Grande, Oregon 97850, (503) 963-3168; FAX (503) 963-4832.

___Eastern Oregon Area, Central Oregon District, District Forester, 220710 Ochoco Hwy., Prineville, Oregon 97754, (503) 447-5658, FAX (503) 447-1469.

___Eastern Oregon Area, Klamath-Lake District, District Forester, 3400 Greensprings Drive, Klamath Falls, Oregon 97601, (541) 883-5681, FAX (541) 883-5555.

Land Conservation and Development Deparfment.

———1175 NE Court St., Salem, OR 97310, (503) 373-0050.

Washington

Washington Department of Fish and Wildlife.

———Region I, 8702 N. Division St., Spokane, WA 99218, (509) 456-4082.

———Region I, 8702 N. Division St., Spokane, WA 99218, (509) 456-4082.

———Region 2, 1550 Alder St. N.W., Ephrata, WA 98823, (509) 754-4624.

———Region 3, 1701 S. 24th Ave., Yakima, WA 98902, (509) 575-2740.

———Region 4. 16018 Mill Creek Blvd., Mill Creek, WA 98012, (206) 775-1311.

———Region 5, 5405 NE Hazel Dell, Vancouver, WA 98663, (360) 696-6211.

———Region 6, 48 Devonshire Rd., Montesano, WA 98563, (360) 586-6129.

Washingfon Deparfmenf of Ecology

———Main office, P.O. Box 47600, Olympia, WA 98504, (360) 407-6000.

———Central Regional Office, 15 West Yakinia Ave., Suite 200, Yakima, WA 98902-3401, (509) 575-2490, FAX (509) 575-2809.

———Eastern Regional Office, N. 4601 Monroe, Suite 100, Spokane WA 99205-1295, (509) 456-2926, FAX (509) 456-6175.

———Northwest Regional Office, 3190-160th Ave. S.E., Bellevue, WA 98008-5452, (206) 649-7000, FAX (206) 649-7098.

———Southwest Regional Office, P.O. Box 47775, Olympia, WA 98504-7775, (360) 407-6300, FAX (360) 407-6305. Washington Department of Natural Resources.

———Habitat Conservation Planning Team, 1111 Washington St. S.E., MS-47011, Olympia, WA 98504-7011, (360) 902-1481, FAX 360-902-1790.

———Photo & Map Sales, P.O. Box 47013, Olympia, WA 98504-7013, (360) 902-1234.

Internet Sources

California Department of Water Resources (DWR) at **http://wwwdrw.water.ca.gov.**

California Department of Fish and Game, Natural Diversity Data Base (NDDB) at http://spock.dfg.ca.gov/Endangered/ endangered.html.

Idaho Department of Fish and Game at http ://www .state. id.us/fishgame/fishgame.html.

Idaho Department of Water Resources at http://www .state.id.us/idwr/idwrhome.html.

Oregon Department of Fish and Wildlife (ODFW), homepage at http://www.dfw.state.or.us. Oregon Rivers Inforination System (ORIS), Northwest Environmental Database, can be accessed through Brent O. Forsberg, Coordinator at forsberg@dfw.or.gov. or the ODFW homepage.

U.S. Department of Agriculture.

———National Resource Conservation Service, National Resources Inventory (NRI) at http://www.ncg.nrcs. usda.gov/nri.html.

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