NORTHWEST FOREST PLAN
THE FIRST 10 YEARS (1994–2003)

Preliminary Assessment of the Condition of Watersheds

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Abstract

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We aggregated road, vegetation, and inchannel data to assess the condition of sixth-field watersheds and describe the distribution of the condition of watersheds in the Northwest Forest Plan (the Plan) area. The assessment is based on 250 watersheds selected at random within the Plan area. The distributions of conditions are presented for watersheds and for many of the attributes that contribute to the condition of watersheds by land use allocation. Under the Plan, management activities were implemented in a way to promote positive changes in the condition of watersheds. This assessment revealed that the growth rate of trees (2 to 4 percent) exceeded losses (1.6 percent owing to stand-replacing fire and harvest), and nine times more roads were decommissioned than were constructed. Fifty-seven percent of the watersheds had higher condition scores in time 2 (1998–2003) than in time 1 (1990–96) across the entire Plan area. Only 3 percent of the watersheds had lower condition scores in time 2, and the scores did not change in the remainder of the watersheds. More key watersheds, which were given the highest priority for restoration activities, increased in condition than non-key watersheds. The greatest positive change in watershed condition occurred in late-successional reserves.

Keywords: Effectiveness monitoring, aquatic ecosystems, riparian ecosystems, watersheds, decision-support models, Northwest Forest Plan, aquatic conservation strategy, Pacific Northwest.

Executive Summary

The goal of the Northwest Forest Plan's aquatic conservation strategy (strategy) is to maintain or restore the condition of watersheds. Ten years have passed since the Northwest Forest Plan (the Plan), a management strategy applied to 24 million ac of federal lands in the Pacific Northwest, was implemented. The purpose of this assessment is to describe the current status of the condition of watersheds and describe how conditions have changed since the Plan was implemented.

In this assessment, we describe the current condition and changes in condition of 250 randomly selected sixth-field watersheds in the Plan area. Watershed monitoring for the Plan has been conducted for only the last 2 years; consequently, only 55 of the 250 randomly selected watersheds have been sampled to establish baseline conditions (status). Upslope and riparian roads and vegetation data were collected by using geographic information systems in all 250 watersheds to describe the changes (trends) in these attributes since the implementation of the Plan. A decision-support model based on local expert judgment was used to aggregate upslope, riparian, and inchannel indicators of watershed condition to estimate the condition of the watershed in a repeatable and objective manner. The distribution of watershed conditions was based on these modeled condition scores in the 250 watersheds. Results of the assessment are presented for the entire Plan area according to the land use allocation categories described in the Plan.

Nearly all the changes in watershed condition scores were very small. However, it appears that effects of the strategy on the condition of watersheds have been positive based on the following evidence: (1) Fifty-seven percent of the watersheds had higher condition scores in time 2 (1998–2003) than in time 1 (1990–96) across the entire Plan area. Relatively few watersheds (3 percent) had lower condition scores in time 2, and the scores did not change in the remainder of the watersheds. (2) Over 70 percent of key watersheds, which were supposed to have the highest priority for restoration activities, increased in condition score. Less than 50 percent of the non-key watersheds increased in condition score. (3) Seven watersheds had strong positive or negative changes: those that increased in condition score were targets of road decommissioning, and those that decreased in condition experienced wildfire (and not management activity). (4) The growth rate of trees (2 to 4 percent) exceeded losses (1.6 percent owing to stand-replacing fire and harvest). Also, nine times as many roads were decommissioned as were constructed.

Currently, the watershed condition evaluations include only road construction and decommissioning and tree growth and stand-replacing loss owing to harvest or fire. Road attributes were generally weighted more heavily in the decision-support models than were the vegetation attributes. Riparian attributes carried heavier weights than upslope attributes. According to the sensitivity analysis we conducted on the decision-support models, decommissioning roads in riparian and hazard areas will have the greatest positive effects on watershed condition scores. A reduction in the number of road-stream crossings often accompanies riparian road decommissioning. Because both of these attributes are evaluated in the models, this activity will cause the greatest change in watershed condition score.

Management activities that increase the density of large (>20 in) conifers in riparian areas will also have strong positive effects on the condition of watersheds and will be a good step toward strengthening the large wood input processes in these watersheds.

Also included in this document is an evaluation of the aquatic and riparian effectiveness monitoring program, the Plan's watershed monitoring program, and a brief description of the issues that have emerged since the implementation of the Plan. The monitoring program was implemented in 2002, and an examination of the program is underway to ensure that the program is running efficiently and that the data collected are relevant and have sufficient accuracy and precision to allow tracking changes in the condition of watersheds through time. We have made considerable changes in the field sampling protocols based on the results of our quality assurance program, to increase accuracy and precision in our sampling, and to be more consistent with the PacFish/InFish monitoring program in effect on the east side of the Cascade Mountain range.

Products of the monitoring program that will be helpful to resource managers include:

- Data from all the watersheds sampled (55 as of October 2003), which have been used for projects such as watershed analysis.
- Decision-support models, which can be used to assess the condition of streams or watersheds and to prioritize for restoration.
- Data quality assurance program, which can be implemented by any aquatic sampling program.
- Protocols for invasive species, which help stop the spread of invasive aquatic species.

Several salmon species have been listed as threatened or endangered since the implementation of the Plan, and consideration of these species is one of the issues that has emerged. Research is now being conducted on the effects of fire and the effects of management in upslope and riparian areas on aquatic- and riparian-dependent species. A brief description of these and other emerging issues is presented.

Preface

This report is one of a set of reports produced on this 10-year anniversary of the Northwest Forest Plan (the Plan). The collection of reports attempts to answer questions about the effectiveness of the Plan based on new monitoring and research results. The set includes a series of status and trends reports, a synthesis of all regional monitoring and research results, a report on interagency information management, and a summary report.

The status and trends reports focus on establishing baselines of information from 1994, when the Plan was approved, and reporting change over the 10-year period. The status and trends series includes reports on late-successional and old-growth forests, northern spotted owl population and habitat, marbled murrelet population and habitat, watershed condition, government-to-government tribal relationships, socioeconomic conditions, and monitoring of project implementation under the Plan standards and guidelines.

The synthesis report addresses questions about the effectiveness of the Plan by using the status and trends results and new research. It focuses on the validity of the Plan assumptions, differences between expectations and what actually happened, the certainty of the findings, and, finally, considerations for the future. The synthesis report is organized into two parts: Part I—introduction, context, synthesis, and summary—and Part II—socioeconomic implications, older forests, species conservation, the aquatic conservation strategy, and adaptive management and monitoring.

The report on interagency information management identifies issues and recommends solutions for resolving data and mapping problems encountered during the preparation of the set of monitoring reports. Information management issues inevitably surface during analyses that require data from multiple agencies covering large geographic areas. The goal of this set of reports is to improve the integration and acquisition of interagency data for the next comprehensive report.

Contents

Chapter 1: Introduction

In the early 1990s, controversy over harvest in old-growth forests led to sweeping changes in management of federal forests in western Washington, Oregon, and northwest California. These changes were prompted by a series of lawsuits in the late 1980s and early 1990s, which effectively shut down federal timber harvest in the Pacific Northwest. In response, President Clinton convened a summit in Portland, Oregon, in 1993, where he issued a mandate for federal land management and regulatory agencies to work together to develop a plan to resolve the conflict. The President's guiding principles followed shortly after the summit in his *Forest Plan for a Sustainable Economy and a Sustainable Environment* (Tuchmann et al. 1996)—otherwise known as the Northwest Forest Plan (the Plan).

Immediately after the summit, a team of scientists and technical experts were convened to conduct an assessment of options (FEMAT 1993). This assessment provided the scientific basis for the environmental impact statement and record of decision (ROD) (USDA and USDI 1994) to amend Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl (*Strix occidentalis caurina*).

The ROD, covering 24 million federal ac, put in place a new approach to federal land management. Key components of the ROD included a new set of land use allocations—late-successional reserves, matrix lands, riparian reserves, adaptive management areas, and key watersheds. Northwest Forest Plan (the Plan) standards and guidelines provided direction regarding how these land use allocations were to be managed. In addition, the Plan put in place a variety of strategies and processes to be implemented. These included adaptive management, an aquatic conservation strategy, late-successional reserve and watershed assessments, a survey and manage program, an interagency organization, social and economic mitigation initiatives, and monitoring.

Monitoring provides a means to address the uncertainty of our predictions and compliance with forest management laws and policy. The ROD stated that monitoring is essential and required (USDA and USDI 1994):

> Monitoring is an essential component of the selected alternative. It ensures that management actions meet the prescribed standards and guidelines and that they comply with applicable laws and policies. Monitoring will provide information to determine if the standards and guidelines are being followed, verify if they are achieving the desired results, and determine if underlying assumptions are sound.

Judge Dwyer reinforced the importance of monitoring in his 1994 decision declaring the Plan legally acceptable: "Monitoring is central to the [Northwest Forest Plan's] validity. If it is not funded, or done for any reason, the plan will have to be reconsidered."

The ROD monitoring plan provided a general framework to begin development of an interagency monitoring program. It identified key areas to monitor, initial sets of questions, types and scope of monitoring, the need for common protocols and quality assurance, and the need to develop a common design framework. In 1995, the effectiveness monitoring program plan (Mulder et al. 1995) and initial protocols for implementation monitoring (Alegria et al. 1995) were approved by the Regional Interagency Executive Committee. Approval of the effectiveness monitoring plan led to the formation of technical teams to develop the overall program strategy and design (Mulder et al. 1999) and monitoring protocols for late-successional and old-growth forests (termed older forests) (Hemstrom et al. 1998), northern spotted owls (Lint et al. 1999), marbled murrelets (*Brachyramphus marmoratus*) (Madsen et al. 1999), tribal relations (USDA and USDI 2002), and watershed condition (Reeves et al. 2004). Socioeconomic monitoring protocols continue to be tested (Charnley et al., in press).

Periodic analysis and interpretation of monitoring data is essential to completing the monitoring task critical to completing the adaptive management cycle. This important step was described in the overall monitoring strategy (Mulder et al. 1999) and approved by the Regional Interagency Executive Committee. This 10-year report is the first comprehensive analysis and interpretation of monitoring data since the ROD.

The primary objectives of this report are to describe the status of aquatic and riparian resources and changes in their condition under the Plan's aquatic conservation strategy. The document is one in a series of assessments describing current status and trends of northern spotted owls (Lint

2005), older forests (Moeur et al. 2005), marbled murrelets (Huff, in press), socioeconomic conditions (Charnley et al., in press), tribal relations (Crespin et al., in press), and implementation or compliance monitoring (Baker et al., in press). This series of reports is accompanied by a synthesis report by a panel of scientists and managers that integrates and interprets the findings from the status and trends reports and offers alternatives to policymakers (Haynes et al., in press).

Because the monitoring program was not implemented until 2002, we have yet to collect much of the data required to conduct a 10-year assessment of the Plan (fig. 1). We present a preliminary assessment of the condition of watersheds in the Plan area—the first quantitative assessment conducted since the Plan was implemented in 1994. Perhaps more importantly, we present the analytical approach used to assess the condition of watersheds in the Plan area. We used data from upslope, riparian, and inchannel attributes to estimate status and trend in watersheds by documenting the distribution of watershed conditions in the 24 million ac of federal land encompassed by the Plan. Standard procedures have yet to be established for determining the condition of watersheds or for conducting watershed monitoring at the large spatial and temporal scales encompassed by the Plan. Numerous approaches could be taken to determine the condition of watersheds. The approach presented here is based on a statistically valid sampling design that enables us to make inferences about watersheds in the Plan area, combined with a decision-support model that incorporates indicators of watershed condition in a way that is consistent and repeatable across time and space (Reeves et al. 2004).

Evaluating the effectiveness of the strategy is based on measuring changes in the distribution of watershed condition scores through time. Few details on the changes in individual watersheds are provided. The strategy does not describe the baseline condition of watersheds, nor does it define a desired distribution. We infer that if the strategy has been effective in maintaining or improving the condition of watersheds, then the distribution of watershed condition scores should either stay the same through time, or it should shift in a direction that indicates improvement. The primary objectives of the Plan's watershed monitoring include determining the baseline distribution of the condition of watersheds and tracking changes in the distribution through time. To spotlight some of the success local units have achieved with project-scale restoration, we describe several case studies in sidebars throughout the report. Some of the projects may have had immediate effects, such as opening up habitat to fish by replacing poorly designed culverts that previously blocked fish passage. But most restoration projects should be viewed as a critical first step in restoring natural watershed processes.

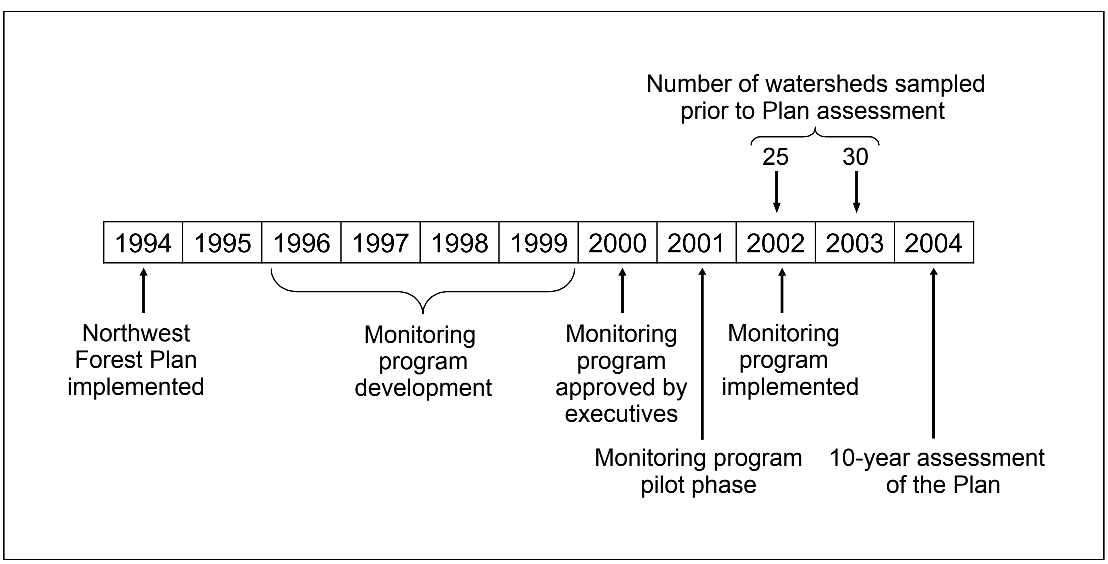


Figure 1—Timeline of the monitoring program development and implementation.

Expectations of the Aquatic Conservation Strategy

The strategy was designed to maintain or improve the ecological health of watersheds. The strategy is based on preserving natural disturbances in watersheds; therefore, not all watersheds are expected to be in good condition at any particular time. Nor is any particular watershed expected to be in a certain (or the same) condition through time. Thus, we examine the distribution of watershed condition through time. The strategy does not identify goals of a specific number or percentage of watersheds that should be in good condition. Nor does the strategy identify a desirable distribution of the condition of watersheds. The strategy does state that because it is based on natural disturbance processes, it will take time–on the scale of decades to perhaps more than a century–for watersheds to respond to the changes in management that resulted from the implementation of the strategy (FEMAT 1993). Consequently, we do not expect to see major changes in the condition of watersheds in a single decade. To examine the effectiveness of the strategy, we compare the distribution of the condition of watersheds in 2003 with the distribution from 1994. If the strategy has been effective, then the distribution of watershed condition scores in 2003 will either be the same as in 1994 or the condition scores of many of the watersheds will be higher in 2003 than they were in 1994.

Overview of the Aquatic Conservation Strategy

The aquatic conservation strategy is a comprehensive, regionwide strategy designed to maintain, restore, and protect those processes and landforms that create good ecological conditions in watersheds, such as providing high-quality habitat for aquatic and riparian organisms and good water quality (FEMAT 1993). The strategy contains nine objectives that describe general characteristics of functional aquatic and riparian ecosystems that are intended to maintain and restore good habitat in the context of ecological disturbance (see app. 1). This approach was intended to prevent further degradation and restore habitat over broad landscapes, as opposed to focusing on individual projects or species (USDA and USDI 1994). Aquatic and riparian organisms evolved in a dynamic environment influenced by natural disturbance. The authors of the strategy believed that stewardship of aquatic resources is most likely to protect biological diversity and productivity when land use activities do not substantially alter the natural disturbance regime to which organisms are adapted (FEMAT 1993). Therefore, the strategy used several tactics to try to maintain the natural disturbance regime in watersheds. The four components of the strategy were intended to work in concert to maintain and restore the health of aquatic and riparian ecosystems:

1. Watershed analysis—used to characterize watersheds and provide a basis (context) for making management decisions.
2. Riparian reserves—used to enhance habitat for riparian-dependent organisms, to provide good water quality, to provide dispersal corridors for terrestrial species, and to provide connectivity within watersheds.
3. Key watersheds—provide high-quality habitat or refugia for aquatic- and riparian-dependent species or would be able to after restoration.
4. Watershed restoration—designed to recover degraded habitat and maintain existing good conditions.

The strategy also includes standards and guidelines that apply to management activities in riparian reserves and key watersheds.

Although late-successional reserves are not listed among the components of the strategy, they provide increased protection for aquatic and riparian ecosystems. Late-successional reserves contain areas of high-quality stream habitat that serve as refuge for aquatic and riparian organisms and as source areas from which organisms may move to recolonize formerly degraded areas (USDA and USDI 1994).

Monitoring was included in the strategy to achieve three goals: ensure that management actions follow the standards and guidelines and comply with applicable laws and policies (implementation monitoring), determine the effectiveness of management practices at multiple spatial scales ranging from individual watersheds to the entire Plan area (effectiveness monitoring), and determine whether the assumptions underlying the strategy are sound (validation monitoring). The first goal was accomplished through the implementation monitoring program (Baker et al., in press). The aquatic and riparian effectiveness monitoring program (monitoring program) was developed to reach the remaining goals.

Overview of the Aquatic and Riparian Effectiveness Monitoring Program

The monitoring program is responsible for the effectiveness monitoring component of the strategy. Procedures for monitoring the effectiveness of a management strategy at such large spatial and temporal scales are not well established. The program is one attempt to characterize the ecological condition of watersheds. Its purpose is to assess current watershed condition, track trends in watershed condition through time, and report on the Plan's effectiveness across the region by integrating information from a set of biological and physical indicators measured in the watersheds (Reeves et al. 2004). The focus is not on the condition of individual watersheds; rather, the results are presented in the form of a distribution of the condition of watersheds across the Plan area. If the Plan is effective, the condition of watersheds should either stay the same or improve over time (Reeves et al. 2004). Note that the Forest Ecosystem Management Assessment Team (FEMAT) scientists did not intend for each of the strategy's objectives to be monitored individually, nor did they expect that the objectives would be met across the Plan landscape at all times.

The monitoring program was pilot tested in 2000 and 2001 to evaluate sampling protocols and determine the funding and crew structure needed to implement the monitoring program (fig. 1). Monitoring officially began in 2002, although funding was about half the amount identified as being needed to fully implement the program. As of fall 2003, 55 of an expected 100 watersheds were sampled.

Monitoring Questions

The monitoring program is charged with answering questions related to evaluating the effectiveness of the aquatic conservation strategy in achieving its goal of maintaining and improving the condition of watersheds in the Plan area (Reeves et al. 2004). The primary question being asked is: what is the status and trend of watershed conditions in the Plan area? Additional questions, whose answers provide insight for evaluating the success of the aquatic conservation strategy, include:

- Are the key processes that create and maintain habitat conditions in aquatic and riparian systems intact?
    - What is the status of upslope processes as indicated by vegetation and roads?
    - What is the status of riparian processes as indicated by vegetation and road-stream crossings?
    - What is the status of inchannel processes as indicated by pools, substrate, water temperatures, large structure in the channel, and rates of channel movement?
- Has the distribution of key indicators shifted in a direction that indicates improved or degraded habitat and biotic condition?
- How does the aggregate quality of the key indicators used to evaluate watershed condition (i.e., the distribution of watershed condition scores) change through time under the Plan?

Assumptions of the Monitoring Program

The Plan was designed to account for the complex and dynamic nature of aquatic ecosystems resulting from the wide range of physical characteristics, natural disturbance events, and climatic features of the region (Benda et al. 1998, Naiman et al. 1992). Consequently, one of the assumptions underlying the monitoring program is that watersheds are dynamic systems, and we do not expect all watersheds to be in good condition at any one time (Naiman et al. 1992, Reeves et al. 1995). Nor do we assume that individual watersheds will remain in a static condition indefinitely. Therefore, the primary product of the monitoring program is a distribution that describes the range of conditions of watersheds in the Plan area. Implementing the strategy should result in a range of watershed conditions across the landscape that represents the natural range of conditions expected in a well-functioning aquatic network.

Study Area

The Plan encompasses more than 24 million ac of federal lands in western Washington, western Oregon, and northwestern California (fig. 2). The Plan area includes the entire geographic range of the northern spotted owl. Stream and riparian habitat conditions differ greatly across the Plan area because of natural and management-related factors. Geologic and climatic history influence topographic relief, landforms and channel patterns, and the dominant erosion processes. Precipitation ranges from more than 200 in per year in some areas near the coast to less than 20 in on the east side of the Cascade Range. Riparian vegetation communities are structured by climate and the disturbance regime of the area, including hydrologic processes and disturbance such as forest fires. Many of these critical components of landscape form and function are in distinctive combinations characteristic of each physiographic province in the region. Physiographic provinces incorporate physical, biological, and environmental factors that shape broad-scale landscapes and therefore reflect differences in responses such as soil development and plant community structure.

The Plan area contains eight aquatic physiographic provinces (fig. 2) including the Olympic Peninsula, North Cascades, Willamette/Puget Trough, West Cascades, Washington/Oregon Coast, High Cascades, Klamath/Siskiyou, and Franciscan. Land ownership in the Willamette/Puget Trough is predominantly private, and none of the watersheds in this province met the minimum federal land ownership criteria for the monitoring program. Consequently, this province is not included in the analysis. Descriptions of the provinces based largely on those presented in FEMAT (1993) are provided in appendix 2.

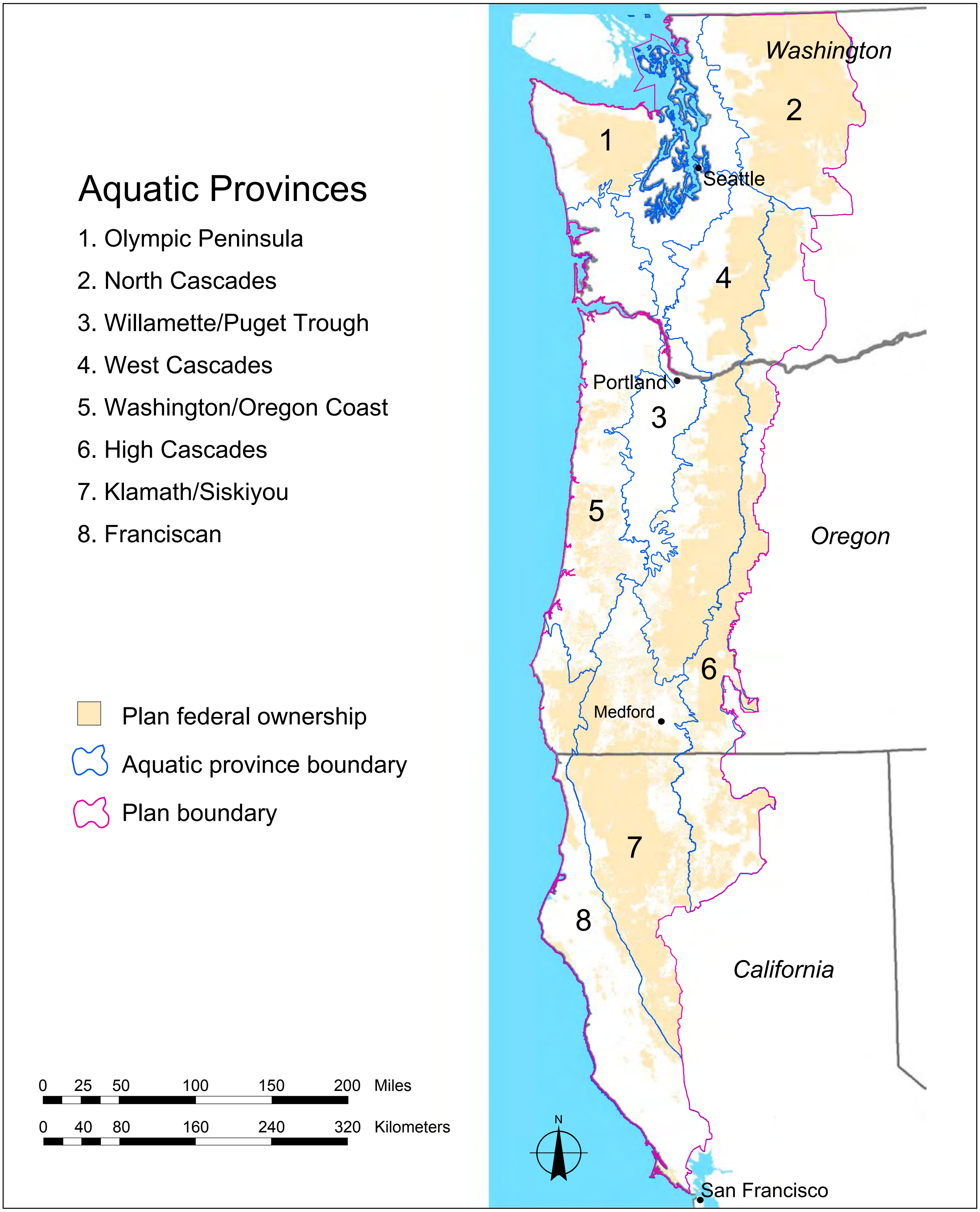


Figure 2—Physiographic provinces in the Plan area. The Plan area extends from the U.S.-Canada border to Point Reyes, California, and includes the eastern flank of the Cascade Mountain range and encompasses the range of the northern spotted owl.

Chapter 2: Methods

Study Design

The subwatershed (sixth-field hydrological unit, hereafter called watershed) formed the basic geographic unit for monitoring. These watersheds are 10,000 to 40,000 ac, and include both complete (contains all headwaters for a main stream) and composite (contains only part of the source waters) watersheds. Because the Northwest Forest Plan (the Plan) applies only to federally managed lands, watersheds must contain a minimum of 25 percent federal ownership (USDA Forest Service, USDI Bureau of Land Management [BLM], or USDI National Park Service) along the total length of the stream (1:100,000 National Hydrography Dataset stream layer) to be considered for sampling in the monitoring program. The ownership criterion was recommended by Reeves et al. (2004) to gauge the influence of the strategy by sampling watersheds in which the strategy was implemented to varying degrees while avoiding sampling watersheds in which the contribution of federal lands to the condition of the watershed was insignificant. The Plan area contains 2,631 watersheds, of which 1,912 contain some land that is federally owned and 1,372 have at least 25 percent federal ownership. The ownership criterion excludes about 10 percent of the federal lands in the Plan area from this analysis.

To assess the effectiveness of the Plan, 250 sixth-field watersheds (app. 3) were randomly selected from the 1,372 watersheds that meet the ownership criterion by using generalized random stratified tessellation survey, a process that guarantees a spatially balanced sample (Stevens and Olsen 2003, 2004). The sixth-field watershed coverage (version 1.1, dated 2002) for the Plan area was used to select watersheds. According to Reeves et al. (2004), 50 watersheds should be sampled each year for 5 years. On year 6, the watersheds sampled the first year will be revisited. Because of funding limitations, we were only able to sample inchannel attributes in a combined total of 55 watersheds in 2002 and 2003, rather than the 100 watersheds as recommended by Reeves et al. (2004). Because of this limitation, we have data from only 22 percent of the watersheds needed to build a baseline distribution for use in evaluating the effectiveness of the strategy. Also, none of the watersheds was sampled more than once; therefore, we have no inchannel data to support the trend analysis.

Inchannel data were collected at multiple sites in each watershed (fig. 3). These sites were selected by using generalized random stratified tessellation survey (Stevens and Olsen 2003, 2004), the same procedure used to select watersheds. The 1:100,000 National Hydrography Dataset stream layer was clipped to the boundary of each watershed. Sample points were placed on the stream layer within the watershed boundary at random. These points represented the downstream starting point for the inchannel surveys.

Because inchannel data were available for only 55 of 250 watersheds, and these data are from only one time period, the data required for the analysis were incomplete. The watershed condition scores (based on road, vegetation, and inchannel data) were used solely to begin building the baseline distribution of watershed condition scores in the Plan area. In describing the current status of the different attributes, we relied on road and vegetation data from the 250 watersheds and inchannel data from the 55 watersheds that have been sampled. For the trend analysis, we relied only on the road and vegetation data in the 250 randomly selected watersheds from two periods.

Definition of Watershed Condition

The definition of watershed condition developed by the monitoring program was based on the goals of the strategy and on guidance provided by Reeves et al. (2004). The condition of a watershed was defined as "good" if the physical attributes were adequate to maintain or improve biological integrity, including diversity and abundance of species—particularly, native or desired fish species. Specific physical attributes included intact upslope and riparian habitats that were biologically and structurally diverse and functioning properly—i.e., banks were stable, large wood was present in the stream channel, and sediment and nutrient inputs were similar to natural levels. Flows should have been adequate to maintain or improve riparian and inchannel habitat. Chemical characteristics and water temperature must have been in a range that maintained biological integrity. Further, the system should have been able to recover to desired conditions when disturbed by large natural events or by

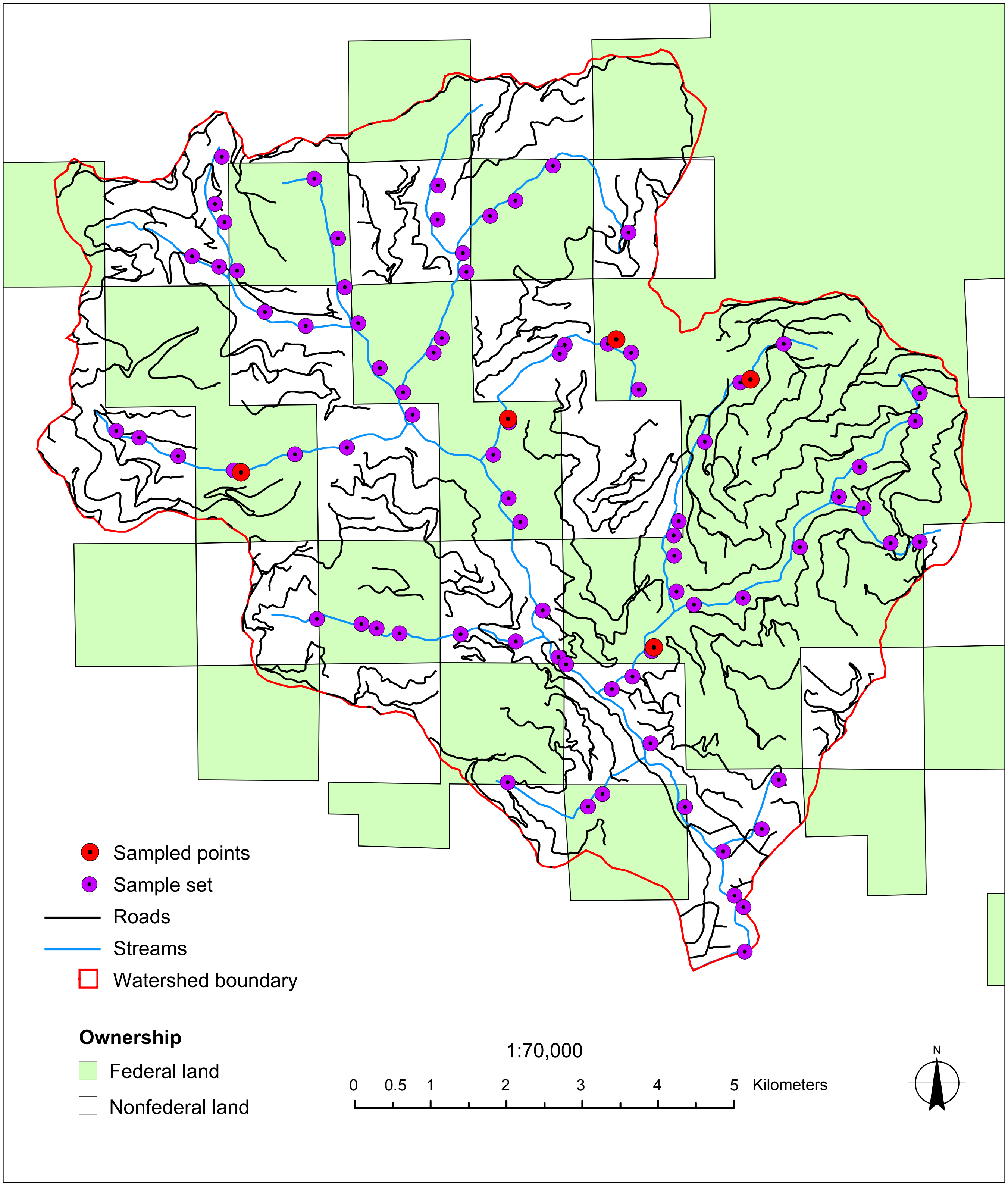


Figure 3—Example of randomly selected sample sites in a sixth-field watershed. The sampled stream reaches (red dots) were selected from 1:100,000 stream layers by using a generalized random stratified tessellation survey, a process that guarantees a spatially balanced sample (Stevens and Olsen 2004).

land management activities. Appendix 4 contains specific criteria used to evaluate the condition of watersheds in each province.

The definition is fish (salmon)-centric, in other words, we define good condition as ability to provide high-quality fish habitat. A watershed with intact processes may not be in good condition in terms of providing quality fish habitat. Watersheds naturally differ in their condition, and they periodically experience natural disturbance. For this reason, we need to recognize that unmanaged watersheds are not necessarily in good condition. Although condition may be improving in a recently disturbed watershed, no watershed is in good condition all the time, regardless of its management history. Further, we expect that the probability that all watersheds would be in good condition at any one time is very low.

Assessment of Watershed Condition

Decision-support models were used to assess the condition of individual watersheds by using locally relevant evaluation criteria. These models are computer-based models that capture evaluation procedures and apply a consistent decision or evaluation process across time and space. Reeves et al. (2004) recommended using these models because they are easy to understand and to replicate.

Decision-support models use data to evaluate a premise. For the analysis described in this report, we evaluated the premise that watersheds are in good condition. Data used in the assessment lend varying levels of support to that premise, ranging from full support to no support. We developed criteria to evaluate each attribute based on available data and expert judgment. Data on individual attributes were compared to these criteria and given an evaluation score that ranged between +1 and –1, where +1 indicates full support and –1 indicates no support for the premise. The evaluation score is positively related to the condition of watersheds, such that the attributes (or watersheds) in good condition should receive an evaluation score of (or near) +1. Evaluation scores for the attributes were aggregated into an overall assessment of watershed condition. Evaluation scores were typically aggregated by using either a weighted or unweighted average. Weights were assigned based on the experts' opinions of the relative importance of an attribute in contributing to the condition of watersheds. In a few cases, an aggregated score weighted toward the lowest evaluation score was used to allow a single variable to override other variables.

A decision-support model was built, refined, and peer-reviewed for each province (n = 7) during workshops attended by local agency professionals (fig. 4). Models were built at the provincial scale to account for the ecological differences that exist between provinces. For example, precipitation and the availability of water in the creeks is an important consideration on the east side of the Cascade crest and in many parts of California and southern Oregon. However, water is rarely a limiting factor in coastal watersheds.

The workshops consisted of an informal group process through which participants came to consensus on the model structure and evaluation criteria. After the workshops, models were built and run and the results returned to the workshop participants. Participants compared the results of the model to their knowledge of the condition of the watersheds and suggested refinements to the model as necessary. Changes were made to the model and the results were reevaluated.

The models differ across provinces in the specific attributes evaluated, the weights assigned to individual attributes, and the evaluation criteria used (app. 4). Although the attributes available for use in the evaluation models were specified by Reeves et al. (2004), workshop participants determined how individual attributes were used in each model. For example, an evaluation of road-stream crossings was included in each of the provincial models, but the specific attribute evaluated differed across provinces (frequency of road crossings was sometimes expressed as number per mile of road and at other times as number per mile of stream). The width of the riparian buffers used also differed across provinces. The models were based on local data and knowledge. Most of the differences between models reflect ecological differences across provinces, but some reflect availability of data used as a basis for the evaluation criteria. We view the modeling effort as an iterative process. In the future, we will work toward making the models more

All photos on this page by Steve Lanigan

Figure 4—Nearly 50 participants provided technical expertise and local knowledge for decision-support model construction and refinement during a series of aquatic province workshops.

similar to the extent possible, given ecological differences between provinces. Advantages and disadvantages of using multiple models in the analysis are discussed in chapter 4. The sensitivity of each of the models to change is presented in appendix 5.

Attributes

The attributes used in this analysis describe existing inchannel conditions and watershed processes. The information and analytical tools necessary to quantify and comprehensively assess watershed processes are currently lacking. Thus, the monitoring program must rely on physical and biological attributes that act as surrogates or indicators of specific watershed processes. Reeves et al. (2004) initially identified 90 potential attributes that represent key functions and processes in watersheds. This number of attributes was reduced based on criteria established by Noon et al. (1999). The remaining attributes represent upslope, riparian, and inchannel processes (table 1).

In individual watersheds, roads and vegetation data in upslope and riparian areas were collected across the entire watershed by using geographic information systems (GIS) data sets. Riparian reserve boundaries have yet to be delineated; therefore, we were not able to include riparian reserves in the analysis. Riparian area for road and vegetation assessment was based on fixed-width buffers that were placed on the stream layer (see following section for details).

Inchannel data (physical and water chemistry attributes) were collected at several sample sites randomly selected in the watershed (fig. 3). Sites are sections of the stream channel that differ in length from 175 to 525 yd, depending on the width of the channel. Crews sampled individual sites until an 8-day sampling period expired. In each watershed, sites were sampled in the order they were selected. Sites located in unwadeable water or private land were not sampled. The number of sites sampled was typically a function of access (i.e., more sites were sampled in

Table 1—Attributes included in the watershed condition assessments listed by ecologic process[a]

General process	Key process	Attribute
Upslope subsystem:		
Vegetative succession, growth, and mortality	Wood production and transport	Vegetation seral stage
Soil cycle	Sediment production and transport	Road density
Soil cycle	Sediment production and transport	Landslides
Riparian flood-plain subsystem:		
Vegetative succession, growth, and mortality	Wood delivery, community structural development	Vegetation seral stage and association
Soil cycle	Sediment production and transport	Stream-crossing density
Soil cycle	Sediment production and transport	Road density
Soil cycle	Sediment production and transport	Landslides
Hydrologic cycle	Water storage and yield	Channel connectivity with flood plain
Inchannel subsystem:		
Channel structural dynamics	Sediment and wood delivery	Channel cross section
Channel structural dynamics	Sediment and wood delivery	Channel sinuosity and gradient
Channel structural dynamics	Sediment and wood delivery	Channel pools
Channel structural dynamics	Sediment and wood delivery	Channel wood
Channel structural dynamics	Sediment and wood delivery	Substrate composition
Channel structural dynamics	Flood-plain connectivity	Off-channel habitat
Energy exchange	Heat delivery	Water temperature
Chemical and nutrient turnover	Chemical and nutrient delivery	Water quality
Hydrologic cycle	Water delivery	Water quantity

[a] Data on these attributes were evaluated in the decision-support models and aggregated to determine the watershed condition score. Source: Adapted from Reeves et al. 2004.

areas that were easily accessed). On average, six sites were sampled in each watershed, with a range from three to eight.

Data Collection and Sources

The evaluation of upslope and riparian conditions in watersheds was tailored to specific physiographic provinces. Although physiographic provinces are useful in describing both terrestrial and aquatic ecosystems, different processes dominate the functioning of these ecosystems. Consequently, the Forest Ecosystem Management Assessment Team (FEMAT 1993) used different physiographic province boundaries for aquatic and terrestrial ecosystems. The physiographic boundaries used in this analysis were developed from those used in the aquatic ecosystem assessment, which were based on broadly drawn precipitation and geologic areas (FEMAT 1993). These province boundaries differ from those used by the other effectiveness monitoring components (e.g., the late-successional old-growth and the northern spotted owl (*Strix occidentalis caurina*)), which were delineated primarily by vegetation type and political boundaries (state lines). The aquatic province boundaries used in FEMAT were not available in a digital format, so the province boundary lines used in FEMAT were refined by using level 4 lines described by Omernik in Oregon and Washington (Bryce et al. 1999), Bailey ecological subsections lines in California (Bailey et al. 1994), and the Cascade crest derived from the Forest Service Pacific Northwest Region sixth-field watershed layer.

The GIS coverages used in the analyses were collected from various sources, including the USDA Forest Service, USDI Bureau of Land Management, USDI National Park Service, and other state and federal agencies. Details on the coverages used in the analyses are provided in appendix 6.

Upslope and Riparian Attributes

Roads—

In each of the 250 watersheds, road density in upslope and riparian areas and the frequency of road-stream crossings were determined. Data were based exclusively on the GIS layers, with no field verification. For these analyses, road and 1:24,000 stream layers were clipped to watershed boundaries. A fixed buffer was placed over streams in the watershed to determine riparian area. These riparian areas used do not represent riparian reserves. The width of the buffer differed across the provinces, and generally was 164 ft on the west side of the Cascade Range and 100 ft on the east side (app. 4). The width of the riparian buffer was determined during the decision-support model workshops. The buffer widths were based on what the participants believed was the relevant area for the riparian process of interest. For example, a narrow buffer was used in evaluating the extent that stream channels were constricted by the presence of a road. Wider buffers were used for evaluating wood and sediment input into streams. Upslope area was defined as the area outside the riparian boundary. For riparian road density analyses, the road layer was laid over the riparian buffer and miles of road inside the buffer were counted. Miles of road outside the buffer were used to determine upslope road density. To estimate the number of road-stream crossings, we counted road and stream intersections. Forty-eight sample watersheds spread across the Plan area were inspected for potential erroneous crossings from digitizing errors. The percentage of suspected false crossings was less than 2 percent for the total sample.

Information on road building and decommissioning conducted (fig. 5) since the Plan was implemented was spotty and incomplete. Although most of the federal road coverages contain attributes that describe whether specific road segments were decommissioned, dates of decommissioning and information on road building on Forest Service land were not available. Historical roads coverages (e.g., from 1994 when the Plan was implemented) were also not available. Therefore, to obtain road data from 1994 (time 1) and the present (time 2) (table 2) to analyze change, we used total road miles (existing + decommissioned) as the time 1 data point and the existing roads as the time 2 data point. We assumed that all the roads were decommissioned later than 1994. The Forest Service and the BLM rarely decommissioned roads before 1990.[1] Although analyzing just the miles of roads that have been decommissioned may seem more straightforward than looking at miles of roads in

[1] Erkert, T. 2003. Personal communication. Road engineer, USDA Forest Service, Pacific Northwest Region, 333 SW First Ave., Portland, OR 97204.

Bengt Coffin

Figure 5—Decommissioned roads are stabilized and disconnected from natural surface hydrological features.

Table 2—Dates of geographic information system layers used to determine the condition of watersheds in time 1 and time 2[a]

	Time 1	Time 2
Forest Service roads	Later than 1990	2002
Bureau of Land Management roads	1994	1998
Other roads	Later than 1990	1998
IVMP	1993–96	2002
CalVeg	1994	2003

[a] Interagency Vegetation Mapping Project (IVMP) and CalVeg are the vegetation layers used in this analysis.

time 1 and time 2, this approach would not allow us to use the decision-support model and determine the distribution of watershed conditions across the Plan area in the two periods.

Vegetation—

The analysis used GIS layers developed by the Interagency Vegetation Mapping Project (IVMP) in Oregon and Washington and by CalVeg in California to assess vegetation characteristics. Both layers were built by using Landsat Thematic Mapper remote sensing data (Moeur et al. 2005). In each of the 250 watersheds, the vegetation layer and the 1:24,000 stream layer were clipped to the watershed boundary. A fixed-width buffer was generated from the stream layer to designate the riparian area (app. 6). The area outside the buffer was defined as upslope.

For change analyses, data from the IVMP or CalVeg layer were used as the time 1 (around 1996) data point (table 2). For the time 2 (2002) data, the vegetation change layer developed for the older forest vegetation monitoring program (Moeur et al. 2005) was used in concert with the IVMP or CalVeg layer. This change layer was built by using data that were independent of the original IVMP and CalVeg data, and was used to update the original baseline layers. The change layers were laid over the IVMP or CalVeg layer, and the vegetation inside polygons that indicated post-1994 disturbance was classified as early seral. We then repeated the analyses conducted for the time 1 assessment. These change layers describe stand-replacing events resulting from harvest and fire (fig. 6), but they do not capture partial losses owing to thinning or surface fire, nor do the layers show tree growth.

To account for tree growth, we used data from about 40,000 plots measured twice since 1994 by the Forest Inventory Analysis (administered by the Forest Service in California) and the Current Vegetation Survey (administered by the Forest Service and BLM in Oregon and Washington).

Mark Isley

Figure 6—The vegetation layers used to identify stand-replacing events, such as this clearcut on nonfederal land were constructed by using satellite imagery.

Moeur et al. (2005) provided the details on the plot data used. We calculated the average percentage of area with trees in one size class in time 1 (e.g., <20 in) that transitioned to the next size class in time 2 (>20 in) since the Plan was implemented. We calculated this percentage for each vegetation type (e.g., pinion-juniper, Douglas-fir forest) in each province. This change rate was used to calculate change factors for each watershed by using the change rate for each of the vegetation types in the watershed, weighted according to the area of the watershed covered by the vegetation type. The change rate reflects the net change in vegetation owing to growth, recruitment, natural mortality, fire, and management activities. By using the change layer (which accounts for stand-replacing harvest and fire) and also applying change rates calculated from the plot data (which accounts for harvest and fire as well as thinning, growth, and natural mortality), we double counted stand-replacing events. According to Moeur et al. (2005), about 1.6 percent of the older forest trees (>20 in) were disturbed by stand-replacing harvest and fire. Thus, we assume that our analysis overestimates the amount of land disturbed by that amount, on average, across the 250 watersheds.

Plot data were not available for the national parks or for BLM lands in California because plots were not installed in these areas in 1994 when the Plan was implemented. We therefore assumed that the transition probabilities calculated in individual provinces applied to parks and California BLM lands in that province. For example, the transition probability calculated from plots on the Olympic National Forest and other areas on the peninsula were applied to the Olympic National Park. Because national parks are not managed for timber production, we likely overestimated stand-replacing disturbance in the national parks.

Inchannel Attributes

Physical and chemical inchannel data were combined with roads and vegetation data from the current period (time 2) for assessing watershed condition in the 55 watersheds that have been sampled as of fall 2003. Information on physical, biological, and chemical characteristics of the reach were obtained from field data. Biological data were not used in this assessment because time was insufficient to build it into the decision-support models. The length of the sample reach was determined as 20 times the average bankfull width, with minimum and maximum reach lengths of 175 and 525 yd, respectively (app. 7). Physical habitat indicators include:

- Bankfull width-to-depth ratio and entrenchment ratio, calculated from cross-sectional profiles (Peck et al. 1999; fig. 7).
- Pool frequency, sinuosity, and gradient, calculated from longitudinal profiles (Peck et al. 1999).
- Wood frequency, by using the protocol developed by the Oregon Department of Fish and Wildlife (Moore et al. 1999; fig. 8).
- Percentage of fine sediments, by using a protocol developed by USDA Forest Service, Pacific Southwest Region (1998; fig. 9) and substrate D_{50} (median particle size), by using a modification of Peck et al. (1999).

Chemical data were collected for total Kjeldahl nitrogen and total phosphorus and analyzed in the laboratory. Additional data were collected for dissolved oxygen, conductivity, pH, and water temperature by using a meter. These data were used to describe water quality in the watersheds.

Statistical Analysis

To test for the direction of change between the time 1 and time 2 distributions, we used a one-tailed Wilcoxon signed rank test. This test examines the differences between the time 1 and time 2 condition scores for individual watersheds and determines whether more watersheds increased or decreased in condition than would be expected by chance. The Wilcoxon test is a nonparametric that does not assume a normal distribution of the data. To avoid type II error, we set $\alpha = 0.10$ in all the analyses conducted.

Wald's F-test was used to test for differences between the distributions for key and non-key watersheds (psurvey. analysis library, v. 2.2; http://epa.gov/nheerl/arm/analysis pages/techinfoanalysis.htm) as described at the U.S. Environmental Protection Agency Aquatic Resource Monitoring-Analysis Web site (http://epa.gov/nheerl/arm/analysispages/monitanalysisinfo.htm) and by Diaz-Ramos et al. (1996).

Linear regression was used to examine the relationship between condition scores and federal ownership in watersheds. For the regression analysis, condition score was the dependent factor, and percentage of federal ownership was the independent factor. Land use allocation was included as a covariate. All analyses were conducted by using S-Plus statistical software, version 6.1 (Insightful Corp. 2002).

Figure 7—A laser level was used to measure cross-sectional profiles at transects placed throughout each stream reach. This information was then used to determine bankfull width-to-depth ratios and entrenchment ratios.

Figure 8—Each piece of wood must meet the following criteria to be counted: (1) be longer than 3 m (9.8 ft) and (2) at least 30 cm (11.8 in) in diameter one-third of the way up from the base or largest end.

Figure 9—A sediment grid was used to quantify the percentage of fine sediments on the surface of pool tail substrate.

Overview of the Decision-Support Model

Decision-support models can be used to conduct objective ecological assessments by integrating diverse kinds of data, such as vegetation, roads, and inchannel habitat indicators. These models are not mathematical or statistical models, they simply apply a decision process consistently across time and space. Advantages of using decision-support models include:

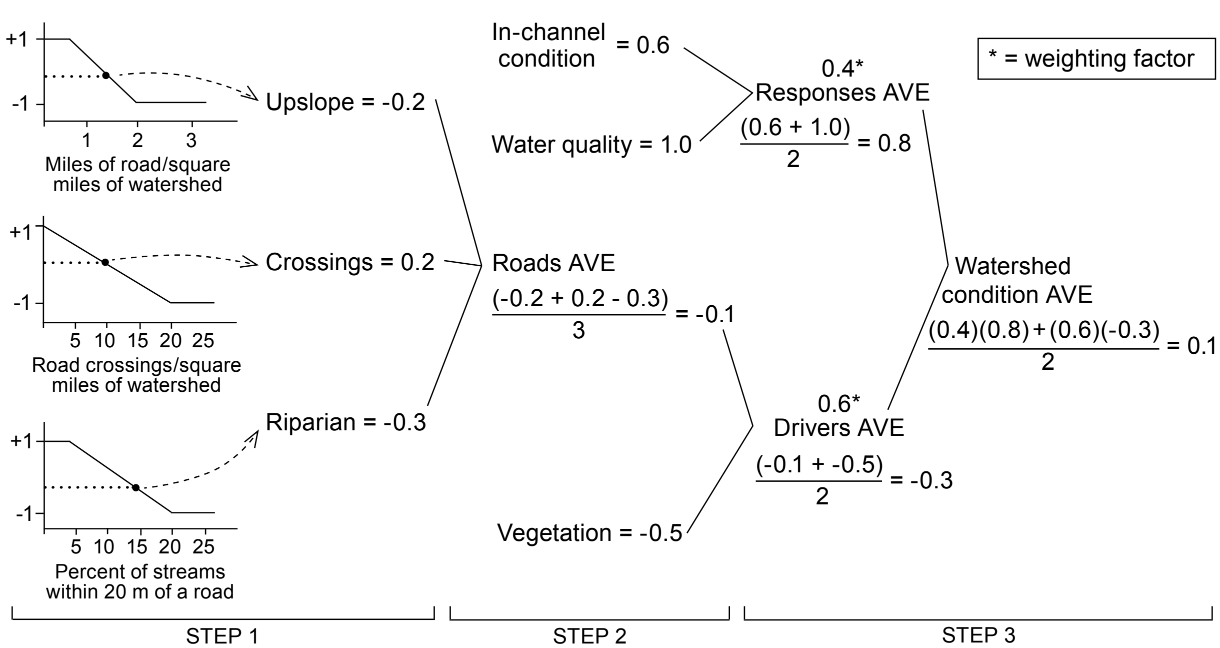
- All aspects of the analysis process are shown; therefore, it is easy to explain to customers.
- Models can be developed to assess ecological condition at any spatial or temporal scale.
- As we learn more about how watersheds function, models can be refined and rerun on data from earlier periods to correct deficiencies.

The following simplified model structure illustrates a decision-support model process for determining watershed condition. The actual model structures we used are presented in appendix 4.

Step 1: Evaluation criteria are determined for each model attribute. The evaluation curves are used to score each attribute between +1.0 (“good”) and -1.0 (“poor”). The curves are based on published literature, field data, and professional judgment. Evaluation curve examples are shown for the road components.

Step 2: The evaluation scores for each of the attributes are aggregated together for each general model component by using user-defined rules. Selection of the rules is based on experts’ knowledge of the system and ecological processes. Rules can produce an aggregated score weighted toward the resource with either the highest or lowest evaluation score, or use the average of scores (as shown in this example). A score can also be based on the weighted or unweighted average of the indicator evaluation scores, e.g., as shown in step 3.

Step 3: The evaluation scores are aggregated based on the model structure. In this model structure, the watershed condition is determined by using the weighted average of drivers (60 percent) and response (40 percent) scores. For the models presented in appendix 4, drivers scores are determined for the entire watershed by using geographic information systems data, whereas the response scores are based on inchannel data. The watershed condition score will always range from -1.0 to +1.0.



Example of a simplified decision-support model. In step 1, individual attributes are evaluated by using evaluation criteria. In steps 2 and 3, the evaluation scores of the attributes are aggregated to determine the overall watershed condition score.

Continue to Next Section

Chapter 3: Results

Results of the assessment were presented for the entire Northwest Forest Plan (the Plan) area and by land use allocation. Information on the current status of inchannel attributes was presented for the Plan area only because the number of watersheds measured (55) was not sufficient to divide into multiple land use allocation categories. Road and vegetation results for each of the land use allocations were based on a poststratification of the 250 watersheds. The land use allocation categories presented here are the same as those described by Tuchmann et al. (1996); however, we added a key watershed category because these areas are an important component of the strategy. Key watersheds are an overlay of the other land use allocations; thus, the categories are not mutually exclusive. We also collapsed some of the land use allocations that have similar guidelines for management (table 3). For example, administratively withdrawn areas were added to the congressional reserve category. Riparian reserves were not included because they have not been mapped. Results for upslope and riparian attributes are based on the riparian buffers described in chapter 2. Boundaries for land use allocations (including key watersheds) did not follow watershed boundaries; consequently multiple land use allocations may have been present in individual watersheds. Watersheds were classified according to the predominant land use allocation (>50 percent of the watershed area), including a nonfederal class. Nine of the watersheds could not be classified according to the described protocols because they contained several land use allocations of similar size. Information on these watersheds is presented in the Planwide analysis only.

Table 3—Collapsed land use allocation categories used in this analysis (category) and the land use allocations (described by Tuchmann et al. 1996 and the aquatic conservation strategy) included in each category

Category	Land use allocation
Adaptive management areas	Adaptive management areas
Congressional reserves	Congressional reserves Administratively withdrawn areas
Key	Tier 1 key watersheds Tier 2 key watersheds
Late-successional reserves	Late-successional reserve 1 Late-successional reserve 2 Late-successional reserve 3 Managed late-successional reserves Adaptive management reserves
Nonfederal	None
Non-key	All federal lands not designated as key watershed
Matrix	Matrix lands and riparian reserves[a]

[a] Riparian reserves have not been mapped; therefore, we were unable to separate them from matrix lands.

Plan Area

Current Status

We could not develop a baseline for the condition of watersheds across the Plan area based on a full set of data because inchannel data have been collected in only 55 of the 250 watersheds. We therefore used condition scores of the "driving" variables for which data were available (roads and vegetation variables) both separately and aggregated into a drivers condition score. The possible watershed condition scores range from -1 to 1. Watershed condition scores are positively related with the condition of watersheds: watersheds in good condition have higher scores than those in poor condition. Condition scores from the 55 watersheds were clustered in the center of the distribution (fig. 10). Maps are presented for the current (time 2) condition of the 55 watersheds (fig. 11), roads scores (fig. 12), vegetation scores from the 250 watersheds (fig. 13), and drivers scores (aggregate of roads and vegetation; fig. 14).

The questions the monitoring program is charged with answering are related to upslope, riparian, and inchannel conditions. Condition scores for upslope vegetation (median 0.35) were generally higher than roads (median 0) in upslope areas (fig. 15). Riparian vegetation had lower condition scores than did riparian roads (fig. 15). Upslope attributes generally have higher condition scores than do riparian attributes. Nearly half of the watersheds had condition scores less than -0.75 for riparian vegetation (fig. 16). Forty percent of the watersheds had condition scores less than -0.75 for riparian roads. In contrast, a maximum of 16 percent of the watersheds had condition scores for either of the upslope attributes that were less than -0.75.

Land Use Allocations Under the Plan (from Tuchmann et al. 1996)

The Plan allocated all federal lands into one of seven land use categories. Specific standards and guidelines for management activities such as timber harvest were developed for each land use allocation. The allocations include:

Congressionally reserved areas: These lands have been reserved by acts of Congress for specific land uses such as wilderness areas, wild and scenic rivers, national parks, and other lands with congressional designations.

Late-successional reserves: These reserves, in combination with the other allocations and standards and guidelines, are designed to restore a functional, interactive, late-successional and old-growth forest (older forest) ecosystem over time. They also serve as habitat for terrestrial and aquatic species that depend on these older forest characteristics. Not all of the reserves are currently in older forest condition. Pending scientific oversight and approval, some silvicultural treatment is allowed to enhance development in stands less than 80 years old and where fire played a dominant role.

Managed late-successional reserves: These lands are either mapped to protect areas where spotted owls are known to exist, or they are unmapped protection buffers. Protection buffers are designed to protect certain rare and endemic species.

Adaptive management areas: Ten areas were identified to develop and test innovative management approaches to integrate and achieve ecological, economic, and other social and community objectives. Each area has a different emphasis, such as maximizing the amount of late-successional forests, improving riparian conditions through silvicultural treatments, or maintaining a predictable flow of harvestable timber and other forest products. Each area considers learning a principal product of their adaptive management activities.

Administratively withdrawn areas: These areas are identified in current forest and district plans and include recreation and visual areas, backcountry, and other areas where management emphasis does not include scheduled timber harvest.

Riparian reserves: Riparian reserves are areas along all streams, wetlands, ponds, and lakes, and on unstable and potentially unstable lands vital to protecting and enhancing the resources that depend on the unique characteristics of riparian areas. These areas also play a vital role in protecting and enhancing terrestrial species.

Matrix: The matrix includes all federal lands not falling within one of the other categories. Most of the scheduled timber harvested will be from matrix lands. They include nonforested as well as forested areas that may be unsuited for timber production.

Key watersheds: This land use allocation was designated as part of the aquatic conservation strategy, and was overlaid on the other land use allocations. Therefore in addition to being in one of the land use allocations above, areas will also be designated as key or non-key watershed. The strategy includes two designations of key watersheds. Tier 1 key watersheds were selected to directly contribute to the conservation of anadromous salmonids, bull trout, and other resident fish species. Tier 2 key watersheds were selected as sources of high-quality water and may not contain at-risk fish stocks.

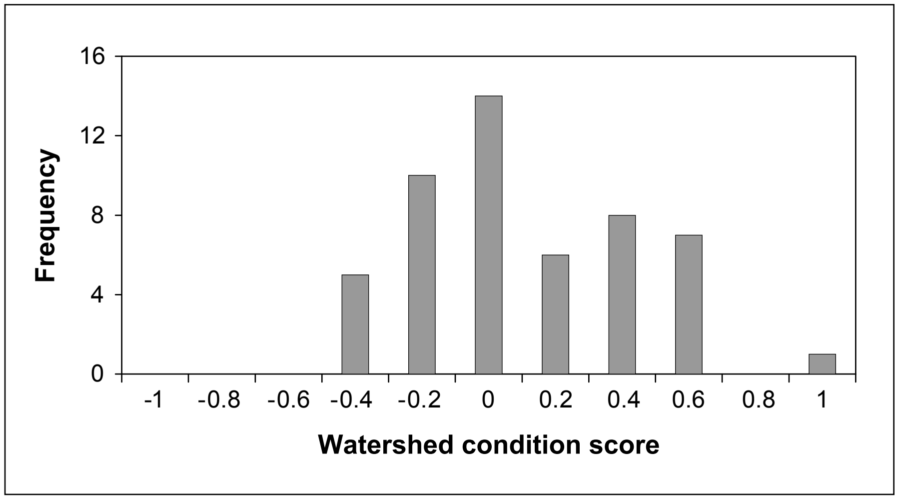


Figure 10—Distribution of watershed condition scores in time 2 for the 55 watersheds for which we have inchannel data. These condition scores are the aggregate of the evaluation scores for roads, vegetation, and inchannel physical and chemical attributes.

Roads—

The density of riparian roads in the 250 randomly selected watersheds ranges from 0 to 0.41 mi of road per mile of stream. The evaluation criteria for most of the provinces rate 0 mi of road in watersheds as good condition with respect to riparian roads and 0.1 mi of road per mile of stream as poor condition. In other words, watersheds that have roads next to 10 percent or more of the stream channel (as identified by the 1:24,000 densified stream layer) are in poor condition with respect to roads. The median riparian road density was 0.15 mi of road per mile of stream (fig. 17). Nearly 4 percent of the watersheds have no riparian roads. More than two-thirds of the 250 watersheds had riparian road densities greater than 0.1 mi of road per mile of stream.

The frequency of road-stream crossings in the 250 randomly selected watersheds ranges from 0 to 4.2 crossings per mile of stream. The evaluation criteria for most of the provinces rate watersheds with no road-stream crossings as good condition and watersheds with one to three crossings per mile of stream (depending on the province) as poor condition. Just over 4 percent of the watersheds contain no road-stream crossings (fig. 17). Nearly 53 percent of the watersheds have more than one crossing per mile of stream, and 15 percent have more than two crossings per mile of stream. In these watersheds, roads cross streams about once every half mile. Less than 1 percent of the watersheds have at least three crossings per mile of stream.

Vegetation—

When evaluating riparian vegetation, we looked for the percentage of the riparian area that has conifers of >20 in diameter at breast height (d.b.h.). In the 250 randomly selected watersheds, the riparian area with large trees ranges from 0 to 93 percent. The evaluation criteria for most of the provinces rate watersheds with large conifers in at least 50 percent of the riparian area as good condition with respect to riparian vegetation, and watersheds with only 30 percent as poor condition. The median value for percentage of riparian area with large conifers is 40 percent (fig. 17). Nearly 38 percent of the 250 randomly selected watersheds have large conifers in at least 50 percent of the riparian area. Twenty-nine percent of the watersheds have large conifers in less than 30 percent of the riparian area.

Inchannel—

Reach condition scores, which are aggregates of the inchannel attributes including wood, pools, and substrate, ranged from -0.9 to 1.0. Reach condition scores tended to be fairly high; fewer than 15 percent of the 281 reaches sampled had condition scores less than 0, which is the center point of the possible range of condition scores (fig. 18). The median reach condition score was 0.4 and about 75 percent of the reach condition scores fell in the 0 to 0.6 portion of the range.

The inchannel habitat variables had fairly high scores overall. Many of the sampled reaches had high condition scores with respect to pools (fig. 19a); nearly 75 percent of the reaches received a condition score of 1. Substrate condition scores were also generally high. Thirty-eight percent of the sample reaches had condition scores equal to +1 (fig. 19b), which suggests that these reaches had median particle sizes that were suitable for spawning habitat and low levels of fine sediment. In contrast, 12 percent of the sample reaches had condition scores equal to -1. These

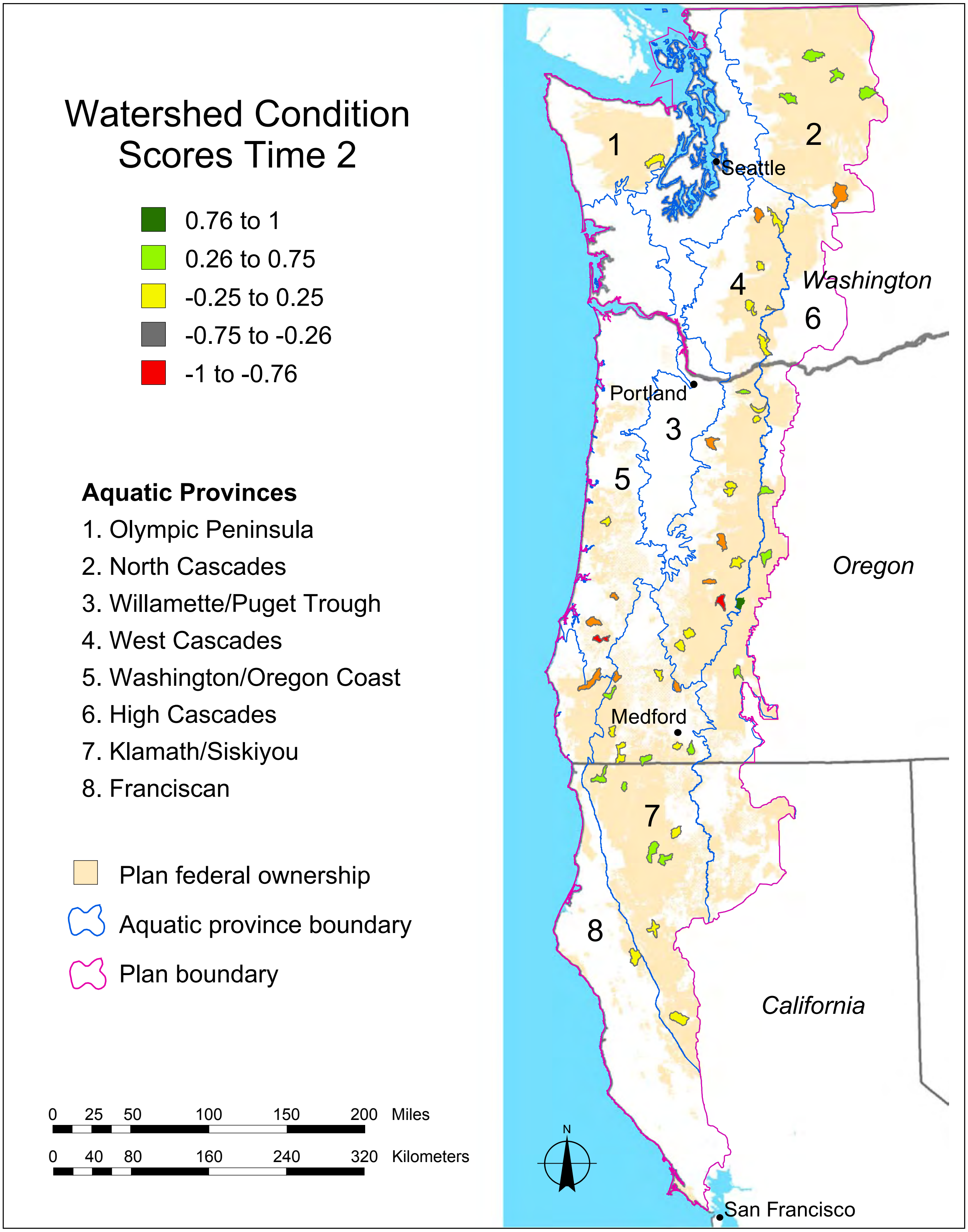


Figure 11—Time 2 watershed condition scores for 55 randomly selected watersheds in the Plan area that have been sampled as of 2003. The watershed condition scores are the aggregate of the evaluation scores for roads, vegetation, and inchannel physical and chemical attributes.

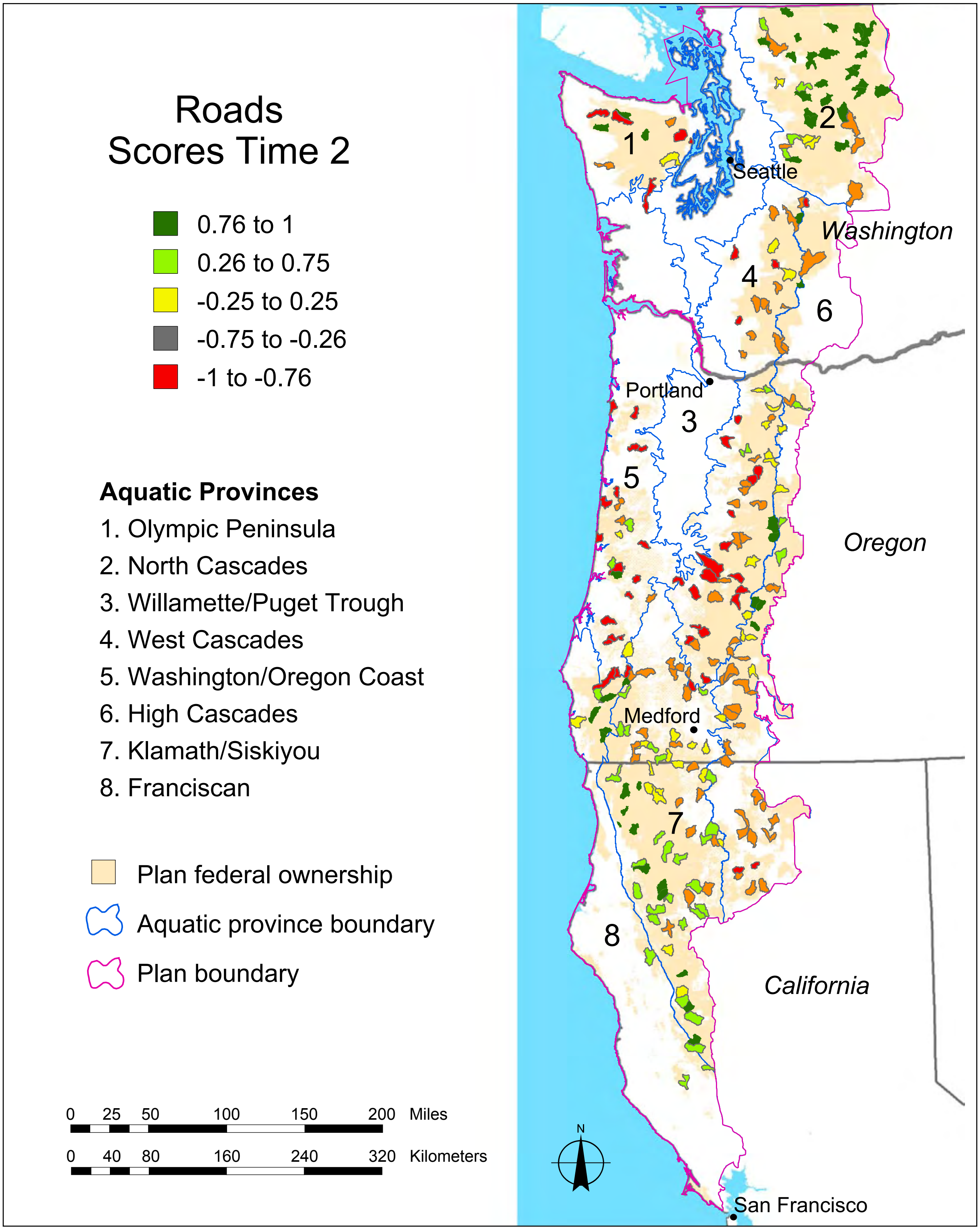


Figure 12—Time 2 road condition scores of 250 randomly selected watersheds in the Plan area. The road condition scores are the aggregate of the evaluation scores for all roads attributes, including density of roads in upslope, riparian, and hazard areas and frequency of road-stream crossings.

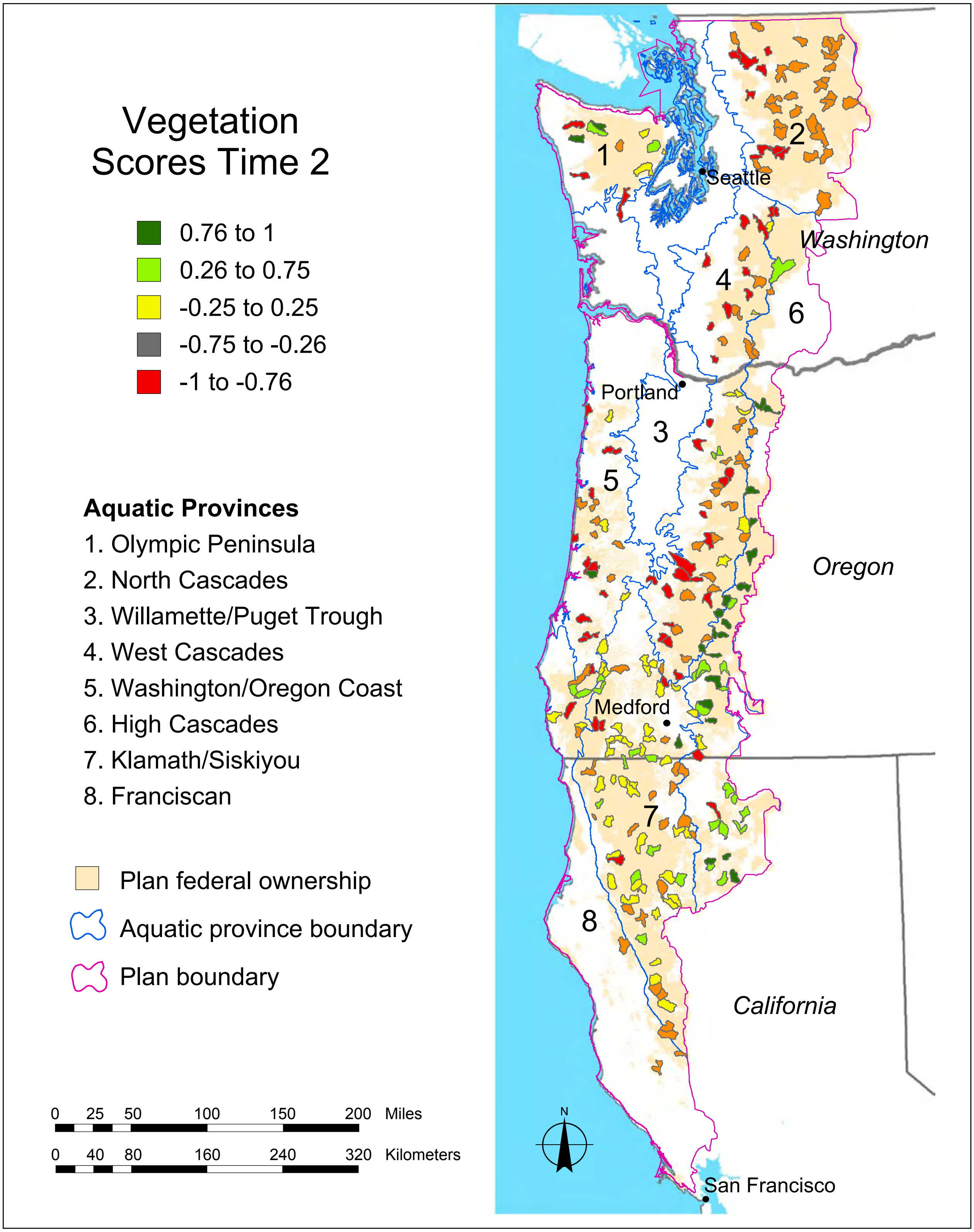


Figure 13—Time 2 vegetation condition scores of 250 randomly selected watersheds in the Plan area. The vegetation condition scores are the aggregate of the evaluation scores for all vegetation attributes, including percentage of cover of conifers greater than 20 in diameter at breast height (d.b.h.) in the riparian area and percentage of cover of conifers less than 10 in d.b.h. in the upslope area.

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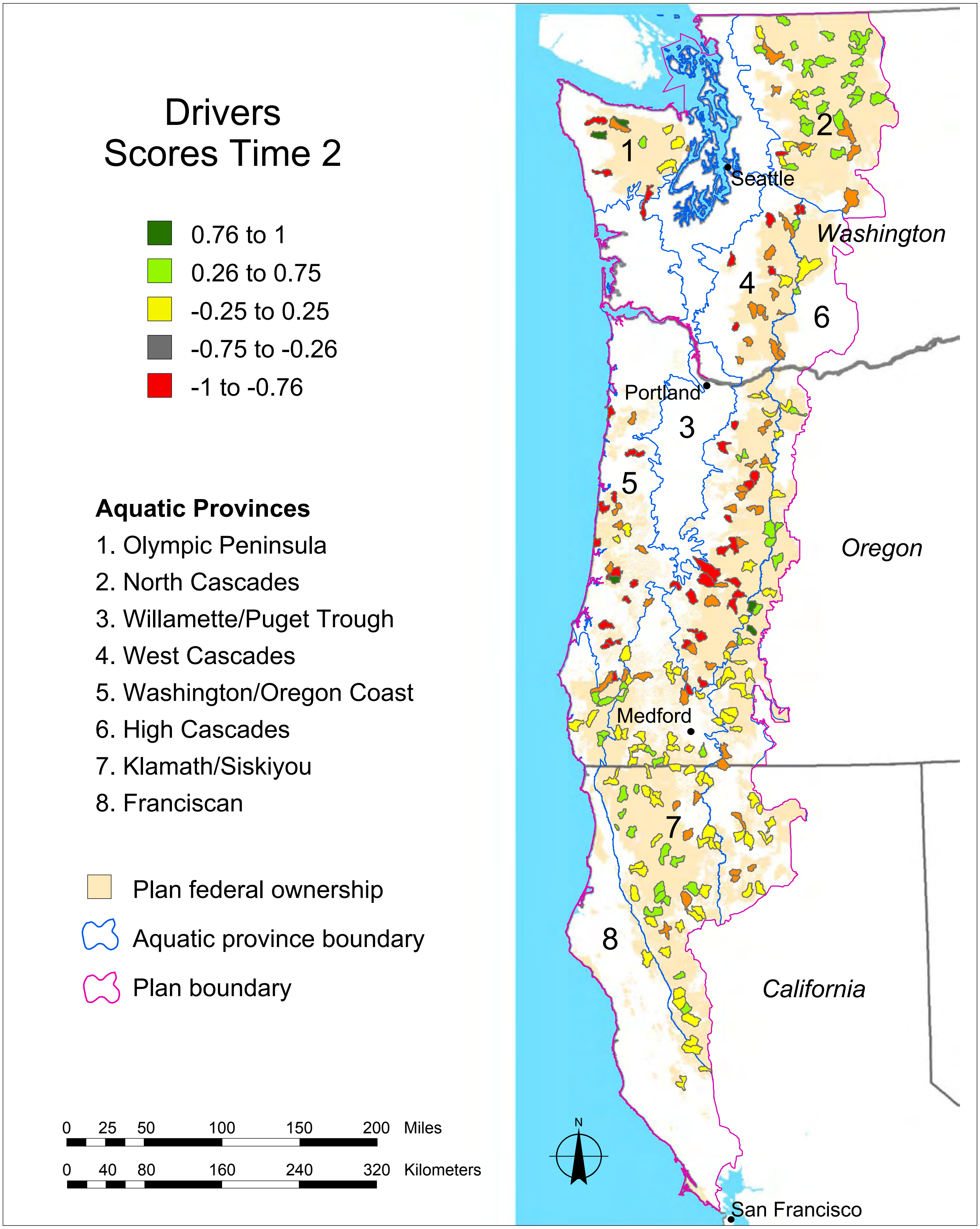
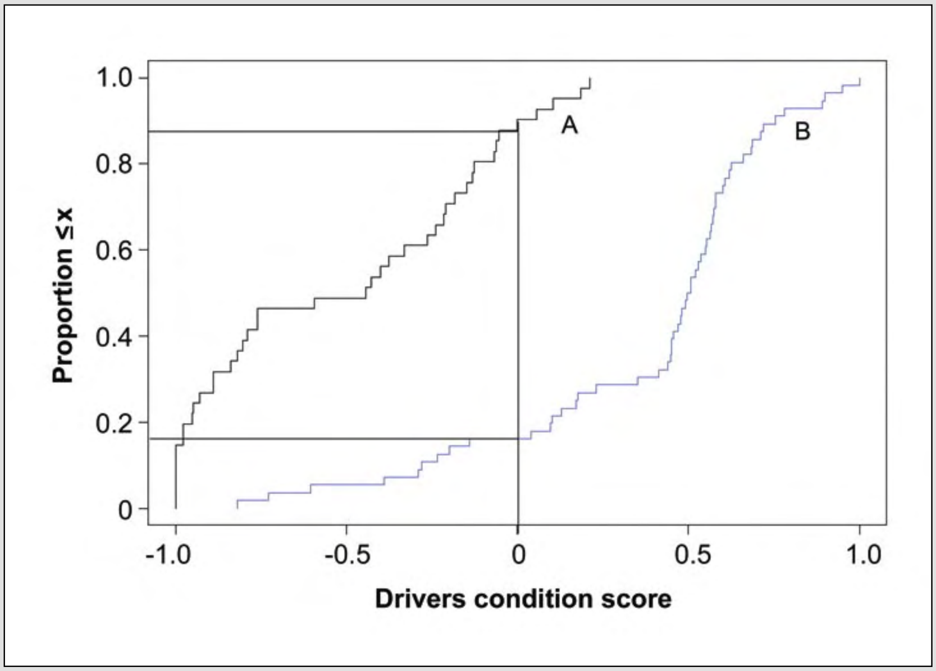


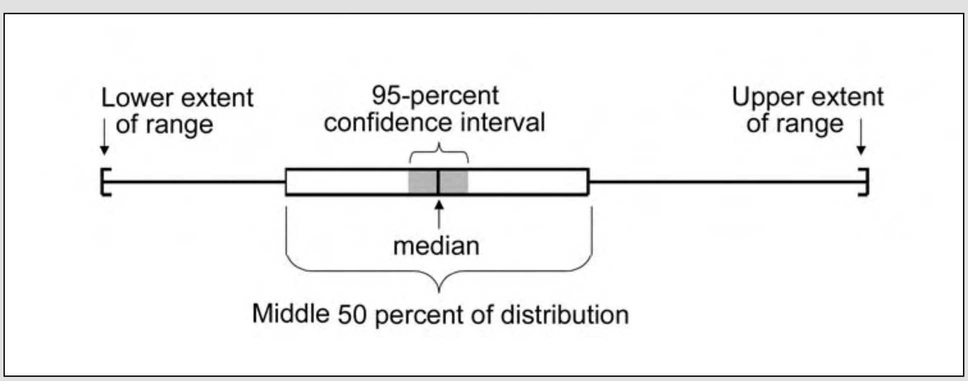
Figure 14—Time 2 drivers condition scores of 250 randomly selected watersheds in the Plan area. The drivers condition scores are the aggregate of the evaluation scores for the roads and vegetation attributes.

Distribution Functions



Cumulative distribution functions are used to describe and compare distributions, on a number of watersheds. The x-axis includes the range of the attribute of interest, which might be condition scores or acres of older forest vegetation in watersheds. The y-axis describes the proportion of units in the distribution (watersheds, in this example) with attribute values less than x. In the example below, we compare condition scores for two distributions, A and B. In this example, more than 80 percent of the watersheds in distribution A have condition scores less than 0. In distribution B, fewer than 20 percent of the watersheds have condition scores less than 0. The shape of the curves is key in interpreting cumulative distribution functions. Notice that the lower part of curve B is relatively flat, but the upper portion becomes very steep. The flat portion of the graph represents few watersheds, whereas the steep portion of the graph represents many watersheds with similar scores. Curve B shows that roughly 60 percent of the watersheds have condition scores between 0.5 and 0.7.

Box and whisker plots also describe distributions. In this example, the box represents the middle 50 percent of the distribution. The line inside the box represents the median of the distribution, and the shaded area describes the 95 percent confidence interval around the median. The whiskers on the plot represent the range of the distribution.



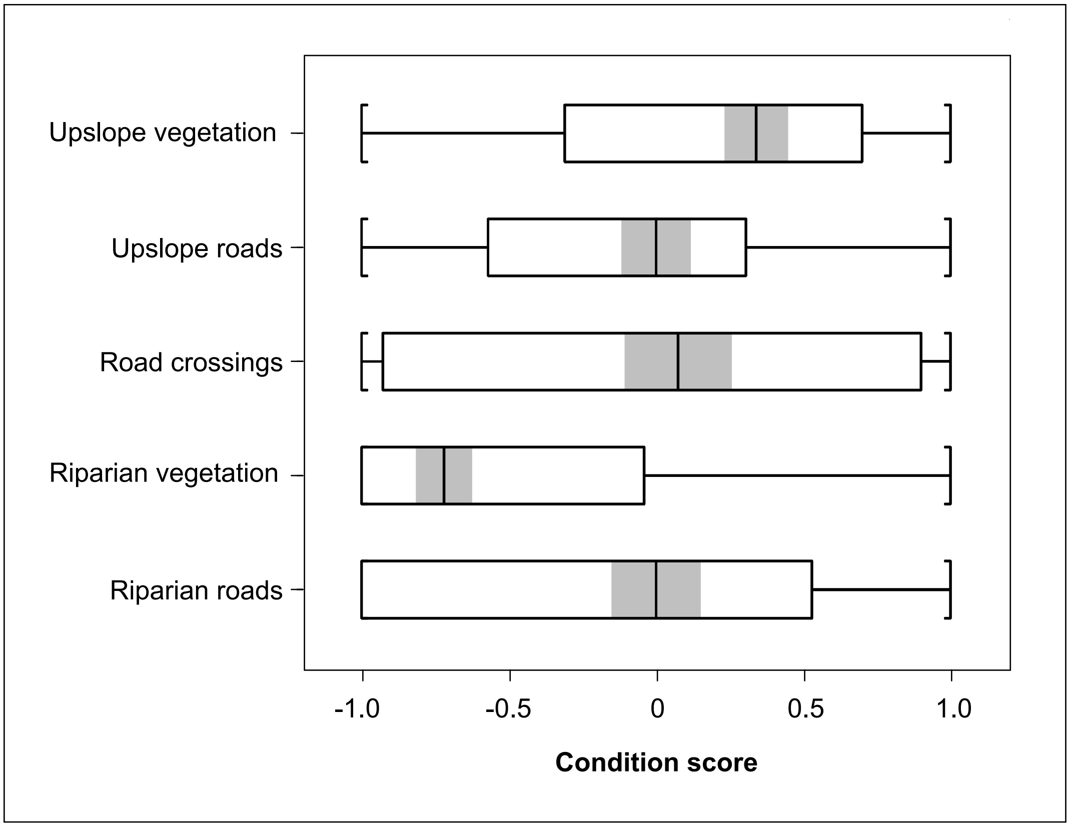


Figure 15—Distribution of time 2 condition scores for upslope and riparian roads and vegetation attributes in 250 randomly selected watersheds in the Plan area. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

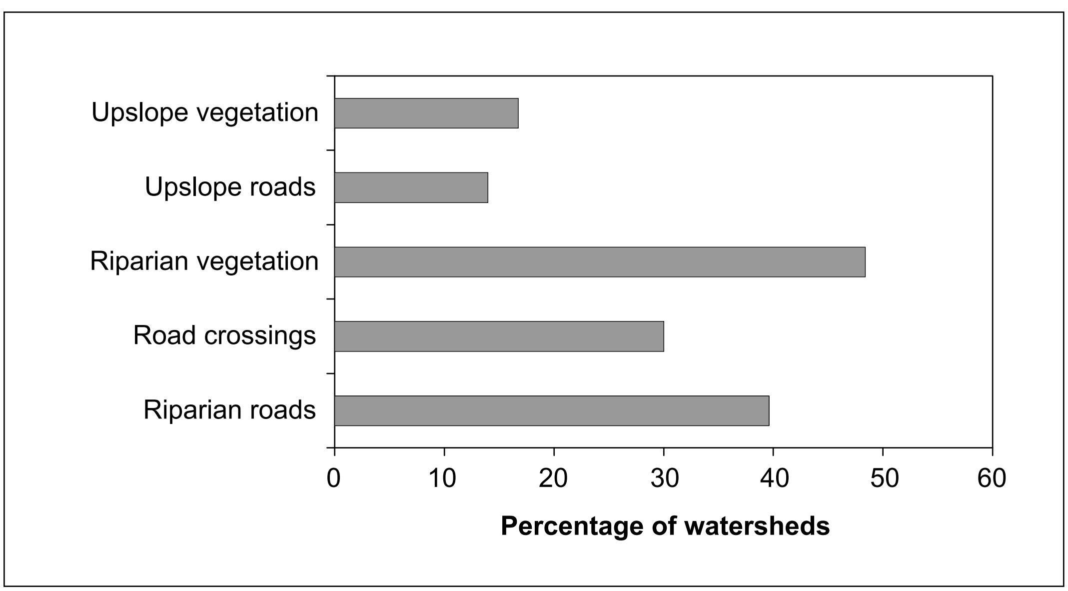


Figure 16—Percentage of watersheds with condition scores lower than -0.75 for upslope and riparian attributes. Data are based on the 250 randomly selected watersheds in the Plan area.

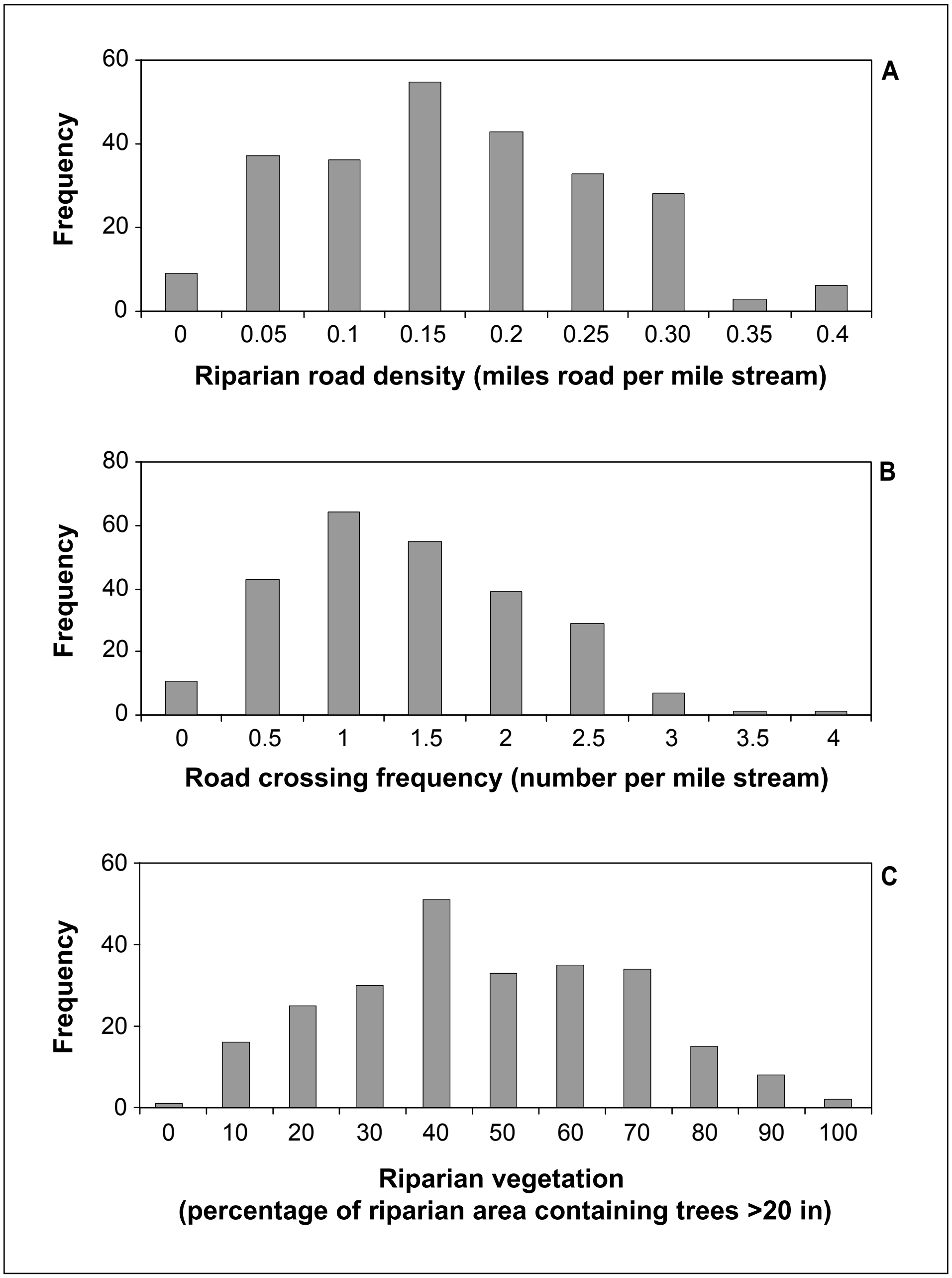


Figure 17—Frequency distribution of time 2 (A) riparian road density, (B) frequency of road-stream crossings, and (C) percentage of the riparian area with conifers >20 in diameter at breast height (d.b.h.) in the 250 randomly selected watersheds in the Northwest Forest Plan area.

reaches either had high levels of fine sediment or were scoured down to bedrock. Wood condition scores tended to be very low (fig. 19c), nearly 70 percent of the sample reaches had scores of -1, suggesting that low levels of large wood are prevalent throughout the Plan area.

The attributes used to evaluate substrate include D_{50} (median particle size) based on pebble measurements and the percentage of fine (<2 mm [<0.08 in]) sediments in pool tail crests. The evaluation criteria for D_{50} typically rate 60 to 100 mm (2.36 to 3.94 in) as desirable. Nearly 20 percent of the sampled reaches had D_{50} values in this range (fig. 20a). Median D_{50} scores were 200 mm (8 in). Fine sediment levels below 11 percent were considered desirable. Nearly 64 percent of the sampled reaches met this criterion (fig. 20b). Sixty percent of the sampled reaches had more than two pools per 100 m (109 yd) (fig. 21a). Wood levels tended to be very low; nearly half the sampled reaches did not contain any large wood (fig. 21b).

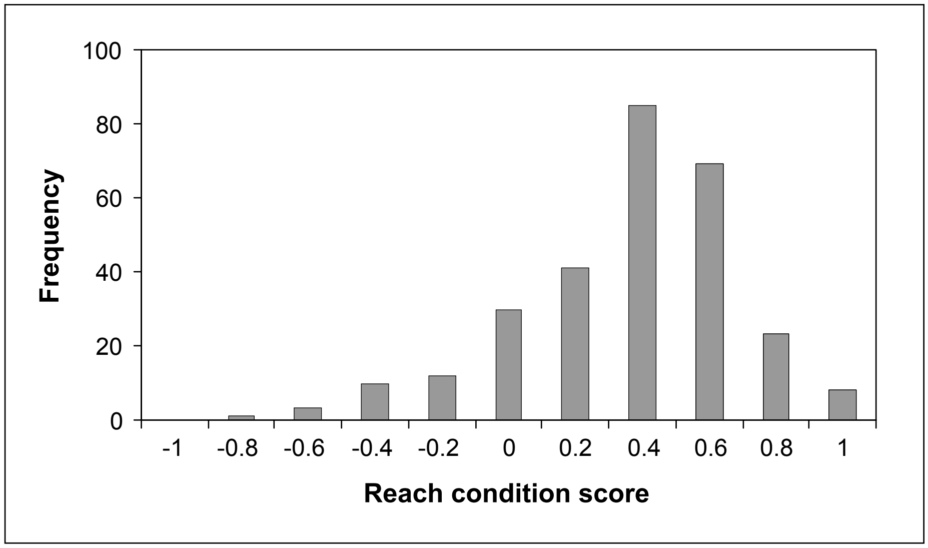


Figure 18—Frequency distribution of condition scores for 281 reaches in 55 watersheds in the Northwest Forest Plan area. Reach condition scores are aggregates of all inchannel attributes, including morphology, wood and pool frequency, and substrate.

Changes Since the Implementation of the Plan

Because historical inchannel data are lacking, change data were presented only for roads, vegetation, and drivers (the aggregate of all roads and vegetation attributes). Unlike the watershed condition scores—which were clustered between -0.4 and 0.6—condition scores for drivers, vegetation, and roads were distributed across the range of possible scores (fig. 22). Condition scores were generally higher in time 2 than in time 1; however, the magnitude of change was very small. The drivers condition score increased in 161 of the 250 watersheds (64 percent) by an average of 0.09 (SD 0.19; table 4). This level of change represents a significantly higher percentage of watersheds than would be expected if the changes were random ($Z = 6.25$, $p < 0.01$). Of the remaining watersheds, 18 (7 percent) had drivers condition scores that were the same in time 1 and time 2, and 71 (28 percent) had scores that were lower in time 2 (table 4). The average decrease in condition scores for those 71 watersheds was 0.14 (SD 0.3). The overall net change in drivers condition score across all 250 watersheds was 0.02 (SD 0.1).

Most of the watersheds changed little during the last 10 years; however, 7 of the 250 watersheds had drivers condition scores that changed by more than 0.2 from time 1 to time 2. Wildfires that burned 31 to 55 percent of the watershed area explain the decrease in drivers score in four of the seven watersheds. The remaining three watersheds had higher condition scores in time 2. Each of these watersheds was the target of road decommissioning. A total of 16 mi of road was decommissioned in one watershed, more than half of which was in the riparian zone. A reduction in the number of road-stream crossings, which were also evaluated in the decision-support models, often accompanies decommissioning of riparian roads. In this case, 34 road-stream crossings were removed. In another watershed, just over 9 mi of road was decommissioned, of which 3 mi was in hazard areas (i.e., prone to failure) and 4.6 mi was in the riparian zone. Fifty road-stream crossings were removed. Nine miles of road was decommissioned in the last watershed, which resulted in the removal of 3 mi of road in the riparian area and 41 road-stream crossings.

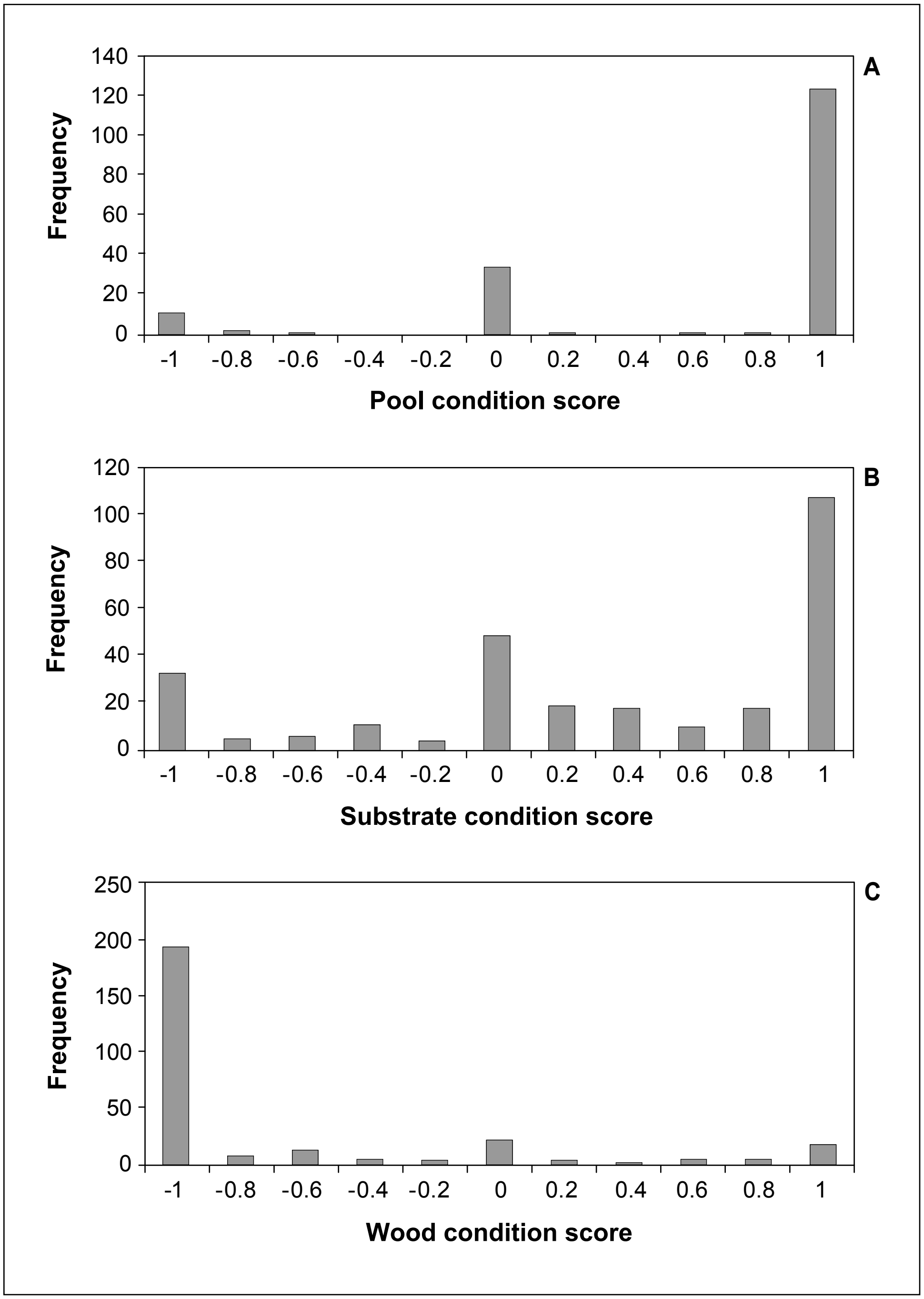


Figure 19—Frequency distribution of the time 2 inchannel attribute condition scores including (A) pools, (B) substrate, and (C) large wood. Graphs are based on 281 sample reaches in 55 watersheds in the Northwest Forest Plan area.

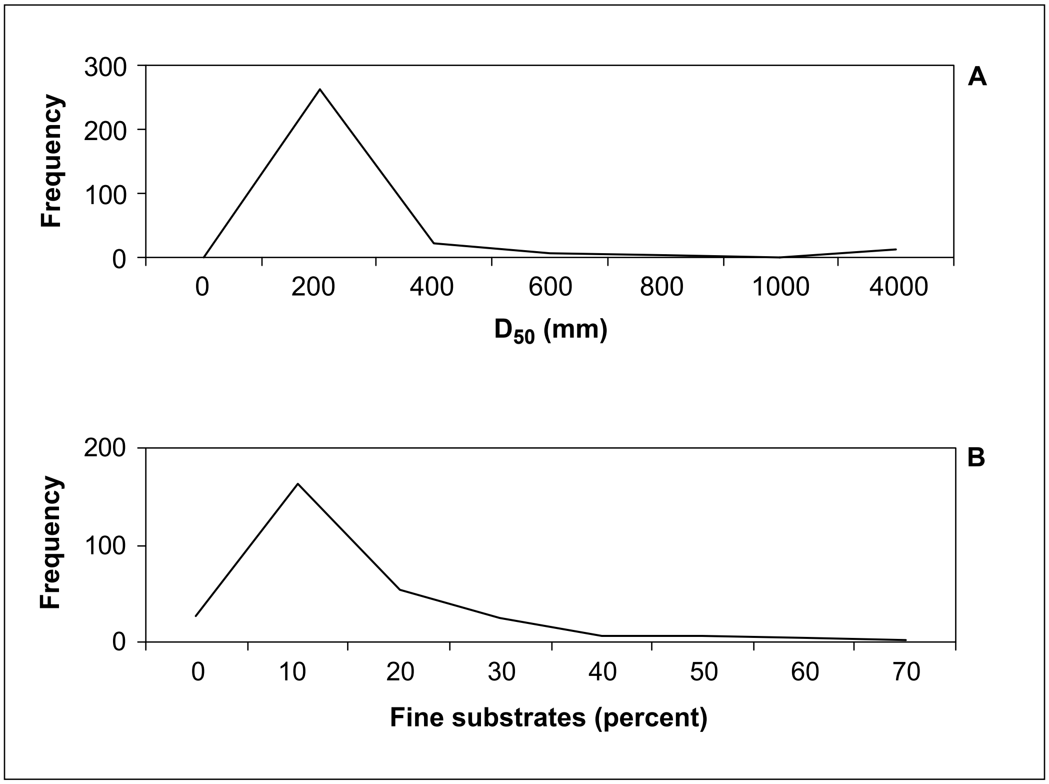


Figure 20—Frequency distribution of time 2 substrate (A) D_{50} and (B) percentage of fine sediment in pool tail crests in 281 sample reaches in 55 watersheds in the Plan area.

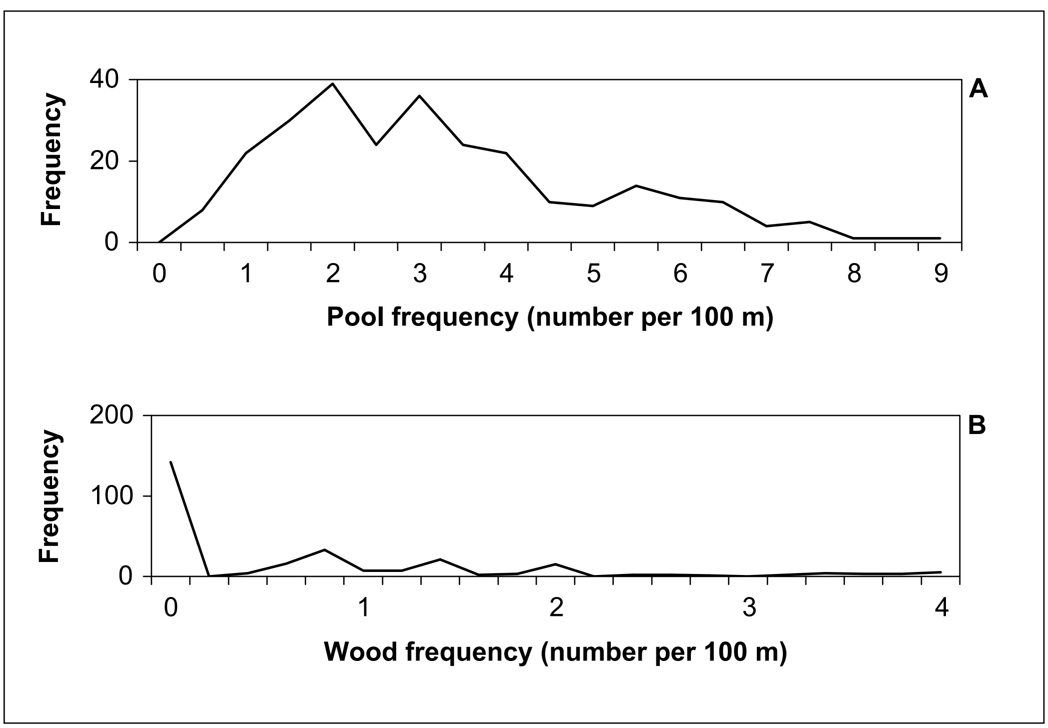


Figure 21—Frequency distribution of time 2 (A) pool frequency and (B) wood frequency in 281 sample reaches in 55 watersheds in the Northwest Forest Plan area.

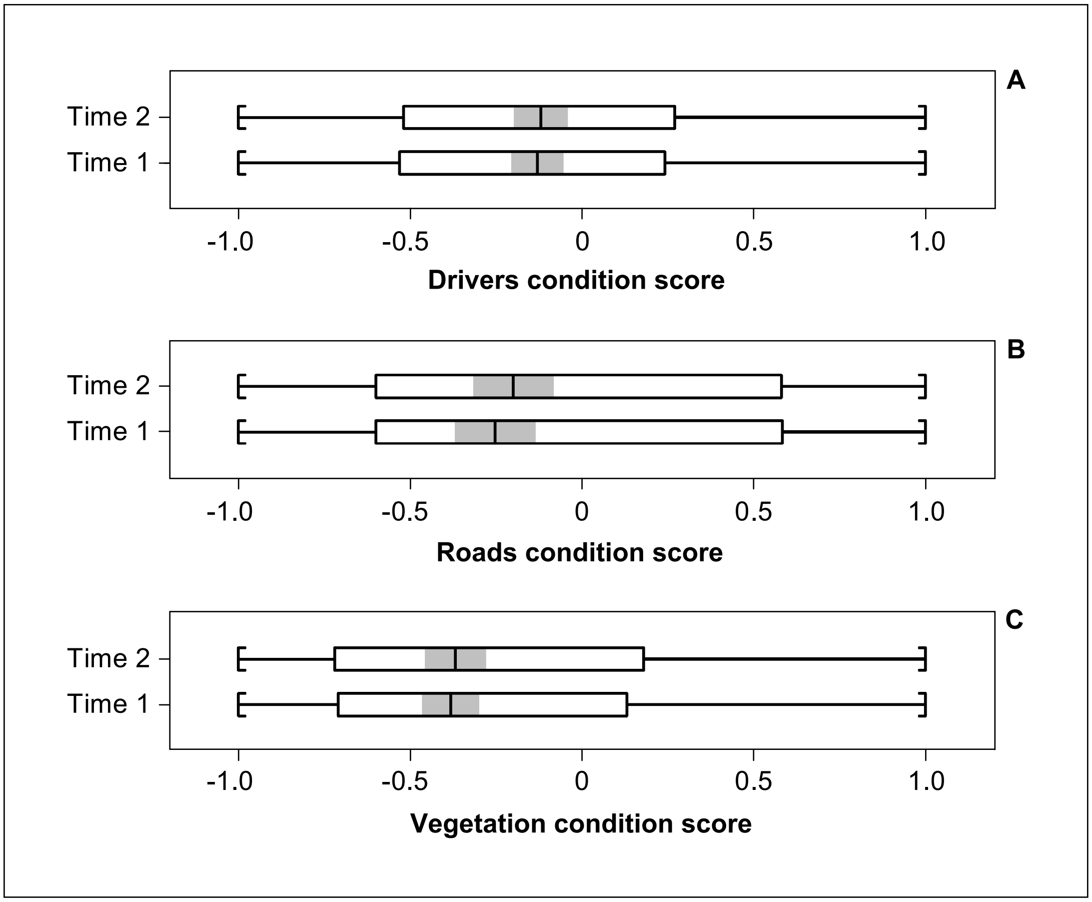


Figure 22—Distribution of evaluation scores for the drivers (the aggregate of roads and vegetation attributes), roads, and vegetation, for 250 randomly selected watersheds in the Northwest Forest Plan area. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

Roads—

In the road condition assessment, about 33 percent of the watersheds had scores that were at least 0.1 higher in time 2, and the remainder of the watersheds did not change (table 4). None of the watersheds decreased in condition by more than 0.1. The net decrease in road miles on federal lands was about 4,300 mi, out of about 91,000 mi of road that existed in 1994 (Baker et al. in press). The effort was spread out across the Plan area; consequently, the miles of roads in the 250 watersheds changed very little (fig. 23). Road building and decommissioning are the only factors that affected road condition in this assessment. We did not account for the 3,085 mi of road improvements made by federal agencies since the Plan was implemented.

Vegetation—

The small changes in the drivers scores were largely owing to higher vegetation scores in the watersheds. Vegetation condition scores were a minimum of 0.1 higher in about 55 percent of the watersheds (table 4). Assessments of vegetation depended largely on the presence of large conifers (typically greater than 20 in d.b.h.). Large trees in riparian areas were usually weighted more heavily than upslope vegetation in the decision-process models. Net tree growth and mortality from stand-replacing fire and harvest were the only factors that affected the change in vegetation in this evaluation. Two to four percent of the trees moved from a size class less than 20 in d.b.h. to greater than 20 in across the Plan area since 1994. Stand-replacing harvest in watersheds on federal

Table 4—Change in drivers, roads, and vegetation condition scores since the Northwest Forest Plan was implemented[a]

		Change[b]										
	N	**-0.5**	**-0.4**	**-0.3**	**-0.2**	**-0.1**	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**
							Percent					
Plan	250											
Drivers		1.6	0	0	0	1.6	39.6	49.2	6.8	0.4	0.4	0
Roads		0	0	0	0	0	66.0	29.2	3.2	0.8	0	0.4
Vegetation		1.6	0	0.8	0.4	1.2	40.8	33.6	13.6	8.0	0	0
Key	88											
Drivers		2.3	0	0	0	0	23.9	61.4	10.2	1.1	1.1	0
Roads		0	0	0	0	0	58.0	34.1	4.5	2.3	0	1.1
Vegetation		2.3	0	0	0	1.1	29.5	33.0	21.6	12.5	0	0
Non-key	162											
Drivers		1.2	0	0	0	2.5	47.5	42.6	4.9	0	0	0
Roads		0	0	0	0	0	69.8	26.5	2.5	0	0	0
Vegetation		1.2	0	1.2	0.6	1.2	46.3	34.0	9.3	5.6	0	0
AMA	18											
Drivers		0	0	0	0	0	27.8	66.7	5.6	0	0	0
Roads		0	0	0	0	0	61.1	38.9	0	0	0	0
Vegetation		0	0	0	0	0	27.8	55.6	11.1	5.6	0	0
CR	62											
Drivers		0	0	0	0	3.2	37.1	51.6	3.2	1.6	0	0
Roads		0	0	0	0	0	75.8	19.4	0	1.6	0	0
Vegetation		0	0	1.6	0	1.6	30.6	38.7	12.9	11.3	0	0
LSR	63											
Drivers		6.3	0	0	0	1.6	14.3	68.3	7.9	0	1.6	0
Roads		0	0	0	0	0	52.4	41.3	4.8	0	0	1.6
Vegetation		6.3	0	1.6	0	0	20.6	39.7	22.2	9.5	0	0
Matrix	41											
Drivers		0	0	0	0	0	43.9	39.0	14.6	0	0	0
Roads		0	0	0	0	0	65.9	17.1	12.2	2.4	0	0
Vegetation		0	0	0	0	0	48.8	31.7	12.2	7.3	0	0
Nonfederal	45											
Drivers		0	0	0	0	0	66.7	31.1	2.2	0	0	0
Roads		0	0	0	0	0	64.4	35.6	0	0	0	0
Vegetation		0	0	0	0	0	73.3	20	4.4	2.2	0	0

[a] Values are the percentage of watersheds in each category. Data are provided for the entire Northwest Forest Plan area (Plan), key watersheds (Key), non-key watersheds (Non-key), adaptive management areas (AMA), congressional reserves (CR), late-successional reserves (LSR), matrix, and nonfederal lands. N is the number of watersheds in each land use allocation.

[b] Change categories reflect the magnitude and direction of change. Positive values indicate that scores were higher in time 2 than in time 1, and negative values indicate that scores were lower in time 2. Category values represent the top of the range (i.e., 0.4 includes the range from 0.31 to 0.4).

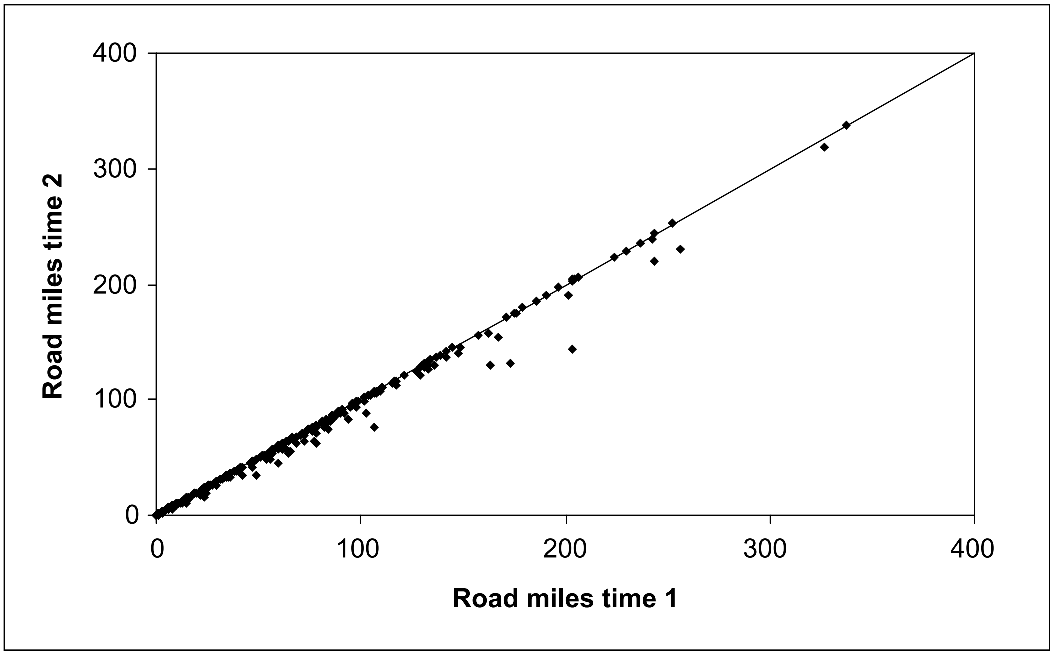


Figure 23—Total road miles in time 1 and time 2. Data points on the line indicate that the total miles of road in the watershed did not change in the last 10 years. Points below the line represent watersheds that have fewer miles of roads in time 2 than in time 1.

lands in Oregon and Washington has decreased to about 15 percent of the 1991 level (fig. 24). Historical harvest data were not available for California. Harvest on nonfederal lands has changed very little since 1972. Although the area harvested in riparian areas has decreased since the implementation of the Plan, riparian harvest as a portion of total harvest has remained fairly constant since 1972, with an average of 25 percent of total harvest in riparian areas of federal lands (range 17 to 35 percent over the time periods) and an average of 30 percent riparian harvest on nonfederal lands (range 23 to 36 percent). Riparian area was defined by using the same buffer width as used for the riparian vegetation evaluation in the decision-support model.

Change in roads and vegetation attributes were also examined relative to their location in the watershed (upslope or riparian area). Shifts in the medians of the distributions were very small for all of the upslope (fig. 25) and riparian (fig. 26) attributes. On average, twice as many roads were decommissioned in upslope areas as in riparian areas (table 5).

Key Watersheds

Key watersheds are one of the primary components of the strategy (fig. 27). They provide high-quality habitat to aquatic and riparian organisms or have the potential to do so. Key watersheds were identified by the strategy independent of the land use allocations in the Plan, thus key and non-key watershed designations do not mutually exclude the other land use allocations. Of the 250 watersheds, 88 have >50 percent of the area designated as key watershed. The remaining 162 watersheds are considered as non-key in this assessment.

Current Status

Roads—

Currently, key watersheds tend to be in better condition overall than non-key watersheds with respect to roads. The range of riparian road densities extends from 0 to about 0.4 mi of road per mile of stream for both key and non-key watersheds. However, riparian road densities generally tend to be lower in key watersheds. Nearly half of the key watersheds have riparian road densities lower than 0.1 mi

Cummins and Tenmile Watersheds, Siuslaw National Forest, Oregon

Restoring a free-flowing coastal river—

A large-scale watershed restoration effort was implemented by the USDA Forest Service, Oregon Department of Fish and Wildlife, National Audubon Society, and a partnership of landowners, environmental groups, watershed councils, and local government agencies in the northwest Oregon coastal area of Cummins Creek and Tenmile Creek during 1994 to 2002 to begin restoring ecological processes altered by the last 150 years of human activities. Restoration activities included stabilizing and decommissioning 116 mi of roads, thinning plantations along 65 mi of streams to promote faster tree growth, planting 150 ac of riparian areas, and adding nearly 300 large wood pieces into 4.5 mi of stream. Activities were focused on areas with the greatest potential to restore watershed processes.

About 75 percent of the 55,000 ac in the Cummins and Tenmile Creek area are designated as key watersheds under the Plan because of existing and potential high-quality coho salmon (*Oncorhynchus kisutch*) habitat (a species listed under the Endangered Species Act). The area's 100 mi of fish-bearing streams also provide habitat for Chinook (*O. tshawytscha*), chum (*O. keta*), steelhead (*O. mykiss*), cutthroat (*O. clarki*), Pacific lamprey (*Lampetra tridentata*), western brook lamprey (*L. richardsoni*), sculpin (*Cottus* spp.), and eulachon (*Thaleichthys pacificus*).

Progress to date—

This successful restoration effort is helping to restore ecological processes, while providing immediate improvements to the watershed. For example, road decommissioning, building, and water-barring have stabilized 53 percent of the roads (63 percent of Forest Service roads).

- The area of deep pools with complex wood cover tripled after wood additions (project and natural) in Tenmile Creek.
- Overwinter survival of coho and steelhead has significantly increased in Tenmile Creek since large wood was added (project and natural) while the no-treatment control basin remained unchanged.
- Steelhead smolt production has doubled since large wood was added (project and natural) to Tenmile Creek.

Jack Sleeper

Jack Sleeper

This valley bottom road was removed to restore valuable riparian and flood-plain processes. Riparian areas on the temperate Oregon coast are highly productive, and streamside vegetation will be quick to recover. Contact Jack Sleeper (jsleeper@fs.fed.us) for more information.

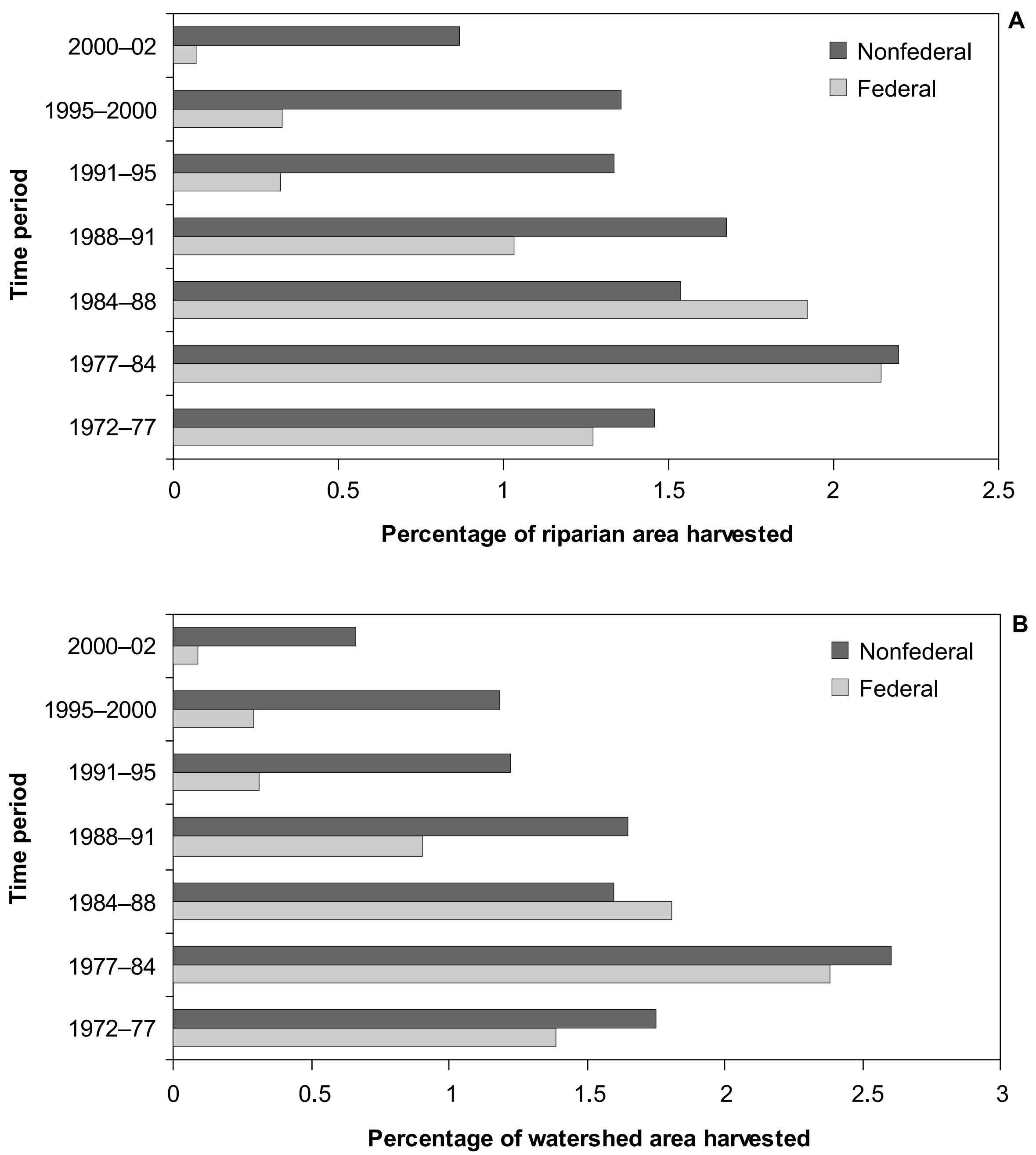


Figure 24—Percentage of (A) riparian area harvested and (B) watershed area harvested on federal and nonfederal lands in various periods ranging from 1972 to 2002. Bars represent the mean across 189 of 250 randomly selected watersheds in Oregon and Washington (the remaining 61 watersheds were not harvested during these periods). Harvest is defined as stand-replacing harvest, such as regeneration harvest.

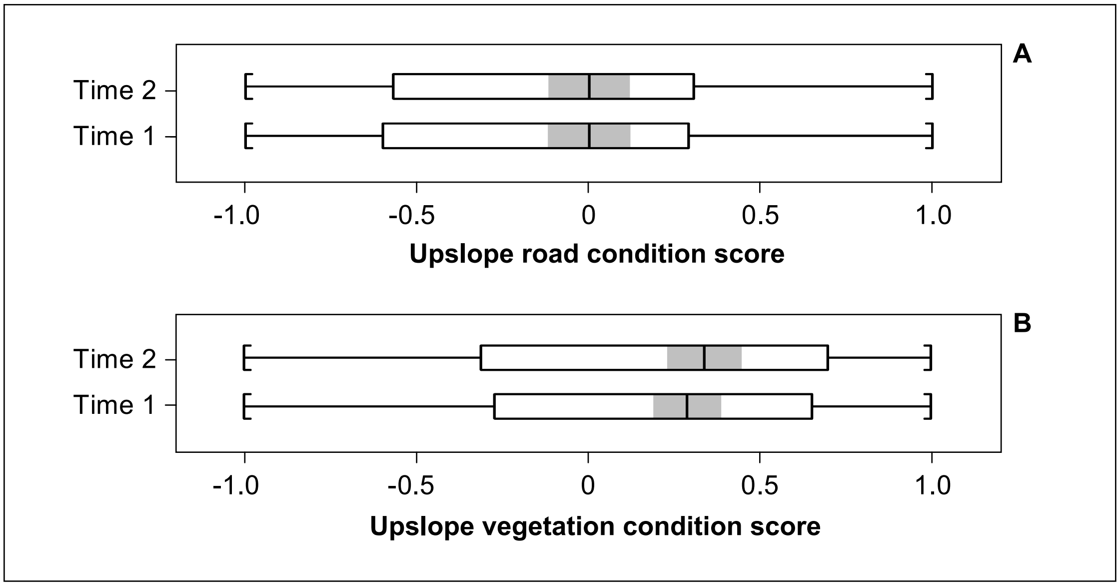


Figure 25—Distribution of time 1 and time 2 condition scores for upslope roads and upslope vegetation for 250 watersheds in the Northwest Forest Plan area. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

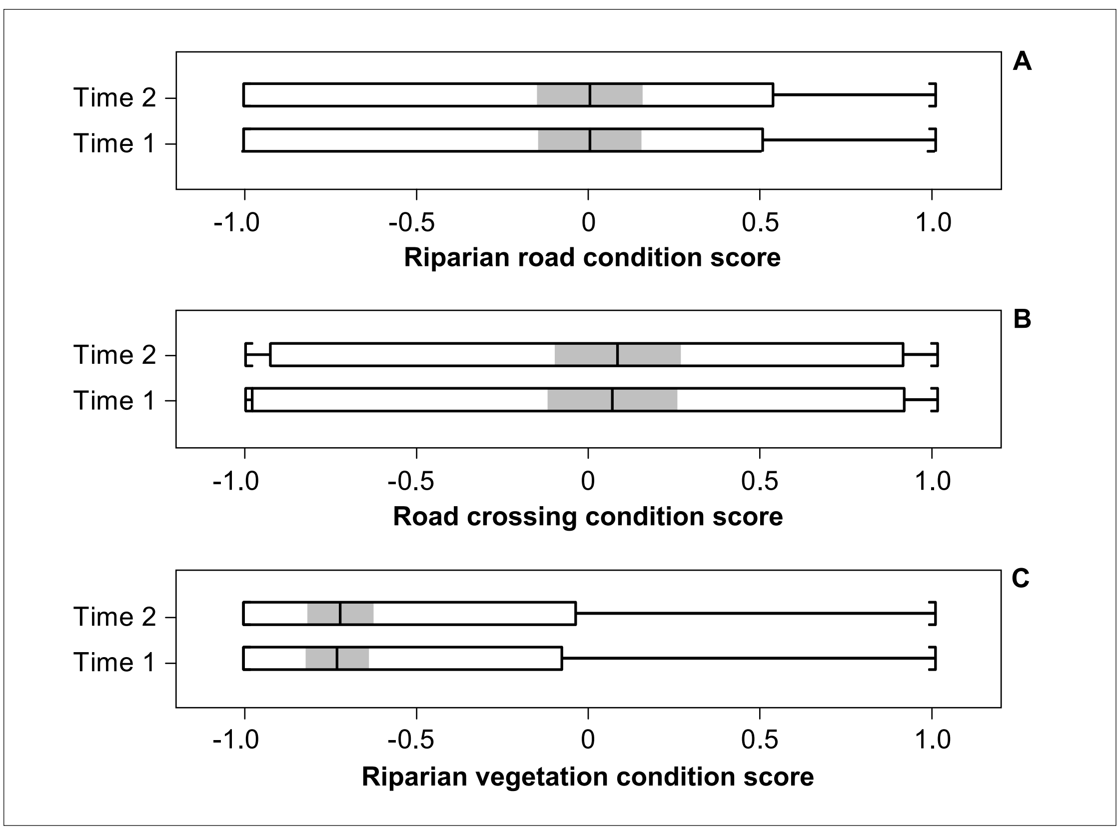


Figure 26—Distribution of time 1 and time 2 condition scores for riparian roads, road-stream crossings, and riparian vegetation for 250 watersheds in the Northwest Forest Plan area. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

Table 5—Average number of road miles decommissioned in upslope and riparian areas in the Plan area and in each land use allocation[a]

Land use allocation	Number	Riparian Average	Riparian SD	Upslope Average	Upslope SD	Total
		Miles				
All	250	0.65	1.79	1.44	4.21	2.09
Key	88	0.96	1.71	2.00	4.30	2.97
Non-key	162	0.57	1.60	0.74	1.90	1.31
AMA	18	0.93	1.93	0.97	1.75	1.90
CR	56	0.23	0.84	0.53	2.01	0.76
LSR	64	0.83	1.53	1.80	3.51	2.64
Matrix	37	0.97	1.88	1.55	4.48	2.52
Nonfederal	41	0.89	2.26	1.20	2.94	2.08

[a] Data are presented for key watersheds, non-key watersheds, and watersheds in adaptive management areas (AMA), congressional reserves (CR), late-successional reserves (LSR), matrix, and watersheds that are predominantly nonfederal.

Kimberly Baker

Figure 27—Tier 1 key watersheds, such as Upper North Fork Coquille River shown here, contribute directly to conservation of at-risk anadromous salmonids, bull trout, and resident fish species. They also have the high potential of being restored as part of a watershed restoration program (USDA and USDI 1994).

of road per mile of stream, compared to 24 percent of non-key watersheds (fig. 28). Road-stream crossings also tend to be lower in key watersheds than in non-key watersheds. Just over 60 percent of key watersheds have road crossing frequency one or less crossing per mile of stream, compared with 40 percent of non-key watersheds (fig. 28).

Vegetation—
Key and non-key watersheds are comparable in condition with respect to riparian vegetation. Just over 20 percent of the key watersheds have <30 percent of the riparian area covered by conifers greater than 20 in d.b.h., compared with 33 percent of non-key watersheds (fig. 29).

Changes Since the Implementation of the Plan

Small shifts in the drivers, roads, or vegetation score distributions were detected in both key watersheds (fig. 30) and non-key watersheds (fig. 31). In general, conditions in key watersheds improved more than those in non-key watersheds. Drivers condition scores in 74 percent of key watersheds and 48 percent of non-key increased by at least 0.1 in time 2 (table 4). Fewer than 4 percent of the watershed declined by that amount in the last 10 years.

Roads—
Key watersheds had significantly higher drivers scores than non-key watersheds in time 2 (Wald F = 4.1, df = 3, 246, $p < 0.01$). The primary difference between key and non-key watersheds was attributed to roads. Not only did key watersheds have higher road condition scores than non-key watersheds at time 1 and time 2, more than twice the miles of roads were decommissioned in key watersheds than in non-key in the last 10 years (fig. 32, table 5). Road condition scores increased by more than 0.1 in 42 percent of key watersheds and 29 percent of non-key watersheds. None of the watersheds had declining road condition scores.

Vegetation—
Vegetation condition scores increased more in key watersheds; 34 percent of key watersheds had scores that were a minimum of 0.1 higher in time 2 than in time 1, compared with 15 percent of non-key watersheds (table 4). Vegetation rates declined by more than 0.1 in less than 4 percent of key and non-key watersheds. Harvest rates were historically lower in key watersheds than in non-key watersheds (fig. 33a). This trend continued after the Plan was implemented (fig. 33b). Harvest rates in key and non-key watersheds were similar for harvest areas less than 100 ac. However, harvests that were larger than 100 ac were found more frequently in non-key watersheds than in key watersheds. Of the

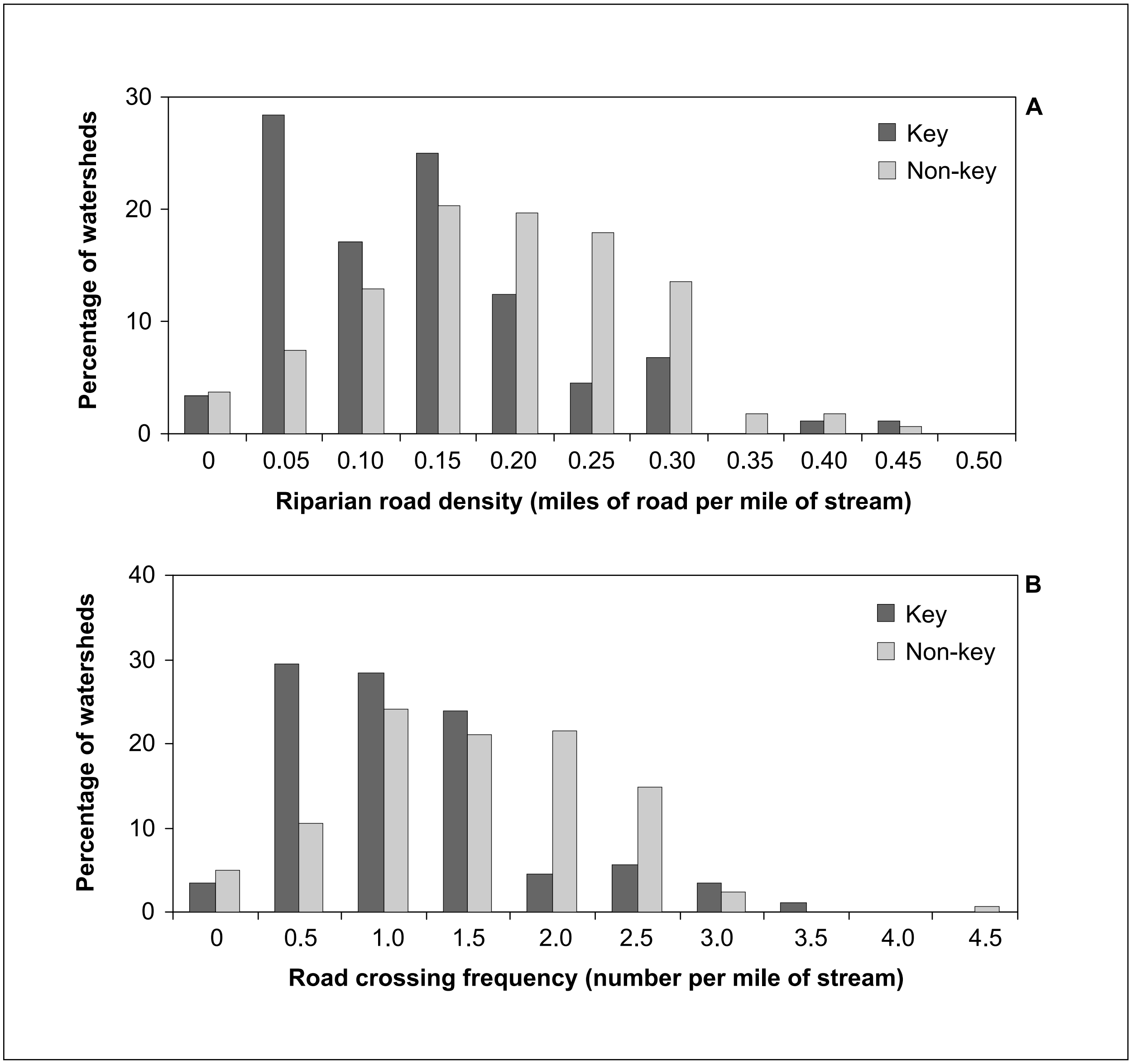


Figure 28—Frequency distribution of time 2 (A) riparian road density and (B) frequency of road crossings (b) in 88 key watersheds and 162 non-key watersheds. These watersheds represent a subset of the 250 randomly selected watersheds in the Northwest Forest Plan area.

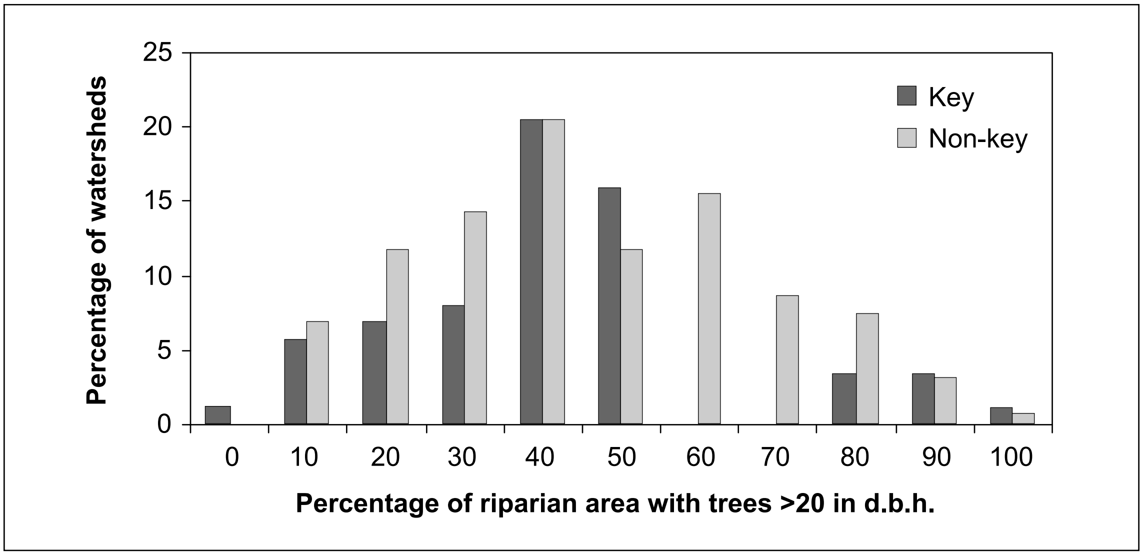


Figure 29—Frequency distribution of the percentage of riparian area with trees >20 in diameter at breast height (d.b.h.) in time 2 in 88 key watersheds and 162 non-key watersheds. These watersheds represent a subset of the 250 randomly selected watersheds in the Northwest Forest Plan area.

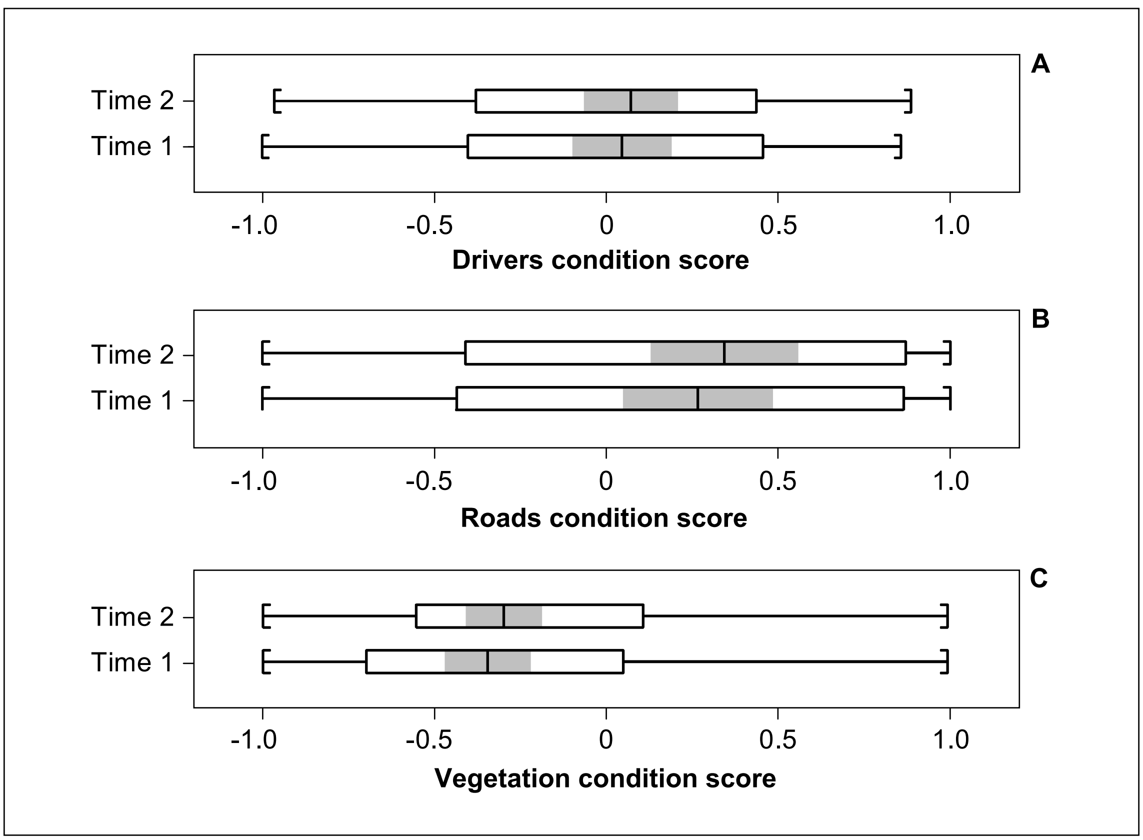


Figure 30—Distributions for (A) drivers, (B) roads, and (C) vegetation condition scores in key watersheds for time 1 and time 2. The distributions are based on 88 of the 250 randomly selected watersheds in the Northwest Forest Plan area that were designated as key watersheds in the aquatic conservation strategy. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

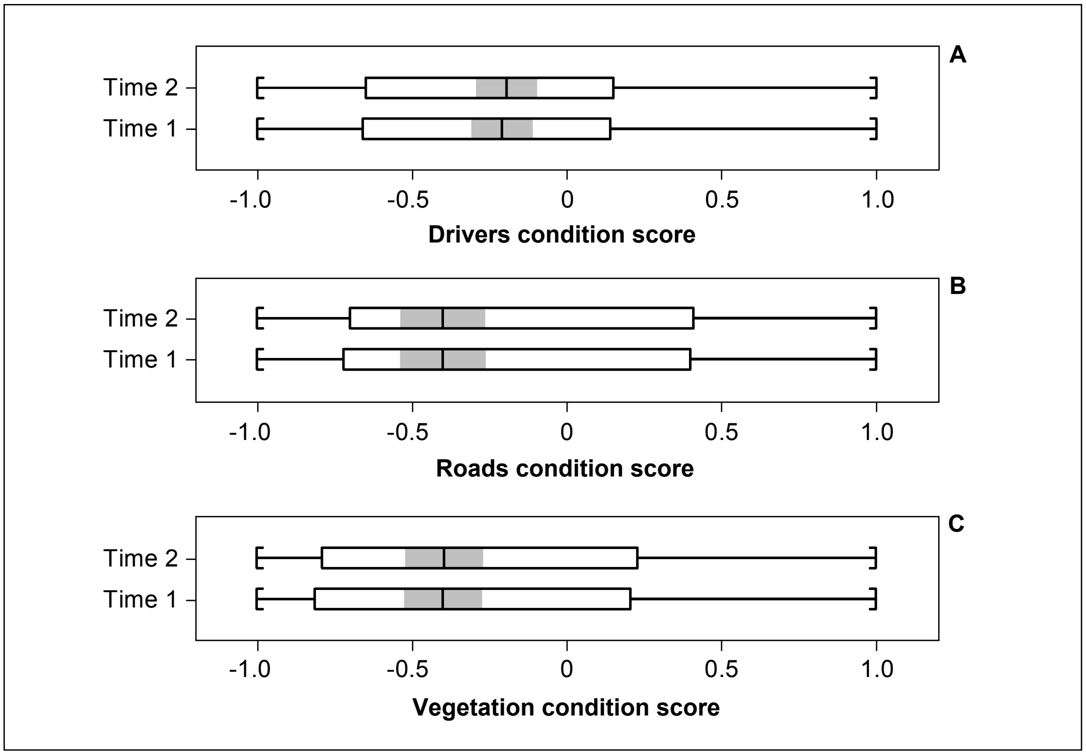


Figure 31—Distributions for (A) drivers, (B) roads, and (C) vegetation condition scores in non-key watersheds for time 1 and time 2. The distributions are based on 162 of the 250 randomly selected watersheds in the Northwest Forest Plan area that were not designated as key watersheds in the aquatic conservation strategy. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

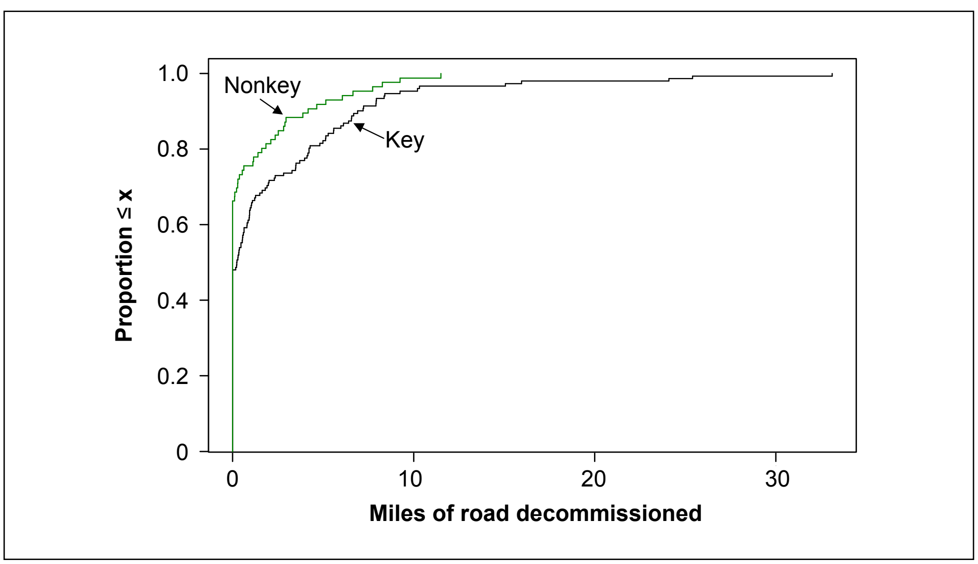


Figure 32—Cumulative frequency distribution of the miles of road decommissioned since the strategy was implemented in key and non-key watersheds. Distributions are based on 250 randomly selected watersheds in the Northwest Forest Plan area subset into key (n = 88 watersheds) and non-key watershed (n = 162 watersheds) designations. The y-axis values represent the proportion of watersheds with fewer road miles decommissioned than the x-axis value of interest.

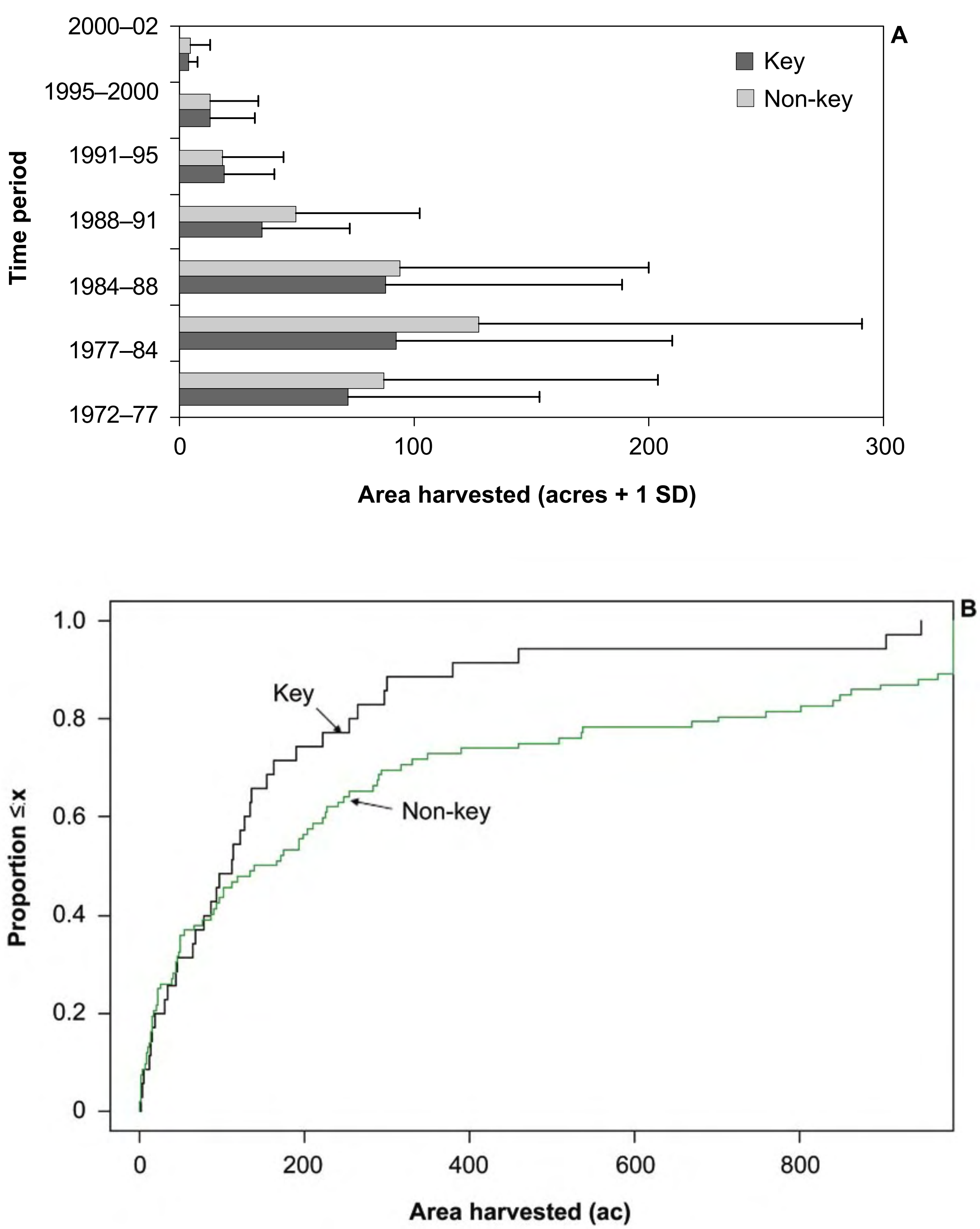
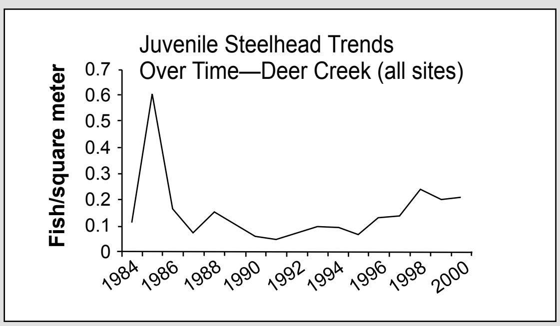


Figure 33—Average harvest in key and non-key watersheds based on 250 watersheds in the Northwest Forest Plan area. In panel A, columns represent average acres harvested during each period from 1972 to 2002. Panel B shows the cumulative distribution of acres harvested in individual watersheds since 1995. The y-axis values on the bottom panel represent the proportion of watersheds with fewer acres harvested than the x-axis value of interest.

Deer Creek, Mount Baker Snoqualmie National Forest, Washington

Road treatments help recover steelhead trout—The long-term goal of restoration efforts in Deer Creek, a tributary to the North Fork Stillaguamish River located in the North Cascades of Washington is the recovery of depressed native fish stocks, with a particular emphasis on summer-run steelhead (*Oncorhynchus mykiss*) trout. About two-thirds of the Deer Creek stream channel network is accessible by anadromous fish and has historically supported runs of steelhead trout, coho salmon (*O. kisutch*), and native char (*Salvelinus malma*). Deer Creek is a Tier 1 key watershed.

The focus of restoration efforts from 1985 to 1995 was to reduce the effects of 50 years of timber harvesting and road building throughout the watershed and to promote a return to the natural hydrologic and erosional regimes. Timber was harvested over the entire lower watershed and on one-third of the federal land in the upper watershed. One area of emphasis was to reduce the effects of coarse sediment input from roads to the downstream channel system.



Fish populations in Deer Creek have increased since 1995. The increase in juvenile fish densities is a reversal of a decade-long decline and is attributed, in part, to improvement of aquatic habitat during the past 5 years.

Progress to date—

- Coarse sediment input to the stream system was reduced by three types of road treatments completed during 1984–94: road storm-proofing, decommissioning, and road upgrading.
- Fifty-five out of sixty-eight mi of federal roads were treated. Despite five major flood events during 1984–2003, little or no major failure on treated roads was recorded.
- Bridges, larger or additional culverts, or hardened dipped crossings (concrete fords and open box culverts) were installed to replace ineffective culverts.
- Culverts were removed from inactive roads to restore the natural drainage.
- Water-bars were installed to intercept water and provide a controlled flow in a drainage ditch.
- Sidecast or settling road fill materials were removed to reduce the risk of mass wasting.

Jim Doyle

Jim Doyle

Twenty-one hardened road/channel crossing sites like these (the earliest was installed in 1985) survived four major floods. The amount and size of the bedload and woody debris deposited at the outlet of this box culvert would have plugged and overtopped a conventional circular culvert. This type of road failure was common in Deer Creek before the application of these flood-proofing structures. Contact Jim Doyle (jdoyle@fs.fed.us) for more information.

watersheds that were harvested, the average area harvested fell from just over 50 ac per watershed per year before the Plan was implemented to 6 ac per watershed per year in key watersheds and from just over 55 to 10 ac per watershed per year in non-key watersheds (table 6).

Adaptive Management Areas

Adaptive management areas were designated as testing grounds for new management approaches. Eighteen of the 250 randomly selected watersheds had greater than 50 percent of the area designated for adaptive management.

Current Status

Adaptive management areas had drivers condition scores that ranged from -1 to 0.3. Adaptive management areas appear to be in similar condition to most of the watersheds in other land use allocations identified in the Plan (fig. 34), with the exception of congressional reserves, which tend to be in better condition than watersheds in other land use allocations.

Table 6—Mean harvest rates in the 250 watersheds in acres harvested per watershed per year[a]

Land use allocation	N	1972–1995	1995–2003
		- - - - - *Acres* - - - -	
Key			
Mean	82	52.8	6.1
SD		47.2	12.9
Non-key			
Mean	152	54.6	10.6
SD		48.4	27.4
AMA			
Mean	18	62.9	5.6
SD		44.9	6.5
CR			
Mean	62	30.8	3.2
SD		31.5	7.9
LSR			
Mean	63	66.8	10.9
SD		54.5	21.9
Matrix			
Mean	41	71.3	21.1
SD		51.2	46.3
Nonfederal			
Mean	45	86.0	44.4
SD		80.3	45.3

[a] Land use allocations include key watersheds, non-key watersheds, adaptive management areas (AMA), congressional reserves (CR), late-successional reserves (LSR), matrix, and watersheds that are predominantly nonfederal.

Roads—

Riparian road densities in adaptive management areas ranged from 0.07 to 0.28 mi of road per mile of stream. Eighty-eight percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream (fig. 35a). Road crossing frequencies ranged from 0.6 to 2.0 crossings per mile of stream. Seventy-eight percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream (fig. 35b). The density of roads in adaptive management areas is among the highest of those on federal lands.

Vegetation—

Riparian area with conifers >20 in d.b.h. ranged from 10 to 70 percent in adaptive management watersheds. Twenty-eight percent of the watersheds had less than 30 percent of the riparian area containing large conifers (fig. 36). Large trees were less abundant in the riparian areas of adaptive management watersheds than in other federally owned watersheds.

Changes Since the Implementation of the Plan

Small positive changes in the distribution of condition scores were detected for drivers, roads, or vegetation (fig. 37). Drivers condition scores increased by at least 0.1 in 72 percent of the watersheds in the last 10 years (table 4). None of the watersheds decreased in condition.

Roads—

Road condition scores increased by a minimum of 0.1 in nearly 40 percent of the watersheds, and the remainder did not change in condition (table 4). The miles of roads decommissioned in adaptive management areas was the lowest of any watersheds. No decommissioning occurred in nearly 70 percent of the watersheds (fig. 38). Of those watersheds that did have roads decommissioned, about 1 mi was decommissioned in riparian areas and 2 mi were decommissioned in upslope areas (table 5).

Vegetation—

Vegetation condition scores increased by a minimum of 0.1 in just over 70 percent of the watersheds in adaptive management areas. Harvest levels in adaptive management areas were low in the past 10 years, comparable with those

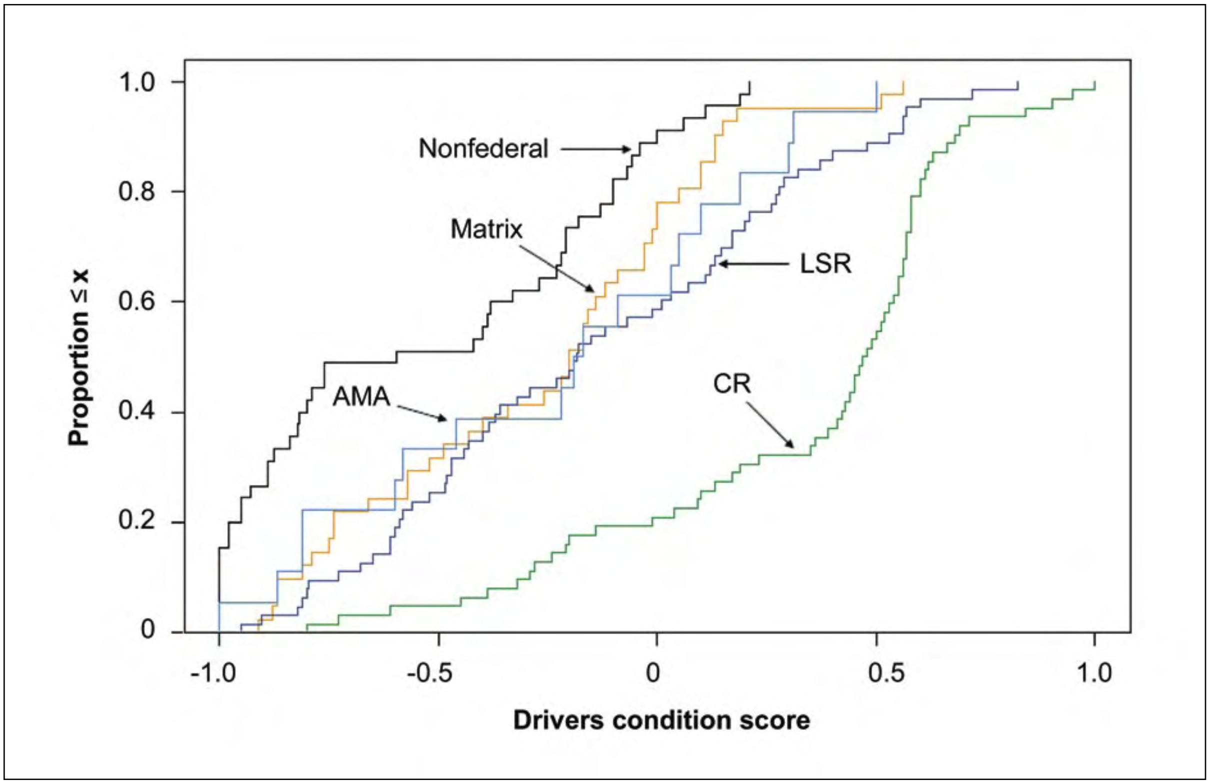


Figure 34—Cumulative distribution function for time 2 drivers condition scores for watersheds in each land use allocation, including predominantly nonfederal (n = 45 watersheds), matrix (n = 41), late-successional reserves (LSR; n = 63), congressional reserves (CR; n = 62), and adaptive management areas (AMA; n = 18). These distributions are based on subsets of 250 randomly selected watersheds in the Northwest Forest Plan area. The y-axis values represent the proportion of watersheds with condition scores less than or equal to the x-axis value of interest.

in congressional reserves (fig. 39). Mean harvest rates in adaptive management areas dropped from about 63 ac per watershed per year prior to 1995 to 5 ac per watershed per year after 1995 (table 6).

Congressional Reserves

Congressional reserves include national parks and monuments, wilderness areas, wildlife refuges, and other areas reserved by the administrative unit or act of Congress (fig. 40). These lands are generally not managed for timber production. Of the 250 randomly selected watersheds, 62 had more than 50 percent of the area designated as congressional reserve.

Current Status

Drivers condition scores range from -0.8 to 1. Condition scores in congressional reserve watersheds are generally higher than all other watersheds (fig. 34). More than 60 percent of the congressionally reserved watersheds had scores higher than 0.5.

Roads—
Road densities in congressional reserves are the lowest of any of the land use allocations. Riparian road densities in congressionally reserved watersheds ranged from 0 to 0.28 mi of road per mile of stream. Fourteen percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream (fig. 35a). Road crossing frequencies ranged from 0 to 2.2 crossings per mile of stream. Eight percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream (fig. 35b).

Vegetation—
Riparian area with conifers >20 in d.b.h. ranged from 0 to 93 percent in congressionally reserved watersheds. Twelve

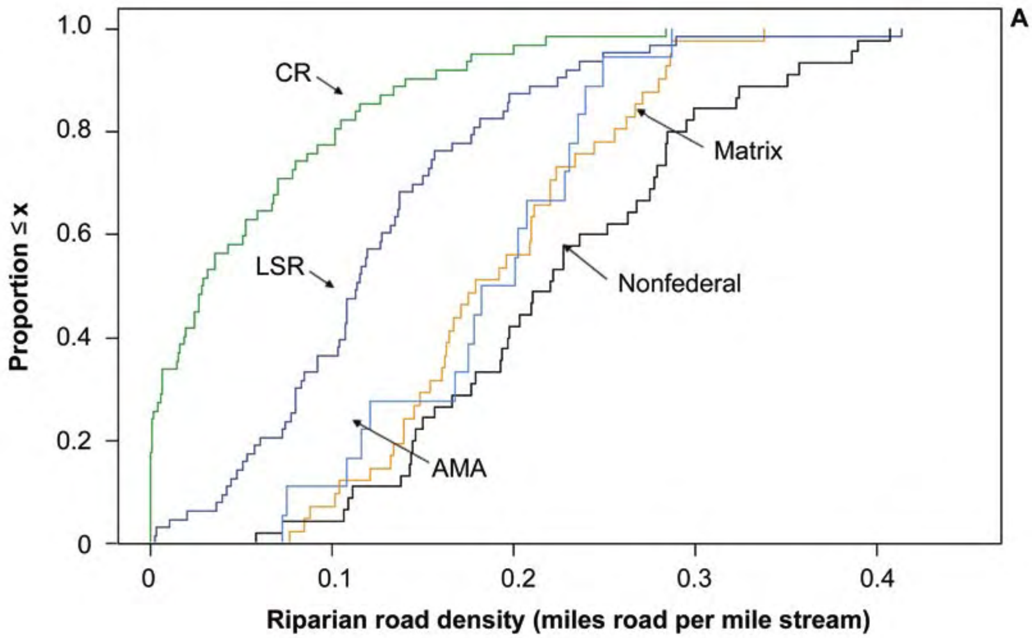


Figure 35—Cumulative distribution function for time 2 (A) riparian road density and (B) road crossing frequency for watersheds in each land use allocation, including predominantly nonfederal (n = 45 watersheds), matrix (n = 41), late-successional reserves (LSR; n = 63), congressional reserves (CR; n = 62), and adaptive management areas (AMA; n = 18). These distributions are based on subsets of 250 randomly selected watersheds in the Northwest Forest Plan area. The y-axis values represent the proportion of watersheds with density or frequency less than or equal to the x-axis value of interest.

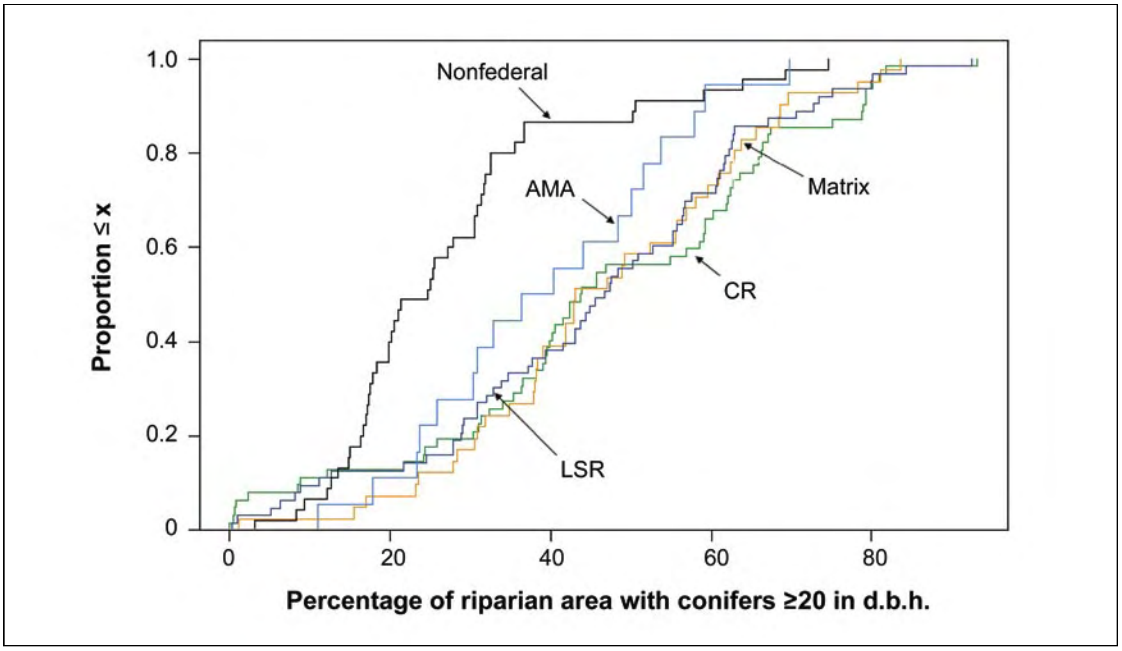


Figure 36—Cumulative distribution function of the percentage of riparian area with conifers >20 in diameter at breast height (d.b.h.) in time 2 for watersheds in each land use allocation, including predominantly nonfederal (n = 45 watersheds), matrix (n = 41), late-successional reserves (LSR; n = 63), congressional reserves (CR; n = 62), and adaptive management areas (AMA; n = 18). These distributions are based on subsets of 250 randomly selected watersheds in the Northwest Forest Plan area. The y-axis values represent the proportion of watersheds with the percentage of riparian area less than or equal to the x-axis value of interest.

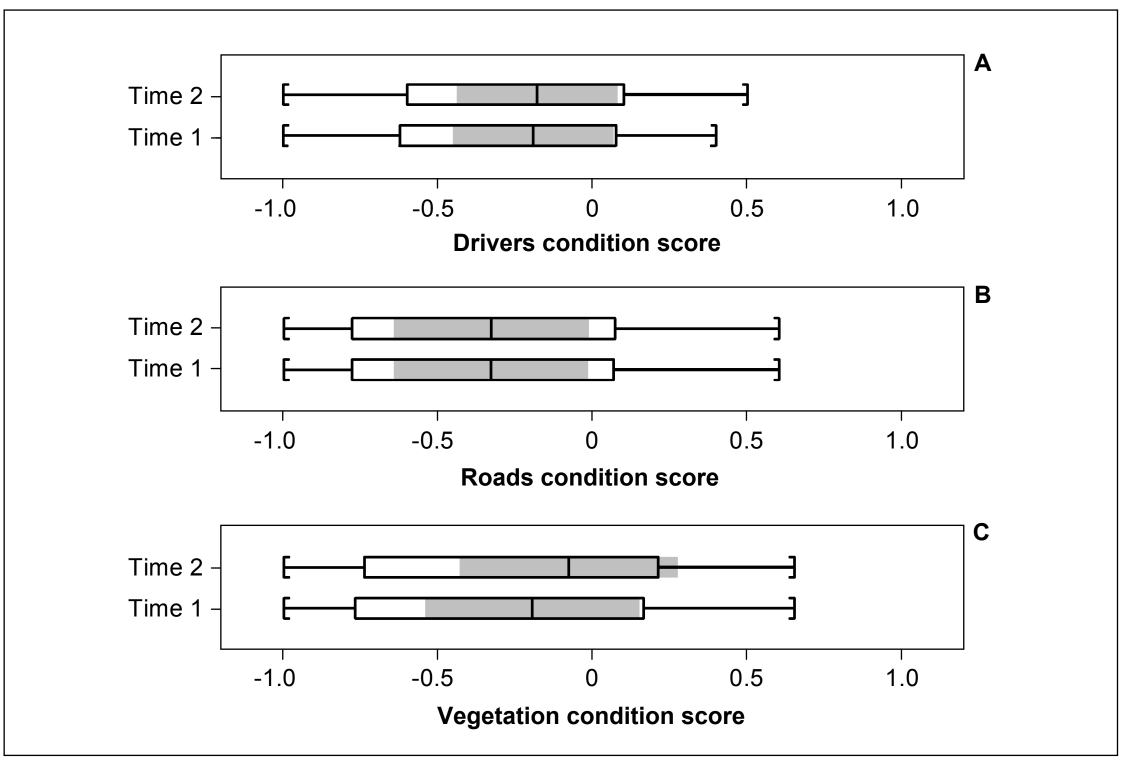


Figure 37—Distribution of (A) drivers, (B) roads, and (C) vegetation condition scores in adaptive management watersheds for time 1 and time 2. The distributions are based on 18 of the 250 randomly selected watersheds in the Northwest Forest Plan area designated as adaptive management areas. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

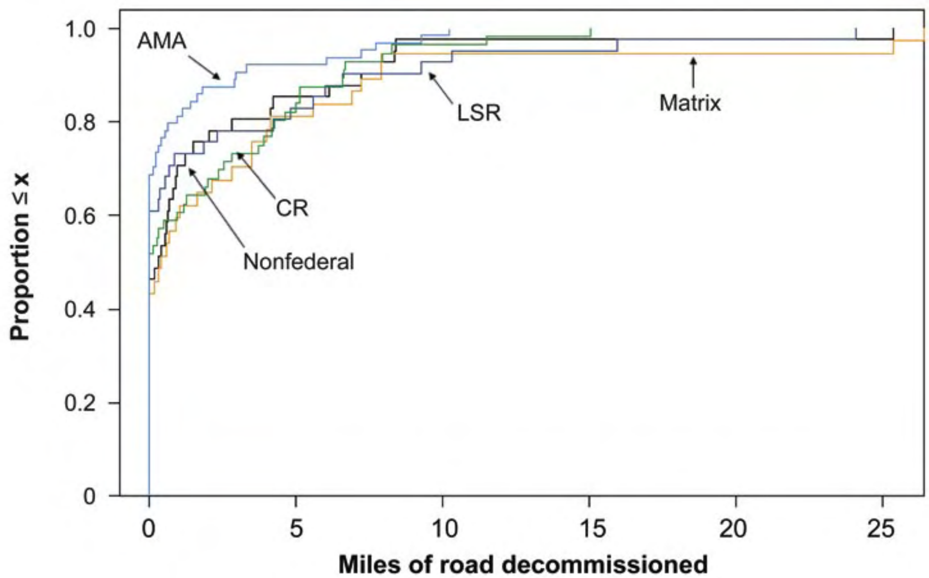


Figure 38—Cumulative frequency distribution of miles of road decommissioned in 250 watersheds by predominant land use allocation, including predominantly nonfederal (n = 45 watersheds), matrix (n = 41), late-successional reserves (LSR; n = 63), congressional reserves (CR; n = 62), and adaptive management areas (AMA; n = 18). These distributions are based on subsets of 250 randomly selected watersheds in the Northwest Forest Plan area. The y-axis values represent the proportion of watersheds with fewer miles of road decommissioned than the x-axis value of interest.

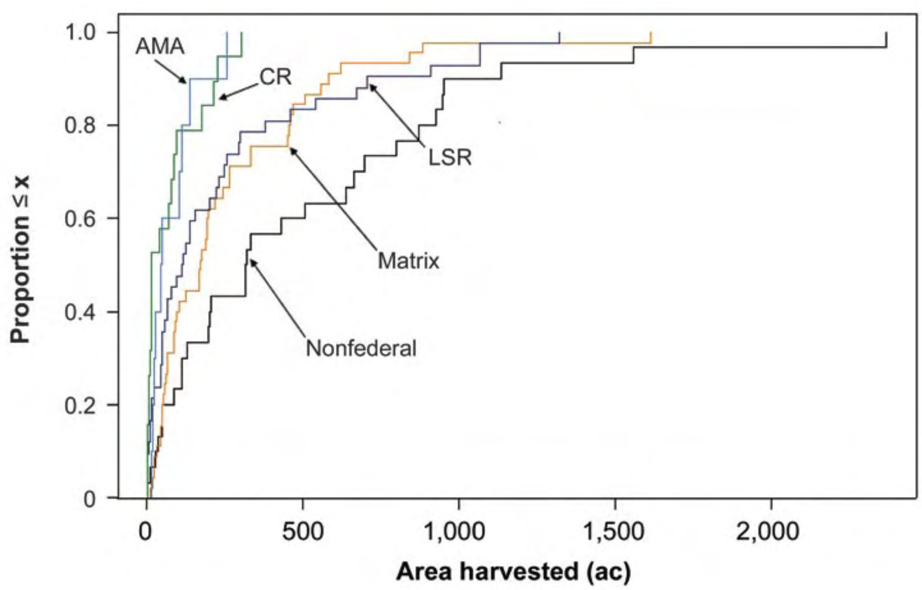


Figure 39—Cumulative frequency distribution of acres harvested in the 250 watersheds by the predominant land use allocation, including predominantly nonfederal (n = 45 watersheds), matrix (n = 41), late-successional reserves (LSR; n = 63), congressional reserves (CR; n = 62), and adaptive management areas (AMA; n = 18). These distributions are based on subsets of 250 randomly selected watersheds in the Northwest Forest Plan area. The y-axis values represent the proportion of watersheds with fewer acres harvested than the x-axis value of interest.

Eric Moberly

Figure 40—Congressional reserves, such as the Glacier Peak Wilderness in the Mount Baker-Snoqualmie National Forest, Washington, often contain upper headwater streams that serve as sources for high-quality water.

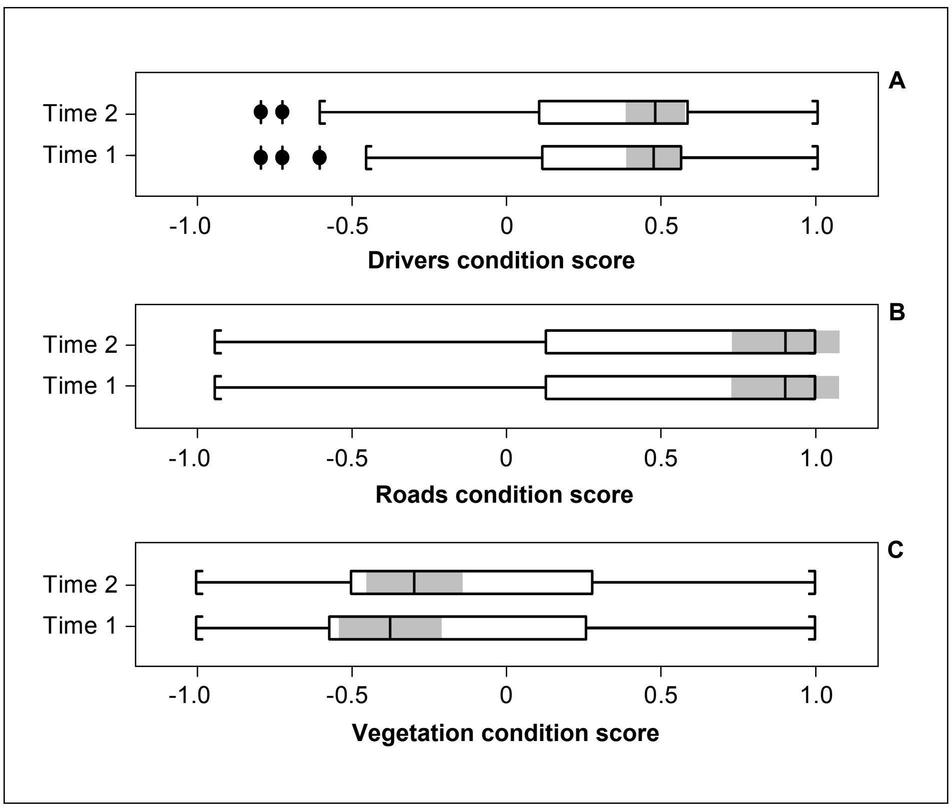


Figure 41—Distribution of (A) drivers, (B) roads, and (C) vegetation scores in congressional reserve watersheds for time 1 and time 2. The distributions are based on 62 of the 250 randomly selected watersheds in the Northwest Forest Plan area designated as congressional reserves. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the 95th quantiles. Dots represent outliers.

percent of the watersheds had less than 30 percent of the riparian area containing large conifers (fig. 36). Abundance of large trees in the riparian areas of congressionally reserved watersheds was comparable to the abundance in other federally owned watersheds (fig. 36).

Changes Since the Implementation of the Plan

A small positive shift in the condition of watersheds was detected in the distribution of drivers condition scores in congressionally reserved watersheds (fig. 41). Fifty-six percent of the watersheds had higher drivers condition scores in time 2, about 3 percent decreased in condition, and the remainder stayed the same.

Roads—
Road condition scores increased by a minimum of 0.1 in about 20 percent of the watersheds, and the remainder did not change in condition (table 4). The average number of road miles decommissioned in congressional reserves was the lowest of any watersheds (table 5), consistent with the low road densities in congressionally reserved watersheds. Less than 0.25 mi of road was decommissioned in riparian areas and 0.5 mi in upslope areas (table 5).

Vegetation—
Vegetation condition scores increased by at least 0.1 in about 63 percent of the watersheds (table 4). Vegetation scores decreased by at least 0.1 in about 3 percent of the watersheds, and stayed the same in the remainder. Harvest rates were very low in these watersheds (fig. 39).

Karnowsky Creek, Siuslaw National Forest, Oregon

Stream Restoration Project—
Karnowsky Creek flows into the Siuslaw River Estuary, just 9 mi from the Pacific Ocean on the central Oregon coast. In the late 1800s, this valley was home to pioneers who cleared trees from the valley floor, farmed and tended livestock, hunted wildlife, and harvested huge cedar trees to build homes and barns.

The 1,800-ac Karnowsky Creek subwatershed is now managed primarily by the Siuslaw National Forest (upper 85 percent) and by three private industrial timber companies (lower 15 percent). A partnership of Forest Service, Siuslaw Soil and Water Conservation District, and the Siuslaw Watershed Council worked together to restore the channel, wetland, and estuarine processes that once made Karnowsky Creek a productive stream for aquatic resources in the Siuslaw basin.

Johan Hogervorst

Johan Hogervorst

A new channel was built and old drainage ditches were plugged to divert water into the new channel.

Progress to date—
The project is extending chum salmon (*Oncorhynchus keta*) habitat as tidal influence is allowed back into the bottom half mile of the project area. Further upstream, Oregon coast coho salmon (*O. kisutch*) (listed as threatened under the Endangered Species Act) will rear in slower moving waters of the new channel, adjacent ponds, and connected flood plain during both summer and winter. Steeper sections of stream channel in the main valley and in three tributary valleys are being restored to provide needed spawning gravels in late fall and early winter for returning adult coho salmon.

Johan Hogervorst

Johan Hogervorst

One hundred-fifty-five whole conifer trees were flown in by helicopter and placed in the flood plain and new channel to increase habitat complexity for aquatic-dependent species and to improve flood-plain interaction during high flow events. Contact Paul Burns (pnburns@fs.fed.us) for more information.

Mean harvest areas declined from 30 ac per watershed per year to 3 ac per watershed per year. These harvest rates are the lowest of any on federal land.

Late-Successional Reserves

Late-successional reserves contain largely old-growth forest and were designated to provide habitat for old-growth-dependent species such as the northern spotted owl (*Strix occidentalis caurina*) (fig. 42). Of the 250 randomly selected watersheds, 63 had more than 50 percent of the area designated as late-successional reserve.

Current Status

Drivers condition scores spanned the full possible range of scores. The drivers condition scores in late-successional reserve watersheds was generally higher than the scores of other federally owned watersheds, with the exception of congressional reserves. About half of the late-successional reserve watersheds had drivers condition scores greater than 0.

Roads—

Riparian road densities in late-successional reserve watersheds ranged from 0.01 to 0.41 mi of road per mile of stream. Sixty-three percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream (fig. 35a). Road crossing frequencies ranged from 0.02 to 4.26 crossings per mile of stream. Forty-three percent of the watersheds had road crossing frequencies greater than one crossing per mile of stream (fig. 35b).

Vegetation—

Riparian area with conifers >20 in d.b.h. ranged from 0.4 to 92 percent in late-successional reserve watersheds. Twenty-four percent of the watersheds had less than 30 percent of the riparian area containing large conifers (fig. 36). Abundance of large trees in the riparian zone was consistent with the abundance in other federally owned watersheds.

Changes Since the Implementation of the Plan

The change in the distribution of the drivers conditions in late-successional reserves was perhaps the most interesting. The entire distribution shifted slightly toward the right, which reflects an overall increase in scores, and the center 50 percent of the distribution became more narrow in range. The median of the distribution was slightly lower in time 2 than it was in time 1 (fig. 43). The seven watersheds that changed by more than 0.3 were all located in late-successional reserves. The positive changes in these watersheds can be attributed to management, specifically road decommissioning, in the watersheds. All of the watersheds that declined in condition were recently burned by wildfires.

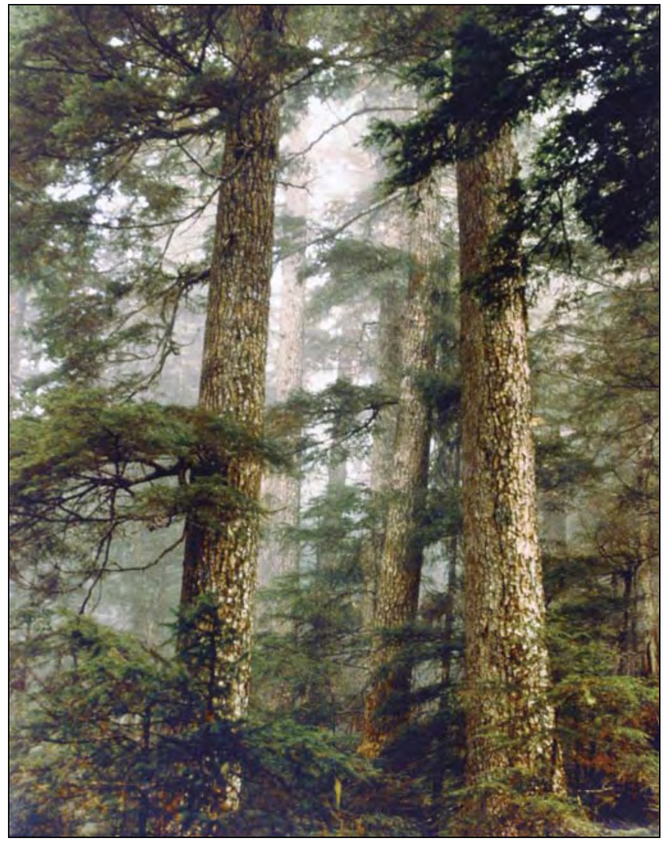

Jon Martin

Figure 42—Late-successional reserves are intended to provide forest habitat for old-growth-dependent species, such as the northern spotted owl.

Roads—

Road condition scores increased in 47 percent of the watersheds and stayed the same in the remainder of the watersheds. Road decommission was conducted in about 40 percent of the watersheds (fig. 38), at an average rate of 2.6 mi of road per watershed (table 5). These average rates were the highest of any on federal land.

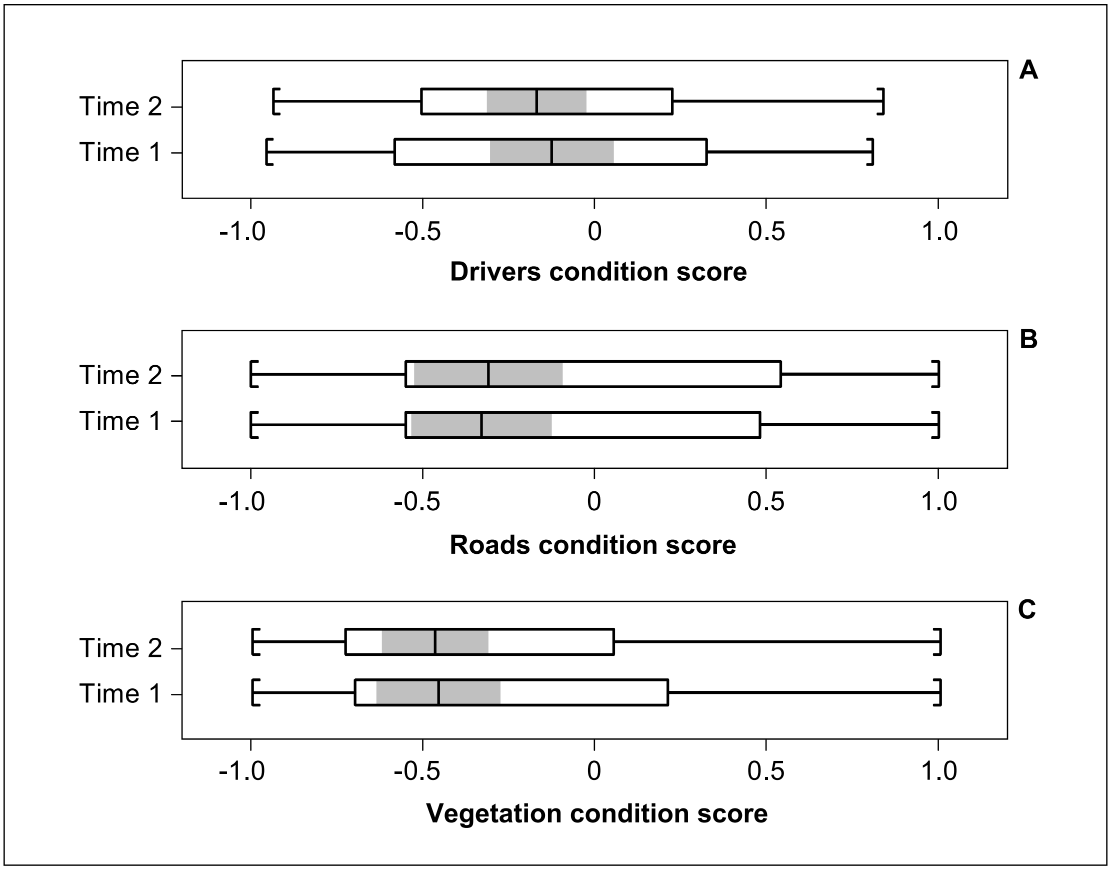


Figure 43—Distribution of (A) drivers, (B) roads, and (C) vegetation condition scores in late-successional reserve watersheds for time 1 and time 2. The distributions are based on 63 of the 250 randomly selected watersheds in the Northwest Forest Plan area that were designated as late-successional reserves. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

Vegetation—

Vegetation condition scores increased in just over 70 percent of the watersheds, decreased in 8 percent, and stayed the same in the remainder of the watersheds (table 4). The decline in vegetation in the watersheds that had lower condition scores in time 2 was attributed to wildfires that burned 30 to 55 percent of the watershed area. Harvest area was fairly high in late-successional reserves, comparable to those on matrix lands (fig. 39). We recognize that harvest objectives in late-successional reserves differ from those on matrix lands; this analysis considers only the harvest itself, not its objectives. Mean annual harvest rates declined in late-successional reserves from about 67 to 11 ac per watershed per year after the Plan was implemented (table 6).

Al Doelker

Figure 44—Matrix lands are expected to produce most of the timber production from federal lands within the Northwest Forest Plan area.

Matrix

The matrix land use allocation includes all lands not included in one of the other allocations (fig. 44). Riparian reserves are included in this land use allocation because the reserves have not been mapped and we were not able to separate them. Matrix areas were expected to have most of the silvicultural activities, including stand-replacing harvest. Forty-one of the 250 randomly selected watersheds had greater than 50 percent of the area designated as matrix.

Current Status

Drivers condition scores ranged from -0.9 to 0.5 on matrix lands. Matrix lands generally had low condition scores compared with other federally managed lands; about 60 percent of the watersheds had scores less than 0 (fig. 34).

Roads—

Riparian road densities in matrix watersheds ranged from 0.07 to 0.33 mi of road per mile of stream. Ninety-three percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream (fig. 35a). Road crossing frequencies ranged from 0.5 to 2.6 crossings per mile of stream. Eighty-three percent of the watersheds had road crossing frequencies greater than one crossing per mile of stream (fig. 35b).

Vegetation—

Riparian area with conifers >20 in d.b.h. ranged from 1.2 to 83 percent in matrix watersheds. Seventeen percent of the watersheds had less than 30 percent of the riparian area containing large conifers (fig. 36).

Mill Creek, Klamath National Forest, California

Fish passage—

The Mill Creek Ford on the Klamath National Forest was rehabilitated to remove a barrier that restricted passage to 5 mi of stream for fish and other aquatic species. This crossing is on a road very popular for sight seeing, hunting, hiking, bicycling, and as an equestrian route to local neighborhoods around Happy Camp, California. The road also provides administrative access into the area for fire suppression and resource protection.

Allan Olson

Old: The old concrete box culvert (left) blocked natural flow at the inlet and always created a buildup of debris. The outlet had eroded the streambed down about 2 ft below the concrete bottom. The narrow 5-ft restriction of the old culvert increased the water velocity to the point that fish and other aquatic species were unable to travel upstream.

Allan Olson

New: The new 20-ft, open-bottomed arch culvert (right) provides coho, steelhead, resident rainbow, Pacific lamprey, and Pacific giant salamanders (*Dicamptodon tenebrosus*) with unrestricted access to 5 mi of upstream habitat. Contact Jack West (jwest@fs.fed.us) for more information.

Changes Since the Implementation of the Plan

Just over half of the watersheds in matrix lands had higher drivers condition scores in time 2 than they did in time 1 (table 4). This change resulted in a small positive shift in the distribution of drivers condition scores on matrix lands (fig. 45). None of the watersheds had lower condition scores in time 2 than they did in time 1.

Roads—
Roads condition scores increased in 32 percent of the watersheds in the last 10 years (table 4). Decommissioning was conducted in about 40 percent of the watersheds in matrix lands (fig. 38). Average decommissioning rates within these watersheds was about 2.5 mi (table 5).

Vegetation—
Vegetation condition scores increased in just over half of the matrix watersheds in the last 10 years (table 4). The number of acres harvested was the highest in matrix lands when compared with the other federal land use allocations (fig. 39), as would be expected under the Plan. Mean harvest rates were 21 ac per watershed per year, down from over 70 ac per year prior to implementation of the Plan (table 6).

Nonfederal Lands

Lands that are not federally owned are not subject to the management guidelines included in the Plan. However, because ownership is mixed in many of the watersheds, it is important to note the contribution federal lands are making to the condition of watersheds as a whole. Forty-five of the 250 randomly selected watersheds had more than 50 percent of the area not federally owned.

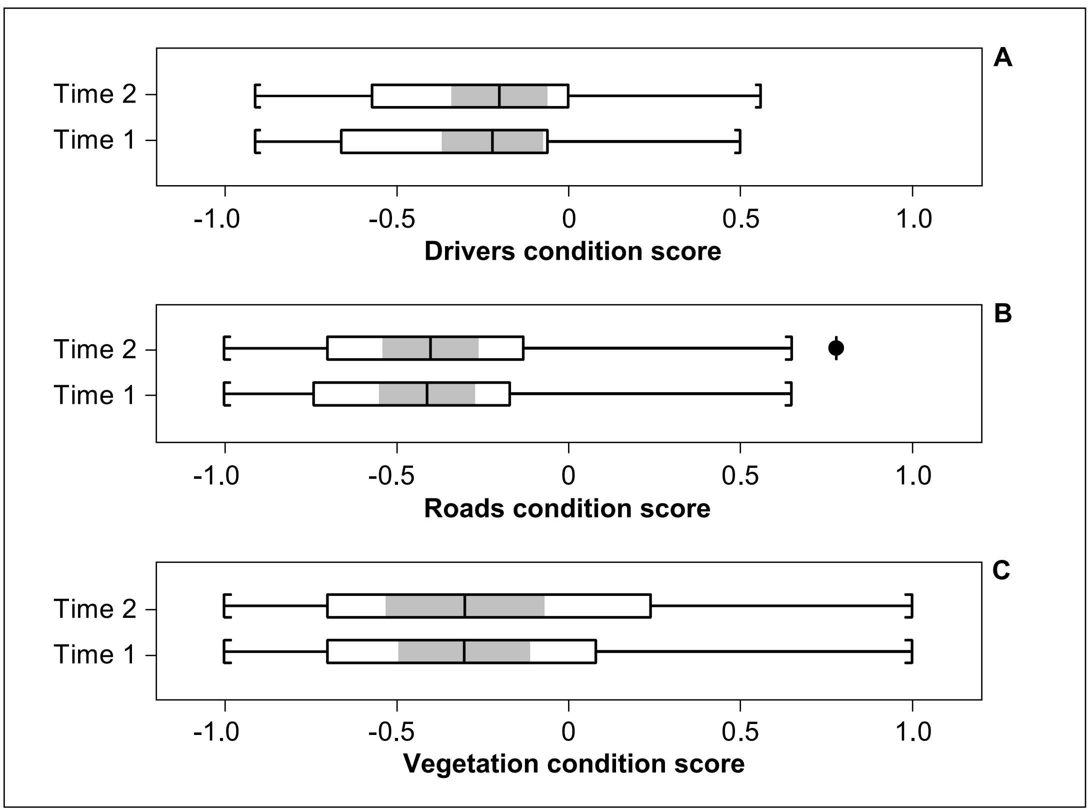


Figure 45—Distribution of (A) drivers, (B) roads, and (C) vegetation condition scores in matrix watersheds for time 1 and time 2. The distributions are based on 41 of the 250 randomly selected watersheds in the Northwest Forest Plan area that were designated as matrix. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the 95th quantiles. Dots represent outliers.

Current Status

Drivers condition scores in watersheds that are predominantly nonfederal ranged from -1 to 0.2. Only 5 of the 45 watersheds had drivers condition scores higher than 0 (fig. 34). Overall, nonfederal watersheds had the lowest condition scores of the land use allocations.

Roads—

Watersheds that contained more than 50 percent nonfederal lands had the highest road densities of the watersheds. Riparian road densities in nonfederal watersheds ranged from 0.05 to 0.41 mi of road per mile of stream. Ninety-six percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream (fig. 35a). Road crossing frequencies ranged from 0.3 to 3.1 crossings per mile of stream. Eighty percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream (fig. 35b).

Vegetation—

Riparian area with conifers >20 in d.b.h. ranged from 3 to 74 percent in nonfederal watersheds. Sixty-two percent of the watersheds had less than 30 percent of the riparian area containing large conifers (fig. 36).

Changes Since the Implementation of the Plan

One-third of the predominantly nonfederal watersheds had higher drivers condition scores in time 2 than in time 1 (table 4). Drivers condition scores did not change in the remainder of the watersheds. The distribution of drivers condition scores moved slightly toward higher scores (fig. 46).

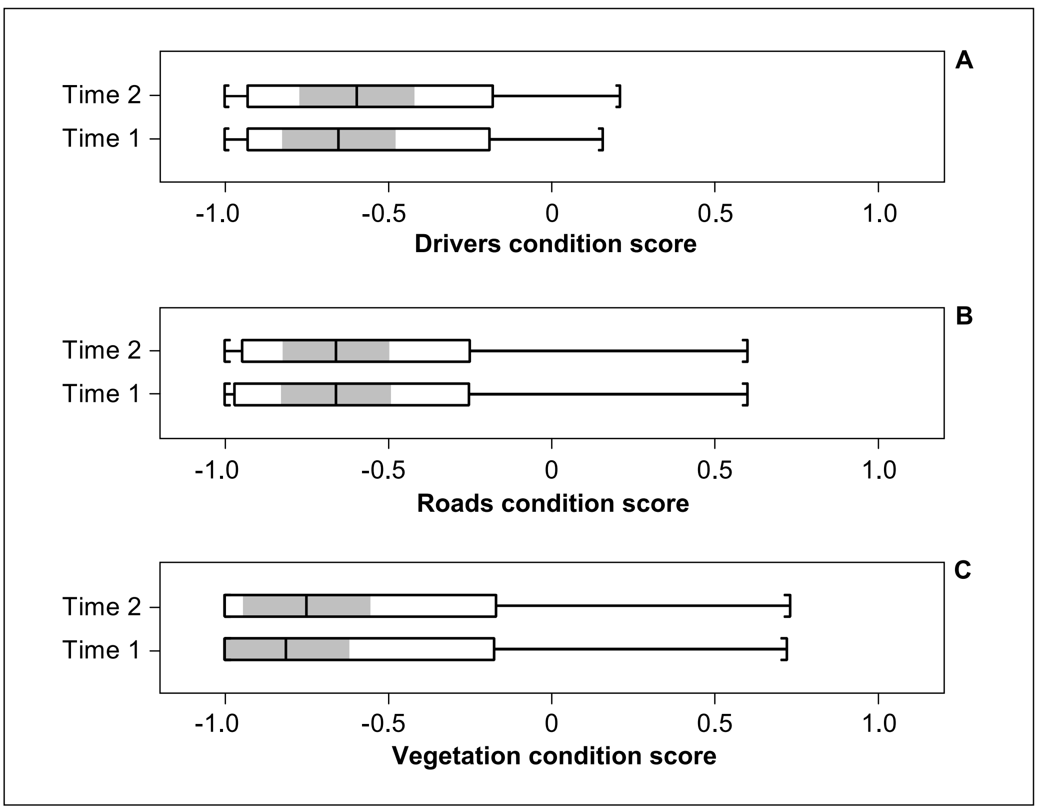


Figure 46—Distribution of (A) drivers, (B) roads, and (C) vegetation condition scores in watersheds that were predominantly nonfederal for time 1 and time 2. The distributions are based on 45 of the 250 randomly selected watersheds in the Northwest Forest Plan area. Bars in the center of the boxes represent the median of the distribution, and shading represents the 95 percent confidence interval around the median. Boxes represent the middle 50 percent of the distribution, and the whiskers represent the range of the distribution.

Roads—

Road condition increased in 36 percent of the watersheds by at least 0.1 (table 4). The number of road miles decommissioned averaged about 2, which was consistent with the average across the Plan area (fig. 38, table 5).

Vegetation—

Vegetation condition scores increased in 27 percent of the watersheds; and stayed the same in the remainder (table 4). More acres of timber were harvested on nonfederal watersheds than in any of the other land use categories (fig. 39).

In general, watersheds that are predominantly nonfederal have the lowest condition scores of all of the watersheds, notably worse than predominantly federal watersheds (fig. 34). The percentage of federal land appears to have little effect on drivers condition scores for the present period (fig. 47). Although the relationship is statistically significant ($t = 8.97$, $df = 248$, $p < 0.01$), the percentage of federal ownership explains only 25 percent of the variance in drivers condition score. When land use allocation is added to the analysis as a covariate, federal ownership explains 37 percent of the variance in drivers condition scores. These results suggest that drivers condition scores are influenced by factors other than the management applied to the watershed.

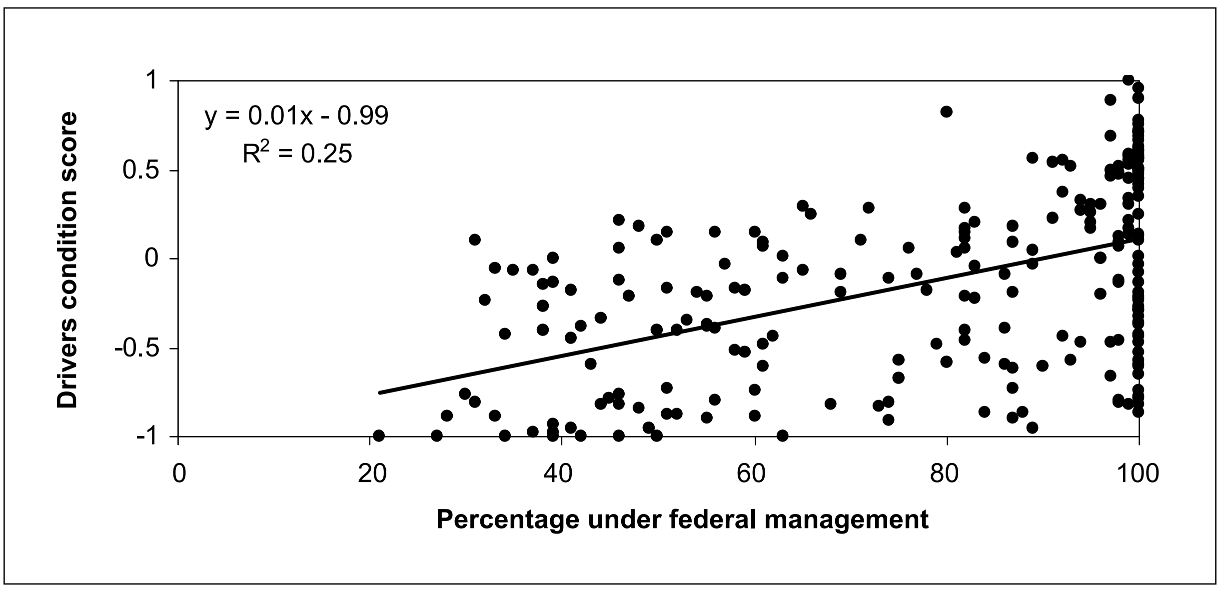


Figure 47—Relation between percentage of the watershed under federal management and the time 2 drivers condition scores based on 250 randomly selected watersheds in the Northwest Forest Plan area.

Continue to Next Section

Chapter 4: Discussion

The authors of the Northwest Forest Plan (the Plan) recognized the complex and dynamic nature of watersheds. Human activities in the past century have altered the processes that create healthy ecosystems (Bisson et al. 1992, Naiman et al. 2000). These processes occur on the scale of decades or centuries. Given the temporal scale of these ecological processes and that degradation of watershed processes has probably occurred gradually for decades, it is unlikely that restoration activities will restore habitat in a short period (Larsen et al. 2004). From this perspective, it is not surprising that changes observed here in the roads and vegetation were very small, except in a few watersheds.

Most of the watersheds had higher condition scores in time 2 than in time 1 across the entire Plan area and in each of the land use allocations except nonfederal. Relatively few watersheds decreased in condition. Given that (1) the growth rate of trees exceeded harvest rates, (2) more roads were decommissioned in the last 10 years than were built, (3) the watersheds that had large increases in drivers condition scores were all targets of road decommissioning, and (4) those watersheds that had lower condition scores were all exposed to wildfire (and not management activity), it appears that the strategy has had positive effects on the condition scores of watersheds in the Plan area. Further, over 70 percent of key watersheds, which were supposed to have first priority for restoration activities, increased in condition. Less than 50 percent of the non-key watersheds increased in condition.

The monitoring program has been charged with answering the following questions:

- **Are the key processes that create and maintain habitat conditions in aquatic and riparian systems intact?**
- **What is the status of upslope processes as indicated by vegetation and roads?**

Because we currently lack the understanding and ability to measure watershed processes directly, we rely on attributes that are surrogates for these processes. Upslope vegetation generally has higher condition scores (median 0.2) than upslope roads. Because the full range of conditions extend from -1 to 1, upslope vegetation appears to be in good condition overall. The median upslope road condition score is about 0, so about half of the watersheds have positive upslope road condition scores and half have negative road condition scores. Roads tend to carry more weight in the models than vegetation; therefore, decommissioning of upslope roads would have a greater impact in improving watershed condition scores with respect to the upslope attributes.

- **What is the status of riparian processes as indicated by vegetation and roads and stream crossings?**

Many of the watersheds had low condition scores for riparian attributes. Riparian vegetation condition scores were lower than those of the riparian road attributes. For riparian vegetation, we examined the percentage of the riparian area with trees 20 in diameter or larger, and about half of the watersheds had very low riparian vegetation condition scores (less than -0.75). Because stand-replacing harvest rates in riparian areas have declined since the Plan was implemented, the condition scores for riparian vegetation should increase in the future as the trees grow into that larger size category. Nearly 40 percent of the watersheds had riparian road condition scores equal to -1, and only 16 percent had scores of +1. Roads in riparian areas can significantly affect the condition of watersheds, and they are heavily weighted in most of the evaluation models. Therefore, removal of roads in riparian areas would have the greatest impact on increasing watershed condition scores.

- **What is the status of inchannel processes as indicated by pools, substrate, water temperatures, large structure in the channel, and rates of channel movement?**

Inchannel attributes tend to have fairly high condition scores. None of the watersheds had reach condition scores less than -0.5. The stream reaches within the 55 sampled watersheds appear to have sufficient numbers of pools and substrates dominated by gravel and cobble. However, adequate amounts of large wood appear to be lacking in many streams.

Smith River, Bureau of Land Management, Umpqua Field Office, Oregon

Fish passage restoration (culverts)—
The Bureau of Land Management Umpqua Field Office implemented an aggressive program for fish-passage culvert replacement and modification in the Smith River watershed during 2003. Eleven fish-passage-barrier culverts were replaced, two culverts were modified to provide adult and juvenile fish passage, and one culvert was removed to allow the site to reestablish the natural grade during winter high flows before it is replaced in 2005. This work improved passage to about 13 mi of upstream habitat.

Under the authority of the Wyden Amendment, the Umpqua Field Office also cooperated with two watershed councils for the replacements of two tide gates, one in the lower Smith River and one in the lower Coos River.

Coos Bay BLM District

Coos Bay BLM District

Upstream fish passage was not possible at these old, poorly installed culverts (left) on South Sisters Creek. A newly installed culvert (right) allows fish passage at all flows. Contact Bill Hudson (bill-hudson@or.blm.gov) for more information.

- **Has the distribution of key indicators shifted in a direction that indicates improved or degraded habitat and biotic condition?**

Currently we have inchannel data to assess habitat and biotic condition for 55 watersheds from the current period only. We are not yet able to look for changes in these attributes.

- **How does the aggregate quality of the key indicators used to evaluate watershed condition, (i.e., the distribution of watershed condition scores) change through time under the Plan?**

The drivers condition scores were at least 0.1 higher in time 2 than in time 1 in 57 percent of the watersheds. Three percent of the watersheds had lower drivers condition scores in time 2, and condition scores stayed the same in the remainder of the watersheds. Most of the watersheds had higher drivers condition scores in time 2 than in time 1 across all land use allocations, with the exception of the nonfederal land use allocation.

Of the 250 watersheds, seven had drivers condition scores that changed by more than 0.2 from time 1 to time 2. Wildfires that burned 31 to 55 percent of the watershed area explain the decrease in drivers score in four of the seven watersheds. The remaining three watersheds had higher condition scores in time 2 than in time 1. Each of these watersheds was the target of road decommissioning. A total of 16 mi of road was decommissioned in one watershed, more than half of which was in the riparian zone. A reduction in the number of road-stream crossings, which were also evaluated in the decision-support models, often accompanied decommissioning of riparian roads. In this case, 34 road-stream crossings were removed. In another watershed, just over 9 mi of road was decommissioned, of which 3 mi was in areas prone to mass wasting and 4.6 mi was in the riparian area. Fifty road-stream crossings were removed. Nine miles of road was decommissioned in the last watershed, which resulted in the removal of 3 mi of road in the riparian area and 41 road-stream crossings.

The complexity of interactions among watershed components, the natural variability of stream conditions, and the lack of data have led most people conducting watershed-based assessments to use methods based on expert judgment rather than statistical analyses (Consulting Science Team 2001, FEMAT 1993, Hulse et al. 2002, O'Keefe et al. 1987, Rieman et al. 2001). Although using expert judgment appears to be the most effective way to synthesize such diverse and incomplete information, such assessments are not necessarily consistent or transparent. To address these shortcomings, we used explicit decision-support models in this assessment to provide a replicable and explainable method (Reeves et al. 2004, Reynolds and Reeves 2003).

The model structures and evaluation criteria provided in appendix 4 identify the attributes used in the evaluation, the weight of each attribute, how each attribute was evaluated, and how the evaluation scores for individual attributes were aggregated. The tables also document the source used to determine the evaluation criteria. The information provided in the appendix should allow readers to understand and replicate the watershed condition assessments we conducted.

Reeves et al. (2004) specified using regional expert teams to build local knowledge into the evaluation models. Experts who participated in the two rounds of workshops covering the seven aquatic provinces seemed to adapt easily to the modeling approach and see its value. The approach was amendable to integrating relationships based on existing data and literature where available, as well as professional judgment. The models clearly reflected regional differences, such as potential natural vegetation conditions, so that the model results would better reflect the conditions on the ground.

Because we used different models in each province, some models are less sensitive to changes in specific attributes than others. We attribute these differences between the models to differences in ecological processes across provinces that affect the condition of watersheds; e.g., they reflect inherent differences in how roads affect watersheds in the different provinces. Reducing the frequency of road crossings by 50 percent produces an increase of about 0.10 in the watershed condition score in the Washington/Oregon Coast province, but, only 0.02 in the North Cascades province. The North Cascades model was more sensitive to riparian road density than to road crossings, in contrast to the Coast model.

The assessments of watershed condition in this exercise lacked critical information. The trend analysis was based exclusively on roads and vegetation. Inchannel data were available for only 20 percent of the watersheds, and data on fish, amphibians, and other aquatic- and riparian-dependent species were not included. These omissions are significant because they are the ultimate response variables for management activities. Many natural resource management decisions consider these species; thus, we must use them to assess the effectiveness of our management activities. Other watershed-scale processes such as mass wasting were also omitted from the analysis. The monitoring program is working toward including biological and mass-wasting attributes in future iterations of the models.

In addition to omitting some key watershed processes, the attributes used in the model to describe watershed condition may be too simplistic. For example, few watersheds with low drivers condition scores were detected in the Klamath/Siskiyou region in Oregon and California. Given the history of mining and channel alterations in that area and the relatively poor condition of the fish populations there, the attributes included in the model may not be sensitive to the management activities in the area. The drivers condition scores are currently affected only by road building and decommissioning, and the growth and loss of vegetation owing to harvest or fire. Vegetation losses are treated the same whether the loss is due to fire or to regeneration harvest, even though these two disturbances likely have different effects on the condition of watersheds. Further, the effect of fires in watersheds may be different depending on whether management activities such as salvage logging or restoration activities were implemented following the fire. Although many management and restoration activities have occurred in the Plan area, we are unable to document how these activities affected the condition of watersheds. Currently, management agencies do not track harvest or road building, decommissioning, or improvement spatially in a database. Consequently, improvements from culvert replacements or other restoration activities are not reflected in watershed (or drivers) condition scores.

The condition scores of roads and vegetation in 250 watersheds extended across the full range of possible scores (-1 to 1). However, the watershed condition scores we found were clumped in the center of the distribution. At least three hypotheses can be posed to explain this finding: thus far, we have sampled only watersheds that were in the center of the distribution; the inclusion of the inchannel data pulls the watershed condition score toward 0; and inclusion of the inchannel data increases the watershed condition score relative to the drivers condition score. In other words, the streams are in better condition than the riparian and upslope areas. The 55 watersheds sampled are a subset of the 250, and some have drivers condition scores that approach or equal -1. Further, watersheds were sampled in the order in which they were selected, so the 55 watersheds should reflect the full range of variation in the target population. Therefore, we reject the first hypothesis. We examined the relationship between the watershed condition score and the drivers condition score in the 55 sampled watersheds and found a positive relationship between the two. Drivers condition score explains 86 percent of the variance in the watershed condition score, but the slope of the equation is only 0.6 and the intercept is 0.14. When the drivers and watershed condition scores from the 55 sampled watersheds are compared, the watershed condition scores are about 0.22 higher than drivers scores (range = -0.2 to 0.74). We conclude that including the habitat data from the sampled reaches has positive effects on the overall watershed condition score.

The participants in the workshops that helped build and refine the models had more trouble building the portion of the model that evaluates the inchannel data than the roads and vegetation portions. Stream channels have a very large range of natural variation, and determining what qualities any particular reach should have is difficult. Consequently, the model may serve only to highlight those stream reaches that are dramatically different from the norm.

The quality and accuracy of the geographic information system (GIS) layers affected the outcome of these results more than model issues. The results of this assessment could change if updated GIS layers are constructed. Problems with the vegetation layers were specific to particular provinces. The Interagency Vegetation Mapping Project (IVMP) layers were built for each of the vegetation provinces (Moeur et al. 2005). In the High Cascades Washington province, the map does not accurately account for large trees. According to the map, about 5 percent of the federal land base is populated by stands of trees greater than 20 in d.b.h. However, according to vegetation plot data from the same area, about 20 percent of the federal land base is covered by stands of large trees.[2] Consequently, vegetation condition scores were lower than they should have been in this area.

Perhaps the largest source of error in the analysis was tied to inconsistent mapping of stream density across the Plan area. Generation of riparian area for road and vegetation analyses was based on the 1: 24,000 stream layer. The layer used was acquired from individual units and pieced together, but the method used to generate the layers was not consistent across units. Consequently, the density of streams changed across administrative unit boundaries (fig. 48). The example in figure 48 shows the difference in stream densities in the Olympic National Forest and the Olympic National Park. The problem exists within individual units as well. For example, stream densities range from 0.7 to 9.5 mi of stream per square mile of watershed

[2] M. Moeur. 2004. Personal communication. Vegetation monitoring lead, Resource Planning and Monitoring, USDA Forest Service Pacific Northwest Region, 333 SW First Ave., Portland, OR 97204.

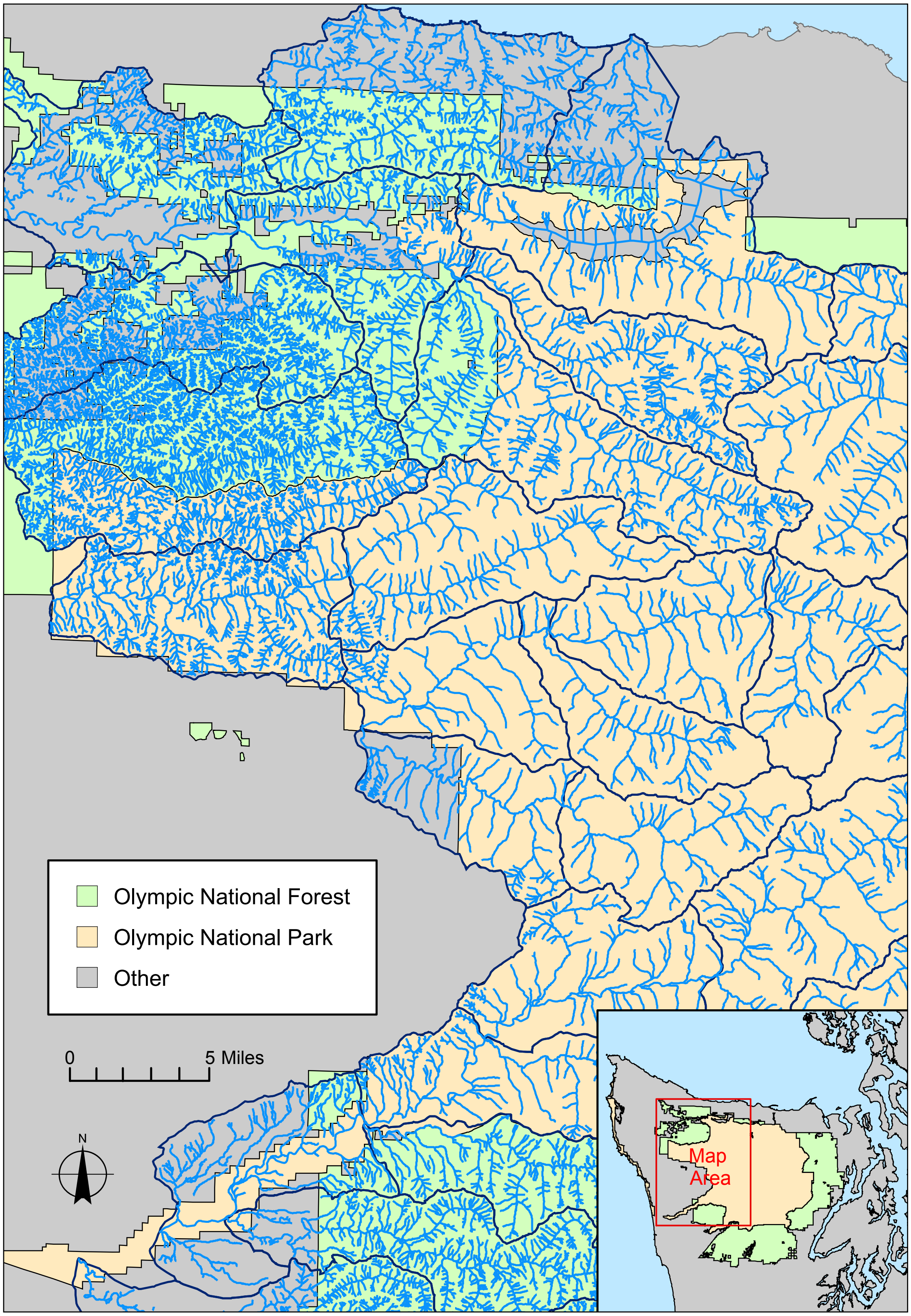
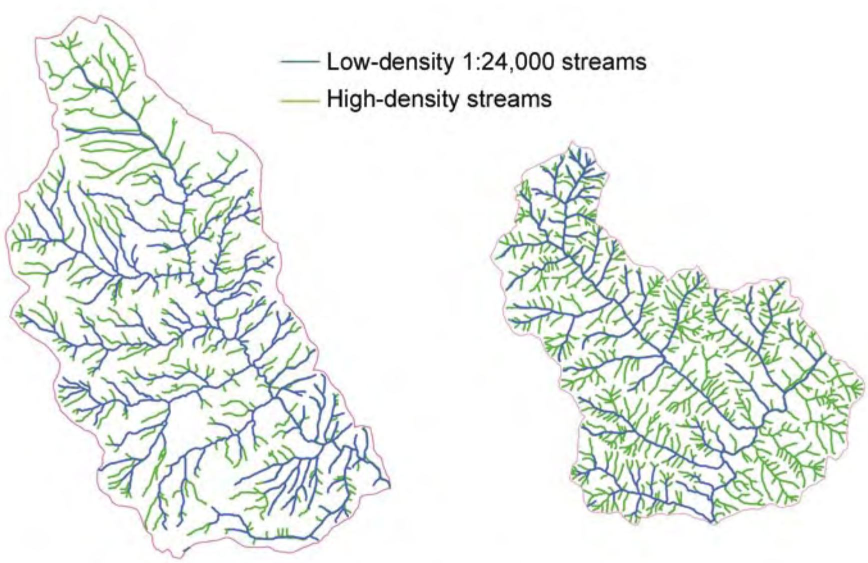


Figure 48—Comparison of stream densities on agency stream layers on the Olympic National Park and the Olympic National Forest.

on the Willamette National Forest. Precipitation and geology, two factors that influence the density of streams, are relatively homogeneous in the forest, so such a large difference in streams is unexpected. The Willamette National Forest was not atypical. In the Methow Valley on the Okanogan National Forest, stream densities ranged from 1 to 13 mi per square mile of watershed.

Stream density differs naturally across the Plan area, but we do not know by how much. We were not able to determine how much of the variation in the stream layer was due to true variation in stream density and how much was due to map error. Nor were we able to assess the effect the stream layers had on the analysis. We considered comparing data from the high-density layers with the lower density 1:24,000 layer, which grossly underestimates stream miles, particularly those that are nonfishbearing. As an example, two watersheds from the Medford BLM district were selected (for no particular reason), and frequency of road crossings and riparian road density were calculated by using the high-density and low-density layers (fig. 49). Although the example clearly showed that we have more road crossings and riparian road density by using the high-density layer, we still have no determination of how accurate the data are or the effect that the increased stream density has on the assessment.

All analyses are based on an underlying assumption that the necessary data are available and of acceptable quality. In this analysis, the validity of this assumption is questionable because the results of the analysis could change if the analysis were repeated on updated GIS layers. This problem illustrates the data management problems faced by all of the Plan's monitoring programs. An information management document (Palmer et al., in press) was prepared in conjunction with the Plan's status and trends documents that identifies the data problems encountered by the monitoring programs and proposes solutions to these problems.



Upper Trail Creek

	Low density	High density
Stream miles	76	138
Road crossings	168	314
Riparian mi^2 (50-m buffer)	4.6	8.2

Hawk Creek

	Low density	High density
Stream miles	57	183
Road crossings	131	491
Riparian mi^2 (50-m buffer)	3.5	10.8

Figure 49—Comparison of high- and low-density stream layers in two watersheds on the Medford Bureau of Land Management district.

Continue to Next Section

Chapter 5: Evaluation of the Aquatic and Riparian Effectiveness Monitoring Program

Lessons Learned While Implementing the Effectiveness Monitoring Component of the Plan

Implementing the monitoring program in the Northwest Forest Plan (the Plan) area provided an array of products and insights for successful large-scale monitoring, and ideas for how to improve the monitoring program. Our first challenge was to successfully implement the following key components described by Reeves et al. (2004).

Probabilistic Survey Design

We worked with U.S. Environmental Protection Agency statisticians to implement a probabilistic sampling strategy they developed that ensures sampling a uniform, random distribution of watersheds throughout the Plan area. The design is well established and allows using a subset of watersheds to describe the status and trend of all watersheds that meet the minimum criteria (>25 percent federal ownership) in the Plan area. Local units can use this same sample design to select sampling sites.

Field Survey Protocols

A thorough review of attributes identified in Reeves et al. (2004) was conducted to identify attributes that did not provide meaningful information, and to look for efficiencies in collecting data. The provincial specialist team's recommendations for which attributes should be included in the decision-support models were used as an initial screen for determining which attributes should continue to be collected. Data variability was also examined and sampling protocols were examined to determine if less time-consuming methods could be used for each attribute.

Concurrent with looking for sampling efficiencies, core attributes shared between the PacFish/InFish Biological Opinion (PIBO) monitoring effort and the aquatic and riparian effectiveness monitoring program were standardized prior to the 2004 field season to enable sharing of data to answer questions across all federal lands in the Pacific Northwest. Even though PIBO has different objectives for monitoring in the interior Columbia River basin, it includes similar survey attributes. Therefore, we reviewed historical data for both programs and compared performance of the different protocols in order to select the "best performing" protocol. These protocols were also designed to be consistent with the *Aquatic Ecological Unit Inventory Technical Guide* (Hixson et al. 2004). This guide is being used to create standards for characterizing aquatic resources on all national forests.

Decision-Support Models

The successful completion of decision-support models for each of the Plan's aquatic provinces provides a template for assessing watershed condition at any scale. This analysis method also makes it easy to add new information to improve the models. Future iterations of the models will incorporate advances in determining relationships among physical, biological, and chemical attributes and their effect on watershed condition. Program personnel are available to advise on applying the models at the forest, district, or even individual watershed scale.

Products Produced by the Monitoring Program

Numerous products produced by monitoring program personnel are now available for use by managers and field personnel.

Data Summaries for Local Units

Annual reports are sent to all the Forest Service and Bureau of Land Management (BLM) units where watersheds are monitored in a given year. Report data include digital photos with their spatial locations, and summaries of stream survey information. Raw data (provided upon request) are being used by fish biologists to assess restoration opportunities and priorities and to provide information for watershed analyses. Annual reports and data will be available on our Web site (http://www.reo.gov/monitoring/watershed/), starting with the 2004 field data.

Annual Technical Reports

Annual technical reports provide a road map of the monitoring program's accomplishments and changes to the program. These reports are posted on our Web site (http://www.reo.gov/monitoring/watershed).

Quality Assessment Program

We developed and implemented a field-data quality assessment program that can be easily implemented by other programs collecting field data. Our program meets criteria established in the Environmental Protection Agency quality control and quality assessment guidelines. Our field data quality assessment program has several components including training of field crews, data collection procedures, remeasurements of field indicators, data-checking procedures, and database quality control.

Field Maps

Maps we create for our field crews are available on our Web site for use by local unit managers and specialists. Area maps and watershed maps both show land ownership, road networks, stream networks, and watershed boundaries. The area maps are based on the most recent local forest or resource area map with the watershed boundary overlaid, whereas the watershed maps focus on the watershed surveyed and have the best local roads layer, ownership boundaries, topography, and the sample sites. Additionally, all data collected in the field is geo-referenced and therefore useful in ArcGIS applications outside the scope of the program.

Protocols to Prevent the Spread of Invasive Species

We proactively worked with federal, state, and tribal specialists to develop protocols to prevent the spread of invasive aquatic species and disease between watersheds by our field crews. Oregon Department of Environmental Quality experts concurred that using our techniques is the best known way to prevent the spread of New Zealand mud snails (*Potamopyrgus antipodarum*), Port Orford cedar root rot (*Phytophthora lateralis*), and sudden oak death syndrome (*P. ramorum*). Simple and easy-to-use techniques include rinsing of wading boots and sampling gear in mild bleach solution and then in boiling water (fig. 50), and using high-pressure car washes to clean vehicles prior to traveling to a new watershed. Our protocol is posted on our Web site (http://www.reo.gov/monitoring/watershed).

Kris Fausti

Figure 50—Sampling gear was cleaned by using bleach solution and boiling water to stop the spread of invasive aquatic species and disease.

Complete Coverage of Sixth-Field Watershed Boundaries

The current version of the interagency hydrologic unit code layer mapped to the sixth-field level covering Washington, Oregon, and northern California is now available for use for analysis, mapping, and maintenance at http://hydro.reo.gov/hu.html. Although this watershed coverage was created to meet the monitoring program's need, (i.e., provide a domain of sixth-field watersheds to randomly sample watersheds from), it also delineates sixth-field watershed boundaries for use at the forest and district level.

Cooperative State, Federal, and Tribal Monitoring Efforts

Cooperative monitoring efforts between state and federal agencies are a natural extension of the monitoring program as we look for ways to reduce costs and gain a better understanding of the interaction of federal, state, and private land watershed management actions within the Plan area. The monitoring program team leader initiated bringing together state agency representatives from Washington, Oregon, and California in 2001 to explore how to reduce monitoring costs by sharing data. This effort evolved to include tribal and Idaho agency representatives and is now known as the Pacific Northwest Aquatic Monitoring Partnership (hereafter referred to as the partnership).

Support for the partnership continues to build, as shown by the signing of a charter by 15 state, federal, and tribal executive signatories to date. Charter agencies also agreed to fund a full-time executive coordinator. The monitoring program team leader is the leader of the Watershed Workgroup, which is currently focused on two key areas to enable agencies to share data with each other: (1) probabilistic sample design and (2) common protocols. Use of a probabilistic sample design and using attributes with standardized sampling protocols will allow data to be combined across state, federal, and tribal lands. This will ultimately allow substantial improvements in efficiency and economy of scale for status and trend monitoring.

Sample Design

A common probabilistic sample design is being developed that any watershed monitoring effort can use. This design will facilitate (1) the creation of annual data summaries and annual report cards on the condition (based on key indicators) of riverine, riparian, and watershed resources, and (2) tracking changes and trends over time at broad regional scales (e.g., state, ecoregion, and interior Columbia River basin). The proposed sample design is based on using the same generalized random tessellation sampling strategy the monitoring program currently uses to select watersheds and stream reaches for sampling. Elements of the sample design proposal include:

- **Sample framework**—The framework will establish broad level (e.g., region, state) sampling of 50 to 100 locations annually for 5 years, with some locations monitored annually and others once during the 5-year period; then repeat the cycle for the next 5 years, and so on. This design would yield data from a total of 250 to 500 locations, which could be used to make "5-year" reports. The sample sites would be spread across federal and nonfederal lands.
- **Flexibility**—The sampling design can be modified over time as we learn more about important "subpopulations" on which to focus monitoring.
- **Scalability**—The design framework would be set up to accommodate finer scale monitoring (e.g., at the forest, district, or watershed level) embedded in the broader scale design to promote data sharing.
- **Use existing sample site information**—The design will allow incorporation of existing sample sites from ongoing probabilistic sample designs, such as data collected by the monitoring program.

Common Protocols

State and federal agencies with large-scale monitoring programs have committed to participating in a side-by-side protocol comparison test in 2005.

Elements of the protocol comparison test will include:

- Identify and recommend a core set of indicators and their associated attributes and protocols that state, federal, and tribal monitoring programs use for assessing status and trends in watershed condition.
- Develop a process for determining what protocols to use (based on cost, precision and variance, trend detection capability, repeatability).
- Develop calibrations for older protocols (also known as a "crosswalk") to preserve the value of legacy data where possible.
- Recommend which physical, chemical, and biological inchannel attributes and robust protocols should be used.

Assessing Watershed Condition for All Watersheds

Determining watershed condition scores for federal and nonfederal lands over large-scale areas may become possible if sufficient data are shared among state, tribal, and federal agencies, along with completing accurate, corporate geographic information systems (GIS) data layers. For example, drivers condition scores (based on vegetation and road information) were determined for all watersheds within the Olympic National Forest and Olympic National Park (fig. 51). By sharing data with other agencies, we could potentially map the condition of all watersheds throughout the Pacific Northwest.

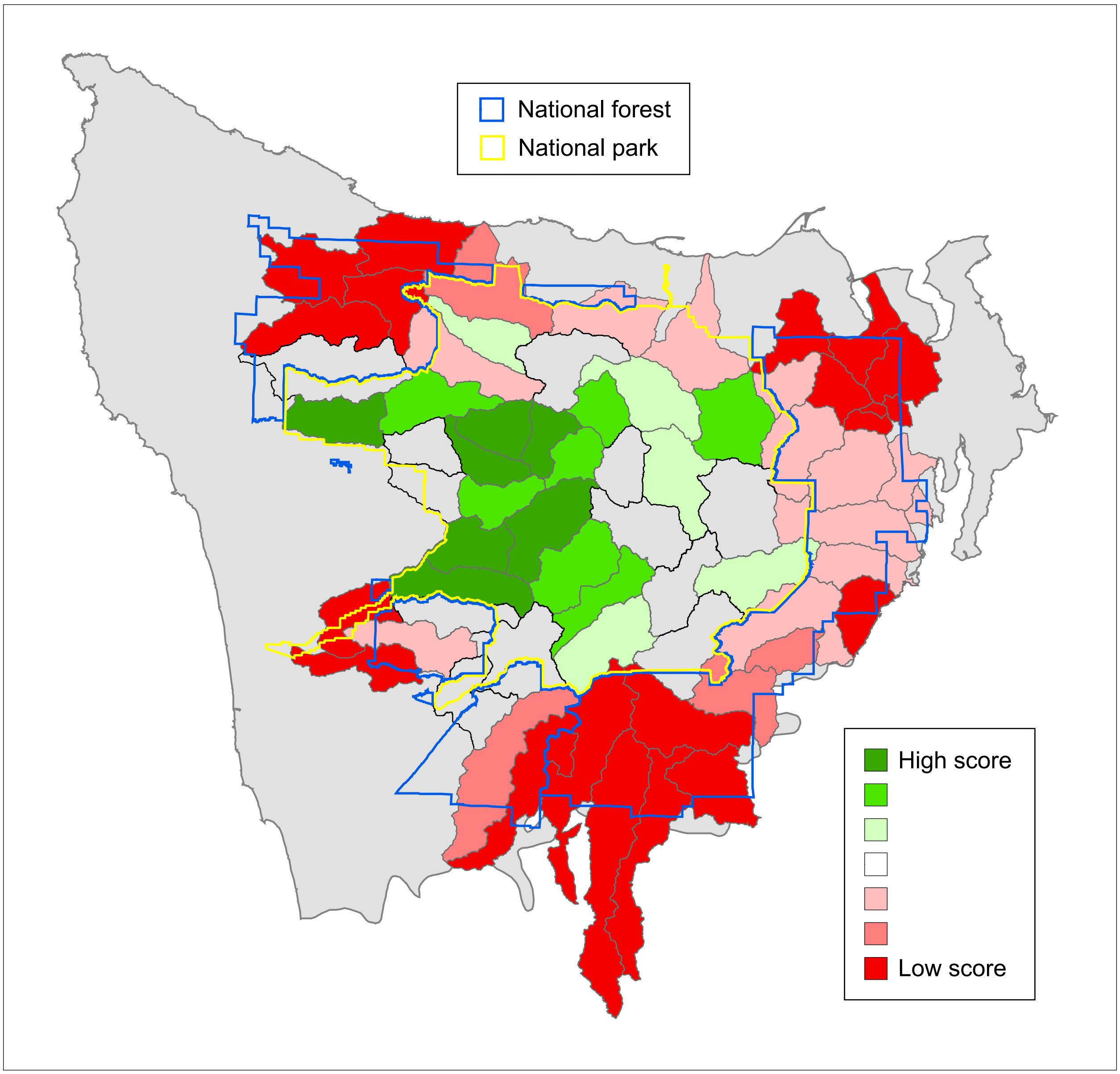


Figure 51—Drivers condition scores for all federally owned watersheds on the Olympic Peninsula. Lands are managed by the Olympic National Park and the Olympic National Forest.

Meeting Future Data Needs

The decision-support modeling process resulted in forest and district specialists identifying data needed to more accurately evaluate watershed conditions. The following additional data needs will improve both the monitoring effort and more localized monitoring efforts.

Better Tracking of Road Improvements

We currently evaluate the effect of roads on watershed condition by using a rather simplistic approach because of the lack of corporate road data. The only road information available is whether a road is present or it has been decommissioned (and is therefore assumed to be benign with respect to sediment delivery to streams). Therefore, decommissioned roads are the only "road improvements" tracked in federal agency databases. However, the term "decommissioned" can be applied to a road that has been closed by a gate or a tank trap, or to a road that has been obliterated. Because other road condition improvements (e.g., outsloping, water bars, drivable fords, hardening surfaces) can also reduce sediment delivery, we are working with Pacific Northwest Research Station scientists to recommend additional road attributes that should be tracked in federal agency databases. Availability of these data will allow future decision-support models to better reflect the effects of roads on watersheds and allow managers to take credit for those improvements. Opportunities and recommendations for how to meet these data needs are detailed in an Information Management Report (Palmer et al., in press).

Landslide Assessments

Monitoring program personnel are leading a multiagency effort to determine the relationship between landslides and topographic features in order to identify areas that have high risk for landslides (fig. 52). The results of this effort will be used in decision-support models to help determine the relationship between management activities (harvest and roads) and frequency of landslides. These results will also provide a valuable watershed analysis tool for land managers.

USDA Forest Service

Figure 52—Landslides are a natural process that brings wood and sediment to streams. However, excessive landslides caused by management activities (harvest and roads) can be detrimental to stream habitat.

Using Biological Data to Assess Watershed Condition

The monitoring program is unique because of the diverse biological information we collect for fish, aquatic and terrestrial amphibians, macroinvertebrates, and periphyton (fig. 53), along with inchannel physical and chemical attributes. A partnership of Pacific Northwest Research Station scientists, university specialists, and monitoring program specialists is examining the monitoring program's biological data to determine (1) what biological species and associated metrics are most valuable for determining watershed condition and (2) how to incorporate biological metrics into decision-support models. The results of this effort will help guide forest and district biologists in interpreting their own biological data.

Exploring New Cost-Effective Technologies

Efforts are underway to find more cost-effective methods for collecting data about watersheds. For example, new technologies such as LIDAR (Light Distance and Ranging–aerial flights with lasers) are being explored as a mechanism for collecting information on vegetation (upslope and riparian), roads (existing, decommissioned, and lost), landslides (volume and direction of movement), and stream channel morphology (gradient, sinuosity, and bankfull width).

Brian Neilson

Steve Lanigan

Steve Lanigan

Figure 53—Fish, aquatic and terrestrial amphibians, macroinvertebrates, and periphyton will be used to develop metrics describing the biological health of watersheds.

Reconciling Sample Design With Funding Limitations

The general technical report that guides the monitoring program recommends sampling a minimum of 50 watersheds a year over a 5-year repeat cycle for a total of 250 watersheds (Reeves et al. 2004). This design was intended to balance our ability to estimate status in the greatest number of watersheds with the repeat sampling required to assess trend. Reeves et al. (2004) also recommend convening a group of survey statisticians to develop a final sampling design that accounts for budgetary and other constraints under which the program is implemented.

The original estimate of the costs to fully implement the monitoring program was $1.8 million each year. Thus far, funding has allowed us to sample about 25 watersheds each year, including resampling one site per watershed as part of our quality assurance/quality control (QA/QC) program and the sampling of "trend sites" (revisits to QA/QC sites sampled the previous year). Expected declines in overall USDA Forest Service and USDI Bureau of Land Management budgets for 2005 and 2006 make any dramatic increases in funding to the monitoring program unlikely.

Given budget constraints, monitoring program personnel are working with statisticians and scientists from the U.S. Environmental Protection Agency, U.S. Geological Survey, and USDA Forest Service Pacific Northwest Research Station to review 3 years of cost and attribute data to determine the best type of sample design to use given probable funding levels and also to determine which attributes provide meaningful status and trend data. Five options are presented for the future monitoring program structure. We will conduct analysis of the data collected by the monitoring program to date to assist in selecting an option. Selection will be based on the cost to implement the option, the time it will take to detect changes in the condition of watersheds, and the power to detect changes. The results of the assessment will be published in a general technical report.

Option 1—Field-based program that relies heavily on detailed stream channel measurements that will be conducted in 25 watersheds per year.

In this option, the current program structure will remain largely unchanged. An evaluation of the attributes and sampling protocols will be conducted, and attributes will be dropped and protocols simplified when possible.

Pros

- Little change will be required to the sampling protocol, training program, or decision-support model.
- No loss of data owing to changed protocols.
- High-quality field data will be produced across a large spatial scale that can be used by managers for watershed analysis and Endangered Species Act consultation.

Cons

- Assessing baseline condition of 250 watersheds will take 10 years instead of 5.
- Time required to measure trend will increase.

Option 2—Field-based program that relies heavily on stream channel measurements that will be conducted in 50 watersheds.

In this option, the current monitoring program will be scaled back in order to sample 50 watersheds. Several alternatives exist for scaling back, including:

- Sampling seventh-field rather than sixth-field watersheds, assuming fewer sites will be needed to characterize seventh-field watersheds.
- Sampling fewer sites in watersheds.
- Sampling fewer inchannel attributes.
- Decreasing the level of detail of the inchannel sampling.
- Reducing the data quality assurance program.
- Reducing the number of trend sites revisited each year.
- Using data collected by other programs where available (and quality is known).

Steinacher Road, Six Rivers National Forest, California

Road decommissioning—
Six Rivers National Forest, in cooperation with the Karuk Tribe of California, decommissioned 7.3 mi of the Steinacher Road. This 30-year-old road was identified as the highest priority for decommissioning in a spring Chinook (*Oncorhynchus tshawytscha*) recovery plan because sediment from the road was being deposited in Steinacher Creek, Wooley Creek, and the Salmon River. All these rivers provide spawning, rearing, and migration habitat for coho (*O. kisutch*) and chinook salmon, as well as steelhead (*O. mykiss*) and native trout.

A partnership consisting of a private foundation, and tribal, state, and federal agencies contributed funding for this project.

The Karuk Tribe also initiated a comprehensive watershed restoration training and implementation program for tribal members and staff. Sixteen Karuk tribal members were trained in heavy equipment application, prescription planning, surveying, and supervision of project sites. This workforce participated in the Steinacher Road decommissioning work and will help decommission more than 65 mi of road in the East Ishi Pishi watershed area. Contact Jerry Boberg (jboberg@fs.fed.us) for more information.

Adam Dresser

Road decommissioning efforts included removing 200,000 yd^3 of fill material.

The pros and cons of this option depend on which of the alternatives are selected to scale back the sampling program.

Pros

- Able to sample 50 watersheds.
- Use of data collected by other programs will facilitate sharing of data among agencies.

Cons

- Sampling fewer sites in a watershed will reduce our ability to characterize watershed condition with respect to inchannel attributes.
- Decreasing the level of detail in the sampling could result in data useful only to the Aquatic and Riparian Effectiveness Monitoring Plan and not to managers or other programs.
- Changing sampling protocol could result in the loss of data collected in previous years.
- Reducing the data quality assurance program could result in collecting lower quality data or in the inability to describe the quality of the data.
- Reducing the number of sites revisited will increase the time required to detect trend.

Option 3—GIS/remote sensing-based program that relies on upslope and riparian indicators as surrogates for watershed condition.

In this option, relationships between attributes such as vegetation, roads, and landslides that can be evaluated by using GIS or remote sensing techniques and watershed condition will be developed. When the relationships are known, these indicators will be used as surrogates for watershed condition. Field sampling will be reduced to validation of the relationships and the GIS layers.

Pros

- Will be able to sample 250 watersheds easily, and could potentially sample all watersheds in the Plan area.
- The relationships between upslope/riparian attributes and watershed condition could help managers make decisions about management activities because they will have a clearer understanding of the consequences (positive or negative) of the proposed management action.

Cons

- Will have to spend money up front updating/improving GIS layers (especially road and stream layers).
- Have to develop relationships between upslope/riparian attributes and watershed condition. We may have to collect additional inchannel data before this can be done.

Option 4—Coordinate monitoring efforts with other federal and state agencies to enable the sharing of data and reduce overall costs.

In this option, state, federal, and tribal monitoring groups would agree to use a common probabilistic sampling design and standardized protocols for a core set of attributes. This will allow each agency or group to answer questions at the appropriate scale for the questions being asked, while contributing data to other monitoring efforts.

Pros

- Will result in greater precision by increasing the amount of data available to each agency.
- Alternatively, it would allow agencies to reduce individual data collection efforts by supplementing their data with data collected by other agencies, while still maintaining the current level of precision.
- Allows data to be aggregated at multiple spatial scales.
- The Pacific Northwest Aquatic Monitoring Partnership is working to make this a feasible option.

Cons

- It is dependent on monitoring programs agreeing to use a common probabilistic sampling design.
- It is dependent on monitoring programs agreeing to use the same protocols for a core set of attributes.
- There is a need to determine how to effectively share data among monitoring programs.
- Standardizing protocols may make it more difficult to answer questions for a specific project.
- Using other agencies' data may result in a watershed's reach condition being determined by only one or two sampled reaches.
- The entire set of attributes used in the decision-support model is not collected by other agencies.

Option 5—Use models to estimate the historical range of variability of vegetation condition and mass wasting across the Plan area. Use this distribution as the "desired" distribution and assess the differences (if any) between the current distribution and the desired distribution.

In this option, we would use models such as those developed by Wimberly et al. (2000) and USDA Forest Service (2002) to estimate the historical range of variability of forest conditions and landslide rates. The monitoring program would rely on GIS to determine whether the current conditions deviate from the desired distribution.

Pros

- Will be able to sample 250 watersheds easily, and could potentially sample all watersheds in the Plan area.
- We will have a desired distribution or a goal to work toward achieving with our land management strategies.

Cons

- Will have to spend money up front updating/improving GIS layers (especially road and stream layers).
- Models that describe the historical range of variability have been developed and validated for the Oregon coast area only. We would need to expand these models or build new ones to describe the entire Plan area.

Eliminate redundant attributes—
Gallo et al. (2002) searched for correlations between attributes that would allow for the reduction of attributes and/or development of models to be used in a predictive sense. Little correlation was detected beyond what was expected; e.g., average bankfull width and stream length (the former was used to determine the latter). Gallo et al. (2002) concluded that the attributes sampled were not redundant and did not recommend dropping any attributes from the sampling effort.

Simplify and eliminate protocols that do not provide needed information—
A thorough review of all protocols was done to identify attributes that were not providing meaningful information and to look for efficiencies in collecting data. The provincial specialist team recommendation for which attributes should be included in the decision-support models was used as an initial screen for suggesting which attributes should continue to be collected. Data variability was examined and protocols were examined to determine if less time-consuming methods could be used for each attribute.

Concurrent with looking for sampling efficiencies, core attributes shared between the PacFish/InFish Biological Opinion monitoring effort and the monitoring program were standardized prior to the 2004 field season to enable sharing of data to answer questions across all federal lands in the Pacific Northwest. These protocols are also designed to be consistent with the *Aquatic Ecological Unit Inventory Technical Guide* (Hixson et al. 2004). This guide is being used to create standards for characterizing aquatic resources on all national forests.

Chapter 6: Emerging Issues

Issues related to the condition of watersheds are expected to emerge as our understanding of processes affecting watershed condition evolves. These issues will be incorporated into future iterations of decision-support models as needed information becomes available. Information management considerations for each of these issues can be found in Palmer et al. (in press). The following highlights some current emerging issues.

- **Distribution of watershed condition scores**—The desired distribution of watershed condition scores was not identified by the strategy. Consequently, we are unable to determine whether goals of the strategy were achieved. This information would allow field unit specialists to determine if planned disturbances will move watershed conditions outside the range of natural variation.
- **Links between management and inchannel habitat and biological indicators**—Thus far, research has yet to determine how management activities in upslope and riparian areas affect fish and other aquatic- and riparian-dependent species.
- **Fire**—The effect of fire suppression and stand-replacing burns on vegetation and stream reach conditions is unknown. Fire condition class, which identifies how vegetation conditions have deviated from historical fire conditions, is likely to be one tool used in future iterations of the decision-support models. Fire condition class is currently being mapped for all federal lands in the Plan area.
- **Restoration projects**—A link between restoration projects and the monitoring program has yet to be established. For example, the decision-support models are sensitive only to road decommissioning, because such improvements are not tracked consistently in a database. Assigning and tracking other road attributes (such as water bar installation and culvert replacement) is needed to better reflect how roads affect the condition of watersheds. A fish-passage barrier (i.e., culverts; fig. 54) database for federal and nonfederal lands is also needed. If these data were available, decision-support models could reflect improved conditions as fish passage barriers are removed. Current efforts are underway to create a fish-passage barrier database for Forest Service lands in the Pacific Northwest.

Al Doelker

Figure 54—Culverts with steep drops at the outlet can be barriers to upstream fish passage.

- **Invasive aquatic species**—The effects of invasive and exotic aquatic species on the aquatic biotic community are usually detrimental to native species. Future biological indices used in the decision-support models will include invasive species.
- **Adequate flow**—Dams and irrigation practices have altered flow regimes in many watersheds. Altered flow regimes include changes in timing and magnitude of peak flow and dewatering that result in insufficient flow during summer.

Wind River, Gifford Pinchot National Forest, Washington

Stream restoration—

The Wind River Watershed Council, a partnership of landowners, businesses, logging companies, government agencies, conservation groups, and schools, encourages the use of land management practices that sustain and improve water quality, fish habitat, and other natural resources, while contributing to long-term economic and community sustainability within the Wind River watershed. Their efforts are focused on accelerating the recovery of riparian, instream habitat, and water quality in which native steelhead evolved. Since 1992, about 100 mi of road has been stabilized or storm-proofed, 35 mi of road has been decommissioned, 120 ac of flood plain has been reclaimed, about 600 ac of riparian area has been planted, and 4,000 pieces of large wood have been placed in 11 river mi of stream.

Progress to date—

Monitoring in Trout and Layout Creek, where most stream restoration work was done during 1995–98, showed encouraging results:

- Large wood (>12 in diameter) increased 333 percent, from 36 to 120 pieces per mi.
- Bank stability increased from 60 to 93 percent.
- Coarse and fine sediment input from eroding banks decreased by 73 percent.
- Six hundred feet of relief and side channel habitat was reconnected to the flood plain.
- Subterranean flow was reduced by 80 percent.

Brian Bair

Brian Bair

The Trout Creek old-growth channel was disconnected from the main channel in 1981 when a logjam that was thought to be a migration barrier was removed (top). The removal of the logjam initiated the main channel to down-cut and leave the old-growth channel high and dry. After a logjam was restored in 1998 (bottom), the streambed aggraded more than 4 ft and again flowed through 0.8 mi of pristine river habitat in the old-growth channel. Contact Brian Bair (bbair@fs.fed.us) for more information.

Chapter 7: Summary

Introduction

The primary objectives of this report are to describe the status of aquatic and riparian resources and changes in their condition under the Northwest Forest Plan's (the Plan) aquatic conservation strategy. We present a preliminary assessment of the condition of watersheds in the Plan area—the first quantitative assessment conducted since the Plan was implemented in 1994. The status assessment is based on road, vegetation, and inchannel data from 55 watersheds in the Plan area. The trend assessment is based on road and vegetation data from 250 watersheds.

We also present the analytical approach used to assess the condition of watersheds in the Plan area. The approach presented is based on a statistically valid sampling design that enables us to make inferences about watersheds in the Plan area, combined with a decision-support model that incorporates indicators of watershed condition in a way that is consistent and repeatable across time and space (Reeves et al. 2004).

The aquatic conservation strategy (hereafter referred to as the strategy) is a comprehensive, regionwide strategy designed to maintain, restore, and protect those processes and landforms that create good ecological conditions in watersheds, such as high-quality habitat for aquatic and riparian organisms and good water quality (FEMAT 1993). Because watersheds are dynamic systems, evaluating the effectiveness of the strategy is based on measuring changes in the distribution of watershed condition scores through time, rather than looking at average conditions. The strategy does not describe the baseline condition of watersheds nor does it define a desired distribution. Thus, we infer that if the strategy has been effective in achieving its goal of maintaining or improving the condition of watersheds, then the distribution of watershed condition scores should either stay the same through time or it should shift in a direction that indicates improvement.

Study Design

Monitoring was conducted in 250 randomly selected sixth-field subwatersheds (hereafter called watershed) that contained a minimum of 25 percent federal ownership (USDA Forest Service, USDI Bureau of Land Management [BLM], or USDI National Park Service) along the total length of the stream. The Plan area contains 2,631 watersheds, of which 1,912 contain some land that is federally owned and 1,372 have at least 25 percent federal ownership. The ownership criterion excludes about 10 percent of the federal lands in the Plan area from this analysis.

According to Reeves et al. (2004), 50 watersheds should be sampled each year for 5 years. On year 6, the watersheds sampled the first year will be revisited. Watershed monitoring officially began in 2002, although funding was about half of the amount identified as needed to fully implement the program. As of fall 2003, 55 of an expected 100 watersheds were sampled. Because of this limitation, we have data from only 22 percent (i.e., 55 of 250 watersheds) of the watersheds needed to build a baseline distribution for use in evaluating the effectiveness of the strategy. Also, none of the watersheds was sampled more than once; therefore, we have no inchannel data to support the trend analysis.

We relied on road and vegetation data from the 250 watersheds and inchannel data from the 55 watersheds that have been sampled to describe the current status of the different attributes. For the trend analysis, we relied only on the road and vegetation data in the 250 randomly selected watersheds from two periods.

Assessment of Watershed Condition

The definition of watershed condition developed by the monitoring program was based on the goals of the strategy and on guidance provided by Reeves et al. (2004). The condition of a watershed was defined as "good" if the physical attributes were adequate to maintain or improve biological integrity, including diversity and abundance of species—particularly, native or desired fish species. Specific physical attributes included intact upslope and riparian habitats that were biologically and structurally diverse and functioning properly—i.e., banks were stable, large wood was present in the stream channel, and sediment and nutrient inputs were similar to natural levels. Flows should have been adequate to maintain or improve riparian and inchannel habitat. Chemical characteristics and water temperature must have been in a range that maintained biological integrity. Further, the system should have been able to recover to desired conditions when disturbed by large natural events or by land management activities.

Decision-support models were used to assess the condition of individual watersheds by using locally relevant evaluation criteria. These models are computer-based models that capture evaluation procedures and apply a consistent decision or evaluation process across time and space. Criteria were developed by expert panels to evaluate individual data parameters. Data were compared to the criteria and given an evaluation score between -1 and 1. The evaluation score is positively related to the condition of watersheds, such that the attributes (or watersheds) in good condition should receive an evaluation score of (or near) +1. Evaluation scores for the attributes were aggregated into an overall assessment of watershed condition.

A decision-support model was built, refined, and peer-reviewed for each province (n = 7) during workshops attended by local agency professionals. Models were built at the provincial scale to account for the ecological differences that exist between aquatic provinces. For example, precipitation and the availability of water in the creeks is an important consideration on the east side of the Cascade crest and in many parts of California and southern Oregon. However, water is rarely a limiting factor in coastal watersheds.

The workshops consisted of an informal group process through which participants came to consensus on the model structure and evaluation criteria. After the workshops, models were built and run and the results returned to the workshop participants. Participants compared the results of the model to their knowledge of the condition of the watersheds and suggested refinements to the model as necessary. Changes were made to the model and the results were reevaluated.

Methods

The evaluation of upslope and riparian conditions in watersheds was tailored to specific physiographic provinces. In individual watersheds, roads and vegetation data in upslope and riparian areas were collected across the entire watershed by using geographic information systems (GIS) data sets.

Upslope and Riparian Attributes

Roads—

In each of the 250 watersheds, road density in upslope and riparian areas and the frequency of road-stream crossings were determined. For riparian road density analyses, the road layer was laid over the riparian buffer and miles of road inside the buffer were counted. Miles of road outside the buffer were used to determine upslope road density. To estimate the number of road-stream crossings, we counted road and stream intersections. Road layers were not available from 1994 when the Plan was implemented; however, current road layers identify roads that have been decommissioned. Therefore, to obtain road data from 1994 (time 1) and the present (time 2) to analyze change, we used total road miles (existing + decommissioned) as the time 1 data point and the existing roads as the time 2 data point.

Vegetation—

The GIS layers developed by the Interagency Vegetation Mapping Project (IVMP) were used in Oregon and Washington, and CalVeg in California to assess vegetation characteristics. In each of the 250 watersheds, the vegetation layer and the 1:24,000 stream layer were clipped to the watershed boundary. A fixed-width buffer was generated from the stream layer to designate the riparian area. The area outside the buffer was defined as upslope.

For change analysis, data from the IVMP or CalVeg layer were used as the time 1 (around 1996) data point. For the time 2 (2002) data, the vegetation change layer developed for the late-successional and old-growth (older forest) vegetation monitoring program (Moeur et al. 2005) was used to update the baseline IVMP or CalVeg layer. The change layers were laid over the IVMP or CalVeg layer, and the vegetation inside polygons that indicate post-1994 disturbance was classified as early seral. These change layers describe stand-replacing events resulting from harvest and fire, but they do not capture partial losses owing to thinning or surface fire, nor do the layers show tree growth.

To account for vegetation growth, we used data from the Forest Inventory Analysis and the Current Vegetation Survey plots. We calculated the average percentage of area with trees in one size class in time 1 (e.g., <20 in) that transitioned to the next size class in time 2 (>20 in) since the Plan was implemented. We calculated this percentage for each vegetation type (e.g., pinion-juniper, Douglas-fir forest) in each province. This change rate was used to calculate change factors for each watershed by using the change rate for each of the vegetation types in the watershed, weighted according to the area of the watershed covered by the vegetation type.

Inchannel Attributes

Inchannel data (physical and water chemistry attributes) were collected at three to eight randomly selected sites in each watershed. Sites are sections of the stream channel that differ in length from 175 to 525 yd, depending on the width of the channel. Sites located in unwadeable water or private land were not sampled. Field data were collected to provide information on physical and chemical characteristics of the reach. Physical habitat indicators include bankfull width-to-depth ratio and entrenchment ratio calculated from cross-sectional profiles; pool frequency, sinuosity, and gradient, calculated from longitudinal profiles; wood frequency; percentage of fine sediments; and substrate D_{50} (median particle size). Chemical data were collected for dissolved oxygen, conductivity, pH, and water temperature.

Statistical Analysis

To test for the direction of change between the time 1 and time 2 distributions, we used a one-tailed Wilcoxon signed rank test. This test examines the differences between the time 1 and time 2 condition scores for individual watersheds and determines whether more watersheds increased or decreased in condition than would be expected by chance. The Wilcoxon test is a nonparametric that does not assume a normal distribution of the data. To avoid type II error, we set $\alpha = 0.10$ in all of the analyses conducted.

Results

Results of the assessment were presented for the entire Plan area and by land use allocation, based on a poststratification of the 250 watersheds. Information on the current status of inchannel attributes was presented for the Plan area only because the number of watersheds measured (55) was not sufficient to divide into multiple land use allocation categories. The land use allocation categories presented here are the same as those identified in the Plan; however, we added a key watershed category and a nonfederal category. Watersheds were classified according to the predominant land use allocation (>50 percent of the watershed area). Condition scores range from -1 to 1, and are positively related to resource condition.

Plan Area

Current status—
Overall, condition scores for riparian attributes were lower than upslope attributes, riparian vegetation, in particular. When evaluating riparian vegetation, we looked for the percentage of the riparian area that has conifers >20 in d.b.h. In the 250 randomly selected watersheds, the riparian area with large trees ranged from 0 to 93 percent. The evaluation criteria for most of the provinces indicate that watersheds in good condition with respect to riparian vegetation have large conifers in at least 50 percent of the riparian area, and watersheds in poor condition have only 30 percent. The median value for percentage of riparian area with large conifers is 40 percent. Nearly 38 percent of the 250 randomly selected watersheds have large conifers in at least 50 percent of the riparian area. Twenty-nine percent of the watersheds have large conifers in less than 30 percent of the riparian area.

The density of riparian roads in the 250 randomly selected watersheds varies from 0 to 0.41 mi of road per mile of stream. The evaluation criteria for most of the provinces indicate that zero mi of road in watersheds suggests that the watershed is in good condition with respect to riparian roads and that watersheds with 0.1 mi of road per mile of stream are in poor condition. The median riparian road density was 0.15 mi of road per mile of stream. Nearly 4 percent of the watersheds have no riparian roads. More than two-thirds of the 250 watersheds had riparian road densities greater than 0.1 mi of road per mile of stream.

The frequency of road-stream crossings in the 250 randomly selected watersheds differs ranging from 0 to 4.2 crossings per mile of stream. The evaluation criteria indicate watersheds with no road-stream crossings are in good condition and watersheds with 1 to 3 crossings per mile of stream (depending on the province) are in poor condition. Just over 4 percent of the watersheds contain no road-stream crossings. Nearly 53 percent of the watersheds have more than 1 crossing per mile of stream, and 15 percent have more than 2 crossings per mile of stream.

Reach condition scores, which are aggregates of the inchannel attributes including wood, pools, and substrate, tended to be fairly high; fewer than 15 percent of the 281 reaches sampled had condition scores less than 0, which is the center point of the possible range of condition scores. The median reach condition score was 0.4, and about 75 percent of the reach condition scores fell in the 0 to 0.6 portion of the range.

Many of the sampled reaches had high condition scores with respect to pools; nearly 75 percent of the reaches received a condition score of 1. Substrate condition scores were also generally high. Thirty-eight percent of the sample reaches had condition scores equal to +1, which suggests that these reaches had low levels of fine sediment and median particle sizes that are suitable for spawning habitat. In contrast, 12 percent of the sample reaches had condition scores equal to -1. These reaches either had high levels of fine sediment or were scoured down to bedrock. Wood condition scores tended to be very low; nearly 70 percent of the sample reaches had scores of -1, suggesting that low levels of large wood in stream channels are prevalent throughout the Plan area.

Changes since the implementation of the Plan— Condition scores were generally higher in time 2 than in time 1; however, the magnitude of change was very small. The drivers condition score (which is the aggregate of roads and vegetation attributes) increased in 161 of the 250 watersheds (64 percent) by an average of 0.09 (SD 0.19). This level of change represents a significantly higher percentage of watersheds than would be expected if the changes were random. Of the remaining watersheds, 18 (7 percent) had drivers condition scores that were the same in time 1 and time 2, and 71 (28 percent) had scores that were lower in time 2 (table 4). The average decrease in condition scores for those 71 watersheds was 0.14 (SD 0.3). The overall net change in drivers condition score across all 250 watersheds was 0.02 (SD 0.1).

Most of the watersheds changed little during the last 10 years; however, 7 of the 250 watersheds had drivers condition scores that changed by more than 0.2 from time 1 to time 2 (4 decreased and 3 increased in condition). Wildfires that burned 31 to 55 percent of the watershed area explain the decrease in drivers condition scores. The three watersheds with higher condition scores in time 2 were targets of road decommissioning. Nine to sixteen miles of road was decommissioned in these watersheds, a significant portion of which was in riparian and hazard areas (i.e., prone to mass wasting).

The small changes in the drivers scores were largely due to higher vegetation scores in the watersheds. Two to four percent of the trees moved from a size class that was less than 20 in d.b.h. to the size class of trees greater then 20 in across the Plan area since 1994. Stand-replacing harvest in watersheds in Oregon and Washington has decreased on federal lands to 15 percent of the 1991 level. Although the area harvested in riparian areas has decreased since the implementation of the Plan, riparian harvest as a portion of total harvest remained fairly constant since 1972, with an average of 25 percent of total harvest in riparian areas of federal lands (range 17 to 35 percent over the time periods) and an average of 30 percent riparian harvest on nonfederal lands (range 23 to 36 percent). The net decrease in road miles on federal lands was about 4,300 mi, out of about 91,000 mi of road that existed in 1994. The effort was spread out across the Plan area; consequently, the miles of roads in the 250 watersheds changed very little.

Key Watersheds

Current status—

Currently, key watersheds tend to be in better condition overall than non-key watersheds. The range of riparian road densities extends from 0 to about 0.4 mi of road per mile of stream for both key and non-key watersheds. However, riparian road densities generally tend to be lower in key watersheds. Nearly half of the key watersheds have riparian road densities lower than 0.1 mi of road per mile of stream, compared to 24 percent of non-key watersheds. Road-stream crossings also tend to be fewer in key watersheds than in non-key watersheds. Just over 60 percent of key watersheds have road crossing frequency less than one crossing per mile of stream, compared with 40 percent of non-key watersheds. Just over 20 percent of the key watersheds have <30 percent of the riparian area covered by conifers greater than 20 in d.b.h., compared with 33 percent of non-key watersheds.

Changes since the implementation of the Plan—

Small shifts in the drivers, roads, or vegetation distributions were detected for key watersheds or non-key watersheds. Drivers condition scores in 74 percent of key watersheds and 48 percent of non-key increased by at least 0.1 in time 2 (table 4). Fewer than 4 percent of the watershed declined by that amount in the last 10 years in either key or non-key watersheds.

The primary difference between key and non-key watersheds was attributed to roads rather than vegetation. Not only did key watersheds have higher road condition scores than non-key watersheds at time 1 and time 2, more than twice the miles of roads were decommissioned in key watersheds than in non-key watersheds in the last 10 years. Vegetation condition scores increased more in key watersheds than non-key watersheds (table 4). Harvest rates were historically lower in key watersheds than in non-key watersheds. This trend continued after the Plan was implemented.

Land Use Allocations

Adaptive management areas—

Adaptive management areas had drivers condition scores that ranged from -1 to 0.3. The density of roads in adaptive management areas is among the highest of those on federal lands. Riparian road densities in adaptive management areas ranged from 0.07 to 0.28 mi of road per mile of stream. Eighty-eight percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0.6 to 2.0 crossings per mile of stream. Seventy-eight percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 10 to 70 percent in adaptive management watersheds. Twenty-eight percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

Small positive changes in the distribution of condition scores were detected for drivers, roads, or vegetation. Drivers condition scores increased by at least 0.1 in 72 percent of the watersheds in the last 10 years. None of the watersheds decreased in condition. The miles of roads decommissioned in adaptive management areas was the lowest of any watersheds. No decommissioning occurred in nearly 70 percent of the watersheds. Of those watersheds that did have roads decommissioned, about 1 mi was decommissioned in riparian areas and 2 mi in upslope areas. Harvest levels in adaptive management areas were low in the past 10 years. Mean harvest rates in adaptive management areas dropped from about 63 ac per watershed per year prior to 1995 to 5 ac per watershed per year after 1995.

Congressional reserves—

Drivers condition scores range from -0.8 to 1. Condition scores in congressional reserve watersheds are generally higher than all other watersheds, more than 60 percent of the congressionally reserved watersheds had scores higher than 0.5. Road densities in congressional reserves are the lowest of any of the land use allocations. Riparian road densities in congressionally reserved watersheds ranged from 0 to 0.28 mi of road per mile of stream. Fourteen percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0 to 2.2 crossings per mile of stream. Eight percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 0 to 93 percent. Twelve percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

Fifty-six percent of the watersheds had higher drivers condition scores in time 2, about 3 percent decreased in condition, and the remainder stayed the same. The average number of road miles decommissioned in congressional reserves was the lowest of any watersheds, consistent with the low road densities in congressionally reserved watersheds. Less than 0.25 mi of road was decommissioned in riparian areas and 0.5 mi in upslope areas. Harvest rates were also very low. Mean harvest areas declined from 30 ac per watershed per year to 3 ac per watershed per year.

Late-successional reserves—

Drivers condition scores in late-successional reserve watersheds were generally higher than the scores of other federally owned watersheds, with the exception of congressional reserves. About half of the late-successional reserve watersheds had drivers condition scores greater than 0. Riparian road densities in late-successional reserve watersheds ranged from 0.01 to 0.41 mi of road per mile of stream. Sixty-three percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0.02 to 4.26 crossings per mile of stream. Forty-three percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 0.4 to 92 percent in late-successional reserve watersheds. Twenty-four percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

Nearly 80 percent of the watersheds had drivers condition scores that were at least 0.1 higher in time 2 than they were in time 1. Road decommission was conducted in about 40 percent of the watersheds, at an average rate of 2.6 mi of road per watershed. These average rates were the highest of any on federal land. Harvest area was fairly high in late-successional reserves, comparable to those on matrix lands. Mean annual harvest rates declined in late-successional reserves from 67 ac per watershed per year to 11 ac after the Plan was implemented.

Matrix—

Drivers condition scores ranged from -0.9 to 0.5 on matrix lands. Matrix lands generally had low condition scores compared with other federally managed lands, about 60 percent of the watersheds had scores less than 0. Riparian road densities in matrix watersheds ranged from 0.07 to 0.33 mi of road per mile of stream. Ninety-three percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0.5 to 2.6 crossings per mile of stream. Eighty-three percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 1.2 to 83 percent in matrix watersheds. Seventeen percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

Just over half of the watersheds in matrix lands had higher drivers condition scores in time 2 than they did in time 1. None of the watersheds had lower condition scores in time 2 than they did in time 1. Road decommissioning was conducted in about 40 percent of the watersheds in matrix lands. Average decommissioning rate within these watersheds was about 2.5 mi in the last 10 years. The number of acres harvested was the highest in matrix lands when compared with the other federal land use allocations, as would be expected under the Plan. Mean harvest rate was 21 ac per watershed per year, down from over 70 ac per year prior to implementation of the Plan.

Nonfederal lands—

Drivers condition scores in watersheds that are predominantly nonfederal ranged from -1 to 0.2. Only 5 of the 45 watersheds had drivers condition scores higher than 0. Overall, nonfederal watersheds had the lowest condition scores of the land use allocation categories. Watersheds that contained more than 50 percent nonfederal lands had the highest road densities of the watersheds. Riparian road densities in nonfederal watersheds ranged from 0.05 to 0.41 mi of road per mile of stream. Ninety-six percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0.3 to 3.1 crossings per mile of stream. Eighty percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 3 to 74 percent in nonfederal watersheds. Sixty-two percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

One-third of the predominantly nonfederal watersheds had higher drivers condition scores in time 2 than in time 1. Drivers condition scores did not change in the remainder of the watersheds. The number of road miles decommissioned in the nonfederal watersheds averaged about 2, which was consistent with the average across the Plan area. More acres of timber were harvested on nonfederal watersheds than in any of the other land use categories.

In general, watersheds that are predominantly nonfederal have the lowest condition scores of all of the watersheds, notably worse than predominantly federal watersheds. The percentage of federal land appears to have little effect on drivers condition scores from the present period. Although the relationship is statistically significant, the percentage of federal ownership explains only 25 percent of the variance in drivers condition score. When land use allocation is added to the analysis as a covariate, federal ownership explains 37 percent of the variance in drivers condition scores. These results suggest that drivers condition scores are influenced by factors other than the management applied to the watershed.

Discussion

The authors of the Plan recognized the complex and dynamic nature of watersheds. Human activities in the past century have altered the processes that create healthy ecosystems (Bisson et al. 1992, Naiman et al. 2000). These processes occur on the scale of decades or centuries. Given the temporal scale of these ecological processes and that degradation of watershed processes has probably occurred gradually for decades, it is unlikely that restoration activities will restore habitat in a short period (Larsen et al. 2004). From this perspective, it is not surprising that changes observed here in the roads and vegetation were very small, except in a few watersheds.

Most of the watersheds had higher condition scores in time 2 than in time 1 across the entire Plan area and in each of the land use allocations except nonfederal. Relatively few watersheds decreased in condition. Given that (1) the growth rate of trees exceeded harvest rates, (2) more roads were decommissioned than were constructed, (3) the watersheds that had large increases in drivers condition scores were all targets of road decommissioning, and (4) those watersheds that had lower condition scores were all exposed to wildfire (and not management activity), it appears that the strategy has had positive effects on the condition scores of watersheds in the Plan area. Further, over 70 percent of key watersheds, which were supposed to have first priority for restoration activities, increased in condition. Less than 50 percent of the non-key watersheds increased in condition.

Currently the watershed condition evaluations include only road construction and decommissioning and tree growth and stand-replacing harvest or fire. Overall, road attributes are weighed more heavily in the decision-support models than are the vegetation attributes. Also, riparian attributes carry heavier weights than upslope attributes. Therefore, decommissioning roads in riparian and hazard areas will have the greatest positive effects on watershed condition scores. A reduction in the number of road-stream crossings often accompanies riparian road decommissioning, so removing a road in the riparian zone can have a large effect on the condition score. Management activities that increase the density of large (>20 in) conifers in riparian areas will also have strong positive effects on the condition of watersheds and will be a good step toward strengthening the wood input processes in these watersheds.

Implementing the monitoring program in the Plan area provided many products and insights for successful large-scale monitoring, and ideas for how to improve the monitoring program. Our first challenge was to successfully implement key components of the program including:

- Implementing a probabilistic survey design.
- Developing field survey protocols, including standardizing field protocols with the PacFish/InFish Biological Opinion (PIBO) monitoring effort.
- Developing the decision-support models.
- Implementing a data quality assessment program.
- Developing and implementing protocols to prevent the spread of invasive species.

Cooperative monitoring efforts between state and federal agencies are a natural extension of the monitoring program as we look for ways to reduce costs and gain a better understanding of the interaction of federal, state, and private land watershed management actions within the Plan area. The monitoring program team leader initiated bringing together state agency representatives from Washington, Oregon, and California in 2001 to explore how to reduce monitoring costs by sharing data. This effort evolved to include tribal and Idaho agency representatives and is now known as the Pacific Northwest Aquatic Monitoring Partnership.

The monitoring program team leader is the leader of the Pacific Northwest Aquatic Monitoring Partnership Watershed Workgroup, which is currently focused on two key areas to enable agencies to share data with each other: (1) probabilistic sample design and (2) common protocols. Use of a probabilistic sample design and using attributes with standardized sampling protocols will allow data to be combined across state, federal, and tribal lands. This will ultimately allow substantial improvements in efficiency and economy of scale for status and trend monitoring.

The general technical report that guides the monitoring program recommends sampling a minimum of 50 watersheds a year over a 5-year repeat cycle for a total of 250 watersheds (Reeves et al. 2004). This design was intended to balance our ability to estimate status in the greatest number of watersheds with the repeat sampling required to assess trends. Thus far, funding has allowed us to sample about 25 watersheds each year, including resampling one site per watershed as part of our quality assurance/quality control (QA/QC) program and the sampling of "trend sites" (revisits to QA/QC sites sampled the previous year). In light of budget constraints, monitoring program personnel are working with statisticians and scientists from the U.S. Environmental Protection Agency, U.S. Geological Survey, and USDA Forest Service, Pacific Northwest Research Station to review 3 years of cost and attribute data to determine the best type of sample design to use given probable funding levels and also to determine which attributes provide meaningful status and trend data. Five options are presented for the future monitoring program structure. We will analyze the data collected by the monitoring program thus far to assist in selecting an option. Selection will be based on the cost to implement the option, the time it will take to detect changes in the condition of watersheds, and the power to detect changes. The options include:

- A field-based program that relies heavily on detailed stream channel measurements that will be conducted in 25 watersheds per year.
- A field-based program that relies heavily on stream channel measurements that will be conducted in 50 watersheds per year.
- A geographic information system/remote sensing-based program that relies on upslope and riparian indicators as surrogates for watershed condition.
- Monitoring efforts coordinated with other federal and state agencies to enable the sharing of data and reduce overall costs.
- Using models to estimate the historical range of variability of vegetation condition and mass wasting across the Plan area. This distribution would be treated as the "desired" distribution to assess the differences (if any) between the current distribution and the desired distribution.

Issues related to the condition of watersheds are expected to emerge as our understanding of processes affecting watershed condition evolves. These issues will be incorporated into future iterations of decision-support models, as needed information becomes available. The following highlights some current emerging issues.

- **Distribution of watershed condition scores**—The desired distribution of watershed condition scores was not identified by the strategy. Historical and current watershed condition scores will allow field unit specialists to determine if planned disturbances will move watershed conditions outside the range of natural variation.
- **Links between management and inchannel habitat and biological indicators**—Thus far, research has yet to determine how management activities in upslope and riparian areas affect fish and other aquatic- and riparian-dependent species.
- **Fire**—The effect of fire suppression and stand-replacing burns on vegetation and stream reach conditions is unknown.
- **Restoration projects**—A link between restoration projects and the monitoring program has yet to be established.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Inches (in)	25.4	Millimeters
Feet (ft)	.3048	Meters
Miles (mi)	1.609	Kilometers
Acres (ac)	.405	Hectares
Square miles (mi^2)	2.59	Square kilometers
Miles per square mile	.62	Kilometers per square kilometer

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Appendix 1: Objectives of the Aquatic Conservation Strategy[1]

Forest Service and Bureau of Land Management-administered lands within the range of the northern spotted owl will be managed to:

1. Maintain and restore the distribution, diversity, and complexity of watershed and landscape-scale features to ensure protection of the aquatic systems to which species, populations, and communities are uniquely adapted.
2. Maintain and restore spatial and temporal connectivity within and between watersheds. Lateral, longitudinal, and drainage network connections include flood plains, wetlands, upslope areas, headwater tributaries, and intact refugia. These network connections must provide chemically and physically unobstructed routes to areas critical to fulfilling life history requirements of aquatic and riparian-dependent species.
3. Maintain and restore the physical integrity of the aquatic system, including shorelines, banks, and bottom configurations.
4. Maintain and restore water quality necessary to support healthy riparian, aquatic, and wetland ecosystems. Water quality must remain within the range that maintains the biological, physical, and chemical integrity of the system and benefits survival, growth, reproduction, and migration of individuals composing aquatic and riparian communities.
5. Maintain and restore the sediment regime under which aquatic ecosystems evolved. Elements of the sediment regime include the timing, volume, rate, and character of sediment input, storage, and transport.
6. Maintain and restore in-stream flows sufficient to create and sustain riparian, aquatic, and wetland habitats and to retain patterns of sediment, nutrient, and wood routing. The timing, magnitude, duration, and spatial distribution of peak, high, and low flows must be protected.
7. Maintain and restore the timing, variability, and duration of flood-plain inundation and water table elevation in meadows and wetlands.
8. Maintain and restore the species composition and structural diversity of plant communities in riparian areas and wetlands to provide adequate summer and winter thermal regulation, nutrient filtering, appropriate rates of surface erosion, bank erosion, and channel migration and to supply amounts and distributions of coarse woody debris sufficient to sustain physical complexity and stability.
9. Maintain and restore habitat to support well-distributed populations of native plant, invertebrate, and vertebrate riparian-dependent species.

[1] From page B-11 of USDA and USDI 1994.

Appendix 2: Description of Physiographic Provinces[1]

Olympic Peninsula Province

The Olympic Peninsula in northwestern Washington is a mountainous region isolated on three sides by water and on the fourth side by a region of extensively harvested state and private lands. Streams flow outward from a central core of rugged mountains onto gently sloping lowlands. Landforms have been influenced by glaciation; main rivers flow in broad, U-shaped valleys, and peaks are surrounded by cirques. Steep slopes developed on resistant rocks are subject to narrow, shallow, rapid landslides (debris flows) originating from the heads of stream channels. Debris flows commonly scour steep tributary streams and deposit debris in fans on the valley floors. Unconsolidated glacial deposits are subject to accelerated streambank erosion and landslides.

Vegetation and climate on the peninsula include a mixture of coniferous rain forests on the western slopes of the Olympic Mountains and relatively dry Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests in the rain shadow on the eastern slopes.

The Olympic National Park occupies the interior of the Olympic Peninsula. It is surrounded by the Olympic National Forest, which is surrounded by extensive areas of private land, Indian reservations, and state-owned lands. Much of the Olympic National Park consists of high-elevation forests and subalpine areas, but lowland valleys in the park contain significant areas of late-successional and old-growth forest (older forest). A fragmented mixture of clearcuts, young plantations, and natural forests ranging from young stands to stands more than 500 years old characterizes the Olympic National Forest. The southern edge of the forest includes an extensive area referred to as the Shelton Sustained-Yield Unit, which was largely clearcut between 1960 and 1985. The forest includes several small wilderness areas on the east slope of the Olympic Range adjacent to the park. Most private, state, and Indian reservation lands on the peninsula have been clearcut in the last 80 years. Some of these areas are now being clearcut for the second time.

North Cascades Province

The North Cascades exhibit extremely high relief in comparison to other provinces. Glaciers have carved deep and steep-sided valleys into both resistant and weak rocks. Tributaries flow at high angles into broad U-shaped valleys such as that occupied by Lake Chelan. Steep slopes are subject to debris flows from the heads of stream channels. Unconsolidated glacial and volcanic deposits are subject to accelerated streambank erosion and landslides.

On the west side of the Cascade crest, lower and middle elevation forests consist primarily of Douglas-fir and western hemlock (*Tsuga heterophylla* (Raf.) Sorg.). The higher elevations support forests of silver fir (*Abies amabilis* Dougl. ex Forbes) and mountain hemlock (*T. mertensiana* (Bong.) Carr.). Although some national parks and wilderness areas in this region include significant areas of mid-elevation older forest, most are dominated by high-elevation areas of alpine or subalpine vegetation. The area on the east side of the Cascade crest is dominated by mixed-conifer forests and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) forests at mid to lower elevations and by true fir forests at higher elevations.

Willamette/Puget Trough Province

The Willamette/Puget Trough province is typically divided into two subprovinces, the Western Washington Lowlands subprovince and the Willamette Valley subprovince. The Columbia River divides the two subprovinces. Land ownership in both subprovinces is predominantly private.

Puget Sound is a depressed, glaciated area that is now partially submerged. Unconsolidated deposits of alluvial and glacial materials are subject to accelerated streambank erosion and landslides. This area also includes extensive agricultural and metropolitan areas.

The Willamette Valley includes the lowland valley area, which lies in a broad structural depression between the Coast Range and Cascade Range in western Oregon. The Willamette River meanders northward along a very gentle valley slope. Unconsolidated deposits of alluvial

[1] Adapted from Appendix V-A in FEMAT (1993).

and glacial materials are subject to accelerated streambank erosion and landslides. This area, which was originally covered by a mosaic of lowland coniferous and deciduous forests and native prairie grasslands, was mostly cleared in the 1800s and early 1900s and converted to farmland, residential areas, and metropolitan areas. Land ownership is largely private.

West Cascades Province

The West Cascades province is distinguished from the High Cascades by older volcanic activity and longer glacial history. Steep, deeply dissected valleys separate ridge crests at similar elevations. Complex eruption materials juxtapose relatively stable lava flows and volcanic deposits that weather to thick soils and are subject to earth flows. Unconsolidated alluvial and glacial deposits are subject to streambank erosion and landslides. Tributary channels flow at large angles into wide, glaciated valleys.

This region is dominated by humid forests of Douglas-fir and western hemlock at lower to middle elevations. Forests in the southern section of the province are largely mixed-conifer forests consisting of Douglas-fir, grand fir, (*A. grandis* (Dougl. ex D. Don) Lindl.) and incense-cedar (*Libocedrus decurrens* Torr.).

Land ownerships include a mixture of private and state lands, and national forests. The Bureau of Land Management administers extensive areas in the province. Private and state lands in this area are mostly cutover, whereas federally administered lands still include significant areas (albeit highly fragmented) of older forest.

Washington/Oregon Coast Range Province

The southern part of the Washington/Oregon Coast Range province generally consists of steep slopes with narrow ridges developed on resistant sedimentary rocks. Westward flowing streams erode headward to mountain passes on the east side of the Coast Range. Many of the higher peaks are composed of resistant igneous rocks. Steep, highly dissected slopes are subject to debris flows. Tributary channels join at relatively low angles, which allows debris flows to travel for long distances. In the area drained by the Wilson and Trask Rivers in Oregon, weaker rocks form gentle slopes with thick soils that are subject to large, thick, slow-moving landslides (earth flows). Earth flows may constrict or deflect stream channels, creating local low-gradient stream reaches upstream.

The Washington portion of the province, which extends south from the Olympic Peninsula to the Columbia River, consists of a mixture of recent clearcuts and young stands on cutover areas. Forests on cutover areas are dominated by even-aged mixtures of Douglas-fir, western hemlock, and red alder (*Alnus rubra* Bong.). The Oregon portion of the province extends from the Columbia River south to the Middle Fork of the Coquille River. This area is dominated by forests of Douglas-fir, western hemlock, and western redcedar (*Thuja plicata* Donn ex D. Don).

The Washington portion of the province is largely in state and private ownership and has been almost entirely clearcut in the last 80 years. The Oregon portion includes a mixture of private, Forest Service, and Bureau of Land Management lands. The northern half is largely in private and state ownership. Heavy cutting and several extensive wildfires during the last century have eliminated most of the older forests in northern Oregon. Older forests in southern Oregon are highly fragmented, especially on Bureau of Land Management lands, which are typically intermixed with cutover private lands in a checkerboard pattern of alternating square-mile sections. Before the advent of fire suppression, the southern portion of the province was subject to frequent fires. As a result, many of the remaining natural forests consist of a mosaic of mature stands and remnant patches of older trees.

High Cascades Province

The High Cascades province consists of volcanic landforms with varying degrees of glaciation. Lava flows form relatively stable plateaus capped by the recent Cascade volcanoes. Drainages are generally not yet well developed or otherwise disperse into highly permeable volcanic deposits. Geologically recent volcanic deposits are subject to large debris flows when saturated by snowmelt.

Silver fir and mountain hemlock forests are found at high elevation in the Washington and Oregon portions of the province. Although some national parks and wilderness areas in this region include significant areas of mid-elevation older forest, most encompass high-elevation areas. Mixed-conifer and ponderosa pine forests are at mid to lower elevations. In California, mixed-conifer or ponderosa pine associations dominate forests.

Land ownership patterns include a mixture of Forest Service, private, state, Indian, National Park Service and Bureau of Land Management lands. Forests in this region are highly fragmented because of a variety of natural factors (e.g., poor soils, high fire frequencies, and high elevations) and human-induced factors (i.e., clearcutting and selective harvest). Before the advent of fire suppression in the early 1900s, wildfires played a major role in shaping the forests of this region. Intensive fire suppression efforts in the last 60 years have resulted in significant fuel accumulations in some areas and shifts in tree species composition from fire-resistant pine-dominated stands to mixed-conifer communities. These changes may have made forests more susceptible to large high-severity fires and to epidemic attacks of insects and diseases. Any plan to protect older forests in this area must include considerable attention to fire management and to the stability of forest stands.

Klamath/Siskiyou Province

The Klamath/Siskiyou province is in southwestern Oregon and northwestern California. The province is rugged and deeply dissected. Tributary streams generally follow the northeast-southwest orientation of rock structure created by accretion of rocks onto the continent. Variable materials juxtapose steep slopes subject to debris flows and gentle slopes subject to earth flows. Scattered granitic rocks are subject to debris flows and severe surface erosion. High rates of uplift have created steep streamside hillslopes known as inner gorges, especially near the coast.

Mixed-conifer and mixed-conifer/hardwood forests dominate this area. Land ownerships include a mixture of Forest Service, Bureau of Land Management, private, and state lands. Forests are highly fragmented by natural factors (e.g., poor soils, dry climate, and wildfires) and human-induced factors (such as harvest and roads). Much of the historical harvest in this area has been selective cutting rather than clearcutting. As a result, many stands logged in the early 1900s include a mixture of old trees left after harvest and younger trees that regenerated after harvest. Hillslope and channel disturbance from mining activities began in the 1850s and still continues. Much of the area in the province is characterized by high fire frequencies. Any plan to protect older forest in this province must include careful consideration of fire management.

Franciscan Province

The Franciscan province consists of the coastal strip that extends south from Coos Bay, Oregon, to Marin County, California. The province consists of accreted rocks, with structural discontinuities reflected in general stream orientations of northwest-southeast. Relatively rapid tectonic uplift has caused the dissected stream channels to become incised, creating inner gorges. Weak rocks are highly fractured along numerous faults and contacts and are weathered to deep soils subject to extensive earth flows. Sediment transport rates are among the highest in the world.

This area is dominated by redwood (*Sequoia sempervirens* (D. Don) Endl.) forests and mixed forests of Douglas-fir and hardwoods. Most of the area is privately owned, but Forest Service lands, Bureau of Land Management lands, and state and federal parks are also present. This area includes the coastal fog belt in which the last remaining stands of old-growth redwoods grow.

Appendix 3: The 250 Randomly Selected Watersheds[a]

Table 7—Watersheds and subwatersheds

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
171003030401	WA/OR Coast	Coos Bay BLM	Middle Umpqua River	Paradise Creek	55.5
171003030504	WA/OR Coast	Coos Bay BLM	Lake Creek	Upper Camp Creek	87.3
171003030701	WA/OR Coast	Coos Bay BLM	Lower Smith River	Upper Lower Smith River	54.7
171003050404	WA/OR Coast	Coos Bay BLM	East Fork Coquille	Brewster Canyon	49.6
171003050405	WA/OR Coast	Coos Bay BLM	East Fork Coquille	Elk Creek	46.5
171003050501	WA/OR Coast	Coos Bay BLM	North Fork Coquille	North Coquille	26.7
180102030101	High Cascades	Crater Lake NP	Wood River	East Fork Annie	100
170703010104	High Cascades	Deschutes NF	Deschutes River/ Charleton Creek	Snow Creek	100
170703010204	High Cascades	Deschutes NF	Deschutes River/ Browns Creek	Lower Odell Creek	100
170703010803	High Cascades	Deschutes NF	Squaw Creek	Upper Trout Creek	100
170703010907	High Cascades	Deschutes NF	Upper Metolius River	Canyon Creek	99.9
170703020203	High Cascades	Deschutes NF	Crescent Creek	Summit Creek	100
170703020204	High Cascades	Deschutes NF	Crescent Creek	Crescent Lake	100
170900020201	West Cascades	Eugene BLM	Mosby Creek	Table Mountain	38.7
170900020304	West Cascades	Eugene BLM	Upper Coast Fork Willamette	Middle Upper Coast Fork Willamette	27.6
171002060301	WA/OR Coast	Eugene BLM	Wildcat Creek	Upper Wildcat Creek	42.7
170701051002	West Cascades	Gifford Pinchot NF	Little White Salmon River	Big Lava Bed Frontal	97.8
170701051004	High Cascades	Gifford Pinchot NF	Little White Salmon River	Middle Little White Salmon River	60.3
170800020102	West Cascades	Gifford Pinchot NF	Upper Lewis River	Twin Falls Creek	100
170800020108	West Cascades	Gifford Pinchot NF	Upper Lewis River	Alec Creek	100
170800020202	West Cascades	Gifford Pinchot NF	Muddy River	Clearwater Creek	100
170800020203	West Cascades	Gifford Pinchot NF	Muddy River	Elk Creek	100
170800020401	West Cascades	Gifford Pinchot NF	Siouxon Creek	Upper Siouxon Creek	100
170800020404	West Cascades	Gifford Pinchot NF	Siouxon Creek	Cougar Creek	67.6
170800020503	West Cascades	Gifford Pinchot NF	East Fork Lewis River	Copper Creek	92.7
170800040205	West Cascades	Gifford Pinchot NF	Middle Upper Cowlitz River	Johnson Creek	99.8
170800040302	West Cascades	Gifford Pinchot NF	Lower Upper Cowlitz River	Willame Creek	99.9
170800040402	High Cascades	Gifford Pinchot NF	Upper Cispus River	Walupt Creek	99.8
170800040408	West Cascades	Gifford Pinchot NF	Upper Cispus River	Blue Lake-Cispus River	100
171100150110	West Cascades	Gifford Pinchot NF	Upper Nisqually River	Little Nisqually River	88.7
180102050102	High Cascades	Klamath NF	Mount Shasta Woods	Unnamed	68.7
180102050103	High Cascades	Klamath NF	Trapper Spring	Unnamed	77.3
180102060802	Klamath/Siskiyou	Klamath NF	Empire Creek	Humbug Creek	49.5
180102060803	Klamath/Siskiyou	Klamath NF	Empire Creek	Vesa Creek	62.5
180102060903	Klamath/Siskiyou	Klamath NF	West Fork Beaver Creek	Bear Creek	51
180102080101	Klamath/Siskiyou	Klamath NF	East Fork Scott River	Upper East Fork Scott River	33.4
180102080103	Klamath/Siskiyou	Klamath NF	East Fork Scott River	Noyes Valley	50.6
180102080203	Klamath/Siskiyou	Klamath NF	South Fork Scott River	Haynes Lake Creek	38.5
180102080402	Klamath/Siskiyou	Klamath NF	Moffett Creek	Indian Creek	52.7
180102080601	Klamath/Siskiyou	Klamath NF	Bridge Flat	Emigrant Creek	54.5
180102090203	Klamath/Siskiyou	Klamath NF	Indian Creek	East Fork Indian Creek	98.4
180102090302	Klamath/Siskiyou	Klamath NF	Elk Creek	Upper Elk Creek	100
180102090303	Klamath/Siskiyou	Klamath NF	Elk Creek	Lower Elk Creek	98.2
180102090402	Klamath/Siskiyou	Klamath NF	Clear Creek	Tenmile Creek	100
180102090501	Klamath/Siskiyou	Klamath NF	Ukonom Creek	Oak Flat Creek	96.4
180102100102	Klamath/Siskiyou	Klamath NF	South Fork Salmon River	Summerville	99.1
180102100106	Klamath/Siskiyou	Klamath NF	South Fork Salmon River	Crawford Creek	98.8

Table 7—Watersheds and subwatersheds (continued)

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
180102100401	Klamath/Siskiyou	Klamath NF	Lower Salmon River	Crapo Creek	98.7
180102111105	Klamath/Siskiyou	Klamath NF	Lower Trinity River	Big French Creek	99.6
171003020603	Klamath/Siskiyou	Medford BLM	Upper Cow Creek	Galesville	58.3
171003020801	WA/OR Coast	Medford BLM	West Fork Cow Creek	Upper West Fork Cow Creek	51.4
171003020803	WA/OR Coast	Medford BLM	West Fork Cow Creek	Elk Valley/Bobby	60.7
171003020901	Klamath/Siskiyou	Medford BLM	Lower Cow Creek	Lower West Fork Cow Creek	54.8
171003070504	West Cascades	Medford BLM	Elk Creek/Rogue River	Hawk Creek	40.9
171003070601	West Cascades	Medford BLM	Trail Creek	Upper Trail Creek	48.3
171003070701	Klamath/Siskiyou	Medford BLM	Rogue River/Reese Creek	Rogue Elk	61.1
171003070802	Klamath/Siskiyou	Medford BLM	Little Butte Creek	Lower North Fork Little Butte Creek	46.2
171003080304	Klamath/Siskiyou	Medford BLM	Evans Creek	Evans Creek	33.6
171003090203	Klamath/Siskiyou	Medford BLM	Upper Applegate River	Star Creek	87.1
171003090302	Klamath/Siskiyou	Medford BLM	Little Applegate River	Middle Little Applegate	82.8
171003090403	Klamath/Siskiyou	Medford BLM	Middle Applegate River	Humbug/Chapman	63.1
171003100403	Klamath/Siskiyou	Medford BLM	Rogue River/Kelsey Creek	Horseshoe Bend	99.8
171003100405	Klamath/Siskiyou	Medford BLM	Rogue River/Kelsey Creek	Kelsey Creek	92.3
171003110304	Klamath/Siskiyou	Medford BLM	Sucker Creek	Lower Sucker Creek	48.5
171003110503	Klamath/Siskiyou	Medford BLM	Deer Creek	Draper Creek	46.1
180102060405	High Cascades	Medford BLM	Jenny Creek	Keene Creek	53.9
180102060502	High Cascades	Medford BLM	Klamath-Iron Gate	Fall Creek	61.3
180102110603	Klamath/Siskiyou	Medford BLM	Weaver-Rush	Grass Valley Creek	60.4
180101030105	Klamath/Siskiyou	Mendocino NF	Lake Pillsbury	Anderson Creek	91.5
180101030202	Klamath/Siskiyou	Mendocino NF	Rice Fork	Lower Rice Fork	83.4
180101040103	Klamath/Siskiyou	Mendocino NF	Wilderness	Balm of Gilead Creek	100
180101040106	Klamath/Siskiyou	Mendocino NF	Wilderness	Howard Creek	88.7
180101040201	Klamath/Siskiyou	Mendocino NF	Black Butte River	Upper Black Butte River	76.2
180101040203	Klamath/Siskiyou	Mendocino NF	Black Butte River	Blue Slide Creek	94.9
180101040204	Klamath/Siskiyou	Mendocino NF	Black Butte River	Lower Black Butte River	66.3
180201160202	Franciscan	Mendocino NF	North Fork Cache Creek	Bartlett Creek	65
171100010201	North Cascades	Mt. Baker-Snoq. NF	Middle Chilliwack River	Silesia Creek	99.1
171100040104	North Cascades	Mt. Baker-Snoq. NF	Upper N. Fork Nooksack River	Glacier Creek	87.3
171100040301	North Cascades	Mt. Baker-Snoq. NF	South Fork Nooksack River	Upper South Fork Nooksack River	94
171100050603	North Cascades	Mt. Baker-Snoq. NF	Cascade River	Middle Cascade River	99.9
171100050702	North Cascades	Mt. Baker-Snoq. NF	Skagit River-Illabot Creek	Skagit River at Corkindale	64.7
171100050806	North Cascades	Mt. Baker-Snoq. NF	Baker River	Lake Shannon	51.5
171100060101	North Cascades	Mt. Baker-Snoq. NF	Upper Sauk River	Sloan Creek	100
171100060106	North Cascades	Mt. Baker-Snoq. NF	Upper Sauk River	Lower White Chuck River	100
171100060201	North Cascades	Mt. Baker-Snoq. NF	Upper Suiattle River	Suiattle River Headwaters	100
171100060203	North Cascades	Mt. Baker-Snoq. NF	Upper Suiattle River	Sulfur Creek	100
171100060303	North Cascades	Mt. Baker-Snoq. NF	Lower Suiattle River	Circle Creek	99.7
171100080102	North Cascades	Mt. Baker-Snoq. NF	North Fork Stillaguamish River	Squire Creek	37.9
171100090104	North Cascades	Mt. Baker-Snoq. NF	Tye and Beckler Rivers	Lower Tye River	74.1
171100090107	North Cascades	Mt. Baker-Snoq. NF	Tye and Beckler Rivers	Lower Beckler River	82.4
171100090201	North Cascades	Mt. Baker-Snoq. NF	Skykomish River Forks	Upper North Fork Skykomish River	100
171100090206	North Cascades	Mt. Baker-Snoq. NF	Skykomish River Forks	Lower South Fork Skykomish River	81.3
171100100102	North Cascades	Mt. Baker-Snoq. NF	North Fork Snoqualmie River	Sunday Creek	70.6
171100100303	North Cascades	Mt. Baker-Snoq. NF	Middle Fork Snoqualmie River	Taylor River	96.7
171100100402	North Cascades	Mt. Baker-Snoq. NF	Lower Snoqualmie River	South Fork Tolt River	30.7
171100130101	West Cascades	Mt. Baker-Snoq. NF	Upper Green River	Green River Headwaters	51.6
171100130102	West Cascades	Mt. Baker-Snoq. NF	Upper Green River	Twin Camp Creek	45.2

Table 7—Watersheds and subwatersheds (continued)

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
171100140104	West Cascades	Mt. Baker-Snoq. NF	Upper White River	Silver Creek	86.5
171100140105	High Cascades	Mt. Baker-Snoq. NF	Upper White River	Upper Greenwater River	100
171100140202	West Cascades	Mt. Baker-Snoq. NF	Lower White River	Clearwater River	46.1
170701050601	High Cascades	Mt. Hood NF	East Fork Hood River	Upper East Fork Hood River	100
170703060901	High Cascades	Mt. Hood NF	Tygh Creek	Upper Badger Creek	97
170800010102	West Cascades	Mt. Hood NF	Salmon River	Draw Creek	100
170800010201	West Cascades	Mt. Hood NF	Zigzag River	Still Creek	99.5
170800010501	West Cascades	Mt. Hood NF	Bull Run River	Blazed Alder Creek	98.6
170800010504	West Cascades	Mt. Hood NF	Bull Run River	Cedar Creek	98.5
170900110101	West Cascades	Mt. Hood NF	Collawash River	Upper Hot Springs Fork Collawash	100
170900110201	West Cascades	Mt. Hood NF	Upper Clackamas River	Cub Creek	100
170900110301	West Cascades	Mt. Hood NF	Oak Grove Fork Clackamas	Upper Oak Grove Fork Clackamas	32.3
170900110304	West Cascades	Mt. Hood NF	Oak Grove Fork Clackamas	High Rock Creek	100
171100150101	West Cascades	Mt. Rainer NP	Upper Nisqually River	Nisqually Headwaters	100
170200090110	North Cascades	North Cascades NP	Stehekin	Boulder Creek	100
171100050401	North Cascades	North Cascades NP	Skagit River-Gorge Lake	Fisher Creek	98
171100050502	North Cascades	North Cascades NP	Skagit River-Diobsud Creek	East Fork Bacon Creek	100
170200080102	North Cascades	Okanogan NF	Lost River	South Fork Lost River	100
170200080103	North Cascades	Okanogan NF	Lost River	Lower Lost River	99.7
170200080203	North Cascades	Okanogan NF	Upper Methow River	Rattlesnake Creek	92.1
170200080204	North Cascades	Okanogan NF	Upper Methow River	Cedar Creek	100
170200080502	North Cascades	Okanogan NF	Twisp River	South Creek	99.2
170200080703	North Cascades	Okanogan NF	Lower Methow River	Gold Creek	98
171100050104	North Cascades	Okanogan NF	Ross Lake	Devils Creek	99.2
171001010601	Olympic Peninsula	Olympic NF	Calawah River	North Fork Calawah River	63
171001020207	Olympic Peninsula	Olympic NF	Salmon River	Salmon River	30.3
171001040103	Olympic Peninsula	Olympic NF	Satsop River	Satsop River Middle Fork	34.4
171100180109	Olympic Peninsula	Olympic NF	Turner/Walkers Creek	Spencer/Marple Creek	62
171100180301	Olympic Peninsula	Olympic NF	Big Quilcene River	Upper Big Quilcene River	100
171100180701	Olympic Peninsula	Olympic NF	Hamma Hamma River	Hamma Hamma River	82.4
171100200302	Olympic Peninsula	Olympic NF	Gray Wolf River	Lower Gray Wolf River	100
171001010401	Olympic Peninsula	Olympic NP	Sol Duc River	North Sol Duc River	100
171001010402	Olympic Peninsula	Olympic NP	Sol Duc River	Head Sol Duc River	100
171001010702	Olympic Peninsula	Olympic NP	Bogachiel River	Upper Bogachiel River	98.7
171100200702	Olympic Peninsula	Olympic NP	Elwha River	Goldie River	100
180102110604	Klamath/Siskiyou	Redding BLM	Weaver-Rush	Indian Creek	31
171003070105	High Cascades	Rogue River NF	Upper Rogue River	Foster Creek	100
171003070112	High Cascades	Rogue River NF	Upper Rogue River	Lower Mill	88.4
171003070113	High Cascades	Rogue River NF	Upper Rogue River	Barr Creek	44.1
171003070203	High Cascades	Rogue River NF	South Fork Rogue River	Bessie Creek	99.3
171003070402	High Cascades	Rogue River NF	Big Butte Creek	Clarks Fork/Forbit	89
171003070403	High Cascades	Rogue River NF	Big Butte Creek	Willow Creek	64
171003070803	High Cascades	Rogue River NF	Little Butte Creek	Upper South Fork Little Butte Creek	100
171003080106	Klamath/Siskiyou	Rogue River NF	Bear Creek	Ashland Creek	88.8
171003090104	Klamath/Siskiyou	Rogue River NF	Upper Applegate River	Lower Elliott	82.9
171003090105	Klamath/Siskiyou	Rogue River NF	Upper Applegate River	Steve Fork Carberry Creek	96.6
171003090107	Klamath/Siskiyou	Rogue River NF	Upper Applegate River	Lower Carberry	82.3
171003020503	Klamath/Siskiyou	Roseburg BLM	South Umpqua River	Stouts Creek	54.4
171003020506	Klamath/Siskiyou	Roseburg BLM	South Umpqua River	Upper Shively Oshea	40.5
171003020902	Klamath/Siskiyou	Roseburg BLM	Lower Cow Creek	Middle Creek	41.4
171003030106	WA/OR Coast	Roseburg BLM	Upper Umpqua River	Yellow Creek	54.7

Table 7—Watersheds and subwatersheds (continued)

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
171003050201	Klamath/Siskiyou	Roseburg BLM	Middle Fork Coquille	Camas Valley	34.8
170900070201	WA/OR Coast	Salem BLM	Rickreall Creek	Upper Rickreall Creek	20.5
170900090503	West Cascades	Salem BLM	Upper Molalla River	Upper Molalla River	39.1
171002040402	WA/OR Coast	Salem BLM	Upper Siletz River	Lower North Fork of Siletz River	38.6
170900110601	West Cascades	Shasta-Trinity NF	Lower Clackamas River	Upper Clear Creek	32.9
180102070201	High Cascades	Shasta-Trinity NF	Grass Lake	Spring Creek	58.9
180102110102	Klamath/Siskiyou	Shasta-Trinity NF	Main Trinity River	Picayume Creek	59.1
180102110103	Klamath/Siskiyou	Shasta-Trinity NF	Main Trinity River	Little Trinity River	47.1
180102110404	Klamath/Siskiyou	Shasta-Trinity NF	Stuart Fork	Stoney Creek	71.5
180102110502	Klamath/Siskiyou	Shasta-Trinity NF	Trinity Reservoir	Lower Trinity Reservoir	61.1
180102110605	Klamath/Siskiyou	Shasta-Trinity NF	Weaver-Rush	Weaver Creek	56
180102111101	Klamath/Siskiyou	Shasta-Trinity NF	Lower Trinity River	Sailor Bar Creek	96.3
180102111104	Klamath/Siskiyou	Shasta-Trinity NF	Lower Trinity River	Little French Creek	96.9
180102120103	Klamath/Siskiyou	Shasta-Trinity NF	Upper South Fork Trinity River	Upper South Fork Trinity River	94.6
180102120204	Klamath/Siskiyou	Shasta-Trinity NF	Middle South Fork Trinity River	Indian Valley Creek	95.8
180102120302	Klamath/Siskiyou	Shasta-Trinity NF	Upper Hayfork Creek	North Fork Hayfork Creek	46.4
180102120402	Klamath/Siskiyou	Shasta-Trinity NF	Lower Hayfork Creek	Philpot Creek	81.6
180102120406	Klamath/Siskiyou	Shasta-Trinity NF	Lower Hayfork Creek	Grassy Flat Creek	94.9
180200031103	High Cascades	Shasta-Trinity NF	Squaw Creek	Lower Squaw Creek	82.1
180200031201	High Cascades	Shasta-Trinity NF	Pit Arm Shasta Lake	Potem Creek	56.7
180200040103	High Cascades	Shasta-Trinity NF	Ash Creek	Horse Creek	36.8
180200040106	High Cascades	Shasta-Trinity NF	Ash Creek	Lower Ash Creek	85.8
180200040401	High Cascades	Shasta-Trinity NF	Squaw Valley Creek	Panther Creek	39.5
180200040403	High Cascades	Shasta-Trinity NF	Squaw Valley Creek	Claireborne Creek	51.7
180200050103	High Cascades	Shasta-Trinity NF	Box Canyon	South Fork Sacramento River	68.7
180200050304	High Cascades	Shasta-Trinity NF	Lower Sacramento River	North Salt Creek	50.1
180200050401	High Cascades	Shasta-Trinity NF	Sacramento Arm Shasta Lake	Middle Salt Creek	41.5
171003050101	WA/OR Coast	Siskiyou NF	Lower South Fork Coquille	Headwaters South Fork Coquille	75.4
171003100602	Franciscan	Siskiyou NF	Rogue River	Shasta Costa Creek	99.9
171003100603	Franciscan	Siskiyou NF	Rogue River	Illahe Creek	93.3
171003110103	Klamath/Siskiyou	Siskiyou NF	East Fork Illinois River	Lower East Fork Illinois River	47.4
171003110303	Klamath/Siskiyou	Siskiyou NF	Sucker Creek	Grayback Creek	82.2
171003110603	Klamath/Siskiyou	Siskiyou NF	Illinois River/Josephine Creek	Sixmile Creek	98.4
171003110604	Klamath/Siskiyou	Siskiyou NF	Illinois River/Josephine Creek	Baker Creek	97.8
171003111101	Franciscan	Siskiyou NF	Lawson Creek	Lawson Creek	99
171003120104	Franciscan	Siskiyou NF	Upper Chetco River	Middle Upper Chetco River	100
171003120106	Franciscan	Siskiyou NF	Upper Chetco River	Boulder Creek	100
171003120501	Franciscan	Siskiyou NF	Hunter Creek	Upper Hunter	37.8
171002030204	WA/OR Coast	Siuslaw NF	Nestucca River	Niagara Creek	79.6
171002031002	WA/OR Coast	Siuslaw NF	Spring Creek/Sand Lake	Sand Creek	42.3
171002050201	WA/OR Coast	Siuslaw NF	Five Rivers/Lobster Creek	Upper Five Rivers	90.2
171002050302	WA/OR Coast	Siuslaw NF	Drift Creek	Middle Drift Creek	49.3
171002050403	WA/OR Coast	Siuslaw NF	Lower Alsea River	Middle Alsea River	78.5
171002050405	WA/OR Coast	Siuslaw NF	Lower Alsea River	Lower Alsea River	44.3
171002050704	WA/OR Coast	Siuslaw NF	Cummins Creek/Tenmile Creek	Mercer Lake	59.7
171002060501	WA/OR Coast	Siuslaw NF	Deadwood Creek	Upper Deadwood Creek	81.7
171002060602	WA/OR Coast	Siuslaw NF	Indian Creek	Lower Indian Creek	77.9
171003030704	WA/OR Coast	Siuslaw NF	Lower Smith River	Wassen Creek	80.4
171003030706	WA/OR Coast	Siuslaw NF	Lower Smith River	Lower North Fork Smith River	43.8
180101010204	Klamath/Siskiyou	Six Rivers NF	Middle Fork Smith River	Shelley Creek	89
180101010301	Klamath/Siskiyou	Six Rivers NF	South Fork Smith River	Prescott Fork	99.7
180101050201	Franciscan	Six Rivers NF	Upper North Fork Eel River	Headwaters North Fork Eel River	81.8
180102090801	Klamath/Siskiyou	Six Rivers NF	Bluff Creek	Cedar Creek	100

Table 7—Watersheds and subwatersheds (continued)

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
180102091001	Klamath/Siskiyou	Six Rivers NF	Blue Creek	Upper Blue Creek	100
180102091004	Klamath/Siskiyou	Six Rivers NF	Blue Creek	Slide Creek	93.8
180102111203	Klamath/Siskiyou	Six Rivers NF	Trinity-South Fork Tish Tang	Horse Linto Creek	95
180102111204	Klamath/Siskiyou	Six Rivers NF	Trinity-South Fork Tish Tang	Tish Tang Creek	56.3
180102120505	Klamath/Siskiyou	Six Rivers NF	Grouse-Madden	Lower South Fork Trinity River	87.4
180201160503	Franciscan	Ukiah BLM	Lakeport	Lower Scotts Creek	39
170900020101	West Cascades	Umpqua NF	Row River	Layne Creek	88
171003010103	High Cascades	Umpqua NF	Diamond Lake	Diamond Lake East	100
171003010204	High Cascades	Umpqua NF	Lemolo Lake	Thirsty Creek	100
171003010301	West Cascades	Umpqua NF	Upper North Umpqua	Warm Springs	100
171003010402	High Cascades	Umpqua NF	Clearwater	Bear Creek	100
171003010501	West Cascades	Umpqua NF	Fish Creek	Clear Creek	100
171003010801	West Cascades	Umpqua NF	Steamboat Creek	City Creek	96.8
171003011101	West Cascades	Umpqua NF	Little River	Little River Canyon	99.3
171003011104	West Cascades	Umpqua NF	Little River	Emile	84.4
171003011106	West Cascades	Umpqua NF	Little River	Upper Cavitt Creek	97.5
171003020203	West Cascades	Umpqua NF	Jackson Creek	Squaw	100
171003020302	West Cascades	Umpqua NF	Middle South Umpqua	Dumont	99.5
171003020403	West Cascades	Umpqua NF	Elk Creek/South Umpqua	Drew Creek	83.6
170200090202	North Cascades	Wenatchee NF	Upper Chelan	Fish Creek	98.8
170200090204	North Cascades	Wenatchee NF	Upper Chelan	Emerald Park Creek	98.2
170200110202	North Cascades	Wenatchee NF	Chiawa River	Middle Chiawa River	100
170200110203	North Cascades	Wenatchee NF	Chiawa River	Lower Chiawa River	92
170200110303	North Cascades	Wenatchee NF	Nason-Tumwater	Chiwaukum Creek	91.3
170200110403	North Cascades	Wenatchee NF	Icicle-Chumstick	Chumstick Creek	58.2
170300010301	North Cascades	Wenatchee NF	Middle Upper Yakima River	Swauk Creek	75.3
170300020302	High Cascades	Wenatchee NF	Tieton River	North Fork Tieton River	100
170900010106	West Cascades	Willamette NF	Upper Middle Fork Willamette	Echo Creek	73.7
170900010201	West Cascades	Willamette NF	Hills Creek	Upper Hills Creek	100
170900010303	West Cascades	Willamette NF	Salt Creek/Willamette River	Lower Salt Creek	99.5
170900010504	West Cascades	Willamette NF	Hills Creek Reservoir	Larison Creek	85.8
170900010603	West Cascades	Willamette NF	North Fork of Middle Fork Willamette	Fisher Creek	100
170900010701	West Cascades	Willamette NF	Lost Creek	Lookout Point Reservoir	72.7
170900010902	West Cascades	Willamette NF	Fall Creek	Hehe Creek	97.6
170900040102	West Cascades	Willamette NF	Upper McKenzie River	Fish Lake Creek	97.2
170900040107	West Cascades	Willamette NF	Upper McKenzie River	Upper White Branch	100
170900040201	West Cascades	Willamette NF	Horse Creek	Upper Separation Creek	100
170900040307	West Cascades	Willamette NF	South Fork McKenzie River	Walker Creek	87.1
170900040501	West Cascades	Willamette NF	McKenzie River	Quartz Creek	45.9
170900050107	West Cascades	Willamette NF	Upper North Santiam River	Boulder Creek	74.4
170900050202	West Cascades	Willamette NF	North Fork Breitenbush River	North Fork Breitenbush River	95.8
170900050203	West Cascades	Willamette NF	North Fork Breitenbush River	Humbug Creek	100
170900050301	West Cascades	Willamette NF	Blow Out Divide Creek	Upper Blowout Creek	100
170900050503	West Cascades	Willamette NF	Little North Santiam River	Gold Creek	99.9
170900060401	West Cascades	Willamette NF	Quartzville Creek	Upper Quartzville Creek	100
170900060503	West Cascades	Willamette NF	Middle Santiam River	Sixes Creek	86.2
170900060604	West Cascades	Willamette NF	South Santiam River	Falls Creek	94.3
170900060607	West Cascades	Willamette NF	South Santiam River	Owl Creek	37.1
180102030202	High Cascades	Winema NF	Klamath Lake	Threemile Creek	97.9

[a] Includes the U.S. Geological Survey hydrologic unit code (USGS HUC), the aquatic province, the national forest (NF), Bureau of Land Management (BLM) unit, or national park (NP) that manages the land, the fifth-field watershed name, the sixth-field subwatershed name, and the percentage of the total watershed area that is federally owned (FED).

Appendix 4: Model Structure and Evaluation Criteria for Each of the Provincial Decision-Support Models

Model Structures

A decision-support model was developed for each aquatic province by a team of local experts. Each provincial model includes an evaluation of watershed-scale and reach-scale attributes. These models hierarchically aggregate a number of attributes into broader indices of reach and watershed condition. The reach condition score also serves as one component of the broader watershed condition score. In this case, the reach condition score used in the watershed model is the average condition score of all the reaches in the watershed. A graphical depiction of the model structures for each province is contained in this appendix (figs. 55 through 66). Some model sections were "turned off" in this iteration because the corresponding data were not available. These unused portions of the models are indicated by gray text.

Attribute Aggregation

After each attribute datum is evaluated, the model begins to aggregate these scores together in a hierarchical fashion. The combined score is passed up to the next level in the model hierarchy, where it is combined again with results from other parts of the model. The modeling software enables a number of different aggregation functions, but we limited choice to the three simplest:

- MIN: take the minimum score from those being aggregated.
- AVE: take the average of the aggregated scores.
- MAX: take the maximum score from those being aggregated.

These functions determine whether the situation is of a "limiting factor" type, where the worst condition score determines the combined score, a "partially compensatory" situation, where scores are all counted equally, or a "fully compensatory" situation, where the best score determines the combined score.

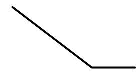
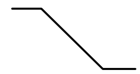
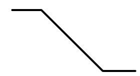
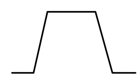
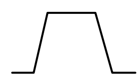
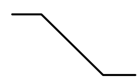
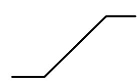
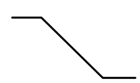
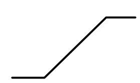
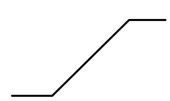
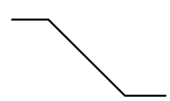
In addition to operators, each node in the model can also be assigned a weight. These weights are listed on the model structure diagrams. For example, the Franciscan/Klamath models (fig. 57) weighted riparian vegetation at 0.7 and upland vegetation at 0.3, so the overall vegetation score comes 70 percent from riparian value and 30 percent from the upland value. These weights are only relevant under the AVE operator.

Attribute Scores

A model begins by reading in a set of data observations, which we call "attributes," for a watershed. These attributes are the rightmost nodes in the model structure diagrams. For example, attributes for the Olympic Peninsula (fig. 63) include average total nitrogen and the area of watershed in urban/agricultural land uses. When the provincial experts constructed the model structure, they also developed evaluation criteria for each attribute (shown in this appendix in the tables that follow each provincial model figure). These evaluation curves determine how any particular data value is scored on a common scale from +1 to -1 according to its contribution toward overall watershed condition. As the attribute data for each watershed are read into the model, they are each compared to their respective evaluation criteria to produce an evaluation score for each between +1 and -1. For the Olympic Province, if there are no riparian roads (density = 0), then the evaluated score would be +1; if road density was 0.3 mi/mi^2 of riparian area or greater, the score would be -1; and if the density falls between 0 and 0.3 mi/mi^2, the attribute receives a score that is a linear interpolation between +1 and -1 (e.g., 0.15 mi/mi^2 would evaluate to 0). Note that there is an important difference between a data value of "zero" and "no data." Data values of zero (e.g., riparian roads example above) are compared to their evaluation curve the same as all other data values. However, if data for a particular attribute are lacking in a particular watershed, then that attribute is given an **evaluated score** of zero, representing a neutral value that does not indicate either good or poor condition.

Attributes for each province are shown in tables 8 through 13. The "attribute and measure" column contains the attribute name, units of measure, and qualifiers if any, (e.g., temperature is evaluated differently in watersheds depending on whether bull trout (*Salvelinus confluentus*) are present). "Data value" and "Evaluation score" columns show how the raw data values correspond to evaluated scores, and the "Curve shape" column gives a graphical depiction of this relationship with data values represented on the x-axis and corresponding evaluation scores on the y-axis. The "Source" column gives the basis on which the curve was constructed, most often the professional judgment of workshop participants but also including data sets and published reports or standards.

Table 8—Evaluation criteria used in decision-support model for Washington/Oregon Coast province

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
Riparian road density—164-ft buffer (mi road/mi stream)	0 0.1	1 -1		Professional judgment AREMP[a] workshop 06/23/04
Road crossing frequency (number of crossings/mi stream)	0.25 1	1 -1		Professional judgment Bob Metzger (OLY) 07/22/04
Urban/agriculture (percentage of watershed)	20 40	1 -1		Professional judgment AREMP workshop 04/01/03
Riparian vegetation, large-conifer cover—164-ft buffer (percentage of area with conifers >20 in d.b.h.)	25 50 75 85	-1 1 1 -1		Kelly Burnett dissertation AREMP workshop 04/01/03
Water temperature (maximum 7-day average, °C)				
Bull trout present	4 6 9 13	-1 1 1 -1		Oregon Department of Environmental Quality standard AREMP workshop 06/23/04
No bull trout	16 23	1 -1		Oregon Department of Environmental Quality standard AREMP workshop 06/23/04
Dissolved oxygen (mg/L)	4 10	-1 1		North Cascades workshop AREMP workshop 06/23/04
Reach model attributes				
Morphology	Rosgen-type F or G All others	-1 1		AREMP workshop 04/01/03
Pool frequency (number of bankfull widths per pool)	8 20	1 -1		ODFW benchmarks AREMP workshop 06/23/04
Pool quality (average residual pool depth in inches)	14 30	-1 1		ODFW benchmarks AREMP workshop 06/23/04
Wood frequency (number of pieces per 100 m) 0.3 × 3 m minimum	10 20	-1 1		ODFW Benchmarks AREMP workshop 06/23/04
Substrate pool-tail fines (percent)	17 11	-1 1		North Cascades workshop AREMP workshop 06/23/04

[a] AREMP = Aquatic and Effectivenesss Monitoring Program.

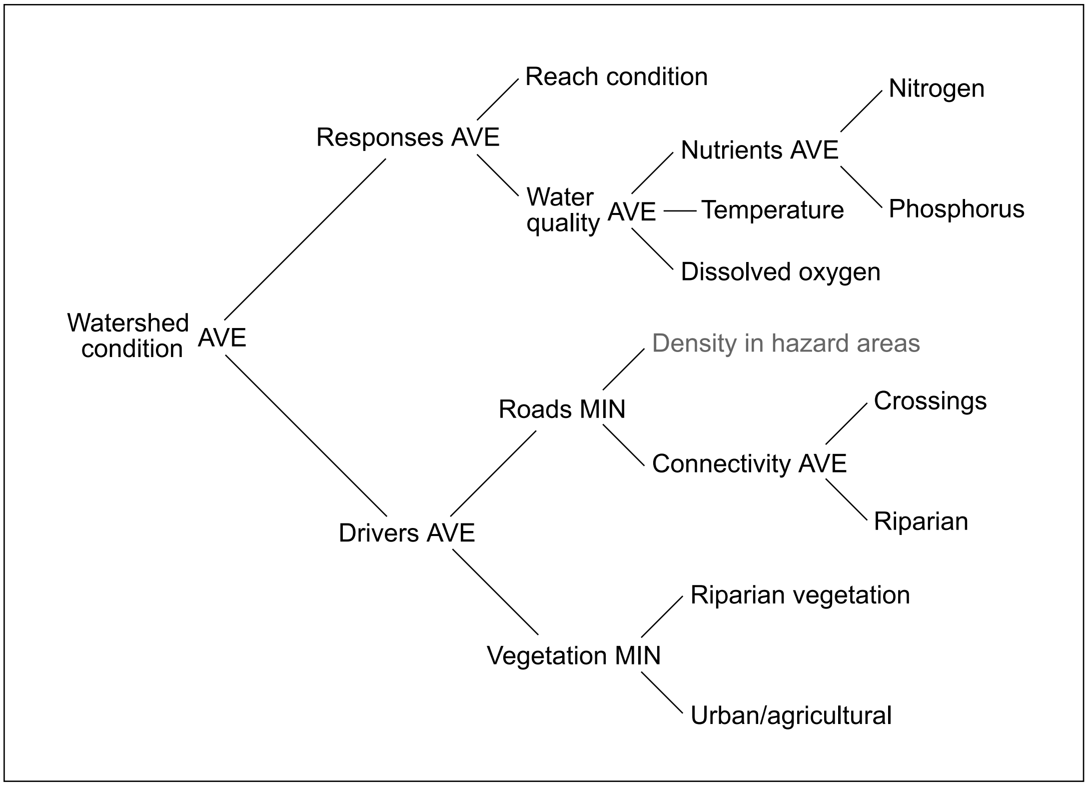


Figure 55—Watershed condition decision-support model used in the Washington/Oregon Coast province. Guidance on interpreting the figures is provided in appendix 4 text.

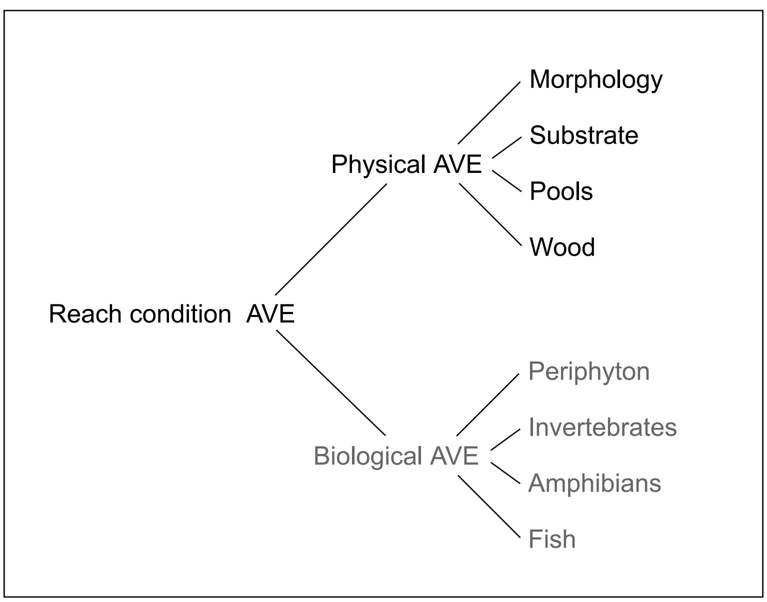


Figure 56—Reach condition decision-support model used in the Washington/Oregon Coast province. Guidance on interpreting the figures is provided in appendix 4 text.

Table 10—Evaluation criteria used in decision-support model for Klamath/Siskiyou and Franciscan provinces

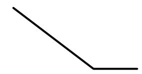
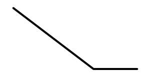
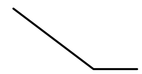
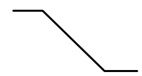
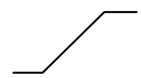
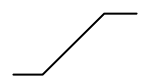
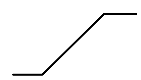
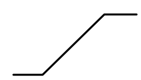
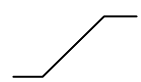
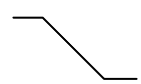
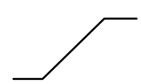
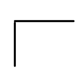
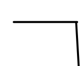
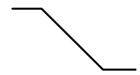
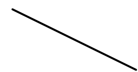
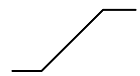
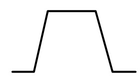
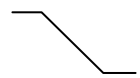
Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
Road density in hazard areas—slope >65 percent and geology sensitive to mass failure (mi road/mi^2 hazard area)	0.5 1.5	1 -1		Randy Frick[a] data
Road density in lower one-third of slope (mi road/mi^2 lower slope)	1 1.7	1 -1		Klamath NF data
Riparian road density—164-ft buffer (mi road/mi^2 riparian area)	0.5 1.5	1 -1		Klamath NF data
Road crossing frequency (number of crossings/mi stream)	1 3	1 -1		Randy Frick data
Upslope vegetation (average percentage of canopy cover)				
Coniferous forest	50 70 85	-1 0 1		Professional judgment
Oak woodland	10 40	-1 1		Professional judgment
Upslope vegetation—small conifer cover (percentage of area with conifers ≤5 in d.b.h.) Wet = precipitation >40 in; dry = precipitation <40 in	25 5	-1 1		Professional judgment
Riparian vegetation—164-ft buffer (average percentage of canopy cover)	50 70 85	-1 0 1		Professional judgment
Riparian vegetation—large-conifer cover, 164-ft buffer (percentage of area with conifers ≥20 in d.b.h.)	40 75	-1 1		Professional judgment
Water temperature (maximum 7-day average, °C)	64 68 70 75	1 0.8 0 -1		Professional judgment
Dissolved oxygen (mg/L)	4 7	-1 1		Professional judgment
Reach model attributes				
Entrenchment ratio Slope <4 percent	<2.2 >2.2	0 1		Professional judgment
Sinuosity Slope <2 percent, entrenchment >1.4	<1.5 >1.5	0 -1		Professional judgment

Table 10—Evaluation criteria used in decision-support model for Klamath/Siskiyou and Franciscan provinces (continued)

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Bankfull width:depth—slope <4 percent	15 35	1 -1		Randy Frick data
Pool frequency (number of wetted widths per pool)	10 14	1 -1		Randy Frick data
Wood frequency (number of pieces per 100 meters) 12 in small end × 25-ft minimum	1 3	-1 1		Randy Frick data
Substrate D_{50} (mm)	2 45 362 4,096	-1 1 1 -1		Professional judgment
Substrate pool-tail fines (percent)	10 30	1 -1		Professional judgment

[a] Randy Frick is a Fisheries Program Manager on the Rogue River National Forest.

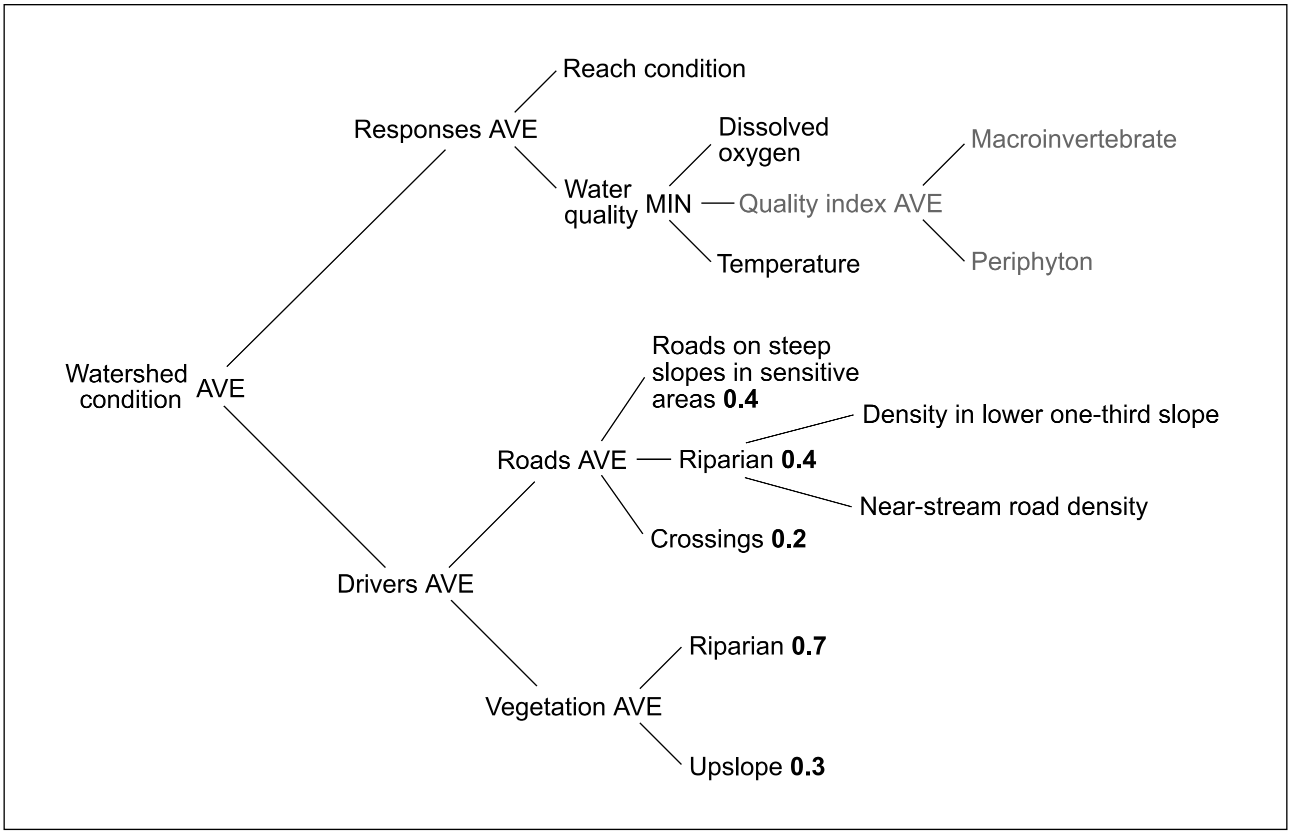


Figure 57—Watershed condition decision-support model used in the Klamath/Siskiyou and Franciscan provinces. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

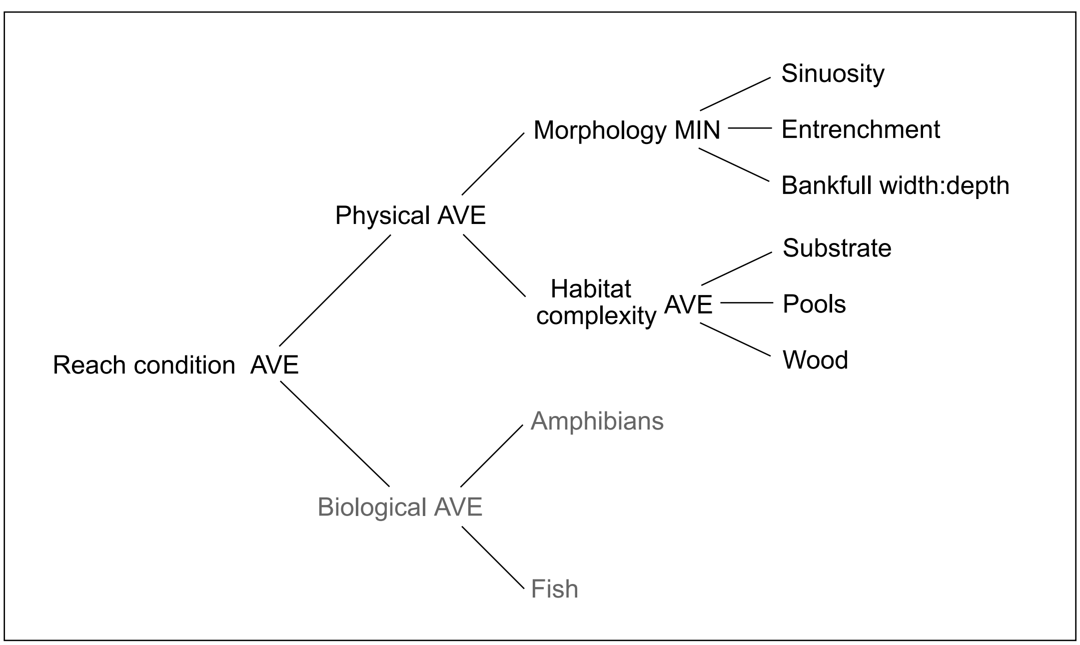


Figure 58—Reach condition decision-support model used in the Klamath/Siskiyou and Franciscan provinces. Guidance on interpreting the figures is provided in appendix 4 text.

Table 9—Evaluation criteria used in decision-support model for High Cascades province

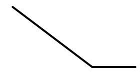
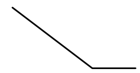
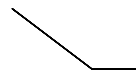
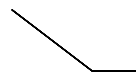
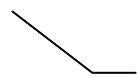
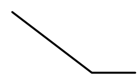
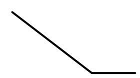
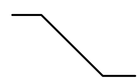
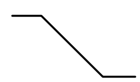
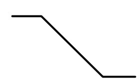
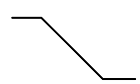
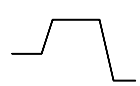
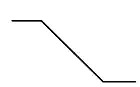
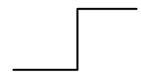
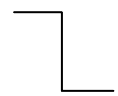
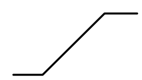
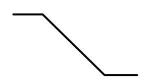
Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
High-slope road density—slope >50 percent (mi road/mi^2 watershed)				
North subprovince	0 0.5	1 -1		AREMP[a] workshop 05/22/03
Central and south subprovinces	0 1	1 -1		AREMP workshop 05/22/03
Upslope road density (mi road/mi^2 watershed)				
North subprovince only	0 4	1 -1		Dose and Roper 1994 AREMP workshop 05/22/03
Riparian road density—164-ft buffer (mi road/mi stream)				
North and south subprovinces	0 0.1	1 -1		AREMP workshop 05/22/03
Central subprovince	0 0.25	1 -1		AREMP workshop 07/07/04
Road crossing frequency (number of crossings/mi stream)				
North and south subprovinces	0 0.5	1 -1		AREMP workshop 05/22/03
Central subprovince	0 1.5	1 -1		AREMP workshop 07/07/04
Upslope vegetation—small-conifer cover (percentage of area with conifers <10 in d.b.h.)				
North and south subprovinces	10 50	1 -1		AREMP workshop 05/22/03
Central subprovince	30 70	1 -1		AREMP workshop 07/07/04
Riparian vegetation—large-conifer cover, 98-ft buffer (percentage of area with conifers ≥10 in d.b.h.)				
North and south subprovinces	30 60 80	1 0 -1		AREMP workshop 05/22/03
Central subprovince	20 60	1 -1		AREMP workshop 07/07/04
Water temperature (maximum 7-day average, °C)				
Bull trout present	3 6 9 13	0 1 1 -1		AREMP workshop 05/22/03
No bull trout	16 18 23	1 0 -1		AREMP workshop 05/22/03

Table 9—Evaluation criteria used in decision-support model for High Cascades province (continued)

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Dissolved oxygen (mg/l)	≤ 4 > 4	-1 1		
Reach model attributes				
Morphology				
Slope Entrenchment ratio Sinuosity Bankfull width:depth	Use to determine Rosgen stream type If D, F, G channel then -1, otherwise +1			Professional judgment AREMP workshop 05/22/03
Pool frequency (number of bankfull widths per pool)				
≤3 percent slope	≤15 >15	1 -1		Professional judgment AREMP workshop 05/22/03
>3 percent slope	≤12 >12	1 -1		
Wood frequency (number of pieces per 100 m)				
South of Broken Top—18 in × 50 ft North of Broken Top—12 in × 50 ft	1.5 4	-1 1		
Substrate pool-tail fines (percent)				
South of White River	20 35	1 -1		Professional judgment AREMP workshop 05/22/03
North (uses original West Cascades curve)(percent)	10 25	1 -1		Professional judgment AREMP workshop 05/22/03

[a] AREMP = Aquatic and Effectivenesss Monitoring Program.

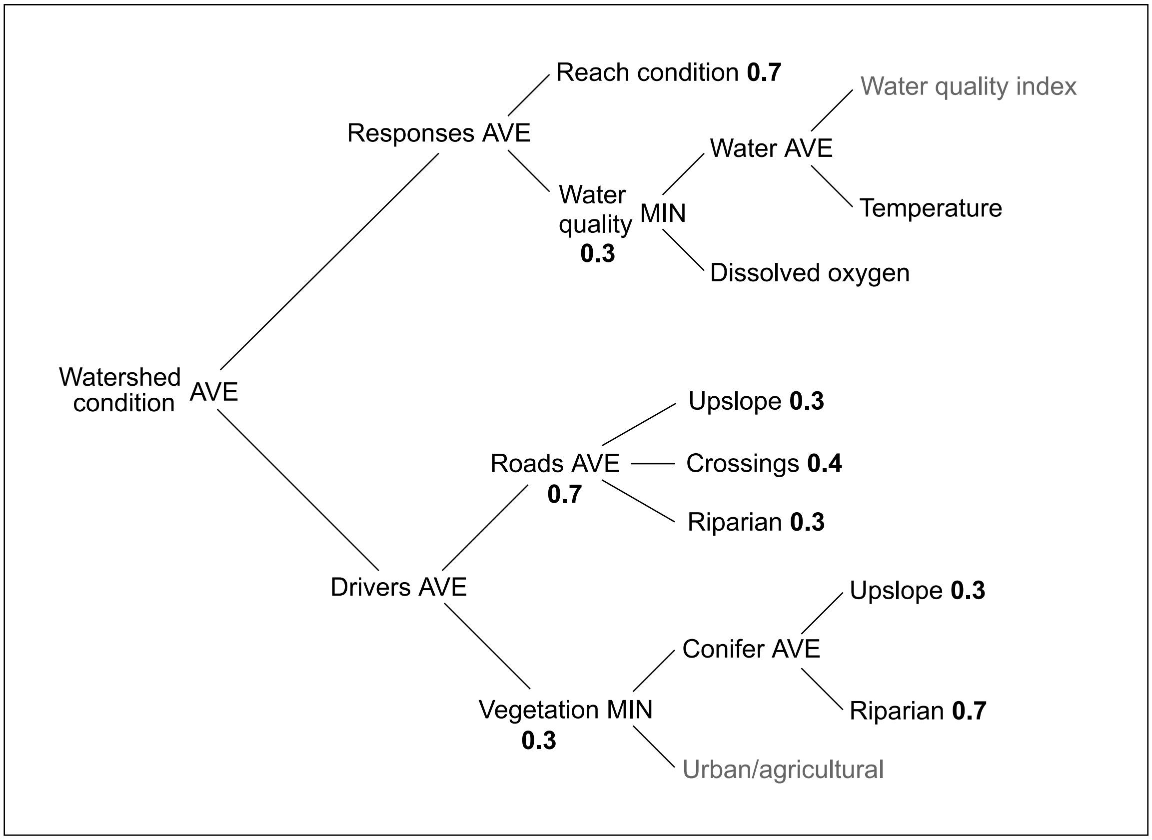


Figure 59—Watershed condition decision-support model used in the High Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

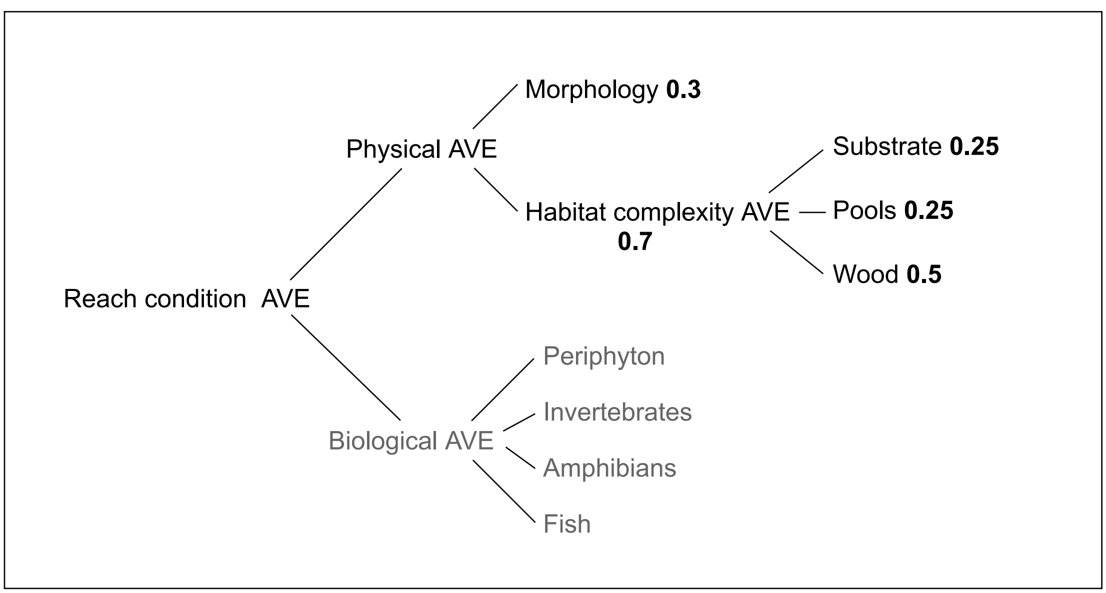


Figure 60—Reach condition decision-support model used in the High Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

Table 11—Evaluation criteria used in decision-support model for North Cascades province

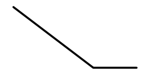
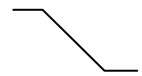
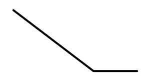
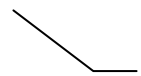
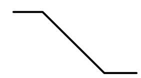
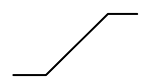
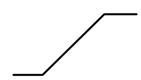
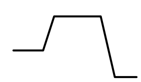
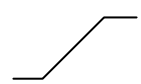
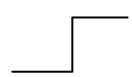
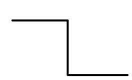
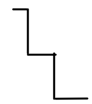
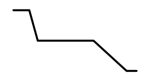
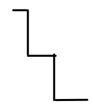
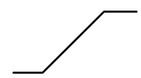
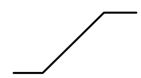
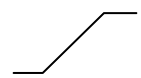
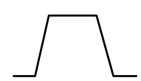
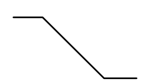
Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
Upslope road density (mi road/mi^2 watershed)	0.7 2.4	1 -1		Cederholm and Reid 1987 AREMP[a] workshop 04/28/03
Riparian road density (percentage of stream mi with road within 66 ft)	5 20	1 -1		Professional judgment AREMP workshop 07/01/04
Road crossing frequency—hazard areas (number of crossings/mi^2 watershed)	0 4	1 -1		Professional judgment AREMP workshop 04/28/03
Road crossing frequency—nonhazard areas (number of crossings/mi^2 watershed)	0 20	1 -1		AREMP workshop 04/28/03
Upslope vegetation—east side of Cascades (area-weighted average of fire condition class in mi$^{2)}$	1 3	1 -1		Professional judgment AREMP workshop 07/01/04
Upslope vegetation—west side of Cascades (percentage of area with canopy cover >70 percent)	65 88	-1 1		Workshop follow-up Gary Ketcheson[b] AREMP workshop 04/28/03
Riparian vegetation—large-conifer cover (percentage of area with conifers ≥20 in d.b.h.) 164-ft buffer—west side of Cascades 98-ft buffer—east side of Cascades	65 88	-1 1		AREMP workshop 04/28/03
Water temperature (maximum 7-day average, °C)	4 6 15 18	0 1 1 -1		AREMP workshop 07/01/04 Ken MacDonald[c] data
Dissolved oxygen (mg/L)	5 10	-1 1		
Reach model attributes				
Entrenchment ratio				
East side of Cascades	≤1.4 >1.4	-1 1		Professional judgment AREMP workshop 04/28/03
West side of Cascades	≤1.2 >1.2	-1 1		North Cascades NP data
Bankfull width:depth ratio				
East side of Cascades	≤40 >40	1 -1		AREMP workshop 04/28/03
West side of Cascades	≤55 >55	1 -1		North Cascades NP data

Table 11—Evaluation criteria used in decision-support model for North Cascades province (continued)

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Pool frequency (number of bankfull widths per pool)				
Eastside gradient >2 percent	<1 1 4 >4	1 0 0 -1		Montgomery and Buffington (1993)
Eastside gradient ≤2 percent	< 5 5 7 >7	1 0 0 -1		Montgomery and Buffington (1993)
Westside—all gradients	≤4 5 14 18	1 0 0 -1		North Cascades NP data
Wood frequency (number of pieces per 100 m)				Okanogan-Wenatchee NF data
Eastside (western subsections)—12 in × 50 ft minimum	1.6 3.1 4.5	-1 0 1		
Eastside (eastern subsections)	0.9 1.9 2.8	-1 0 1		Okanogan-Wenatchee NF data
Westside <3 percent slope—12 in × 25 ft minimum	0.5 2.5 7.5	-1 0 1		North Cascades NP data
Substrate D_{50} (mm)	20 30 100 500	-1 1 1 -1		Professional judgment AREMP workshop 04/28/03
Substrate pool tail fines (percent)	11 17	1 -1		Professional judgment AREMP workshop 04/28/03

[a] AREMP = Aquatic and Effectivenesss Monitoring Program.
[b] Gary Ketchison is a hydrologist on the Mount Baker-Snoqualmie National Forest.
[c] Ken MacDonald is a Fisheries Program Manager on the Okanogan National Forest.

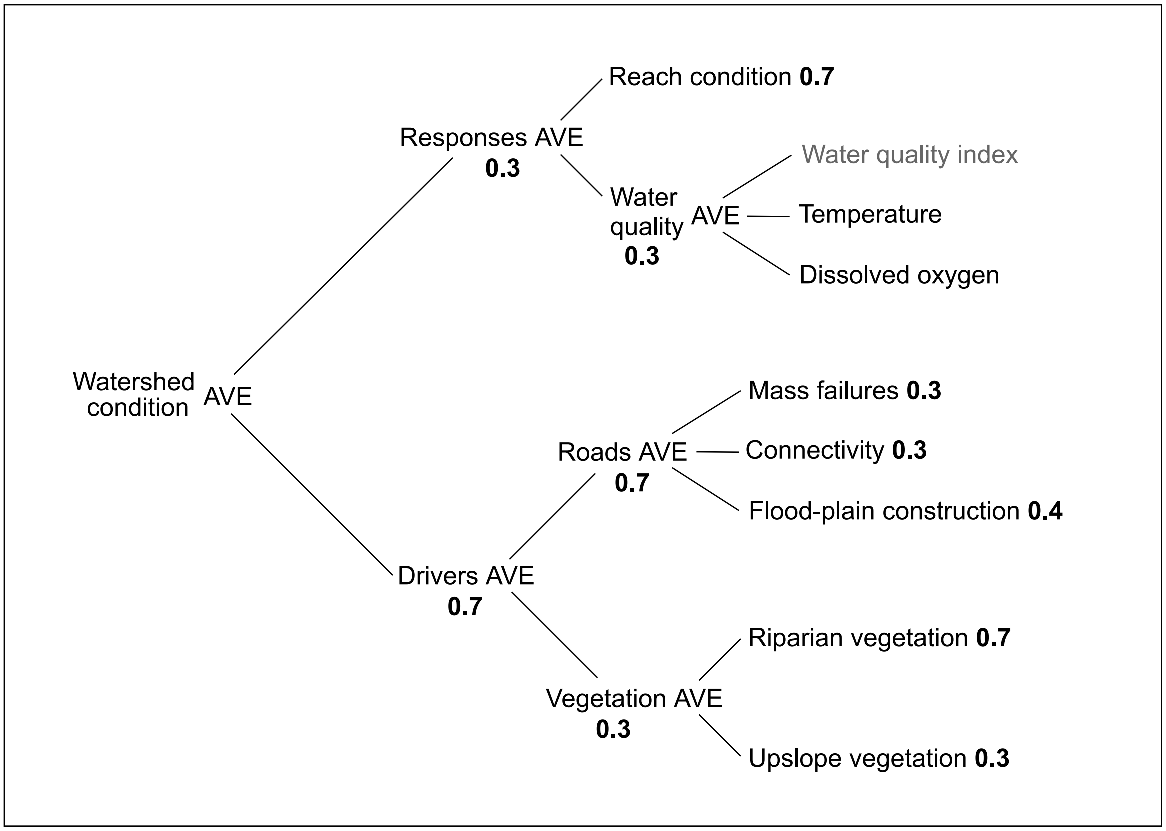


Figure 61—Watershed condition decision-support model used in the North Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

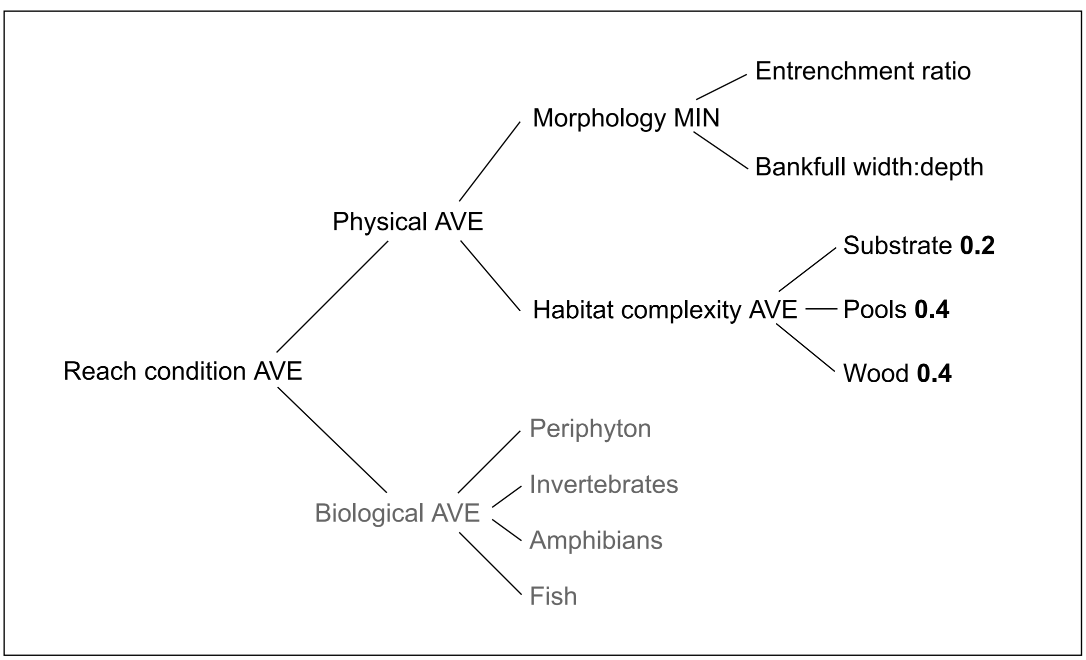
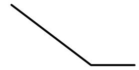
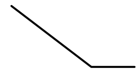
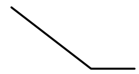
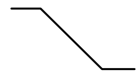
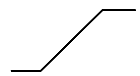
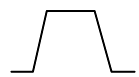
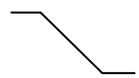
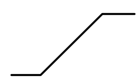
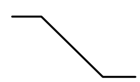
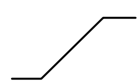
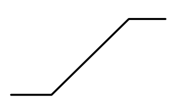


Figure 62—Reach condition decision-support model used in the North Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

Table 12—Evaluation criteria used in decision-support model for Olympic province

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
Hazard road density (mi road/mi^2 watershed)	0 0.5	1 -1		Professional judgment West/High Cascades workshop
Riparian road density (mi road/mi stream)—164-ft buffer	0 0.3	1 -1		Professional judgment Olympic/Coast workshop 1
Road crossing frequency (number of crossings/mi stream)	0 4	1 -1		Professional judgment Olympic/Coast workshop 1
Urban/agriculture (percentage of watershed)	20 40	1 -1		Professional judgment Olympic/Coast workshop 1
Riparian vegetation, large-conifer cover—164-ft buffer (percentage of area with conifers ≥20 in d.b.h.)	25 50	-1 1		Kelly Burnett[a] dissertation Olympic workshop 07/15/04
Water temperature (maximum 7-day average, °C) Bull trout present	4 6 9 13	-1 1 1 -1		Oregon Department of Environmental Quality standard
No bull trout	16 23	1 -1		Oregon Department of Environmental Quality standard
Dissolved oxygen (mg/L)	4 10	-1 1		Professional judgment
Reach model attributes				
Morphology	Rosgen type F or G All others	-1 1		Professional judgment Olympic/Coast workshop 1
Pool frequency (number of bankfull widths per pool)	8 20	1 -1		Oregon Department of Fish and Wildlife (ODFW) benchmarks
Pool quality (average residual pool depth in inches)	14 30	-1 1		ODFW benchmarks (averaged)
Wood frequency—12 in × 10 ft minimum (number of pieces per 100 m)	10 20	-1 1		ODFW Benchmarks

[a] Kelly Burnett is a fisheries biologist with the Corvallis Forestry Sciences Laboratory.

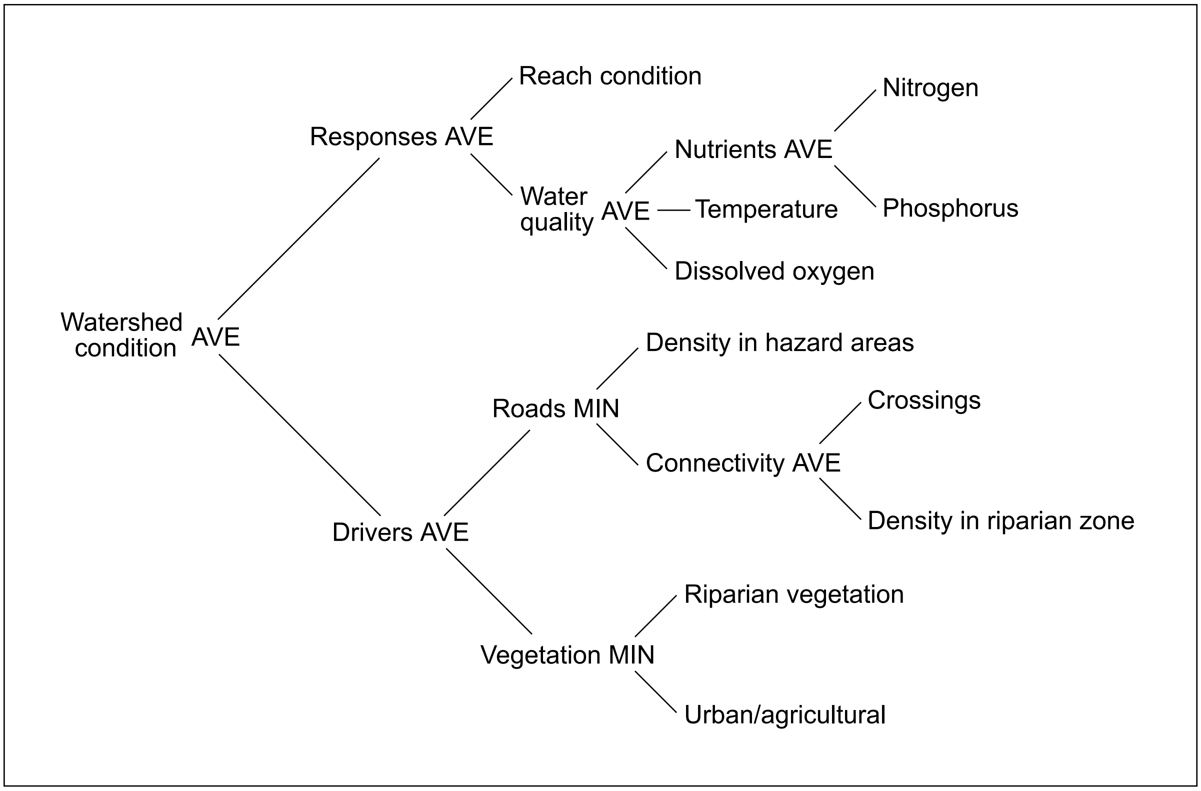


Figure 63—Watershed condition decision-support model used in the Olympic Peninsula province. Guidance on interpreting the figures is provided in appendix 4 text.

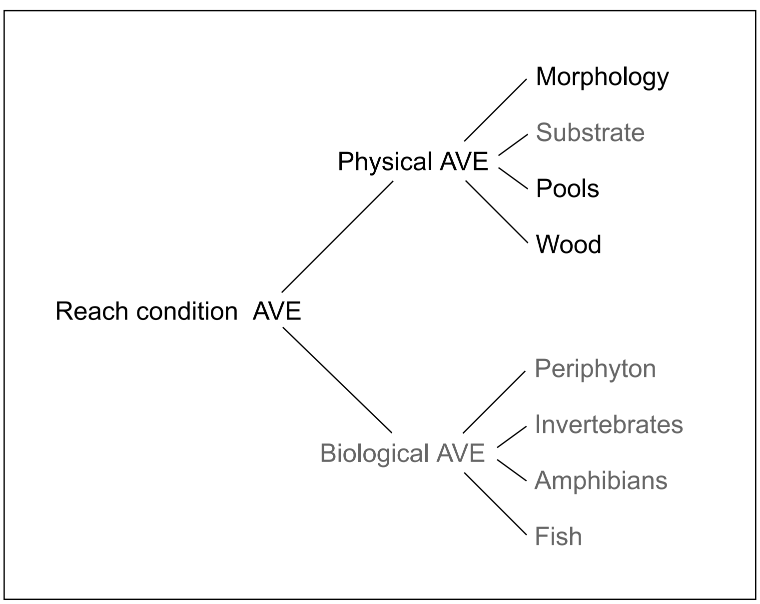
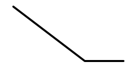
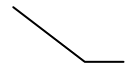
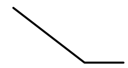
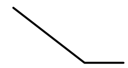
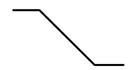
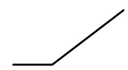
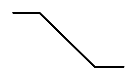
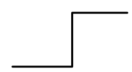
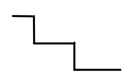
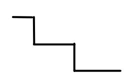
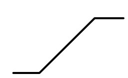
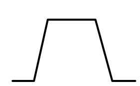
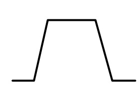


Figure 64—Reach condition decision-support model used in the Olympic Peninsula province. Guidance on interpreting the figures is provided in appendix 4 text.

Table 13—Evaluation criteria used in decision-support model for West Cascades province

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
High-slope road density (mi road/mi^2 watershed)	0 0.5	1 -1		AREMP[a] workshop 05/22/03
Upslope road density (mi road/mi^2 watershed)	0 4	1 -1		Dose and Roper 1994 AREMP workshop 05/22/03
Riparian road density (mi road/mi stream)—164-ft buffer	0 0.1	1 -1		AREMP workshop 07/01/04
Road crossing frequency (number of crossings/mi stream)	0 1.75	1 -1		AREMP workshop 07/01/04 Willamette NF data
Upslope vegetation—small-conifer cover (percentage of area with conifers <10 in d.b.h.)	10 40	1 -1		AREMP workshop 05/22/03
Riparian vegetation, large-conifer cover—197-ft buffer (percentage of area with conifers ≥20 in d.b.h.)	60 100	-1 1		AREMP workshop 07/01/04 d.b.h. from wildlife handbook Dose and Roper 1994 harvest roads vs. condition >30 percent of watershed impacted
Water temperature (maximum 7-day average, °C) Bull trout present	16 18 23	1 0 -1		AREMP workshop 05/22/03
Dissolved oxygen				
Percentage of saturation	<50 ≥50	-1 1		AREMP workshop 05/22/03
Mg/L	<4 ≥4	-1 1		
Reach model attributes				
Morphology				
Slope Entrenchment ratio Sinuosity Bankfull width:depth	Use to determine Rosgen stream type If D, F, G channel then -1, otherwise +1			Professional judgment
Pool frequency (number of bankfull widths per pool)				
≤3 percent slope	≤5 5 7 >7	1 0 0 -1		Montgomery and Buffington (1997)
>3 percent slope	<1 1 >4	1 0 -1		
Wood frequency (number of pieces per 100 m)	1 4	-1 1		Professional judgment
Substrate D_{50} (mm)				AREMP workshop 05/22/03
≤5 percent slope	40 60 140 200	-1 1 -1 1		
>5 percent slope	40 60 200 500	-1 1 1 -1		Professional judgment

[a] AREMP = Aquatic and Effectivenesss Monitoring Program.

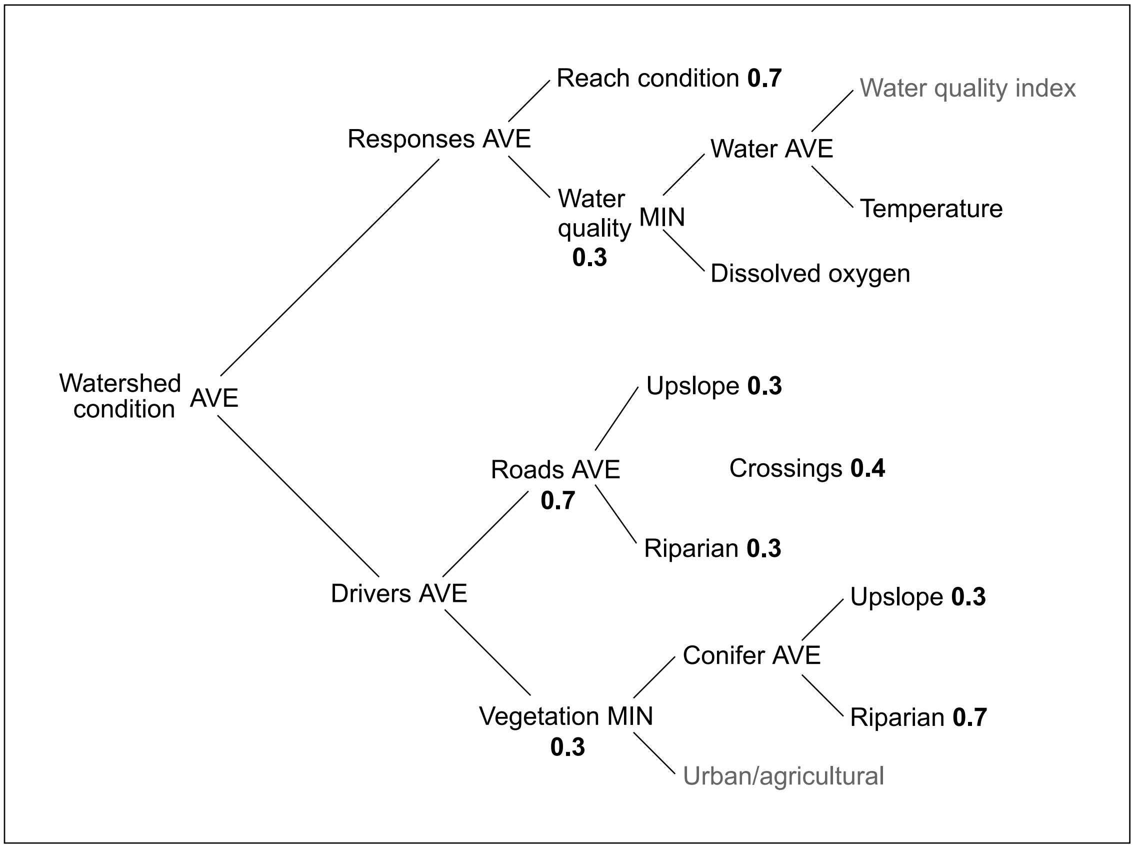


Figure 65—Watershed condition decision-support model used in the West Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

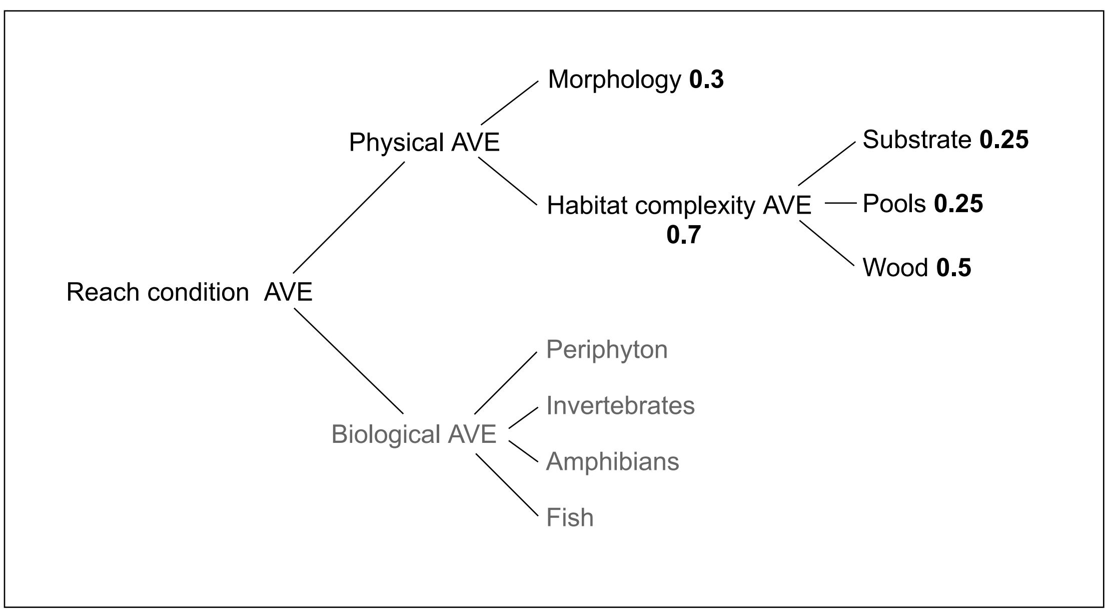


Figure 66—Reach condition decision-support model used in the West Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

Appendix 5: Sensitivity Analysis of the Decision-Support Models

Each of the provincial models was analyzed to determine how sensitive it was to changes in individual watershed attributes. This evaluation differed from typical sensitivity analyses that vary the model parameters to determine how the results are affected by their values. Here we make a first attempt at developing relationships between management activities (road building and decommissioning and vegetation harvest) and watershed condition score. For each attribute, we selected the value that would produce an evaluation score of 0 as a starting point (selected for ease of interpretation) and then changed the value of that attribute by 5, 25, 50, and 100 percent in a direction intended to improve watershed condition scores (e.g., roads attributes were decreased and vegetation attributes were increased). We ran each model on the data set generated for the analysis and examined the effect of changing each attribute on the watershed condition score (figs. 67 through 73).

To examine the sensitivity of each model to change, we looked at the effect that changing individual attributes has on the overall watershed condition score. Two main factors influence the sensitivity of the models: the evaluation criteria used and the weights given to individual attributes. Curves generally have one of two shapes, linear or asymptotic. Asymptotes occur at the point that the attribute data evaluated meet or exceed the +1 (or -1) evaluation curve value. Linear curves describe attribute data that have yet to approach the asymptote. The magnitude of change that can occur before reaching the asymptote is related to the distance (in terms of the units of the attribute data evaluated) between the -1 and +1 evaluation criteria values. For example, in the Olympic Peninsula model, riparian vegetation can increase by 50 percent before the asymptote is achieved (fig. 72). Once the asymptote is achieved, then additional increase in the attribute will not contribute positively to the watershed condition score. In contrast, the density of hazard roads can be reduced by 100 percent without reaching the asymptote. The asymptote that corresponds to the -1 evaluation criterion indicates the attribute level that must be reached before the condition score increases. As an example, in the Washington/Oregon Coast province, most of the watersheds received a -1 evaluation score for riparian roads. Most watersheds have riparian road densities more than twice the -1 evaluation criterion (fig. 74). In this case, riparian road densities in these watersheds must be reduced to 0.1 mi of road per mile of stream before any improvement in watershed condition will be realized.

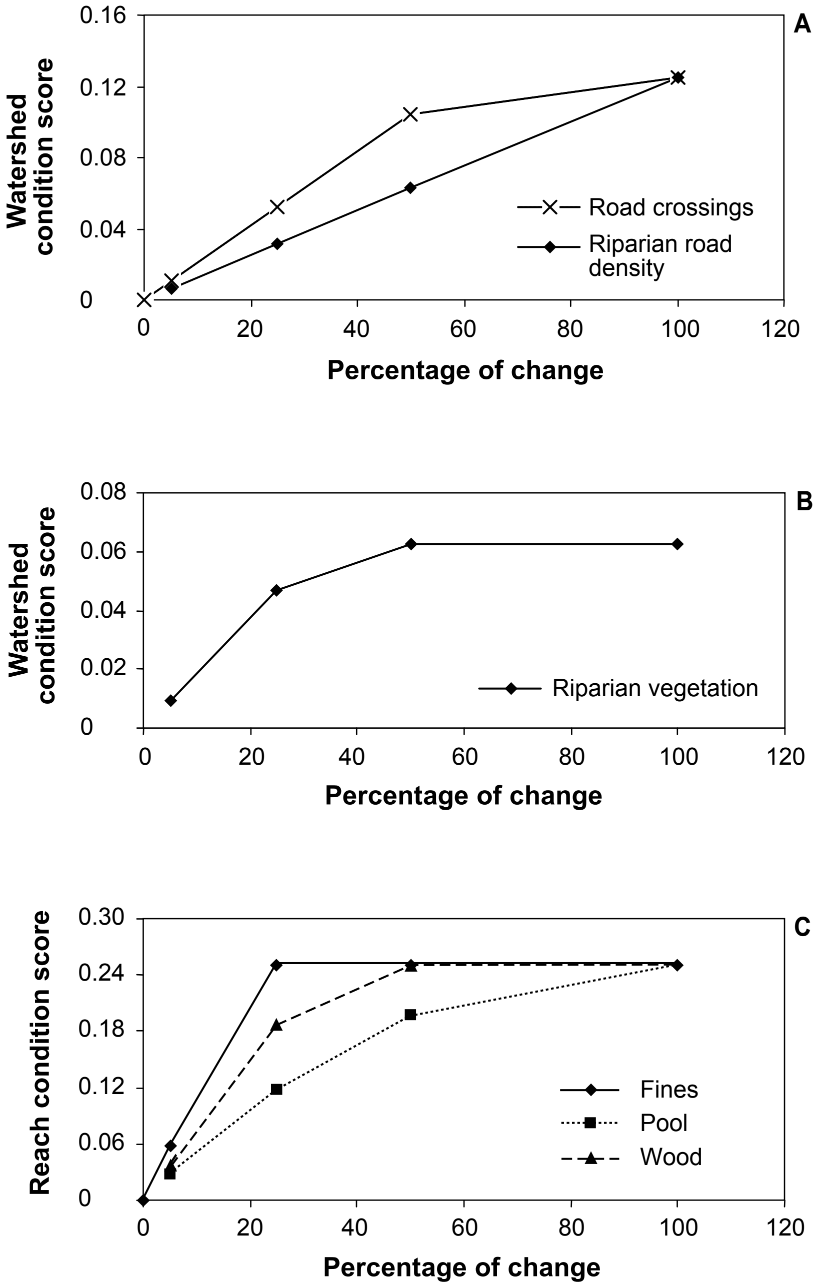


Figure 67—Sensitivity analysis results from the Washington/Oregon Coast province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

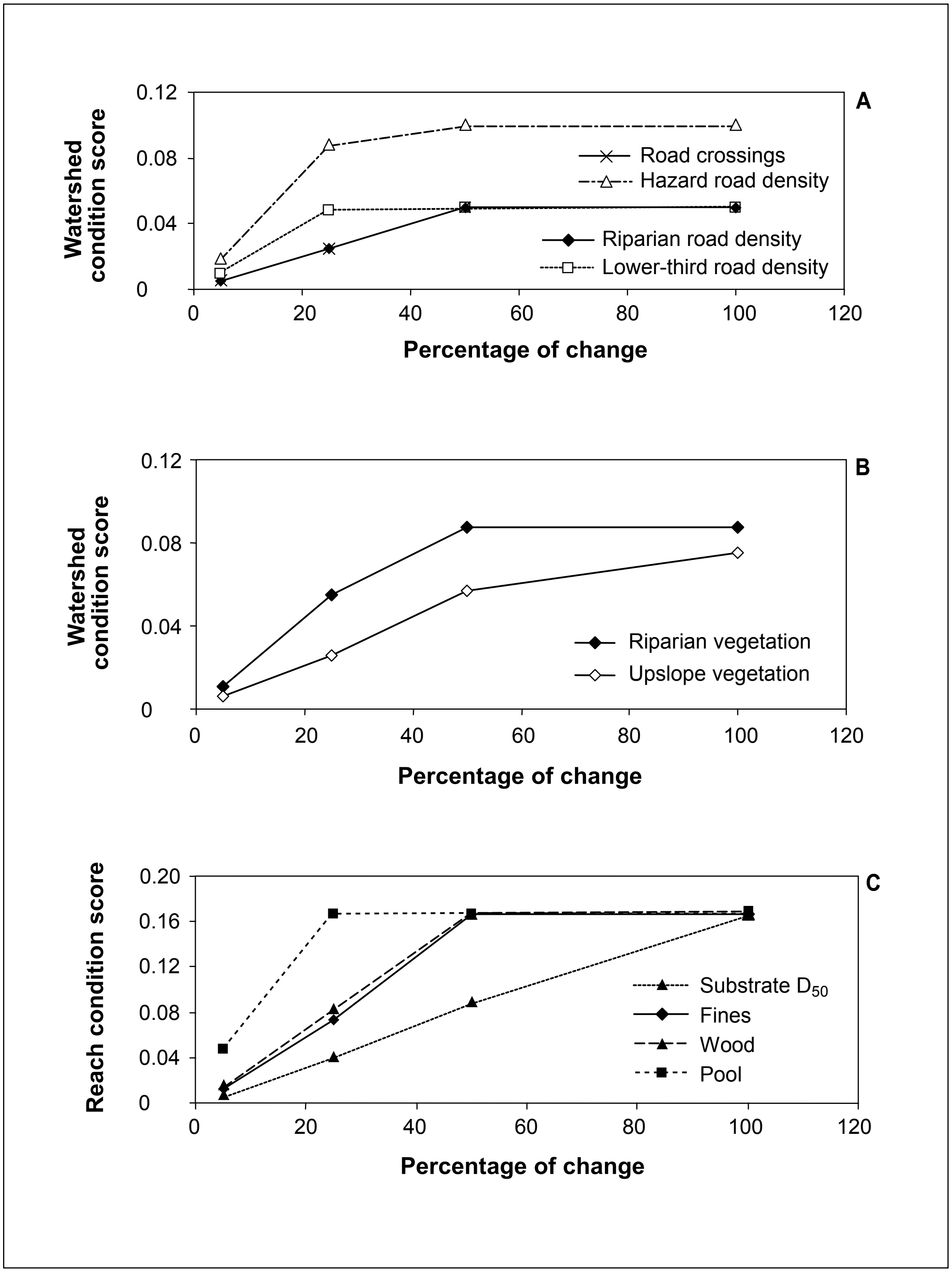


Figure 68—Sensitivity analysis results from the Franciscan province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

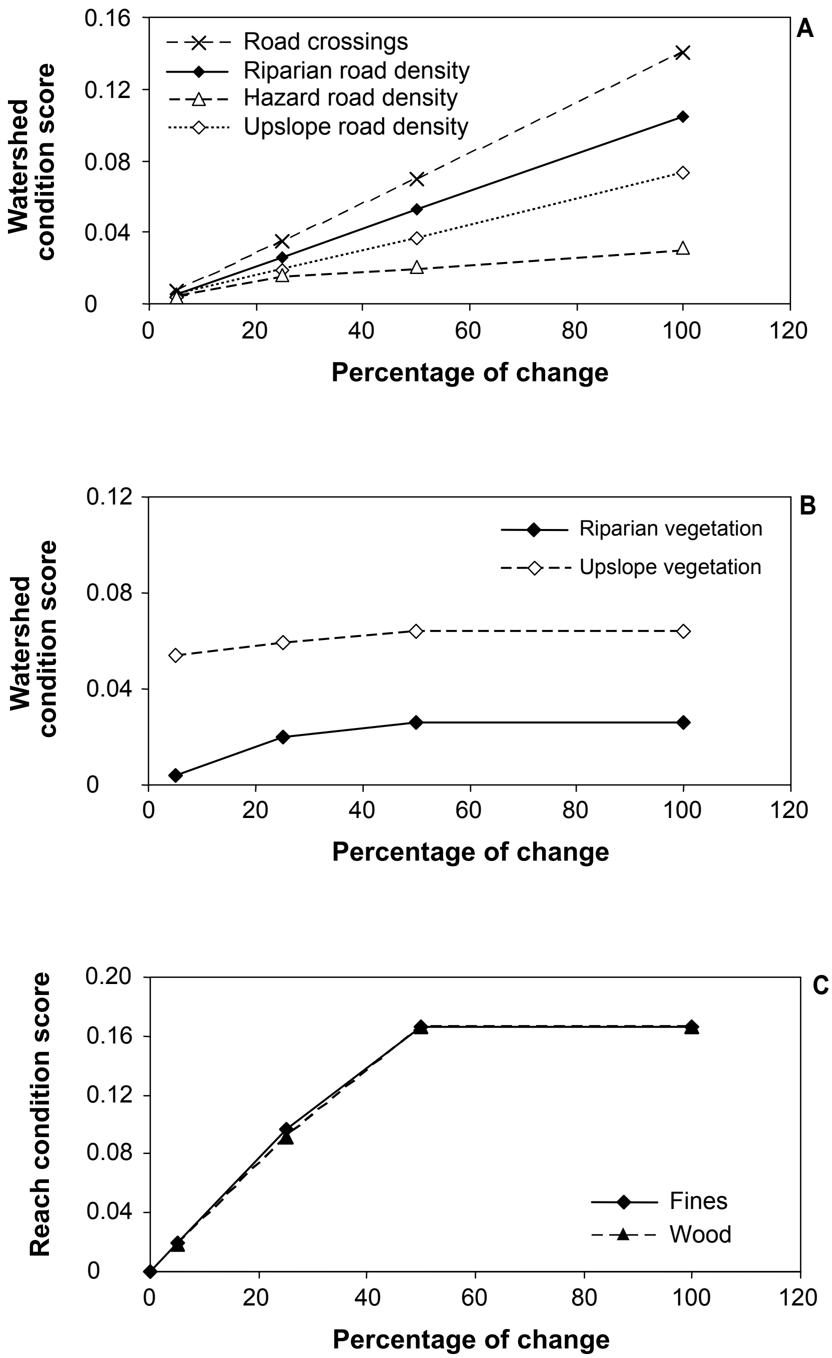


Figure 69—Sensitivity analysis results from the High Cascades province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

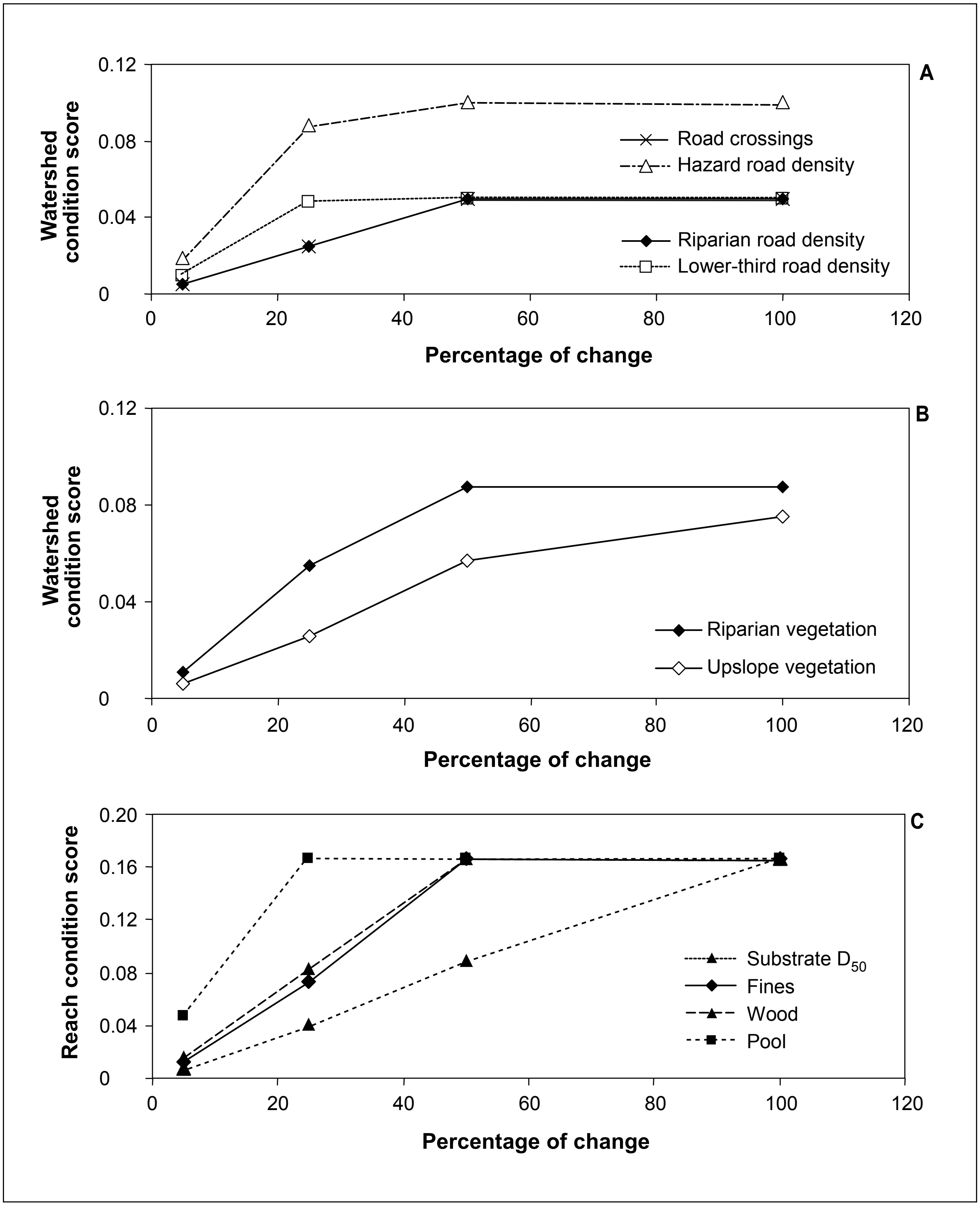


Figure 70—Sensitivity analysis results from the Klamath/Siskiyou province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

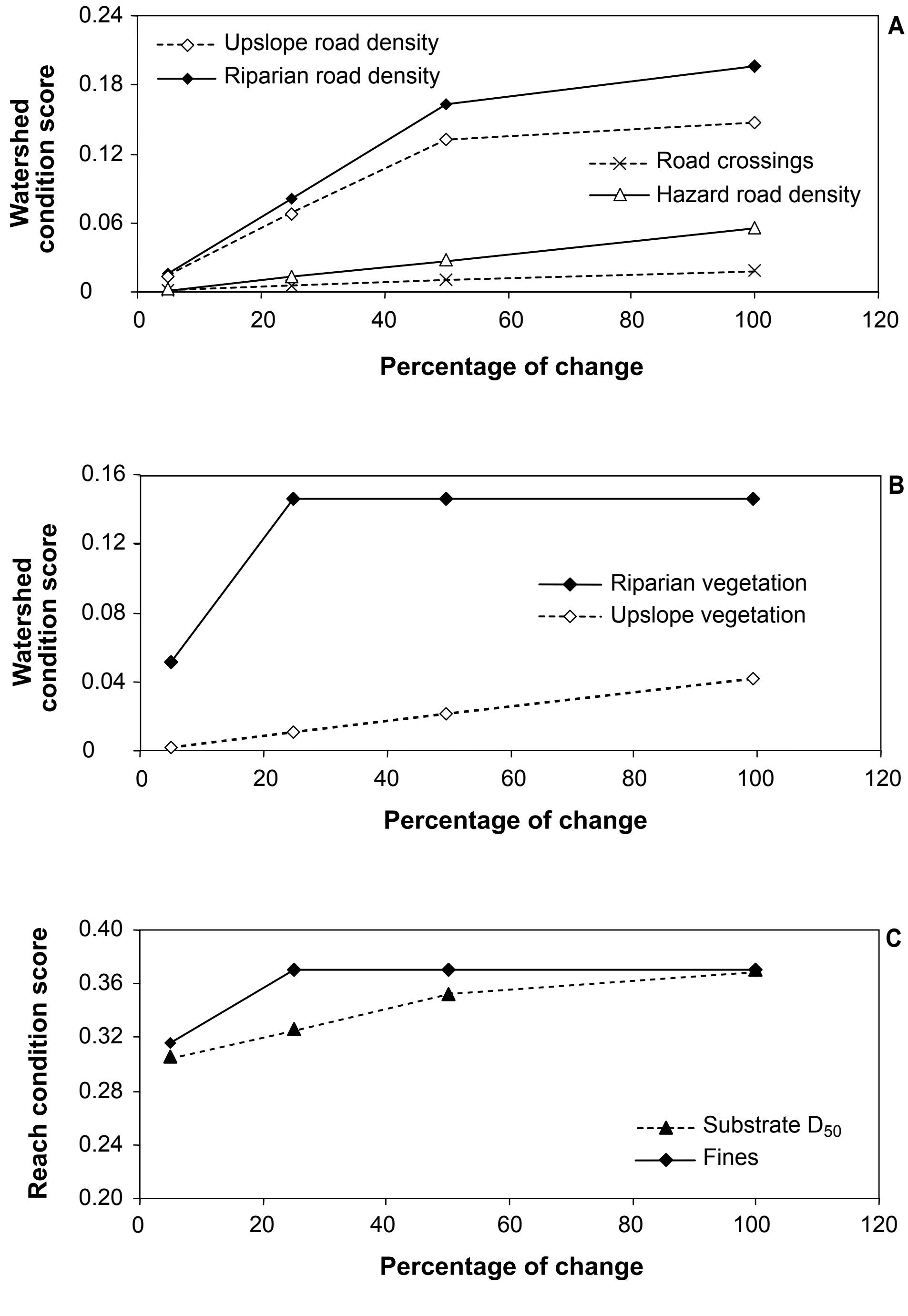


Figure 71—Sensitivity analysis results from the North Cascades province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

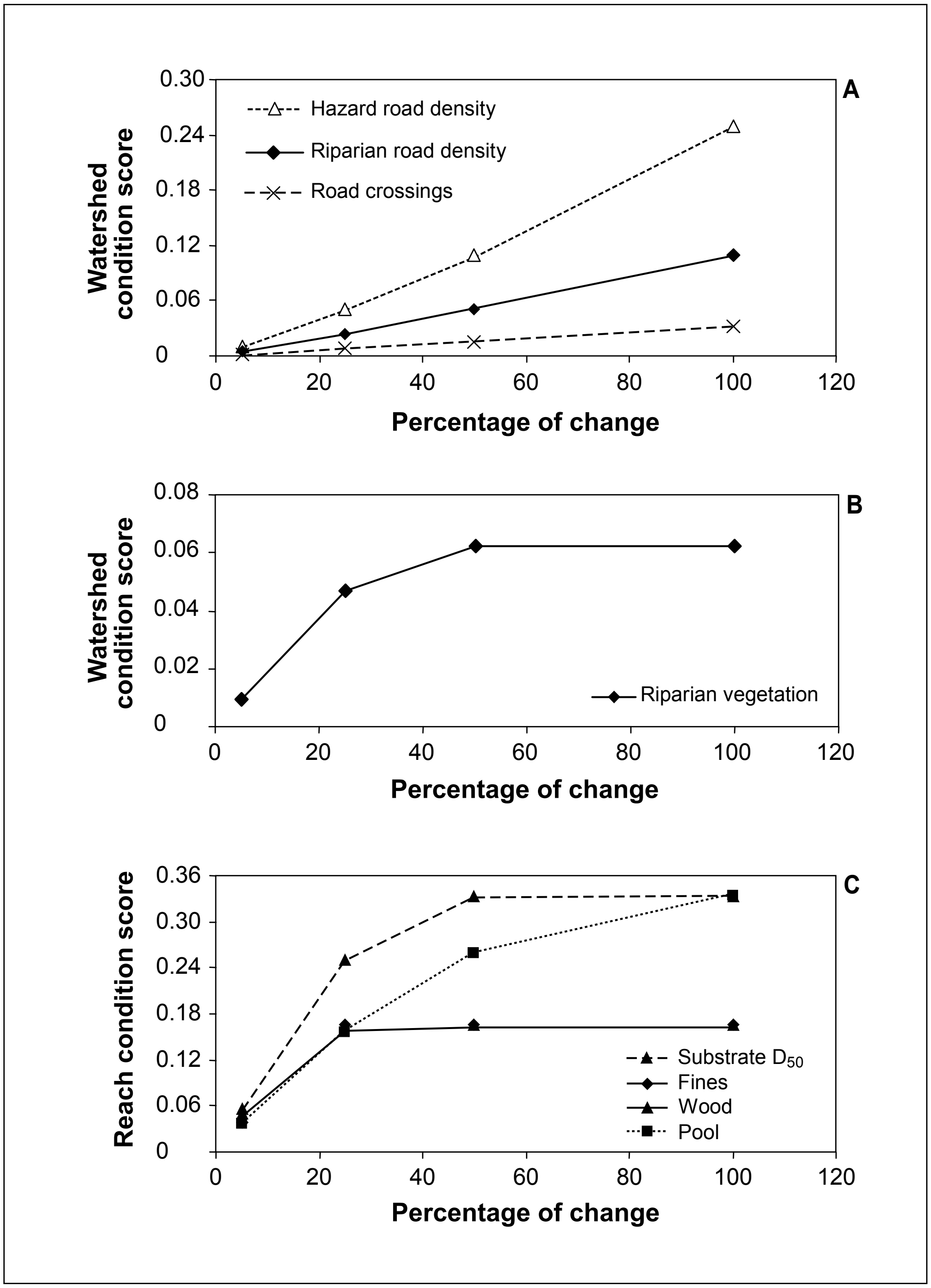


Figure 72—Sensitivity analysis results from the Olympic Peninsula province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

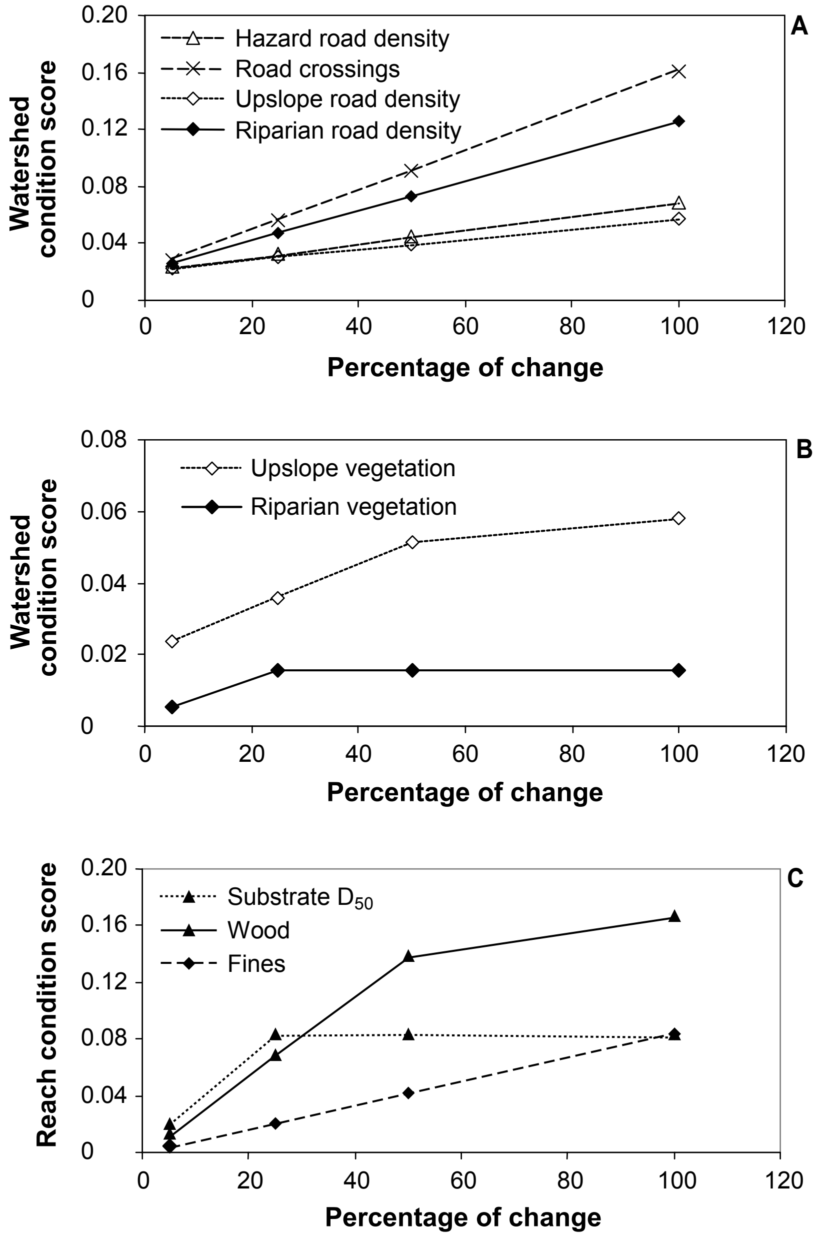


Figure 73—Sensitivity analysis results from the West Cascades province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

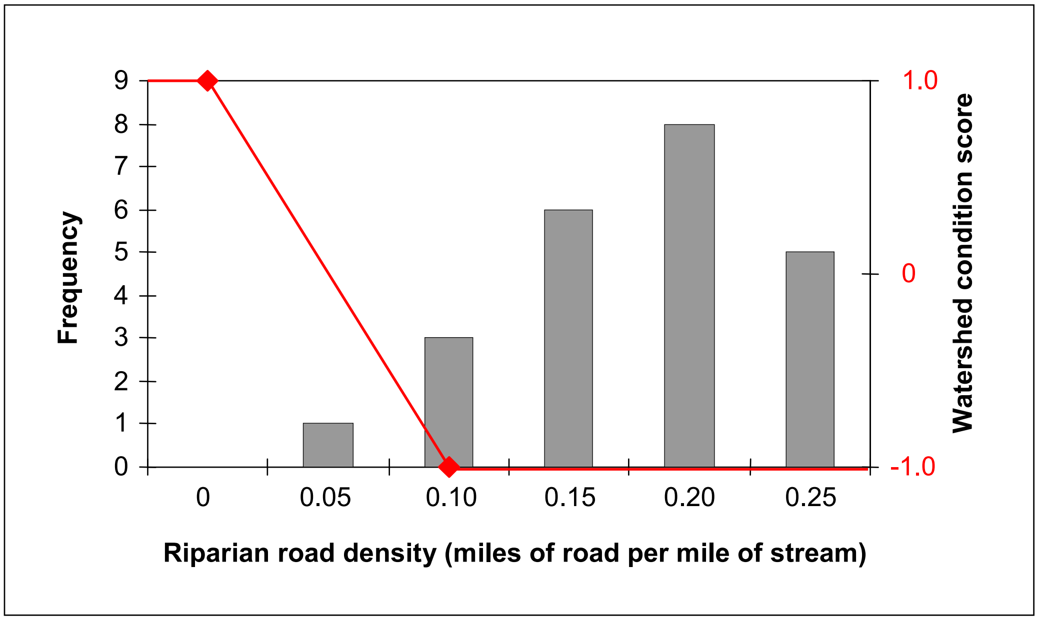


Figure 74—Riparian road density distribution in the Washington/Oregon Coast province. The evaluation criteria used to evaluate riparian road density in this province is shown in red. Watersheds that have riparian road density higher than 0.10 mi of road per mile of stream will have an evaluation score of -1 for riparian roads.

Appendix 6: Road and Vegetation Analyses Conducted by Province

Common Geographic Information System (GIS) Coverages Used for All Provinces

- **Roads**. Road layers used in Oregon and Washington were a combination of USDA Forest Service (FS) road coverages with the USDI Bureau of Land Management (BLM) ground transportation coverage. The FS coverages were obtained from each of the national forests in the Northwest Forest Plan (the Plan) area. The FS coverages included attributes from the infrastructure application (INFRA) core table attached to the road segments, and the coverage was clipped to the administrative boundary of the forest. The FS administrative areas were removed from the BLM coverage and the FS coverages were pasted in by using a "cookie cutter" process. No edge matching was done. The FS coverages were dated 2002, and the BLM data are a collection of data from various sources and years. The final Oregon and Washington road coverage has decommissioning and year-built attributes. The BLM roads have both decommissioning and year-built attributes, whereas the FS only has decommissioning, which is tracked in the INFRA attributes. The decommissioning and year-built attributes were used to determine the change in the road system since 1994. The FS Pacific Southwest Region (Region 5) remote sensing laboratory constructed the California coverage.
- **Streams and lakes**. The Oregon and Washington streams were the result of the FS Pacific Northwest Region hydrography framework project, which pieced together the best available stream data from various sources. The project has not been completed; thus some of the data used in the analysis were preliminary. The coverage data varied in density depending on the source. The California coverage was pieced together by the FS Region 5 remote-sensing laboratory by using a combination of FS, BLM, and cartographic feature file data. The resulting coverage also had varying stream density depending on the source. Stream data were at the 1:24,000 scale except for some areas in California where only 1:100,000 scale data were available.
- **Digital elevation models (DEM)**. 30-m (98.4-ft) DEMs were obtained in 2001 from the National Elevation Dataset (NED) compiled by U.S. Geological Survey (USGS).
- **Watershed boundaries**. The boundaries used were from the first draft of the sixth-field hydrologic unit code boundaries developed by the Regional Ecosystem Office dated 2002. The first draft was used because it was all that was available when we selected the 250 watersheds.
- **Stream buffers**. Stream buffer widths differed by province, and different buffer widths were sometimes used for road-stream interactions and vegetation. The first step was to buffer the stream lines by the prescribed width. Streams wide enough to be represented by a double line were buffered separately and the resulting buffer added to the single-line stream buffers. Lakes were removed from the final buffered coverage.
- **Vegetation**. Interagency vegetation mapping project (IVMP) was used for Oregon and Washington. CALVEG 1998 data was used for California. The IVMP versions used are as follows:

  Eastern Cascades, OR—1.1
  Western Cascades, OR—2.2
  Klamath, OR—1.0
  Coast, OR—3.0
  Eastern Cascades, WA—1.0
  West Cascades, WA—2.0
  Olympics, WA—2.1
  Western Lowlands, WA—1.0

Franciscan Province

Roads

Analyses include:

- Road density in steep areas (>65-percent slope) expressed as miles of road per square mile of steep area. For this analysis, DEMs were used to generate >65-percent-slope polygons. The road coverage was then laid over these areas, and the miles of road in the steep areas were summed.
- Number of road crossings expressed as number of crossings per mile stream. For this analysis, road and stream coverages were clipped to watershed boundaries and the number of road-stream intersections counted.
- Riparian road density expressed as miles of road per square mile of riparian area. The road and stream layer was clipped to watershed boundaries. A 50-m (164-ft) buffer was created on the streams to represent the riparian area. The road coverage was laid over the delineated riparian area and the total miles of road summed.
- Road density on the lowest one-third slope expressed as miles of road per square mile of lowest slope. The lowest one-third of the slope was determined by running a slope position Arc Macro Language (AML) script that uses DEMs and creates a grid with the slope numbered from 1 to 100, with 1 being the bottom and 100 the top. The numbers 1 to 33 were used to define the lower one-third of the slope. The lower one-third area was turned into a polygon layer and intersected with the roads.

Vegetation

Additional GIS coverages used in the analyses include:

- Average annual precipitation from 1961 to 1990, created by Oregon State University in 2000.

Analyses include:

- Percentage of cover of riparian forest (conifer and broadleaf). Riparian is defined as a 50-m (164-ft) buffer around the 1:24,000 stream layer.
- Percentage of riparian area covered in conifers >20 in diameter at breast height (d.b.h.). Riparian is defined as a 50-m (164-ft) buffer around the 1:24,000 stream layer.
- Percentage of cover of upslope forest, when percentage of conifers is greater than 10 percent. Upslope is defined as the area outside the riparian buffer. In California, oak woodland was separated from other forest types and evaluated for percentage of cover separately.
- Percentage of upslope area covered in conifers <5 in d.b.h. Upslope is defined as the area outside the riparian buffer.

High Cascades Province

Roads

Analyses include:

- Road density in areas that have slope >50 percent. Expressed as miles of road per square mile of watershed. Digital elevation models were used to locate areas within watersheds that had gradient >50 percent. The road layer was laid over the stream areas and the miles of road within the steep areas summed.
- Upslope road density expressed as mile of road per square miles of watershed (North of White River only).
- Riparian road density expressed as miles of road per mile of stream. Riparian buffer is defined as 60 m (197 ft) on both sides of the stream.
- Frequency of road crossings expressed as number of crossings per mile of stream.

Vegetation

Analyses include:

- Percentage of conifers in riparian zone that are >10 in d.b.h. Riparian buffer is defined as 30 m (98 ft) on both sides of the stream.
- Percentage of conifers in upslope areas that are <10 in d.b.h. Upslope is all areas outside the riparian buffer.

Klamath/Siskiyou

Roads

Analyses include:

- Road density in steep areas (>65-percent slope) expressed as miles of road per square mile of steep area. For this analysis, DEMs were used to generate >65-percent-slope polygons. The road coverage was then laid over these areas, and the miles of road in the steep areas were summed.
- Number of road crossings expressed as number of crossings per mile of stream. For this analysis, road and stream coverages were clipped to watershed boundaries and the number of road-stream intersections counted.
- Riparian road density expressed as miles of road per square mile of riparian area. The road and stream layer was clipped to watershed boundaries. A 50-m (164-ft) buffer was created on the streams to represent the riparian area. The road coverage was laid over the delineated riparian area and the number of miles of road counted.
- Road density on the lowest one-third of the slope expressed as miles of road per square mile of lowest slope. The lowest one-third of the slope was determined by running a slope position AML that uses DEMs and creates a grid with the slope numbered from 1 to 100, with 1 being the bottom and 100 the top. The numbers 1 to 33 were used to define the lowest one-third of the slope. The lowest one-third area was turned into a polygon layer and intersected with the roads.

Vegetation

Additional GIS coverages used in the analyses include:

- Coverage of average annual precipitation from 1961 to 1990, created by Oregon State University in 2000.

Analyses include:

- Percentage of cover of riparian forest (conifer and broadleaf). Riparian is defined as a 50-m (164-ft) buffer around the 1:24,000 stream layer.
- Percentage of riparian area covered in conifers >20 in d.b.h. Riparian is defined as a 50-m (164-ft) buffer around the 1:24,000 stream layer.
- Percentage of cover of upslope forest, when percentage of conifers is greater than 10 percent. Upslope is defined as the area outside the riparian buffer. In California, oak woodland was separated from other forest types and evaluated for percentage of cover separately.
- Percentage of upslope area covered in conifers <5 in d.b.h. Upslope is defined as the area outside the riparian buffer.

North Cascades

Additional GIS coverages used in the analyses include:

- Hazard areas, based on land type associations on the east side of the Cascades. The land type associations were obtained from Wenatchee and Okanogan National Forests in 2003. The shallow rapid hazard areas were Fa2, Fb7, Fb8, Fb9, Ff9, Ka2, Ka5, Ka7, K68, K69, Kc6, Kf5, Kf7, Kj2, Kj8, Kk7, Qu2, and Qu8. Deep-seated hazard areas were Bu6, Tu3, Tu5, Tu7, Tu8, Uu7, and Uu8. On the west side of the Cascades, we used the grid produced by the Washington Department of Natural Resources with the Shalstab model in 2000. We used the areas coded as high hazard for shallow landslides. Information for deep-seated landslides was not available on the west side.

Roads

Analyses include:

- Upslope road density expressed as miles of road per square mile of upslope area. Upslope area was defined as all land outside riparian buffer. Riparian buffer defined as 50 m (164 ft) on the west side of the Cascades and 30 m (98 ft) on the east side.
- Riparian road density expressed as percentage of stream with road within a 20-m (66-ft) buffer. Applies only to streams that have gradient >3 percent.

- Number of road-stream crossings in nonhazard areas, expressed as number of crossings per square mile of watershed.
- Number of road-stream crossings in hazard areas expressed as number of crossings per square mile of watershed.

Vegetation

Additional GIS coverages used in the analyses include:

- Plant association groups (PAG) that have been modeled by the Forest Service in Oregon and Washington, by using the PAG model in 2003.
- Fire regimes developed from land type association layer, fuel condition class derived from vegetation, crown closure, and slopes. Developed by the Wenatchee and Okanogan National Forests.
- Subalpine areas derived from the plant association groups above.

Analyses include:

West side of Cascades—

- Percentage of forested upslope area with conifer cover ≥70 percent. Upslope area defined as the area outside a 50-m (164-ft) stream buffer. To determine forested area, subtract the area naturally nonforested (such as lakes, glaciers, subalpine, etc.) from the total upslope area.
- Percentage of cover of conifers >20 in d.b.h. in riparian areas. Riparian buffer defined as 50-m (164-ft) buffer on either side of the stream.

East side of Cascades—

- Mesic/wet areas—Percentage of upslope area with conifers less than 5 in d.b.h. Total cover (conifer + broadleaf) had to be greater than or equal to 50 percent to be included in the analysis. Wet/mesic and dry was determined by using a plant-association layer, the following plant categories are dry:
    - All ponderosa pine and Douglas-fir PAGs or zones
    - Grand fir-pinegrass
    - Grand fir-pinegrass-lupine
    - Grand fir-pinemat manzanita
    - Grand fir-oceanspray-pinegrass
    - Grand fir-mountain snowberry
    - Grand fir-spirea-bracken fern
    - Grand fir-snowberry-pinegrass
    - Shrub-steppe
- Dry areas—Percentage of cover of trees >20 in d.b.h. in upslope areas that are not subalpine areas.
- Average fire condition class—Weighted based on area of watershed in each class.
- All of east side—Percentage of conifers >20 in d.b.h. in riparian area that are not subalpine areas. Riparian area defined as the area within a 30-m (98-ft) buffer of the stream.

Olympic Peninsula

Roads

Additional GIS coverages used in the analyses include:

- Road hazard layer developed by the Olympic National Forest, which identified high-hazard roads based on a variety of factors including geology, fish presence, and road-stream crossings.

Analyses include:

- Road density in hazard areas expressed as miles of road per watershed area.
- Riparian road density expressed as miles of road per mile of stream (based on 1:24,000 high-density layer).
- Number of road-stream crossings expressed as number of crossings per mile of stream.

Vegetation

Analyses include:

- Percentage of cover of conifers (mixed or pure stands) in the riparian zone >20 in d.b.h. Riparian zone is defined as a 50-m (164-ft) buffer along both sides of the stream.
- Percentage of watershed covered by urban and agricultural land.

Washington/ Oregon Coast

Roads

Analyses include:

- Riparian road density expressed as miles of road per mile of stream.
- Number of road-stream crossings expressed as number of crossings per mile of stream.

Vegetation

Analyses include:

- Percentage of cover of conifers (mixed or pure stands) in the riparian zone >20 in d.b.h. Riparian zone defined as a 50-m (164-ft) buffer along both sides of the stream.
- Percentage of watershed covered by urban and agricultural land.

West Cascades

Roads

Analyses include:

- Upslope road density expressed as miles of road per square mile of watershed.
- Road density in areas that have slope >50 percent. Expressed as miles of road per square mile of watershed.
- Riparian road density expressed as miles of road per mile of stream. Riparian buffer is 60 m (197 ft) on both sides of the stream.
- Frequency of road crossings expressed as number of crossings per mile of stream.

Vegetation

Analyses include:

- Percentage of conifers (mixed or pure stands) in the riparian zone >20 in d.b.h. Riparian buffer is 60 m (164 ft) on both sides of the stream.
- Percentage of conifers (mixed or pure stands) in the upslope area <10 in d.b.h. Upslope is defined as all areas outside the riparian zone.

Appendix 7: Synopsis of Field Protocols Used by the Monitoring Program

Introduction

Field data collected provide information on physical habitat, chemical properties, and the biota. Physical habitat indicators include bankfull width-to-depth ratio, entrenchment ratio, pool frequency, sinuosity, gradient, wood frequency, percentage of fine substrate, and substrate D_{50}. Discharge and water chemistry data were also collected. Biological indicators include periphyton, benthic macroinvertebrates, aquatic and terrestrial amphibians, and fish.

The stream data will be combined with upslope and riparian information (primarily vegetation and road density) to provide an estimate of watershed condition. Condition will be determined by using a decision-support model that aggregates all indicators. The stream data collected in the field represent about two-thirds of the data included in the decision-support model.

Site Selection

Eighty potential sampling sites were randomly chosen along the stream network in the sixth-field subwatershed. In the field, sites were considered for sampling beginning with number 1 and continuing through the list, omitting sites that could not be sampled. The only reasons sites cannot be sampled include:

- The site is on private land or cannot be accessed without crossing private land.
- The site is not safely accessible; i.e., the site cannot be reached without putting the crew in danger. Long hikes down into steep canyons do not qualify.
- The stream is too small or physically cannot be sampled. The minimum stream size is about 3 ft wide (wetted width) and 4 in deep in riffle habitats.
- The stream is too large to physically sample (i.e., not wadeable) and is a safety concern for crews.
- The site is in a lake or pond.

The goal was to sample eight sites in a subwatershed. The length of the site was 20 times the bankfull width, with minimum 150 m (164 yd) and maximum 500 m (547 yd) reach lengths.

Physical Habitat Mapping

Cross-Sectional Profiles

Channel cross-sectional and longitudinal profiles were mapped by using a laser rangefinder. Cross-sectional profile information was used to calculate bankfull width-to-depth ratios and entrenchment ratios. In nonconstrained reaches, 11 cross-sectional profiles were mapped, equally spaced along the length of the sample reach. At each cross section, 11 shots were taken on increments in the bankfull prism, with measurements taken at both wetted edges and the thalweg (fig. 75). Of the 11 cross sections, two randomly selected profiles extended beyond flood-prone area to determine flood-prone width. Only one point was taken outside bankfull in the remaining cross sections. In the constrained reaches, six profiles were mapped as described for nonconstrained reaches.

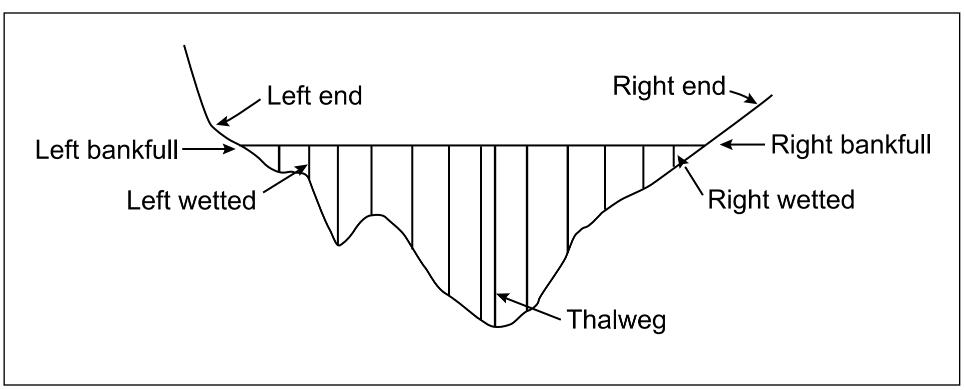


Figure 75—Cross-sectional profile with point labeling (looking downstream).

Longitudinal Profiles

Longitudinal profiles were used to calculate sinuosity, gradient, and pool frequency by shooting points with the laser rangefinder. Shots were taken on an increment that was about 1/100 of the sample site length. Additional measurements were taken at each pool tail crest, maximum pool depth, and pool head. The same protocol was used in all sample reaches.

Substrate

The protocol for measuring substrate is similar to that used by the Environmental Protection Agency's Environmental Monitoring and Assessment Program (Peck et al. 1999). In nonconstrained reaches, 11 substrate measurements were taken at each of the 11 transects. Substrate measurements were taken on evenly spaced increments in the bankfull channel. In constrained reaches, measurements were taken at each of the six transects, and at five intermediate transects as well. The intermediate transects were set up midway between the primary transects (Peck et al. 1999). Percentage of fine sediment was measured in the tails of scour pools as described by the USDA Forest Service Pacific Southwest Region stream condition inventory protocol (1998). Three measurements were taken by using a Klamath grid in each pool tail in the reach (maximum of 12 pools).

Large Wood

The large wood protocol was adapted from that used in the Oregon Department of Fish and Wildlife's Stream Habitat Surveys (Moore et al. 1999). In each reach, pieces of large wood were counted if they had a minimum length of 10 ft and were at least 12 in diameter at breast height (d.b.h.). Length and d.b.h. were estimated for each piece. Measurements of length and d.b.h. were taken on the first 10 pieces in the reach and every fifth piece thereafter. In addition, notes covered location in the channel, whether the piece was natural or artificial (i.e., had a cut end or was part of an artificial structure), and whether the piece was single or part of an accumulation. Large wood in jams (defined as five or more pieces) was not measured, but the presence of the jam and its approximate size was documented.

Other Chemical and Physical Parameters

Discharge was taken at one location in the sample site by using a flow meter. Water samples for nutrient analyses (total Kjeldahl nitrogen and total phosphorus) were taken at one location in the subwatershed, at the lowest point in the subwatershed on federal land. Additional information on temperature, dissolved oxygen, pH, and conductivity was collected at each sample site. All of these physical and chemical data were used as support data for the biological sampling. An overview of the sampling is shown in figure 76.

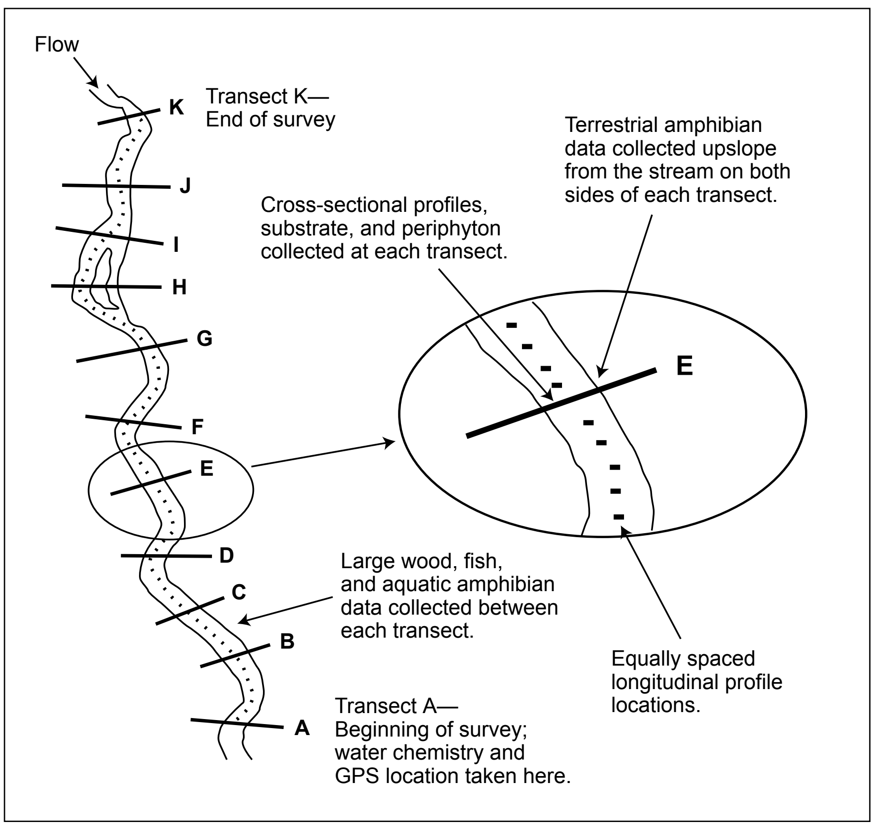


Figure 76—Overview of site layout including sampling strategy for nonconstrained sample sites. GPS = global positioning system.

Appendix 8: Quality Assurance Assessment of Geographic Information System and Inchannel Data

We conducted a quality assurance/quality control assessment on the geographic information system (GIS) layers used for the roads and vegetation analyses and on the inchannel data collected in the field. Details on how we conducted these analyses and the results are presented.

Roads

Methods

Road coverages from multiple sources were collected for use in the analysis. The quality and density of the coverages differed, depending on their source and land ownership. Mapping on private lands was often less intensive than on federal land. To assess the accuracy of the road coverages, we used digital orthquads (DOQ) from two periods (1990 or 1994 and 1998 or 2000) to develop a road layer to compare with the agency (i.e., Forest Service or Bureau of Land Management [BLM]) coverages in 38 of the 250 randomly selected watersheds. Individual watersheds were selected based on availability of DOQs, and the number of watersheds was based on the available budget. Roads were drawn along linear clearings on the DOQs. Obvious nonroads, such as skid trails, were not included on the DOQ-based layer because we did not expect these features to be included on the agency layer. If these features had been included on the DOQ layer, we would have confounded our comparison with the agency layer. In each watershed, the agency road network was laid over the DOQs from the two periods. Each segment of road on the DOQ layer that did not match the agency coverage was placed into one of the following classes:

Moved	The road segment was more than 200 ft from where it appeared on the agency coverage and was moved to match the DOQ image.
Added	The road segment appears on both the 1994 and recent DOQ but not on the agency coverage.
Deleted	The road segment does not appear on either the 1994 or the recent DOQ but is on the agency coverage.
Built	The road appears on the recent DOQ but not the 1994 DOQ; it was assumed to have been built since 1994.

We calculated riparian road density and frequency of road crossings in 38 watersheds by using the agency road coverages and on the layer developed from the DOQs, as described for the roads analysis above.

To examine the differences between the agency road layers and the layer drawn from DOQs for the road quality-assurance assessment, we used a paired, two-tailed t-test to determine whether the results derived from the two layers were significantly different.

Results

Examination of the road layers suggests that a significant number of roads on agency GIS layers appear to be missing (table 14). About 17 percent more road miles were found on the digital orthoquads (DOQ) than on the agency roads layers. Differences between the two layers were due primarily to the number of roads on nonfederal lands, which were not well represented on the agency layers (fig. 77, right panel). About 37 percent of the roads on nonfederal lands were missing on the agency layer, compared to 10 percent on BLM lands and 15 percent on Forest Service lands.

The roads missing on federal lands include spur roads, temporary roads, and others not maintained as part of official road networks. Without field verification, we could not determine whether these roads are passable by wheeled vehicles. We did remove what appeared to be skid trails from the analysis. Although some of these roads may not be passable, their effects on watershed processes are assumed to be similar to those of unimproved roads.

The increased number of roads found on the DOQ layer compared to the agency layer suggests that we underestimated the number of roads in this analysis (fig. 78). Average frequency of road crossing was 1.6 crossings per mile of road (SD 1.1) on the DOQs, and 1.2 (SD 0.7) on the agency layer, an increase of 33 percent. Average riparian road density across the 37 watersheds was 2.8 mi of road per square

Table 14—Results from the roads layer quality assessment[a]

USGS HUC	Watershed name	Agency	Agency	Built	Deleted	Percent difference[b]
		- - - - - - - - - - - - - *Miles*	- - - - - - - -	- - - - - - - -	- - - - - - - -	
180101030105	Anderson Creek	61.13	26.31	0	6.03	33.2
171003080106	Ashland Creek	66.46	7.86	.28	1.54	9.9
171003070113	Barr Creek	120.49	23.49	8.89	5	22.7
170703010403	Benham Falls	131.18	27.86	.13	3.07	19.0
170200090110	Boulder Creek	16.81	.39	.44	18.35	-104.2
170703010907	Canyon Creek	104.73	6.42	.78	3.26	3.8
171003110503	Deer-Draper	130.15	78.73	21.1	1.42	75.6
170800010102	Draw Creek	5.6	3.19	0	0	57.0
171003020302	Dumont	124.32	8.58	.22	.36	6.8
180102030101	East Fork Annie	43.6	8.39	2.88	1.03	23.5
170200080703	Gold Creek	53.52	3.52	2.91	2.7	7.0
171100180701	Hamma Hamma River	65.97	12.07	.48	.66	18.0
180101050201	Headwaters North Fork Eel River	159.17	35.82	2.91	3.22	22.3
171003050101	Headwaters South Fork Coquille River	242.54	21.77	12.35	.38	13.9
171003111101	Lawson Creek	71.47	23.16	1.42	.21	34.1
171003011101	Little River Canyon	149.57	4.73	0	0	3.2
171003110103	Lower East Fork Illinois River	235.33	50.68	12.35	1.42	26.2
170900010504	Middle Fork Willamette River/ Larison Creek	69.81	7.2	.26	2.01	7.8
170200110504	Mission Creek	150.78	42.76	7.6	2.47	31.8
170900010603	North Fork Middle Fork Willamette/ Fisher Creek	46.36	4.85	.99	1.16	10.1
170900040501	Quartz Creek	137.84	22.11	2.98	2.07	16.7
170200080203	Rattlesnake Creek	49.73	6.65	1.72	1.39	14.0
171003100403	Rogue-Horseshoe Bend	57.48	18.16	1.52	.85	32.8
180101010204	Shelley Creek	90.86	25.01	.85	2.56	25.6
170900060503	Sixes Creek	51.08	4.53	.09	0	9.0
171003110603	Sixmile Creek	34.48	10.72	.12	.97	28.6
170703010104	Snow Creek	72.45	14.04	37.37	4.99	64.1
170800010201	Still Creek	27.25	4.64	.26	1.1	13.9
180102100102	Summerville	68.56	3.04	.21	15.65	-18.1
170703020203	Summit Creek	5.6	3.19	0	0	57.0
170300010301	Swauk Creek	313.1	58.9	10.68	23.25	14.8
180102030202	Threemile	31.61	1.65	0	.31	4.2
180101040201	Upper Black Butte River	202.46	73.62	10.03	21.51	30.7
171003030504	Upper Camp Creek	61.14	.81	1.45	.57	2.8
171002050201	Upper Five Rivers	61.2	4.95	3.59	1.1	12.2
171003030701	Upper Lower Smith River	109.19	31.69	18.27	.51	45.3
170900010106	Upper Middle Fork Willamette River/ Echo Creek	140.74	6.39	3.54	1.13	6.3
170900060401	Upper Quartzville Creek	76.49	17.87	.09	.09	23.4
171003020801	Upper West Fork Cow Creek	78.93	4.29	0	0	5.4
171003030704	Wassen Creek	32.43	17.91	5.69	.39	71.6

[a] Included is the USGS hydrologic unit code (HUC), the name of the watershed, the miles of road in the watershed identified on the agency layer, miles of roads added according to the digital orthoquad (DOQ) layer, miles of roads built based on the DOQ layers, miles of road deleted according to the DOQ layer. Percentage difference (the net difference in road miles between the agency and DOQ road layers) was calculated as added + built – deleted/agency × 100.

[b] Percent difference is derived by added + built - deleted ÷ agency × 100.

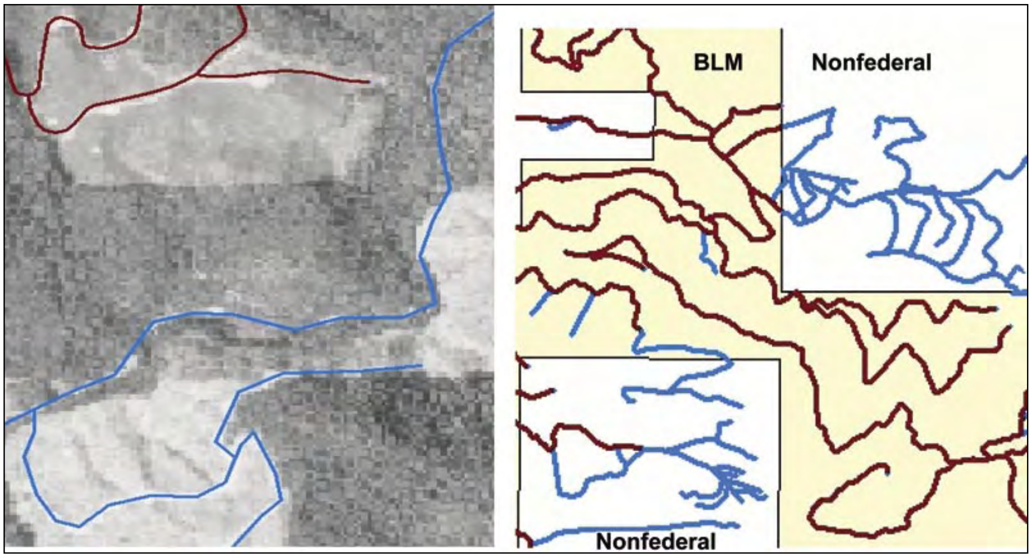


Figure 77—Comparison of agency and digital orthoquad (DOQ)-derived road layers in two watersheds. In both watershed panels, roads marked in red represent those included on the agency road layer, and those in blue represent roads present on the layer based on DOQs but not found on the agency layers. Left panel: roads were drawn in linear clearings visible on DOQs. Right panel: nonfederal land is shown in white, and Bureau of Land Management (BLM) land is shown in yellow. Roads on nonfederal lands are underrepresented on agency road layers.

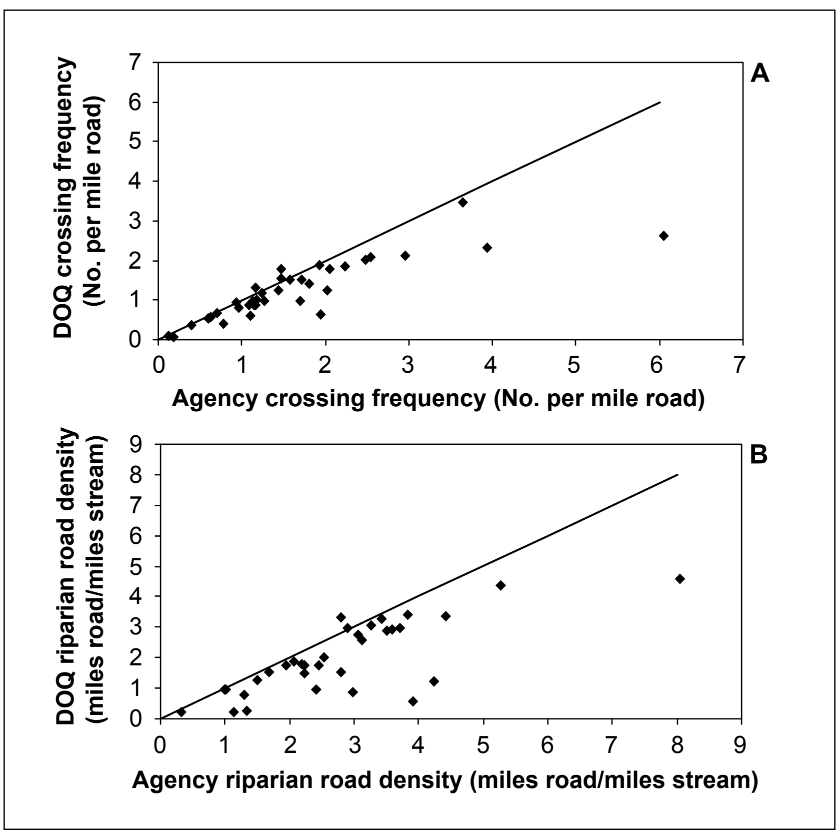


Figure 78—(A) Frequency of road crossings and (B) riparian road density based on agency roads data and on a layer developed from digital orthoquads (DOQ).

mile of riparian area (SD 1.5) on the DOQs and 2.0 (SD 1.2) on the agency layer, an increase of 40 percent.

The differences between the two road layers were less important when condition scores were compared, particularly when attribute condition scores have been aggregated. Drivers condition scores based on the two layers were highly correlated, and the slope between the two was equal to 1 (fig. 79a). The slope between the two layers was also equal to 1 for riparian road density, but was 0.88 for road crossings, suggesting that scores derived from the agency layer for this attribute are 12 percent less than those derived from the DOQ layer (fig. 79c and d).

Vegetation

Methods

The vegetation layers created by Interagency Vegetation Mapping Project (IVMP) and CalVeg were intended for landscape- or provincial-scale analysis, not for project-scale analysis. We were unsure whether the 25-m (82-ft) pixels used to build the layers would provide fine enough resolution for use at the sixth-field hydrologic unit scale, particularly for analysis of riparian vegetation. We conducted an exercise with aerial photographs to assess the accuracy of the monitoring program's use of the vegetation layers.

We analyzed 14 of the 250 randomly selected watersheds distributed throughout Northwest Forest Plan (the Plan) area. These watersheds were among those sampled in 2002 and were included in this analysis because we had some local knowledge of the watershed. The number of watersheds included in the analysis was based on available budget. In each watershed, a 100-m (328-ft) buffer was laid on either side of the stream channel to separate riparian and upslope areas. Riparian area was defined as being in the buffer, and upslope was the area outside the buffer. A 10 × 10 grid was laid over both the riparian and upslope areas. Grid points were placed on aerial photographs, and vegetation-class data were collected in a 75- by 75-m (246- by 246-ft) area (the equivalent of nine pixels on the IVMP layer) at the grid intersections (n = 100 data points in both riparian and upslope). Data from the air photos

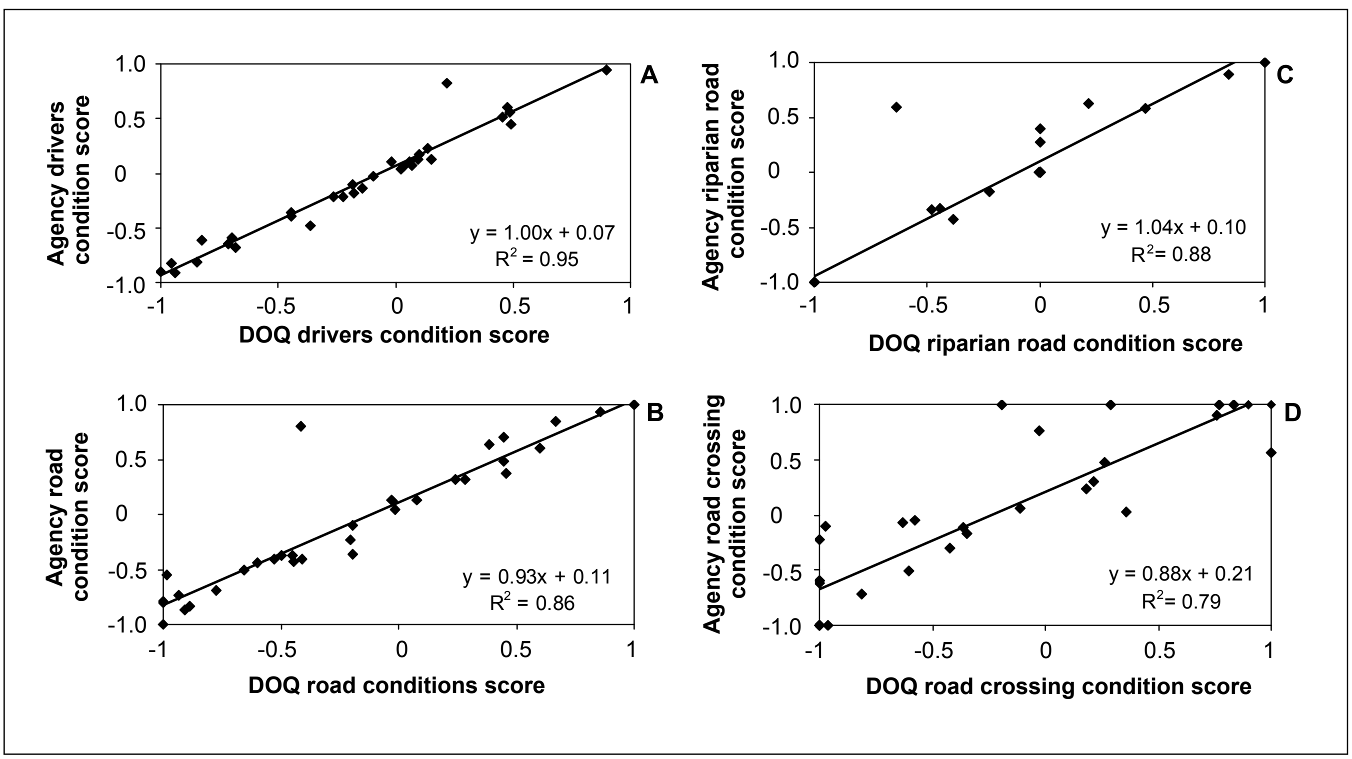


Figure 79—Relation between (A) drivers, (B) roads, (C) riparian roads, and (D) road crossing condition scores determined from the digital orthoquad (DOQ)-derived road layer and the agency road layer.

were compared with data from IVMP and CalVeg layers to determine the accuracy of the monitoring program's use of these layers. The vegetation classes analyzed for the accuracy assessment were based on the classes evaluated for the monitoring program's assessment of watershed condition. We did not conduct field verification of the aerial photograph interpretation; thus we are unable to describe the accuracy of the interpreted data.

Results

In general, accuracy assessments derived from the aerial photography exercise were consistent with the accuracy assessments derived by the IVMP and CalVeg. The accuracy of the maps differed widely between watersheds, however. Across all watersheds, overall accuracy of the vegetation layers averaged 65 percent in the riparian area (range = 49 to 97 percent; table 15); and 72 percent in the upslope area (range = 57 to 86 percent; table 16). We did not field verify the air photo data (i.e., the reference data), so we are unable to describe its accuracy. We are not able to determine whether differences in map accuracy across watersheds can be attributed to the map or to the reference data. The maps did not consistently overestimate or underestimate the size of trees relative to the reference data; therefore, we are unable to evaluate how the accuracy of the maps affected the outcome of this analysis.

Inchannel Attributes

Methods

A quality system management plan (quality plan) was developed for all the effectiveness monitoring programs under the Plan (Palmer 2002). Its goal was to ensure that all data collected were scientifically sound and of known quality. The monitoring program implemented a data-quality-assurance program in 2001 and has continued to develop the program since then as described by the quality plan. The quality-assurance program had multiple components, including formalized field training, remeasurement of a subset of sample sites by an independent field crew, field audits, and crew exit-surveys.

Analysis of the remeasured subset of sample sites (generally referred to as the paired set of initial-survey and secondary-survey data) was conducted to determine the repeatability of the sample data. These paired survey results were examined to distinguish between environmental and measurement effects. Environmental effects are the differences that occur naturally between watersheds and between sites in watersheds; these effects are considered uncontrollable. Measurement effects include differences in measurements between crews and unexplained error; these effects are considered controllable through training, refinements in field protocols (to reduce subjectivity), and improvement in equipment. A forthcoming report (Moyer and Chambers, n.d.) will detail the methods and results of the quality-assessment program with particular emphasis on the field data.

Results

The results of the remeasurements differed considerably depending on the attribute in question. For example, 75 to 95 percent of the total variability in average bankfull width from the sites measured in each year from 2001 to 2003 was explained by the natural variation that exists in the environment (i.e., streams vary in width naturally within and across watersheds), and the balance was due primarily to unexplained (residual) variation. In spite of a wide range of unexplained variation across years, the signal:noise ratio (S:N; calculated as described by Kaufmann et al. 1999) was ≥ 4, indicating the data were useful in detecting a change if a change actually occurred on the landscape. The result further indicates that the current methods were performing satisfactorily and do not need improvement. In contrast, the total number of pools counted in each site did not perform to these same standards. Only 30 to 50 percent of the total variability was attributed to the environment, indicating that field crews had a difficult time identifying the same number of pools between the two surveys. The S:N values for all 3 years were <1; therefore, a change in the data could not be attributable to an actual change on the landscape. These results indicated that a change in field technique was warranted. The results for the remainder of the attributes are described in Moyer and Chambers (n.d.).

Table 15—Accuracy assessment of the vegetation layers in the riparian zone[a]

			Photointerpretation			
			<20 in	≥20 in	Sum	Accuracy
			- - - No. of plots - - -			*Percent*
North Fork Eel						
	CalVeg	<20 in	40	4	44	
		≥20 in	25	8	33	
		Sum	65	12	77	62.3
Summerville						
	CalVeg	<20 in	16	27	43	
		≥20 in	6	37	43	
		Sum	22	64	86	61.6
Upper Black Butte						
	CalVeg	<20 in	25	19	44	
		≥20 in	10	28	38	
		Sum	35	47	82	64.6
North Coquille						
	IVMP	<20 in	38	6	44	
		≥20 in	15	9	24	
		Sum	53	15	68	69.1
Still Creek						
	IVMP	<20 in	7	40	47	
		≥20 in	0	34	34	
		Sum	7	74	81	50.6
Big Lava Bed						
	IVMP	<20 in	33	7	40	
		≥20 in	33	17	50	
		Sum	66	24	90	55.6
Fisher Creek						
	IVMP	<20 in	19	7	26	
		≥20 in	15	11	26	
		Sum	34	18	52	57.7
Swauk Creek						
	IVMP	<20 in	35	0	35	
		≥20 in	37	1	38	
		Sum	72	1	73	49.3
Willame Creek						
	IVMP	<20 in	30	14	44	
		≥20 in	16	22	38	
		Sum	46	36	82	63.4
Upper West Fork Cow						
	IVMP	<20 in	37	15	52	
		≥20 in	3	26	29	
		Sum	40	41	81	77.8
Snow Creek						
	IVMP	<20 in	71	2	73	
		≥20 in	0	2	2	
		Sum	71	4	75	97.3
Steve Fork Carberry						
	IVMP	<20 in	22	9	31	
		≥20 in	15	21	36	
		Sum	37	30	67	64.2
Headwaters South Fork Coquille						
	IVMP	<20 in	41	8	49	
		≥20 in	14	16	30	
		Sum	55	24	79	72.2
Hamma Hamma						
	IVMP	<20 in	31	15	46	
		≥20 in	19	16	35	
		Sum	50	31	81	58.0

[a] Number of plots was chosen based on average conifer size in the photointerpreted plots and by the Interagency Vegetation Mapping Project (IVMP) or CalVeg method. Accuracy assessments are the total number of plots that were mapped the same by using the two methods divided by the total number of plots, times 100.

Table 16—Accuracy assessment of the vegetation layers in the upslope area[a]

Watershed	Method	Class	Photointerpretation <10 in	Photointerpretation ≥10 in	Photointerpretation Sum	Accuracy
			- - - No. of plots - - -			*Percent*
North Fork Eel						
	CalVeg	<10 in	7	8	15	
		≥10 in	14	49	63	
		Sum	21	57	78	71.8
Summerville						
	CalVeg	<10 in	8	38	46	
		≥10 in	3	46	49	
		Sum	11	84	95	56.8
Upper Black Butte						
	CalVeg	<10 in	17	26	43	
		≥10 in	4	34	38	
		Sum	21	60	81	63.0
North Coquille						
	IVMP	<10 in	6	5	11	
		≥10 in	9	51	60	
		Sum	15	56	71	80.3
Still Creek						
	IVMP	<10 in	3	13	16	
		≥10 in	3	64	67	
		Sum	6	77	83	80.7
Big Lava Bed						
	IVMP	<10 in	3	26	29	
		≥10 in	4	39	43	
		Sum	7	65	72	58.3
Fisher Creek						
	IVMP	<10 in	9	3	12	
		≥10 in	3	10	13	
		Sum	12	13	25	76.0
Swauk Creek						
	IVMP	<10 in	10	9	19	
		≥10 in	10	44	54	
		Sum	20	53	73	74.0
Willame Creek						
	IVMP	<10 in	15	13	28	
		≥10 in	6	48	54	
		Sum	21	61	82	76.8
Upper West Fork Cow						
	IVMP	<10 in	13	8	21	
		≥10 in	20	27	47	
		Sum	33	35	68	58.8
Snow Creek						
	IVMP	<10 in	11	13	24	
		≥10 in	0	46	46	
		Sum	11	59	70	81.4
Steve Fork Carberry						
	IVMP	<10 in	12	5	17	
		≥10 in	5	51	56	
		Sum	17	56	73	86.3
Headwaters South Fork Coquille						
	IVMP	<10 in	11	7	18	
		≥10 in	13	46	59	
		Sum	24	53	77	74.0
Hamma Hamma						
	IVMP	<10 in	8	6	14	
		≥10 in	13	32	45	
		Sum	21	38	59	67.8

[a] Number of plots was based on average conifer size in the photointerpreted plots and by the Interagency Vegetation Mapping Project (IVMP) or CalVeg method. Accuracy assessments are the total number of plots that were mapped the same number of plots by using the two methods divided by the total number of plots.

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