

WHAT HAVE WE LEARNED, AND WHAT IS NEW IN WATERSHED SCIENCE?¹

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Abstract. Important new lessons are not in technical details, but in how to scale up the details to apply to large watersheds and landscapes. Nearly three years of experience with the Northwest Forest Plan have revealed some major new challenges in the fields of watershed science. In particular, managers and resource specialists engaged in watershed analysis continue to struggle in three principal areas: 1) issue identification and integration of information from multiple disciplines; 2) establishing the context of issues within a multiplicity of spatial scales; and 3) establishing the context of issues within a multiplicity of temporal scales.

Watershed analysis has forced a shift of focus from areas defined by political boundaries or particular projects to areas on the scale of large watersheds. This change is admirable. But in the zeal, or the requirement, to complete watershed analyses throughout the Pacific Northwest, analysts often forget the relation of the watershed to the larger scales of river basin, province, and region, scales at which many of the issues of concern are played out. Similarly, temporal scales selected for consideration often do not represent those appropriate to the important issues. Nowhere is this more evident than in the development and execution of restoration plans, which too often focus on an individual ownership, stream reach, or road segment.

Key words: watershed analysis, watershed restoration, Redwood Creek basin, geomorphology, ecosystems, interdisciplinary approach

[Ed. Note: This paper is based on a transcript of the oral presentation given by Bob Ziemer.]

INTRODUCTION

The title assigned to me is a bit presumptuous. There is a lot of new technology like GPS and GIS and computers are getting bigger and faster. This new technology has helped us run bigger and better models faster, but I wonder if perhaps we are now simply capable of producing the wrong answers faster. What I'm going to talk about today is certainly not new, because it is an approach that has been used by geomorphologists and others for centuries. The approach was

used by G. K. Gilbert in 1917. The implementation of the Northwest Forest Plan (FEMAT 1993; USFS & USBLM 1994) requires employees of federal agencies to think about problems differently than they have in the past.

Watershed specialists, resource managers, and regulatory agencies are struggling with three principal areas.

1) Issue identification and integration of information over disciplines. Agencies are still very provincial in the way that they approach problems.

2) Establishing the context of these issues within a multiplicity of spatial scales. The focus is often at the project or site level scale. The Northwest Forest Plan is forcing agencies to think at larger watershed, basin, and province scales. However, agencies now seem to be stuck at the watershed scales and are ignoring the context of the watershed within larger spatial scales.

3) Establishing the context of these issues within a multiplicity of temporal scales. The focus is often on time scales that are much shorter than that required by ecological processes.

These problems come about largely because agencies have tended to hold on to traditional approaches to problem solving even though the types of problems to be solved have changed.

PROBLEM APPROACH AND SHAPE

The Underlying Shape of the Problem

Assume that an important issue in a watershed, river basin, or province is "Disappearing Salmon". Figure 1 is a boxes-and-arrows diagram of a number of human activities (rounded rectangles) and physical/biological factors (rectangles) that influence Disappearing Salmon. The arrows connecting the boxes are the linkages and feedback loops. Such a diagram might appear to be overwhelmingly complicated. However, by clearly defining an issue and then explicitly identifying the conditions and processes that affect that issue, a lot of bad projects that have no relevance to solving the target problem could be averted (Reid et al 1996).

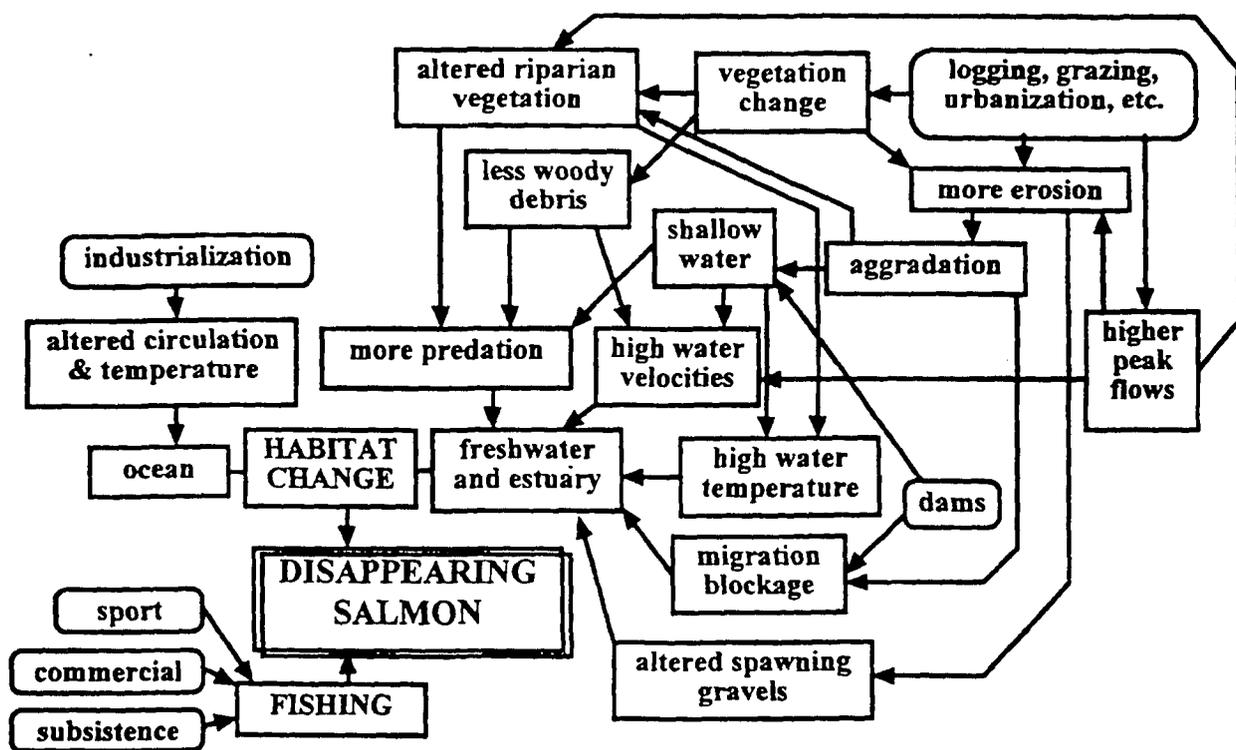
In the example of Disappearing Salmon (figure 1), there are a number of human activities identified: industrialization that affects ocean conditions; various types of fishing that harvest fish directly; and land use activities that modify the fresh-

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Figure 1.

THE SHAPE OF THE PROBLEM



water environment. Any of these activities may have role in Disappearing Salmon. It is the job of the analyst to identify those boxes that are most important to Disappearing Salmon in the watershed, river basin, province, and region. It is important to consider how the relative importance of each box varies at the different spatial scales. If land management agencies only consider their specific spatial niche and totally ignore the other influences, then it is no wonder that many programs fail. For example, it does not make a lot of sense to produce great steelhead habitat under the assumption of "if you build it, they will come" when all of the fish are caught in the lower river and never reach your great habitat.

The Traditional Shape of the Problem

Unfortunately, problem-solvers of the past have often seen only a small piece of a large problem. Instead of developing a comprehensive diagram of the problem as illustrated in figure 1, it is not uncommon for an organization or interest group to make a shortcut focus on their favorite box "less woody debris" in figure 2. This approach would immediately lead to a recommendation to manage the woody debris in the stream. However, if the particular stream of interest happened to be upstream of a dam, one would not expect such a woody debris program to result in more salmon.

Another approach that has often been used to simplify analysis is to select some easily measured index (figure 3). Some examples of the index approach are the Equivalent Routed Acres (ERA) method used by the USDA Forest Service Region 5 (USFS 1988) and Total Maximum Daily Load (TMDL) used by the U.S. Environmental Protection Agency (USEPA 1991). There are numerous other examples of the index approach, such as the use of spotted owls as a surrogate for salmon or for the general ecological conditions found in pristine old-growth forests. The danger in using the index approach is that seldom does the selected index adequately represent the conditions and linkages affecting the underlying target issue.

In both of these cases, approaches were developed to simplify what otherwise appear to be intractably complicated problems enough so that they become manageable. Unfortunately, these approaches to simplification often simplify the valid solutions out of the problem as well.

The Integrative View

At this point, then, what is needed is an approach or view that simplifies the problem while maintaining the important aspects of complexity — those that make a valid solution possible. There are several ways to look at issues that help accomplish this task. One is the Bottom-up Approach (figure 4). In this case, the first step is to identify an issue or something that is impacted. In this example, it is "Bridge Washed Out". Then all the important conditions and link-

ages that could have caused the bridge to wash out are identified, together with the links and feedback mechanisms. These mechanisms are in turn linked to the land-disturbing activities in the area that could lead to the bridge wash-out. The next step is to rank the boxes according to which have the highest probability of causing that specific bridge to wash out.

Another approach is the Top-down Approach (figure 5). This method starts with the land-disturbing activity, then describes the on-site changes, and their subsequent effects on the impact mechanisms that ultimately produce undesirable consequences.

Once a draft of these diagrams are produced and shared amongst members of an analysis team, a dialog will begin where people from different disciplines and different perspectives will comment, "Oh, but you forgot this", or "this is much more important than that." By involving the public, multiple agencies, multiple disciplines, and multiple interest groups, these types of diagrams can begin to tease out what is really going on in the watershed. That is, what are the important processes and what are people thinking about the issue. In this way, we begin to identify biases, prejudices about data, and assumptions concerning how the watershed works.

The Bottom-up and Top-down approaches can be merged (figure 6). The Bottom-up Approach first identifies the issues, then the impacts on each issue, and then the impact mechanisms affecting each issue. The Top-down Approach describes the land use, then the on-site changes resulting from each land use, and then the effects of those changes on impact mechanisms. At this point the two approaches converge and the boxes are prioritized by local importance. The area is then subdivided or stratified by common conditions or processes. Then the specific information and the precision required to address a particular box is decided upon. That information is collected, the importance of missing information is evaluated, and finally the information is used to address the objective.

This is very different from the more common approach, where a huge effort is first expended to conduct basic inventories of soil, geology, vegetation, roads, and harvest history under the assumption that such inventories are required before any analysis is possible. However, a vegetation inventory designed to predict timber growth and volume would not be very useful to evaluate the distribution of salamanders or fish. It is not uncommon to complete a very expensive and time-consuming inventory only to find that it provides no useful information for evaluating the issue at hand. This is not to suggest that such basic inventories have no value, but neither can they be expected to anticipate the type of information required to answer the diverse ecological issues that arise in any given watershed. In many cases, detailed inventories are not needed to understand the functioning of

Figure 2.

THE *TRADITIONAL* SHAPE OF THE PROBLEM

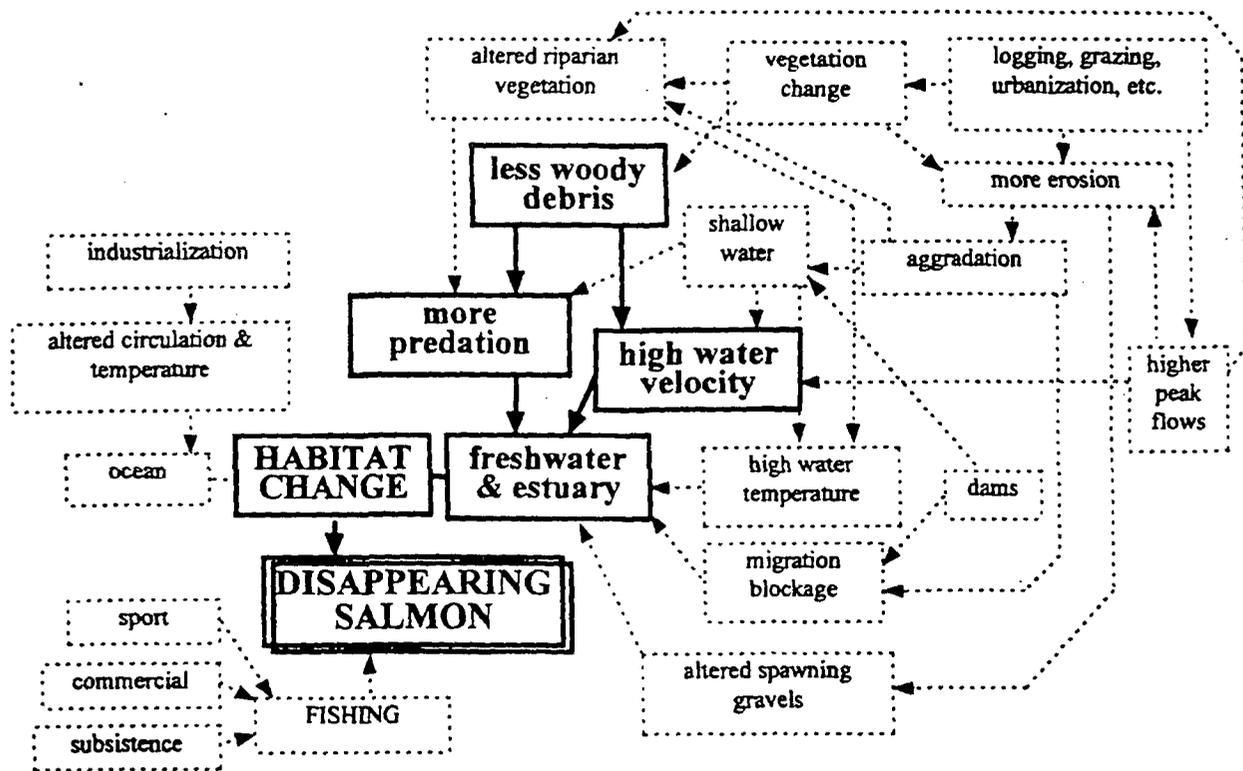


Figure 3.

THE INDEX APPROACH

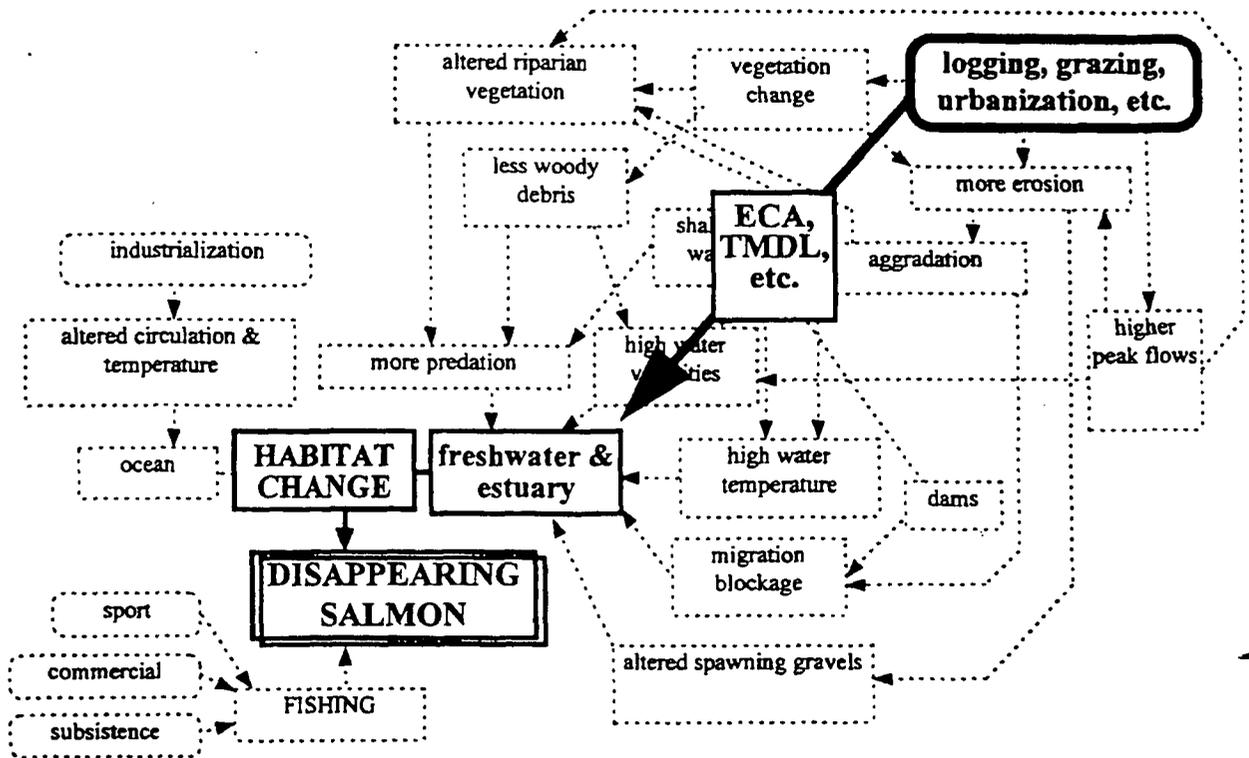
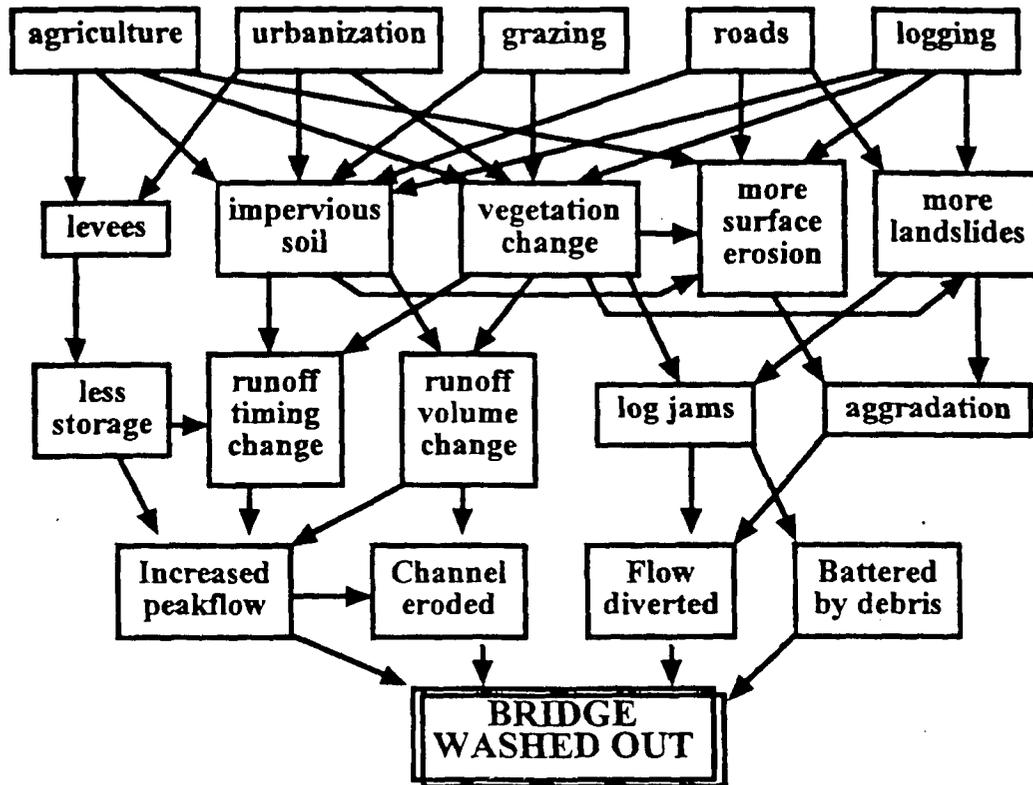


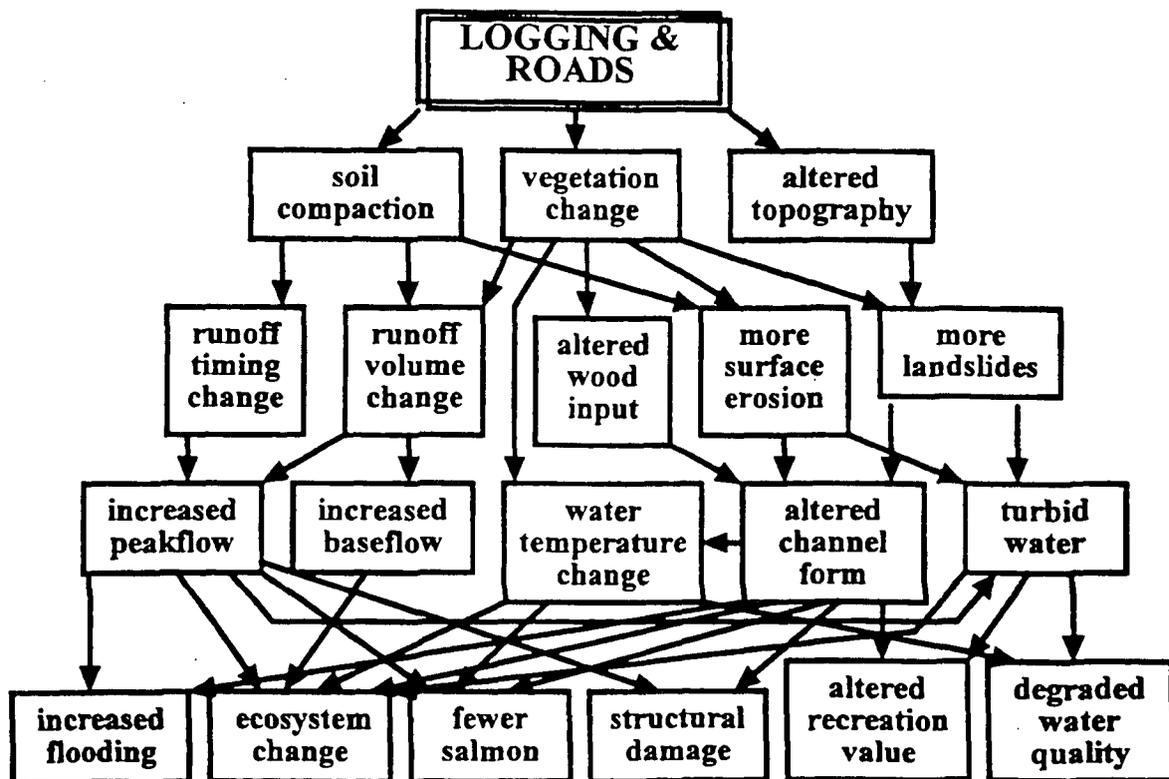
Figure 4.



BOTTOM-UP APPROACH

Figure 5.

TOP-DOWN APPROACH



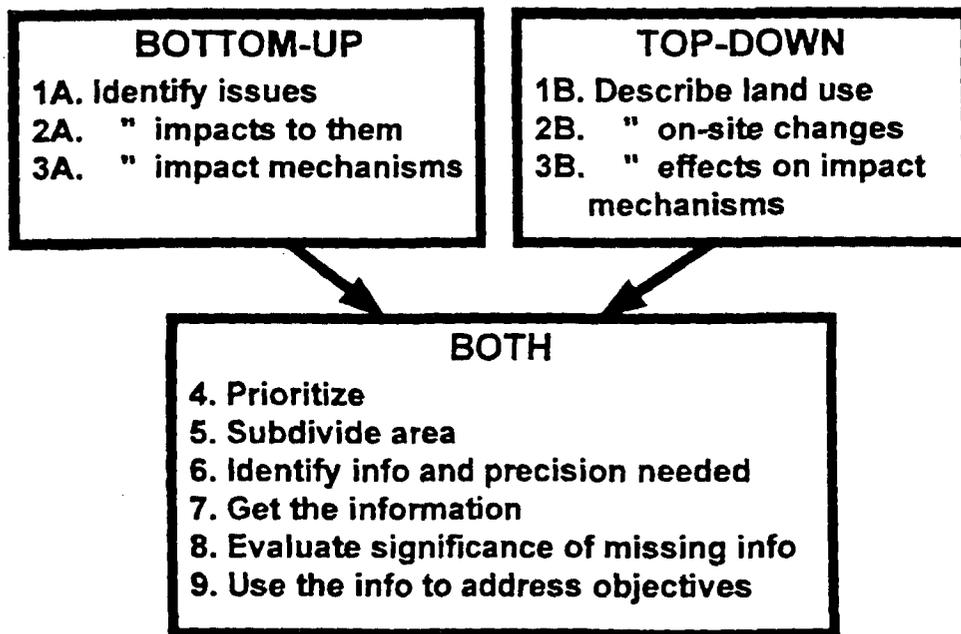


Figure 6. Merging of Bottom-Up and Top-Down Approaches

a watershed. An educated guess by the analyst will often suffice.

ANALYSIS SCALES

Spatial Scale

Historically, management agencies spent a lot of time focused on planning project-level operations and much less time evaluating the effect of these small-scale projects on larger-scale issues. The result has been a host of cumulative effects problems. Now, however, the Northwest Forest Plan Record of Decision (USFS & USBLM 1994) prescribes a multiplicity of analysis scales that would be used simultaneously (table 1). Unfortunately, the Record of Decision also identified one specific scale, the watershed scale (20 to 200 square miles), at which watershed analysis would be required before certain land-disturbing activities could be conducted.

Because of this explicit requirement to conduct an analysis at the watershed scale, the land management agencies undertook watershed analysis in a big way, ignoring the river basin and regional scales with the unspoken assumption that these could be put off indefinitely since management activities are not contingent on their completion. The fallacy in that approach, however, is that all of these scales are important to establish the context of land management activities for a multiplicity of issues. For example, for the issue of Disappearing Salmon (figure 1), the appropriate large spatial scale is the full range of the salmon from Alaska to central California, including the ocean and freshwater habitats. Then, we need to understand how our particular river basin fits into the context of the overall Pacific Northwest salmon issue. It could be that this particular river basin is very important to maintaining residual stocks of salmon, or, conversely, our basin may play such a minor role that it is not important in the larger scheme. The basin scale then establishes the context for asking a similar question for each individual watershed within that river basin.

For example, if the job is to conduct a watershed analysis for Blue Creek (figure 7), it is important to understand the context of Blue Creek with respect to other watersheds in the Klamath River basin. In other words, projects in Blue Creek intended to address the issue of Disappearing Salmon cannot ignore what is going on in other watersheds in the Klamath River Basin. It may be that the same amount of money and same amount of effort would have a great deal more efficacy in affecting the issue of Disappearing Salmon if transferred to another watershed (for example, Clear Creek). Now the decision becomes political, because Clear Creek happens to be in someone else's district. For watershed analyses to be useful, they must consider the context of that watershed within multiplicity of scales that range from large to small and from small to large, for each issue. And for watershed analysis results to be effectively used, intra-

and inter-agency cooperation must be developed to the point that decisions are based primarily on resource needs rather than on jurisdictional labels.

Temporal Scale

It is just as important to consider multiple temporal scales (table 2) as it is to consider multiple spatial scales. Not only does a distinct suite of time scales shape physical and biological issues, but people's perceptions of relevant time scales are shaped by political and psychological factors. For example, corporations are very often run and managed on a basis of the quarterly profit-loss sheet. A 50-year planning horizon may mean nothing to the management of a corporation that loses money for several consecutive quarters. The stockholders may simply replace the managers with someone that can improve their quarterly dividend. Politicians are often most interested election cycles; they really want to get something accomplished before their next election. Humans have life spans that range up to about a century, but human operational memory is often much shorter. For example, after an area experiences a flood, people continue to be concerned about flooding for a few years. But, after a while, concern wanes and flooding no longer is thought to be a problem, even though the probability of another flood remains unchanged.

The appropriate temporal scale depends on the specific issue being considered. Insects may have several life cycles in a year. Anadromous fish have life cycles that range from three to five years, depending upon the species. Humans have life cycles up to a century. Trees have life cycles that are calculated in centuries. No single time scale will be appropriate for all issues.

Domestic water users might become concerned every time they turn on the water tap and receive muddy water. Consequently, the water company might focus on turbidity during individual storms that occur several times a year. In contrast, physical river channel adjustments that establish channel morphology may occur once a century or once a millennium.

REDWOOD CREEK WATERSHED

To summarize some of these points, let us look at a specific example, Redwood Creek, a 285-square mile watershed located in northwestern California. Redwood National Park was initially established in 1968. The Park was expanded in 1978 because logging and road construction were thought to threaten survival of the world's tallest trees, which grow on alluvial flats in the lower portion of Redwood Creek. Redwood National and State Parks control most of the lower 116 square miles of Redwood Creek, about 40% of the watershed. Coarse sediment (bedload) was identified as being one of the principal threats to the alluvial redwood groves. Most of this material was deposited into upper and middle

Table 1.
SPATIAL ANALYSIS SCALES

REGIONAL
Multi State

RIVER BASIN
1,000s of square miles

WATERSHED
20 - 200 square miles

PROJECT
< 1 square mile

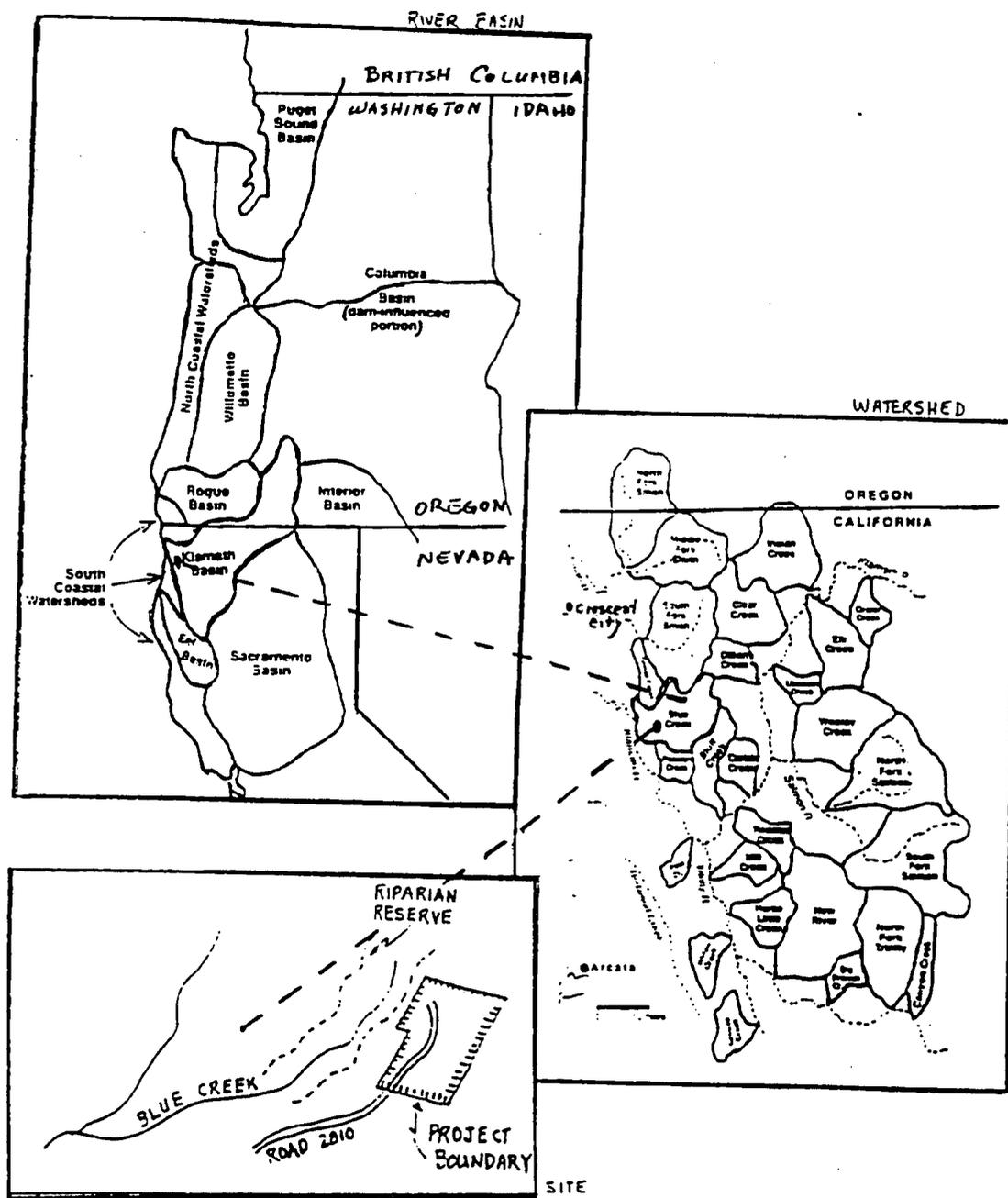


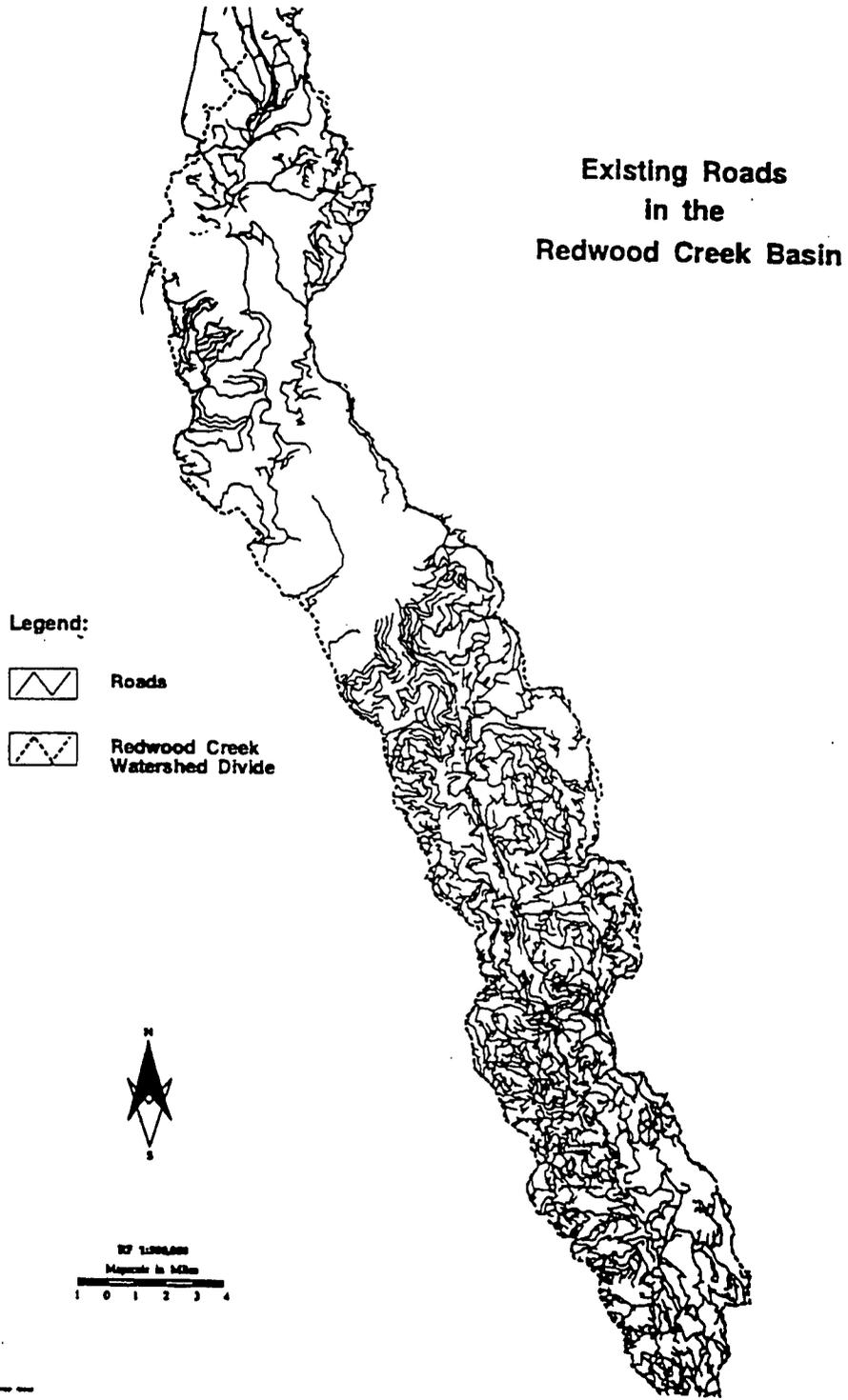
Figure 7. Spatial Scale and Watershed Analysis for Blue Creek

Table 2.

APPROPRIATE TIME SCALES

| | | |
|---------------------|------------------------------|------------------|
| Corporations | Quarterly profits and losses | 0.25 years |
| Politicians | Election cycles | 2, 4, or 6 years |
| Humans | Operational memory | 1 to 20 years |
| Humans | Life span | 50 to 100 years |
| <hr/> | | |
| Insects | Life cycle | 1 year |
| Anadromous fish | Life cycle | 2 to 4 years |
| Humans | Life cycle | 50 to 100 years |
| Trees | Life cycle | 100 to 250 years |
| <hr/> | | |
| Domestic water user | Individual storm | 0.2 to 5 years |
| Channel adjustments | Aggradation | 1 to 1000 years |

Figure 8.



portions of the watershed during the 1964 flood, and most is still stored in the channel today. Landslides and other processes have continued to add coarse sediment to the channel. However, for the past 20 years, there have been no major storms to move this sediment. For the past 30 years, bedload movement has been mostly a redistribution of sediment deposited in the drainage basin in 1964.

Roads were identified in the Redwood National Park legislation (P.L. 95-250) as being one of the primary problems that need attention. In 1978, there were about 1,400 miles of road and 5,400 miles of skid trails in the Redwood Creek watershed (Redwood National and State Parks, 1996). Of these, about 400 miles of roads and 3,500 miles of skid trails were located within the Park. In 1978, the density of roads within and outside the Park was about the same. Between 1978 and 1992, a large rehabilitation program treated about 175 miles of logging roads within the Park, while during that same period about 127 miles of new roads were constructed and 111 miles of old roads were rebuilt in the watershed above the Park (Redwood National and State Parks, 1996). This effort cost about \$10 million to rehabilitate the roads. In addition, \$100 million was paid to displaced workers when the Park acquired the land, and about \$364 million was expended to buy the land and improvements.

Today, a look at the road distribution within the watershed (figure 8) demonstrates a serious spatial issue related to the objective of protecting the world's tallest trees. The Park Service has reduced the road density within the Park, where it has control of the land and authority to spend federal restoration funds. However, the lands above the Park are privately owned. Timber harvesting and associated road construction on private land is regulated by the California Department of Forestry and Fire Protection. The Department has regulatory authority over roads only within about the first three years after a timber harvest plan is completed. After three years, the Department has no jurisdiction. Further, many of the roads are constructed for ranching or private home sites where there is little or no regulation by anyone.

So, while a principal concern in Redwood Creek is to protect the Tall Trees Grove and roads have been identified as the major threat, at the watershed scale, more roads have been constructed since 1978 than have been obliterated. This

occurred despite a massive effort by the Park Service to rehabilitate and obliterate roads. At the Park scale, the rehabilitation effort is successful, but at the watershed scale, it must be considered a failure. How much of a failure? We will not know until the next really large storm hits.

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WHAT IS WATERSHED STABILITY?

*A review of the foundation concept of Dynamic Equilibrium
in watershed management*

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