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Ecological Health of River Basins in Forested Regions of Eastern Washington and Oregon

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ABSTRACT

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A retrospective examination of the history of the cumulative influences of past land and water uses on the ecological health of select river basins in forest regions of eastern Washington and Oregon indicates the loss of fish and riparian habitat diversity and quality since the 19th century. A physiographic framework of the eastern Washington and Oregon in terms of spatial and temporal geologic, climatic and hydrologic conditions provides a regional perspective for reviewing influences of human patterns of settlement, resource development and management on the river basins. The study focuses on impacts of timber harvest, fire management, livestock grazing, mining and irrigation management practices on stream and riparian ecosystems. Extensive reviews of ecosystem damage and fish losses caused by hydroelectric and large irrigation projects, highway and railroad construction and other factors are beyond the scope of this analysis but are summarized. Case histories of the chronology of natural resource uses and health of select river basins, the Okanogan, Methow and Little Naches River basins (Cascade Mountains of Washington) and the Grande Ronde and John Day River basins (northeastern and central Oregon) show that during European settlement period livestock grazing, mining, and irrigation developments were the major land and water uses impacting streams and riparian ecosystems. After the 1940s, timber harvest, road construction and irrigation were the major management impacts. The examination of past environmental management approaches for assessing stream, riparian, and watershed conditions in forest regions shows numerous advantages and shortcomings. The select management approaches include: instream flow incremental methodology (IFIM) for the evaluation of the effect of water diversion on steam flows and salmonid habitats; the equivalent clear-cut method (ECA) for assessing the hydrologic effects of logging; a watershed cumulative effects model (KWCEA) for evaluating the effects of logging and roads on soil loss; and procedures for addressing soil compaction problems. The study concludes by providing recommendations for ecosystem management with emphasis on monitoring and restoration activities.

Keywords: History, land uses, rivers, streams, riparian, salmonid, timber, livestock, irrigation, water.

Contents

INTRODUCTION

This document reviews cumulative influences of past land and water uses on the ecological health of select river basins in eastern Washington and Oregon. The first section presents a physiographic framework of eastern Washington and Oregon in terms of spatial and temporal geologic, climatic, and hydrologic conditions. It provides a regional perspective for reviewing the influences of human patterns of settlement, resource development, and. management on the health of river basins. The next section is a brief regional overview of land and water uses and their effects on stream and riparian ecosystems, focusing on management practices related to timber harvest, fire management, livestock grazing, mining, and irrigation, although damage to stream and riparian ecosystems and fish losses are caused by other factors—such as hydroelectric and large irrigation projects, highway and railroad construction, agriculture and forest chemicals, recreational activities and management, flood control, dam passage mortalities of fish, and fish lost to mixed-stock ocean fisheries—these considerations are beyond the scope of this analysis and are acknowledged only with key references.

The regional overview sets the stage for more-detailed case histories for select river basins of the region. The case histories focus on the chronology of natural resource uses and health of select river basins in eastern Washington and Oregon: the Okanogan and Methow River basins (north-central Washington), the Little Naches River of the Yakima River drainage in the eastern Cascade Mountains, the Grande Ronde River basin (Blue Mountains of eastern Oregon), and The John Day River basin in north-central Oregon. The history of the Okanogan and Methow River basins focuses on the chronology of events during the last century and the early 1900s that shaped current landscapes and socioeconomic conditions in eastern Washington and Oregon. Summaries of the histories for the Little Naches, Grande Ronde, and John Day River basins provide more-specific reviews of land and water uses that have influenced stream and riparian ecosystems in these river basin landscapes.

The next section reviews select management approaches that have been used to improve and protect watershed, stream, and riparian ecosystems . The review includes select applications of the instream-flow incremental methodology (IFIM) for evaluating the effect of water diversion on stream flows and salmonid habitats (Methow River, WA); the equivalent clearcut method (ECA) for assessing the hydrologic effects of logging; a watershed cumulative effects model (KWCEA) for evaluating the effects of logging and roads on soil loss; and procedures for addressing soil compaction problems.

The concluding section provides recommendations for ecosystem management. The recommendations focus on developing perspectives of river basin or landscape management with emphasis on monitoring and restoration activities. We acknowledge ongoing reports that are developing various action plans for restoring and maintaining watersheds and stream and riparian ecosystems in the Columbia River basin.

Sources of information that complement this document directly include papers by McIntosh and others (1993) and USDA Forest Services PACFISH Strategy, (in press). The review by McIntosh and others (1993) focuses on how stream habitats of salmon have changed in tributaries of the Methow, Wenatchee, Yakima, and Grand Ronde River basins over the past 50 years. Management concepts and recommendations being incorporated into the PACFISH Strategy reflect those developed in the Upper Grande Ronde River Anadromous Fish Habitat Protection, Restoration, and Monitoring Plan (Anderson 1992).

EASTERN WASHINGTON AND OREGON PHYSIOGRAPHY

Geological Landforms

Eastern Washington and Oregon have four general physiographic areas (table 1), each differing from the others in climate, topography, and natural resources. These conditions, along with the unique geology, have broad influences on the ecology of a natural ecosystem and human economy. The major landforms in the eastern part of the State include the Northeastern Highlands or Okanogan Highlands, the Columbia Plateau, the Blue Mountains, and the Cascade Range. These landforms began to develop about 200 million years B.P. (before the present).

Table 1—Geologic landforms of eastern Washington and Oregon*.

1) Northeastern Highlands or Okanogan Highlands
2) Columbia Plateau
3) Blue Mountains
4) Cascade Mountains
North Cascade Subcontinent
Cascade Volcanoes

*Alt, D.D. and D.W. Hyndman (1984)

The drifting movement of the North American continent during the early Mesozoic Era initiated the formation of geologic regions in the Pacific Northwest (Alt and Hyndman 1984). Two hundred million years ago, the North American continent began to move away from Europe. As North America moved west, the floor of the Pacific Ocean began slipping below the westward moving continent and disappearing into the mantle. The collision of North America with the ocean floor crushed the old coastal plain into a belt of tightly folded sedimentary rock. This belt of folded rock, the Kootenay Arc, extends through eastern Washington and British Colombia. The Kootenay Arc disappears beneath younger rock west of Spokane. The Blue Mountains and the Wallowa Mountains of Oregon may be the southward continuation of the Kootenay Arc.

As North America moved west, it collided with small island continents, forming other distinct geologic regions. The first addition, the Okanogan Subcontinent, formed about 100 million years ago (late Mesozoic-early Cenozoic Era) and is now the high land between the Columbia and Okanogan Rivers. Afterwards North America was still moving west and the Okanogan Trench, in the vicinity of the Okanogan valley, formed where the ocean floor collided with the Okanogan Subcontinent.

Fifty million years ago during the Tertiary period, the North Cascade Subcontinent collided with North America and obliterated the Okanogan Trench just west of the Okanogan Valley. The North Cascade Subcontinent contained active volcanoes that lasted until 25 million years ago. For the next 10 to 15 million years, the Cascade volcanic activity subsided. The focus of volcanic activity shifted east to form the Columbia Plateau (black basalt lava flows). After this period the activity shifted back to the Cascade to form the high Cascade Range.

Climate Change and the Development of River Drainages

As the Columbia Plateau was being built by eruptions, the Pacific Northwest appeared to have a wet tropical climate. When the eruptions subsided, the climate became dry (Pliocene Epoch, 8 to 30 million years ago). About 2 to 3 million years ago, the Earth's climate became unstable. Since that time, the Pleistocene epoch (duration of ~ 10,000 to 2 million years B.P.) experienced several ice ages (Dunne and Leopold 1978). During the last two ice ages, large glaciers covered most of the northern two thirds of Washington as well as the higher mountains. Glaciers left morainal ridges and expanses of outwashes. Moraines were formed of till consisting of fragments ranging from clay to boulders. Outwashes were formed by torrential flows of summer meltwater that transported large amounts of sediments off the ice to form gravel and sand deposits below moraines.

Glaciation during the Pleistocene played a significant role in forming many river basins in north Washington. For example, before glaciation, the Columbia River flowed across rather than around what is now the Colville Indian Reservation. In the vicinity of Omak, the river flowed through what are now Big Goose Lake and Omak Lake, then turned south following the present course of the Okanogan River. A glacier formed in the Okanogan valley and blocked this passage, forcing the Columbia into its present course and leaving Omak Lake. Later advances of glacial lobes also blocked the Columbia River causing the river to carve out the Grand Coulee (Wilson 1990).

The North Cascades were glaciated by alpine glaciers before the continental ice sheet, which covered all but the highest mountains in both the North Cascades and the Okanogan Highlands. The continental ice did not greatly alter the basic shapes of alpine glaciated landforms (cirques, pointed peaks, and U-shaped valleys between steep, highly dissected ridges) of the North Cascades but removed most depositional material left by the alpine glaciers. In contrast, in the Okanogan Highlands, where alpine glaciation did not precede the continental ice sheet, landforms were smoothed, leaving moderate slopes and broad rounded summits (Williams and Lillybridge 1983).

During the Pleistocene, the landscape geomorphology of eastern Washington landscape was altered by large, catastrophic floods. Large ice dams and lakes formed by glaciers were breached, releasing massive volumes of water. The largest flood, the Spokane flood, occurred when the ice dam of Glacial Lake Missoula in western Montana broke and released 2500 km^3 of water into eastern Washington, forming channeled scapelands, as well as altering the Columbia River's mainstream channel (Baker and others 1987). The chronology of other geologic, geomorphic, and climate factors influencing eastern Washington and Oregon landscapes since the Pliocene are summarized in table 2.

Table 2—Chronology of geologic, geomorphic and climate factors influencing eastern Washington and Oregon landscapes since the Pliocene Epoch. Modified from ERDA 1979.

EPOCH	Age Years BP	Geologic Units	Geologic and Related Events	Climatic Trends
HOLOCENE	Modern	Landslides	Hydrologic induced landsliding	Cooler, moister
		Ash deposits	Eruption of Mt. St. Helens	
	4,000			
		Palouse soils & dunes	Dune creation, little mass wasting	
			Columbia River at low flow	
	6.000	Ash deposits	Eruption of Mt. Mazama	
	8,000			
		Eolian sediments		
			Extinction of many large mammals, early man known in basin	
	10,000			
		Landslides	Floods & landslides	
		Ash deposits	Eruption of Glacier Peak	Warmer & drier
	12,000			
PLEISTOCENE				
		Flood deposits	Continued anticlinal uplift & basining, floods, grazing animals in region	
	18,000 22,000	Flood deposits & erosion	Catastrophic floods from Glacial Lake Missoula, extensive erosion,	
			landsliding and sediment deposition	
	50,000	Early flood deposits	Glacial ice dams breach & flood	Onset of ice age
	1 - 2 Million			

Studies of the Holocene epoch (duration of modern to ~ 10,000 years B.P.) have provided insight into the effect of climate changes on riverine ecosystems. During the middle Holocene, the Hypsithermal interval of 6000 to 9000 years B.P. provides a model of the effects of future warming temperatures on river ecosystems of the Pacific Northwest region (Chatters and others 1991). For the region, the Hypsithermal interval appeared to have temperatures averaging 1 to 2° C warmer and 33 to 38 percent drier than today. Timber-lines in the Cascade and Rocky Mountains were between 150 and 300 m higher during the middle Holocene than they are now (Osborn and Luckman 1988). Reconstruction of prehistoric stream conditions from floodplain deposits and fossil mussel shells, and from moisture estimates from pollen data, suggests stream flows approached 33 percent less than today. The warm water, the reduction in stream flows, altered stream hydrographs, and finer stream substrates conditions of the mid-Holocene may have been common for riverine ecosystems throughout the Columbia River basin. If such conditions existed today, perennial streams might be intermittent, the warmer waters uninhabitable by salmonids. The reconstruction of mid-Holocene climate suggests how future climate warming periods might influence stream ecosystems. For example, a Hypsithermal interval and drier climates combined with today's depressed salmon populations could further reduce fish abundance. Such conditions might also increase evaporation, and reduce forest and riparian cover, and surface runoff (Chatters and others 1991, Neitzel and others 1991).

Ecoregions and Hydrology

Ecoregions—Landscapes that contain river drainage basins and their tributary watersheds can be described by a hierarchy that places ecoregions at the largest spatial scale. Nested within ecoregions are geomorphic components of decreasing size. They include river basins, tributary watersheds, and stream and riparian habitats. Ecoregions have been defined as areas of relative homogeneity in ecological systems (Hughes and others 1990, Omernik 1987) and their components such as forests, soils, and fish and wildlife assemblages and distributions, as well as relations with hydrologic, climatic, geological conditions, and fire regimes. Some of the most pronounced differences occur between "arid" ecoregions of eastern Washington and Oregon and ecoregions of high rainfall near the eastern crest and west of the Cascade Range. Six ecoregions occur in eastern Washington and Oregon. River basins in arid ecoregions commonly have dominant contributions of discharge in headwaters and minimal downstream water sources. In contrast, drainages in high rainfall ecoregions commonly have significant contributions of discharge both in headwater and downstream portions of a river basin.

Depending on geological formations, such as basalt bedrock and glacial alluvium, rivers in mountain valleys of many eastside ecoregions can exhibit shallow to deeply entrenched channels. Although the geology relative to hardness and permeability) is highly variable, fluvial geomorphic processes of erosion and deposition also contribute to many large-scale morphological characteristics of the drainage basins. Although lithology can provide bedrock channels in deep and narrow valleys, erosion and deposition produce semiconfined and unconfined channels in alluvial valleys and broad floodplains (Rosgen 1985, Schumm 1985). Geologic and geomorphic features of headwater tributary watersheds, such as streambank failures and landslides from hillslopes, usually control modes of delivery of debris to stream and riparian habitats, as well as influence the type and size of sediment supplied to downstream valleys (Baker and others 1988). Factors like hillslope relief, stream channel drainages, density characteristics of watersheds, climatic conditions, and peak flow events influence cumulative effects of material delivery and transport (Horton 1945, Parker 1977, Patton 1988).

Hydrologic and climatic characteristics—More than 75 percent of the continental U.S. water supply has its origin on forested lands. In Washington and Oregon, more than 95 percent of usable streamflow can come from forested and alpine lands. Washington and Oregon can be stratified into major hydrologic regimes based on precipitation as rain and snow and average winter temperatures. Major topographic features of mountain ranges and marine influences, such as oceanic currents, create climates that yield definite hydrologic regimes and patterns of vegetation. These interactions influence the development and location of agricultural, industrial, and urban centers.

Climate—Coastal river basins in warm maritime-subclimatic zones along the North Pacific coast have flow patterns characterized by rainfall-induced floods in fall and winter. Such river basins are usually short, originating in mountainous coastal regions. These river basins can have distinct subclimates because of interactions between atmospheric circulation patterns and abrupt coastal mountains that serve as barriers to the movement of air masses. The basins have west-facing mountains with dense clouds and high precipitation.

Warm coastal subclimates are a result of the coastal climate being largely controlled by macro-scale atmospheric processes (Thomas 1977). The usual circulation pattern during the winter is produced by a strong temperature gradient between tropical and polar latitudes. Winter low pressures over the Gulf of Alaska and high pressures on the continent combine to produce strong pressure gradients on the North Pacific coast where southerly surface winds prevail. As a result, numerous storms develop rapidly over the Pacific Ocean, with small-scale frontal systems breaking away from storm centers and impinging on the coast. These fronts bring the strong southwesterly flows of warm air that are responsible for coastal rainfalls. Summer atmospheric circulation patterns are weaker, being controlled by a large high pressure center over the north Pacific Ocean and coast. The result is weaker pressure gradients, northwesterly winds, and low frequency and intensity of Pacific storms.

Variations in precipitation, when frontal systems impinge on diverse landscapes for different river basins in the Pacific Northwest, are caused by circulation patterns and interactions with local topographic features such as elevation, slope, and aspect. These characteristics are reflected in the different flood regimes of river basins. For example, extreme floods do not result from the same flood-producing mechanisms on all drainage basins. River basins west of the Cascades can have rainfall-induced flood regimes, either as rainfall runoff only, or as rain-on-snow runoff in fall and winter; other watersheds both west and east of the Cascades have snowmelt-induced flood regimes in spring or summer. Some western basins can have both rainfall-induced and rain-on-snow flood regimes. Eastern Washington and Oregon drainages feature snowmelt-induced flood regimes (spring/summer) typical of cold interior or continental regions (Melone 1985). Select river basins east of the Cascade can sometimes be influenced by rain-on-snow runoff events.

Hydrologic regions—River basins of eastern Washington and Oregon can be grouped by major hydrologic regions, based on precipitation inputs and average winter temperatures (table 3). This approach is based on the dominance of the maritime climatic patterns and interactions of climate and topographic features with inland landforms, which form definite hydrologic zones and distinct snow accumulation patterns (Wooldridge 1972). The hydrologic regions include the Blue Mountains Basins, The Great Basin, Columbia Plateau Basins, Columbia South Cascade Basins, Columbia North Cascade Basins, and the Northcentral and Eastern Upland Basins (table 3). All the rivers are tributaries to the Columbia River, the major source of water in Washington and Oregon.

Table 3—Major hydrologic regions and rivers in eastern Washington and Oregon.*

Blue Mountains Basins	
	Grande Ronde River, OR
	John Day River, OR
	Powder River, OR
	Malheur River, OR
Great Basin	
	Owyhee River, OR
Columbia Plateau Basins	
	Snake River, WA and OR
	Crab Creek, WA
Columbia South Cascades Basins	
	Deschutes River, OR
	Yakima River, WA
Columbia North Cascades Basins	
	Methow River, WA
	Chelan River, WA
	Wenatchee River, WA
Northcentral and eastern Upland Basins	
	Okanogan River, WA
	Kettle River, WA
	Colville River, WA
	Pend Oreille Rivers

***Modified after Wooldridge (1972) and Highsmith and Kimerling (1979).**

Snow accumulation patterns and streamflows-The concept of hydrologic regimes being controlled by the form of precipitation released for streamflow can be studied by examining snow accumulation zones. Once the water reaches the Earth's surface, hydrologic regimes are influenced by basin characteristics such as topography, relief, length, stream gradient, vegetation, and soils. In mountainous regions, the most obvious and dominant influences are elevational and orographic features. These factors have considerable influence on the source and timing of streamflow.

Three general snow zones exist in Washington: the No Snow Zone, the Warm Snow Zone, and the Cold Snow zone. The No Snow Zone includes the coastal and Puget Sound lowlands. The coastal lowlands cover areas below 2000 ft along the Pacific Ocean. Summers are cool and humid with temperatures averaging 55° F and little rainfall. Precipitation averages 90 in/year below 2000 ft and over 150 in/year above 2000 ft. Most of the rainfall (50 percent) occurs during November, December, and January. Snow accumulates above 2000 ft in the interior mountains. Hydrologic regimes in the No Snow Zones have their highest flows during the wettest month of January because of vigorous winter rainstorms. The Puget Sound lowland's climate is moderated by Puget Sound and forms a boundary with the Warm Snow Zone. Winter temperatures range in the 30 to 40's and in the summer exceed 60° F. Intermittent snow falls below 2000 ft, and continuous snow cover usually exists above 2000 ft, varying with topography and solar radiation. Small drainage basins usually show rapid response to rainfall. Very low flows occur in the dry months of July, August, and September. Orographic influences are common throughout the year, increasing during late summer to a maximum in November. Very high winter rains during December, January, and February may negate orographic effects of elevation.

The Warm Snow Zone extends from the rainfall zone to 5000 feet in the Cascades Range but higher in the Olympic Mountains. Snow cover can occur from October to March. Deep snow accumulations from 5 to 20 feet can occur in the Cascades, with records near Paradise, Mount Rainier. This zone can spill over to the eastside of the Cascades. Intermittent Warm Snow Zones may develop, where orographic conditions permit, in mountainous areas in the Colville National Forest of northern Washington and the Idaho Panhandle. Warm air masses of 50 to 60° F can occur for a few days in winter and are usually accompanied by moderate to heavy rainfall. Under these conditions, the warm snowpack, which is usually isothermal, can respond rapidly to significant rainfall because the snowpack transmits water in a manner similar to the soil matrix. The result can be significant flooding events during periods of rain or warm air mass movement. The effects of the warm snow zone on streamflow vary with topography, timberline, glaciation, soil depth, and forest conditions.

The Cold Snow Zone occurs above 5000 feet in the western Cascades and in eastern Washington and Oregon. Temperatures below freezing result in continuous snow accumulation as a cold snowpack. Precipitation follows maritime patterns but most of the streamflow occurs during the annual melt of May, June, and July. The Cold Snow Zone can be subdivided into a high precipitation zone of the high Cascades (> 5000 ft with > 50 in/year with extended snow cover periods) and a low precipitation zone (10 to 15 in/year) at lower elevations east of the Cascades. In eastern Washington and Oregon, elevations below 2000 ft usually do not contribute significantly to streamflows. The transition zone between the ponderosa pine forests and the brush-grassland vegetation types is at 1500 to 2000 ft elevation. A climatic anomaly to this plant-rainfall association occurs in the Okanogan Highlands. This area receives a large portion of its annual rainfall in the summer allowing commercial forests to grow at lower elevations on drier sites.

The Wenatchee River (eastern Cascades) and Colville River (northeastern Washington) basins are examples of Cold Snow Zone river basins. Rugged-high elevations of the Wenatchee River basin are above timberline, with some glaciers and snowfields. Commercial forests are at lower elevations than the subalpine forests. They consist of mixtures of Douglas-fir, Pacific silver fir, and western hemlock. Ponderosa pine occupy a wide range of transitional elevations. In contrast to the wide elevational zones of the Wenatchee basin, the Colville River, basin consists of gently rolling foothills.

In the Wenatchee River basin, the rain shadow and orographic effects of the Cascades cause low water yields at lower elevations. Variations in run-off patterns are caused by differences in topography and orientation of subbasins. These variations at lower elevations and higher solar-radiation earlier in the year increase contributions of snow melt. These influences can shift flow peaks into April. The Colville River basin is typical of the Cold Snow Zone, with maximum runoff in late spring due to snowmelt. The monthly distribution of runoff is similar to the Wenatchee River.

REGIONAL OVERVIEW

The following sections provide overviews of the status of stream and riparian ecosystems and of the primary effects of land and water uses on these ecosystems in river basins of eastern Washington and Oregon. These reviews set the stage for case histories of select river basins of the region. The case histories focus on the chronology of natural resource uses and the health of streams and riparian ecosystems. The river basins include the Okanogan and Methow River (north-central Washington), the Little Naches River of the Yakima River drainage (central Washington), the Grande Ronde River (eastern Oregon), and the John Day River basin in north-central Oregon.

Information about other river basins in eastern Washington and Oregon that complement this document includes the review of the management history of salmonid habitats in eastern Washington and Oregon (McIntosh and others 1993). This review focuses on changes in salmon habitat over 50 years (1935-92) in tributaries of the Grande Ronde, Yakima, Wenatchee, and Methow River basins. Other important sources of information about the chronologies of major settlement, natural resource uses, and related historical events and developments in eastern Washington and Oregon include Dicken and Dicken (1979), Highsmith and Kimerling (1979), Kerr (1931), Steele (1904), and Wilson (1990), and more local histories of National Forests such as Holstine (1987).

Stream and Riparian Ecosystems

Both historically and today, the landscapes of eastern Washington and Oregon, like most of the Pacific Northwest, contain numerous watershed, stream, and riparian ecosystems that have and are being continuously degraded by a combination of agriculture and irrigation, timber harvest and forest management, road building, livestock grazing, mining, and tie combined or cumulative effects (Peterson and others 1992, NCASI 1992) of these and other land- and water-use practices. Examples of significant changes in stream- and riparian-habitat qualities that indicate degraded conditions in different river basins of eastern Washington and Oregon are given below. Major habitat changes include the loss of riparian vegetation and increased canopy opening widths adjacent to stream channels; loss of riparian vegetation and decline of large woody debris in stream channels; increases in water temperatures from minimal shading by riparian canopies and shallow-sediment and debris ladened stream channels; accumulation of fine sediments and loss of gravel and pool attributes in stream channels because of land-uses that alter streamflow regimes and sediment budgets; and loss of water in stream channels and riparian areas because of water diversion practices. Much information for eastern Washington and Oregon relates to changes in stream and riparian habitats and responses of salmonids to habitat alteration-changes, for example, in the following: riparian canopy widths (Smith 1993); large woody debris distribution in streams (Bilby and Wasserman 1989); water temperatures (Berman and Quinn 1991, Li and others 1992, Maloney and others, in press); substrate conditions (Chapman 1988, Corner 1992, McIntosh and others 1993, Smith 1993); and water diversion and streamflows (Caldwell and Catterson 1992). A recent synthesis document provides valuable information that focuses exclusively on the past and present conditions of stream habitats and salmonid stocks in the central Columbia River basin of Washington (Mullan and others 1992).

Stream conditions and salmonid stocks-Much of the eastside region that exhibits stream and riparian degradation is found in upland forests and range areas. Major land and water uses affecting these stream and riparian ecosystems include timber harvest practices, fire management, livestock grazing, mining, and irrigation. Although detailed accounts of other human activities altering stream and riparian ecosystems are beyond the scope of this analysis, the following summary describes some important modifications of these ecosystems and related responses of ecologically sensitive salmonid stocks in eastern Washington and Oregon. These modifications include hydroelectric and large irrigation projects, and dam passage mortalities of salmon and fish lost to mixed-stock ocean fisheries.

During the 1930s and 1940s, permanent blockage of riverine channels by large mainstream dams, such as the Chief Joseph and Grand Coulee dams, assured the loss and degradation of salmon and steelhead habitat. Dams with no feasible fish passage facilities have inundated rivers, destroying rearing and spawning habitats and increasing downstream migration time. Losses in anadromous fish habitat in the Columbia (above Bonneville Dam) and Snake Rivers between 1850 and the present have been estimated at 35 percent, a decrease from about 11,700 to 7600 miles of stream. Cumulative passage mortality for juvenile fish moving downstream to the ocean is estimated to be about 77 to 96 percent and the corresponding mortality for adults moving upstream is 37 to 51 percent (NPPC Staff 1986).

Fish losses in mixed: stock ocean fisheries have been attributed to equal rates of fishing pressure suffered by both upper and lower Columbia River runs, resulting in overfishing of the weaker upriver and wild fish runs. Fish harvest rates are commonly set for the stronger down river runs, which includes runs, below Bonneville Dam. These fish runs are stronger because they have received considerable hatchery supplementation. The Mitchell Act (16 U.S.C. -750) for hatchery programs in 1949 caused downstream river hatchery production in the 1960s to surpass natural production. This extensive production of hatchery fish along with overfishing of wild and upriver runs and permanent blockage by large dams, has led to the elimination of some fish runs as well as changes in the genetic character of many stocks (NPPC Staff 1986). Additional losses of habitat and runs have occurred throughout the Columbia River basin because of damage and reclamation actions related to forestry, grazing, mining, farming-irrigation, and other practices. Finally, although the environmental problems facing salmon and steelhead are extensive and cumulative, their environmental effects are often confounded by natural biotic interactions including introductions of disease, exotic species, and predators.

Riparian conditions—Riparian ecosystems in eastern Washington and Oregon, as in most climatic regions, reflect interactions between hydrologic and geomorphic processes associated with landforms, terrestrial and aquatic ecosystems, and river basin landscapes. Riparian ecosystems are water dependent systems adjacent to aquatic ecosystems. They contain plant and soil systems with both wetland and upland attributes that provide the vital transition between forest and stream, hillslope and valley, and terrestrial and aquatic ecosystems. Important functions include water movements and the transport of sediments, nutrients, and exotic and toxic materials (Belt and others 1992, Debano and others 1990, Gregory and others 1991, Leonard and others 1992, Minshall and others 1989, Wissmar and Swanson 1990).

In eastern Washington and Oregon, riparian ecosystems are high-use areas desired by many elements of society for many purposes. Riparian areas are commonly subjected to intensive management practices to promote water conservation and to provide grazing for livestock. Grazing, irrigation, timber harvest, mining, road construction and maintenance, agricultural practices, and high runoff events over the past 100 to 150 years have caused considerable habitat damage and neglect of riparian ecosystems (Beschta and others 1991, Elmore and Beschta 1987, Kauffman 1988, Kauffman and Krueger 1984). Conflicts over control of riparian resources by user groups-water, timber, livestock, wildlife, recreational, and environmental-are intense and cause complex management problems. Hanson (1987) in a report for the Oregon Environmental Council qualitatively identified the most apparent factors contributing to the deterioration of riparian areas in 11 different river basins of eastern Oregon (table 4). The order of importance of the major factors affecting riparian areas appears to be livestock grazing > timber harvest practices > agricultural practices > road construction > flood events. The next section contains a summary of livestock grazing in eastern Washington and Oregon.

Table 4—Summary of the "major factors affecting, riparian areas" in the different river basins of eastern Oregon (Hanson 1987).

	"Major Factors Affecting Riparian Areas"												
River Basin	Grazing	Logging	Roads	Stream Channelization	Floods	Irrigation	Spraying Chemicals	Mining	Agriculture	Dams	Natural Erosion	Rural Devel.	Recreation
Malheur L.	x	x	x		x	x	x		x				
Malheur R.	x	x	x		x	x		x	x				
Owyhee R.	x				x					x			
Goose & Summer L.	x	x	x								x		
Klamath R.	x	x	x		x				x				
Deschutes R.	x	x		x					x		x	x	x
Hood R.	x	x	x				x		x		x		
John Day R.	x	x	x	x	x	x		x	x				
Umatilla R.	x	x		x	x			x	x				
Grande Ronde R.	x	x	x	x	x			x	x				
Powder R.	x	x						x					

Although minimal information exists about the quantity, types, and conditions of riparian ecosystems in eastern Washington, the U.S.D.A. Forest Service has started inventorying riparian ecosystems associated with grazing allotments (Quigley and others 1989). Preliminary estimates are being made by the Pacific Northwest Region of the Forest Service of the amounts and status of riparian vegetation in grazing allotments of the 10 National Forests of eastern Washington and Oregon. For all 10 Forests, current estimates for acres of range with riparian vegetation and Forest Plan management objectives suggest 4 percent are riparian (399,043 riparian acres). The Forests with the highest percentage of riparian acres were the Winema (11 percent) and Umatilla (6 percent), those with the lowest were the Wallowa-Whitman (1 percent) and the Wenatchee, Deschutes, and Malheur at 2 percent each. Estimates of the total riparian acres in grazing allotments for each National Forest are shown in figure 1.

Estimates of total riparian acres within allotments were partitioned into categories as follows: acres meeting or moving toward Forest Plan objectives; acres not meeting or moving toward Forest Plan objectives; and acres of undetermined status (Quigley and others 1989). For nine of the Forests (no data available for the Wallowa-Whitman), the mean percentages of the total riparian acres (399,043 acres) in these categories were 50 percent meeting or moving toward the objectives, 13 percent not meeting or moving toward the objectives, and 37 percent in the undetermined status. For each Forest, the percentages in these categories are presented in figure 2. The percentage of riparian acres meeting or moving toward the objectives ranged from 22 to 79 percent with the highest values in the Malheur, Deschutes, and Fremont (56 to 59 percent), and in the Ochoco and Colville Forests (78 and 79 percent). Percentages of riparian acres not meeting or moving toward the objectives ranged from 1 to 41 percent with all Forests being less than 10 percent except the Umatilla (20 percent), Fremont (26 percent), and Wenatchee (41 percent). Five of the Forests had riparian acres of undetermined status ranging from 35 to 76 percent, with the highest percentage in the Okanogan (fig. 2). This Forest Service information is preliminary and needs to be further clarified in terms of Forest Plan objectives; definition of riparian acreages and boundaries between terrestrial and riparian systems; and riparian acreages within allotments versus the total riparian acreage for the respective National Forests (Pacific Northwest Region, fiscal year-92 Range Report).

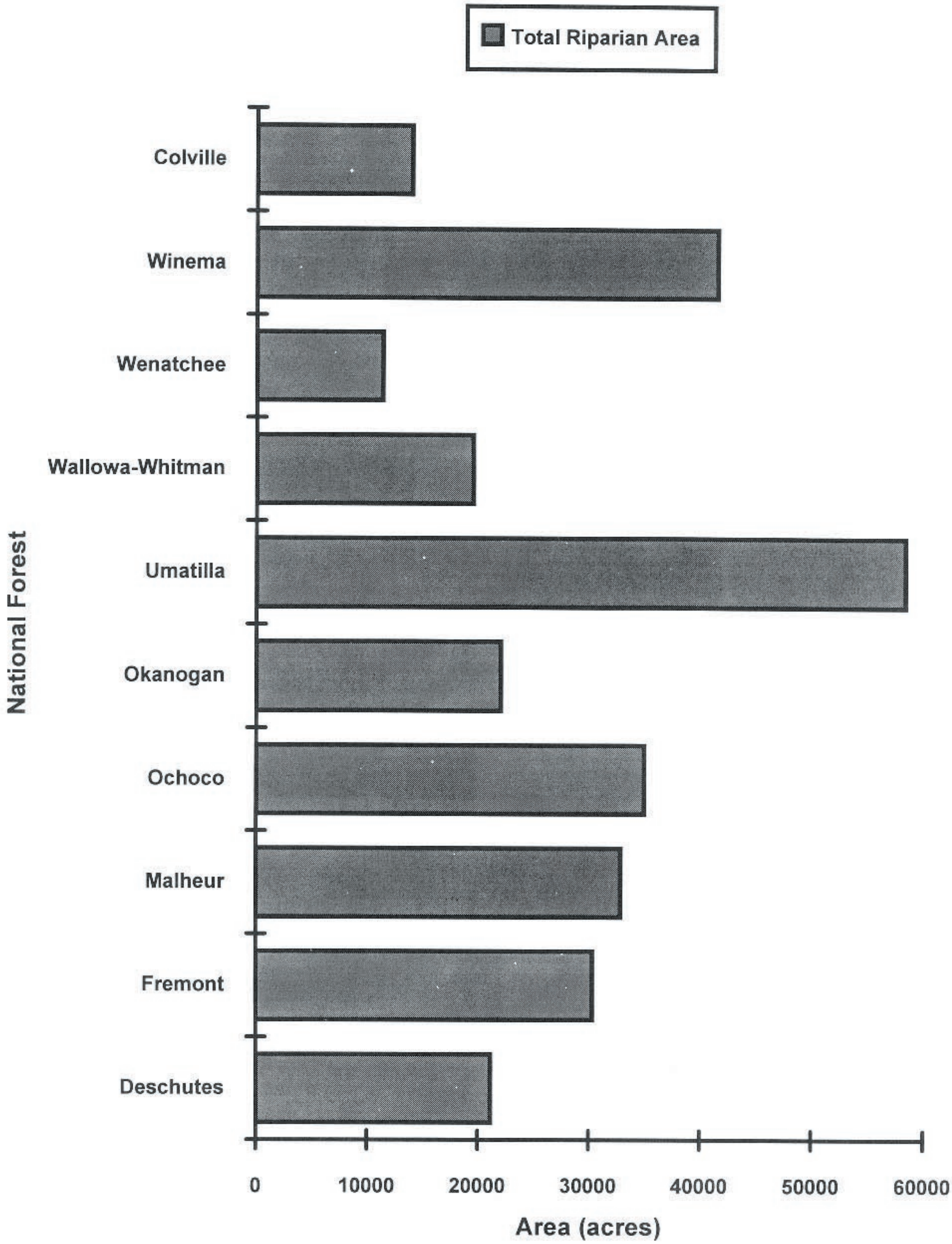

Figure 1. Estimates of total riparian area in grazing allotments of National Forests in eastern Washington and Oregon (Region 6, FY-92 Range Report, Portland, OR).

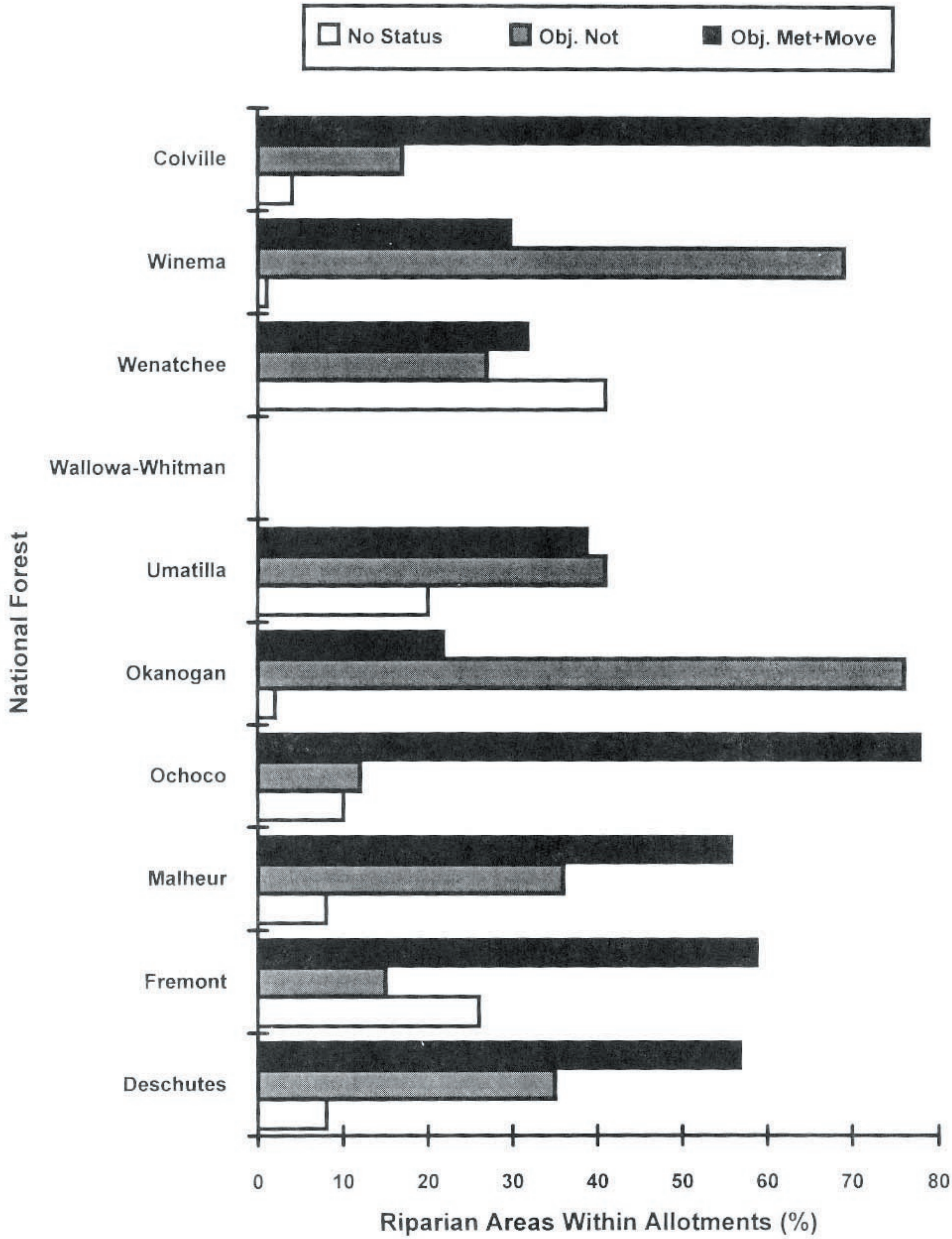

Figure 2. Estimated percentage of total riparian area in grazing allotments for three categories of Forest Plan objectives for National Forests in eastern Washington and Oregon (Region 6, FY-92 Range Report, Portland, OR). The categories include: a) acres meeting or moving toward Forest Plan objectives; b) acres not meeting or moving toward Forest Plan objectives; and c) acres of undetermined status.

Primary Resource Uses Affecting Stream and Riparian Ecosystems

This section summarizes stream and riparian habitat conditions in river basins relating to forest management practices and other land- and water-use effects of fire management, livestock grazing, mining, and irrigation. Stream and riparian ecosystem changes and fish losses caused by other factors are important but beyond the scope of this analysis. These factors include modification of riverine ecosystems by hydroelectric and large irrigation projects, highway and railroad construction (Furniss and others 1991), agriculture and forest chemicals (Morris and others 1991), recreational activities and management (Clark and Gibbons 1991), flood control (R.W. Beck Associates 1973), dam passage mortalities of fish, and fish lost to mixedstock ocean fisheries. Additional information about the influences of these land- and water-use activities in the Pacific Northwest region on stream and riparian ecosystems can be found in Meehan (1991) and Mullan and others (1992).

Timber harvest and road construction—Numerous studies have documented the history of the effects of timber harvest practices and related transportation systems (such as roads, landings, and skid trails) on watersheds and changes in hillslope stability, water quality, riparian and stream habitat stability, water yield, peak flows, and related conditions (Meehan 1991, NCASI 1992, Peterson and others 1992, Salo and Cundy 1987). During the last century and the early 1900s initial entry into the forests of eastern Washington and Oregon was made through river valleys, riparian areas of floodplains, and adjacent hillslopes. Harvest techniques were a variety of high grading and other select strategies. Early reports indicate minimal rates of harvest until World War II and the next four decades (Oregon Department of Forestry 1985, Plummer 1900, Washington State Department of Natural Resources 1985). Harvest records have been kept by the Forest Service, Washington State Department of Natural Resources, and the Oregon Department of Forestry since about 1925. These records indicate two different patterns of timber harvest in eastern Oregon and Washington (fig. 3). Harvest rates increased dramatically before and after World War II in eastern Oregon and have increased steadily up to the present. In contrast, harvest in eastern Washington has remained at fairly stable rates since 1925, increasing slightly over the past 65 years. Harvest rates in eastern Washington have been about one-third those of eastern Oregon (fig. 3, where total harvest = private + State + Federal). These differences can be partially attributed to about 65 percent of the Forest Service lands in eastern Washington being in Wilderness and roadless condition.

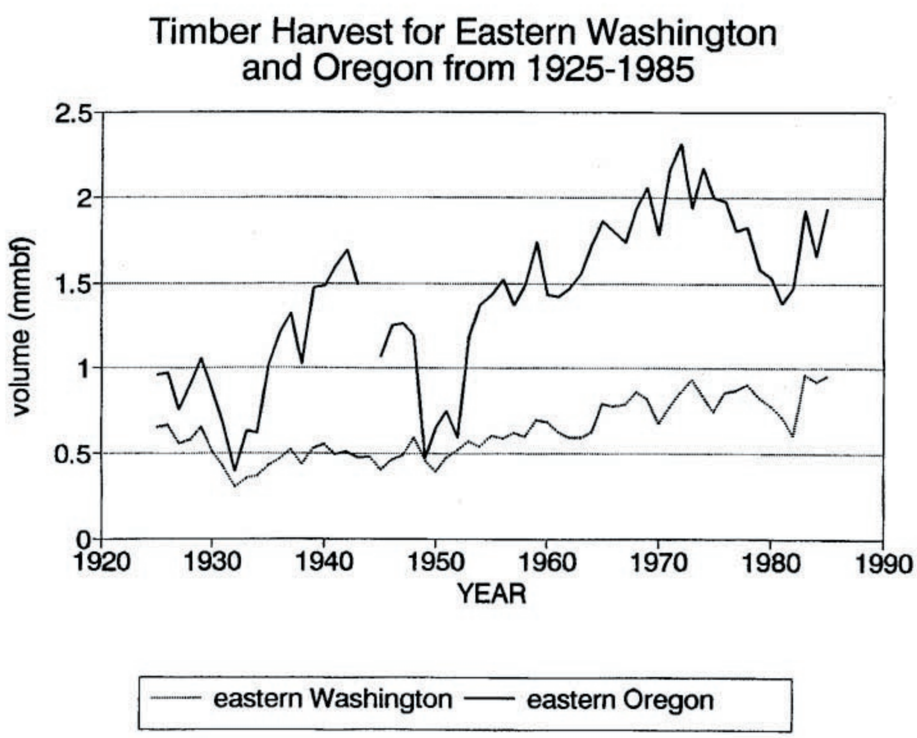

Figure 3. Timber harvest rates in eastern Washington and Oregon, 1925-85 (Washington Department of Natural Resources 1985; Oregon Department of Forestry 1985).

A common management approach used by the National Forest system in countering adverse effects on water quality requires applying site-specific best management practices, (MacDonald and others 1991). Cumulative effects of individual, dispersed, timber-harvest and road-related activities, however, commonly increase system-wide damage, recovery times, and susceptibility to large runoff events and related disturbances (Peterson and others 1992). Depending on the physiographic characteristics of a watershed, such events can adversely affect not only water quality but also riparian and aquatic habitats. Common hillslope, floodplain, riparian, and stream responses include mass wasting, streambank erosion, and changes in channel geomorphology. When adverse effects occur, they are usually in violation of Section 319 of the Clean Water Act.

The management methods used to counter adverse effects illustrate many of the issues pertaining to influences of timber harvest on forest hydrology. Important issues include de-synchronization or alteration of stream flow regimes caused by logging and the reduction of tree cover; soil compaction thresholds and streamflow; and wetted soil mantle and runoff practices after clearcutting (Harr 1987). These issues, related problems, and the management approaches to address adverse effects of timber harvest and road building are discussed in the select stream and watershed management approaches section and the recommendations section.

Fire management—Forests of differing stand structures and landscape patterns in eastern Washington and Oregon have developed under natural fire regimes of both high-intensity crown fires and low-intensity underburns. Because of the dry climate and natural fire history, most forest stands tended to be less than 400 years old. Frequent but low-intensity fires maintained open stands and favored fire-tolerant species. During the past century, however, fire suppression has altered the natural fire regime and therefore the stand compositions of eastside forests. These forests now contain fewer fire-tolerant tree species and dense understory vegetation (Mullah and others 1992). High fuel accumulations have caused more intense and destructive fires than in the past. Frequently, over the past few decades, extensive fires in eastern Washington have been hot fires with substantial effects on forest nutrient status and soil conditions (Grier 1975, Tiedmann and others 1979).

The increased severity of these fires can alter the amounts and qualities of nutrients, sediments, and organic debris delivered to stream channels. For example, studies of nutrient transfer to streams in eastside forests of Washington and Oregon indicate that amounts of organic nitrogen roughly doubled during the first year (Tiedmann and others 1979). The most significant effects of fires on streams and rivers are the increases in water, sediment, and debris delivered to the channels. Studies in eastern Washington have shown that streamflows increased after fires (Klock and Helvey 1976). The cumulative effects of rapid snowmelt, high-intensity rainstorms, and the destruction of aboveground and belowground vegetation in denuded watersheds of the Entiat River basin, for example, resulted in massive debris torrents with frequencies 10 to 28 times greater than before fires (Helvey 1980). Such large inputs of sediments and debris can overload the channel transport capacities, thereby altering stream habitat complexity. Although the redistribution of fine sediments and spawning gravels can destroy fish eggs and displace juvenile fish and aquatic insects, both the relocation of gravels and large woody debris can create new spawning and rearing habitats.

Livestock grazing—Much of the land area of eastern Washington and Oregon is favorable for livestock grazing. For example, about 50 percent of the Columbia River basin is suitable range and most of this is managed by the Forest Service and the Bureau of Land Management. A recent Federal report on the condition of these range lands indicates considerable over-use and damage during the past century. About 50 percent of the Forest Service and Bureau of Land Management range lands in the western United States were reported in fair to poor condition based on vegetative potential (General Accounting Office 1988; figs. 4A, B). In 1985, a similar report for non-Federal range lands in Oregon indicates that about 78 percent of private lands were also in poor to fair condition based on vegetative capacity (Soil Conservation Service 1985; fig. 5).

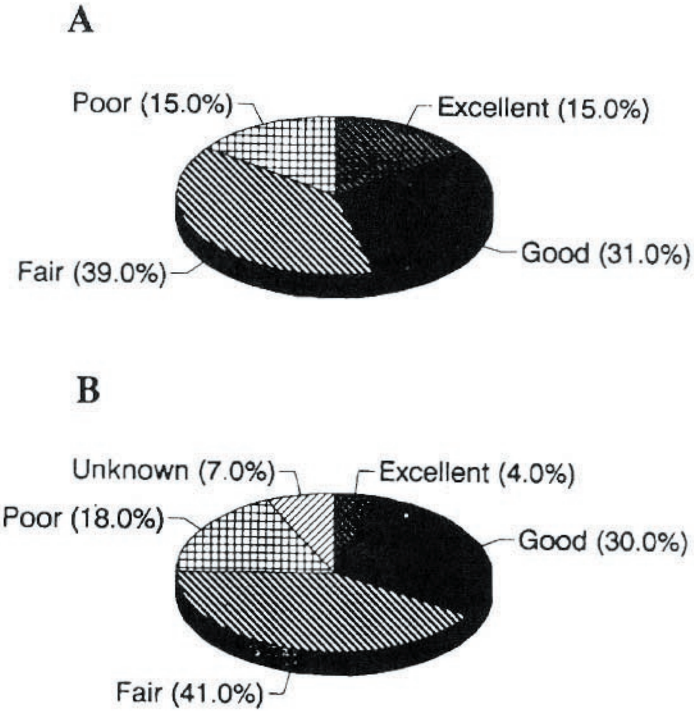

Figure 4. Range conditions on lands in the western United States in 1987: A) Forest Service lands; and B) Bureau of Land Management (BLM) lands (Government Accounting Office 1988).

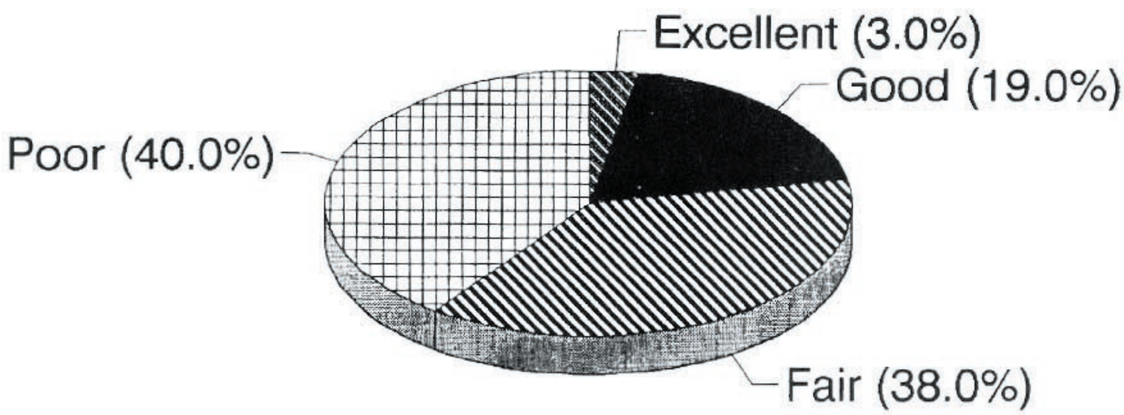

Figure 5. Range conditions on non-federal rangelands in Oregon (Soil Conservation Service 1985).

Livestock grazing began with the arrival of miners and settlers during the second half of the 19th century. Overstocking and overgrazing of the available ranges during the late 1800s and early 1900s caused widespread damage, altering plant diversity and compacting soils (Elmore 1992). Over time this grazing has caused ranges to become highly vulnerable to increased soil erosion, with degraded riparian and wetland vegetation, degraded streambanks, and lowered water qualities and flows. Changes in stream and riparian habitat structure commonly followed heavy grazing because of increases in surface runoff and sedimentation, and decreases in groundwater infiltration (Hibbert 1976, Plans 1981). Erosion and sedimentation in streams reduced or destroyed fish habitats and riparian habitats changed from trees/willows/sedges to brush and bare soil (Kovalchik 1987; Kovalchik and Elmore, in press).

The growth of the livestock industry in eastern Washington and Oregon increased the number of animals beyond the carrying capacity of the available rangeflatts 1991). By the 1920s overgrazing of Forest Service lands and drought conditions caused further deterioration. By 1934, range conditions became so serious that Congress passed the Taylor Grazing Act to improve public rangelands. Through the 1960s and 1970s the Forest Service, Bureau of Land Management, the U.S. Soil Conservation Service, and private landowners improved grazing practices through a variety of management strategies. But even more attention was needed to accurately assess the influences of grazing on riparian and stream ecosystems at the river basin or landscape scale. For example, improved range conditions have mainly occurred in upland ranges, with minimal gain in riparian and stream conditions (Behnke and Raleigh 1978). Concern has developed about whether present grazing strategies are applicable to solving grazing effects on riparian and stream habitats. The livestock industry's recent shift from grazing sheep to cattle is an example: cattle prefer streamside areas, and increased grazing pressures have stimulated concerns about the deterioration of riparian and stream habitats (Plans 1981, 1991). Although, at specific sites various grazing strategies can be used to restore riparian habitat, how riparian and stream ecosystem function together across larger landscapes like river basins is poorly understood (Elmore 1988, Elmore and Beschta 1987, Wissmar and Swanson 1990). The case studies for select river basins below provide information about regional grazing histories.

Mining—Mining in eastern Washington and Oregon has been based on minerals such as gold, silver, copper, nickel, and chromium, as well as gravel and building stone. Because many of the deposits were low grade and widely scattered, however, mining has declined during the past half century. Nevertheless, mining continuously influences stream and riparian ecosystems because of habitat modifications of past placer and hydraulic methods (1860s-1900), erosion and leachates from deposits of lode mining (after 1900), and bucketline dredges (1900 to 1930). Because water was scarce for working placer and hydraulic operations, from the 1860s to 1900, long ditches were commonly used to divert large amounts of water to the mining areas. In the Blue Mountains of Oregon, for example, the El Dorado ditch led more than 100 miles from the headwaters of the Burnt River to the placers at Malheur, near Willow Creek (Dicken and Dicken 1979). Pits and scars from these mining operations can still be seen in some localities. An excellent history of the influences of mining and the extraction of minerals on streams is in Nelson and others (1991).

More recent effects of mining on stream and riparian ecosystems include leachates from leach mining, such as cyanide chemical-leach mining for gold-based on mineral extraction processes in old mine deposits; and the excavation of stream channels and floodplains for sand and gravel. Currently, leach mining near Chesaw in the Okanogan Highlands are under consideration by the Battle Mountain Gold Company and the Washington State Natural Resources Committee.

Okanogan County is an excellent example of the value of nonmetallic mining products. Historically, the value of sand, gravel, gypsum, and limestone products has been several times that of precious metals (Wilson 1990). The same trend is apparent in most of the counties in eastern Washington and Oregon (Highsmith and Kimerling 1979). The mining of river bed gravel deposits and the construction of levees can both be detrimental to salmonid habitats (Pauley and others 1989, Rivier and Sequier 1985). Historically, gravel was removed by dredging within the wetted perimeter of a river as well as from gravel bars. Since 1983 in the State of Washington, gravel has been mined by taking alluvial material only above the summertime low-water wetted perimeter, and by using such equipment as bulldozers and front-end loaders (Pauley and others 1989).

Gravel mining in rivers can create biological imbalances by altering flow patterns in channels and overloading aquatic habitats with sediments (Carting 1987, Rivier and Sequier 1985). The resultant changes are evident in key physical factors such as substrate composition, depth, velocity flow patterns, turbidity, suspended sediments, and temperature that determine the abundance and biodiversity of aquatic organisms (Binns and Eisermann 1972, Bjorn and Reiser 1991). For example, excessively turbid waters can reduce light penetration and increase deposition and silting by fine sediments. These physical changes can limit photosynthesis and alter feeding, migration behaviors, population structures, and usable habitat of different macroinvertebrate and fish assemblages (Etnier 1972, Milner and others 1981). The duration of effects and the resultant erosion and deposition of streambed materials can be related to the length and width of channel habitat disturbed, stability of substrates, and type of alteration (Moore and Gregory 1988, Wydoski and Helm 1980).

Irrigation—Water withdrawal uses in eastern Washington and Oregon include rural domestic, stock watering, irrigation, public water supply (municipal and light industrial), and industrial. Of the three most important off—channel uses-irrigation, industries and municipalities—the dominant off-channel use is irrigation. Irrigation accounts for about 10 times the combined volume of water withdrawn by municipal and industrial systems (Highsmith and Kimerling 1979). The major regional problems related to water withdrawal for irrigation include water storage and drainage, high water temperatures, pollutants, and low streamflows in smaller drainages. Dewatering of streams affects salmonid habitats, riparian ecosystems, and associated wetlands.

High water temperatures and gas supersaturation, serious problems in the lower Snake River, can also pose problems in the polluted Yakima River. Although improved water treatment facilities have been responsible for decreased biochemical oxygen demand (BOD), an apparent widespread problem in stream waters is caused by organic and inorganic toxic materials and sediments from nonpoint sources of pollution. More than 20 million acre feet of irrigation return flows dominate cumulative nonpoint sources in eastern Washington and Oregon (Highsmith and Kimerling 1979). Other major problems include drainage from over-irrigation and seepage, increases in soil salinity, flood plain damage, and alteration of groundwater storage .

Irrigation and related water uses have expanded during the past 25 years in eastern Washington and Oregon. Increased withdrawal of water is related to new types of sprinklers and other irrigation based developments. Out-of-state promotions of developments emphasizing farming, recreation and retirement have been stimulated by irrigation from wells and by large tracts of cheap land. This has greatly increased water demands and the possibilities of insufficient recharge of wells. When combined with increased cutover lands in marginal forests and expanded conversions to cropland, these problems suggest increases in resource conflicts in the near future (Dicken and Dicken 1979, National Research Council 1992a).

HISTORY OF LAND AND WATER USES IN SELECT RIVER BASINS

The case histories focus on the chronology of natural resource uses and the health of streams and riparian ecosystems. The select river basins include the Okanogan and Methow River (north-central Washington), the Little Naches River of the Yakima River drainage (central Washington), the Grande Ronde River (eastern Oregon), and the John Day River basin (north-central Oregon). The chronology for the Okanogan and Methow River basins focuses on the events and developments of the last century and early 1900s that shaped the present day landscapes and on socioeconomic conditions in eastern Washington and Oregon. Summaries for the Little Naches, Grande Ronde, and John Day River basins review specific land and water uses that have influenced stream and riparian ecosystems in eastern Washington and Oregon.

Okanogan and Methow Rivers (North-Central Washington)

The history of settlement, natural resource use, and conflicts in the Okanogan country represents a mesocosm or time capsule of the events that shaped present landscapes and socioeconomic conditions. The Okanogan valley, as well as most of north-central Washington, was isolated but not insulated from the principle east-west corridors of commerce in the Pacific Northwest. The valley's location and the late arrival of the railroad slowed development and preserved frontier-like conditions into the 20th century. Fur trading, overland exploration, mining, encounters between Euro-Americans and Indians, creation and modification of Indian reservations, cattle drives, homesteading, conflicts between sheepmen and cattlemen, overgrazing of ranges, railroad building, irrigation development, logging and dam building-all were significant aspects of frontier life and development in north-central Washington. Many of these activities had substantial effects, as can be seen from the following summary and in table 5.

Table 5—Chronology of major settlement, natural resource uses and related developmental events in north central Washington. Asterisks (*) indicates historical activities with potential effects on the health of riparian areas, stream habitats and watersheds of riverine valleys. Major sources include Steele 1904, Kerr 1931 and Wilson 1990.

Date	Event	Activity
1811	Fur trade begins	John Jacob Astor (Pacific Fur Co.) establishes trading post at the confluence of the Okanogan and Columbia Rivers.
1816	Fur trading	* Supply of beaver nearly exhausted in the Okanogan country suggesting beaver removal changed riparian and stream conditions.
1846	U.S.- British boundary	International boundary set at 49th parallel.
1847	Fur trade ends	Hudson Bay Co. ends fur trade.
1853	Washington Territory created	Isaac Stevens first governor of Washington Territory.
1855	Yakima Reservation created	Yakima Indian Reservation formed (1 .2 million acres).
1858	Gold discovered in British Columbia	* Gold rush on the Cariboo Trail in the Okanogan country.

Table 5—cont.

Date	Event	Activity
1859	Gold discovered in Okanogan	* Gold discovered in lower Similkameen. Placer mining of river channel and banks may have degraded the river ecosystem.
1860-1880	Water diversion in lower Methow River	* China Ditch constructed above mouth of Methow River to deliver large volumes of water to sluice boxes for placer mining suggest potential damage to riparian and stream habitats. Facility converted to irrigation in the 1920's by the China Ditch reclamation district, destroyed by 1948 flood.
1860's	Cattle drives on the Cariboo Trail	* Overgrazing of ranges suggests potential for erosion in the floodplains of the Okanogan River. Cattle drives on the Cariboo Trail supplied mining towns in B.C.
	Settlement in Okanogan	Hiram F. Smith near Lake Osoyoss first resident cattle rancher.
	Salmon harvest	* Weir across the Okanogan River by settlers and catching salmon leads to possible over harvest of returning adult fish, about 20 wagon loads of salmon per day.
1870	Population, 34 non-Indians	Federal census of the Okanogan valley.
1872	Colville Reservation created	Colville Indian Reservation formed to resolve land ownership questions caused by patterns of white settlements. Area east of Okanogan River included today's Ferry County (2.5 million acres).
1878	Population, 44 non-Indians in Okanogan	Stevens County census. Area of Stevens County form 1864 until 1888 included district today's counties of Okanogan, Chelan, Ferry, Stevens and Pond Oreille.
1879-80	Moses reservation created	Area west of Okanogan to crest of Cascade Mts and from Lake Chelan north to the 49th parallel.
1880's	Settlements increase in Okanogan valley	* Population of settlers begins to increase suggesting land clearing and conversion of riparian areas.
1886	Okanogan mining boom	* Mining boom began west of Okanogan River and miners, ranchers and settlers move onto the Moses Reservation. Placer mining of river channel and banks, lode mining and numerous poorly designed concentrating and flotation mills, high daily water demands (e.g., 60,000 gallons) , and production of sediment wastes may have degraded several river ecosystems.
	Moses Reservation	Moses reservation opened to miners and settlers.
1883-1916	Railroads	See Text
1888	Okanogan County created	Included today's Okanogan & Chelan Counties.
1889	Washington becomes a State	

Table 5—cont.

Date	Event	Activity
1890	Population of 1,509 non-Indians in Okanogan	Okanogan County census. Okanogan County included today's counties of Okanogan and Chelan.
1893	Okanogan mining declines	Price of silver declines during U.S. recession.
1894	Flood	* 100 year flood and debris-dam break flood destroy towns of Conconully and Silver. High probability of major changes in stream and riparian habitats.
1890s	Mining in the Methow	Slate Creek district (Mammoth Mine) near Hart's pass supplied by new town of Winthrop (1891). The Red Shirt & Alder Mines of the Twisp district were major producers.
1895	Mining resumes in Loomis District	* Numerous rich mines resume operations. Ten years of intense lode mining (1895-1905) and numerous poorly designed concentrating and flotation mills, high daily water demands, and production of sediment wastes may have degraded river ecosystems.
1899	Okanogan County reduced in size	Formation of today's Okanogan & Chelan Counties. Populations were 2,839 in Okanogan and 1,321 in Chelan counties (Steele 1904).
~ 1900	Sheep arrive the Okanogan	* Sheepmen begin to settle in the Okanogan.
	Sheep drives	* Overgrazing of summer ranges suggest increased erosion of watersheds and modification of riparian & stream habitats.
1905	Irrigation development	* Removal of water from rivers and streams reduced or negated the development of riparian & stream habitats.
1910	USFS created	
~ 1916	Railroad building	* Alteration of river valleys led to erosion, removal and constrainment of geomorphic features of riparian & stream habitats.
1916	Homestead Act	* Opened homesteading and decreased open range.
+ 1920s	Logging	* Alteration of watersheds led to erosion, changes in hydrologic and geomorphic features of riparian & stream habitats.
+ 1930s	Dam building	* Created migration barriers and altered riverine habitats for fish (e.g., changed temperature and predator conditions).

The British first established a presence in the region in 1811, with the beginning of the fur trade. In 1816, the British-owned North West Company built Fort Okanogan on the same site as J.J. Astor's trading post. Furs coming out of British Columbia (New Caledonia) and Fort Colville were collected and shipped downstream, and supplies were received from Fort Vancouver down river at the mouth of the Columbia. In 1821, the Hudson Bay Company took over the North West Company. During 1834-36, the original Fort Okanogan was replaced with a new Fort Okanogan closer to the Columbia River.

In 1846, the international boundary was set at the 49th parallel, ending joint occupation by British and Americans. The large influx of immigrants to Oregon during the 1840s assured American control of the Northwest. The following year, the Hudson Bay Company ended fur trade between British Columbia and Fort Okanogan. The British and Americans expended considerable effort in surveying the 49th parallel between 1858 and 1861.

The next decade was relatively quiet but, in 1858, a gold rush in the upper Frazer River country drew large parties of miners to the Cariboo Trail along the Columbia and Okanogan Rivers. The previous discovery of gold in the vicinity of Colville and the Yakima River of Washington in 1855 had already enticed miners to the north country (Steele 1904). A large party of miners (about 160) traveling to Frazer River gold strikes had initial, violent encounters with Indians of the region. Three were killed and 20 wounded by Indian ambush in McLoughlin Canyon, about 20 miles south of the Canadian border on the Cariboo Trail.

In 1859, gold was discovered in the lower Similkameen River valley near the Enloe Dam, west of Oroville, Washington (table 5). Mining claims were not regulated until the 1872 Mining Act. From 1859, the booming population of 1200 to 3000 placer miners worked the Similkameen River channel, until they stampeded north to large gold strikes in the Cariboo country of British Columbia during 1860.

In the early 1860s, another direct effect on riverine ecosystems appeared: the overharvesting of returning adult salmon in the Okanogan River by settlers. John Utz, who had settled near Lake Osoyoos, constructed a weir across the river. He trapped as many as 20 wagon loads of salmon a day to sell to Indians. These early actions combined with the later effects of intensive commercial fishing, the building of the Columbia River dams, and other habitat losses in the Okanogan basin, devastated anadromous fish runs. Spring Chinook salmon became extinct, native summer/fall Chinook salmon and summer steelhead stocks were virtually eliminated, and sockeye salmon runs were depressed (Jim Spotts, pers. comm.).

From the 1860s to 1900, mining took place throughout the Okanogan country, from the Chelan Mountains eastward across the Methow to the Conconully Range. Some of the most extensive silver and gold strikes (placer and lode mining) were on Silver Creek, northeast of today's Okanogan City in the Salmon and Ruby Districts-the towns of Ruby, Conconully-Loop Creek, and along the Similkameen River near Loomis. During the 1886-93 boom years, the Ruby-Conconully Districts were considered among the richest mining areas in the Pacific Northwest (Wilson 1990). Other important districts were the Palmer Mountain, Chesaw, Methow, and Twisp. The first discovery in the Methow valley was in 1887 at the town of Silver near Twisp. During the boom period and the 1890s, the abundance of natural resources and the area's mild climate also induced settlement by farmers, stockmen, and lumbermen.

Maps of mining districts (Hodges 1897) suggest that the locations of numerous mining claims were in stream channels and adjacent streamside areas of rivers and their tributaries. Placer mining of river channel and banks, lode mining, and wastes from numerous poorly designed concentrating and flotation mills may have degraded several river ecosystems (35 to 40 mills in Okanogan County). The Salmon Creek watershed is a prime example of an affected ecosystem, a watershed altered by the rapid construction of the Ruby and Conconully townsites and by development of claims throughout the subbasin. By 1888, Ruby City extended a quarter of mile on Salmon Creek about 13 miles northeast of Okanogan City. The destruction would have been particularly devastating to spring Chinook salmon, a salmon run now extinct in the Okanogan basin.

Mines of the region were supplied by stern-wheeled riverboats on the Columbia River from Wenatchee to Brewster and by the North Pacific railroad. Railroads came to Spokane Falls and Ellensburg in 1883, Colville in 1890, Wenatchee in 1892, and the Okanogan valley in 1916 (Steele 1904, Kerr 1931). The effect of railroads on population growth was evident in Chelan County, where the population increased from 1321 in 1899 (table 5) to 3931 in 1900, and 7547 in 1903. Twenty percent of the population was in Wenatchee during 1903 (Steele 1904).

Cattle began to appear in considerable numbers during the 1860s in north-central Washington. The cattle were driven along the Cariboo Trail, the same trail that led to the gold strikes in the Frazer River and Cariboo mining districts north of the Canadian border. Six hundred miles from The Dalles to the upper Frazer River valley, the Cariboo Trail supplied beef, which often originated in the Willamette and Yakima valleys, to the northern mining camps. During the peak years of 1862-64, British customs at Osoyoos Lake collected duty on 7720 cattle, 5378 horses, 1317 sheep, and 948 mules. Ben Snipes, a principle cattlemen using the Caribou Trail, reportedly grazed over 100,000 head of cattle and 20,000 horses in the Yakima valley (Wilson 1990).

The Yakima valley was also the principal supplier of cattle to Seattle. Originally supplied with beef driven from the Yakima valley across Snoqualmie Pass, the range of the Yakima valley became over crowded with cattle in the 1870s, and the cattle company Phelps and Wadleigh shifted some of their operations to the Okanogan. Until the winter of 1880-81 forced them into receivership, they were the largest cattle buyers in the Washington territory. Such winter weather demonstrated the problems of grazing livestock in the Okanogan valley throughout the year. Nevertheless, the cattle industry of the valley managed to survive. In 1896, cattle were being driven from the Okanogan valley to Wenatchee for shipment via the Great Northern Railroad to Seattle.

The Caribou Trail opened the Okanogan country to the outside world and led to the first white settlers in the area in the early 1860s. Hiram F. Smith, the first resident cattle rancher of the Okanogan settled near Lake Osoyoss in about 1860. He planted an apple orchard, ran a trading post, and made the first discovery of gold-bearing rock. Opening of Colville Reservation in 1896 and 1898 led to mining claims and premature staking of lands for farmland and stock ranges. Mineral production during the mining boom of Okanogan County in Washington State ranked behind Ferry, Stevens, and Chelan counties.

As settlers began to move into the Okanogan County, the number of horses and other livestock climbed steadily between 1890 and 1905. Although these increases were considerable, other counties with earlier settlement and growing populations as well as higher agricultural production of wheat, for example, showed even greater increases in livestock. In 1904, Whitman County had 26,706 horses and 44,074 cattle compared to Okanogan's 7000 horses and mules and 21,058 cattle (table 6).

Table 6—Changes in numbers of livestock in Okanogan County between 1890 and 1904.*

	1890	1900	1901	1902	1903	1904
Horses and mules	2,328	4,930	5,731	6,460	6,942	7,000
Cattle	4,744	9,157	10,997	12,805	16,411	21,058
Sheep	—	2,098	6,078	25,888	28,770	31,757
Wagons and carriages	206	657	869	1,025	1,126	1,283

*** Modified after Wilson (19901. Data source include State of Washington, Its Resources, Natural, Industrial and Commercial, c. 1905, The Washington State Bureau of Statistics.**

Sheepmen began to locate in Okanogan County in about 1900. Sheep grazing attracted the attention of established cattle ranchers, who believed that sheep ruined pasture for livestock. One incident near the town of Okanogan (during the winter of 1902-03) resulted in a night raiding party and the slaughter of an estimated 900 sheep in a corral.

In Okanogan County during the turn of the century, sheep numbers increased dramatically, from less than 2000 before 1890 to about 31,757 in 1904 (table 5). Many other pre-settled counties had even more sheep, however; Yakima, the greatest sheep producing county, had about 147,000 sheep in 1904.

During the mid-1890s, agriculture replaced mining as the principal economic activity and, in Okanogan County between 1900 and 1903, crops increased from about 1500 acres to 13,000 acres. Farmable lands with minimal irrigation were in river floodplains. The extent of the Okanogan River floodplains and presence of wetlands (mainly from Tonasket to Osoyoss Lake) is suggested by reports in 1882 of dense swarms of mosquitoes (Pierce 1882). By 1900, water was clearly the limiting factor and irrigation projects would be needed to sustain population growth and agricultural development.

The Okanogan Reclamation Project was authorized by Congress in 1905, and was one of the first irrigation projects undertaken by the U.S. Reclamation Service. The project was approved without sufficient investigation into water supply in terms of the local climate and hydrologic regime of the watersheds. The Reclamation Service encountered problems not only because of the failure of the watershed to furnish sufficient runoff, but because of poor management practices. These problems included inexperienced contractors, water being put on lands with sandy soils not suited for irrigation, and public funds being misused by providing water for private lands. By 1931 when a majority of the irrigated land was under the Okanogan Irrigation District, electric pumps and not irrigation ditches provided most of the water from the Okanogan River (Kerr 1931).

Irrigation systems caused problems for migrating salmon. The main irrigation canals on the floodplains of Okanogan River, for example, ran parallel with the river channel, intercepting tributary streams, and effectively blocking access to tributary stream by anadromous fish migrating from the main river. Such systems of irrigation canals were less extensive in the Methow and Similkameen River valleys.

Little Naches River: Yakima River Basin Central Washington)

This case history of land and water uses covers two topics: settlement and resource uses in the Yakima River basin; and land-use and changes in stream and riparian habitats in the Little Naches River. The Little Naches River is a tributary to the Naches River in the headwaters of the Yakima River system. The basin is 45 miles northwest of Yakima, Washington, slightly north and east of Mount Rainier.

Settlement and resource uses in the Yakima River basin—Before 1850, the Yakima River basin was primarily unsettled by pioneers; most of the population was Native American. Although, the Native society was primarily one of hunting and gathering, canal systems for irrigated crop cultivation had been built under Catholic missionary authority (Davidson 1953). Catholic missions at Parker Bottom, Tampico, and Naneum were the first non-native settlements in the valley. Once the missionaries were established, settlers followed rapidly. The McClellan exploration party surveyed the Naches Pass area for a route to Puget Sound during the 1840s and stimulated the flow of immigrants (Gossett 1979). The first permanent settlers arrived around 1860 near Moxee, bringing several hundred head of cattle. Not long after, the Yakima Valley became one of the primary areas for cattle ranching east of the Cascades. Sheep grazing soon became one of the primary uses of the upper tributary watersheds, however, sheep were driven along "driveways" into the forests for the summer foraging from June through October, then driven back to the valley for the winter. Cattle were also driven into the upper tributaries, grazing on the alluvial flats and glacial valleys. The cattle drives peaked during the 1880s Sheep ranching peaked at the turn of the century, and again during World War I, when prices and demand for sheep products were at their greatest. Before full establishment of permitting and allotment systems in 1905, records on numbers of cattle and sheep are incomplete. Records for 1907 indicate 260,000 sheep were permitted in the Naches and Tieton basins (Uebelacker 1980). During this period, the Naches basin held 55 percent of the sheep grazed in the Yakima Valley and 83 percent of the cattle and horses (Carter 1990).

By 1907, the public recognized that areas of the Forest were being overgrazed. Livestock grazing, the use of driveways, and burning of the forest to promote pasture all were in direct conflict with other uses of the forest, such as watershed-irrigation projects, recreation, and timber. Sheep and cattle driveways had been established along most of the ridge crests between tributary drainages. Many of these areas naturally are sparsely vegetated with erosive soils. The driving of thousands of sheep and cattle over them during the dry season likely exacerbated the situation during the wet seasons. Most upland tributaries of the Yakima drainage basin exhibit increased surface runoff and erosion during the rainy season. Surface erosion and debris slides are common and can be long-term sources of sediment. Furthermore, wildfires and localized burning to increase grazing areas likely added to surface erosion and sediment-supply problems. By 1909, the Manastash, Cle Elum Ridge, and the main Taneum valley were all closed because of overgrazing. Situations like this sparked large-scale conflict between the sheep growers and the ever-increasing agriculture and orchard industry. By 1930, the numbers of sheep permitted on remaining allotments was probably less than 10 percent of peak numbers. During this period, sheep were being trucked to their range because driveways were banned. Valley bottoms and meadows were closed to grazing.

In general, the early effects of the sheep and cattle industry were heavily concentrated in the headwaters and tributaries-such as the Little Naches of the Yakima River system. In contrast, the burgeoning irrigation systems and agricultural industry were concentrated in the Yakima Valley proper and other tributary valleys. The development of irrigation systems changed the face of the area and parallels the development of the valley. In 1860, the Toppenish-Simcoe canal system was started near the Yakima Indian Reservation and, by 1869, the large drainage canal from the Naches had been built to irrigate lands below the confluence of the Naches with the Yakima River. The construction of the Sunnyside Canal in 1893 kicked off the agricultural and development boom. Irrigation and the extension of the Northern Pacific Railroad into the Yakima valley opened thousands of acres of previously unarable land to development. Originally, hay and feed crops were grown to supply the cattle and sheep industry, but eventually these gave way to row crops, permanent crops such as hops and grapes, and orchards.

In 1905, the Federal Bureau of Reclamation took over control of irrigation systems. The Reclamation Enabling Act gave them full power to appropriate waters for irrigation, including eminent domain for rights of way for canals and reservoirs. No minimum fish flows or other fish protection measures were designated in the Act. Fish ladders and screens were not required until the Fish Ladder Law was enacted in 1915. Between 1905 and 1915, migrating and resident fish populations were devastated. Many of the early systems, such as the Sunnyside Canal and the Tieton Canals, had been constructed without fish ladders or screens. Although some fish ladders were built after 1915, screens, which keep juvenile salmon from being trapped in the canals, were not placed until the 1930s An estimated 90 percent of the annual runs of salmon and steelhead trout had been destroyed by the early 1990s. The primary factors leading to the decline are (Fast and others 1991) construction of dams and canals without adequate fish passage facilities, such as ladders and screens; log drives tearing up spawning and rearing habitat; and indiscriminate local and commercial fishing.

In the areas below the city of Yakima, other major effects on fish production were the increase in water temperature, high suspended sediment loads, and chemical pollutants from agricultural runoff. In tributary areas, construction of reservoirs and 100 percent appropriation of water for irrigation contributed to dangerously low flows during summer.

Although agriculture is still one of the major industries in the Yakima area and the associated effects from irrigation still remain, the large-scale impacts of livestock grazing practices on the forest areas has probably diminished since the early decades of the twentieth century. Sediment input from chronically eroding areas may still be a problem in many places, but the relative impact has probably lessened. But the advent of accelerated timber harvesting, road construction and improvement of harvesting methods followed closely on the heels of grazing. Full recovery of forest streams is highly unlikely to have been achieved before the effects of timber harvest were felt.

Land-uses and changes in stream and riparian habitats in the Little Naches River—The Little Naches River is a fifth-order basin with a drainage area of 398 km^2. The mainstem and Middle Fork of the River is the boundary between Kittitas County to the north and Yakima County to the south. It drains east and south from the Norse Peak Wilderness, Pyramid Peak, Blowout Mountain, and Quartz Mountain in the southern Cascades. Almost the entire river basin lies within the Wenatchee National Forest, with portions of the upper basin under checkerboard ownership with Plum Creek Timber Co. The mainstem of the river is about 21.2 km long up to the confluence with the Middle and North Forks. The valley roughly alternates between constrained and unconstrained reaches, with the lower end generally more constrained between basalt slopes, and the upper end spreading out into broadly unconstrained alluvial valleys.

Peak flows occur in May and June, with another smaller peak in December and January. Low flows occur August through October, lowest in late August to September. Average annual stream flow for 1966 to 1987 was 204 cfs and the average peak flow was 758 cfs (unpublished data, Bureau of Reclamation, Ellensburg, WA). The upper end of the basin near Pyramid Peak receives more than 100 inches of rain per year, the middle basin from the North Fork to the South Fork receives 60 to 80 inches, and the lower basin 45 to 60 inches of rain.

The Naches River drainage is the largest tributary in the Yakima system. The upper reaches of the Naches provide summer and fall rearing habitat for 30 to 37 percent of the anadromous salmonid fry and smolts in the Yakima Basin (Fast and others 1991). In addition, 59 percent of the remaining harvestable timber in the Yakima basin is in the Naches drainage (Wenatchee National Forest 1990). The Little Naches River is one of the primary harvest areas with a large percentage of uncut timber. The Forest Plan (Wenatchee National Forest 1990) indicates that more than 50 percent of the basin will be cut under intensive and selective methods over the next decade. Since the 1960s, 35 percent of the harvestable acres in the basin have been cut. If the goals of the Forest Plan are met, the percentage harvested will be near 90 percent by the year 2000.

Many species of fish are native to the Little Naches basin-sculpin[1], dace, suckers, whitefish, sunfish, and of course, salmonids. Besides original runs of spring and fall Chinook, winter and summer steelhead, and cutthroat, before the 1950s a small run of coho had been reported. Today, only a few spring Chinook return to the Little Naches and an even smaller number of steelhead. Spring Chinook redds have increased in the Little Naches since 1981, however, and between five and 11 redds have been sighted above Salmon Falls since the construction of the fishway in 1987 (Woods and Russell 1991).

Since 1985, steelhead have been planted in Crow Creek and other tributaries in the Little Naches River from hatchery stock, but smolt survival has been poor. Resident populations of rainbow, and brook trout, are still present. Each year, about 45,000 individuals of these species were stocked in the upper tributaries of the Naches River to boost the sport fishery opportunities. Besides these commercially or recreationally important species, several other fish species reside in the Little Naches basin: sculpin, dace, lamprey, and suckers.

[1] Scientific names for all taxa are given in Appendix A.

Land-use history—Land uses in the Little Naches River basin consisted of intensive grazing (from 1880 to 1930), small-scale selective harvest in the valley bottoms, and considerable recreational use. Before 1900, no developed roads were in the Little Naches Basin, except the Naches Pass trail, built into a road in that year (the "1900" road). The Naches Pass trail was finally completed as a wagon train route to the Greenwater River basin in 1853. Since its inception, the trail was continually being used, improved, and surveyed for development. At one point, it was slated to become the next cross-Cascade pass.

Before 1910, the Chinook Pass road (Highway 410) had been completed 6 miles up the American River, including the bridge across the Little Naches. The real turning points for the basin itself, however, were improvements in the F.S. Rd. 1900 road by graveling in 1929 and paving in 1934 (6 miles from the mouth up to jungle Creek). The original Raven's Roost road was up Crow Creek, built in 1934 for the purpose of constructing and operating a lookout tower. No new roads were built between 1934 and 1962, but increased timber harvesting after 1962, caused additional road building to access harvest areas. The FS Rd. 1900 road was eventually improved and extended all the way to Pyramid Peak, which spurred increased road density and use of the entire watershed. From the turn of the century to 1962, only 20 to 30 miles of roads were in the basin, but between 1962 and 1990, an additional 300 miles were constructed. Road densities in 1990 ranged from 1.6 to 5 mi/mi^2 (Ehinger, pers. comet.).

Before timber harvesting, the single greatest effect on the basin was the widespread grazing that lasted for 60 to 70 years. Before the allotment and permitting systems were established, areas used for grazing and the number of animals grazed was uncontrolled. The ridge crests were heavily used as grazing, sorting, and driveway areas.

Small-scale burning of meadows and low brush areas by the local Native Americans and sheepherders was common from the 1850s through the 1920s. Much of the crestal uplands along the south and north ridges were repeatedly burnt. Surface erosion and debris slides from these areas could have contributed significantly to open riparian canopies in the headwater streams. Also, wildfires can damage vegetation and soils and initiate intermittent to continuous long-term erosion and delivery of sediment and organic debris to streams (Swanston 1991). In the Little Naches River, chronically eroded areas were identified in aerial photos as long as 50 years after the burning and grazing had been diminished (Smith 1993).

The allotment system was begun in the 1880s in response to complaints about the grazing and burning of the forest. The system was not fully in place until 1905, but the numbers of sheep and cattle were drastically reduced. In 1923, six allotments were present along the entire westside and up the Matthew Creek drainage, which altogether permitted 7300 ewes plus lambs from June through October (Carter 1990). The valley bottom was used for horses as well as sheep. Reports to Congress in the 1930s indicate that the grazing areas in the Forest were heavily degraded (Anonymous 1930, Cooperative Western Range Association 1938). Driving of sheep to summer range was discontinued in the 1930s and sheep had to be trucked to the range. By 1950, many of the allotments were abandoned or severely reduced in number.

One of the unique aspects of the Little Naches land-use history is the relatively late timber harvest relative to harvest on the westside of the Cascades. The basin was fairly isolated and access from the Yakima Valley was difficult, partly because of steep landforms in the Horseshoe Bend area of the Naches River (Gosset 1979). Before the late 1950s harvest was limited to extracting large trees from the lower valley bottoms and adjacent slopes. Most of the timber was used for building local homesteads, fences, cabins for miners and trappers, and firewood. Later, when the orchard industry was flourishing in the valley, timber was needed for boxes and palettes. Trees were mostly removed by horse and wagon or floated down the river. No records exist of the amount or location of timber removed before the development of the Forest Reserve.

Truck logging began in 1931, after the road through Horseshoe Bend was improved and access by truck extended up the Naches valley. This improvement allowed a greater volume of timber to be removed. Most of the private timber land below the Forest Reserve was completely logged by 1944. Truck logging also led to the need for road improvements. Through the 1970s, selective-cut sales were extended throughout the mainstem valley and lower portions of the tributary drainages below Jungle Creek. Between 1963 and 1975, 17 percent of the harvestable acres of the Little Naches River basin were harvested. Commercial thinning and high grading on overstocked stands started around 1975.

The first clearcut sales were made in the lower basin of the Little Naches River basin. In 1975, partial cuts were extended into the area above Jungle Creek and the South Fork in both the mainstem valley and tributary slopes. From 1975 to 1985, harvesting was extended throughout the basin, including the headwater areas of the South Fork, Middle Fork, Sand Creek, and Matthew Creek. Clearcuts on the private checkerboard lands also started in 1975. By 1985, about 26 percent of the harvestable acres in the basin had been cut, by 1990 32 percent, and by 1992 35 percent.

The recreational patterns that developed in the Naches River basin were largely determined by the road and trail systems and their continued expansion and improvement. Early recreation was limited to picnicking and camping in the summer season when trails were passable, but became a year round pursuit as trails and roads improved. In the late 1800s, camping and picnicking along the alluvial flats were the first major recreational usages, followed in popularity by foraging for berries and fishing and hunting by horseback in the upper elevations.

By the 1950s, off-road uses had become popular, and they continue to be significant today. Back country camping and fishing is popular, but car camping along the edges of the river remains both the most extensive recreational use of the area, and possibly the most disturbing to riparian vegetation and stream bank erosion. Favorite camping areas have become compacted and devoid of understory vegetation, leading to increasing runoff and weakening root strength. At trail and road crossings, streambanks have become eroded. Also, to protect campgrounds from being eroded as the stream shifts its course, riprap and other channelization practices have been used .

To complicate matters, evidence exists of an extensive and extremely hot wildfire around 1850. This fire covered much of the northwestern portion of the basin from Crow Creek to the Middle Fork and twothirds of the mainstem valley (Gossett 1979, Plummer 1900, Uebelacker 1980). Coupled with various landuses, this event could have had long-term and cumulative effects on the stream network and forest composition. In this area, heavy sediment input to the tributaries and mainstem could help explain the sparse riparian vegetation and braided pattern of the mainstem channel in unconstrained areas. Presently, none of this area has been harvested and the upland forest stands are of the dense, mature type rather than old growth.

Changes in stream habitats 1935 to 1992—From 1990 to 1992, the Pacific Northwest Research Station, in cooperation with the University of Washington and the Wenatchee National Forest, resurveyed over 80 km of historically surveyed tributary streams in the Yakima River Basin (U.S. Bureau of Fisheries, 1930s and 1940s). The resurveys included the Little Naches River, Rattlesnake Creek, and the American River of the Naches River Basin, and Taneum Creek. Taneum Creek, near Ellensburg in the Upper Yakima basin, is an example of a basin that experienced early grazing and timber harvest affects common to the upper Yakima drainage. The results from these resurveys, conducted from 1990 to 1992, indicate that pool habitat has increased in both managed and unmanaged portions of the Yakima River basin (McIntosh and others 1993, Smith 1993). Over the same period, the dominant substrate has shifted from gravel to coarser rubble and fine particles in Taneum Creek and the Little Naches River, but remains the same in Rattlesnake Creek. More detailed results on habitat changes in the Yakima Basin are presented in Smith (1993) and McIntosh and others (1993).

In 1990, the University of Washington initiated the resurveys and intensive studies of changes in stream and riparian habitats in the Little Naches River Basin (Smith 1993). The initial hypothesis was that pool habitats of streams had declined between 1935 and 1990. The 1990 resurvey indicated that the frequency of large pool habitat had in fact increased from 1.7 to 4.6 /km, and substrate composition had become coarser. The percentage of spawning size gravel for salmon was reduced by 50 percent throughout the mainstem channel. In addition, fine sediments (> 6 mm) had increased to 6 percent throughout the mainstem of the river (Smith 1993).

These results, along with anecdotal information from the 1935 survey, suggest that pool habitat had already been significantly degraded by human disturbance by 1935. Furthermore, although an increase was shown in 1990, pool habitat abundance and quality is still below present Wenatchee National Forest standards of one primary pool/three bankfull channel widths. Because much of the mainstem is constrained, this system may lack the capacity for an abundance of large pools, especially in the lower reaches. Channels constrained between valley walls can have more high-gradient channel units, such as boulder cascades (Grant 1987) except at meander bends, where large pools may form and persist (Lisle 1986). For drainages like the Little Naches River, current Forest standards may need to be revised and rehabilitation efforts to create large pools should be reconsidered.

In the constrained reaches of the Little Naches River, repeated scouring of the channel bed has coarsened the substrate and increased the exposure of bedrock, creating more frequent and larger pools. Roads and riprap have greatly confined the main channel, magnifying the effects of scour at high flows and the displacement of streambed substrates. The 1990 survey indicated that the majority of pools were bedform scour pools controlled by large substrate and bedrock.

The increase in percent fines (< 6 mm) in the Little Naches, along with the high degree of embeddedness, suggests that fine sediment has increased since 1935. At the same time, large rubble also increased significantly, now comprising almost 50 percent of the surface substrate. When other roughness elements are lacking (such as large woody debris and riparian vegetation) large rubble becomes an important poolforming component. If the substrate is heavily armored and embedded, however, the habitat capacity of large substrate may be reduced. Furthermore, armoring the bed promotes bank erosion and impedes pool development through reduced bed scour. In the Little Naches River, armoring, through embeddedness (> 30 percent embedded for over 50 percent of the channel) of fine sediments in large rubble and medium rubble substrates, appears to have the long-term effect of reducting channel diversity and roughness. Where increased deposition of fines occurs in interstices of large streambed substrates, the effect may be a delay in the onset of bed movement during large flows, which in turn influences channel dimensions (Beschta and Platts 1986). This aggradation of fine sediments could also increase the effectiveness of moderate discharge rates to transport gravels and small rubble (Lisle 1982), therefore altering or eliminating spawning beds.

Conditions of the current stream habitat and those of riparian vegetation along the mainstem of the Little Naches River suggest possible lower riparian buffering capacities against stream flow and erosive processes. In arid eastside river basins, riparian areas can be limited to narrow strips along stream channels. In these areas, soil organics can be poorly developed and highly erosive. Under such conditions, the growth rate of riparian and upland vegetation can be slow for desired timber or conifer species. As a consequence, regrowth of riparian vegetation and hydrologic recovery (Sidle and others 1985) after disturbances of livestock grazing, recreation, and timber harvest may be slow. A brief synopsis presented below from the Little Naches River illustrates these trends in riparian vegetation and composition.

Changes in riparian vegetation—Although streams in the Yakima Region differ in habitat structures and hydrology, stream responses and damage from temporal and spatial patterns of land-use influences are generally similar throughout the region. Likewise, land use impacts on the health of riparian vegetation and its slow recovery may be similar throughout the region. Direct and indirect disturbances to riparian vegetation include grazing, road construction, recreation, fires, and timber harvest. Responses in riparian ecosystems generally appear as losses in vegetation, shifts to younger conifers with greater portions of deciduous and shrub species, the narrowing or constriction of the riparian zones, and increased soil erosion (Gregory and Ashkenas 1990, Gregory and others 1991, Kauffman 1988).

The Little Naches can be divided into three general zones of effects. The lower mainstem, upper mainstem, and tributaries. The effect of grazing, fires, roads, recreation, and timber harvest act on these areas differently because of differences in valley geomorphology and the timing of the effects. The lower mainstem is naturally constrained by basalt bluffs except in a few areas such as Kaner Flats. Riparian vegetation is limited to small areas along the channel with some upland species extending to the channel margin. Trail and road construction further limit riparian development in the unconstrained areas and increase the amount of bare ground exposed to erosion-especially along the left bank, where the riparian area ranges from 28 percent to 56 percent of the channel length along the river's mainstem channel (Smith 1993). Conifers are dominant, but diminishing, and the age class has become younger over time. Between 1949 and 1985 the most dramatic changes occurred on the left side of the river. The percentage cover of conifers in the riparian area decreased from 66 percent in 1949, to 23 percent in 1962, and 12 percent in 1985 (fig. 6). In these riparian assemblages, the proportion of mature and old-growth trees decreased from 67 percent in 1949, to 13 percent in 1962, and then 50 percent in 1985. On the right side of the river, the percentage decline in conifers was less dramatic, from 78 to 53 percent. Here, the proportion of mature and oldgrowth areas decreased from 56 percent in 1949, to 14 percent in 1962, and increased to 37 percent in 1985. Interestingly, on the left bank, the conifer forest was replaced by bare ground (28 to 56 percent) and mixed conifer and deciduous trees (fig. 7). On the right bank, the loss of conifer cover was replaced by a young mixed forest.

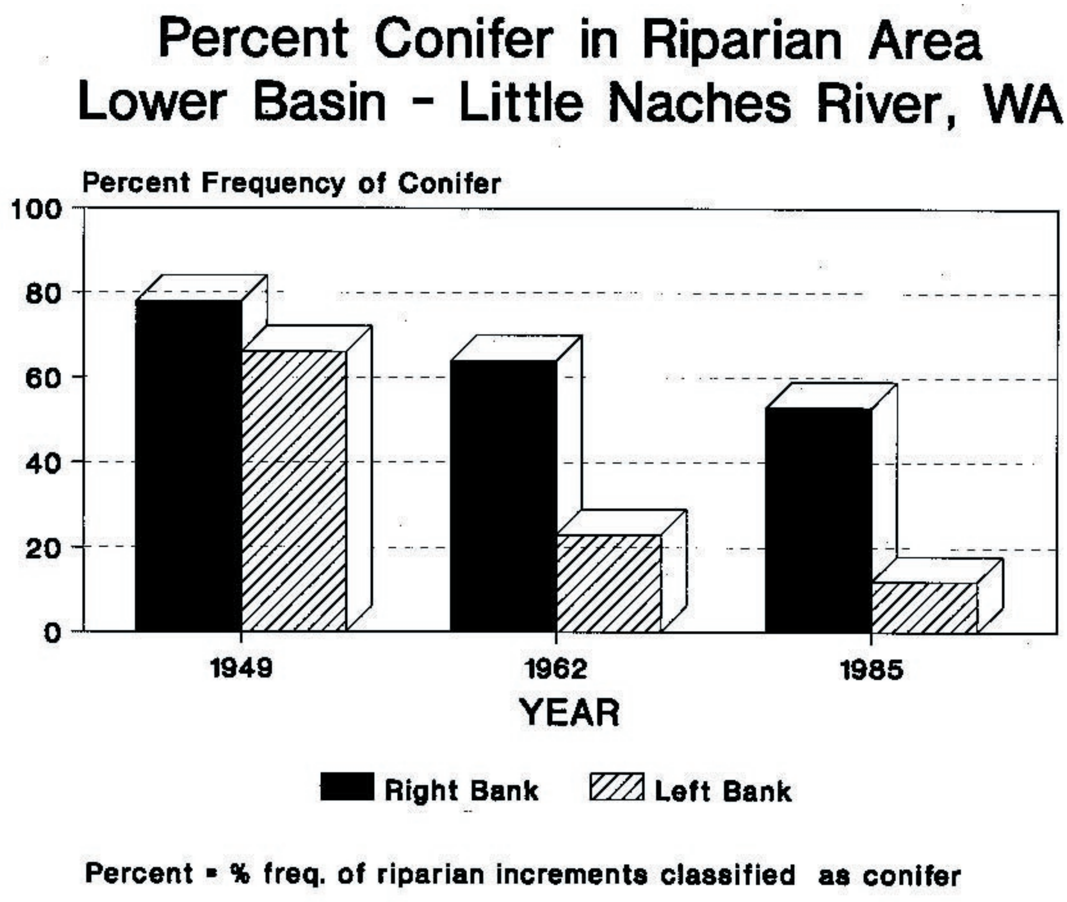

Figure 6. Percentage of riparian area in conifer vegetation in the lower mainstem of the Little Naches River, WA. Left and right banks are assigned by looking downstream. Data taken from aerial photos and expressed as percents of the channel length in mainstem (Smith 1993).

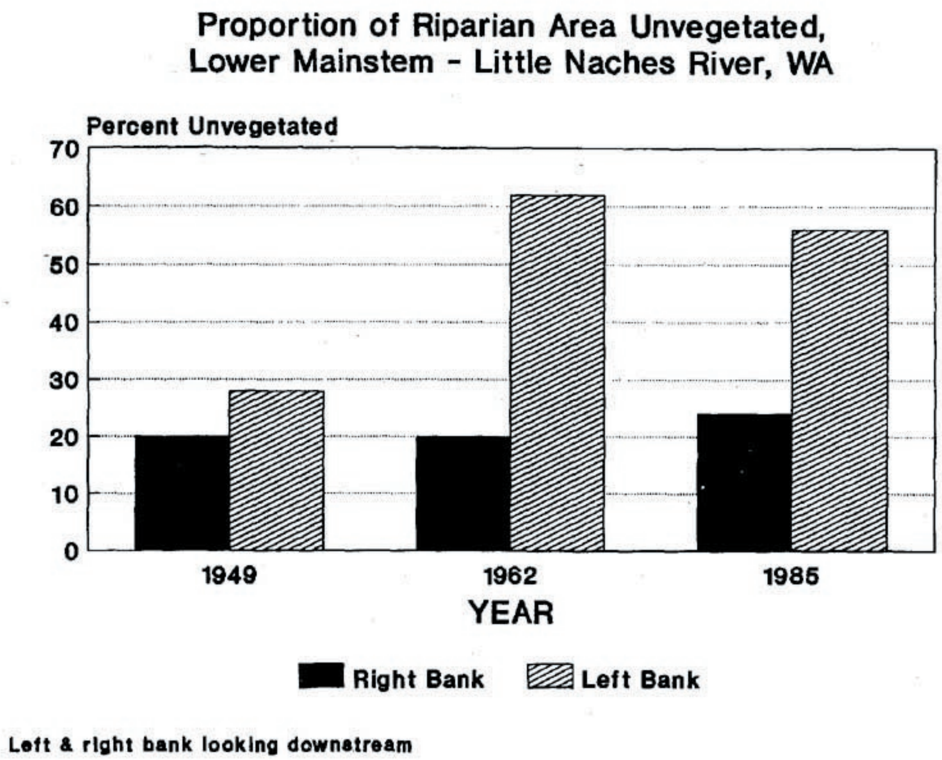

Figure 7. Percentage of unvegetated riparian area in the lower mainstem of the Little Naches River, WA. Left and right banks are assigned by looking downstream. Data taken from aerial photos and expressed as percents of the channel length in mainstem (Smith 1993).

The changes in percentage and age structure of conifers, increases in bare ground, and increases in riparian canopy openings adjacent to the stream channels suggest that the effects of different disturbances were combined. These disturbances include selective harvest in the 1960s, subsequent flood events in 1964 and 1977, increased recreational use, and reconstruction of the main road along the stream. Measurements of riparian canopy opening over the last 40 years show a significant increase in the mean canopy opening from 36 m in 1949 to 67 m in 1985 (fig. 8).

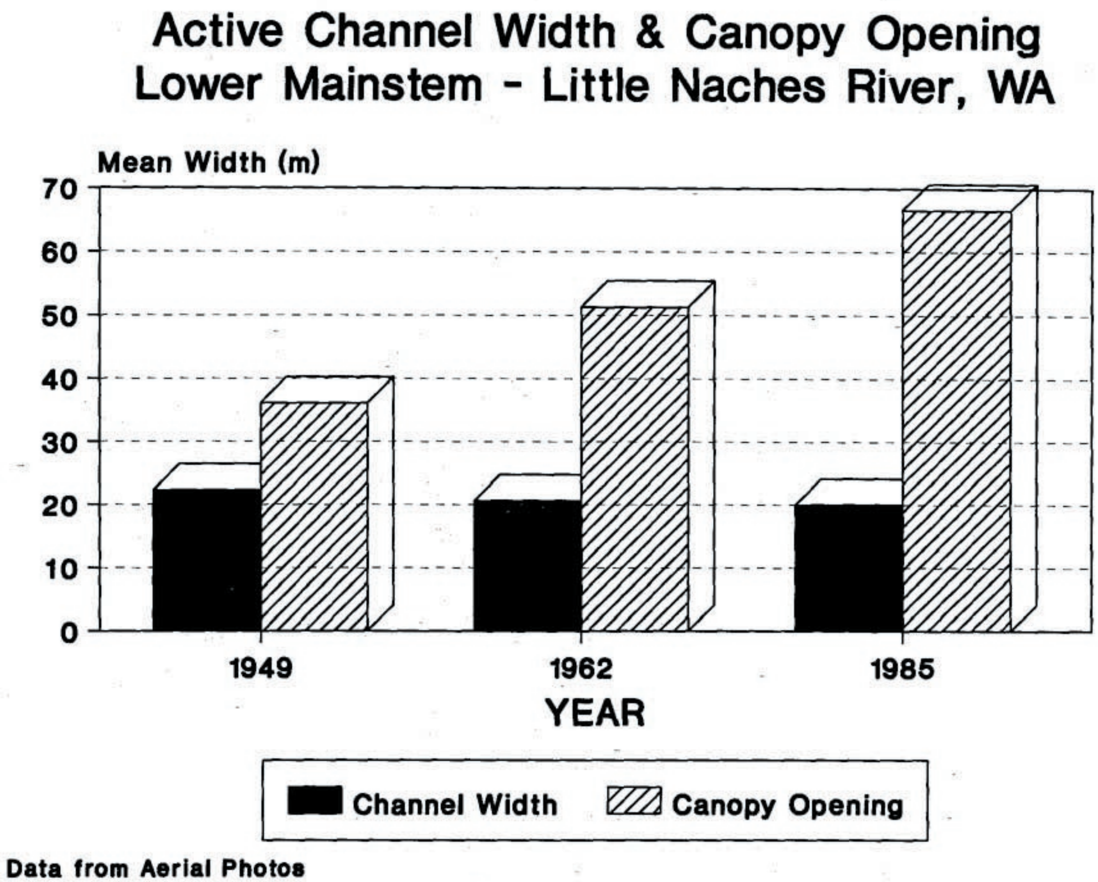

Figure 8. Mean active channel width and canopy opening width in the lower mainstem Little Naches river, WA. Active channel width is defined as the proportion of the channel bottom influenced by bedload transport. Data are from aerial photos (Smith 1993).

The upper mainstem is less constricted than the downstream, with larger areas of open alluvial valleys. The riparian zone has potential for greater development as the channel meanders across the valley through well-developed soils. Both the riparian and stream habitat characteristics of this area are prime indicators of past patterns of land-use and disturbance. In general, the degradation of riparian vegetation and stream habitats by grazing most likely persisted through the early 1940s. The following 20 to 35 years was a hiatus from intensive land-use disturbance, which allowed the channel to accommodate excess sediment deposited over time and the riparian vegetation to grow and mature. Both mean canopy opening and mean active channel widths decreased 30 to 40 percent from 1949 to 1962 (fig. 9). The delay of harvest until 1975 in this area could explain the lack of change in canopy and active channel widths from 1962 to 1985. These “stable” stream and habitat conditions persisted, despite the effects of the 1964 and 1977 large flood events, and concurrent increases in road building and timber harvesting throughout the headwaters and tributary valleys. The cumulative effects may not be evident now.

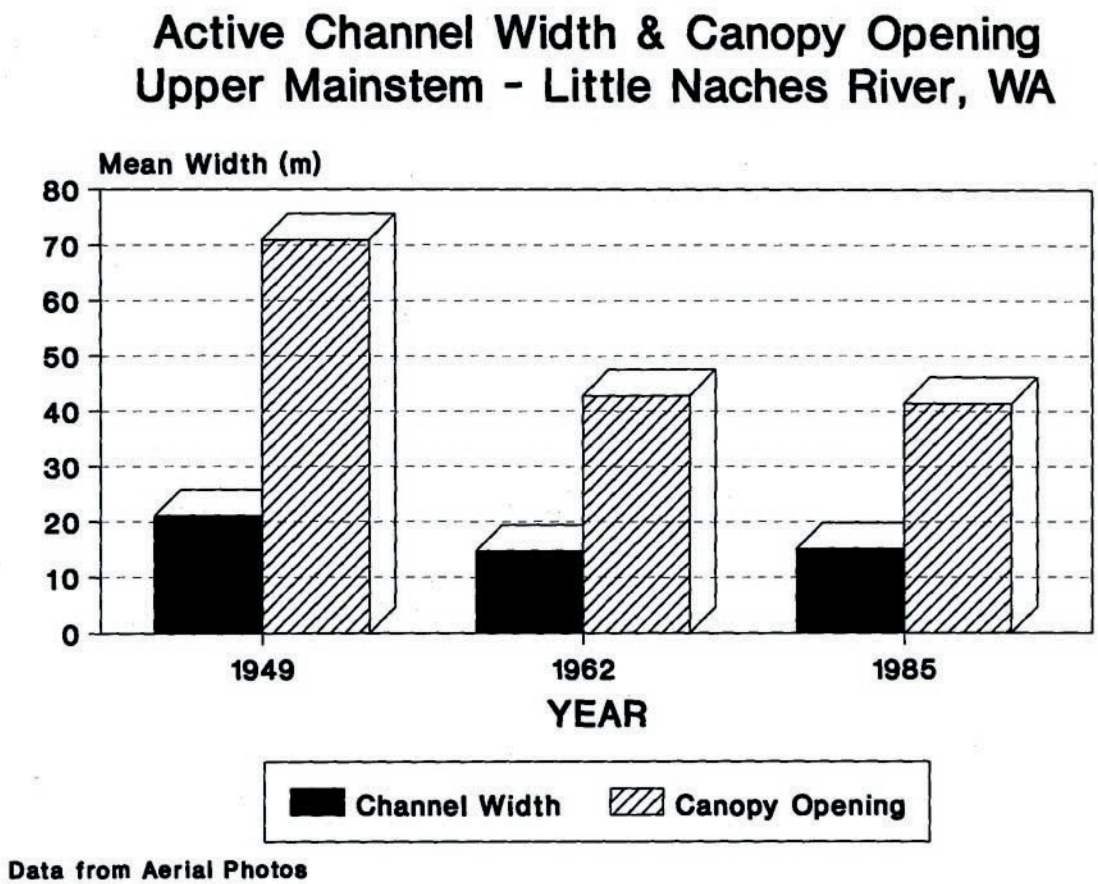

Figure 9. Mean active channel width and canopy opening width in the upper mainstem Little Naches river, WA. Active channel width is defined as the proportion of the channel bottom influenced by bedload transport. Data are from aerial photos (Smith 1993).

The riparian vegetation is still dominated by conifers (34 to 70 percent), but the age class has shifted from old and mature trees to young and small trees. In addition, conifer decreased more than 50 percent on the left bank because the main road was extended through this section (fig. 10).

Conclusions and recommendations—The tributaries of the Little Naches River are conduits for sediment

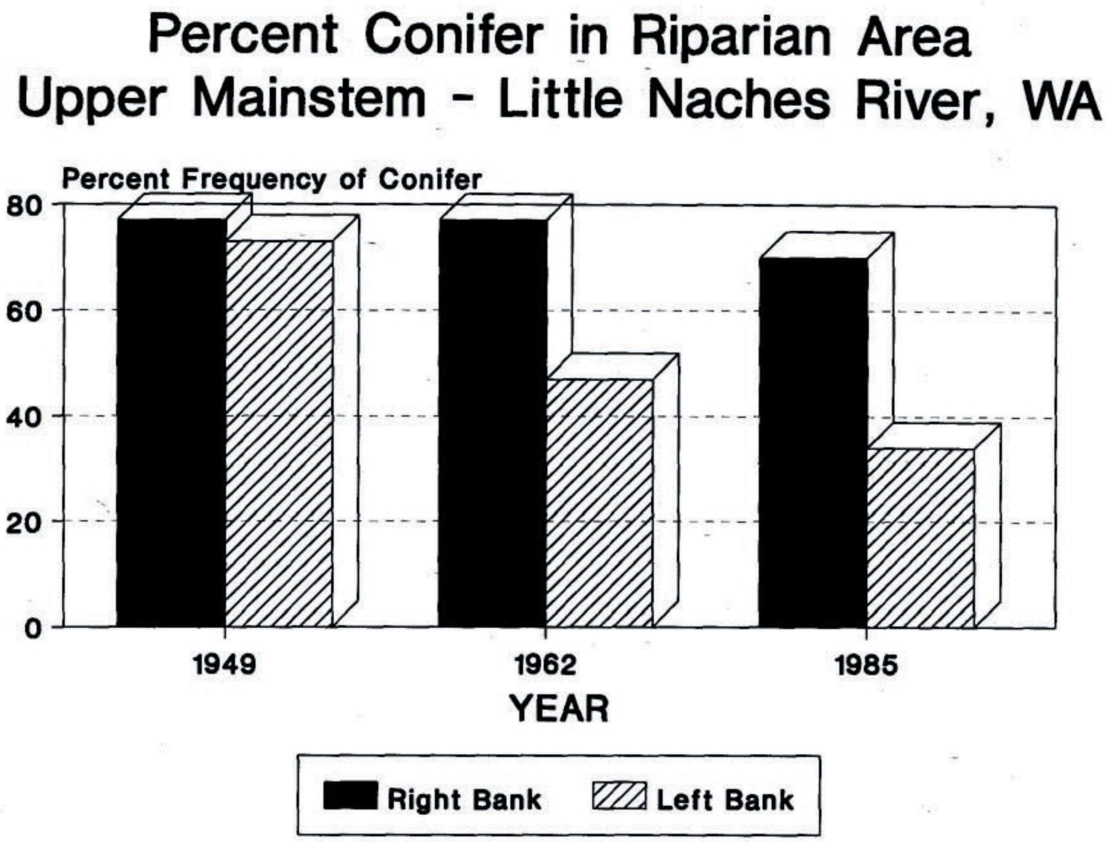

Figure 10. Percentage of riparian area in conifer vegetation in the upper mainstem of the Little Naches River, WA. Left and right banks are assigned by looking downstream. Data collected from aerial photos and expressed as percents of the channel length in mainstem (Smith 1993).

transport to the mainstem. They can either buffer the affects of land uses in the headwaters or they transport those effects to the lower drainage. Certain tributaries were more heavily used in the grazing era and show the effects in the photo record. Others were not affected greatly until the onslaught of road construction and timber harvest. Furthermore, because these activities have been occurring for only a relatively short time (10 to 15 years), we may not be seeing the full effect at present. Further analysis of aerial photos and survey data is needed to assess changes to the riparian areas in the upper tributaries.

The changes in the riparian zone in the Little Naches River have implications for the health of the watershed. Loss or constriction of the riparian area reduces the buffering by riparian vegetation of streams from upland effects (such as, road use and timber harvest) that cause soil erosion and produce fine sediments. The increasing percentage of bare erodible area weakens the resistance of the channel banks to erosion and also indicates a general lack of overhanging vegetative and cover for fish. Increasing canopy opening allows more solar radiation to elevate water temperatures during summer low flow. The 1990 survey data showed that water temperatures in the mainstem Little Naches commonly exceeded the Forest standard of 61° F (Ehinger 1990). Finally, the reduction of the proportion of conifer and mature conifer implies an increasing deficit of high-quality large woody debris available to the stream in the future.

Although pool habitats increased over time in the Little Naches River during the last 55 years, other habitat components critical to abundant and healthy spawning and rearing habitats have been reduced. Off-channel habitat, riparian cover, riparian edge and channel complexity, and spawning gravel decreased over time. During this period, substrate embeddedness, percentage of fines, and water temperatures were elevated. Without proper management and protection, these habitat conditions could degrade further with planned timber harvest and present recreational pressures. Furthermore, the condition of the riparian zones buffering the stream may be inadequate to mitigate the land-use effects over the next decade.

A period of relative inactivity in the tributary portions of the Yakima Basin, followed by much later entry for timber harvest, may explain some of trends in improving stream habitat. These trends must be viewed in the perspective of current standards for pool habitat, however. None of the streams we have surveyed comply with current Forest Service standards for pool habitat. Although the trend in improving habitat is encouraging, the stream habitats we surveyed are still in poor condition. Furthermore, given the late entry for timber harvest, stream habitats may not yet be fully expressing the cumulative effects of harvest activities. Management priorities for stream protection as well as enhancement projects should emphasize monitoring to better define trends in habitat changes.

Grande Ronde River (Eastern Oregon)

Land uses and changes in stream habitats—In 1990, the Pacific Northwest Research Station conducted a study to examine how anadromous fish habitat had changed over time in the Upper Grande Ronde River Basin (McIntosh 1992). Using a U.S. Bureau of Fisheries stream survey from 1941 (Parkhurst 1950, Rich 1948), the Pacific Northwest Region documented a 60 percent loss in pool habitat, along with high concentrations of fine sediments throughout Chinook salmon spawning habitat. At the time of the 1941 Bureau of Fisheries survey, the upper Grande Ronde River basin had already experienced considerable human-induced disturbance. Complementary research on wilderness streams in the Columbia River Basin has shown that pool habitat has improved or stayed the same over the same period (McIntosh and others 1993, Sedell and Everest 1990). McIntosh (1992) demonstrated that anadromous fish habitat in the Upper Grande Ronde Basin has been severely degraded by land-use activities over the past 50 years.

When the loss of pool habitat is added to the previously documented (James 1984, ODFW 1987, NPPC 1990) problems of highly degraded riparian habitat and extreme water temperatures, both winter and summer, the condition of anadromous fish habitat becomes much more critical. In addition, current stream surveys from the Wallowa-Whitman National Forest indicate that more than 70 percent of the stream miles in the Upper Grande Ronde River basin fail to meet current Forest Plan standards for fine sediments, stream shading, and water temperature, and much of the stream system is lacking in large woody debris. The changes since 1941 indicate that the cumulative effects of land use have caused extreme degradation of stream and riparian habitat on the scale of a large watershed. Rearing habitat for juvenile fish, resting habitat for migrating adult fish, and refugia for adults and juveniles from catastrophic events—such as drought, fire, and winter-icing (Sedell and others 1990)—has been severely reduced by loss of pool habitat. Susceptibility to disease and predation is likely to have increased because fish are crowded into fewer areas.

Surface fines are high (> 20 percent) throughout the headwaters of the Upper Grande Ronde River. The measured amounts remain above those currently recognized by the Forest Plan as necessary for high egg survivability (< 20 percent surface fines). This area represents the primary spawning habitat for the spring Chinook stock in the Upper Grande Ronde, currently listed as threatened under the Endangered Species Act. Substrate composition is important in influencing the quantity and extent of spawning habitat and both provides summer and winter cover for juvenile fish and influences aquatic biological production. A considerable body of literature has demonstrated the detrimental effect of fine sediments on salmonid reproduction (Chapman 1988, Everest and others 1987). The extremely low return of adults (1990 estimates of < 100 fish) suggests that silt-laden spawning habitats, as well as ocean-based commercial fisheries, depress spring Chinook runs in the upper Grande Ronde.

Land-use records indicate that domestic livestock grazing, splash dams and associated log drives, and mining, significantly affected anadromous fish habitat before 1941. Stream channelization—feasible because heavy equipment was available after World War II—also greatly reduced stream habitat diversity throughout many portions of the upper Grande Ronde. Timber harvest and road construction have increased substantially since the 1950s becoming the dominant land-use activities in the upper Grande Ronde River basin (fig. 5). The legacy of historical land uses, coupled with the effects of current upslope management practices, are pervasive and continue to forestall recovery.

Land-uses and changes in streamflows—Analysis of long-term streamflow and climate records indicate significant changes since 1904. Base flow has increased, and annual and winter precipitation, along with snowpack, have decreased. The timing of peak discharge appears to have shifted to one month earlier in the year. The near doubling in base flow while precipitation has declined suggests that the increase is not due to climate. The altered base flow regime may be the result of extensive defoliation from insect infestations and timber harvest. The reduction in moisture lost to transpiration, resulting from decreased leaf area by insect defoliation and timber harvest, could result in more precipitation being retained as soil moisture, eventually being released to the stream channel through subsurface flow. The higher base flow did not translate into increased annual discharges. Base flow may be more sensitive to increased subsurface flow than annual discharge because base flow is less than 3 percent of the annual water yield.

Change in the timing of peak discharge to one month earlier in the year could also be a result of land-use practices. Research in western Oregon has shown that snowfall accumulations are greater in the clearcuts and that they melt earlier because of increased exposure to solar radiation (Harr 1983). The high rate of timber harvest in the upper Grande Ronde River basin may have created similar conditions.

The shift in timing of peak flows may have implications for the emigration of salmon smolts from the basin because their migration is timed largely to peak flows. If the smolts are forced to migrate earlier, they may not be physiologically ready; or if they do not migrate, they risk leaving later, when conditions may be uncertain. The migration of smolts is a highly evolved process that represents a critical juncture in the life history of anadromous salmonids.

Conventional wisdom holds that the rearing capability of streams in eastern Oregon is limited by base flow. The increased base flow in the upper Grande Ronde River indicates there may be sufficient summer flow, but habitat conditions of both stream and riparian ecosystem cannot function together and adapt to changes in flow conditions. For example, in-stream habitats (pools and riffles) and riparian plant assemblages that have been altered by different land and water uses may not be able to utilize increased base flows (Elmore and Beschta 1987, Sedell and Beschta 1991).

Restoration efforts—We recommend that historical perspectives of cumulative land- and water-use effects on stream and riparian ecosystems within different river basins of eastern Washington and Oregon be used to provide useful time frames for identifying desired conditions and opportunities for restoration. For example, for the Grande Ronde River, pool habitats are not distributed evenly along the stream network, but tend to be grouped in patches. The majority of the pool habitat, both historically and currently, is found in unconstrained reaches of streams, providing the geomorphic context to habitat distribution. In 1941, these unconstrained reaches represented 40 percent of the stream length, but contained 69 percent of the pool habitat in the Upper Grande Ronde River. By 1990, these four reaches held 48 percent of the pool habitat.

Unconstrained reaches are the most dynamic, complex, and productive portions of the riverine environment (Gregory and others 1991, Sedell and others 1990). These complex and productive habitats are the result of frequent interactions between the channel and the associated floodplain and riparian vegetation. Research in western Oregon has shown that unconstrained reaches have the highest biotic productivity (Gregory and others 1989, Lamberti and others 1989, Moore and Gregory 1989).

To expedite recovery of stream and riparian habitat, thus improving anadromous fish habitat, recovery efforts for the near term should be focused on unconstrained reaches. These areas should exhibit fast rates of physical and biological recovery. Efforts should focus on restoring and enhancing the natural processes that cause these reaches to be so highly dynamic, complex, and productive.

Restoration of stream and riparian habitat in the upper Grande Ronde River basin will require changes in upland management practices and a long-term commitment to good watershed stewardship. A framework for this stewardship has been developed in the upper Grande Ronde River Anadromous Fish Habitat Protection, Restoration, and Monitoring Plan (Anderson and others 1992). In the near term, anadromous fish stocks need relief from highly unfavorable rearing and spawning conditions. The emphasis of management should be a focus on accelerating recovery through sound and biologically defensible methods. These efforts should be concentrated on those areas most important to the rearing and spawning of anadromous salmonids and should in no way forestall the long-term recovery of the upper Grande Ronde River basin.

John Day River (North Central-Oregon)

Land-use history—The John Day River has a drainage area of about 21,000 km^2 comparable in size to the State of Massachusetts. Historical accounts of the John Day River describe its banks as covered with dense growths of aspen, popular, and willow. Anecdotal reports, such as the inability of Peter Skene Ogden, a fur trader during the 1820s, to ford horses across the river near the town of Prairie City during summer low flows, suggests that the hydrograph has changed substantially (Hudson Bay Historical Society 1950). Beaver were also reported to be abundant. Historical photographs of the river at Picture Gorge show cottonwood galleries a quarter mile wide, where only a few trees now exist (Bancroft Library, University of California, Berkeley). Before settlement, the basin supported substantial runs of spring and fall Chinook salmon and summer steelhead. Currently, fall Chinook appear extinct and spring Chinook runs range from 2000 to 5000, and steelhead from 15,000 to 40,000 fish (Northwest Power Planning Council 1989).

The first settlement in the basin came when gold was discovered in 1862. Most of the mining was in the upper mainstem of the John Day near Canyon City, the Middle Fork of the John Day near Galena, and the North Fork of the John Day near Sumpter, Oregon. Placer mining—and later, dredge mining—drastically changed the character of the landscape. Dredging disturbed riparian vegetation, overturned bottom substrates, channelized streams, and devastated spawning gravels with the deposition of fine sediments. The legacy of this period remains today, with many kilometers of dredge spoils, especially in the North and Middle Forks of the John Day. Settling ponds in the upper North Fork remain a source of toxic heavy metals (Hudson Bay Historical Society 1950). Streamflow in several creeks in the Malheur National Forest goes subsurface because of the disruption of the stream bed.

During this same period, irrigation and logging began. The first sawmill was established in 1862 (OWRD 1986). Cattle grazing operations began during the 1860s, primarily near Lower Rock Creek and the towns of Clarno and Shaniko. Sheep were introduced in the 1880s and, by the 1900s when the railroad was established, Shaniko became one of the world's largest shipping centers of wool. Early aerial photographs by the Oregon Historical Society show the hillsides so thick with sheep that, on first glance they appear to be snow drifts. Throughout this period, grazing intensity was high. For example, Alder Creek, a small watershed of 89 km^2, had heavy grazing by 30,000 sheep over a few years. Soon after sheep were introduced, cattle followed. The introduction of exotic herbivores was especially damaging because the vegetation of eastern Oregon and Washington evolved without large, grazing herbivores (Mack and Thompson 1982). The native bunchgrasses were displaced by exotic flora, such as cheatgrass.

Before the settlement by Euro-Americans, fire return intervals ranged from 45 to 75 years in Wyoming big sagebrush communities, and 10-15 years in mountain big sagebrush, ponderosa pine associations (J. Boone Kauffman, pers. comm.). Grazing, fire suppression, and the introduction of exotic plants have greatly altered plant community composition and disturbance cycles. Natural fire cycles have been disrupted, thereby changing nutrient cycling and patterns of plant succession. The present plant communities bear little resemblance to the original flora. Undoubtedly, these changes have altered the natural hydrologic cycle.

Native plant communities changed as a result of the expansion of western juniper and sagebrush, and exotic plants and species not palatable as forage began to crowd out native bunchgrasses. The present plant communities are less subject to the low-intensity range fires of the past, which reinforces the present plant assemblage structure (J. Boone Kauffman, pers. comm.). The expansion of juniper is especially noticeable when historical and recent photographs of specific locations are compared. For instance, aerial photographs taken of the area surrounding John Day and Canyon City show that juniper was confined to small pockets in 1939 (Oregon Water Resources Department 1986). Photographs taken in 1986 show that junipers now dominate the landscape. Western juniper can intercept and transpire as much as 25 percent of the precipitation. Junipers in central Oregon range from 186 to 421 trees/acre. James R. Sedell (pers. comm.) estimates that for a 400,000-acre watershed, with 250 junipers per acre, water lost through transpiration could be equivalent to 3500 to 7500 cfs per day.

The Blue Mountain Forest Reserve was established in 1906 and, by the 1920s, timber harvest had become an important activity in the basin. Currently, timber harvest is the major land-use activity in the Ochoco, Umatilla, and Malheur National Forests. The historical record indicates that timber harvest steadily increased until about 1950, and has remained at these rates (fig. 11).

Land uses and changes in stream and riparian ecosystems—The combined effects of all human activities

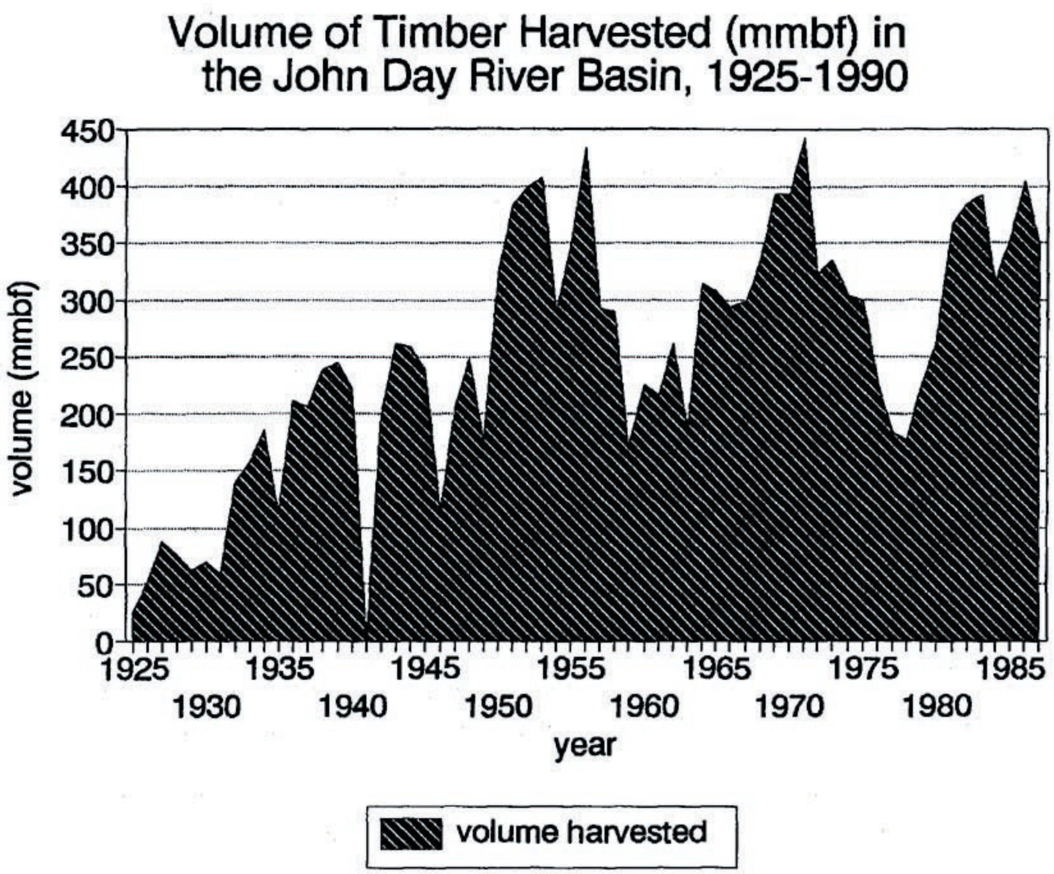

Figure 11. Volume of timber harvested in the John Day River basin, 1925-90 (Oregon Department of Forestry 1990).

have dramatically changed the riverine system of the John Day basin. The hydrograph has changed significantly, with base flows increasing in all managed watersheds and remaining the same in the wilderness drainage (McIntosh and others 1993). This finding suggests that the headwaters have lost riparian and stream habitats and their capacity to store water for release during the low-flow periods of summer (McIntosh and others 1993). No direct proof has been found, but flash floods and their subsequent effects, appear to be more frequent and severe. Recent research has indicated that the effects of flash flooding are far more deleterious on fish communities in highly altered stream reaches than those in more natural conditions (Pearsons and others 1992). Turbidity in some parts of the basin, such as Cottonwood Creek, a tributary to the North Fork, is notoriously high after storm events. The resulting siltation of stream beds results in decreased aquatic insect production and degraded spawning gravels.

The riparian canopy is completely gone in many parts of the watershed with less stream cover and shading than the recommended 75 percent closure (Li and others 1992). A study of several small watersheds indicated the effect on riparian vegetation can be severe where the riparian habitat has been altered through human-caused activities, such as sheep and cattle grazing (Pearsons and others 1992). Severe increases in water temperatures, both summer and winter, are critical limiting factors for salmonids over many portions of the watershed (Adams and others 1990, Li and others 1992, Li and others, in press). Tiedmann and Higgins (1989) found that the short-term threshold for rainbow trout (23.8°C), as recommended by U.S. Environmental Protection Agency, was regularly exceeded in streams where experimental grazing was tested. They could not attribute this to grazing practices, however, Li and others (in press) found that daily temperatures regularly exceeded the upper incipient lethal temperature (26.5° C, Bidgood and Berst 1969) for steelhead trout in Rock, Mountain, and Alder Creeks, where the primary disturbance was cattle grazing.

Hypotheses have been advanced that the inland rainbow trout populations of the John Day basin are more adaptable to high temperature than other strains. Li and others (1992), however, found that rainbow trout selected cold-water habitats when the ambient temperature of the main stream approached 24° C. Interestingly, rainbow trout were rarely in cold-water habitats when the stream temperature was below 20° C. Cold-water refugia are critical in stream systems where temperatures regularly approach lethal heights (Berman and Quinn 1991). Unless maps of temperature microhabitats are described, inferences concerning temperature adaptability of inland rainbow trout may be misleading.

High temperatures can have several different effects in stream ecosystems. Fish can be subject to lethal or sublethal thermal stresses that impose severe metabolic costs. In the John Day basin, some stream reaches that exceed 32° C during the diel cycle in the summer are devoid of fish (Li and others in press). Studies for the John Day using the metabolic model of Wurtsbaugh and Davis (1977) suggest that the metabolic maintenance demand by juvenile steelhead increased 23 to 43 percent from the coolest to the warm stream reaches (Li and others 1992, in press).

The lack of thermal cover by riparian ecosystems in the John Day Basin also appears to affect fish food webs. Higher solar radiation at stream surfaces and benthic algal production can induce or alter the development of prey types that may or may not be available as fish food. (Tait and others, manuscript submitted). For example, in the John Day basin, standing crops of algae become higher in exposed reaches (no riparian cover) of streams because of light enhancement of primary production. The increased algal forage base for aquatic insects, however, did not translate into greater prey availability for the fishes. The algae supported additional invertebrate biomass comprised of large, stone-cased, caddisflies. These aquatic insects, because of their protective cases, were invulnerable to predation by fish.

Evaluation of habitat rehabilitation programs—Stream and riparian ecosystems of the John Day and other eastern Oregon watersheds have suffered from poor livestock and forestry practices (Beschta and others 1991, Kauffman 1988, Kauffman and Krueger 1984). Although most of the evidence is anecdotal, conventional wisdom holds that the carrying capacities of these streams for salmonids have been greatly diminished. As a result, large sums of money have been invested in habitat restoration in eastern Oregon as part of the long-term plan to restore anadromous salmonids in the Columbia River System. For example, the Bonneville Power Administration spent about $6,000,000 in the John Day basin (Rick Stoots, pers. comm.). Unfortunately, no funds were allocated for monitoring projects because evaluation was not considered in the design of restoration work. The result of this policy is that how effective various restoration efforts are is unknown.

Despite not having monitoring data from before or after enhancement projects, three evaluations of habitat rehabilitation efforts have been conducted. These evaluations include a bioeconomic study of habitat restoration (Adams and others 1990); a study of log sill/log weir emplacements in Camp Creek of the John Day basin (Li and others 1992); and a field review of stream-enhancement projects in eastern Oregon (Beschta and others 1991). Adams and others (1990) found that different stream factors limited the capacity of habitats in different physiographic settings. They suggested that increased summer streamflow and reduced temperatures could increase fish use of habitats. Li and others (1992) found that the installation of log weirs in Camp Creek did not address the critical problem of water temperature, the major limiting factor there. The objective of the habitat-enhancement program was to increase the number of pools in a riffle-dominated system. The effect of installing about 280 log weirs (at about $750 per log weir) was to increase pool volume by 4 percent. Moreover, increased rainbow trout density and use of habitat were insignificant. Li and others (1992) demonstrated that variations in water temperatures caused fish populations to be food limited.

The evaluation of habitat rehabilitation projects by Beschta and others (1991) used visual assessments of the status of riparian vegetation and geomorphic conditions in stream channels. They concluded that efforts to rehabilitate stream habitat on a site-specific basis without examining the entire river and riparian landscape contributed to the lack of success of many projects. Beschta and others (1991) suggest that the most effective means of restoring habitat is to permit natural riparian plant succession to occur and to reduce the most detrimental source of disturbance, livestock grazing. They suggest that cattle exclosures can be excellent tools for habitat restoration. Hard structure emplacements in stream channels appeared to create minimal benefits at the cost of disrupting the natural processes of the stream channels and interactions with floodplains.

All three studies indicate that most of the enhancement programs do not help address the basic causes of habitat changes. Furthermore, evaluation of current habitat rehabilitation programs, because basic physical and ecological information are lacking, could be creating the illusion that habitat restoration can be quickly accomplished through technological means. For enhancement programs to succeed, they need better landscape information about habitat structure and function. These data can be obtained through long-term monitoring programs. Finally, restoration efforts need to give careful consideration to temporal scales of salmonid life cycles, fish relations to stream-habitat changes and riparian plant succession patterns.

SELECT STREAM AND WATERSHED MANAGEMENT APPROACHES

Instream Flow Incremental Methodology (IFIM)

Effect of water diversion on stream flows and salmonid habitats (Methow River, WA)—A major historical and contemporary water issue in eastern Washington and Oregon is the effect of water diversion on river flows, habitats, and salmonid populations. An excellent case study of the problem is the Methow River basin. Wild anadromous fish populations of the Methow River are depressed. The major factors limiting salmonid production include dams on the Columbia River, seasonal losses of water in the tributaries, and historical cumulative effects of past land and water uses. Although the nine dams on the Columbia River currently limit fish passage and create other survival problems (such as predation and temperature) the Methow River was completely blocked from 1912 until the 1930s by a hydroelectric dam at Pateros near the river mouth. The Pateros dam caused the extinction of a colic, salmon run and perhaps other salmonids. After the dams' removal, the Methow River was planted with hatchery and trap-release salmon and possibly colonized by straying Columbia River fish. Historically and today, irrigation withdrawals during low-flow periods also limit salmonid production in the river. Water withdrawals are considered detrimental because fish production in the Methow River appears naturally limited by low flows, losses of water to groundwaters (dewatering) in porous substrates, and high-gradient and erosive conditions in tributary watersheds. Current anadromous salmon runs include summer steelhead, spring Chinook, summer Chinook, and fall Chinook. Resident fish populations include rainbow, cutthroat and brook trout, bulltrout (or dolly warden), whitefish, suckers, and sculpins. Information sources and additional data about salmon population sizes, limiting factors, management goals, life history, and the timing and location of spawning include the Methow and Okanogan Rivers Sub-basin Salmon and Steelhead Production Plan (Washington Department of Wildlife and others 1989); Kahn (1987, 1988, 1989); Edson (1990); Meekin (1991); and Langness (1991).

The Methow River case involves recent interactions of the valley's Pilot Planning Project (PPP). The PPP includes different caucuses (business, agricultural, recreational, environmental) comprised of the local residents and other key representatives such as the Methow Valley Irrigation District, Okanogan County officials, Washington State Department of Ecology, and the Yakima and Colville Tribes. Representing Washington State, the Department of Ecology is responsible for reviewing previously adopted minimum instream flows and assessing the effect of new water-right appropriations on salmon habitat. Since 1983, the Department of Ecology has used the Instream Flow Incremental Methodology (IFIM) to provide information for adoption of minimum instream flows (Bovee 1982, Milhous and others 1976, 1989). The IFIM defines fish habitat in terms of water depth, velocity, substrate, and cover. Participants in the Department of Ecology's Methow project include the Washington State Department of Fisheries, Washington State Department of Wildlife, the Yakima Indian Nation, Colville Confederated Tribes, Okanogan County, and U.S. Fish and Wildlife service.

Today, a majority of the PPP's caucus members and the irrigators disagree with the findings of the IFIM study of minimum instream flows (Caldwell and Catterson 1992). The major concerns are IFIM assumptions pertaining to where and at what times water is withdrawn and where the water goes when irrigation diversions cease. Some members believe that all the water returns to the river and others assume that none of the water gets back to the river. The Department of Ecology suggests that a solution to water losses during irrigation might be to adopt conservation strategies for agricultural uses. An additional concern of the caucus members is that the IFIM study prompted theYakima Indian Nation to request a moratorium on new wells in the Methow Valley. The Department of Ecology study has not set a optimum flow regime for the Methow River because a consensus is needed by State and Federal agencies and the tribes on the effects of assessed environmental conditions on fish.

The Department of Ecology maintains that setting minimum instream flows will preserve fish habitat during low-flow periods. The most important flows are during the low-flow period of August to October when adult salmon return to the river. The Department of Ecology recommends that future minimum instream flows for the Methow River basin need to include the relative importance of different river reaches, salmon species and life-stages and the peak weighted-usable-area (index of fish habitat). Such information is needed because different fish species and life-stages co-exist in the river and each has a different flow requirement. The Department of Ecology suggests that minimum instream flows also need to consider those necessary for incubating salmon eggs, smolt out-migration, adult fish passage to spawning grounds, and the prevention of stranding of fry and juveniles. Specific environmental factors should also be considered: water temperature; water quality; and sediment loads (Caldwell and Catterson 1992).

In the Methow River basin, some of the concerns were discussed in the EIS for the Early Winters Alpine Winter Sports Study (Okanogan National Forest 1990). Little attention, however, was given to potential cumulative effects of proposed land uses on the quality of surface water runoff, groundwater, pollution, and water allocation on river and riparian ecosystems. Future effects included expansion of a proposed ski area, land exchanges, and practices such as urban storm runoff and golf-course fertilization, waste treatment, waste disposal, and air pollution through precipitation inputs. Together, these actions through time could have been highly detrimental to the water quality and health of river and riparian ecosystems and their wildlife and anadromous fish habitats.

The EIS (Okanogan National Forest 1990) recognized that the groundwater system of the Methow Valley, and its high hydraulic connectivity with surface waters function as the key component of the valley's hydrology, influencing seasonal streamflows. During the spring and early summer, the Methow River is an influent river and, for example, recharges the aquifer, but in the fall and early winter, the river is effluent-fed by groundwater discharge. The EIS points to the extreme importance of protecting surface waters and all groundwaters in significant hydraulic continuity with surface waters (Washington State Water Resources Act 1971, RCW Chapter 90.54), but gives minimal attention to the productivity of riverine and riparian ecosystems.

Recent research findings for the Flathead River in Montana have demonstrated the importance of hydraulically connected aquifers and channels to river ecology (Stanford and Ward 1988). The Flathead River has an extensive valley-floodplain aquifer and alluvial geomorphology that is very similar to the Methow Valley's. The floodplain, extending up to several kilometers from the channel, is hydraulically connected to channels and supports deep below-ground habitats (~ 10 m) penetrated by riverine animals. These animals and estimates of mass transport of nutrients from flowing groundwater habitats (hyporheic habitats, Stanford and Ward 1988) point to their extreme importance to the biotic productivity of the channel and riparian ecosystems. Underground waterways can serve as refuge for animals during time of drought or other stresses. In addition, the belowground habitats are commonly rich in bacteria that cycle nitrogen and other nutrients. These nutrients are in demand by both river and riparian organisms. The diversity of life is so great in these underground habitats that they may serve to help clean rivers of contaminants.

Our review for the Methow River suggests that the IFIM method's "instream perspective" does not adequately consider hydraulic continuity between groundwater and surface water and their relation to irrigation-canal flows. In alluvial river basins like the Methow River, glaciers left deposits of porous and permeable sands, gravels, and cobbles that form aquifers with a high degree of hydraulic continuity between groundwater and surface waters. Surface waters in the Methow River basin, as discussed above, are lost and gained during different seasons and in different reaches as the river flows downstream (colder Associates 1991). Groundwater flows can reverse directions, causing water levels in wells to vary as flows change in the river channel (GeoEngineers 1990). Because of these geomorphic and hydrologic characteristics, much uncertainty exists as to where water goes when the irrigation diversions cease (Caldwell and Catterson 1992).

Additional information about these geomorphic features and flow regimes is needed to understand the relations of irrigation-canal flows to the discharge rates in the Methow River and to establish minimum instream flows to ensure the survival of fish eggs and juveniles in river reaches that dewater. Knowledge of these physical conditions is also central to determining water requirements for developing wells for drinking water, recreational, and commercial development and for protecting water quality from potential pollution from urban growth, agricultural activities, and landfill waste sites (Willms and Kendra 1990).

The pollution of groundwater by nitrogen could be a major worry in managing water quality in regions like the Methow Valley. The evaluation of pollution problems should take into account the chemical behavior of the mobile nitrate ion in groundwaters and the biological or chemical processes comprising sources and losses for various nutrients. For example, consideration should be given to processes relating to the formation and loss of ammonium. Ammonium usually cannot be considered a product of natural purification processes of surface and groundwaters, but as a contaminant resulting from practices such as urban-agricultural fertilization and cattle grazing. Ammonium is also a major source of nitrate.

Equivalent Clearcut Area Method (ECA): Hydrologic Effects of Logging

Forest managers have assumed that desynchronization or alteration of flows, caused by logging-induced diversity of snowmelt conditions, benefits soils and water resources (Harr 1987). This conception is based on studies in several regions of influences of timber harvest patterns on snow accumulation and melt (Halverson and Smith 1974, Troendle and King 1987). These findings may or may not apply in eastern Washington and Oregon, however, because of variable ecoregions, drainage basins, and hydrologic regimes that may be either beneficial or detrimental to streamflows. Harr (1987) points out that desynchronization or synchronization of flows depends on how flows combine from different runoff sources and tributaries to produce streamflow regimes in downstream reaches. For most situations east of the Cascade Range, little scientific information exists about how flows combine under natural conditions and little understanding of whether the effects on streamflow are beneficial or detrimental to streams. In reality, managers in many forested regions of eastern Washington and Oregon would have great difficulty evaluating the influences of logging-induced diversity of forest stands on snow and stream hydrologic responses (Wasson and others 1992). Available research on logged watersheds indicates that regardless of the changes in flow, assumptions cannot be made that logging patterns either desynchronize or synchronize flows or can be termed beneficial or detrimental to soils or water resources (Harr 1987).

Recent research findings in northern Idaho by King (1989), using the equivalent clearcut area procedure to evaluate the effects of timber removal by road building on streamflows, may have some applicability to portions of eastern Washington and Oregon. Forest Service resource specialists have used versions of this method to forecast streamflow responses to vegetation removal by timber harvesting, road building, and fire. The equivalent clearcut area procedure is designed to estimate the effects of past activities on streamflow and to develop timber harvest schedules of entry for future forest-management activities in third- and fourth-order watersheds (U.S. Department of Agriculture, Forest Service 1974, 1977). Equivalent clearcut area timber-harvest guidelines commonly place limits on expected increases in the monthly streamflow during spring runoff to prevent increases in high flows that may alter stream channels. Short duration high streamflows, however, are usually responsible for sediment bedload movement and suspended transport that change channel conditions (King 1989). King (1989) recommends that maximum daily streamflows would provide better stream protection than monthly increases in streamflow. Consideration to applying these maximum daily streamflows to smaller first- and second-order streams of headwaters should also be given, where large increases in maximum daily streamflows can occur after timber harvest. These recommendations recognize the importance of high-quality local streamflow and precipitation records for calibrating the equivalent clearcut area procedure.

The Watershed Cumulative Effects Analysis Model (KWCEA): Logging, Roads, and Soil Loss

Soil loss can be viewed as the major response of water and soils to problematic land- and water-use practices. The watershed cumulative effects analysis (KWCEA) model was designed to address many of these problems. The KWCEA model is an adaptation of the universal soil loss equation (LISLE) and other watershed analytical procedures (Klock 1985). The model is designed for small watersheds (>4000 ha) to assess the potential effects of forest practices on downstream aquatic ecosystems. The KWCEA model is also designed to facilitate the scheduling of future timber harvest and other forest management practices. The specific region for its application is the east side of the Cascade Range. The model provides a condition index for a watershed when a past-effects threshold has been reached and when significant downstream water-quality or ecosystem degradation has been documented; the index value suggests relative, cumulative effects and provides risk-rating levels of past, current, and future, forest management practices, and of worst-case conditions (Klock 1985).

Forest managers on the east side of the Cascade Range have found the KWCEA model useful because it was developed for the eastside (central Washington); contains scientifically based information; uses parameters that are easily attainable; allows risks to be compared between harvest alternatives; and facilitates scheduling timber harvests to minimize risks over time (Bill Garrigues, pers. comm.). The parameters of the KWCEA watershed cumulative-effects analysis value include: R = site erosivity energy potential based on precipitation; E = site surface erosion factor; S = slope stability factor; H = hydrologic sensitivity characteristic; T = topographic factor; A1 = total area of activity; and A2 = total area of watershed (Klock 1985). Applications include the evaluation of harvest units and road segments. Independent evaluations can be made for all the above parameters to derive a cumulative-effects risk value, ranging from 0 to 6, for each unit. Ratings less than 1.0 indicate a low cumulative-effects risk with a potential no greater than expected risk from natural hydrologic events. Ratings between 1.0 and 2.5 indicate a moderate risk, and ratings from 2.5 to 6.0 indicate a high risk.

Some of the limiting characteristics of the KWCEA model include the absence of, or need for mathematical validation of model behavior; statistical validation of risk values; improved data-compilation procedures; and the addition of predictive hydrologic and meteorological information. Some of these problems arise from the model's being developed for research on specific basins (Mullan and others 1992) and the basic short-comings of key components derived from the universal soil loss equation and other procedures.

The agriculturally based technology for predicting water erosion, known as the universal soil loss equation and its various versions have been the most common approach taken by management organizations over the past 20 years (Slaughter and Aldrich 1989), especially for predicting sheet and rill erosion. The procedure was derived from the basic equations of Zingg (1940) for the effect of slope length and steepness on erosion. The equation is an empirical approach with a lumped model structure that severely limits the potential for increasing accuracy. This "black box" model requires a large mass of data. The equation does not define separate factor relationships for the fundamental hydrologic processes of rainfall, infiltration, and runoff, and for the basic erosional processes of substrate detachment by raindrop impact and flow, or transport by splash and flow dynamics and deposition by flow. A new generation of water erosion predictive technology for use by the USDA Soil Conservation Service, Forest Service and the Bureau of Land Management is currently under development (Foster 1987).

Soil Compaction

Management agencies, such as the Forest Service and Bureau of Land Management, have developed procedures to organize soil compaction data related to timber harvest, road building, recreational activities in riparian areas, and related activities in watersheds. A common assumption is that soil compaction on 12 percent of total watershed area is a threshold for detrimental changes in streamflow. The origin of this threshold appears unclear and poorly documented. A recent synthesis of research findings (Harr 1980, Harr and others

1975, 1979) shows a relation between flow increase and the amount of compaction and has demonstrated some major problems with using 12 percent as a threshold. Harr (1987) defined a curvilinear relation showing that flow increased exponentially with soil compaction, a relation that does not indicate a threshold. For example, a soil compaction of 12 percent corresponded with a 32 percent increase in peak flow, which indicates considerable adverse effects in streams. Such a relation suggests that different streams with varying channel geomorphologies would most likely be adversely affected by much lower flows than a 32 percent increase. These results indicate that the physical characteristics of a particular stream must be considered so as not to arbitrarily set the amount of compaction the same for all streams. The development of management thresholds and guidelines should include information about stream gradient, critical particle size, and channel geomorphology that relate to hydraulic principles and to the erosive power of the stream reach of interest (Grant 1987).

RECOMMENDATIONS

River Basin Perspectives of Cumulative Effects

Cumulative effects of land and water uses over the past century have greatly altered the health of river basins in eastern Washington and Oregon. Environmental effects resulting from timber harvest, fire management, livestock grazing, mining, and irrigation and other factors over long periods of time have become significant collectively. As shown in this document, cumulative effects include human activities and a wide range of hydrologic, landform, riparian forest, and stream channel interactions that couple together by an intricate series of causes and effects. The Council on Environmental Quality defines cumulative effects as “the impact on the environment which results from incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions” (CEQ Regulation 40 CFR 1508.7). Cumulative effects can be difficult to define both scientifically and practically. For example, potential combined effects induced by upland forestry practices within a watershed may include changes in hydrology, temporary and long-term sediment production, transport and storage, and offsite or downstream effects (Swanson 1986). This paper recommends that cumulative effects in upland forests and adjacent regions, which can result both from management practices and from natural events, need to be better defined in terms of the relations between water and sediment transport regimes and changing stream channel and riparian conditions (Baker 1977, Graf 1983, Hack and Goodlet 1960, Knighton 1987).

We recommend that the evaluation of cumulative effects be coordinated between managers and researchers to improve monitoring of the size and duration of flood events, as well as measuring various cause-and-effect factors. For example, as flood events become more influenced by landslides and road failures, monitoring projects should be able to evaluate sediment delivery in source areas, sediment transport and storage patterns in streams, the stability of streambanks, and riparian vegetation (DeBano and others 1990, Ziemer 1981). Monitoring projects should therefore include an array of methods that assess changing stream and riparian conditions. Important measurements should include estimates of sizes of sediment particles moved in relation to discharge; channel adjustment relations of widths, slopes, and peak-flow increases for different channel types; and riparian species presence under different streambank conditions (Grant 1987, Harvey 1987, MacDonald and others 1991, Simon and Hupp 1987).

Long-term monitoring programs need to be applied by researchers and managers to better define changes in temporal and spatial dimensions and mechanisms involved in natural and human induced disturbances. Any assessment of hydrologic characteristics and the responses of stream channels and riparian habitats should consider the findings and recommendations of Baker and others (1988), Dunne and Leopold (1981), Grant (1987), Miller (1990), and Pfankuch (1975). Important goals should include determining peak flow increases for different stream drainage networks; predicting the relation between different peak flows and movements of channel and bank materials; and assessing the causality of changes in channel structure and stability of stream and riparian habitats.

For forests west of the Cascade Range the evidence is currently contradictory, and no agreed-on approaches for assessing how harvested portions of a drainage basin might affect watershed hydrologic and geomorphic conditions (Harr 1979, Harr 1987, Ziemer 1981). The strong possibility exists that dispersion of timber harvest units affects runoff differently in coastal landscapes from the inland forests of eastern Washington and Oregon. Research on inland forests of Colorado shows timber harvests cause significant increases in peak flow (Troendale and King 1987), but harvest patterns applied west of the Cascades may have little effect on peak flows. The more arid and continental inland forests of eastern Washington and Oregon differ from the rain-dominated forests of the westside (Harr 1979) by having harsher climates as well as different hydrologic regimes, geologic-geomorphic formations, and soils and plant associations (Williams and Lillybridge 1983).

Long-Term Monitoring

Concepts, planning, and design procedures needed in developing cumulative-effect programs for watershed, stream, and riparian ecosystems should focus on long-term monitoring (Wissmar, in press). Longterm monitoring programs should be the key component for bringing together management organizations, researchers, and policy makers to improve the management of natural resources. The keystones of such ecosystem monitoring are long-term data records that provide the basis for analysis of environmental assessment objectives, with predictions of outcomes that can be used to modify and improve future projects.

We recommend that management organizations plan to use monitoring actions and information to facilitate decision processes for conserving and allocating resources for future beneficial uses. Wissmar (in press) presents procedural requirements for developing long-term stream-monitoring programs, including reviews of background and historical information to provide precise definitions of long-term objectives, planning considerations, and monitoring methods. Examples are given of specific procedures that need to be identified during the planning process. These procedures include applying management standards to variable conditions encountered in natural ecosystems and detecting the timing of recovery phases of ecosystem development after a disturbance. The procedures are essential for improving the application of management standards to stream and riparian ecosystems.

Ecosystem restoration—We recommend that long-term monitoring plans should be the central component for applying and evaluating restoration programs for degraded watershed, stream, and riparian ecosystems (Maurizi and Poillon 1992). The first step in restoration should be stating the objective of the monitoring plan: for example, to assess the effectiveness of the ecosystem restoration program. Other, more specific objectives include assessing whether, over time, the restored ecosystem is providing the planned functions and beneficial uses (Hildebrand and others 1987). These objectives can be addressed by using a long-term monitoring program that includes separate monitoring procedures for implementing, evaluating, and validating the planned activities (MacDonald and others 1991).

The next step is to define success criteria for the restoration effort. Criteria for success of projects can be defined by scrutinizing plan objectives and components. Important components needed in developing the restoration plan include background information; long-term objectives; planning considerations, and long-term monitoring procedures. Examples of background data needed to plan the restoration of stream and riparian ecosystems includes historical review of disturbances induced by natural events and human activities; landscape information in terms of topographic scales, bedrock geology, geomorphic landforms, hydrologic regimes, and distribution of stream and riparian habitats (MacDonald and others 1991, Platts and others 1983); stability of streambanks with and without riparian vegetation; and the feasibility of conserving riparian and transitional upland vegetation buffers as filters for surface water and debris movement, and as habitats for wildlife (Gregory and Ashkenas 1990).

The formation of long-term objectives can be the most important component of the restoration process (Wissmar, in press). Long-term objectives can include criteria for success thus providing a basis for assessing ecosystem conditions after restoration (Gore 1985, Maurizi and Poillon 1992, Turner 1987). The longterm objectives can be defined in three ways: as endpoints or points in time; as plan predictions; and as monitoring parameters expressed as standards required for assessing the success of predictions. The key question to be answered when forming these objectives is: What is the desired recovery or developmental stage in the ecosystem that meets your objectives?

To address many of the issues and challenges facing the long-term monitoring of ecosystems and to meet the objectives of restoration plans, we recommend that procedures to detect long-term recovery phases of altered and restored ecosystems should be simple. Most conventional sampling design and statistical methods require various levels of resolution of data and complex analytical approaches that can be difficult to apply to large ecosystem-monitoring programs. Wissmar (in press) discusses a simple procedure for detecting recovery phases in stream ecosystems. In response to land-use disturbances such as logging, stream ecosystems exhibit various stable and degrading phases. Additional research is needed to detect these different phases and to forecast recovery times.

Monitoring parameters and thresholds—Long-term monitoring procedures should give consideration to the scale of the program. Stream and riparian restoration programs have different monitoring requirements than do smaller site-specific projects. Ecosystem-scale programs require monitoring procedures and parameters capable of assessing the influences of natural and human-induced disturbances and land-water interactions that play important roles in causing cumulative effects. These procedures should have parameters with reliable and robust qualities suitable for accurately recording changes in natural conditions of ecosystems and capable of providing variability statements. These parameter qualities are required to improve the application of management standards to dynamic ecosystems.

Management organizations commonly apply standards in terms of desired threshold concepts with undefined limits of acceptability. The use of thresholds is questionable when they do not take into account the natural variability of an ecosystem. A more meaningful procedure is to apply standards that define the limits of acceptable and unacceptable conditions within the spatial and temporal variabilities inherent in dynamic ecosystems (Wissmar, in press). We suggest that a useful and simple definition of the variability of a standard involves the confidence interval (C.I.) of a sample mean. The sample mean and confidence intervals can be obtained through analysis of ecosystem monitoring records. The use of these statistics can bring greater certainty to decision processes.

The definition of the confidence intervals (C.I.) of a sample mean can be demonstrated through analysis of monitoring data for large woody debris in stream channels. In the Pacific Northwest, large woody debris is critical to the structure and function of stream and riparian habitats (Bilby and Ward 1989, Carlson and others 1990). Both the retention and mobility of large woody debris within stream ecosystems can alter flow patterns that create pools and other habitat types by influencing sediment storage and transport, streambank stabilities, and associated fluvial-geomorphic conditions. The recruitment of large wood to stream channels depends on riparian forest-stand characteristics, hillslope gradients and other landform characteristics, and the frequency of natural disturbance events (Wissmar and Swanson 1990).

For large woody debris, an important objective for the analysis of monitoring data can be the development of a standard applicable to stream-channel reaches throughout a watershed (Bilby and Wasserman 1989). This standard can be expressed as the amounts and distributions of different sizes of large woody debris stratified by channel-width categories for upstream and downstream reaches of a stream. The first step is to calculate the sample mean for large woody debris for each of the width categories of a reach. The next step provides the confidence intervals of sample means. At this stage, a decision can be made about the desired level of significance—for example, 10 percent or $p = 0.1$. This probability level can be used to evaluate whether the mean of a large woody debris population lies between the confidence intervals. If so, only 1 chance in 10 may exist that the large woody debris value and the related decision are mismatched.

We recommend that applying confidence intervals as variability statements to managing ecosystems is most useful when the confidence intervals for the mean of a standard represent natural baseline conditions of unmanaged ecosystems, such as large woody debris in streams in wilderness areas. Confidence intervals for natural variations can be compared to large woody debris values from altered stream ecosystems. Values falling outside the confidence interval can be denoted as exceeding the means expected for natural baseline conditions. Extreme deviations that can be attributed to conditions caused by both natural and unnatural disturbances can also receive attention.

Multiple standards and landscape considerations—The evaluation and validation of standard variability should also consider the possible use of multiple standards for identifying and forecasting ecosystem conditions (Wissmar, in press). But multiple standards, like large woody debris densities, stream substrate compositions, and soil stabilities vary according to their spatial positions in landscapes. Thus, applying these standards must consider the entire landscape, including watershed, stream, and riparian ecosystems. Examples of considerations for stream ecosystems include changes in scale of stream-channel widths and gradients, as well as changes in entrenchment and sinuosity relative to larger spatial features like geomorphic deposits, valley landforms, watershed reliefs, and drainage density.

Multiple standards make possible the assessment of potential degradation in environmental conditions caused by both natural and management-induced disturbances. Potential for degradation can be identified when several standards simultaneously approach or fall outside the confidence intervals for their respective means. If the confidence intervals are exceeded for different standards of a stream, an ecosystem may be very sensitive to disturbances.

The use of different standards to identify sensitive ecosystems should be an asset in future management activities in landscapes with different management histories and from different geologic, hydrologic, and climatic regions. In such circumstances, monitoring records of management practices and changing natural conditions should provide information feedback useful in future planning so as to avoid sensitive areas in ecosystems. Sensitive areas of stream and riparian ecosystems can span several spatial scales in a watershed. The largest sensitive areas might include stream reaches whose geomorphic conditions are susceptible to potential cumulative effects resulting from land-use practices. Smaller landscape units can include stream habitats that are sensitive in terms of an animal's life-history requirements, for example, fish spawning and rearing habitats.

Institutional considerations—The Forest Service as a management organization historically has favored developing long-term monitoring programs for forest, stream, and riparian ecosystems. The Forest Service has the longest history of land-use planning of any government agency. The initial legal basis was laid by the Organic Act of 1897, which gave the Forest Service a wide management window to plan for improving and protecting National Forests for "securing favorable conditions of water flow, and to furnish a continuous supply of timber." The requirement for continuous supplies of resources implies the need for sustained monitoring activities with the objective of better management and conservation.

The National Forest Management Act of 1976 (NFMA) presents a strong precedent for developing longterm programs for both stream and terrestrial ecosystems. The Act requires comprehensive Forest Plans for each of the 154 National Forests, thereby focusing Forest Service management. The NFMA requires several planning documents. As required by NFMA, most attributes of a Forest Plan can be implemented and improved by developing long-term monitoring programs. With continuous evaluations of objectives and their refinements through iterative amendment processes, this objective can be accomplished.

In the Pacific Northwest, examples of Forest Service implementation plans that attempt to address the needs of stream monitoring programs can be found in *Steps of the Journey: Forest Plan Implementation Strategy* (U.S. Department of Agriculture, Region 6, 1990) and the *Columbia River Basin Anadromous Fish Habitat Management Policy Implementation Guide* (U.S. Department of Agriculture, Regions 1, 4, 6, 1991). A summary of the types of information needed to implement such plans can be found in Meehan (1991). This publication presents a 10-step Forest Service planning procedure for streams in forest and rangeland ecosystems in addition to reviewing other U.S. Federal agency planning processes (Brouha 1991).

Other complementary information includes a review of changes in salmonid habitat over 50 years in eastern Washington and Oregon (McIntosh and others 1993) and the USDA Forest Service PACFISH Strategy (in press). Many of the concepts being incorporated into the PACFISH Strategy were developed in the Upper Grande Ronde River Anadromous Fish Habitat Protection, Restoration, and Monitoring Plan (Anderson 1992). Other groups developing plans for restoring and maintaining salmonid populations in the Columbia River include The University Task Force (1992), The Pacific Rivers Council, Inc. (1993) and related resource projects of the American Fisheries Society and the Wilderness Society, and the timber industry (for example, the Oregon Forest Industry Council). Additional recent sources of river-basin information include the Washington Department of Fisheries ongoing revisions of inventories of salmon and steelhead stocks, Wild and Scenic River management issues (Wissmar and others, in press), and the National Research Council reports on natural-resource restoration and conservation (for example, National Research Council 1990, 1992a, 1992b). Some very useful insights about ecosystem restoration can be obtained by reviewing How To Restore Our Trout Streams, by J.S. Van Cleef (1885).

REFERENCES

Anonymous. 1930. Report to the Secretary of Agriculture on inquiry into the condition of watersheds in the Wenatchee National Forest. 33 p. On file with: Wenatchee National Forest, Wenatchee, WA.

Adams, R.M.; Klingeman, P.C.; Li, H.W. 1990. A bioeconomic analysis of water allocations and fish habitat enhancements, John Day Basin, Oregon. [Location of publisher unknown]: [Publisher unknown]; completion report, U.S.G.S. Grant Number 14-68-0001-61479. 168 p.

Alt, D.D.; Hyndman, D.W. 1984. Roadside geology of Washington. Missoula, MT: Mountain Press Publishing Co.

Anderson, J.W. 1992. Upper Grande Ronde River anadromous fish habitat protection, restoration and monitoring plan. [Location of publisher unknown]: Upper Grande Ronde Tech. Working Group. 24 p.

Baker, V.R. 1977. Stream-channel response to floods, with example from central Texas. Geological Society of America Bulletin. 88: 1057-1071.

Baker, V.R.; Greeley, R.; Komar, P.D. [and others]. 1987. Columbia and Snake River plains, In: Graf, W.L. ed. Geomorphic systems of North America. Centennial Spec. Vol. 2. [Location of publisher unknown]: Geological Society of America: 403-468.

Baker, V.R.; Kochel, R.C.; Patton, P.C. eds. 1988. Flood geomorphology, New York: John Wiley & Sons.

Behnke, R.J.; Raleigh, R.F. 1978. Grazing and the riparian zone: impact and management perspectives. Forum: Interactions between grazing and other riparian/stream ecosystem uses; 1978 November 3-4; Denver, CO. [Location of publisher unknown]: [publisher unknown]: 263-267.

Belt, G.H.; O'Laughlin, J.; Merrill, T. 1992. Design of forest riparian buffer strips for the protection of water quality: analysis of scientific literature. Rep. 8. Moscow, ID: Idaho Forest, Wildlife and Range Policy Analysis Group, University of Idaho. 35 p.

Berman, C.H.; Quinn T.P. 1991. Behavioural thermoregulation and homing by spring Chinook salmon, *Oncorhynchus tshawytscha* (Walbaum) in the Yakima River. Journal of Fish Biology. 39: 301-312.

Beschta, R.L.; Platts, W.S. 1986. Morphology features of small streams: significance and function. Water Resources Bulletin 22(3): 369-379.

Beschta, R.L.; Platts, W.S.; Kauffman, J.B. 1991. Field review of fish habitat improvement projects in the Grande Ronde and John Day river basins of eastern Oregon. BPA report; project Nl. 91-069. Portland, OR, Bonneville Power Administration, Division of Fish and Wildlife-PJ.

Bidgood, B.F.; Berst, A.H. 1969. Lethal temperatures for Great Lakes rainbow trout. Journal of the Fisheries Research Board of Canada, 26: 456-459.

Bilby, R.E.; Ward, J.W. 1989. Changes in characteristics and function of woody debris with increasing size in streams in western Washington. Transactions of the American Fisheries Society. 118: 368-378.

Bilby, R.E.; Wasserman, L.J. 1989. Forest practices and riparian management in Washington State: data based regulation development. In: Gresswell, R.E., Barton, B.A., Kershner, J.L., eds. Practical approaches to riparian resource management. Billings, MT: U.S. Department of the Interior, Bureau of Land Management: 87-94.

Binns, N.A.; Eisermann, F.M. 1972. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society. 108: 215-228.

Bjorn, T.C.; Reiser, D.W. 1991. Habitat requirements of salmonids in streams. In: Meehan, W.M. ed. Influences of forests and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication. 19: 83-138.

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Pap. 12. FWS/OBS-82/26. Fort Collins, CO: U.S. Fish and Wildlife Service.

Brouha, P. 1991. Fish habitat planning. In: Meehan,W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication. 19: 587-597.

Caldwell, B.; Catterson, D. 1992. Methow River basin fish habitat analysis using the instream flow incremental methodology. Pub. 92-82. Olympia, WA: Washington State Department of Ecology, Water Resources Program.

Carling, P.A. 1987. Bed stability in gravel streams, with reference to stream regulation and ecology. In: Richards, K. ed. River channels: environment and process. New York: Basil Blackwell Inc.: 321-347.

Carlson, J.Y.; Andrus, C.W.; Froelich, H.A. 1990. Woody debris, channel features, and macroinvertebrates of streams with logged and undisturbed riparian timber in northeastern Oregon, USA. Canada Journal of Fisheries and Aquatic Sciences. 47: 1103-1111.

Carter, Susan. 1990. A history of livestock grazing on the Wenatchee National Forest. Unpublished report. On file with: Supervisors Office, Wenatchee National Forest, Wenatchee, WA.

Chapman, D.W. 1988. Critical review of variables used to define effects of fine in redds of large salmonids. Transactions of the American Fisheries Society. 115: 662-670.

Chatters, J.C.; Neitzel, D.A.; Scott, M.J.; Shankle, S.A. 1991. Potential impacts of global climate change on Pacific Northwest spring Chinook salmon (*Oncorhynchus tshawytscha*): an exploratory case study. Northwest Environmental journal. 7: 71-92.

Clark, R.N.; Gibbons, D.R. 1991. Recreation. In: Meehan, W.M., ed. Influences of forests and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication. 19: 459-481.

Cooperative Western Range Study. 1938. An analysis of range problems in Kittitas County, WA and a plan for their solutions. [Location of publisher unknown]: [Publisher unknown].

Corner, R.A. 1992. Effect of clearcutting and mechanical scarification on stream sedimentation in small mountain watersheds of northeast Washington. Pullman, WA: Washington State University: 71 p. M.S. thesis.

Davidson, F.A. 1953. Historical notes on development of Yakima River Basin. Ellensburg, WA. [Publisher unknown].

DeBano, L:F.; Grant, G.E.; Stokes, G.; Schmidt, L.J. 1990. Wildland riparian areas: vital areas in need of expanded research emphasis: issue paper. In: National watershed and aquatic workshop; 1990 March; Fort Bragg, CA. [Location of publisher unknown]: [Publisher unknown].

Dicken, S.N.; Dicken, E.F. 1979. The making of Oregon: a study in historical geography. Portland, OR: Oregon Historical Society, 208 p.

Dunne, T.; Leopold, L.B. 1978. Water in environmental planning. New York: W.H. Freeman and Co., 818 p.

Edson, S.A. 1990. Spring Chinook spawning ground surveys of the Methow River basin. Toppenish, WA: Yakima Indian Nation, Fisheries Resource Management.

Ehinger, W. 1990. Personal Communication. U.S. Department of Agriculture, Wenatchee National Forest. Wenatchee, WA.

Ehinger, W. 1990. Little Naches River stream survey project report, Naches Ranger District, Wenatchee National Forest. [Location of publisher unknown]: [Publisher unknown].

Elmore, W. 1988. Rangeland riparian systems. In: California riparian systems conference proceedings; [dates of meeting unknown]; [location of meeting unknown]. Gen. Tech. Rep. PSW-110. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 93-95.

Elmore, W. 1992. Riparian responses to grazing practices. In: Naiman, R.J., ed. Watershed management: balancing sustainability and environmental change. New York: Springer-Verlag: 442-457.

Elmore, W.; Beschta, R.L. 1987. Riparian areas: perceptions in management. Rangelands. 9(6): 260-265.

ERDA, 1979. Final environmental statement, waste management operation, Hanford Reservation. ERDA1538. Richland, WA: [publisher unknown].

Etnier, D.A. 1972. The effect of annual rechanneling on a stream fish population. Transactions of the American Fisheries Society. 101: 372-375.

Everest, F.H.; Beschta, R.L.; Scrivener, J.C.; [and others]. 1987. Fine sediment and salmonid production: a paradox. In: Salo, E.O.; Cundy, T.W., eds. Streamside management: forestry and fishery interactions: Proceedings of a symposium; [dates of meeting unknown]: [location of meeting unknown]. Seattle, WA. University of Washington Institute of Forest Resources: 98-142.

Fast, D.; Hubble, J.; Kohn, M.; Watson, B. 1991. Yakima River spring Chinook enhancement study. [Location of publisher unknown]: [Publisher unknown]; final report to Bonneville Power Administrution.

Foster, G.R. comp. 1987. User requirements: USDA-water erosion prediction project (WEPP). NSERL Rep. 1. W. Lafayette, IN: National Soil Erosion Research Laboratory. U.S. Department of Agriculture, Agricultural Research Service. 430 p.

Furniss, M.J.; Roelofs, T.D.; Yee, C.S. 1991. Road construction and maintenance. In: Meehan, W.M., ed. Influences of forests and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication. 19: 297-323.

Garrigues, B. Personal Communication. U.S. Department of Agriculture, Wenatchee National Forest, Wenatchee, WA.

GeoEngineers. 1990. Report of phase 3 hydrologic services, proposed spring Chinook satellite facility, Winthrop, Washington. [Location of publisher unknown]: [Publihser unknown]; prepared for the Douglas County Public Utility District.

Golder Associates. 1991. Ground-water modeling of the upper Methow valley: a report to the early Winters Resort Project. 893-1169.001. [Location of publisher unknown]: Golder Associates. 26 p.

Gore, J.A. 1985 (ed.). The restoration of rivers and streams: theories and experience. Boston: Butterworth Publishers. 280 p.

Gossett, G. 1979. Beyond the bend: a history of the Nile Valley in Washington State. Fairfield, WA: Ye Gallon Press.

Graf, W.L. 1983. Flood related channel changes in an arid region river. Earth Surf. Proc. Landsc., 8: 125-139.

Grant, G.E. 1987. Assessing effects of peak flow increases on stream channels: a conditional approach. In: Proceedings, California watershed management conference; 1986 November 18-20, West Sacramento, CA. [Location of publisher unknown]: [Publisher unknown]. 142-149.

Government Accounting Office. 1988. Range land management. GAO/RCED-88-80. Washington, DC.

Gregory, S.V.; Lamberti, G.A.; Moore, K.S. 1989: Influence of valley landforms on stream ecosystems. In Proceedings of the California riparian systems conference: protection, management, and restoration for the 1990; 1988 September 22-24; Davis, CA. Gen. Tech. Rep. PSW-110. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture: 3-8.

Gregory, S.; Ashkenas, L. 1990. Riparian management guide: Willamette National Forest. [Location of publisher unknown]: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Gregory, S.V.; Swanson, F.J.; McKee, W.A.; Cummins, K.W. 1991. An ecosystem perspective of riparian zones. BioScience. 41(8): 540-550.

Grier, C.C. 1975. Wildfire effects on nutrient distribution and leaching in a coniferous ecosystem. Canadian Journal of Forest Research. 5: 599- 607.

Hack, J.T.; Goodlet, J,C. 1960. Geomorphology and forest ecology of a mountain region in the central Appalachians. Geological Survey Professional Paper 347: 1-66.

Halverson, H.G.; Smith, J.L. 1974. Controlling solar light and heat in a forest by managing shadow sources. Res. Pap. PSW-102. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Experiment Station. 14 p.

Hanson, M.L. 1987. Riparian zones in eastern Oregon. Portland, OR: Oregon Environmental Council. 74 p.

Harr, R.D. 1979. Effects of timber harvest on streamflow in the rain-dominated portion of the Pacific Northwest. In: Proceedings, Workshop on scheduling timber harvest for hydrologic concerns; 1979 November 17-19; Portland, OR. U.S. Deptartment of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, 45 p.

Harr, R.D. 1980. Streamflow after patch logging in small drainages within the Bull Run Municipal Watershed, Oregon. Res. Pap. PNW-268. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 16 p.

Harr, R.D. 1983. Potential for augmenting water yield through forest practices in western Washington and western Oregon. Water Resources Bulletin. 19(3): 383-393.

Harr, R.D. 1987. Myths and misconceptions about forest hydrologic systems and cumulative effects. In: Proceedings, California watershed management conference; 1986 November 18-20, West Sacramento, CA. [Location of publisher unknown]: [Publisher unknown].

Harr, R.D.; Fredricksen, R.L.; Rothacher, J. 1979. Changes in streamflow following timber harvest in southwestern Oregon. Res. Pap. PNW-249. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 22 p.

Harr, R.D.; Harper, W.C.; Krygier, J.T.; Hsieh, F.S. 1975. Changes in storm hydrographs after road building and clear-cutting in the Oregon Coast Range. Water Resource Research. 11: 436-444.

Hartman, G.F.; Scrivener, J.C. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fish and Aquatic Sciences. [volume unknown]: 223.

Harvey, A.M. 1987. Sediment supply to upland streams: influence on channel adjustment. In: Thorne, C.R.; Bathurst, J.C.; Hey, R.D., eds. Sediment transport in gravel-bed rivers. New York: John Wiley and Sons Ltd.

Helvey, J.D. 1980. Effects of a north central Washington wildfire on runoff and sediment production. Water Resource Board, American Water Resource Association. 16(4): 627-634.

Hibbert, A.R. 1976. Percolation and streamflows in range and forest lands. In: Heady, H.F.; Falkenborg, DJ.; Riley, J.P., eds. Proceedings, 5th workshop on watershed management on range and forest lands; [Dates of meeting unknown]: [Location of meeting unknown]: Logan, UT: United StatesAustralian Rangelands Panel, Utah State University, Utah Research Laboratory. 61-72.

Highsmith, R.M.; Kimerling, J.K. eds. 1979. Atlas of the Pacific Northwest. 6th ed. Corvallis, OR: Oregon State University Press. 135 p.

Hildebrand, S.G.; Barnhouse, L.W.; Suter, G.W. 1987. The role of basic ecological knowledge in environmental assessment. In: Daggan, S.; Cohrssen, J.J.; Morrison, R.E., eds. Preserving ecological systems: the agenda for long-term research and development. New York: Praeger: 51-69

Hodges, L.K. 1897. Mining in the Pacific Northwest. Seattle WA: Seattle Post-Intelligencer.

Holstine, C.E. 1987. Forgotten corner: a history of the Colville National Forest, Washington. Colville, WA: Colville Statesman-Examiner, Inc. 133 p.

Holtze, K.E.; Hutchinson, NJ. 1989. Lethality of low pH and Al to early life stages of six fish species inhabiting precambrian shield waters in Ontario. Canadian Journal of Fisheries and Aquatic Sciences. 46: 1188-1202.

Horton, R.E. 1945. Erosional development of streams and their drainage basins: hydrological approach to quantitative morphology. Geologic Society of America Bulletin. 565: 272-370.

Hormay, A.L. 1970. Principles of rest-rotation grazing and multiple-use land management. Training Text 4(2200). Washington, DC: U.S. Department of Agriculture, Forest Service.

Hudson Bay Society Record. 1950. Peter Skene Ogden’s Snake Country journals, 1824-25 and 1825-26. London: Publications of the Hudson’s Bay Record Society.

Hughes, R.M.; Whittier, T.R.; Rohm, C.M. 1990. A regional framework for establishing recovery criteria. Environmental Management. 14 (5): 673-683.

James, G. 1984. Grande Ronde River Basin: recommended salmon and steelhead habitat improvement measures. Pendleton, OR: Confederated Tribe of the Umatilla Indian Reservation. 59 p.

Kauffman, J.B. Personal communication. Department of Rangeland Resources, Oregon State University, Corvallis, OR.

Kauffman, J.B. 1988. The status of riparian habitats in Pacific Northwest forests. In: Raedeke, K.J. ed. Streamside management: riparian wildlife and forestry interactions. Contrib. 59. Seattle, WA: University of Washington Institute of Forest Resources: 45-55.

Kauffman, J.B.; Krueger, W.C. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management, 37: 430-437.

Kerr, H.J. 1931. A history of the town of Okanogan. Okanogan, WA: Okanogan Independent. 112 p.

King, J.G. 1989. Streamflow responses to road building and harvesting: a comparison with the equivalent clearcut area procedure. Res. Pap. INT-401. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, 13 p.

Klock, G.O.; Helvey, J.D. 1976. Soil-water trends following wildfire on the Entiat Experimental Forest. Proceedings, Tall Timbers Fire Ecology Conference. 15: 193-200.

Klock, G.O. 1985. Modeling the cumulative effects of forest practices on downstream aquatic ecosystems. Journal of Soil and Water Conservation. 40: 237-241.

Knighton. A.D. 1987. River channel adjustment-the downstream dimension. In: Richards, K.. ed., River channel environments and processes. Oxford: Blackwell. 95-128.

Kohn, M.S. 1987. Spring and summer Chinook spawning ground surveys, Methow and Okanogan River basins. Toppenish, WA: Yakima Indian Nation, Fisheries Resource Management.

Kohn, M.S. 1988. Spring and summer Chinook spawning ground surveys, Wenatchee, Methow and Okanogan River basins. Toppenish, WA: Yakima Indian Nation, Fisheries Resource Management.

Kohn, M.S. 1989. Spring and summer Chinook spawning ground surveys, Methow and Okanogan River basins. Toppenish, WA: Yakima Indian Nation, Fisheries Resource Management.

Kolvalchik, B.L. 1987. Riparian zone associations of the Deschutes, Ochoco, Fremont and Winema National Forests. R6 ECOL TP-297-87. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 171 p.

Kovalchik, B.L.; Elmore, W. [in press]. The effects of cattle grazing systems on willow-dominated plant associations in central Oregon. In: Symposium on ecology and management of riparian shrub communities; 1991 May 19-21; Sun Valley, ID. [Location of publisher unknown]: [Publisher unknown].

Lamberti, G.A.; Gregory, S.V.; Ashkenas, L.R. [and others]. 1989. Influence of channel morphology on retention of dissolved and particulate matter in a Cascade mountain stream. In: Proceedings of the California riparian systems conference: protection, management, and restoration for the 1990s; 1988 Sept. 22-24; Davis, CA. Gen. Tech. Rep. PSW-110. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, U.S.D.A. Forest Service: 256-261

Langness, O.P. 1991. Summer Chinook salmon spawning ground surveys of the Methow and Okanogan River basins in 1990. Nespelem, WA: Confederated Tribes of the Colville Reservation, Fish and Wildlife Department.

Leonard, S.G.; Staidl, G.J.; Gebhardt, K.A.; Prichard, D.E. 1992. Viewpoint: range site/ecological site information requirements for classification of riverine riparian ecosystems. Journal of Range Management. 45: 431- 435.

Li, H.W.; Pearsons, T.N.; Tait, C.K. [and others]. 1992. Approaches to evaluate habitat improvement programs in streams of the John Day Basin. [Location of publisher unknown]: [Publisher unknown]; completion report to the Oregon Department of Fish and Wildlife; project F-147-R2. 167 p.

Li, H.W.; Lamberti, G.A.; Pearsons, T.N. [and others]. [In press]. Cumulative effect of riparian disturbances on high desert trout streams of the John Day basin. Transactions of the American Fisheries Society.

Lisle, T.E. 1982. Effects of aggradation and degradation on riffle-pool morphology in natural gravel channels, northwestern California. Water Resources Research. 18(6): 1643-1651.

Lisle, T.E. 1986. Stabilization of a gravel channel by large streamside obstructions and bedrock bends, Jacoby Creek, northwestern, California. Geological Society of America Bulletin. 87: 999-1011.

MacDonald, L.; Smart, A.; Wissmar, R.C. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. EPA/910/9-91-001. Ann Arbor, MI: Edwards Brothers Press. 166 p.

Mack, R.N.; Thompson, J.N. 1982. Evolution in steppe with few large, hooved mammals. American Naturalist. 119: 757-773.

Maloney, S.B.; Higgins, D.A.; Marx, D.B. [and others]. [In press]. Stream temperatures in grazed forested watersheds of eastern Oregon. Journal of Environmental Quality.

Maurizi, S.; Poillon, F. (eds). [n. d.]. Restoration of aquatic ecosystems: science, technology and public policy. Washington, DC: National Academy Press. 552 p.

McIntosh, B.A. 1992. Historical changes in anadromous fish habitat in the Upper Grande Ronde River, Oregon, 1941-1990. Corvallis, OR: Oregon State University. 88 p. M. S. thesis.

Meehan, W.R. ed. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication. 19. 751 p.

Meekin, T. 1991. Spring Chinook spawning ground surveys, Methow and Okanogan River basins. Toppenish, WA: Yakima Indian Nation, Fisheries Resource Management.

Melone, A.M. 1985. Flood producing mechanisms in coastal British Columbia. Canadian Water Resources journal. 10: 46-64.

Milhous, R.T.; Sorlie, G.; Richardson, D. 1976. The water resources of the Methow basin. Office Rep. 56. Olympia, WA: Department of Ecology.

Milhous, R.T.; Updike, M.A.; Schneider, D.M. 1989. Physical habitat simulation system reference manual: version II. Instream Flow Info. Pap. 26. Fort Collins, CO: U.S. Fish and Wildlife Service.

Miller, A.J. 1990. Flood hydrology and geomorphic effectiveness in the central Appalachians. Earth Surf. Proc. and Landforms. 15: 119-134.

Milner, NJ.; Scullion, J.; Caning, P.A.; Crisp, D.T. 1981. The effects of discharge on sediment dynamics and consequent effects on invertebrates and salmonids in upland rivers. Advanced Application Biology. 6: 153-220.

Mineral and Water Resources of Washington, State of Washington, 1966. Rep. 9. Olympia, WA: Division of Mines and Geology.

Minshall, G.W.; Jensen, S.E.; Platt, W.S. 1989. The ecology of stream and riparian habitats of the Great Basin region: a community profile. Biol. Rep. 85(7.24). [Location of publisher unknown]: U.S. Fish and Wildlife Service. 142 p.

Moore, K.M.; Gregory, S.V. 1988. Response of young-of-the-year cutthroat trout to manipulation of habitat structure in a small stream. Transactions of American Fisheries Society 117: 162-170.

Moore, K.S. and S.V. Gregory. 1989. Geomorphic and riparian influences on the distribution and abundance of salmonids in a Cascade mountain stream. In: Proceedings of the California riparian systems conference: protection, management, and restoration for the 1990s, 1988 Sept. 22-24; Davis, CA. Gen. Tech. Rep. PSW-110, Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 256-261.

Mullan, J.W.; Williams, K.R.; Rhodus, G. [and others]. 1992. Production and habitat of salmonids in midColumbia River tributary streams. Monogr. I. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 489 p.

National Council of the Paper Industry for Air and Stream Improvement Inc. 1992. Status of the NCASI cumulative watershed effects program and methodology, Tech. Bull. 634. New York: 23 p.

National Research Council. 1990. Forestry research: a mandate for change. Washington DC: National Academy Press, 84 p.

National Research Council. 1992b. Water transfers in the west: efficiency, equity and the environment. National Academy Press. Washington DC. 300 p.

National Research Council. 1992a. Restoration of aquatic ecosystems. Washington DC: National Academy Press. 84 p.

Neitzel, D.A.; Scott, M.J.; Shankle, S.A.; Chatters, J.C. 1991. The effect of climate change on stream environments: the salmonid resource of the Columbia River basin. Northwest Environmental journal. 7: 271-293.

Nelson, R.L.; McHenry, M.L.; Platts, W.S. 1991. Mining. In: Meehan, W.M. ed. Influences of forests and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication: 425-457.

Northwest Power Planning Council Staff. 1986. Compilation of information on salmon and steelhead losses in the Columbia River. Portland, OR: Columbia River Basin Fish and Wildlife Program, Northwest Power Planning Council. Appendix D.

Northwest Power Planning Council. 1989. John Day River subbasin salmon and steelhead production plan. Portland, OR: Columbia Basin System Planning, Northwest Power Planning Council; Agencies and Indian Tribes of the Columbia Basin Fish and Wildlife Authority.

Northwest Power Planning Council. 1990. Grande Ronde River subbasin salmon and steelhead production plan. Portland, OR. 129 p. [Draft report].

Norris, L.A., Lorz, H.W., Gregory, S.V. 1991. Forest chemicals. In: Meehan, W.M., ed. Influences of forests and rangeland management on salmonid fishes and their habitats. 83-138. American Fisheries Society Special Publication: 207-296.

Okanogan National Forest. 1990. Draft supplement to the final environmental impact statement: early winters alpine winter sports study. Okanogan, WA: U.S. Department of Agriculture, Forest Service, Okanogan National Forest.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers. 77: 118-125.

Oregon Department of Fish and Wildlife. 1987. Grande Ronde River basin fish habitat improvement plan. Portland, OR. 29 p.

Oregon Department of Forestry. 1985. Oregon timber harvest report. Salem, OR.

Oregon Department of Forestry. 1990. Oregon timber harvest report. Salem, OR.

Osborn, G., Luckman, B.H. 1988. Holocene glacier fluctuations in the Canadian Cordillera (Alberta and British Columbia). Quaternary Science Reviews. 7: 115-128.

Oregon Water Resources Department. 1986. John Day River basin report, Oregon Water Resources Department (OWRD), Salem OR.

Parker, R.S. 1977. Experimental study of drainage basin evolution and its hydrologic implications, Hydrol. Pap., 90. Fort Collins, CO. Colorado State University.

Parkhurst, Z.E. 1950. Survey of the Columbia River and its tributaries, part 6, area V: Snake River from the moutlY'through the Grande Ronde River. Spec. Sci. Rep., Fish. 39. [Location of publisher unknown]: U.S. Fish Wildlife Service. 58 p.

Patton, P.C. 19$8 drainage basin morphology and floods. In: Baker, V.R., Kochel, R.C., Patton, P.C. eds. Flood geomorphology. New York: John Wiley & Sons.

Pauley, G.B.; Thomas, G.L.; Marino, D.A.; Weigand, D.C. 1989. Evaluation of the effects of gravel bar scalping on Juvenile salmonids in the Puyallup River drainage. Seattle, WA: University of Washington; final report to Washington Department of Fisheries: contract 1620.

Pearsons, T.N.;Li, H.W.; Lamberti, G.A. 1992. Influence of habitat complexity on resistance to flooding and resilience of stream fish assemblages. Transactions of the American Fisheries Society. 121: 427-436.

Peterson, N.P.; Hendry, A.; Quinn, T.P. 1992. Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions. TFW-F3-92-001. Seattle, WA: Center for Streamside Studies, University of Washington. 75 p.

Pfankuch, D.J. 1975. Stream reach inventory and channel stability evaluation. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 25 p.

Pierce, Lt. H.H. 1982. Report of an expedition from Fort Colville to Puget Sound, Washington Territory, by way of Lake Chelan and Skagit River during the months of August and September 1982. [Location of publisher unknown]: U.S. Government Printing Office.

Planas, D.; Lapierre, L. 1989. Structural organization and species composition of a lotic periphyton community in response to experimental acidification. Canadian Journal of Fisheries and Aquatic Sciences. 46: 827-835.

Platts, W.S. 1981. Sheep and cattle grazing strategies on riparian-stream environments. In: Proceedings, wildlife-livestock relationships symposium; [Dates of meeting unknown]: [Location of meeting unknown]. Moscow, ID: University of Idaho, Forest, Wildlife and Range Experiment Station: 251-270.

Platts, W.S. 1991. Livestock grazing. In: Meehan, W.M., ed. Influences of forests and rangeland management on salmonid fishes and their habitats. 83-138. American Fisheries Society Special Publication: 389-423.

Platts, W.S. [and others]. 1983. Methods for evaluating stream, riparian and biotic conditions. Gen. Tech. Rep. INT-138. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Plummer, F. 1900. Mount Rainier Forest Reserve, Washington. Part V: Forest reserves. 21st Ann. Rep. [Location of publisher unknown]: U.S. Geological Survey.

The Pacific Rivers Council, Inc. 1993. Watershed and salmon habitat restoration in the Pacific Northwest: rationale and framework for legislation. Eugene, OR.

Quigley, T.M.; Dillard, D.S.; Reese, J.B. [and others]. 1989. New criteria for measuring range management activities. Gen. Tech. Rep. PNW-GTR-248, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 27 p.

Rich, W.H. 1948. A survey of the Columbia River and its tributaries with special reference to the management of its fishery resources. Special Scientific Report 51. [Location of publisher unknown]: U.S. Fish Wildlife Service. 25 p.

Rivier, B.; Sequier, J. 1985. Physical and biological effects of gravel extraction in river beds. In: Alabaster, J.S. ed. Habitat modification and freshwater fisheries. London: Butterworths: 131-146.

Rosgen, D.L. 1985. A stream classification system. Gen. Tech. Rep. RM-120. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 25 p.

R.W. Beck Associates. 1973. Flood plain information Methow River: Mazma to Twisp, Okanogan Co., WA. Olympia, WA: State of Washington Department of Ecology. 14 p.

Salo, E.O.; Cundy, T.W. 1987. Streamside management: forestry and fishery interactions. Contr. 57. Seattle, WA: Institute of Forest Resources, University of Washington. 471 p.

Schumm, S.A. 1985. Patterns of alluvial rivers. American Review of the Earth Planetary Sciences. 13: 5-27.

Sedell, J.R. Personal Conversation. U.S. Deptartment of Agriculture, Forest Service, Pacific Northwest Research Station, Corvallis Forestry Sciences Laboratory, Corvallis, OR.

Sedell, J.R.; Everest, F.H. 1990. Historic changes in habitat for Columbia River basin salmon under study for TES listing. Corvallis, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. [Draft report].

Sedell, J.R.; Reeves, G.H.; Hauer, F.R. [and others]. 1990. Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. Environmental Management. 14: 711-724.

Sedell, J.R.; Beschta, R.L. 1991. Bringing back the "bio" in bioengineering. American Fisheries Society Symposium. 10: 160-175.

Sidle, R.C.; Pearce, A.D.; O'Loughlin, C.L. 1985. Hillslope stability and land use. Washington, DC: American Geophysics Union. 140 pp.

Simon, A.; Hupp, C.R. 1987. Geomorphic and vegetative recovery processes along modified Tennessee streams: an interdisciplinary approach to disturbed fluvial systems: Proceedings of the Vancouver, Aqut, [Dates of meeting unknown]: [Location of meeting unknown] IAHS-AISH Publ. 167. [Location of publisher unknown]: [Publisher unknown]. 251-272.

Slaughter, C.W.; Aldrich, J.W. 1989. Annotated bibliography on soil erosion and erosion control in subarctic and high-latitude regions of North America. Gen. Tech. Rep. PNW-GTR-253. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 234 p.

Smith, J.E. [In press]. Retrospective analysis of changes in stream and riparian habitat characteristics between 1935 and 1990 in two eastern Cascade streams. Seattle, WA: University of Washington. M.S. thesis.

Soil Conservation Service. 1985. Oregon's soil: a resource condition report. Portland, OR: 26 p.

Spotts, J. Personal Communication. U.S. Deptartment of Agriculture, Forest Service, Okanogan National Forest, Okanogan, WA.

Stanford, J.A.; Ward, J.V. 1988. The hyporheic habitat of river ecosystems. Nature. 335: 64-66.

State of Washington, Bureau of Statistics. 1905. Its resources, natural, industrial and commercial. [Location of publisher unknown]: [Publisher unknown]. [Reprinted in the Heritage, Fall 1982].

Steele, Richard, F. 1904. History of north Washington: Stevens, Ferry, Okanogan and Chelan Counties. Spokane, WA: Western Historical Publication Co. 867 p.

Stoots, R. Personal Communication. Bonneville Power Administration.

Swanson, F.J. 1986. Comments from a panel discussion at the AGU symposium on cumulative effects, In: Cumulative effects-the UFO's of hydrology. Tech. Bull. 490. New York: National Council of the Paper Industry for Air and Stream Improvement, Inc.: 66-69.

Swanston, D.N. 1991. Natural processes. In: Meehan, W.M., ed. Influences of forests and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication: 139-179.

Tait, C.K.; Li, J.L.; Lamberti, G.A. [and others]. [Manuscript in preparation]. Influences of riparian cover on benthic community structure in high desert streams.

The University Task Force. 1992. Alternative actions for restoring and maintaining salmonid populations on the Columbia River system. PNW 407. [Location of publisher unknown]: [Publisher unknown].

Thomas, M.K. 1977. Mean monthly sea level pressure maps for north and central America. CDS 4-77. [Location of publisher unknown]: Environment Canada.

Tiedmann, A.R.; Conrad, C.E.; Dieterich, J.H. [and others]. 1979. Effects of fire on water resources: National fire effects workshop; 1979 April 10-14; Denver, CO. Gen. Tech. Rep. WO-10. U.S. Department of Agriculture, Forest Service. 29 p.

Tiedmann, A.R.; Higgins, D.A. 1989. Effects of management strategies on water resources. In: Quigley, T.M., Sanderson, H.R., Tiedemann, A.R., eds. Managing interior northwest rangelands: the Oregon range evaluation project. Gen. Tech. Rep. PNW-GTR-238. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 57-100.

Troendle, C.A.; King, R.M. 1987. The effect of partial and clearcutting on streamflow at Deadhorse Creek, Colorado. Journal of Hydrology. 90: 145-157.

Turner, M.G., ed. 1987. Landscape heterogeneity and disturbance. New York: Springer-Verlag. 214 p.

Uebelacker, M. 1980. Land and life in the Naches River basin: a cultural resource overview: report to Wenatchee National Forest. [Location of preparer unknown]: [Preparer unknown].

U.S. Department of Agriculture, Forest Service. 1974. Forest hydrology part II-hydrologic effects of vegetation manipulation. Missoula, MT: U.S. Department of Agriculture, Forest Service. 229 p.

U.S. Department of Agriculture, Forest Service. 1977. A computer model for determining water yield from forest activities. Coeur d' Alene, ID: U.S. Department of Agriculture, Forest Service, Idaho Panhandle National Forests. 36 p.

U.S. Department of Agriculture. 1992. Background report for development of Forest Service management strategy for Pacific salmon and steelhead habitat. Prepared by: Pacific salmon work group and field team. On file with: Forest Service, Washington, DC. 41 p.

U.S. Department of Agriculture, 1992. Background report for development of Forest Service manatement strategy ofr Pacific salmon and steelhead habitat. Prepard by: Pacific salmon work group and field team. On file with: Forest Service, Washington DC. 41p.

Van Cleef, J.S. 1885. How to restore our trout streams. American Fisheries Society. 14: 51-55.

Washington Department of Natural Resources. 1985. Eastern Washington timber harvest by ownership. Olympia, WA.

Washington Department of Wildlife: Yakima Indian Nation: Colville Indian Reservation; Washington Department of Fisheries. 1989. Methow and Okanogan Rivers subbasin salmon and steelhead production plan. Portland, OR: Columbia Basin System Planning, Northwest Power Planning Council.

Wasson, B.; Ragan, R.H.; Bernhardt, B.; Smith, C. 1992. Hydrologic recovery for the Colville National Forest, Colville, WA: U.S. Department of Agriculture, Forest Service, Colville National Forest.

Wenatchee National Forest. 1990. Final environmental impact statement-land and management plan. Wenatchee, WA: U.S. Department of Agriculture, Forest Service, Wenatchee National Forest.

Williams, C.K.; Lillybridge, T.R. 1983. Forested plant associations of the Okanogan National Forest. R6Ecol-132b-1983, [Location of publisher unknown]: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 140 p.

Willms, R.; Kendra, W. 1990. Methow River water quality survey and assessment of compliance with water quality standards. Environmental investigations and laboratory services program. Olympia, WA: Washington Department of Ecology.

Wilson, B.A. 1990. Late frontier: a history of Okanogan County, Washington (1800-1941). Okanogan, WA: Okanogan County Historical Society. 360 p.

Wissmar, R.C.; Swanson, F.J. 1990. Landscape disturbance and lotic ecotones. In: Naiman, R.J.; Decamps, H. eds. Ecology and management of aquatic-terrestrial ecotones, London: Parthenon Press: 65-89.

Wissmar, R.C. [In press]. The need for long-term monitoring in stream ecosystems of the Pacific Northwest. Environmental Assessment and Monitoring.

Wissmar, R.C; Halbert, C.; Chu, J.; Doyle, J. [In press]. Skagit Wild and Scenic River: management status and issues. In: Riparian management common threads and shared interests. Conference proceedings; 1993 Feb. 4-6; Albuquerque NM. Tucson, AZ: Water Resources Research Center, College of Agriculture, University of Arizona.

Woods, D.; Russell, K. 1991. Little Naches River passage project annual report. DOE-BP-602661-1. [Location of publisher unknown]: [Publisher unknown].-85 p.

Wooldridge, D.D. 1972. Forest and water resources of Washington State. Project 3A, Study D. Olympia, WA: Washington State Department of Ecology. 79 p.

Wurtsbaugh, W.A.; Davis, G.E. 1977. Effects of temperature and ration level on growth and food conversion efficiency of Salmo gairdneri Richardson. Journal of Fish Biology. 11: 87-98.

Wydoski, R.S.; Helm, W.T. 1980. Effects of alterations to low gradient reaches of Utah streams; summary. [Location of publisher unknown]: U.S. Department of the Interior, Fish and Wildlife Service; contract 14-16-0008-1141. 13 p.

Ziemer, R.R. 1981. Storm flow response to road building and partial cutting in small streams of northern California, Water Resources Research. 17(4): 907-917.

Zingg, A.W. 1940. Degree and length of land slope as it affects soil loss in runoff. Agricultural Engineering. 21(2): 59-64.

APPENDIX A

Common Name	Scientific Name
Fish	
Brook trout	*Salvelinus fontinalis* Mitchell
Bull trout	*Salvelinus Confluentus*
Chinook	*Oncorhynchus tshawytscha* Walbaum
Coho	*Oncorhynchus kisutch* Walbaum
Cutthroat	*Oncorhynchus clarkii* Richardson
Dace	*Rhinichthys* sp.
Lamprey	Petromyzonidae
Rainbow	*Oncorhynchus mykiss*
Sculpin	Cottidae
Steelhead	*Oncorhynchus mykiss* Richardson
Sucker	Catostomidae
Sunfish	*Lepomis* sp.
Whitefish	*Prosopium Williamsoni* Girard
Insect	
Caddisfly	*Dicosmoecus gilvipes*
Plants	
Aspen	*Populus tremuloides* Mich ex.
Big mountain sagebrush	*Artemisia tridentata vaseyana*
Cottonwood	*Populus trichocarpa* Torr. & Gray
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws.
Poplar	*Populus* spp.
Western juniper	*Juniperus occidentalis* Hook
Willow	*Salix* spp.
Wyoming big sagebrush	*Artemisia tridentata wyomingensis*

GLOSSARY

Allotment (grazing)—Area designated for the use of a prescribed number and kind of livestock under one plan of grazing management.

Alluvial—Deposited by running water.

Aggradation—Deposition in one place of material eroded from another; aggradation raises the bottoms of streambeds, floodplains, and other water bodies.

Anadromous—Moving from the sea to fresh water for reproduction.

Aquifer—A saturated permeable material (often sand, gravel, sandstone, or limestone) that contains or carries groundwater.

Armor layer—Erosion-resistant layer of relatively large particles on the surface of a streambed; such layers typically result from removal of finer particles by erosion

Bankfull width—Channel width between the tops of the most pronounced banks on either side of a stream reach; also, width of stream channel at the normal flood flow.

Base flow—Typical flow for a given stream at a particular time of year.

Basin (drainage area, watershed)—The area of land that drains water, sediment, and dissolved materials to a common point along a stream channel.

Bed load—Sediment moving on or near the streambed.

Canopy cover (of stream)—Vegetation projecting over a stream, including crown cover and overhanging cover species.

Clear-cut—Area from which all trees have been removed by cutting.

Constrained—A narrow valley limited in width by adjacent landforms, with a valley floor width less than two active channel widths; valley walls are usually steep, the stream cannot meander and the channel is single and simple.

Cumulative effects—Effects on the environment resulting from individual events that become collectively—significant over time.

Degradation—Erosional removal of materials from one place to another; degradation lowers the elevation of streambeds and floodplains.

Debris (organic)—Logs, trees, limbs, branches, leaves, and bark that accumulate, often in streams or riparian areas; debris may be naturally occurring or the result of human activities.

Discharge—Volumes of water flowing past a reference point per unit time (such as m'/sec).

Ecosystem—A complete interacting system of organisms considered together in their environment; a biotic community and its abiotic environment.

Embeddedness—Degree to which large particles (boulders, rubble, gravel) are surrounded or covered by fine sediment, usually measured in classes according to percent coverage.

Evapotranspiration—Loss of water by evaporation from the soil and transpiration from plants.

Exclosure—Area from which livestock or other animal are excluded.

Floodplain—Level lowland bordering a stream onto which the stream spreads at flood stage; relatively large surfaces adjacent to active channels, formed by deposition of sediments during flood events; it may be covered by water at flood flows.

Gradient—The rate of vertical elevation change per unit horizontal distance; also known as slope.

Habitat—The area where a plant or animal lives and grows under natural conditions; habitat consists of living and nonliving attributes, and provides all requirements for food and shelter.

Holocene age—Most recent geological epoch, comprising the 10,000 or so years since the last continental glaciation.

Hydraulic mining—Use of high-pressure water jets to erode ore-bearing alluvial deposits.

Monitoring—Actions undertaken to assess and evaluate, including the results of management activity on a species or process.

Nonpoint-source pollution—Pollution from sources that cannot be defined as discrete points, such as areas of timber harvesting, surface mining; and construction.

Peak flow—Greatest stream discharge recorded over a specified period of time, usually a year, but often a season.

Placer mining—Mining of placer deposits by washing, dredging, or hydraulic methods; placer deposits are fluvial or glacial deposits of gravel and sand containing heavy ore minerals.

Pool—Portion of a stream with reduced current velocity, often with deeper water than surrounding areas and with a smooth surface.

Recovery—Return of an ecosystem to a defined condition after a disturbance.

Rehabilitation (restoration)—The process of restoring a site to a former state or desired condition.

Resident fish—Fish species that complete their entire life cycle in fresh water.

Rearing habitat—Areas required for successful survival to adulthood by young animals.

Riparian vegetation—Vegetation growing on or near the banks of a stream or other body of water in soils that exhibit some wetness characteristics during some portion of the growing season.

Run (fish)—A group of fish migrating in a river (most often on a spawning migration) that may comprise one or many stocks.

Sediment—Material carried in suspension by water, that will eventually settle to the bottom.

Spawning gravel—Sorted, clean gravel patches of a size appropriate for the needs of resident or anadromous fish.

Stock—Group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction.

Substrate—The material forming the underlying layer of streams; substrates are bedrock, gravel, sand, clay, boulders.

Stream reach—Section of stream between two specified points.

Unconstrained—A wide valley floor, generally greater than two active channel widths, with extensive floodplain surfaces; the stream can meander to form a complex channel.

Upland—The portion of the landscape above the valley floor.

Wissmar, Robert C.; Smith Jeanette E.; McIntosh, Bruce A.; Lt, Hiram W.; Reeves, Gordon H.; Sedell, James R. 1994. Ecological health of river basins in forested regions of eastern Washington and Oregon. Gen. Tech. Rep. PNW-GTR-326. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 65 p. (Everett, Richard L., assessment team leader; Eastside forest ecosystem health assessment; Hessburg, Paul F., science team leader and tech. ed., Volume III: assessment.)

A retrospective examination of the history of the cumulative influences of past land and water uses on the ecological health of select river basins in forest regions of eastern Washington and Oregon indicates the loss of fish and riparian habitat diversity and quality since the 19th century. The study focuses on impacts of timber harvest, fire management, livestock grazing, mining and irrigation management practices on stream and riparian ecosystems. An examination of past environmental management approaches for assessing stream, riparian, and watershed conditions in forest regions shows numerous advantages and shortcomings. Recommendations for ecosystem management with emphasis on monitoring and restoration activities are provided.

Keywords: History, land uses, rivers, streams, riparian, salmonid, timber, livestock, irrigation, water

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