United States Department of the Interior

FISH AND WILDLIFE SERVICE

Western Washington Fish and Wildlife Office
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Memorandum

MAY 16 2006

To: Assistant Regional Director, Ecological Services
Portland, Oregon
Attention: Larry Salata

From: Manager, Western Washington Fish and Wildlife Office
Lacey, Washington

Ken S. Berg

Subject: Biological Opinion for the Issuance of a Section 10(a)(1)(B) Incidental Take Permit to the State of Washington for the Forest Practices Habitat Conservation Plan (FWS Reference: 1-3-06-FWI-0301)

This document transmits the U.S. Fish and Wildlife Service's Biological Opinion regarding the proposed issuance of an incidental take permit (PRT-TE121202-0) to the State of Washington for the implementation of the Washington Forest Practices Habitat Conservation Plan. Issuance of an incidental take permit is pursuant to Section 10(a)(1)(B) and Section 7(a)(2) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Your November 4, 2005, request for formal consultation was received on November 9, 2005.

The State of Washington is requesting 50-year coverage of incidental take for the federally threatened bull trout (*Salvelinus confluentus*) that may arise from forest practices activities they regulate across 9.3 million acres in Washington State. Forty-seven other unlisted species will also be included on the U.S. Fish and Wildlife Service's incidental take permit, including 40 fish and 7 amphibian species. The State of Washington is also making a similar request to the National Marine Fisheries Service.

Attachments

Endangered Species Act – Section 7 Formal Consultation

Biological Opinion

Washington Forest Practices Habitat Conservation Plan

(Service Reference Number: 1-3-06-FWI-0301)

Agency:

U.S. Fish and Wildlife Service
Region 1
Portland, Oregon

Consultation Conducted by:

U.S. Fish and Wildlife Service
Western Washington Fish and Wildlife Office
Lacey, Washington

May 16, 2006

Ken S. Berg, Manager
Western Washington Fish and Wildlife Office

U.S. FISH and WILDLIFE SERVICE'S

BIOLOGICAL and CONFERENCE OPINION

for the

PROPOSED ISSUANCE

of a

SECTION 10(a)(1)(B) INCIDENTAL TAKE PERMIT

(PRT-TE-X121202-0)

to the

STATE OF WASHINGTON

for the

FOREST PRACTICES HABITAT CONSERVATION PLAN

May 2006

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Acronyms

BMP	(Best Management Practices)
CFR	(Code of Federal Regulations)
CMER	(Cooperative, Monitoring, Evaluation, and Research committee)
CMZ	(channel migration zone)
dbh	(diameter at breast height)
DFC	(Desired Future Condition)
DPS	(Distinct Population Segment)
ELZ	(Equipment Limitation Zone)
EPA	(Environmental Protection Agency)
ESA	(Endangered Species Act)
FEMAT	(Forest Ecosystem Management Assessment Team)
FMO	(Foraging, Migration, and Overwintering Habitat for bull trout)
FPHCP	(Forest Practices Habitat Conservation Plan)
FFR	(Forests and Fish Report)
FPA	(Forest Practices Application)
FWS	(U.S. Fish and Wildlife Service)
GIS	(Geographic Information Systems)
HCP	(Habitat Conservation Plan)
LWD	(large woody debris)
NMFS	(National Marine Fisheries Service)
PCE	(Primary Constituent Element)
RCW	(Revised Code of Washington)
RMAP	(Road Maintenance and Abandonment Plans)
RMZ	(Riparian Management Zone)
SEPA	(State Environmental Policy Act)
SOSEA	(Spotted Owl Special Emphasis Area)
TFW	(Timber, Fish, and Wildlife)
TMDL	(total maximum daily load)
USDA	(U.S. Department of Agriculture)
USDI	(U.S. Department of the Interior)
WAC	(Washington Administrative Code)
WDFW	(Washington Department of Fish and Wildlife)
WDNR	(Washington Department of Natural Resources)
WDOE	(Washington Department of Ecology)
WRIA	(Water Resource Inventory Area)

1. INTRODUCTION

This document constitutes the U.S. Fish and Wildlife Service's (FWS) Biological and Conference Opinion (Opinion) regarding the FWS's issuance of an incidental take permit (Permit) to the State of Washington (State) for the Forest Practices Habitat Conservation Plan (FPHCP) and its effect on the threatened bull trout (*Salvelinus confluentus*), threatened northern spotted owl (*Strix occidentalis caurina*), threatened marbled murrelet (*Brachyramphus marmoratus marmoratus*), threatened bald eagle (*Haliaeetus leucocephalus*), 47 unlisted aquatic species, and on critical habitat for the northern spotted owl, marbled murrelet, and bull trout. The 47 unlisted aquatic species are included because the State is seeking incidental take authorization for these species should they become listed during the term of the Permit. This document was prepared in accordance with section 7 of the Endangered Species Act (16 U.S.C. 1531 et seq.; ESA).

This Opinion is based primarily on information provided in the FPHCP (WDNR 2006), which is incorporated by reference, and the sources cited herein. A complete administrative record of this consultation is on file at the FWS's Western Washington Fish and Wildlife Office.

1.1 BACKGROUND

In 1999, the Washington State Legislature passed the Salmon Recovery Funding Act (Engrossed Substitute House Bill 5595) which identified forest practices as a critical component for salmon recovery. Through that act, the Legislature recognized a report known as the Forests and Fish Report (FFR) as being responsive to its policy directive for a collaborative, incentive-based approach to support salmon recovery; ESA coverage and regulatory certainty being key incentives of implementation of the FFR. The FFR was developed though a collaborative, multi-stakeholder process to create forest-practices prescriptions that would protect riparian and aquatic habitat for the conservation of listed salmonid species and other unlisted fish and stream-associated amphibian species.

The groups that contributed to the development of the FFR included groups representing all six caucuses of Timber, Fish, and Wildlife (TFW): State agencies, Federal agencies, Native American Tribes, industry, nonindustrial forest landowners, and environmental groups. At the conclusion of the discussions leading to the submittal of the FFR, the environmental caucus and some individual Tribes withdrew their support and chose to not be listed as authors of the report. Authors include State agencies: Washington Department of Natural Resources (WDNR), Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology (WDOE), Governor's Office; Federal agencies: FWS, National Marine Fisheries Service (NMFS), Environmental Protection Agency (EPA); the Colville Confederated Tribes, other Washington Tribes, the Northwest Indian Fisheries Commission; the Washington State Association of Counties; the Washington Forest Protection Association; and the Washington Farm Forestry Association.

Also in 1999, the Washington State Legislature passed the Forest Practices Salmon Recovery Act (Engrossed Substitute House Bill 2091) which directed the Washington Forest Practices Board to adopt new Washington Forest Practices Rules, encouraging the Forest Practices Board to follow the recommendations of the FFR. In its rulemaking procedures, the Forest Practices Board conducted an evaluation of the FFR, as well as alternatives to the FFR. This evaluation included an Environmental Impact Statement under the Washington State Environmental Policy Act (SEPA). The Final State Environmental Impact Statement, entitled *Alternatives for Forest Practices Rules for Aquatic and*

Riparian Resources, was published in April 2001. The Forest Practices Board adopted new permanent Washington Forest Practices Rules in 2001 based on the FFR. As directed by the Washington State Legislature, through the Forest Practices Salmon Recovery Act, (Revised Code of Washington (RCW), Chapter 77.85.190(3)), Governor Gary Locke designated the Commissioner of Public Lands, Doug Sutherland, to negotiate on behalf of the State with the relevant Federal agencies to satisfy Federal requirements under the ESA and the Federal Water Pollution Control Act (Clean Water Act) (33 U.S.C. 1251 *et seq*.).

Since 2001, the State has worked with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (together known as the Services) to develop a Habitat Conservation Plan (HCP) under Section 10(a)(1)(B) of the ESA based on the Washington Forest Practices Rules adopted in 2001. The Services formally initiated an environmental review of the project through publication of a Notice of Intent to prepare an Environmental Impact Statement in the Federal Register on March 17, 2003 (68 FR 12676). The State submitted a formal application to the Services for Permits from each agency on February 9, 2005. On February 11, 2005, (70 FR 7245 – 7247), a draft of the FPHCP was released for 90-day public comment period, along with a Draft Environmental Impact Statement as directed by the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321-4347) (NEPA). The comment period began on February 11, 2005, and closed on May 12, 2005.

The Services and the State prepared a Final Environmental Impact Statement, Response to Comments, and a final FPHCP. These documents were made available to the public on January 27, 2006, for a 30-day public review period.

1.2 CONSULTATION HISTORY

Informal consultation on the proposed action considered herein was initiated on February 9, 2005. A request for formal consultation on the proposed action was transmitted via memorandum from the FWS's Pacific Regional Office to the Western Washington Fish and Wildlife Office on November 4, 2005 The FWS analyzed the potential for effects to all listed, proposed, and candidate species that occur within the proposed action area for the FPHCP. The determinations, of effects to species, of "no effect" and "not likely to adversely affect" are documented in a FWS memorandum (USFWS "no effect and NLAA determinations memo" May 12, 2006). The remainder of this Opinion analyzes the effects to all other listed, proposed, candidate, and covered FPHCP species in the proposed action area.

The National Marine Fisheries Service is also conducting formal consultation on the proposed action on anadromous salmonids and a few other marine fish species that are under their jurisdiction.

On April 17, 2006, the FWS provided FFR stakeholders (e.g., representatives from State and Federal agencies, Tribes, private landowners, and environmental organizations) with the majority of our draft Biological Opinion for their review and comment. We considered these comments during the revisions to this final Biological Opinion. The comments we received from stakeholders are included in our administrative record for this Opinion.

2. BIOLOGICAL AND CONFERENCE OPINION

3. DESCRIPTION OF THE PROPOSED ACTION

The FWS proposes to issue a 50-year Permit under the authority of section 10(a)(1)(B) of the ESA to the State to cover the incidental take of the bull trout and 47 unlisted aquatic species (should they become listed). This Permit would address incidental take that may be caused by the State's implementation of the FPHCP. The State is requesting a Permit that would cover its actions as regulator and permitter of forest practices activities in Washington State. Such a Permit would cover the regulatory actions of the State, and, in turn, would be an umbrella for the forest practices of third-party operators and landowners regulated by the State.

3.1 LANDS COVERED BY THE FPHCP

The FPHCP covers approximately 9.3 million acres of forestland in Washington, about 6.1 million acres of which are located west of the crest of the Cascade Range, and approximately 3.2 million acres are in eastern Washington. Ownership patterns range from individuals and families who own small forest parcels to large holdings owned and/or managed by private corporations and public agencies.

Covered lands are forestlands within the State subject to the Washington Forest Practices Act, chapter 76.09 of the RCW. Forestland means "all land which is capable of supporting a merchantable stand of timber and is not being actively used for a use which is incompatible with timber growing" (WAC 222-16-010). For purposes of road maintenance and abandonment planning and implementation for small forest landowners, "forestland" excludes the following: residential home sites; crop-fields; orchards; vineyards; pastures; feedlots; fish pens; and land on which appurtenances necessary to the production, preparation, or sale of crops, fruits, dairy products, fish, and livestock exist (WAC 222-16-010).

Forestlands covered by existing federally approved HCPs are generally not considered part of FPHCP covered lands (Washington Administrative Code (WAC) 222-12-041). However, there are two exceptions. One is the 5-year Western Pacific Timberlands (*nee* Boise Cascade Corporation) single-species HCP (Boise Cascade Corporation 2001) that encompasses 620 acres and provides coverage for the northern spotted owl, but does not include coverage for aquatic species. The other exception is approximately 228,000 acres of managed land on the east side of the Cascade Crest that were included in the approximately 1.6 million acres addressed by the Washington State Department of Natural Resources HCP (WDNR) (WDNR 1997). The WDNR State Lands HCP provides coverage for some listed terrestrial species east of the Cascade Crest (e.g., wolves, spotted owls, and bald eagles), but does not include coverage for aquatic species. The forestland contained within these two areas is considered part of the covered lands under the FPHCP.

Covered lands may change over time as lands are bought and sold, or change land-use status. For instance, covered lands may increase if another existing HCP is terminated and those lands then become subject to the standard Washington Forest Practices Rules covered by the FPHCP. Lands may decrease if a new HCP is developed and those lands are no longer subject to the standard Washington Forest Practices Rules. Forest lands purchased and included as Federal lands would no longer be covered by the FPHCP. Land exchanges between landowners of covered lands and Federal, State, or other, existing HCP lands could both increase and decrease FPHCP covered lands. Lands that are converted from forestry to other land uses would no longer be subject to the Washington Forest Practices Rules or the FPHCP. Lands that become newly forested could become subject to the Washington Forest Practices Rules and the FPHCP. For instance, if an old field is planted to hybrid poplar and is harvested before it is 25 years old, it remains subject to agricultural rules; but, if that plantation is allowed to grow past 25 years of age, it would become subject to the Washington Forest Practices Rules and, thereby, to the proposed FPHCP.

3.2 SPECIES COVERED BY THE FPHCP

The State seeks incidental take coverage under the ESA for FWS species listed in Table 3-1.

Table 3-1. Species covered in the Incidental Take Permit for the State of Washington's Forest Practices Habitat Conservation Plan

Common Name	*Scientific Name*
Threatened Species	
Bull trout	*Salvelinus confluentus*
Unlisted Fish Species	
Dolly Varden	*S. malma*
Cutthroat trout [1]	*Oncorhynchus clarki*
Rainbow/ Redband trout [2]	*O. mykiss*
Kokanee	*O. nerka*
Pacific lamprey	*Lampetra tridentata*
River lamprey	*L. ayersi*
Western brook lamprey	*L. richardsoni*
Pygmy whitefish	*Prosopium coulteri*
Mountain whitefish	*P. williamsoni*
Olympic mudminnow	*Novumbra hubbsi*
Chiselmouth	*Acrocheilus alutaceus*
Redside shiner	*Richardsonius balteatus*
Longnose dace	*Rhinichtys cataractae*
Speckled dace	*R. osculus*
Leopard dace	*R. falcatus*
Umatilla dace	*R. umatilla*
Northern pikeminnow	*Ptychocheilus oregonensis*
Tui chub	*Gila bicolor*
Lake chub	*Couesius plumbeus*
Peamouth	*Mylocheilus caurinus*
Largescale sucker	*Catostomus macrocheilus*
Bridgelip sucker	*C. columbianus*
Longnose sucker	*C. catostomus*
Mountain sucker	*C. platyrhynchus*
Salish sucker	*C. carli (species pending)*
Three-spine stickleback	*Gasterosteus aculeatus*
Sandroller	*Percopsis transmontana*
Coastrange sculpin	*Cottus aleuticus*

Table 3-1. Species covered in the Incidental Take Permit for the State of Washington's Forest Practices Habitat Conservation Plan (continued)

Common Name	*Scientific Name*
Prickly sculpin	*C. asper*
Reticulate sculpin	*C. perplexus*
Riffle sculpin	*C. gulosus*
Shorthead sculpin	*C. confusus*
Torrent sculpin	*C. rhotheus*
Slimy sculpin	*C. cognatus*
Paiute sculpin	*C. beldingi*
Margined sculpin	*C. marginatus*
Mottled sculpin	*C. bairdi*
Longfin smelt	*Spirinchus thaleichthys*
Burbot	*Lota lota*
White sturgeon [3]	*Acipenser transmontanus*
Unlisted Amphibian Species	
Columbia torrent salamander	*Rhyacotriton kezeri*
Cascade torrent salamander	*R. cascadae*
Olympic torrent salamander	*R. olympicus*
Dunn's salamander	*Plethodon dunni*
Van Dyke's salamander	*P. vandykei*
Pacific tailed frog	*Ascaphus truei*
Rocky Mountain tailed frog	*A. montanus*

[1] The cutthroat trout includes two subspecies: the coastal cutthroat (*Oncorhynchus clarki clarki*) and the westslope cutthroat (*Oncorhynchus clarki lewisi*).

[2] The rainbow trout includes two subspecies: the coastal rainbow trout (*Oncorhynchus mykiss irideus*) and the Columbia (a.k.a. Interior) redband trout (*Oncorhynchus mykiss gairdneri).*

[3] White sturgeon in this opinion excludes the endangered Kootenai River Distinct Population Segment. The Kootenai population is located wholly upstream and outside of this action area. Those sturgeon that are landlocked and occur within Washington State, and those that are marine and/or anadromous (downstream of Bonneville Dam), are addressed in this consultation.

3.3 ACTIVITIES COVERED BY THE FPHCP

Forest-practices activities covered by the FPHCP include road and skid-trail construction, road maintenance and abandonment, final and intermediate harvesting, pre-commercial thinning, reforestation, timber salvage, and brush control. In addition, adaptive management research and monitoring activities—some of which include experimental treatments—are also covered by the FPHCP. The FPHCP includes protection measures to avoid, minimize, and mitigate potential impacts caused by these activities. These activities are described in Chapter 4 of the FPHCP in greater detail, as well as in this section below and under Effects to the Environment.

3.3.1 FPHCP Conservation Program

The applicant (Washington State) developed the FPHCP as a programmatic plan. The programmatic nature of the FPHCP would provide ESA coverage for forest landowners through the Forest Practices Program. Forest landowners would conduct forest practices activities according to Washington Forest Practices Act and Rules as described in the FPHCP, and therefore become beneficiaries of take coverage for which the State has applied.

The Forest Practices Program includes State statutes and the Washington Forest Practices Rules that govern forest-practices activities in Washington. The program also includes the public and private agencies and organizations that work cooperatively to administer the program throughout the State. The Forest Practices program includes both regulatory and collaborative dimensions. Collaborative efforts include adaptive management (discussed below) as well as the overall TFW process.

The Forest Practices program has been in existence for many years and is administered by the WDNR – Forest Practices Division. The Forest Practices Program includes staff and managers in each region, as well as oversight in the headquarters office in Olympia. Many standardized procedures and interpretations have been developed over the years, by WDNR, in cooperation with other TFW stakeholders, and upheld through the courts. These procedures and interpretations are supported by: (1) staff that make consistent findings and determinations in the field, (2) a series of training classes provided in cooperation with other TFW stakeholders, (3) standardized operating guidance, (4) procedures for automated public involvement, (5) oversight and technical participation by TFW stakeholders, and (6) legal staff in the State's Attorney General's office.

Forest practices foresters review and approve forest practices applications. These FPA documents are available on-line to the requesting public for review and comment to WDNR. Once an application is approved, forest-practices foresters may consult on operations and issue approval for minor adjustments in the field. These adjustments may have been requested by the landowner or operator, by WDNR, or any other reviewer of an FPA. WDNR makes final approval decisions on FPAs. These are often recorded in the form of Informal Conference Notes and are signed by all participating parties. Often, when adjustments are more significant, regardless of who requested the adjustment, WDNR may issue a Notice to Comply. When WDNR observes infractions or resource damage occurring from authorized activities, they issue a Stop Work Order. Work on that activity must cease until the issue is resolved. WDNR also has the ability to levy civil penalties in extreme cases. These processes are part of the framework of the Forest Practices program.

Although not covered by the proposed FPHCP, the WDFW administers a program whereby they issue Hydraulic Project Approval (HPAs). That program, authorized by the "Hydraulic Code" (Chapter 77.55 RCW), is referenced several times in the body of this Opinion as the activities described are often subject to additional limitations associated with HPAs. HPAs are required to conduct any construction activity that will use, divert, obstruct, or change the bed or flow of State waters (including streams within lands regulated by the Forest Practices Act). The purpose of the program is to prevent damage to the State's fish, shellfish, and their habitat. WDFW has area and regional biologists that administer that program at the field-level, as well as support from headquarters in Olympia. The HPA program is not proposed for coverage by the FPHCP, this information is merely provided to apply context to discussions within this Opinion. However, the approval of some forest practices applications on Type N streams serves as approval for specific forest practices-related hydraulic projects, effective June 1, 2005.

3.3.2 Compliance Monitoring

A number of efforts are ongoing that would address compliance monitoring of activities conducted under the FPHCP. They are as follows:

- The existing forest practices enforcement program would continue whereby forest practices foresters check on a number of FPAs prior to, during, and following activities. Visits prior to activities may be conducted to verify existing pre-activity conditions and review the site for sensitive resources. Visits during activities may be conducted to ensure activities are occurring, or being avoided, as planned. Close-out visits may be conducted to verify that post-activity conditions meet applicable requirements. The specific FPAs to visit, and the timing of such visits, are determined by WDNR forest practices foresters. The amount and distribution of effort depends on the sensitivity of the resources involved as well as local and practical knowledge regarding the individual operations.

WDNR would continue the inspection of forest lands, before, during, and after the conducting of forest practices as necessary for the purpose of ensuring compliance with the Washington Forest Practice Rules and to ensure that no material damage occurs to the natural resources of the State as a result of such practices. Any authorized representative of WDNR shall have the right to access forest land at any reasonable time to enforce the provisions of the Washington Forest Practices Rules (RCW 76.09.150).

- There is ongoing involvement in the compliance of forest practices by other TFW staff, specifically WDFW and tribal biologists, who review forest practices in their local geographic area on a regular basis. Irregularities observed during the course of such visits are brought to the attention of WDNR. This level of cooperative activity is variable across the State and depends on the commitment of the local TFW staff.

- WDNR has initiated an FPHCP Compliance Monitoring Program. The Washington Forest Practices Rules, WAC 222-08-160 (4), define the WDNR compliance monitoring responsibilities as:

> "The department shall conduct compliance monitoring that addresses the following key question: "Are forest practices activities being conducted in compliance with the Washington Forest Practices Rules?" The department shall provide statistically sound, biennial compliance audits and monitoring reports to the board for consideration and support of rule and guidance analysis. Compliance monitoring shall determine whether Washington Forest Practice Rules are being implemented on the ground. An infrastructure to support compliance will include adequate compliance monitoring, enforcement, training, education and budget."

  This program resides within the WDNR Forest Practices Division and is still undergoing refinement. Preliminary data have been gathered and reported. This program's goal is to characterize the level of compliance that is occurring; therefore, a substantial emphasis is placed upon adequate sample sizes and unbiased procedures for site selection so that WDNR can determine if forest landowners/operators in the State of Washington are conducting forest practice activities in accordance with the Washington Forest Practices Rules. Over time, the information gained from this program will help the WDNR to more-effectively utilize limited forest practices resources. Information gathered will also assist the Washington Forest Practices Board in the development of new and/or revised Washington Forest Practices Rules.

- The U.S. Fish and Wildlife Service and the National Marine Fisheries Service would monitor the implementation of the FPHCP. The Services would bring specific issues of non-compliance to the attention of WDNR to resolve in coordination with the Services. In addition, the Services are participating in the ongoing development and refinement of the FPHCP Compliance Monitoring Program as described in #3 above.

The FPHCP consists of two parts: an administrative framework and a set of protection measures. The administrative framework supports the development, implementation, and refinement of the Washington Forest Practices Rules and therefore contributes to the overall effectiveness of the FPHCP in meeting the needs of the covered species. The administrative framework bears on the protective aspects of the FPHCP in that it includes the Washington Forest Practices Rules and guidance, the forest practices permitting process, compliance monitoring, enforcement actions, and training and technical support. The administrative framework also incorporates an adaptive management process to address uncertainty associated with the effectiveness of protection measures. The adaptive management program is designed to assess the effectiveness of the protection measures in achieving established resource objectives. It also includes programs to monitor the status and trends of key environmental parameters and to evaluate watershed-scale cumulative effects.

The protection measures are described in the FPHCP, the Washington Forest Practices Rules, and Forest Practices Board Manual guidance and are designed to minimize and mitigate forestry-related impacts and conserve habitat for species covered by the FPHCP. The protection measures determine the level of on-the-ground habitat protection for covered species. The two major sets of protective measures are presented as two separate, but related, conservation strategies: Riparian Strategy and Upland Strategy.

3.3.3 Description of Washington Forest Practices Rules under the Proposed FPHCP

This summary description is provided for the convenience of the reader. This summary does not supplant or supersede the operating conservation program as described in the FPHCP, nor the contents of the applicable Washington Forest Practices Rules. In matters where such documents are in disagreement, the reader should consult the Washington Forest Practices Rules, including WAC (Title 222 WAC). The authority for such rules can be found in Chapters 76.09, 76.13, 77.85 RCW. These rules are available on the WDNR website at www.dnr.wa.gov. The Forest Practices Board Manual should not be interpreted as rules, but as guidelines to assist landowners and operators in meeting the intent of the rules.

3.3.3.1 Definitions

Below is a summary of the Water and Wetland Typing Systems. Full details are contained in the Washington Forest Practices Rules cited above.

Water Typing System

The WDNR in cooperation with WDFW and WDOE, and in consultation with affected Native American Indian Tribes will classify waterbodies, including streams, lakes, and ponds. The WDNR will prepare water type maps showing the location of Type S, F, and N (Np and Ns) Waters within the forested areas of the State. The maps will be based on a multiple-parameter, field-verified geographic information system (GIS) logistic-regression model. The multiple-parameter model will be designed to identify fish habitat by using geomorphic parameters such as basin size, gradient, elevation, and other indicators. The modeling process shall be designed to achieve a level of statistical accuracy of 95 percent in separating fish-habitat streams from those that do not contain fish habitat. Furthermore, the demarcation of waters supporting and not supporting fish habitat shall be equally likely to over and under estimate the presence of fish habitat. Water-type maps will be updated every 5 years where necessary to better reflect observed, in-field conditions. Until water-type maps delineating fish habitat are adopted by the Forest Practices Board, the Interim Water Typing System will continue to be used.

The waters will be classified using the following criteria:

"Type S Water" means all waters, within their bankfull width, as inventoried as "Shorelines of the State" under chapter 90.58 RCW including periodically inundated areas of their associated wetlands. Estuarine and marine shorelines are classified as Type S waters.

"Type F Water" means segments of natural waters other than Type S Waters, which are within the bankfull widths of defined channels and periodically inundated areas of their associated wetlands, or within lakes, ponds, or impoundments having a surface area of 0.5 acre or greater at seasonal low water and which in any case contain fish habitat or are described by a number of factors including diversion for domestic use by more than a specified number of users and will extend upstream for a specified distance; diverted for use by fish hatcheries; waters, which are within a campground of specified size; and riverine ponds, wall-based channels, and other channel features that are used by fish for off-channel habitat.

"Type Np Water" means all segments of natural waters within the bankfull width of defined channels that are perennial streams without fish habitat. Perennial streams are waters that do not go dry any time of a year of normal rainfall. However, for the purpose of water typing, Type Np Waters include the intermittent dry portions of the perennial channel below the uppermost point of perennial flow. If the uppermost point of perennial flow cannot be identified with simple, nontechnical observations, then Type Np Waters may be determined by the size of the contributing basin area.

"Type Ns Water" means all segments of natural waters within the bankfull width of the defined channels that are not Type S, F, or Np Waters. These are seasonal streams without fish habitat in which surface flow is not present for at least some portion of a year of normal rainfall, and are not located downstream from any stream reach that is a Type Np Water. Ns Waters must be physically connected by an above-ground channel system to Type S, F, or Np Waters.

Wetland Typing System

The WDNR in cooperation with WDFW, WDOE, and affected Native American Indian Tribes shall classify wetlands in order to distinguish those which require wetland management zones and those which do not. Wetlands which require wetland management zones shall be identified using the following criteria:

"Nonforested wetlands" means any wetland or portion thereof that has, or if the trees were mature would have, a crown closure (generally interpreted as canopy cover) of less than 30 percent.

> "Type A Wetlands" are all nonforested wetlands which are greater than 0.5 acre in size, including any acreage of open water where the water is completely surrounded by the wetland; and are associated with at least 0.5 acre of ponded or standing open water. The open water must be present on the site for at least 7 consecutive days between April 1 and October 1 to be considered for the purposes of these rules. All forested and nonforested bogs greater than 0.25 acres shall be considered Type A Wetlands.
>
> "Type B Wetlands" are all other nonforested wetlands greater than 0.25 acre.

"Forested wetland" means any wetland or portion thereof that has, or if the trees were mature would have, a crown closure of 30 percent or more.

3.3.3.2 FPHCP Riparian Strategy

The Riparian Strategy addresses practices affecting certain ecological functions that are important for creating, restoring, and maintaining aquatic and riparian habitats. The strategy protects these functions along typed waters by restricting forest practices activities from the most sensitive parts of riparian areas and by limiting activities in other areas. The strategy accomplishes protection within the riparian management zone (RMZ) and the equipment limitation zone (ELZs) for typed waters. RMZs are areas adjacent to Type S, Type F, and Type Np waters where trees are retained so that ecological functions such as large woody debris (LWD) recruitment, shade, litterfall, streambank stability, and nutrient cycling are maintained. ELZs apply to Type Np and Type Ns waters and are areas where equipment use is limited so that forest practices-related erosion and sedimentation are minimized. Other riparian protection measures that apply to typed waters include restrictions on the salvage of down woody debris and the disturbance of stream banks. Some riparian requirements differ between western and eastern Washington.

Western Washington

Protection measures for typed waters in western Washington include establishing riparian management zones along Type S, Type F, and Type Np waters. The FPHCP applies no-harvest buffers adjacent to Type Np-associated sensitive sites. The FPHCP applies ELZs along Type Np and Type Ns waters. Note that all measurements regarding buffers and ELZs are measured horizontally, not on-the-slope.

Type S and Type F Waters

RMZs associated with Type S and Type F waters in western Washington are made up of three sub-zones: the "core zone," the "inner zone" and the "outer zone." The core zone is closest to the water, the inner zone is the middle zone and the outer zone is farthest from the water (FPHCP Figure 4.5).

Core Zone

The core zone begins at the bankfull or channel migration zone (CMZ) edge and is 50 feet wide. No timber harvest is allowed in the core zone except for the construction and maintenance of road crossings and the creation and use of yarding corridors in accordance with applicable rules. Any trees cut for, or damaged by, yarding corridors in the core zone must be left on-site. Any trees cut as a result of road construction to cross a stream may be removed from the site, unless they are to be used as part of an LWD placement strategy (see Inner Zone discussion below) or as needed to reach stand requirements.

Inner Zone

The inner zone begins at the outside edge of the core zone, and its width depends on site class, bankfull width, and the management option selected by the landowner. Management options in the inner zone include: (1) thinning from below, (2) leaving trees closest to the water, (3) hardwood conversion, and (4) no harvest. Timber harvest is allowed within the inner zone if certain stand requirements are met. Stand requirements apply to the combined core and inner zones, and are minimum values for the following parameters: (1) the number of conifer trees per acre, (2) the basal area of conifer per acre, and (3) the proportion of conifer.

If stand-level requirements are met, the combined core and inner zones are capable of attaining a target condition known as "desired future condition" (DFC). DFC is the condition of a mature riparian forest stand at 140 years of age and is based on basal area per acre. DFC targets for basal area per acre have been developed for five site classes in western Washington.

Growth modeling is used to determine if a particular stand meets the DFC basal area target. Stand-attribute data are collected and input to a model that "grows" the stand to 140 years of age. If, at age 140, the estimated future basal area would exceed the DFC target, harvesting may occur within the inner zone in accordance with applicable rules. In these cases, only the "surplus" basal area (i.e., basal area beyond that needed to meet the DFC basal area target) may be harvested. When the combined core and inner zones for a particular riparian stand do not meet the DFC stand requirements, no harvest is allowed in the inner zone, except in cases where the landowner chooses the hardwood-conversion option. When no harvest is permitted in the inner zone, or the landowner elects to forego harvesting in the inner zone, the width of the core, inner, and outer zones follow the requirements in FPHCP Table 4.5.

Landowners can harvest within the inner zone of stands not meeting stand requirements, to convert a hardwood-dominated inner zone to one that is dominated by conifers. The site must meet certain minimum requirements such as evidence that the site can be successfully converted to conifer, a maximum number and size of existing conifers, and contiguous ownership upstream and downstream of the site. Even in these situations, the FPHCP limits the spatial extent of conversion and the number and type of trees that can be harvested.

Harvesting in the inner zone must be either thinning from below (thinning), or leaving trees closest to the water (packing). Under thinning from below, harvesting focuses on retention of most co-dominant and all dominant trees in the stand. Larger trees generally provide greater ecological benefits, particularly in terms of LWD recruitment and shade. The width of the core, inner, and outer zones must follow the requirements in FPHCP Table 4.6. In addition, harvesting cannot decrease the proportion of conifers in the stand. Any harvest within 75 feet of the bankfull edge or CMZ edge must meet minimum shade requirements. Following harvest, there must be at least 57 conifer trees per acre in the inner zone. These 57 conifer trees must be 12 inches or larger in diameter at breast height (dbh).

Under the harvests leaving trees closest to the water, the width of the core, inner, and outer zones must follow the requirements in FPHCP Table 4.7. This option only applies to Site Class I, II, and III RMZs on streams less than or equal to 10 feet bankfull width and to Site Class I and II RMZs on streams greater than 10 feet bankfull width. In addition, inner zone harvest must meet the prescriptions described in FPHCP Table 4.6 and 4.7. Within the inner zone, areas harvested using even-aged methods must leave 20 conifer trees greater than 12 inches dbh per acre of harvest. A minimum of 20 conifers per acre will be retained in any portion of the inner zone where harvest occurs (e.g., within the harvest unit), and these trees will not be counted or considered towards meeting the applicable stand requirements.

STREAM-ADJACENT PARALLEL ROADS

When the basal area component of the stand requirements cannot be met due to the presence of a stream-adjacent parallel road in the core and/or inner zones, two parameters must be estimated: 1) the basal area that would have been present if the road was not occupying the space, and 2) the corresponding shortfall in the basal area component of the stand requirements.

The total basal area equivalent to the shortfall must be retained elsewhere in the inner and/or outer zones as mitigation. If the inner and/or outer zones contain insufficient trees to address the shortfall, trees within the RMZ of other Type S or Type F waters in the same harvest unit or along Type Np or Ns waters in the same harvest unit must be retained as mitigation. In cases where other in-unit RMZs are unavailable, the landowner may implement an LWD placement strategy to address the shortfall in basal area (see Forest Practices Board Manual Section 26 for guidelines).

YARDING CORRIDORS IN CORE AND INNER ZONES

When yarding corridors are necessary to facilitate harvesting within RMZs, all calculations of the basal area component of the stand requirements are to be made as if the corridors were established prior to any other harvest activity. All trees cut in the core zone must be left on site. Inner-zone trees cut or damaged by yarding may be removed if they represent surplus basal area. Trees cut or damaged by yarding in a unit that does not meet the DFC basal area target may not be removed from the site. The size and spacing of corridors are limited by the Washington Forest Practices Rules (see Cable Yarding).

Outer Zone

The outer zone begins at the outside edge of the inner zone and—like the inner zone—its width is dependent on site class, bankfull width, and management option selected by the landowner (see FPHCP Tables 4.5 through 4.7). Timber harvest is allowed in the outer zone; however, 20 riparian leave trees per acre must be retained in either "dispersed" (even distribution throughout), or "clumped" (grouped around sensitive features to the extent the features are present in the outer zone). Under either leave tree strategy, retained trees must be conifers and 12 inches minimum dbh.

An LWD placement strategy involves the voluntary placement of woody debris in stream channels by forest landowners. The intent of the strategy is to enhance fish habitat in streams on managed forestlands by creating incentives for landowners to place wood. Guidance for placing woody debris in streams is found in Section 26 of the Forest Practices Board Manual. Wood-placement projects require an HPA permit from WDFW and are subject to additional requirements under the State's Hydraulic Code.

Type Np and Type Ns Waters

Protection measures for waters without fish in western Washington include the establishment of ELZs adjacent to Type Np and Type Ns waters and the establishment of RMZs adjacent to Type Np waters and associated sensitive sites. ELZs minimize ground and soil disturbance, protecting streambank integrity and preventing sediment delivery to waters without fish. ELZs apply to all Type Np and Type Ns waters, are 30 feet wide and are measured from the bankfull width.

To minimize equipment-based exposure of soil on more than 10 percent of the surface area of the ELZ, the FPHCP includes mitigation measures regarding operating ground-based equipment, constructing and using skid trails and stream crossings, and yarding partially suspended, cabled logs. Mitigation measures to address lost function as it relates to the prevention of sediment delivery include—but are not limited to—water bars, grass seeding, and mulching.

Protection of Type Np waters includes the establishment of no-harvest RMZs along portions of Type Np waters and around sensitive sites. The RMZs are either 50 or 56 feet in width (depending on the feature being protected). Requirements ensure that two-sided RMZs are established along at least 50 percent of the Type Np water length. The approach targets the most ecologically sensitive parts of Type Np waters, resulting in a discontinuous network of buffers that protects areas most important to aquatic resources (FPHCP Figure 4.6). No timber harvest is permitted in an area within 50 feet of headwall seeps and side-slope seeps, and within 56 feet of a point of intersection of two or more Type Np waters, headwater springs, or points of initiation of perennial flow. No timber harvest is allowed within an alluvial fan. Beginning on the point of confluence with a Type S or Type F water, 50-foot RMZs will be established for the greater of 300 feet or 50 percent of the entire length of the Np water, up to a maximum of 500 feet. Additional buffered reaches may be needed according to tables in the Washington Forest Practices Rules.

Required areas for RMZ protection include the lower reaches of Type Np waters immediately above the confluence with Type S or Type F waters and designated sensitive sites including seeps, springs, Type Np confluences, Type Np initiation points, and alluvial fans. If RMZ establishment adjacent to these areas does not protect 50 percent of the Type Np water length, additional buffers must be left along other priority areas, including low-gradient stream reaches, tailed-frog habitat, groundwater-influence zones, and areas downstream from other buffered reaches. To the extent that it is reasonable, yarding corridors and road crossings will be avoided through RMZs for Np streams, as well as sensitive sites and associated buffers. Should cable yarding or roads affect the sensitive sites, landowners must leave additional acres to account for those removed.

The width of RMZs adjacent to sensitive sites varies according to the type of sensitive site. Headwall and side-slope seep RMZs are measured from the perennially saturated soil edge and are 50 feet wide. RMZs for Type Np confluences, headwater springs, and Type Np initiation points are measured from the center of the feature or point of confluence, are circular in shape and are 56 feet wide (i.e., have a radius of 56 feet). No-harvest RMZs along areas not designated as sensitive sites are 50 feet wide, measured from the bankfull edge. Harvest is not allowed within the full extent of alluvial fans—irrespective of shape or size.

Eastern Washington

Protection measures for eastern Washington waters are 3-fold. First, measures include the establishment of RMZs along Type S, Type F, and Type Np waters. Second, the FPHCP provides for the protection of Type Np-associated sensitive sites. Finally, the FPHCP establishes ELZs adjacent to Type Np and Type Ns waters.

Type S and Type F Waters

RMZs associated with Type S and Type F waters in eastern Washington consist of three sub-zones; the "core" zone, the "inner" zone, and the "outer" zone. The core zone is closest to the water, the inner zone is the middle zone and the outer zone is farthest from the water (FPHCP Figure 4.5).

Core Zone

The core zone is 30 feet wide, beginning at the bankfull or CMZ edge. No timber harvest or road construction is allowed in the core zone except for the construction and maintenance of road crossings and the creation and use of yarding corridors. Any trees cut for, or damaged by yarding corridors in the core zone must be left on-site. Any trees cut as a result of road construction to cross a stream may be removed from the site unless they are to be used as part of an on-site, LWD replacement project. LWD placement projects are required in cases where a landowner wants to reduce the number of outer zone leave trees below the standard requirement (see description outer zone below).

Inner Zone

The inner zone begins at the outside edge of the core zone and its width depends on bankfull width (FPHCP Tables 4.9 and 4.10). The inner zone width is 45 feet for waters with bankfull widths of 15 feet or less. For waters with bankfull widths that exceed 15 feet, the inner zone width is 70 feet. FPHCP tables 4.9 and 4.10 provide more-detailed information on zone widths prescribed in the FPHCP and are incorporated here by reference.

Inner zone harvest includes leave-tree retention. Leave-tree requirements vary by timber habitat type. Three timber habitat types are recognized: 1) ponderosa pine, 2) mixed conifer, and 3) high elevation.

The ponderosa pine timber habitat type is 2,500 feet or lower in elevation, the mixed-conifer timber habitat type is 2,501 to 5,000 feet in elevation, and the high-elevation timber habitat type is above 5,000 feet. Inner-zone, leave-tree requirements for each timber habitat type are described below.

Ponderosa Pine Timber Habitat Type

The FPHCP divides stands in the ponderosa pine timber habitat type into two classes: 1) stands with high basal areas, and 2) stands with low basal areas and high densities.

For stands with high basal area (greater than 110 square feet per acre for all species in the inner zone), harvest is allowed within the inner zone. Harvest must retain at least 50 trees per acre (21 largest and 29 over 10 inches dbh) and at least 60 square feet of basal area per acre must be retained following harvest. Where there are not 29 trees over 10 inches in dbh, the landowner will retain the 29 next largest trees. Where the 60 square feet of basal area per acre cannot be met with 50 trees per acre, the landowner will be required to leave additional trees to achieve basal area per acre target. The landowner may be required to retain up to 100 trees per acre.

For stands with low basal area and high density, harvest is also allowed. Thinning is permitted if the basal area of all species is less than 60 square feet per acre and there are more than 100 trees per acre. The 50 largest trees must be retained as well as another 50 trees that are either greater than 6 inches dbh, or the next largest diameter. The landowner is required to retain 100 trees per acre.

To the extent down wood is available on-site prior to harvest, at least 12 tons of down wood per acre must be left following harvest. Where available, at least 6 pieces greater than 16 inches diameter and 20 feet in length and 4 pieces greater than 6 inches diameter and 20 feet in length must be left. These requirements apply both to stands with high basal area and stands with low basal area and high density.

Mixed-Conifer Timber Habitat Type

Washington Forest Practices Rules divide stands in the mixed conifer timber habitat type into two classes: 1) stands with high basal areas, and 2) stands with low basal areas and high densities. Stands must meet existing criteria by site index in order to be harvested. Inner zone leave tree requirements differ between the two stand classes.

For stands with high basal area (110 to 150 square feet per acre of all species, depending on site index), harvest is allowed and must retain at least 50 trees per acre in addition to a variety of basal-area requirements (70 to 110 square feet per acre of all species, depending on site index). The 50 trees per acre must be composed of the 21 largest and 29 over 10 inches dbh. Where there are not 29 trees over 10 inches in dbh, the landowner will retain the 29 next largest trees. Where the basal-area requirements cannot be met with 50 trees per acre, the landowner will be required to leave additional trees over 6 inches dbh to achieve basal area per acre target. The landowner may be required to retain up to 100 trees per acre.

For stands with low basal area and high density, harvest is allowed in the inner zone of RMZs depending on number of existing trees and density. Following thinning, a minimum of 120 trees per acre must be retained. The 120 trees must be composed of the 50 largest trees plus 70 trees greater than 6 inches dbh or next largest available.

To the extent down wood is available on-site prior to harvest, at least 20 tons per acre of down wood of certain sizes must be left following harvest. The FPHCP requires retention of down wood, where available.

HIGH-ELEVATION TIMBER HABITAT TYPE

Harvesting in the inner zone of RMZs in the high-elevation timber habitat type is allowed if stand requirements can be met. Stand requirements and harvest rules are the same that apply to inner zone harvest for western Washington RMZs for Type S and Type F. To the extent down wood is available on-site prior to harvest, at least 30 tons per acre of down wood of certain sizes must be left following harvest, where available.

STREAM-ADJACENT PARALLEL ROADS, ALL TIMBER-HABITAT TYPES

For sites limited by roads in the inner zone, the allowable harvest is determined by the bankfull width and proximity of the road to the outer edge of the bankfull width or CMZ. Minimum shade requirements must be met whether or not the inner zone contains a stream-adjacent parallel road. No harvesting is allowed in that portion of the inner zone located between the road and water. When the edge of the road closest to the water is located within 75 feet (for waters with a bankfull width of more than 15 feet) or 50 feet (for waters with a bankfull width of less than 15 feet) of the outer edge of the bankfull width or CMZ, the FPHCP requires the retention of leave trees near streams in or adjacent to the harvest unit to offset those missing because of the road. Where WDNR identifies leave-tree limitations, the FPHCP prescribes site-specific management strategies to replace lost riparian functions. Such management strategies may include placement of LWD in streams.

Outer Zone

The outer zone begins at the outside edge of the inner zone and its width depends on site class and bankfull width (see FPHCP Tables 4.9 and 4.10). Timber harvest is allowed in the outer zone. Harvests must retain riparian leave trees depending on the timber habitat type. In the ponderosa pine timber habitat type, a minimum of 10 dominant or co-dominant trees per acre must be retained. In the mixed conifer timber habitat type, a minimum of 15 dominant or co-dominant trees per acre must be retained. Finally, requirements for high-elevation timber habitat type follow those for western Washington RMZs for Type S and Type F waters (e.g., 20 trees per acre).

Minimum tree counts must be met regardless of stream-adjacent parallel road presence. Outer zone leave-tree requirements for eastern Washington RMZs for Type S and Type F waters may be reduced to 5 trees per acre in the ponderosa pine timber habitat type, 8 trees per acre in the mixed-conifer timber habitat type and 10 trees per acre in the high-elevation timber habitat type if the landowner implements a LWD placement plan consistent with guidance contained in Forest Practices Board Manual Section 26.

Type Np and Type Ns Waters

As in western Washington, the FPHCP protection measures for non-fish-bearing waters in eastern Washington include ELZs adjacent to Type Np and Type Ns waters, RMZs adjacent to Type Np waters, and mitigating the effects of stream-adjacent parallel roads within RMZs of Type Np waters. ELZs would apply to all Type Np and Type Ns waters, are 30 feet wide and are measured from the bankfull width. As for ELZs in western Washington, operations exposing soil on more than 10 percent of a site in an ELZ requires mitigation. Mitigation will include replacing the equivalent lost riparian function, particularly as it relates to the prevention of sediment delivery. Example measures include—but are not limited to—water bars, grass seeding and mulching.

RMZs for Type Np waters in eastern Washington consist of 50-foot wide RMZs on each side of the water. The FPHCP does not proscribe management strategies (i.e., partial or clearcutting) within these RMZs, except that the clearcutting option is not provided within 500 feet of a Type S or Type F confluence. For partial cuts, the FPHCP requires the same minimum basal area requirements as it does for Type S and Type F inner zones (see FPCHP, pp 184-188). For clearcut management, the FPHCP requires a 50-foot wide no-harvest RMZ along each side of a stream reach in the harvest unit. The RMZ must be equal in total length to the unbuffered portion of the stream reach in the harvest unit. Unbuffered portions may not exceed 30 percent of the stream length within the harvest unit. On a harvest unit basis, no more than 30 percent may be unbuffered, another 30 to 70 percent may be contained in no-harvest buffers, and up to another 40 percent may be partial harvest buffer. It is also possible for greater portions of the stream length to be managed with partial-harvest buffers.

Stream-Adjacent Parallel Roads within Type Np Riparian Management

If a road exists in a Type Np RMZ, and the basal area required to be left cannot be met within 50 feet of the outer edge of bankfull width of the stream due to the presence of the road, then the distance of the road to the stream determines the allowable harvest. If the edge of the road closest to the water is between 30 feet and 49 feet from the outer edge of the bankfull width, a total of 100 feet of RMZ (both sides of the stream count towards the total) must be left in a manner to provide maximum functions. If harvest is occurring on only one side of the water, an RMZ that is 50 feet wide must be retained that does not include the width of the stream-adjacent parallel road. If the edge of the road closest to the water is less than 30 feet from the outer edge of the bankfull width, in addition to the previous requirement, all trees between the water and the edge of the road closest to the water must also be retained.

Exempt Parcels

State law exempts parcels that are 20 contiguous acres or less and are owned by individuals whose total ownership is less than 80 forested acres statewide. These parcels are not subject to certain FPHCP riparian requirements. However, State law requires RMZs for Type S and Type F waters. The RMZ width cannot be less than 29 feet measured from the bankfull width (as opposed to bankfull width or CMZ as with standard Washington Forest Practices Rules) nor more than the maximum widths listed in FPHCP Table 4.7. When the RMZ overlaps a Type A or B wetland or wetland management zone (see Section 4d), the measure that best protects public resources must be applied.

Leave-tree requirements for Type S and Type F waters on exempt 20-acre parcels in western Washington are listed in FPHCP Table 4.8. The required ratio of conifer to deciduous leave trees—and the number and minimum diameters of leave trees—varies with water type and bankfull width. The number of leave trees also differs between gravel/cobble-bedded waters and boulder/bedrock waters. Landowners must still meet shade requirements on Type S or Type F streams as outlined in WAC 222-30-040; however, the 75-foot shade requirement would be measured from the bankfull width.

Along Type Np waters, WDNR can require tree retention on exempt 20-acre parcels where necessary to protect public resources. Washington Forest Practices Rules authorize WDNR to require the retention of at least 29 trees, 6 inches dbh, on each side of every 1,000 feet of stream length within 29 feet of the stream. More information on riparian protection on exempt 20-acre parcels in western Washington is contained in WAC 222-30-023(1).

In eastern Washington, RMZs for Type S and Type F waters in exempt parcels associated with partial harvests cannot be less than 35 feet or more than 58 feet. For other harvest types, buffers cannot be less than 35 feet, must average 58 feet, and are limited to a maximum width of 345 feet. Leave-tree requirements apply to these zones. When the RMZ overlaps a Type A or B wetland or wetland management zone, the measure that best protects public resources must be applied.

However, for eastern and western Washington, an exemption exists for situations where greater than 10 percent or more of the harvest unit lies within any combination of a riparian management zone of a Type S or F water, or a wetland management zone, then only 50 percent of the required trees must be left. Even so, the shade rules still apply.

Along Type Np waters in eastern Washington, WDNR can require tree retention on exempt 20-acre parcels where necessary to protect public resources. Washington Forest Practices Rules authorize WDNR to require the retention of 29 trees of at least 6 inches dbh on each side of every 1,000 feet of stream length within 29 feet of the stream.

Statewide Requirements

In addition to the riparian protection measures that are specific to western and eastern Washington, the Washington Forest Practices Rules include riparian requirements that apply throughout the State. These include requirements for the retention of shade along Type S and Type F waters, restrictions on the salvage of down trees and woody debris, and requirements for the maintenance of streambank stability. Each set of protection measures is described below.

Shade Retention

Shade requirements differ for forestlands within the Bull Trout Overlay and lands outside the Bull Trout Overlay. The Bull Trout Overlay includes portions of eastern Washington streams containing bull trout habitat as identified on FPHCP Figure 4.7. Within the Bull Trout Overlay, all available shade must be retained within 75 feet of the bankfull edge or CMZ edge, whichever is greater.

Outside of the Bull Trout Overlay, a temperature-prediction method must be used to determine shade requirements. The temperature-prediction method is used to establish the shade level necessary to meet the temperature standard. If pre-harvest shade levels do not meet the shade requirement, no harvest is allowed within 75 feet of the bankfull edge or CMZ edge. If pre-harvest shade levels exceed the shade requirement, harvest in the RMZ inner zone is allowed provided that shade levels are not reduced below the minimum required and that all other applicable rules are met. If anti-degradation standards under the State water quality standards are modified in the future, we expect that the Washington Forest Practices Rules would be modified as needed.

Salvage Logging

Washington Forest Practices Rules protect ecological functions and associated habitats by restricting salvage of down wood in typed waters, CMZs, and RMZs. Salvage logging is not allowed within the bankfull width of any typed water or within a CMZ, including salvage logging of any portion of a tree that may have fallen from outside the zone. Salvage logging within an RMZ for a Type S or Type F water is based on the sub-zone (core, inner, and outer zones) from which the tree originated, applicable stand requirements, and extent of previous harvest activity in the zone (FPHCP Table 4.11). Salvage logging is not allowed within an RMZ for Type Np water or associated sensitive site, but may occur adjacent to Type Ns waters and the unbuffered portions of Type Np waters.

Streambank Integrity

Activities in the RMZ core zone for Type S and Type F waters and in RMZs for Type Np waters must ensure streambank integrity is maintained. Activities must avoid disturbing stumps, root systems, and any logs embedded in the streambank, as well as brush and other similar understory vegetation. Where necessary, high stumps must be left to prevent felled and bucked timber from entering the water. Trees with large root systems embedded in the stream bank must also be left.

3.3.3.3 FPHCP Wetland Protection Strategy

The FPHCP includes measures to avoid, minimize, and mitigate forest practices-related impacts to wetland habitats. Measures are intended to protect important ecological functions such as LWD recruitment, shade retention, sediment filtration, and the maintenance of surface and shallow subsurface hydrology. Protection measures include a wetland typing system, a wetland management zone (WMZ) adjacent to Type A and Type B wetlands, and the use of low-impact harvest systems in forested wetlands. Wetland protection measures are the same statewide.

Wetland Typing System

The FPHCP covers two broad categories of wetlands: forested and non-forested. Forested wetlands include any wetland or portion thereof that has—or if the trees present were mature would have—at least 30 percent canopy closure. Non-forested wetlands include any wetland or portion thereof that has—or if the trees present were mature, would have—less than 30 percent canopy closure. Non-forested wetlands are classified as either Type A or Type B. Type A wetlands include all non-forested wetlands greater than 0.5 acre in size, including any acreage of open water where the water is completely surrounded by the wetland, and are associated with at least 0.5 acre of ponded or standing open water. The open water must be present on the site for at least seven consecutive days between April 1 and October 1, or are bogs greater than 0.25 acre in size. Type B wetlands include all other non-forested wetlands greater than 0.25 acre in size.

Protection Measures for Forested Wetlands

The FPHCP allows harvest in forested wetlands. Harvest is limited to low-impact harvest systems to minimize effects on soils and hydrology. Low-impact harvest systems generally include ground-based equipment with tracks (e.g., shovel), cable-yarding machines, helicopters, and balloons. Also, when yarding logs, operators must keep at least one end of the log suspended when feasible.

When forested wetlands lie within a proposed harvest unit, landowners are encouraged to leave 30 to 70 percent of required wildlife reserve trees within the wetland. Wildlife reserve trees are defective, dead, damaged, or dying trees that provide or have the potential to provide habitat for wildlife species dependent on standing trees. In western Washington, the Washington Forest Practices Rules require the retention of three wildlife reserve trees and two green recruitment trees (i.e., trees left for the purpose of becoming future wildlife reserve trees) for each acre harvested. In eastern Washington, two wildlife reserve trees and two green recruitment trees must be retained for each acre harvested.

Protection Measures for Non-Forested Wetlands

Protection measures for Type A and Type B non-forested wetlands include limitations on harvesting in the wetlands. Harvest is not allowed in a Type A wetland that meets the definition of a bog. Individual trees or forested wetlands less than 0.5 acre in size that occur within a non-forested wetland, must be retained. They may be counted toward the WMZ leave tree requirement (see below). Harvest of upland areas or forested wetlands surrounded by a Type A or Type B wetland must be conducted in accordance with a plan that has been approved by WDNR in writing. No trees can be felled into or yarded across a Type A or Type B wetland without written approval from WDNR.

Non-forested wetlands are also protected through WMZ. WMZs must be established adjacent to all Type A and B wetlands. They are measured horizontally from the wetland edge or the point where the non-forested wetland becomes a forested wetland (see Forest Practices Board Manual Section 8 for delineation procedures). The required WMZ width depends on the wetland type and size. The average WMZ width must meet the requirement listed in FPHCP Table 4.12. To meet the average width, it can vary from the minimum width to the maximum width listed in FPHCP Table 4.12. When a WMZ overlaps an RMZ, the requirement that best protects public resources must be applied.

Harvest is allowed within WMZs according to several conditions. At least 75 trees per acre must be retained. These 75 trees should be greater than 4 inches in eastern Washington or 6 inches for western Washington. Of those 75 trees, 25 trees shall be greater than 12 inches dbh, of which 5 trees shall be greater than 20 inches dbh, where they exist. Leave trees shall be representative of the species found within the WMZ. The Washington Forest Practices Rules encourage that wildlife reserve trees should be located within the WMZ where feasible.

Partial cutting or removal of groups of trees within the WMZ is acceptable, within constraints of maximum width and spacing. Tractors, wheeled skidders, or other ground-based harvest equipment is not allowed within the minimum WMZ width without written approval from WDNR. And finally, when at least ten percent of a harvest unit lies within a WMZ, and either the harvest unit is a clearcut of 30 acres or less or the harvest unit is a partial cut of 80 acres or less, at least 50 percent of the 75 trees-per-acre requirement must be retained within that WMZ.

3.3.3.4 Protective Approaches in Logging Practices

The FPHCP includes protection measures that regulate the methods of harvest in riparian and wetland areas. Measures include limits on the felling and bucking of timber, on the use of ground-based equipment, and on cable yarding. Many of these measures are designed to minimize soil disturbance and reduce the potential for erosion and sedimentation and maintain other ecological functions as described below.

Felling and Bucking

Felling trees and bucking logs (cutting felled trees to length) in or adjacent to typed waters and RMZs must be conducted in a manner that protects riparian and in-stream habitat and water quality. Limitations on felling include no felling into the RMZ core zone of Type S or Type F waters, sensitive sites, or Type A or Type B wetlands. There is a limited exception for safety. Within the RMZ inner and outer zones of Type S and Type F waters, and within WMZ, felling must facilitate yarding away from typed waters. Trees may be felled into Type Np waters, but logs must be removed as soon as practical. Slash introduced to the Type Np water as a result of the falling must be removed. Reasonable care must be taken to fell trees in directions that minimize damage to residual trees. Bucking or limbing of any portion of a tree lying within the bankfull width of a Type S, Type F, or Type Np water; in the core zone of RMZs, in sensitive sites, or in open water areas of Type A or Type B wetlands is not allowed.

Ground-based Equipment

Ground-based equipment use is prescribed to limit direct physical impacts to waters and wetlands and to minimize indirect impacts such as soil disturbance and associated erosion and sedimentation. Ground-based equipment is not allowed in Type S or Type F waters except with approval by WDNR and with an HPA issued by WDFW. Ground-based transport of logs across Type Np and Type Ns waters must minimize the potential for damage to public resources, and an HPA may be required. For Type A and Type B wetlands, ground-based equipment is not allowed. Where harvest occurs in forested wetlands, ground-based logging is limited to low-impact harvest systems. Ground-based equipment operating in wetlands is only allowed during periods of low soil moisture or frozen soil conditions.

In RMZs, use of ground-based equipment within an RMZ must be approved in writing by WDNR. When yarding logs in or through an RMZ with ground-based equipment, the number of routes through the zone must be minimized. Logs must be yarded to minimize damage to leave trees and vegetation in the RMZ.

In WMZs, ground-based equipment is not allowed within the minimum WMZ width unless approved in writing by WDNR. Where feasible, logs must be skidded with at least one end suspended from the ground to minimize soil disturbance and minimize damage to leave trees and vegetation in the WMZ.

Finally, skid trails must be sized, shaped, and located to minimize the contribution to overland sediment transport, through erosion and other means. Placement of side-cast material is limited to above the 100-year flood level. Skid trails running parallel or near parallel to waters must be located outside the no-harvest portions of RMZs and at least 30 feet from the bankfull edge of unbuffered portions of Type Np or Ns waters, unless approved in writing by WDNR. Skid trails must cross the drainage point of swales at an angle that minimizes the potential for delivering sediment to typed waters or where channelization is likely to occur. Skid trails out of use must be water-barred to prevent soil erosion. Skid trails located within 200 feet of any typed water that directly delivers to the stream network must have water bars, grade breaks, and/or slash to minimize sediment delivery to the water. Water bars must be placed at a frequency that minimizes gullying and soil erosion. In addition to water barring, skid trails with exposed, erodible soil that may be reasonably expected to cause damage to a public resource must be seeded with a non-invasive plant species (preferably native to the State) and adapted for rapid revegetation of disturbed soil, or be treated with other erosion control measures acceptable to WDNR.

Cable Yarding

No cable yarding in or across Type S or Type F waters, except where logs will not materially damage the bed of waters, banks of sensitive sites or RMZ. Yarding corridors through RMZ of a Type S or Type F water must be no wider or more numerous than necessary to accommodate safe and efficient transport of logs. On Type S or Type F streams, logs must be fully suspended unless exempted by an HPA. On Type Np or Ns streams, logs must be fully suspended unless exempted by a Forest Practices permit. When yarding logs across flowing Type N waters, the log must be fully suspended. A Forest Practices permit cannot be used to allow partial-suspension yarding across flowing waters. Generally, yarding corridors should be located at least 150 feet apart (measured edge to edge), and each should be no wider than 30 feet. Total openings resulting from yarding corridors must not exceed 20 percent of the stream length associated with the forest practices application. When changing cable locations, care must be taken to move cables around or clear of the riparian vegetation to avoid damaging it. In Type A and Type B wetlands, cable yarding is not allowed without written approval from WDNR.

Yarding from or across FPHCP protected areas requires reasonable care to minimize damage to the vegetation that provides shade to the water, and to minimize disturbance to understory vegetation, stumps, and root systems. Uphill yarding is preferred. Where downhill yarding is used, reasonable care must be taken to lift the leading end of the log to minimize downhill movement of slash and soils. When yarding parallel to a Type S or Type F water, and below the 100-year flood level or within the RMZ, reasonable care must be taken to minimize soil disturbance and to prevent logs from rolling into the water or RMZ.

3.3.3.5 Other Programs for Riparian Protection

The FPHCP includes two programs that provide for the long-term conservation of riparian and aquatic habitats. The Forestry Riparian Easement Program and the Riparian Open Space Program were established to acquire, through purchase or easement, the most ecologically important habitats for species covered under the FPHCP. Unlike most FPHCP protection measures, the Forest Riparian Easement Program and Riparian Open-Space Program are voluntary programs that complement the mandatory requirements of the Washington Forest Practices Act and Rules. As part of the complete set of protection measures, these voluntary programs will help ensure that the Forest Practices program meets its goals, resource objectives and performance targets.

Forestry Riparian Easement Program

The Forestry Riparian Easement Program provides long-term protection for aquatic resources by acquiring easements from small forest landowners in riparian areas and other ecologically important areas. Easement areas typically include CMZs, RMZs, and WMZs, but may also include other areas, such as unstable slopes. Landowners interested in participating in the Forestry Riparian Easement Program must meet the definition of a “small forest landowner,” which is related to his/her prior 3-year average harvest level. Forestry Riparian Easement Program easements apply to “qualifying timber” and not the land on which the trees grow. “Qualifying timber” is trees that are covered by a forest practices application and that the small forest landowner is required to leave unharvested for the duration of the easement (i.e., 50 years). Landowners are compensated for the value of the qualifying timber between 50 and 100 percent of the value. This easement provides no public access to the property. The landowner may remove timber that is not part of the qualifying timber with the inner zone.

Riparian Open Space Program

Riparian Open Space Program ensures the long-term conservation of aquatic resources by acquiring a fee interest in, or easement on, lands and timber within a specific type of CMZ known as an “unconfined avulsing CMZ.” These areas typically have very high ecological value as spawning and rearing habitat for salmon and other fish species. Under the Washington Forest Practices Rules, no timber harvesting or road construction may occur within CMZs due to their ecological importance. The Riparian Open Space Program provides financial compensation for landowners with these types of CMZs who voluntarily sell the land to WDNR or place a permanent easement on the trees, land, or both. Participation is based on available WDNR funding and priorities.

3.3.3.6 Upland Protection and Roads

The FPHCP Upland Strategy consists of protection measures that are implemented in upslope areas outside riparian zones and wetlands. These measures are intended to limit forest practices-related changes in physical watershed processes—such as erosion and hydrology—that may adversely affect the quality and quantity of riparian and aquatic habitat lower in the watershed. The goal of the Upland Strategy is to prevent, avoid, minimize, or mitigate forest practices-related changes in erosion and hydrologic processes and the associated effects on public resources. Specific objectives of the Upland Strategy include preventing forest practices-related landslides, addressing the affects of forest roads on fish passage at all life stages, limiting sediment delivery to all typed waters, surface water and other hydrologic management, woody debris passage, protecting streambank stability, minimize the construction of new roads, and ensure that there is no net loss of wetland function.

Unstable Slopes

Protection measures related to unstable slopes and landforms are outcome-based, rather than prescriptive. Measures are derived through process in which, WDNR evaluates proposed timber harvest and road-construction activities on unstable slopes to determine if the activities will have a "probable significant adverse impact." The only exception to this outcome-based, decision-making process occurs in areas where watershed analysis has been conducted and approved, management prescriptions are in place to address unstable slopes, the prescriptions are specific to the site or situation and do not call for additional analysis, and the prescriptions are followed on the proposed activities.

The FPHCP recognizes four classes of unstable slopes: 1) landforms typically associated with debris avalanches, flows, and torrents (inner gorges, bedrock hollows, and convergent headwalls with slopes greater than 35 degrees or 70 percent); 2) landforms susceptible to debris avalanches (toes of deep-seated landslides with slopes greater than 33 degrees or 65 percent and the outer edges of meander bends along valley walls or high terraces of unconfined meandering channels); 3) groundwater-recharge areas of deep-seated landslides in glacial sediments; and 4) areas with indicators of potential slope instability that cumulatively indicate the presence of unstable slopes.

The FPHCP summarizes the process through which unstable slopes are identified in forest practices applications, and the procedures by which management practices are derived for each area identified. When unstable slopes are identified, the application must include an expert geotechnical assessment. WDNR staff also conduct an evaluation of proposals involving unstable slopes.

After review, WDNR issues a decision under the SEPA considering several issues. The first is if the proposal is likely to increase the probability of mass movement on or near the site. The second issue is whether sediment or debris would be delivered to a public resource or be delivered in a manner that would threaten public safety. Finally, the WDNR will consider whether such movement and delivery are likely to cause significant adverse impacts.

If WDNR determines the effects are likely to be significant under SEPA, the WDNR will accord mitigation measures. These will range from avoiding unstable slopes to altering the methods or techniques used in timber harvest and/or construction operations. Unstable slopes avoidance is the most commonly used mitigation measure and results in the lowest hazard and risk. Where timber harvest and/or construction activities occur on unstable slopes, a variety of mitigation measures are employed to reduce the likelihood of mass wasting. Harvest-related mitigation measures typically include minimum stand-density requirements to maintain rooting strength and slope hydrology, and full-suspension log yarding to reduce soil disturbance and damage to residual vegetation. Construction-related mitigation measures often relate to the design and/or location of roads and landings. Full-bench end-haul (i.e., no fill or side-cast material) construction techniques are routinely required on unstable slopes. Where fill material is necessary, the use of quarried rock rather than "native" soil or fill is often required to increase the structural strength of road prisms and stream crossings. These are just a few examples of the many mitigation measures used to address unstable slopes issues. The measures used in a given situation are dependent upon the nature of the impact being mitigated.

Forest Roads

The FPHCP includes the Washington Forest Practices Rules that are designed to minimize negative road impacts through the proper location, design, construction, maintenance, and abandonment of forest roads.

Location and Design

Roads must fit to the topography to minimize alteration of natural features. This includes avoiding at-risk areas such as surface waters, wetlands, CMZs, RMZs, sensitive sites, unstable slopes, and ELZs. The FPHCP prohibits new road construction that would lead to duplicative or unnecessary roads. Design standards are mainly related to construction techniques and water management. The FPHCP encourages road designs that utilize balanced cut-and-fill construction to avoid side-casting of excess fill material. In steep terrain (>60 percent slopes), the FPHCP requires "full-bench" designs in which no fill material is used to construct the road prism and waste material is end-hauled or over-hauled to stable locations (e.g., on slopes less than 60 percent). Water-management requirements focus on maintaining hydrologic flow-paths and minimizing sediment delivery by limiting road-induced rerouting of water. Forest practices under the FPHCP include design standards for culvert sizing and drainage-structure spacing. The Washington Forest Practices Rules also require that roads be designed so that ditch water is relieved onto the forest floor to facilitate infiltration and minimize sediment delivery.

Construction

Road-construction requirements focus on maintaining stable road prisms and water-crossing structures, and on minimizing sediment delivery to surface waters and wetlands. The requirements are also intended to limit impacts to habitat during the construction process. New roads must maintain stable, intact prisms and water crossing structures to control erosion and sediment delivery. Road prism-related measures include limiting the volume of organic matter that can be incorporated into the road prism, compacting fills, removing construction-related debris and slash from culvert inlets, installing ditches and drainage structures concurrent with construction, depositing waste materials in stable locations and preventing side-casting of excess fill material on steep slopes. Measures that focus on maintaining the stability of water-crossing structures require the installation of structures that pass the 100-year flow, the construction of fills and embankments to withstand the 100-year flow, and the construction of headwalls and catch basins to accommodate the 100-year flow.

Road-construction measures in the FPHCP are designed to minimize sediment delivery from roads during and after construction. Requirements include limiting construction to periods of low soil moisture, end-hauling or over-hauling of waste material when side-casting would deposit sediment in areas where delivery to waters or wetlands may occur, sloping roads and landings to prevent water accumulation, and stabilizing exposed soils by seeding or other techniques approved by WDNR. If WDNR determines that the installation of a water crossing structure would result in unacceptable water quality impacts, the agency may require flow diversion around the site during construction.

Construction must also minimize impacts to riparian and in-stream habitats. The channel bed, stream banks, and riparian vegetation disturbance will be minimized. Disturbed areas must be stabilized and restored according to established schedules and procedures.

Maintenance and Abandonment

The FPHCP includes a road maintenance and abandonment program to prevent sediment- and hydrology-related impacts to public resources. Forest landowners must operate according to Road Maintenance and Abandonment Plans (RMAP) for roads within their ownership. Planning requirements differ for small and large forest landowners.

Large Landowners

The FPHCP requires large forest landowners to prioritize road maintenance and abandonment planning based on a "worst first" principle. Prioritization criteria include: 1) the presence of Federal or State listed threatened or endangered fish species or 303(d) listed water bodies; 2) the presence of sensitive geologic formations with a history of mass wasting; 3) the presence of planned or ongoing restoration projects; and 4) the presence of roads likely to have a high amount of forest-practices use in the future. Within each RMAP, maintenance and abandonment work is also prioritized: 1) removing fish blockages; 2) preventing or limiting sediment delivery; 3) disconnecting the road and stream networks; 4) repairing or maintaining stream-adjacent parallel roads; 5) restoring hydrologic flow-paths; and 6) capitalizing on operational efficiencies.

Small Landowners

Small forest landowners have two options for meeting road maintenance and abandonment planning requirements. Small forest landowners may follow the RMAP process for large landowners described above, or they may submit a "checklist" RMAP with each forest practices application or notification. Where watershed analysis has been conducted and approved, small forest landowners may elect to follow the watershed administrative unit-road maintenance plan rather than working under an RMAP. The smallest landowners (individual ownership of less than 80 acres of forestland in Washington and an application to operate on 20 acres or less) are not required to submit an RMAP or checklist RMAP for that parcel.

RMAP Implementation

Road maintenance and abandonment work carried out under a WDNR-approved RMAP must: 1) keep drainage structures functional, 2) divert captured groundwater from ditchlines onto stable portions of the forest floor, 3) maintain road surfaces to minimize erosion and delivery of water and sediment to typed waters, and 4) slope or waterbar road surfaces to prevent water accumulation. When abandoning roads, landowners must slope or waterbar roads to minimize erosion and maintain drainage, leave ditches in a condition that minimizes erosion, block roads so that 4-wheel off-road vehicles cannot pass the point of closure, and remove water-crossing structures and fills.

Practices Addressing Rain-on-Snow

The FPHCP addresses road-induced changes in hydrology by establishing standards for road construction, maintenance, and abandonment in areas affected by snowmelt. The Washington Forest Practices Rules address rain-on-snow effects in two ways in areas that have either undergone watershed analysis or have not. Watershed analysis in Washington State includes an assessment of timber-harvest-induced changes in rain-on-snow generated peak flows and potential impacts to fish habitat, water quality, and public capital improvements. Specific management prescriptions are developed to address rain-on-snow effects in parts of the Watershed Analysis Unit (WAU) where significant hydrologic change is likely to occur and resources are sensitive to those changes. Prescriptions typically involve limits on clearcut harvesting.

Where watershed analysis has not been performed, a forest practices rule commonly known as the "rain-on-snow rule" gives WDNR authority to set conditions on permits for forest practices applications and notifications that propose clearcut harvesting in the significant rain-on-snow zone. Under the rain-on-snow rule, WDNR may limit clearcut size when it determines that peak flows have caused material damage to public resources including water, fish, wildlife, and public capital improvements. WDNR has prepared conditioning guidelines for implementing the rain-on-snow rule (FPHCP Appendix M). The guidelines describe the process for evaluating forest practices applications and notifications, and rely on a risk-based approach when conditioning clearcut size. Maximum clearcut size decreases as the risk of rain-on-snow effects increases. The guidelines direct applicants and WDNR to consider alternatives to clearcutting in high-risk situations.

3.3.3.7 Alternate Plans

An alternate plan is a tool forest landowners can use to develop site-specific management plans for forest practices regulated under the Forest Practices Act. WAC 222-12-0401 describes the alternate plan process, including their review by interdisciplinary teams. An alternate plan may deviate from the standard Washington Forest Practices Rules, as long as the plan provides public resource protection at least equal in overall effectiveness to the protections afforded by the Washington Forest Practices Act and Rules. Each plan must contain: 1) a map of the area covered; 2) a description of how the alternate plan provides public resource protection to meet the WDNR approval standard; 3) a list of the Washington Forest Practices Rules that the alternate plan is intended to replace; 4) descriptions of any monitoring or adaptive management strategies associated with the plan; 5) a description of an implementation schedule; and 6) justification showing that sufficient common physical characteristics exist for forest practices applications submitted separately under the same alternate plan.

Upon receipt of a forest practices application associated with an alternate plan, WDNR appoints an interdisciplinary team to determine if the plan provides resource protection at least equal in overall effectiveness to the protections afforded by the Washington Forest Practices Act and Rules. The composition of the interdisciplinary team is determined by WDNR; however, representatives of FWS, NMFS, WDFW, WDOE, and affected Native American Tribe are invited to participate. The team determines if the proposal meets the WDNR approval standard. If the interdisciplinary team provides WDNR with a consensus recommendation regarding alternate-plan approval, conditional approval, or disapproval, the agency is directed to give substantial weight to that recommendation when making its decision.

Guidelines for alternate plans are in the Washington Forest Practices Rules and Board Manual and include template prescriptions specific for small forest landowners. Template prescriptions are prescriptions for common situations that are repeatedly addressed in alternate plans. If a small landowner chooses to follow a template, the standardization of a template alternate plan will make the plan layout and approval process more efficient, while continuing to maintain protection of public resources. An example of a small forest landowner template is provided for overstocked conifer stands in western Washington (Forest Practices Board Manual section 21). The template includes a forest practices application for the overstocked stand template that small forest landowners would fill out and submit to

WDNR when proposing harvest in an overstocked conifer stand. The forest practice application includes information on how the prescriptions in this alternate-plan template provide for public-resource protection at least equal in overall effectiveness to the protections afforded by the Washington Forest Practices Act and Rules.

It is anticipated that the alternate-plan process for large and small forest landowners will continue to evolve and improve over the life of the FPHCP. Alternate plans for small forest landowners may incorporate longer timeframes and encompass a landowner's entire forestland property. WDNR's approval criteria for longer-term management plans will be developed in conjunction with the Federal agencies and will meet Federal ESA requirements. WDNR is responsible for conducting audits of landowners' compliance with the terms of alternate plans. The audit includes review and approval of each landowner's scheduled performance reports (either in the office or on-site) when a performance report is required. The audits will be consistent with the terms of any agreements with the Federal government regarding the protection of fish and water quality.

3.3.4 Administrative Framework within the FPHCP

The FPHCP administrative framework is the structure within which program participants work cooperatively to develop, implement, and refine the Forest Practices program over time. The four administrative components are: 1) program participants; 2) program development; 3) program implementation; and 4) adaptive management. The first three components are briefly summarized below.

Participants in the Forest Practices program include the Washington Forest Practices Board, certain programs within the WDNR, the Forest Practices Appeals Board, cooperating agencies, Native American Tribes, other natural-resource organizations, and the general public. These entities do the work of the program. They develop, implement, and refine the Forest Practices program to help it meet its goals.

Program development includes the processes by which the Washington Forest Practices Rules, Forest Practices Board Manual guidelines, internal policies, and technology-based tools are created. Forest practices activities conducted on covered lands must adhere to the Washington Forest Practices Rules; therefore, the rules represent the habitat-protection measures for covered species. Forest Practices Board Manual guidelines, WDNR internal policies, and technology-based tools supplement the protection measures by providing WDNR staff, forest landowners, and cooperating agencies and organizations with additional direction and information related to rule implementation.

Forest Practices program implementation follows program development. Once new or revised Washington Forest Practices Rules, Forest Practices Board Manual guidelines, internal policies, and technology-based tools have been developed, WDNR works with those program participants affected by the change to implement the new program components. This typically includes forest landowners who must comply with provisions of the Washington Forest Practices Act and Rules, and cooperating agencies and organizations that support WDNR in program implementation.

3.3.4.1 Adaptive Management and Program Refinement

The FPHCP includes a formal, structured adaptive management program that includes each of these components. The Services define adaptive management as a method for examining alternative strategies for meeting measurable biological goals and objectives and then, if necessary, adjusting future conservation management actions according to what is learned. The Services require an adaptive management strategy for HCPs that pose a significant risk to covered species at the time a Permit is issued due to significant data or information gaps. The adaptive management strategy should: 1) identify the uncertainty and the questions that need to be addressed to resolve the uncertainty; 2) develop alternative strategies and determine which experimental strategies to implement; 3) integrate a monitoring program that is capable of detecting the necessary information for strategy evaluation; and 4) incorporate feedback loops that link implementation and monitoring to a decision-making process that results in appropriate changes in management. The FPHCP adaptive management approach follows the Services definition and requirements. The adaptive management program, like the broader Forest Practices program, consists of multiple components, each of which has a specific role in the adaptive management process. The following sections describe the components of the adaptive management program, the process by which adaptive management occurs, and the research and monitoring programs currently underway.

Components of the Adaptive Management Program

The Washington Forest Practices Rules instruct the Forest Practices Board to manage three adaptive management program participants: TFW Policy Committee (Policy); the Cooperative Monitoring, Evaluation, and Research (CMER) Committee; and the Adaptive Management Program Administrator (Administrator). The adaptive management program is divided into three functions: Policy; Science; and Implementation. WDNR is responsible for implementation.

The Forest Practices Board, established under the Act, is an independent State agency that establishes the Washington Forest Practices Rules. By law, the 12-member Board is constituted as follows: Commissioner of Public Lands (an elected official), four State Agency Directors, one elected member of a county commission or council (and appointed by the Governor), and six members of the general public, each of whom serves a four-year term after being appointed by the Governor. The law requires that one of those members own less than 500 acres of forest land; another member must be an independent logging contractor.

The Forest Practices Board manages the adaptive management program. The Board approves CMER Committee members, establishes key research and monitoring questions and resource objectives, approves research and monitoring priorities and projects, approves CMER budgets and expenditures, oversees fiscal and performance audits of CMER, participates in the dispute resolution process and considers recommendations from Policy for adjusting the Washington Forest Practices Rules and Board Manual guidance.

Policy makes recommendations to the Forest Practices Board regarding CMER priorities and projects, final project reports and the Washington Forest Practices Rule and/or Board Manual guidance amendments. Policy membership is self-selecting and generally includes the WDNR, WDFW, and WDOE; Federal agencies (including NMFS, FWS, EPA, and the USDA Forest Service (Forest Service)); forest landowners; Native American Tribes; local governments; environmental interests; and the Governor’s office.

The CMER oversees and conducts research and monitoring related to Forest Practices program goals, resource objectives and performance targets. Its purpose is to advance the science needed to support the adaptive management process. CMER is charged with developing and managing, as appropriate: 1) scientific advisory groups and sub-groups; 2) research and monitoring programs; 3) a set of protocols to define and guide the execution of the CMER process; 4) a baseline dataset used to monitor change; and 5) a process for policy approval of research and monitoring projects and use of external information.

CMER is composed of individuals who have expertise in scientific disciplines to address forestry, fish, wildlife, and landscape-process issues, including mass wasting, hydrology, and fluvial geomorphology. Membership is approved by the Forest Practices Board and is open to the WDNR, WDFW, and WDOE; Federal agencies (including NMFS, FWS, and EPA); forest landowners; Native American Tribes; local governments; and environmental interests.

The Administrator is a full-time employee of WDNR and is responsible for overseeing the adaptive management program and for supporting CMER. The Administrator makes regular reports to Policy and the Forest Practices Board on program and project priorities, status, and expenditures. The Administrator has credentials as a program manager, scientist, and researcher.

CMER contracts the Scientific Review Committee (SRC) to carryout an independent, peer review process to determine if work performed by CMER is scientifically sound and technically reliable. The SRC is comprised of individuals who have experience in scientific research and who have no affiliation with CMER. SRC members are selected by the SRC coordinator and can be nominated by CMER. CMER determines what products should be subject to review by the SRC; however, the SRC generally reviews final reports of CMER studies, study proposals, final study plans, certain CMER recommendations, and pertinent studies not published in a CMER-approved, peer-reviewed journal. Other products that may require review include external information or data, work plans, requests for proposal, and progress reports.

Scientific review is conducted in a manner similar to the peer-review process used by many scientific journals. Communications are handled through the Administrator and include roles for a Managing Editor and Associate Editors. The Managing Editor receives materials from the Administrator, evaluates their readiness for review, and then transfers them to the appropriate Associate Editor. The Associate Editor selects a panel of two or three reviewers from a list developed by the Managing Editors, with nominations from Associate Editors and CMER. Forest Practices Board Manual Section 22 provides a more-detailed description of the adaptive management program and the guidelines for conducting adaptive management.

Research and Monitoring in Adaptive Management

The CMER Committee produces an annual work plan that describes the various adaptive management research and monitoring programs, associated projects, and work schedule. The plan will include several types of monitoring including Extensive, Intensive, Effectiveness, and Validation Monitoring. Effectiveness monitoring is designed to evaluate the degree to which Washington Forest Practices Rules and guidance meet performance targets and resource objectives. Validation monitoring will determine if the performance targets are appropriate for meeting the stated resource objectives. Effectiveness and validation monitoring are conducted at a site scale and generally focus on specific rule prescriptions or practices.

"Extensive" monitoring evaluates the statewide status and trends of key watershed processes and habitat conditions across lands covered under the FPHCP. Extensive monitoring is a landscape-scale assessment of the effectiveness of the Washington Forest Practices Rules to attain specific performance targets. This is different from effectiveness monitoring, which evaluates the effect of specific prescriptions or practices at the site scale. Extensive monitoring is designed to provide periodic measures of rule effectiveness that can be used in the adaptive management process to determine if progress is consistent with expectations. For example, extensive monitoring might address the question: Are higher than expected stream temperatures on covered lands decreasing with time and, if so, at what rate is the reduction occurring?

"Intensive" monitoring is a watershed-scale research program designed to evaluate cumulative effects and provide information that will improve our understanding of the interactions between forest practices and covered resources. An evaluation of cumulative effects at a watershed scale requires an understanding of how individual actions or practices influence a site and how the associated responses propagate downstream through the system. This understanding will enable the evaluation of the effectiveness of forest practices applied at multiple locations over time. Evaluating biological responses is similar and requires an understanding of how various actions interact to affect habitat conditions, and how system biology responds to habitat changes.

The FPHCP includes so-called "rule-implementation tools" that are projects designed to develop, refine, or validate protocols, models, and targets used to facilitate the implementation of the Washington Forest Practices Rules. Two types of "rule-tool" projects have been identified. First, Methodological Projects involve the development, testing, or refinement of field protocols and models used in the identification and location of important landscape features such as water-type breaks, unstable slopes, and sensitive sites. Current projects focus on developing a GIS-based, water-typing model, and a statewide landslide-hazard screen. Second, target verification projects are designed to assess the validity of performance targets thought to have an uncertain scientific foundation, such as the DFC basal-area targets for RMZs.

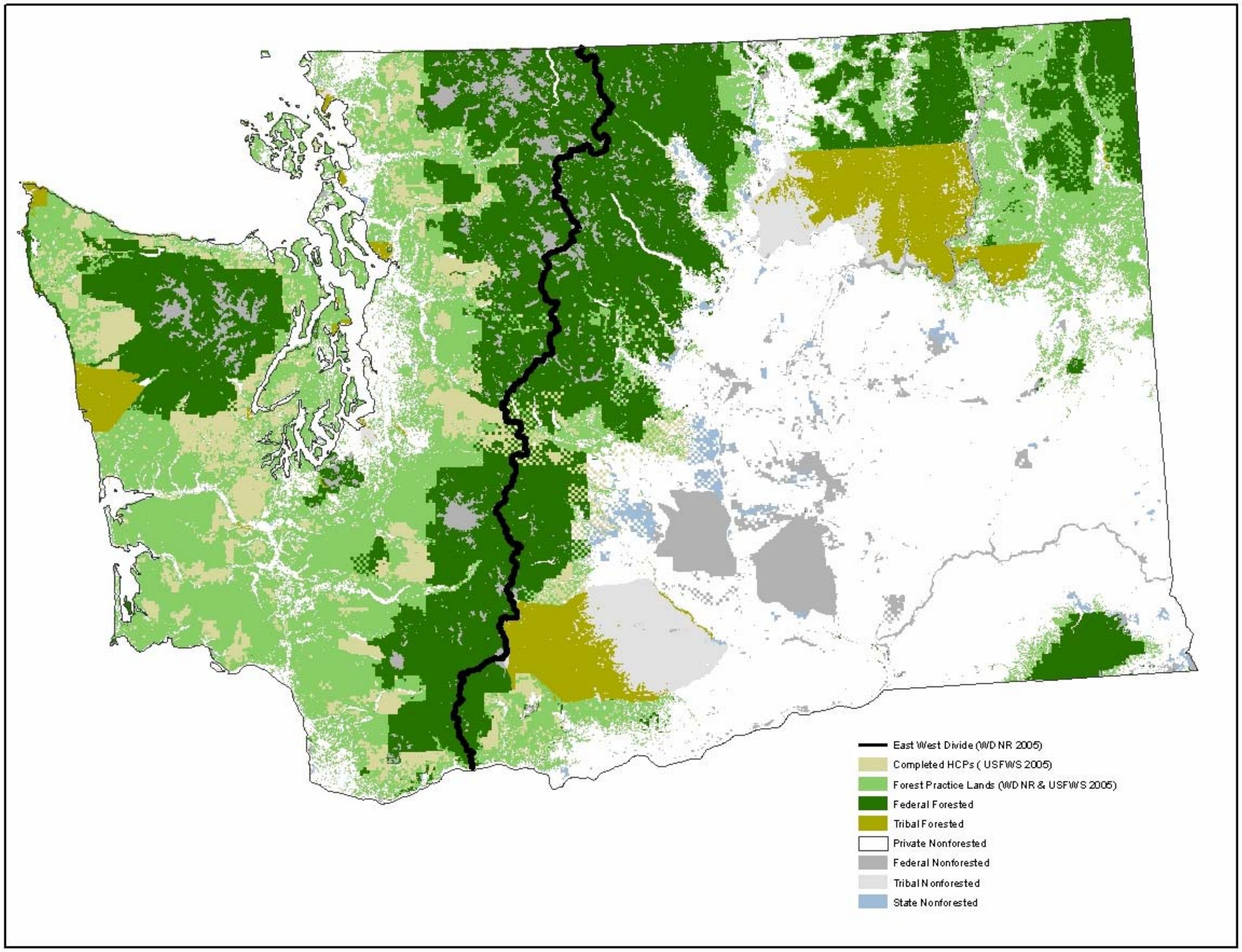
4. ACTION AREA

'Action area' means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). For purposes of this consultation, the action area includes all of the approximately 9.3 million acres of non-Federal, non-tribal forestland included as covered lands under the FPHCP; approximately 6.1 million acres of which are located west of the crest of the Cascade Range, and approximately 3.2 million acres are east of the crest of the Cascade Range in Washington (Figure 4-1). This acreage excludes all forestlands covered under existing, currently permitted HCPs with two exceptions. One is the Western Pacific Timberlands (*nee* Boise Cascade Corporation) single-species HCP that encompasses 620 acres and provides coverage for the northern spotted owl, but does not include coverage for aquatic species. The other is approximately 228,000 acres of the WDNR HCP on the eastside of the Cascade Crest of Washington. East of the Cascade Crest, the WDNR HCP provides coverage for a limited set of listed terrestrial species in this area (grizzly bears, wolves, spotted owls, and bald eagles), but does not include coverage for aquatic species. The forestlands contained within the Boise HCP and the WDNR HCP (on the eastside of the Crest) are considered covered lands under the FPHCP (FPHCP, Section 1-5 Lands covered by the plan, 2004).

Because physical effects from the proposed action may propagate onto other lands and waters, the action area also includes the following:

- The streams, rivers, and all stream-and river-associated wetlands downstream of the covered lands to the extent that physical effects such as turbidity or sedimentation may continue to be transported downstream. Although in most cases, the physical effects will cease to be measurable prior to confluence with the Columbia River, Snake River, and near-shore marine waters; however, those waters may in some cases be considered part of the action area.
- Lands surrounding the covered lands, where effects from factors such as windthrow, noise, and smoke may emanate as far as 400 feet onto those surrounding lands. The estimate of 400 feet resulted from estimated distances the above factors would travel with noticeable physical effects, and in consideration of typical distances from property boundaries that these activities would occur.

Figure 4-1. Forest lands proposed for coverage under the Forest Practices HCP, Washington



- Along roads adjacent to the covered lands, which are not on forested lands and are neither Federal or tribal lands, where roads located on adjacent lands may be subjected to additional effects resulting from hauling to and from the covered lands. These effects would only be measurable on smaller arterial and spur roads which are not generally managed for public use.

Much of the lands adjacent to covered lands are also forested (Federal, tribal, and HCP lands), but nonforested lands are also found adjacent to covered lands and may be considered to be part of the action area. As mentioned earlier, the action area may in some cases also include major rivers, lakes, and near-shore marine areas.

Finally, some FPHCP covered lands are adjacent to Canada, Idaho, and Oregon. Also, some FPHCP streams flow into Canada, Idaho, and Oregon. Therefore, minor portions of the action area may occur outside Washington State.

5. COMPREHENSIVE ENVIRONMENTAL BASELINE

Regulations implementing the Act (50 CFR § 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the action area. Also included in the environmental baseline are the anticipated impacts of all proposed Federal projects in the action area that have undergone section 7 consultation, and the impacts of State and private actions that are contemporaneous with the consultation in progress.

The proposed action directly and indirectly affects major portions of Washington State. To adequately describe the current baseline, it is necessary to discuss many of the current conditions and past and on-going activities on a statewide basis. Various statistics used to describe these conditions and activities are not available specifically for the action area alone. This section of the Opinion will first describe a broad set of conditions and activities within Washington State. Much of the background provided in this section will provide a foundation for discussions regarding the context in which project-related effects are assessed and will provide information to be used in assessing cumulative effects.

The landscapes in the state of Washington are diverse: ranging from coastal rain forests, lowlands, and rich marine and estuarine habitats along the coast and Puget Sound in western Washington to prairies, forests, agricultural fields, and semi-deserts in eastern Washington. The Olympic Mountains and the Cascade Range, along with several volcanic mountains, contribute to the vast climatic differences in the state, creating rain shadows in some areas, and supporting rainfall amounts of over 180 inches per year in other areas. The State also contains numerous rivers, the largest of which, the Columbia River, flows over 1,200 miles and connects two countries and seven states to the Pacific Ocean.

The numerous ecosystems in Washington State support many different species of biota, including at least 140 mammal species, 470 freshwater and saltwater fish species, 341 bird species, 150 additional vertebrate species, 20,000 invertebrate species, and 3,100 vascular plants (Carlson 2005). Animal species may be permanent or seasonal residents of the state, with some using the available habitat as a resting and foraging stopover during migration to other areas.

5.1 POPULATION GROWTH AND DEVELOPMENT

Population growth in Washington affects the natural resources of this state on a day-to-day basis. As numbers of people increase, the demand for and use of natural resources increases, resulting in conversion of lands and the extraction and expenditure of numerous types of resources for residences, employment centers, recreation opportunities, utilities, and associated new or expanded infrastructure to support this development. This section and the following sections will discuss population growth and associated development in Washington State, as well as some of the changes that have occurred as a result of population pressure.

Between 1990 and 2000, Washington's population grew by 1,027,452 people to a total of 5.9 million (U.S. Census Bureau). Approximately 62.7 percent of the state's population growth resulted from net migration (WSDH 2002). In 1998, the WDNR (1998a) estimated that in the following two years, Washington would experience a net gain of one person every five minutes. On the western side of the Cascades, the increase in the Puget Sound area accounted for 50 percent of the total population growth in the 1990s, down from 75 percent in the 1980s (U.S. Census Bureau 2000). In 1999, the Puget Sound portion of the Georgia Basin (i.e., the watershed of the Straits of Georgia, Juan de Fuca, and the Puget Sound) was home to nearly 3.9 million people—double the population of the mid-1960s. In Washington, as of 2004, approximately four million people live in the counties that border Hood Canal and Puget Sound (PSAT 2005).

Eleven Washington counties had populations of over 100,000 in 2000 (U.S. Census Bureau 2000): King, Pierce, Snohomish, Spokane, Clark, Kitsap, Yakima, Thurston, Whatcom, Benton, and Skagit Counties. In western Washington, which contains more than 75 percent of the state's residents (WSDH 2002), population growth and residential development are centered in the Puget Trough near Seattle (King County), Tacoma (Pierce County), and Olympia (Thurston County), as well as in Vancouver (Clark County). These developed areas have expanded east toward the Cascade foothills and passes, west toward the Kitsap Peninsula, and north and south along the Interstate 5 corridor. Residential and commercial development generally has tended to occur in low-elevation, low-gradient flood plains. This pattern of development has permanently converted other land-use types to a developed land base with increasing effects to, and with fewer benefits for, the natural environment. Population increases have generally occurred in the areas surrounding metropolitan areas. From 1990 to 1997 in western Washington, Thurston, Kitsap, Skagit, and Snohomish county population increases exceeded 20 percent. King and Pierce Counties gained the most in absolute terms (U.S. Census Bureau 2000).

The most-concentrated, major populations in Eastern Washington are found in metropolitan areas. According to the 2000 census, the Wenatchee area surpassed the 50,000-population threshold needed to designate the community as a metropolitan area, becoming the fourth such area in eastern Washington, along with Spokane, Yakima, and the Tri-Cities. While many counties have experienced growth in eastern Washington, most of the growth has centered around these largest cities.

As the population has grown, housing and infrastructure development has also increased. Approximately 45,727 housing permits were issued in Washington in 1998. The average home requires 120,528 pounds of concrete, 15,300 pounds of concrete block, 75,400 pounds of sand, gravel, and bricks, and 14,105 board feet of lumber (WDNR 1998a), which must ultimately be mined or harvested from natural sources and manufactured or processed. These figures do not include the raw materials necessary for the associated increases in commercial, industrial, community, and recreational facilities, such as schools, hospitals, and stores.

Aside from procurement of materials, urbanization results in other impacts to natural resources (Ferguson et al. 2001). Riparian habitats and their associated buffering abilities are reduced or lost as vegetation is reduced or replaced by impervious surfaces, structures, and bank stabilization. Materials such as LWD, snags, and trees are often removed, limiting and sometimes eliminating future recruitment of LWD in aquatic systems, along with the complex habitat components (e.g., pools, riffles, off-channel habitats) that are formed by LWD. Streams and wetlands are often directly affected by dredging, filling, channelization, culverts, and other activities that impact biota and habitats. Water quality is degraded by inputs of pesticides, herbicides, and other contaminants via stormwater runoff on lawns, streets, and other impervious surfaces. Fluctuations in surface water and groundwater levels affect hydrology and biotic communities in the watershed. While each of these impacts is significant, their collective effects can be highly destructive to ecosystems without adequate planning.

Statewide efforts have been implemented to deal with large-scale development and habitat issues. The Washington State Legislature passed the Growth Management Act (GMA) (RCW 36.70A) in 1990 to encourage local jurisdictions to develop comprehensive plans to address several areas, including but not limited to, urban growth, reduction of sprawl, transportation, housing, economic development, natural-resource industries, and the protection of open space and the environment (RCW 36.70A.020). The Shoreline Management Act (SMA) was adopted by a public referendum in 1972 “to prevent the inherent harm in an uncoordinated and piecemeal development of the state’s shorelines.” The SMA applies to all counties and cities that have shorelines of the state located within their jurisdictional boundaries. Planning efforts for incorporating GMA and SMA goals in local jurisdictions is ongoing. While these and other tools have the potential to significantly reduce impacts of development on habitats and biota, the planning process is relatively complex and the outcome varies by jurisdiction. Because these processes are relatively new, are often considered controversial in many areas, and have not been finalized in all jurisdictions, any attempts to determine the relative success of the GMA and SMA in adequately protecting Washington’s ecosystems would be premature.

5.2 INDUSTRY

Washington State supports a variety of industries (Washington State Employment Security Department 2005). These include, but are not limited to, transportation, manufacturing of durable (e.g., wood, metals, machinery, etc.) and nondurable (e.g., petroleum, chemical, plastics, paper and paper products, etc.) goods, construction, logging, agriculture, and mining.

Although not by definition an industry, there is also a network of military bases in Washington, with major facilities in several counties: Pierce (Ft. Lewis, McChord Air Force Base), Kitsap (Bangor and Bremerton Naval Stations, Keyport Undersea Warfare Center, Northwest Regional Maintenance Center), Snohomish (Naval Station Everett), Island (Naval Air Station Whidbey, Spokane (Fairchild Air Force Base), and Yakima (Yakima Training Center) Counties.

The impacts to natural resources from these entities vary, but many contribute to air pollution, water pollution and/or diversion, and habitat modification or destruction. To address these impacts, some companies and/or their associated regulatory agencies have initiated or participated in planning, restoration, or recovery efforts for species and habitats. Such efforts include, but are not limited to, HCPs, recovery plans (e.g., for bull trout, marbled murrelets, etc.), or project-specific conservation measures designed to reduce impacts to species and their habitats.

5.3 TRANSPORTATION

Extensive transportation networks have been constructed within the Puget Sound region. The construction and maintenance of these networks result in a number of impacts to ecosystems.

Construction and maintenance require extraction, transportation, and often the manufacture of materials. For example, some of the materials required for a construction project might include rock (e.g., gravel, riprap, etc.), asphalt, metal (e.g., for railroad tracks), concrete, creosote (e.g., to treat wooden bridge piers), and other natural resources that must be extracted, treated, processed, and hauled to the construction site via large vehicles. Impacts to species and habitats often result during the extraction and/or creation of these materials. Species and habitats may also be affected by physical modification of the environment as a result of construction, through fragmentation of habitat, reductions in floodplain connectivity and/or area, and the placement of barriers to fish and wildlife. For example, as bridges, culverts, and other artificial structures have been placed in various locations across Washington, associated impacts such as erosion, chemical contamination, and fish-passage barriers have degraded habitat for fish and other aquatic species.

Use of the transportation networks also contributes to ecosystem degradation as a result of spills, air pollution, contaminants from stormwater runoff, and other factors. Pipelines transport oil, gasoline, and other fuels throughout the region. Spills can occur from a variety of events, including transfer activities, vehicle collisions, and leaks. Air pollution comes from a number of sources, including, but not limited to, cars, trucks, ships, and other vehicles, as well as transportation network construction and maintenance activities. Roads and other impervious surfaces provide pollutants quick passage into waterbodies throughout Washington.

The following sections will describe the main categories of transportation in the state of Washington. These include unimproved and improved roadways, railways, ferry systems, pipelines, and ports.

5.3.1 Roadways

As of 1994, the State had approximately 80,000 miles of road which carried over 5 million vehicles (Green et al. 2000). The majority of these roads were in the Puget Sound area, with other significant areas in or near Spokane, Vancouver, and Yakima.

There are four major highway systems within western Washington, which also support a number of associated arterial networks. These include the Interstate 5 corridor running north and south along Puget Sound, which crosses all west Cascade river systems discharging into Puget Sound, the State Route 20 corridor running east and west through the Skagit River watershed, the U.S. Route 2 corridor running east and west through the Snohomish-Skykomish watershed, and the Interstate 90 corridor running east and west through portions of the Lake Washington and Snoqualmie watersheds. The most-intensive development in the region has occurred along these transportation corridors. Numerous arterial networks expand along these corridors, but the densest are associated with the urban centers along the Interstate 5 corridor.

There are two main interstate highways in eastern Washington. Interstate 90 bisects the state east to west, from Seattle through Spokane, and Interstate 82 provides a north-south route from Ellensburg through the Tri-cities into eastern Oregon. Secondary highways are the primary road link to international trade with Canada.

Pollutants from vehicles and roads include leaks (e.g., gasoline, oil, grease, transmission and radiator fluids), traction materials, de-icing chemicals, grit and contaminants from the roadways and easements, and air pollutants (e.g., carbon monoxide, nitrous oxides, particulates, lead, and trace toxins) (Green et al.

2000). On contact with rain, pollutants are dissolved from the air and can become water pollutants (Green et al. 2000).

5.3.2 Railways

In western Washington, a number of railways have been constructed along the lower reaches of major watersheds, along the Puget Sound nearshore, and roughly adjacent to the Interstate 5 corridor. These railways have links to the major shipping ports in the region, the Ports of Tacoma and Seattle, which are located in what was once extensive estuarine habitat (WSCC 1999b; KCDNR and WSCC 2000). Similar to the highway and arterial road networks in the region, these railway corridors cross numerous stream systems, or travel along or across nearshore habitat areas.

Railways are also extensive in eastern Washington. Three main lines cross west over the Cascades, generally paralleling U.S. Highway 2, Interstate 90, and Washington 14; eastbound lines cross into Idaho through Spokane and Clarkston. In addition, railways extend north into Canada along U.S. Highway 97 and 395, and Washington Highway 25, and are a primary link to international trade with Canada. Railways also extend south into Oregon near the Tri-cities. A well-developed rail network is associated with the U.S. Department of Energy Hanford site, but is controlled by the Federal government and does not carry commercial products.

Construction of these railways has contributed to the loss of side-channel habitat, the filling of estuarine habitat, the degradation of nearshore habitat, and constrained river CMZs (WSCC 1999a; WSCC 1999b; KCDNR and WSCC 2000; WSCC 2002a; WSCC 2002b). Spills or leaks may also occur during operations.

5.3.3 Ferries

A unique transportation network in western Washington is the Washington ferry system. Ferries have operated in the state since the early 1900s, with Washington State Ferry (WSF) Service beginning in 1951. Existing WSF service includes 10 routes, 20 terminals, and 28 vessels[1]. The WSF system transported over 11 million vehicles and 26 million people in fiscal year 1999. Other smaller systems, such as the Pierce County ferry system and the Kitsap Ferry Company, are also in use in western Washington.

Although relatively small when compared to other transportation networks, the construction and maintenance of infrastructure associated with ferry terminals have contributed to loss in continuity and degradation of some nearshore habitats. For example, treated-wood dolphin pilings and sheet pilings have contributed creosote or other contaminants, which are toxic to aquatic biota, into the substrate and water column in areas surrounding ferry terminals. Spills or leaks from a vessel or the vehicles it carries may also occur during operations or during collisions. Shading from infrastructure and turbulence generated from vessel propellers during arrival and departure has the potential to damage aquatic habitats (e.g., eelgrass beds).

[1] Washington State Ferry statistics are from the Washington State Department of Transportation website, accessed November 7, 2005. (http://www.wsdot.wa.gov/ferries/your_wsf/index.cfm?fuseaction=our_history)

5.3.4 Pipelines

Washington State contains approximately 43,000 miles of pipeline, including both large- and small-diameter pipes[2]. Natural-gas transmission, distribution, and/or associated service lines comprise the largest components of interstate (1,650.0 miles) and intrastate (>40,000 miles) pipeline transmission in Washington, with the remaining volume consisting of hazardous liquids (e.g., anhydrous ammonia, highly volatile liquids, crude oil, and other refined products). In addition to these pipelines, other Washington facilities transport water, wastewater, and other products.

Pipeline spills can happen due to a number of events[3]. For example, causes attributed to reported liquid pipeline spills over the past decade (with an average of 732.0 barrels/year from 1995-2004) included failure of a component, corrosion, incorrect operation, pipe failure, damage from outside forces, and "other" (undefined). Causes of natural-gas pipeline incidents for the same time period were similar to those for liquid pipeline spills, with incidents also caused by damage from excavation in the vicinity of the pipeline, fire and/or explosion, and problems with the equipment (e.g., weld). Spills can result in water pollution and air pollution, impacting habitats and species in the short or long-term.

5.3.5 Ports and Navigation

Washington supports a great deal of transportation that is dependent on water and air. There are a number of major water-based ports in several areas of Washington, including Puget Sound, Grays Harbor, the Columbia River, and the Snake River (WDNR 2000a). Washington is also home to 139 public-use airports[4] and other facilities.

Much of the navigation in western Washington is commercial, although recreational navigation is also extensive. The ports in Puget Sound are a significant and highly diversified destination for commercial shipping operations, with the Seattle and Tacoma ports hosting the second-highest volume of container traffic in the United States (PSAT 2005). Most navigation in eastern Washington waterways is recreationally based; commercial navigation occurs primarily on the lower Columbia and Snake Rivers, moving grain barges from as far as Lewiston, Idaho. There are also a number of barges that transport materials and equipment to and from the Hanford site.

Several types of activities have occurred to create and maintain the water-based ports. Tidelands have been filled, and waterways are dredged, channelized, and otherwise modified to accommodate deep-draft shipping vessels. In the Duwamish waterway in Seattle, more than 1,400 acres were filled by 1917, with approximately seven miles of dredged and channelized river currently associated with the port (WDNR 2000a). Industry is often concentrated in areas near ports, and can contribute to the introduction of contaminants into waterways. The shorelines of the lower Duwamish River have been used for port activities and industry since the early 1900s, and is on the National Priority List of Environmental Protection Agency Superfund Sites. As shipping traffic has increased over time, there has been an

[2] From Office of Pipeline Safety Communications, accessed December 1, 2005. (http://www.cycla.com/stakeholders/StatePages/Washington.htm)

[3] From Office of Pipeline Safety Communications, accessed December 1, 2005. (http://www.cycla.com/stakeholders/StatePages/htmGen/WA_detail1_dd.html)

[4] Washington State Department of Transportation, accessed November 17, 2005. (www.wsdot/wa/gov/aviation/DocLibrary/WAStatePublicUseAP.pdf)

increased need for additional land-based transportation (e.g., trucks and rail cars) to transport goods that are transferred through the ports (WDNR 2000a)

Washington is one of the country's leading petroleum-refining centers. Large amounts of crude oil and petroleum products enter and leave the Georgia Basin (which includes Puget Sound and the Straits of Juan de Fuca and Georgia) via tankers, barges, and pipelines. Approximately 15 billion gallons of crude oil and other refined petroleum products are transported through Puget Sound annually (PSAT 2005). About 28 ocean-going commercial cargo vessels transit the Strait of Juan de Fuca daily, carrying up to two million gallons of heavy fuel oil (PSWQAT 2000). In the northern part of the State and southern British Columbia, spills (greater than 1,000 barrels) of crude oil are expected every 2.5 years and of all petroleum products every 1.3 years. Chronic oil pollution, including small spills, bilge seeps, dumping, and undetected slow leaks from coastal tanks, pumps, and pipelines is poorly documented, making an assessment of the level of threat difficult. More than 418,500 gallons of oil were spilled in the Puget Sound basin from 1993 to 2003, primarily from a single major pipeline spill and spillage from vessels (PSAT 2005). Spills during fueling and from pumping bilges of small commercial and recreational boats occur fairly commonly and may go unreported. Although individual spill releases of this type may be small, repeated releases to sensitive and productive near-shore areas can be very damaging to the Puget Sound environment. (PSWQAT 2000).

5.4 EFFECTS TO NATURAL RESOURCES

Human activities have significant and sometimes devastating effects on species and habitats through pollution and/or modification of the environment. Anthropological effects to surface water and groundwater resources generally occur through actions that influence water quantity or water quality, or both (Everest et al. 2004). Air-quality effects often result from emission from vehicles, industry, and other sources.

There are many different kinds of habitat-modification activities that have occurred in Washington throughout its settlement history. Habitat modifications in Washington include water diversion and storage, shoreline development, replacement of pervious surfaces with impervious surfaces, and loss of riparian buffers and wetlands. While human-induced impacts have occurred in Washington throughout its settlement history, recent activities have also included strategies and actions to reduce these impacts.

5.4.1 Water Quantity

There are approximately 265,129 stream miles in Washington; of these, 98,433 stream miles are located on lands subject to the Washington Forest Practices Rules, including existing HCPs (USFWS and NMFS 2006). Approximately 75,975 stream miles are located in western Washington, which includes the northern, southern, and western Puget Sound regions, together with the Islands region, Olympic coast, southwest Washington, and the Lower Columbia River regions. The remaining 22,458 stream miles are in eastern Washington, in the Middle and Upper Columbia River regions, the Columbia basin, and a portion of the Snake River basin that occurs in Washington.

Stream channels in many areas have been significantly altered by dredging, channelization, and the construction of dikes and revetments for flood control and bank protection. These activities have simplified once complex stream channels, degrading and eliminating important foraging, migration, and overwintering habitat for salmonids and other biota. Such changes can also result in the removal of riparian vegetation, precluding recruitment of LWD. Developments such as these can also reduce or preclude options for restoration of floodplain areas important for reestablishing off-channel habitats and maintaining groundwater recharge.

5.4.2 Water Diversion

Dikes, levees, dams, and other diversions have reduced the level of watershed connectivity in several areas of Washington. Diversion projects have been implemented for a number of human needs, including but not limited to, flood control, conversion of wetlands to agricultural lands, bank protection, water supply, road construction, or a combination of these objectives.

Impacts to species and habitats from these actions have been significant. Palmisano et al. (1993) report that the most-severe effects to wild anadromous salmonids from dams and other fish-passage barriers have occurred in the Columbia River Basin, although there are several problem areas in western Washington.

5.4.2.1 Dikes and Levees

Many of the streams in Washington have been channelized, diverted, and confined through the construction of dikes, levees, berms, revetments, embankments, and other structures. The shapes and configurations of the structures vary based on their purpose; however, the construction of each kind of structure results in physical and biological impacts to the stream morphology and community (Bolton and Shelberg 2001). The construction of flood-control structures, tide gates, and water-diversion structures have contributed to the degradation and fragmentation of migratory corridors, and elimination of historical foraging, migration, and overwintering habitats within the region. Channelization (and often its associated bank armoring) results in simplification of the stream, and has resulted in changes in flow, velocity, and movement of water in many streams. These changes are often at least a portion of the goal of a project, which may be designed to reduce flood damage to property, exclude water, or store water for future use. While these changes may be favorable to property owners or project proponents, such actions often result in substantial changes to aquatic and terrestrial habitats and their use by biota.

The construction of dikes and levees has affected parts of the state since the 1800s. In western Washington, dikes were constructed to create and protect farmland, particularly in the lower-elevation areas of watersheds, including mainstem rivers, major tributaries, and estuaries. For example, the Nooksack, Lower Skagit, Stillaguamish, Snohomish-Skykomish, and Puyallup watersheds have been significantly altered by diking of their floodplains and estuaries. The Skagit River delta, the largest estuary in Puget Sound, was one of the first to be converted from tidal wetlands to agriculture. The Nooksack is one of the few rivers in Puget Sound where significant estuarine habitat loss from diking has not occurred, although the river was diverted from Lummi Bay to Bellingham Bay about 100 years ago. Levees have been constructed for flood protection and other purposes. Some levees are constructed or maintained by government agencies (e.g., U.S. Army of Corps Engineers); others are maintained by local entities (e.g., counties or diking districts).

Dikes and levees result in a number of impacts to aquatic species and habitat. Aside from loss of estuarine habitat from construction, dikes reduce tidal flushing, sometimes resulting in increased sedimentation; dikes also may have marked effects on tidal channel biota on the seaward side of the structure (Hood 2004). The construction of dikes may result in decreased sinuosity and complexity in certain channels, and prevent energy dissipation during flood events.

Recent restoration efforts have focused on the benefits of restoring ecosystem functions affected by diversion structures. In 2002, the Nisqually Tribe removed a portion of a dike in Red Salmon Slough, reconnecting 31 acres of former pastureland to the Nisqually River Estuary (SPSSEG 2002, Carlson Personal Communication, 2005a). This action was undertaken to benefit juvenile salmonids, other fish species, and migratory birds. At Spencer Island in Snohomish County, two 250-foot-long breaches were made in an estuary dike to reconnect approximately 250 acres of estuarine marsh (Carlson, Personal Communication, 2005b).

5.4.2.2 Culverts and Other Fish-Passage Barriers

Improperly installed, sized, or failed culverts have been identified as barriers for fish movement and migration throughout Washington. WDFW estimates that 33,300 road crossings are high-priority (partial or complete) fish-passage barriers, and impair access to 40,000 miles of significant upstream habitat (B. Peck, Personal Communication 2005a). Approximately 8 percent of these barriers occur on state-owned land, while higher percentages occur on Federal (14 percent), county and local jurisdictional (14 percent), and private lands (64 percent) (B. Peck, Personal Communication 2005a). WDFW also estimates that an additional 13,000 barrier culverts exist with limited upstream habitat, and 5,600 dams are barriers to fish passage in Washington (B. Peck, Personal Communication 2005a).

Although historically placed, fish-passage barriers continue to impede fish passage in many streams in Washington. A number of groups have made efforts to inventory and remove fish barriers under their jurisdiction, often either removing barrier culverts or replacing them with a more-suitable structure (Peck, Personal Communication, 2005b). Removal of fish barriers may be achieved through several different kinds of activities (Peck, Personal Communication, 2005c). Several design options are described in detail and design criteria are provided in WDFW's Design of Road Culverts for Fish Passage (Bates et al. 2003). Removal of a barrier culvert is often undertaken when a crossing is no longer needed. If a crossing is necessary, other options include bridges or other specific methodologies: stream simulation, roughened-channel design, no-slope methodology, or hydraulic design.

Statewide, WDFW is coordinating with other entities to correct fish-passage barriers at a rate of approximately 10 barriers per year, and estimate an additional 30-60 barriers are addressed annually by other entities (B. Peck, Personal Communication 2005a). Examples of planned or recently completed projects include culvert removals in Stearns Creek (Lewis County), Peterson Creek (Mason County), and Glover Creek (Snohomish County); respectively, these projects will allow access by salmonids to over 7.5 miles (12,000 meters), 3.5 miles (5,600 meters), and 1.2 miles (2,000 meters) of rearing and spawning habitat (B. Peck, Personal Communication, 2005b). The Washington State Department of Transportation reports that 142 barriers have been removed as of March 2005[5], with more than 391 miles (630 linear kilometers) of salmonid habitat reopened. The Salmon Recovery Funding (SRF) Board (2005) provided funding for projects to modify or remove 132 barriers for fish passage, reporting an estimated 456 miles of habitat access for salmonids. The South Puget Sound Salmon Enhancement Group (SPSSEG) (2002) reported the replacement of a culvert with a bridge to remove a barrier for salmonids on Sherwood Creek (Mason County). Other barrier culverts and/or tidegates have been replaced in several areas, including Jefferson County (Upper Tarboo Creek) and Skagit County (McElroy Slough), reconnecting spawning grounds and refugia areas for anadromous salmonids (Carlson, Personal Communication, 2005b). Recent

[5] From WSDOT website: http://www.wsdot.wa.gov/environment/fishpass/default.htm (accessed November 7, 2005)

examples in eastern Washington include culverts replaced by the Okanogan and Wenatchee National Forests in the Entiat and Twisp Rivers (Krupka, Personal Communication, 2005).

5.4.2.3 Dams

There are currently approximately 1,025 dams obstructing the flow of water in Washington, with approximately 10 new dams added each year, generally small facilities on off-channel or side streams (WDNR 2000a; Green et al. 2000). Dams are built for many purposes, including power generation, irrigation, flood control, recreation, and water supply (WDNR 2000a). These facilities have far-reaching effects on both aquatic and terrestrial habitat and biota. The controlled flow from a dam facility often slows the movement of the rivers, and changes the natural cycle of river flows, resulting in areas that are either drier than normal (because the water is being held behind the reservoir) or flooded by much higher levels of water. Changing the depth and flow of rivers also affects the water's temperature, either increasing or decreasing temperatures from the normal state. Dams affect the flow of many different materials (e.g., sediments, nutrients, and other materials such as LWD) carried in the river waters. Free-flowing rivers regularly flood and recede, collecting and depositing these materials both laterally and downstream. For example, rivers carry a great deal of sediment and nutrients down river, eventually depositing it in the deltas and estuaries where freshwater enters saltwater. Dams arrest this process; consequently, reservoirs eventually fill with sediments and inadequate amounts of sediment reach the downstream deltas and estuaries. Coastal beaches in turn lose the source of sand normally deposited on them by coastal currents that would ordinarily redistribute the sediments.

Dams often delay or block passage of anadromous fish to upstream reaches of the stream; such an obstacle can increase predation rates on these fish, cause injury or mortality as fish are trapped in unscreened canals or attempt to travel through turbines. In many cases, dams have likely been constructed at or near historical natural barriers to anadromous fish passage (USFWS 2004). The ability of anadromous fish to access areas above man-made barriers is important not only for the survival of individuals and populations of the species, but also for the integrity of the ecosystems they support (Cederholm et al. 2000). Anadromous fish provide organic matter and nutrients to both aquatic and terrestrial habitats via their carcasses, eggs, milt, excrement, and fry. Staging and spawning adults are also consumed as prey by aquatic and terrestrial predators. The organic matter and nutrients contributed by anadromous fish enrich macroinvertebrate and terrestrial communities, which in turn provide food for other organisms, including anadromous salmonid fry and juveniles. Scavenging and predatory fish, birds, mammals, and other animals also consume fry, juvenile, and adult salmon, their eggs, and their carcasses, often leaving remnants of carcasses in a more-accessible form for smaller scavenging fauna. Rich marine-derived nutrients from anadromous fish are transported to the reach of stream in which they die, into the lower reaches of the stream and estuary through downstream drift, and across habitat or ecosystem boundaries by mobile mammals, birds, and fish.

Certain facilities have implemented fish-passage structures or transport systems to allow upstream movement of anadromous fish; however, the risk of disease, stress, and other interference with migration and reproduction may occur as a result of these systems. The major facilities for each subregion of Puget Sound[6] and the Columbia Basin are described below.

[6] Some regions of Puget Sound do not have major dams associated with them, although smaller facilities may exist. These include the Island (e.g., San Juan Islands) and Olympic Coast regions.

Western Washington/Puget Sound

A number of dams exist in the Northern Puget Sound region. Two dams on the upper Skagit River and two dams on the Baker River are major hydropower storage facilities that modify the seasonal and daily discharge in the Skagit River, and have a substantial impact on the Skagit System (WSCC 2003). Smaller dams are scattered elsewhere, but have relatively little effect on mainstem hydrology. The upper Skagit River, above the Gorge Dam, was naturally inaccessible to anadromous fish, with the possible exception of steelhead. The Skagit River dams have prevented the transport of large wood to downstream areas; in conjunction with past wood-removal efforts, this has significantly contributed to the reduction of historical habitat complexity in the Lower Skagit River mainstem and estuary (USFWS 2004).

The dams on the Baker River have altered the historical anadromous connectivity with the rest of the lower Skagit system. The Baker River dams have upstream and downstream fish-passage structures. A trap-and-haul facility exists at the Lower Baker Dam and smolt traps are used at both Baker and Shannon Lakes. In recent years, these structures have functioned well enough to contribute to the recovery of Baker River sockeye salmon (Gary Sprague, Personal Communication, WDFW, 2003).

A small hydropower project reduces total discharge on the Tolt River, a tributary to the Snoqualmie River. In addition, at least four run-of-the-river hydropower projects exist in the region; one on the Nooksack River and three on the Snoqualmie River. Except for run-of–the-river projects, these river facilities have been trapping substrate for decades, and the downstream reaches are gravel deficient. Most of the dam sites also intercept LWD and do not pass it downstream. These two actions can cause the downstream channel to incise and/or become simplified, thus impacting fish habitat. Water withdrawal can reduce available fish habitat and alter sediment transport. Hydropower projects can also fluctuate stream flows, stranding and often killing fish and reducing aquatic invertebrate productivity (Hunter 1992).

The southern region of eastern Puget Sound also contains several dams. The Cascade headwaters of the Cedar and Green Rivers are both managed as municipal water supplies and are dammed to provide storage to meet summer water demands for urban areas. The activities of Seattle and Tacoma are addressed by HCPs; U.S. Army Corps of Engineers' dams are not covered by HCPs. The Mud Mountain Dam on the White River diverts flow to Lake Tapps, a recreational and residential development. Discharge from Lake Tapps is used to generate power. Both facilities use trap-and-haul facilities for adult anadromous salmonids, although the timing of operations (e.g., year round or seasonally) have varied throughout their history. The Electron Dam is a run-of-the-river project that reduces flow in the upper Puyallup River for approximately 8 miles. A new fishway was constructed at this facility to improve upstream fish passage and has been fully operational since October 13, 2000 (USFWS 2004).

The Nisqually River watershed is affected by three major dams. The upper Nisqually River has two large dams, the Alder and LaGrande. Alder Dam is the largest in this region. For nearly 30 years, the facility at LaGrande was operated for peak power, creating rapid changes in downstream flows. This was especially adverse during the summer and fall low-flow months, and is attributed with driving Nisqually spring Chinook salmon to the point of extinction by the early 1950s (NCRT 2001). In downstream reaches of the watershed, the Yelm Hydropower Project on the lower Nisqually River reduces flow in a 10-mile stretch of the river. This project historically provided varying degrees of fish passage, with a standard fish ladder installed in 1955.

Except for the two run-of-the-river projects, these dams have been trapping substrate for decades, and the downstream reaches are gravel-deficient. Most of the dam sites also intercept LWD and do not pass it downstream. These two actions tend to promote downstream channel incision and/or simplification, limiting fish habitat. Water withdrawals reduce available fish habitat and alter sediment transport. Hydropower projects often result in fluctuating flows, which often strand and kill fish and reduce aquatic invertebrate productivity (Hunter 1992). At some storage dam sites, benefits to fish habitat may be realized by increased summer flows.

In the western Puget Sound region, hydropower storage dams are operating on the Elwha River and the North Fork Skokomish River, and both dams contribute to downstream gravel depletion (WSCC 1999, WSCC 2003b). Other small hydropower projects and municipal water diversions may have localized impacts to the aquatic environment (WSCC 1999, WSCC 2003b). The Elwha River dams (Elwah and Glines Canyon dams) block anadromous fish access to 70 miles of the upper Elwha River (however these dams are slated for removal in 2008). The dams on the Elwha are examples of structures that result in significant downstream impacts. The dams have impacted the estuary, beach morphology, and eelgrass beds. The dams have prevented recruitment of fluvially transported sediment, and at least 366 meters of shoreline have been eroded during the period from 1939 to 1994 (WSCC 2000a; USFWS 2004).

On the North Fork Skokomish River, historical anadromous fish access to the dam sites is uncertain; however, the hydropower plant diverts flow directly to Hood Canal, and thus bypasses a substantial portion of the flow from 17 miles of habitat. Loss of flow in the North Fork Skokomish River has resulted in reduced sediment-transport capacity, loss of fish spawning and rearing habitat, reduced channel capacity, and more-frequent flooding (USDA 1995). Reduced flows have also significantly altered sediment size and sedimentation patterns in the delta, which has resulted in increased erosion at the outer edge of the delta and increased sediment deposition at the inner edge. These impacts to the intertidal zone have contributed to reduced biological productivity of the estuary and reduced sizes of eelgrass beds at the mouth of the Skokomish River. Herring, a prey species for many piscivores, rely on eelgrass beds for spawning habitat (O'Toole et al. 2000). Eelgrass beds also provide important habitat for juvenile salmonids. Decreasing eelgrass beds create negative cascading effects on these and other aquatic species.

Southwest Washington

Medium-sized dams currently exist on the Wynoochee River and Skookumchuck River. These dams capture sediment and contribute to channel incision and bedrock dominated channels downstream. Gravel supplementation is currently occurring at the Wynoochee Dam. Both the Wynoochee Dam and the Skookumchuck Dam use storage to enhance summer flows (WSCC 2001). The Wynoochee River Dam has upstream and downstream fish-passage facilities. The downstream passage facilities are still only partially effective (DeMond, Personal Communication, 2003); however, self-sustaining runs of coho and other species return to the upper river. The Skookumchuck Dam has upstream fish-passage facilities, which are used to pass steelhead above the dam.

Columbia and Snake Rivers

There are 15 major hydroelectric dams on the main stems of the Columbia and Snake rivers in Washington. This is the most hydroelectrically developed river system in the world (WDNR 2000a). According to Bonneville Power Administration, there are 55 major hydroelectric projects on the Columbia River and its tributaries, 30 of which are owned and operated by the U.S. Army Corps of Engineers, and the remaining 25 facilities are operated by various private and public entities. The dams erected in the river and its tributaries created large reservoirs that provide flood control and water for vast irrigation systems on the Columbia Plateau. As with dams in western Washington, these dams have caused drastic changes in seasonal flow, sediment discharge, water temperature, fish communities and water chemistry. General impacts to salmonids, other biota, and habitats from the Federal Columbia River Power System include the following (USFWS 2002; WDNR 2000a):

- fish-passage barriers and entrainment
- inundation of fish spawning and rearing habitat
- modification of the stream-flow and water-temperature regime
- dewatering of shallow water zones during power operations
- reduced productivity in reservoirs
- gas supersaturation of downstream reaches
- loss of native riparian habitats
- water-level fluctuations interfering with establishment of riparian vegetation along reaches affected by power-peaking operations, and establishment of non-native vegetation along affected reaches
- loss of sediment loads at the mouth of the Columbia River, and associated lack of distribution to other coastal areas by north-south currents along the Pacific Coast

Lower Columbia River

Three dams were constructed on the Cowlitz River, the latest of which (Cowlitz Falls) was constructed in the early 1990s. These facilities significantly modified gravel supply, resulting in a decline in the quality of downstream spawning substrate. A number of studies suggest that much of the natural spawning occurring below the dams is from hatchery strays, and not a result of self-sustaining natural production (DeVore 1987 in WSCC 2000b). The third dam on the Cowlitz River (Cowlitz Falls) was constructed in the early 1990s. Downstream fish-passage screens were constructed as part of the structure. Currently, juvenile fish coming down the river are trapped and trucked around the dams; many of these fish would have previously residualized in Riffe Lake, the large reservoir behind the second dam. This trap has been mostly successful in establishing self-sustaining runs of spring Chinook, coho, and steelhead in the upper Cowlitz basin. However, the downstream migrant trap cannot capture fish during flood flows; thus many juvenile out-migrants still end up in Riffe Lake (Craig Olds and Lauri Vigue, Personal Communication, 2003). Even if this trap becomes completely successful, only part of the historical potential of this watershed would be restored. A substantial section of the middle Cowlitz Basin remains inundated or inaccessible.

Three hydropower dams were built on the Lewis River, modifying the hydrology and gravel supply. The mainstem of the Lewis River below the lowest dam is largely bedrock and boulders. Flow fluctuations from hydropower peaking may cause stranding and fish kills (WSCC 2000a). The dams on the Lewis River remain a total blockage to anadromous fish use (WSCC 2001).

The construction of the Cowlitz and Lewis River dams constitute the two largest losses of anadromous fish access in western Washington State. In both systems, the loss of natural fish production was compensated with the construction of hatcheries, a common practice during 1940s and 1950s when these dams were constructed. Over 300 miles of accessible fish habitat were lost above Mayfield Dam on the Cowlitz, and roughly 150 miles above Merwin Dam on Lewis River. In both cases, 80 to 90 percent of the production potential had been lost (WSCC 2000b, 2000d).

Following the eruption of Mt. St. Helens, a sediment-retention structure (SRS) dam was constructed on the North Fork Toutle River. A fish trap was constructed to pass fish over the SRS dam. Despite elaborate measures to flush silt out of the trap, operation of the trap was only partially successful. Since the habitat above the dam is still recovering from the eruption and associated disturbances, fish production above this structure is quite limited at this time. However, most of the land above the SRS is preserved in parks and wildlife refuges, thus the long-term prospects for habitat recovery are good (Craig Olds, Personal Communication, WDFW, 2003).

Condit Dam, on the White Salmon River, was built in 1913, and blocked anadromous fish access to most of the basin. Negotiations are currently underway to remove this dam and restore access. Hydropower dams on the Lower Columbia mainstem that affect fish passage include Bonneville, The Dalles, and McNary dams.

Middle Columbia River

Of the five major storage reservoirs in the Yakima Core Areas (Kachess, Keechelus, Cle Elum, Bumping, and Rimrock), all but Rimrock Lake (Tieton Dam) were historically natural lakes. The dams built across the lake outlets greatly enlarged their surface area and flooded large areas of stream habitat. In 1948, the Columbia Basin Project began transporting Columbia River water to more than 600,000 acres on farms in Central Washington. Construction of dams within the Yakima River Basin in the 1900s to provide water storage for irrigation precluded anadromous salmonid passage to 112 miles of highly productive reaches upstream. Downstream of the Cle Elum, Tieton, Wapatox, Keechelus, Sunnyside, and Prosser Dams, the dewatering of extensive reaches of the Yakima River precluded upstream migration of adult salmonids, reduced spawning habitat, dewatered redds, and impaired/eliminated juvenile salmonid rearing in these reaches (WSCC 2001).

Within the Columbia River mainstem, hydropower operations have resulted in either complete or partial fish-passage barriers both up and downstream. Power operations have also affected fish movement through reservoirs by stranding fish in shallow areas and removing access to important spawning areas in tributary streams during drawdowns (Mainstem/Systemwide Habitat Summary 2002). Adult and juvenile salmonids have been precluded from historical spawning and rearing habitats by dams at major storage reservoirs (e.g., Tieton, Bumping, Cle Elum, Keechelus, and Kachess dams within the Yakima; Hemlock Dam within the Wind; Ice Harbor, Lower Monumental, Little Goose, and Lower Granite in the Middle Columbia mainstem). In addition, upstream adult fish passage was precluded at Roza Dam from its completion in 1940 until the installation of the fish ladder in 1989.

Upper Columbia River

Twenty-one dams exist within the U.S. portion of the Okanogan watershed. The Similkameen River is impassable to all anadromous salmonids at Enloe Dam, with 95 percent of the available potential fish habitat upstream. Diversions in Loup Loup, Salmon Creek, and Antoine Creek prevent full use of the habitat potentially available in those systems (Okanogan/Similkameen Subbasin Plan 2002). Dams are also present in the Entiat system. With the construction of the Grand Coulee Dam in 1939, anadromous salmonids were barred from 1,140 miles of potential spawning and rearing habitat in the upper Columbia River drainage (Fish and Havana 1948, WSCC 2000). Grand Coulee Dam is a complete barrier to anadromous fish.

There are also a number of dams located above Grand Coulee Dam. Five hydroelectric dams, all lacking fish-passage facilities, are located on the Pend Oreille River (WDFW 1998). The construction and operation of Albeni Falls, Box Canyon, and Boundary Dams on the Pend Oreille River have fragmented habitat and negatively impacted migratory salmonid trout. Other dams and diversions without fish-passage facilities in tributaries to the Pend Oreille River have further fragmented habitat and reduced connectivity (USFWS 2002). These dams have altered habitats (i.e., stream flows, sediment, temperature regimes), migratory corridors, and interspecific interactions. Upper Columbia River mainstem dams have changed the habitat from that of a cold fast-moving river, to a warm reservoir and include Priest Rapids, Wanapum, Rock Island, Rocky Reach, Wells, and Chief Joseph (NPPC 2001). Typical spawning, rearing, and overwintering habitat in a free-flowing river with pools, glides, riffles, and side-channel habitats have been eliminated (USFWS 2002). The historical salmon fishery, already in decline, was brought to an abrupt end by the construction of Little Falls Dam on the Little Spokane River in 1910 (WDNR 1997a).

Within the upper Columbia River mainstem, hydropower operations have resulted in impacts to fish passage that are similar to those in the mainstem of the Mid-Columbia (Mainstem/ System-wide Habitat Summary 2002).

Snake River

Storage dams and their associated impoundments have eliminated spawning and rearing habitat and have altered the natural hydrograph of the Snake River, decreasing spring and summer flows and increasing fall and winter flows (Mainstem/Systemwide Habitat Summary 2002). Snake River dam construction has also converted riverine habitat to more reservoir-like habitat, impacting species composition and increasing predator abundance (USFWS 2002). Dams within the Tucannon River and Asotin Creek watersheds have had significant historical impacts on salmonids in both streams. Two of these dams are still present and may be affecting salmonid migrations.

With the completion of four dams on the lower Snake River during the 1970s, a series of slack-water lakes was created that allows barges to navigate more than 465 miles from the Pacific Ocean to the inland port of Lewiston, Idaho. Tow boats push the barges up through navigation locks on eight of the major dams on the Columbia and Snake Rivers.

5.4.3 Water Use

The diversion, storage, and use of water is based on increasing demand, fueled by population and economic growth. The amount of water available has remained relatively constant, although it varies based on annual weather patterns and may change in the future as climate change affects weather patterns and water supply (WDOE 2000). WDOE (2000) reports that year-round water withdrawals are no longer available from approximately 350 lakes and streams, to protect aquatic species and existing water rights; over 200 additional waterbodies have partial closures or flow limits.

A significant amount of water is used for irrigation of agricultural lands, which can affect ecosystems. In 2000, approximately 3,005 million gallons of water per day (mg/d) were used for irrigation, the largest water-use category when compared to industrial water use (681 mg/d), domestic water use (674 mg/d), and irrigation of golf courses (23.6 mg/d) (Lane 2004). The Columbia and Yakima River basins are the two major irrigation regions in the State (Green et al. 2000), and most of this water (92 percent) was used in eight eastern Washington counties (Lane 2004): Grant, Yakima, Franklin, Benton, Kittitas, Adams, Walla Walla, and Okanogan. The key structure of the Columbia Basin Project, Grand Coulee Dam, is on the mainstem of the Columbia River about 90 miles west of Spokane. The extensive irrigation works extend southward on the Columbia Plateau 125 miles to the vicinity of Pasco, where the Snake and Columbia Rivers join. There are over 300 miles of main canals, about 2,000 miles of laterals, and 3,500 miles of drains and wasteways on the project, which delivers water to about 1.1 million acres of land previously used only for dry farming or grazing. The Yakima Project provides irrigation water for a comparatively narrow-strip of fertile land that extends for 175 miles on both sides of the Yakima River in south-central Washington. The irrigable lands presently being served total approximately 464,000 acres.

Irrigation systems are more extensive in eastern Washington than in lands west of the Cascades. However, an extensive irrigation system exists within the Dungeness River Valley (WSCC 2000a). Approximately 70 to 80 percent of the agricultural land in the Dungeness Valley is irrigated with water diverted from the Dungeness River and area streams through approximately 280 kilometers of main ditch canals and secondary ditches and laterals (Montgomery 1999 *in* WSCC 2000c).

In addition to agriculture, irrigation is heavily used in eastern Washington to maintain urban irrigated lands, forest nurseries, seed orchards, and recreational areas. In the U.S. Columbia River Basin, approximately 7.6 million acres receive irrigation (USDOE et al. 1991). Water withdrawal also occurs as a source for rural domestic use, stock watering, municipal and light industrial water supply, and for industrial use; however, the dominant off-channel water use is for irrigation (Wissmer et al. 1994).

Effects associated with irrigation-water withdrawal includes effects from water storage and drainage, increased water temperatures (which can become thermal barriers for salmonids and other aquatic species), pollutants (such as runoff containing pesticides and fertilizers), high sediment levels, and lower stream flows (Wissmer et al. 1994; Krupka, Personal Communication, 2005). Lower flows and associated stream dewatering affect aquatic habitat and biota (Wissmer et al. 1994). Diversions and fish ladders associated with irrigation also have a variety of effects since not all are screened or pass all life stages of fish; irrigation systems may also divert a substantial amount of stream flow. The effects of these structures in aggregate to anadromous fish and other aquatic biota can be severe. However, through permitting and the Federal Energy Regulatory Commission relicensing processes, several efforts have been initiated to reduce existing effects. These efforts include, but are not limited to: proper screening of existing diversions and other structures; reduction of temperature, sediment, and pesticide effects to waterways; reduction of the quantity of water diverted to provide access; and reduction of fish-passage barriers.

There have been several attempts to reduce impacts from dams, irrigation-water withdrawal, and other water-diversion activities. Some of the efforts to minimize effects to anadromous fish were undertaken relatively early (Palmisano et al. 1993). For example, irrigation diversions were screened in the 1930s, although the screens did not protect all life stages, nor were they adequately maintained. More recently, watershed-planning units have been organized in some areas in response to the Watershed Planning Act, to address issues regarding water availability and quality, instream flow, and habitat protection (WDOE 2000). Some projects have been proposed specifically to address flow issues. For example, between 2000 and 2004, the Salmon Recovery Funding Board (2005) funded projects to alter river flows over 85 acres, slowing the stream flows to enhance salmon spawning and rearing habitats. As mentioned previously, certain dams have been slated for removal (e.g., Elwha, Glines Canyon, and Condit dams) because it has been determined that they are no longer necessary.

5.4.4 Water Quality

Good water quality is essential to the health of Washington habitats and the biotic communities that depend on them. Poor water quality affects both aquatic terrestrial species and communities through the food chain. There are many different kinds of pollutants or contaminants that affect water quality in Washington's waterways, many of which are direct results of the activities described elsewhere in the baseline discussion. In addition to contaminants, such as metals or fecal coliform, water quality is also determined by abiotic (temperature, dissolved oxygen levels, pH, turbidity, etc.), and biotic (invertebrates, fish, etc.) indicators.

This analysis will look at a number of contaminants in Washington's aquatic habitats, and then examine water quality from the perspective of abiotic and biotic indicators associated with marine and freshwater environments. It should be noted that analyses of many pollutants that "exceed recommended levels" are based on statistics for human exposure and health. While effects to animals (e.g., fish) are often used in acute and chronic tests, such tests generally are limited to observations of mortality or relatively short-term growth and development, and are not commonly performed on Washington species of concern (such as bull trout). Sublethal effects, such as behavior and long-term survival, are also not generally analyzed.

5.4.4.1 Contaminants

Contaminants enter waterways through a variety of pathways. Contaminants in stormwater runoff, for example, may include oil, grease, and heavy metals from roadways and other paved areas, and pesticides from residential developments. Recent observations of high numbers of pre-spawn mortalities in coho salmon returning to small streams in urban and developing areas of Puget Sound have caused increasing concern over stormwater runoff (Ylitalo et al., *in litt*. 2003). Other sources of toxic contaminants are discharges of municipal and industrial wastewater, leaching contaminants from treated wood (e.g., creosote) and other components of shoreline structures, and channel dredging, which can result in resuspension of contaminated sediments. Discharges from sewage-treatment plants may be treated prior to discharge into receiving waters. However, according to the literature, the treatment likely does not adequately remove potentially harmful compounds that are considered persistent, bioaccumulative, and toxic, or those that may have endocrine-disrupting properties (Bennie 1999; CSTEE 1999; Daughton and Terns 1999; Servos 1999). Estuarine and nearshore areas (such as Bellingham Bay and Commencement Bay) are on the State 303(d) list for a number of industrial-and development-related contaminants.

Many of the contaminants are associated with sediments, and are taken up by bottom-dwelling biota and many of the organisms at the base of the food chain. Many sediment contaminants do not break down very quickly. According to studies in Puget Sound, approximately 5,700 acres of submerged habitat are considered highly contaminated, with many of these sediments present in industrial areas (PSAT 2005); other areas covered by the survey showed 179,000 acres were of intermediate quality, while the remaining 400,000 acres of the areas surveyed were considered clean[7]. While the areas that are considered contaminated are relatively small, the effects from these areas can be far-reaching. Animals that live in contaminated sediments can accumulate high levels of these substances, with concentrations in biota sometimes thousands of times higher than background levels in the surrounding habitat. As these animals move into other areas, or are preyed upon by more-mobile animals, the contaminants are transmitted up the food chain and may biomagnify. Consequently, predators can have very high

[7] The study area was limited to certain locations within Puget Sound and did not include the sediments in the entire basin, which consists of approximately 1.8 million submerged acres.

contaminant levels, even if they have spent little or no time within the contaminated areas. For example, Chinook salmon in Puget Sound have levels of polychlorinated biphenyls (PCB) that are three times higher than Chinook in other areas.

Several contaminants have been examined in various areas of the State. These contaminants (and their concentrations in the environment) vary by region and habitat type, and include inorganic (e.g., metals) and organic chemicals (e.g., certain pesticides, pthalates). Some chemicals, such as chlorinated organic compounds and their breakdown products, persist in the environment because bacteria and chemical reactions break them down slowly. (PSWQAT 2000). Although the effects from many of these chemicals have been at least partially analyzed, little is known about the synergistic effects of the chemicals; in many areas, multiple substances are present in the habitat and/or biota. The synergistic effects of these chemicals to aquatic and terrestrial biota are unpredictable at best.

Inorganic Chemicals

Inorganic chemicals include, among other substances, metals and certain pesticides. Sources of mercury, lead, and other metals in Puget Sound and other parts of Washington include hazardous material spills, pipes, vehicle emissions, discarded batteries, paints, dyes, and stormwater runoff and can cause neurological or reproductive damage in humans and other animals (PSAT 2005). Metals, especially zinc, nickel, lead, and tri-butyl tins (used in some paints, for example), occur at relatively high concentrations at a few Puget Sound locations (PSAT 2005). The presence of certain metals in marine waters have triggered fish and shellfish consumption advisories in many areas. Overall, however, levels of arsenic, copper, lead, and mercury have either declined or remained steady (as opposed to increasing) in sediments and shellfish tissues during the past decade (PSAT 2005).

Organic Chemicals

A variety of organic chemicals have been detected in Washington, including, but not limited to, polycyclic aromatic hydrocarbons (PAHs), PCBs, poly-bromated diphenyl ethers (PBDEs), chlorinated pesticides (e.g., DDT [(dichloro diphenyl trichloroethane]), dioxins, certain pharmaceuticals and other emerging compounds.

PAHs are present in fossil fuels and other sources; certain types of PAHs are formed when fossil fuels and other organic materials are burned. Other sources include coal, oil spills, leaking underground fuel tanks, creosote, and asphalt. PAHs are found in urban and industrial areas, and have been associated with liver lesions in English sole in small concentrated areas of sediment or “hot spots” (PSAT 2005). Fish and shellfish consumption advisories have been issued in some areas due to the presence of this chemical. Exposure is linked to increased risks of cancer and to impaired immune function, reproduction, and development. Concentrations of PAHs in the Sound are often quite high compared to concentrations measured elsewhere around the United States.

Another group of organic chemicals of concern are PDBEs (e.g., flame retardants), members of a class of brominated chemicals. Flame retardants are added to a number of products to reduce the risk of the products catching fire if exposed to high heat or flame. PDBEs have been detected in several Pacific Northwest[8] aquatic species and their predators, including Dungeness crab (west coast of Canada), bald eagle (Lower Columbia River) and heron (British Columbia) eggs, orca (northeastern Pacific Ocean),

[8] WDOE and WSDH (2004) also report detections in biota from other parts of North America, including Murre, Fulmar, and Herring gull eggs, Beluga whales, lake trout, and carp.

mountain whitefish (Columbia River, Spokane River, British Columbia), rainbow trout (Spokane River), and largescale sucker (Spokane River) (WDOE and WSDH 2004). Although there is still some debate as to the effects of these substances, the molecule is similar to the thyroid hormone, which affects growth and reproduction (PSAT 2005); growth and reproduction of fauna could be affected by this contaminant. WDOE and Washington State Department of Health (2004) indicate that there are differences in the way species either metabolize or accumulate PDBEs; although the overall risk to different species of biota is unknown, there is sufficient evidence to merit concern.

Chlorinated organic compounds, such as PCBs, dioxins, and DDT are found in solvents, electrical coolants and lubricants, pesticides, herbicides, and treated wood (PSAT 2005). These compounds and their breakdown products persist in the environment because bacteria and chemical reactions break them down slowly (PSWQAT 2000). The use of PCBs was common until the 1970s when they were phased out in the United States and Canada. These chemicals are now banned in the United States; however, they continue to leach from landfills, other disposal sites, and contaminated sediments in Puget Sound. PCBs enter Washington’s natural environments and biota from these sources and from airborne fallout deposited after circulating across the globe from continuing sources in Asia (WDNR 2000a). PCBs are slow to degrade, float in air and water, permeate soil, and accumulate in animal fat. Generally speaking, the higher an animal is on the food chain, and the longer lived, the greater the concentrations of these toxins. In Puget Sound, concentrations of PCBs are found primarily in urban and industrial areas, and concentrations do not appear to be declining in recent years, unlike many other chemicals that were introduced historically into the waters and sediments of Puget Sound. The sources of PCBs include certain solvents, electrical coolants and lubricants, pesticides, herbicides, and some types of treated wood (PSAT 2005).

Chemicals such as dioxins and furans are generated as industrial process byproducts, and are linked to cancer, liver disease, and skin lesions in humans. Chlorinated pesticides, such as DDT, are linked to liver disease, cancer, hormone disruption, the thinning of bird eggshells, and reproductive and developmental damage. Fry (1995) identified organochlorine compounds as a prevalent non-oil pollution threat within the range of the murrelet. Specifically, polychlorinated dibenzo-dioxins (PCDD) and polychlorinated dibenzo-furans (PCDF) which are contained in pulp-mill discharges, cause significant injury to fish, birds, and estuarine environments. PCDDs and PCDFs bio-accumulate in marine sediments, fish, and fish-eating birds and impair bird health and production. There has been no record of bio-accumulated residues or breeding impairment in marbled murrelets to date, although murrelets that feed in areas of historical or current discharge from bleached-paper mills could be at risk from eating fish with bio-accumulated organochlorine compounds. Active chlorine-bleach mills in Washington were located in Port Angeles, Bellingham, Everett, and Gray’s Harbor as recently as 1997, and may still exist.

Other chemicals include phthalates, which come from plastics, certain soaps, and other products. Much of the exposure from these chemicals to biota occurs via wastewater from treatment plants. The effects from these chemicals are not well known, but may affect growth and development in fish (PSAT 2005). Pharmaceuticals and personal-care products, such as oral contraceptives, antibiotics, and other prescription drugs, as well as soaps, fragrances, and other compounds, enter the aquatic environment through sewage and wastewater-treatment plants. Effects and risks to aquatic biota from these substances have not been fully analyzed; however, Daughton and Ternes (1999) note that even substances that are not persistent but are frequently or continually released may impact aquatic species, which may have exposure throughout entire life-cycles and multiple generations. Daughton and Ternes (1999) also note that many of these products are being released worldwide in volumes comparable to chemicals associated with agriculture.

Fecal Coliform

The presence of fecal coliform bacteria is a significant water-quality issue in some areas of Washington. Fecal waste enters waters from sources such as poorly managed septic systems, wastewater treatment facilities, stormwater (which washes fecal matter in upland areas into waterways), and animal operations, and contains bacteria and viruses that can result in the contamination of shellfish beds and other resources (WDOE 2000, PSAT 2005). In Puget Sound, fecal coliform is reported to make up approximately 41 percent of the water-quality problems in the basin. Since 1980, 30,000 acres of commercial shellfish beds have been closed because of pathogens from fecal waste. Since 1995, the following areas experienced at least a partial or temporary closure: Drayton Harbor, Rocky Bay, Port Gamble, Portage Bay, Lilliwaup Bay, Burley Lagoon, Dungeness Bay, Similk Bay, Nisqually Reach, Henderson Inlet, and Filucy Bay (PSAT 2005).

This water-quality issue is being addressed through a number of actions to limit the amount of fecal matter and associated bacteria and viruses that affects the waterways of Washington State, including education and outreach, modifications in the amount and types of treatment at treatment facilities, fencing of livestock away from streams, and other activities. Even with these measures being used in some areas, the problem continues to exist. During the past two years, 1,655 acres of shellfish growing areas were added to the list of approved growing areas, indicating improvement; however, the growing areas that are on the list of threatened shellfish beds doubled from 1997 (nine sites) to 2004 (18 sites).

Levels of fecal coliform in streams and rivers are measured along with other water-quality parameters. The WDOE (2000) reports that 52 freshwater monitoring stations have been consistently surveyed since 1995 for fecal coliform, and that, with one exception, the stations are indicating that stream conditions regarding this parameter are either improving or there has been no change (i.e., no significant deterioration) in stream conditions.

Excess Nutrients

Excessive amounts of nutrients can come from many sources, including lawn fertilizers applied to yards and other areas, agricultural chemicals applied to fields, and fecal matter[9] from septic fields and failing septic systems. Excess nutrients can affect both surface water and groundwater. For example, WDOE (2005a) reports that seven percent of public-water-supply wells have high nitrate-nitrogen levels, with many of the affected sites clustered in highly populated and rural farming areas. As a result of the input of excess nutrients, aquatic systems and the biota that depend on them have experienced a number of effects (WDNR 2000a). Excessive nutrients in water cause algae and phytoplankton to grow prolifically. This prolific growth results not only in increased photosynthesis, but also in increased respiration by algae, phytoplankton, and other aquatic plants, which depletes the oxygen necessary for aquatic fauna survival. An increase in numbers of algae and phytoplankton decreases light penetration, reducing the depth to which freshwater and marine aquatic plants (e.g., eelgrass) can grow, especially in lacustrine and marine environments. In turn, there are fewer aquatic plants to provide oxygen and high volumes of decomposing organic matter further consumes valuable oxygen. Although Puget Sound has two tidal

[9] To clarify, bacteria (and viruses) are associated with fecal matter, and these concerns are discussed in the fecal coliform section; in addition to bacteria and viruses, feces also contribute excess nutrients in the form of nitrates.

cycles per day, marine waters in some areas of Puget Sound appear to be sensitive to water-quality problems that might be caused by the excess addition of nutrients because of the physical mixing characteristics in these areas (e.g., Hood Canal) (PSWQAT 2000).

Toxic algae blooms are another result of excess nutrient input into aquatic systems. In the past, toxic algae blooms occurred in warm summer months, and in the northern part of Puget Sound; more recently, toxic blooms have resulted in closures during the winter months, and have been reported in other areas of Puget Sound (WDNR 2000a). Certain types of algae cause Paralytic Shellfish Poisoning, also known as red tide, which affects organisms (including humans) that consume shellfish, although they seem to be harmless to the shellfish themselves.

5.4.4.2 Other Pollutants

In addition to the pollutants listed above, other contaminants have impacted Washington's aquatic (and terrestrial) habitats. Hazardous waste is generated by a variety of sources (WDOE 2000). Large industries, which generate most of the hazardous waste in Washington, include (in order of decreasing contributions) equipment manufacturing, primary and fabricated metals, chemicals and petroleum, lumber and wood products, and other sources. Smaller businesses, such as dry cleaners, printers, and auto repair shops, also generate hazardous waste, which can pollute aquatic and terrestrial habitats if the waste is not handled properly. According to WDOE (2000), the amount of hazardous waste being generated per person has been decreasing since 1992, and the decrease is likely attributable to reductions in the amounts of hazardous chemicals used in industrial business practices.

Nuclear waste has been generated at the Hanford Nuclear Reservation beginning in the 1940s (WDOE 2000). Approximately 54 million gallons of highly radioactive waste was reported to remain in 2000 (WDOE 2000). Many of the tanks are either leaking or are suspected of leaking, with reports of waste having contacted groundwater, potentially impacting habitats and biota.

Solid waste (i.e., trash) is generated in almost all aspects of society. As populations have grown in Washington, the amount of solid waste generation has also increased. Solid waste in Washington is generated primarily from municipal sources (74 percent), and to a lesser degree from demolition, inert, and wood waste (13 percent); industrial and commercial waste (7 percent); petroleum-contaminated soil (4 percent); and other sources (3 percent) (WDOE 2000). WDOE (2000) notes that the amount of daily solid waste generated per capita increased slightly from 1991 to 1998, averaging between six and eight pounds/day per person during this period. During the entire study period, a large part of the disposed waste consisted of materials that were otherwise potentially recyclable. In addition, approximately one ton of litter accumulates along each mile of interstate highway annually, with this amount increasing to 1.5 tons along urban stretches of highway (Thomas 2000). The primary components were glass, wood products, tires, metals, and plastic materials. Leakages from landfills as well as unauthorized dumping of garbage and waste chemicals can be a problem whether they occur directly into waters or whether they occur on land with the potential to later impact aquatic habitats.

5.4.4.3 Remediation of Contaminated Sites

The WDOE (2005a) has identified 142 contaminated sediment sites (Table 5-1). Of these, the majority are marine (81 percent); however, new contaminated freshwater sites are being identified as a higher rate than marine sites, as the agency has focused increasing attention on the freshwater environment. Sources of contamination for the these sites include a historical municipal landfill; wood, timber, paper, mining, petroleum, and other industrial sites; shipping and shipyard operations; military operations; combined sewer outfalls; leaking underground storage tanks; spills; and stormwater (WDOE 2005a). WDNR (2000) reported that, of the contaminated sites identified in 2000 by the WDOE in the state, over half occur from industrial activities; the remaining sites were a result of other activities: combined sewer overflows (13 percent), U.S. Navy operations (11 percent), stormwater (10 percent), and "other" activities (14 percent).

Most of the cleanup activities in the state are found in a few urbanized marine embayments, harbors, lakes, and rivers. Other contaminated sites are likely to be identified in the future, particularly in areas that have been less studied. On average, total numbers of identified sites increases by 5 percent annually.

Other projects have been recently undertaken to better understand the effects of chemicals on biota. For example, the effects of carbaryl on the ability of a salmonid (cutthroat trout) to avoid predation was assessed in relation to the use of a pesticide (carbaryl) to control mud shrimp and ghost shrimp in shellfish culturing areas in estuarine littoral flats in Washington (Davis and Scholz 2005a). The use of carbaryl in Willapa Bay has been investigated because of concerns with its effects on native biota. The effects of this pesticide are not limited to the area in which it is applied, as it is transported to other areas through tidal activity. In this study, cutthroat trout did not show an olfactory response to the presence of carbaryl, nor did they try to avoid carbaryl-contaminated seawater as they might with other contaminants such as copper; however, exposure to carbaryl appeared to affect the swimming performance of cutthroat trout, and made them more vulnerable to predation. Other studies have been performed in Longfellow and Des Moines Creeks (King County) to investigate the effects of other pollutants on salmonids (Davis, Personal Communication, 2005). The researchers determined that results to date suggest that stormwater runoff has important negative impacts on both the survival and reproductive success of salmonids in urban and urbanizing watersheds.

Table 5-1. Sediment cleanup sites: location and estimated areas of sites (WDOE 2005a)

Waterbody	# Sites	Total Reported Area[1]	Estimated Area[2]
Bellingham Bay	12	466	466
Columbia River	7	0	80-160
Commencement Bay	13	276	322-368
Duwamish River (lower waterway)	12	495	495
Elliott Bay/Harbor Island	24	377	377
Everett/Port Gardner	11	131	177-223
Fidalgo Bay	8	4	80-160
Kitsap Peninsula/Sinclair Inlet	16	367	367
Lake Union	7	107	107
Lake Washington	6	23	23
Other waterbodies	26	191	380-598
Total	142	2,407	2,510-2,980

5.4.4.4 Water Quality Indicators

Abiotic Indicators

In addition to the presence of contaminants, other parameters are also indicative of water quality. These indicators include (but are not limited to) temperature, dissolved oxygen, pH, turbidity, and instream flow. Many of the activities discussed elsewhere in the baseline section can have effects on these indicators. For example, sediment erosion may transport substances such as pesticides or fertilizers into a stream. The addition of excess nutrients from fertilizers often result in a decrease in the levels of dissolved oxygen as described above, potentially resulting in impaired function in the stream. The excess amount of sediments introduced during an acute or chronic erosion event may also result in suspended sediment and turbidity impacts to aquatic biota, which would further stress fauna experiencing low impact levels. An increase in temperature (as a result of removal of shading riparian vegetation, for example) is another type of stressor on aquatic biota, and when such an increase occurs in concert with other impacts, the result can be devastating to aquatic biota. If conditions do not result in lethal or sublethal effects to biota, they may influence the amount of time a mobile organism spends in the affected reach of a stream.

The WDOE has several monitoring activities to evaluate water quality in freshwater environments. For long-term trend and annual monitoring, basin stations are used to monitor 12 water-quality parameters and flow at several stations across the state. In 2003, 86 percent of the monitoring stations identified at least one of the water-quality indicators as impaired, or does "not support aquatic life and recreational uses" (Butkus 2004). These stations are found in a number of different WRIAs (Table 5-2). Although these stations indicate impaired function, Butkus (2004) also notes that statewide, a "slight but statistically significant improvement in water quality conditions," with the most improvement reported in the Columbia Basin Ecoregion.

Table 5-2. Basin monitoring stations showing 2003 conditions that did not meet water quality standards (Butkus 2004)

WRIA	WRIA Name	Stream	Indicators not meeting water-quality standards (and month not met)
10	Puyallup/White	Puyallup River	Mercury (Aug)
		White River	pH (May)
15	Kitsap	Union River	Fecal coliform bacteria (Oct-Dec, Jun, Jul), Dissolved oxygen (Nov, Sep)
		Little Mission Creek	Fecal coliform bacteria (Dec, Jun)
		Stimson Creek	Fecal coliform bacteria (Dec)
		Big Mission Creek	Fecal coliform bacteria (Dec), Temperature (Jul)
		Olalla Creek	Fecal coliform bacteria (Nov, Dec, Jul)
23	Upper Chehalis	Chehalis River	Temperature (Jun-Aug)
28	Salmon/Washougal	Columbia River	Temperature (Jul-Aug)
32	Walla Walla	Touchet River	Temperature (Jun-Aug), Fecal coliform bacteria (Jul-Sep), Dissolved oxygen (Jul, Aug)
		Mill Creek	Fecal coliform bacteria (Oct), Dissolved oxygen (Aug)
41	Lower Crab	Lind Coulee	Fecal coliform bacteria (Aug, Sep), Temperature (Jul, Aug), pH (Nov, Feb, Jun)
43	Upper Crab/Wilson	Goose Creek	Dissolved oxygen (Nov)
45	Wenatchee	Chumstick Creek	Fecal coliform bacteria (Aug, Sep)

		Brender Creek	Fecal coliform bacteria (Aug, Sep)
		Mission Creek	Fecal coliform bacteria (Aug, Sep), Temperature (Aug), pH (Oct, May)
		Eagle Creek	Fecal coliform bacteria (May)
		Noname Creek	Fecal coliform bacteria (Oct-Feb, Apr, Jun-Sep)
62	Pend Oreille	Pend Oreille River	Temperature (Jul-Sep), pH (Aug)

Other types of monitoring evaluate temperature and fecal coliform in water bodies (Butkus 2004). Continuous temperature monitoring is conducted at 54 of the basin and long-term monitoring stations in both eastern and western Washington to determine whether streams are meeting current and proposed water-quality standards. In 2003, temperatures exceeded current standards at 83 percent of the stations. Fecal coliform was evaluated in a sampling project at 10 lakes in King and Pierce Counties in western Washington; of these, five had at least one fecal coliform exceedance based on current water-quality standards. Additionally, 13 percent of surveyed streams had bacterial levels that exceeded the recommended levels for swimming. These streams are listed in Table 5-3, which indicates the amount of reduction required to allow safe contact by humans; however, it is likely that levels would have to be reduced even further to minimize lethal or sublethal effects to aquatic life. Furthermore, basins that meet swimming standards for fecal coliform may not necessarily meet fecal coliform levels necessary to sustain aquatic biota.

Table 5-3. Locations where 2003 bacteria levels were higher than recommended for swimming, and the pollution reduction needed to meet water quality standards (Butkus 2004)

WRIA	WRIA Name	Stream	Reduction Required
34	Palouse	South Fork Palouse River	91%
56	Hangman	Hangman (Latah Creek)	70%
34	Palouse	Palouse River	51%
13	Deschutes	Deschutes River	44%
54	Lower Spokane	Spokane River	37%
8	Cedar/Sammamish	Cedar River	9%
35	Middle Snake	Tucannon River	8%
10	Puyallup/White	Puyallup River	7%

When specific problem areas have been identified, plans have often been introduced to address the problem; the actual amount of success depends on local conditions and causes as well as funding issues and other factors. Butkus (2004) listed several specific examples of water-quality problems that have been recognized throughout Washington and the ways in which they have been addressed. In the Snoqualmie River basin, several plans (total maximum daily load or TMDLs) were initiated to control biochemical oxygen demand (related to dissolved oxygen), ammonia, and fecal coliform bacteria exceedances. Through cooperation with a variety of public and private entities, impacts from several different nonpoint pollution sources were addressed, including dairy waste and other livestock management, septic systems, and other factors for the protection of groundwater quality. Although there are occasional problems with fecal coliform bacteria, Butkus (2004) indicates that the overall changes have been positive.

Many sites have ongoing issues that have yet to be successfully addressed. For example, Hood Canal in western Washington has historically experienced relatively low dissolved oxygen levels due to the topography and circulation dynamics of the water body. In recent times, however, Hood Canal has experienced deterioration of conditions resulting in increasing levels of hypoxia. The available evidence suggests that human-related sources of excess nutrients are likely contributing to the increased hypoxia. Fagergren et al. (2004) identified major categories of human-influenced nitrogen sources which collectively introduced 86 to 319 tons of nitrogen per year. Human sewage (onsite systems) made up the largest component (at 39 to 241 tons annually). Other contributors with maximum estimated levels less than 25 tons annually were: stormwater runoff (including lawn fertilizers), agriculture/animal waste, forestry, and discharges from point sources, with the last two contributors ranging from 0.5 tons to 5 tons (forestry) and 0.3 tons to 3 tons (point sources) annually. This area is an example of how many different kinds of impacts can collectively impact an ecosystem. Although a number of groups have been working together for the past two decades to improve water quality in Hood Canal, Fagergren et al. (2004) report that hypoxia has continued to increase in frequency and extent in Hood Canal, and continued efforts to address the problem will be necessary.

Biotic Indicators

Certain types of organisms have been used to indicate the health of aquatic systems. The species evaluated may focus on specific concerns, such as the effects of fisheries on certain fish populations, or may provide general information regarding water-quality trends. For example, the status of two types of fish has been evaluated by Puget Sound Action Team (PSAT) (2005) as indicators for the health of Puget Sound. Rockfish and Pacific herring populations have been monitored for several years, and have life histories that provide insight into the result of various impacts to Puget Sound waters. Rockfish are a category of long-lived, slow-maturing fish that grows more fecund as it ages. Sexual maturity is reached at five to seven years, and some species live up to 100 years. Some rockfish populations are at less than 7 to 12 percent of their historical levels; the causes for their decline are not fully understood, but fishing pressure is believed to be a contributor (WDNR 2000a).

The evaluation of herring populations may provide insight into water-quality issues. Pacific herring and other small marine fish, such as the sand lance and surf smelt, are called “forage fish,” because they are important prey species for many other organisms. They make up a large part of the diet of several species of fish, marine mammals, and birds. WDNR (2000) reports that the following species depend on herring for a large percentage of their diet: lingcod (71 percent), Chinook (62 percent), coho (58 percent), Pacific halibut (53 percent), Pacific cod (42 percent), Pacific whiting (32 percent), and harbor seal (32 percent).

There are 19[10] known stocks of Pacific herring in Puget Sound. Of these populations, 15 are considered healthy or moderately healthy, three are considered depressed or critical, and the status of the remaining stock is unknown. According to WDNR (2000), herring spawning stocks decreased from over 20,000 tons in the 1970s to less than 10,000 tons in recent years. Cherry Point, within the Strait of Georgia, supports the largest herring stock in Washington and has experienced a precipitous decline. The decline of this stock may be affecting the forage base for salmonids in this region of Puget Sound. There is a moderate likelihood that organic contaminants are incrementally affecting this stock. Past research has shown that exposure to contamination reduces reproductive capability, growth rates, and resistance to disease, and may lead to lower survival for salmon (WDNR 2000a).

[10] A spawning ground at Wollochet Bay was not included in surveys prior to 2002. In previous publications, the number of stocks of Pacific herring has been reported at 18 (PSAT 2005).

Other fish have also experienced declines, and can be considered biotic indicators. A number of salmon stocks have declined in abundance in the Puget Sound region. On March 24, 1999, the NMFS listed the Puget Sound Chinook salmon Evolutionarily Significant Unit as threatened (64 FR 14308), while the Puget Sound-Strait of Georgia coho salmon Evolutionarily Significant Unit remains a species of concern.

Other predators that may be affected by contaminants or other water-quality issues include marine mammals such as harbor seals and whales, which eat fish and other aquatic life from all over Puget Sound. Harbor seals (*Phoca vitulina*) are considered to be indicator species because they eat a large variety of fish, including herring, bottom fish, and salmon. Some scientists surmise that if harbor seals are at risk from eating contaminated aquatic organisms, other marine mammals such as whales are likely to be at risk as well. Orcas (*Orcinus orca*) are among the most-contaminated aquatic mammals in the world, and PCBs are the main contaminant of concern. Elevated levels of chemicals in these animals probably have come from contaminated food (WDNR 2000a).

A number of marine bird species have declined by 50 percent or more in the past 20 years. Scoters declined by 57 percent in the past 20 years. During the same period, 13 out of 18 other marine diving birds in Puget Sound have showed significant population losses. Marbled murrelet numbers have declined by more than 90 percent in Puget Sound (PSWQAT 2002). More information is needed to determine the cause(s) of these declines, including water quality causes.

Not all biotic indicators are considered "charismatic megafauna" (such as orcas). Aquatic invertebrates can also provide site-specific information on the health of aquatic systems such as streams, lakes, or estuaries. For example, protocols have been designed to assess water quality and habitats by sampling benthic invertebrates in streams (Barbour et al. 1999) and in estuarine environments (Simenstad et al. 1991). Biological monitoring was also conducted for 31 sites throughout Washington in 2003. Biological monitoring provides better information for aquatic biota because degradation of sensitive ecosystem processes is more often detected. This type of monitoring directly measures the most sensitive at-risk resources, and looks at human influence on stream characteristics over time. Of the 31 sites, data on 24 reaches were reported (Butkus 2004). Results of this monitoring indicated that 50 percent of the sites were not meeting conditions supportive of the aquatic community, and only 21 percent were designated as fully supportive.

5.4.5 Air Quality

There are many sources of air pollution in Washington State (WDOE 1999). The main source of air pollution is motor vehicles, which contributes an annual average of 57 percent of the total air pollution in the state. Motor vehicles contribute carbon monoxide and ozone, with many of the urban areas of the state (e.g., King, Pierce, Snohomish, Spokane, and Clark Counties) experiencing significant problems. Although the sources of these emissions may be concentrated in urban areas, certain pollutants, such as ozone, can travel great distances, affecting downwind areas. Emissions checks have been instituted in the State, reducing air-pollution levels by approximately 146,400 tons each year, this reduction is partially offset by annual increases in both the number of cars and the total miles traveled (WDOE 1999).

Other sources of air pollution in Washington include industrial emissions (17 percent), woodstoves and fireplaces (11 percent), outdoor burning (5 percent), and other sources (10 percent), such as lawnmowers, boats and other recreation vehicles, aircraft, and trains (WDOE 1999). The amounts from each category have shifted in the past decade, when industrial emissions comprised 25 percent of emissions, while woodstoves and outdoor burning contributed 20 percent and 10 percent, respectively. These shifts likely occurred from increases in emission of vehicles and miles driven, improvements in certain instances of industrial air-quality emissions through state or local permitting processes, and restrictions on outdoor burning.

While air quality is generally good in eastern Washington, health advisories associated with agricultural burning are not uncommon, particularly in the Spokane area. This is exacerbated during the fall and winter months, when local inversions afflict many communities and trap pollutants in the airshed. Prescribed fire also impacts air quality in the spring and fall when State, Federal and tribal entities burn areas as part of natural-resource management. Wildland fire is a fairly common occurrence, but is unpredictable in its location, intensity, and duration. As a result, substantial investment is being made in and around eastern Washington forestlands to restore forest structure and disturbance regimes, often resulting in more prescribed burning and air-quality degradation. Areas commonly impacted by smoke include the Methow Valley (Winthrop and Twisp), Chelan, Leavenworth, and Wenatchee.

5.4.6 Habitat Modification

Washington’s habitats have been modified to varying degrees throughout human history. The earliest modifications likely included the use of fire to encourage or discourage the growth of certain plant communities. The extent of modification has increased through time, with much of Washington’s lands used for agriculture, forestry, urban and industrial development, and/or mining. Each of these land-use types affects species and habitats differently. The following paragraphs discuss some of the general types of habitat impacts that have been caused by development. Subsequent sections will discuss impacts from various categories of land-use activities.

5.4.6.1 Shoreline Development

Significant development and urbanization has occurred within much of Washington. In western Washington, the greatest impacts have been to mainstem river channels, estuarine, and nearshore marine habitats, but many sub-basins in the lower part of major watersheds have been altered as well. Impacts have also occurred in salmonid spawning and rearing areas, which may be well upstream of the lowlands. In western Washington, approximately one-third of Puget Sound’s shoreline has been modified, with over half of the main basin of Puget Sound having been altered (PSWQAT 2000). In eastern Washington, shoreline development has also affected the region’s lakes and reservoirs, many of which were created with the construction of dams.

In western Washington lowlands, more than 50 percent of the tidal flats and intertidal areas in major embayments of Puget Sound have been lost since 1850 (Bortleson et al. 1980 *cited in* PSWQAT 2000). Some highly urbanized areas, such as Commencement Bay, have lost more than 99 percent of historical marsh habitat and more than 89 percent of historical intertidal mudflats (USACOE et al. 1993). Recent reports state that over 98 percent of the historical intertidal and subtidal habitats in Commencement Bay have been lost (WSCC 1999b). Many estuarine and nearshore areas of Puget Sound have been filled or have had overwater structures installed to provide upland development sites for commercial/industrial uses and, to some extent, residential development. They have also been dredged extensively to maintain navigation and provide access to piers.

Significant portions of nearshore and shoreline habitats in estuarine areas and certain freshwater lakes (e.g., Lake Washington, Lake Whatcom) have been altered with vertical or steeply sloping bulkheads and revetments to protect various developments and structures (e.g., railroads, piers) from wave-induced erosion, to stabilize banks and bluffs, to retain fill, and to create moorage for vessels (BMSL et al. 2001). Nearly 100 percent of the Duwamish estuary and Elliott Bay shoreline has been modified by some type of armoring (BMSL et al. 2001). In areas where nearshore habitats currently remain intact or are only partially modified, development continues to threaten these habitats (WSCC 1999a; BMSL et al. 2001). Habitats at risk from direct human alteration include riparian buffers, freshwater habitats (e.g., streams, lakes), and Puget Sound's fringe of shallow subtidal, intertidal, and shoreline habitats known collectively as the "marine nearshore." Depending on placement in relationship to drift cells, and other shoreline characteristics, armoring of the shoreline can interrupt the natural inputs of sand from landward bluffs, resulting in sediment deficits within the landscape.

Shoreline development has affected many sensitive habitats in western Washington. One such sensitive habitat type is eelgrass. Eelgrass beds grow in the intertidal zone and in mud and sand in the shallow sub-tidal zone and support numerous aquatic species, from geese and dabbling ducks to spawning forage fish. Available information suggests eelgrass has declined substantially over last 100 years (WDNR 2000a). Significant areas containing eelgrass beds have been impacted due to harbor development, dock building, dredging, and bottom trawling. Shipping, docks, bulkheads, and other shoreline developments likely contribute to the reduction in eelgrass and other spawning and rearing areas for forage fish.

In eastern Washington, poor compliance with the state's GMA, in conjunction with extensive dam and irrigation networks, has dramatically affected shoreline development and resulted in degraded conditions. Increased development along larger lakes (e.g., Lake Chelan, Potholes Lake, Lake Wenatchee) has strained septic designs, making sewer hookups the only feasible approach to restore water quality. Increased impervious surface accompanies increased development, degrading water quality by collecting contaminants, and affecting hydrologic function. Land conversion into residential development has also directly impacted shorelines, as waterfront property is often very desirable.

In response to some of these changes, enhancement and restoration activities have been planned and implemented in many areas throughout Washington. For example, a number of restoration projects have been constructed in the lower Duwamish waterway (Tanner 2000), an urbanized and heavily used ship channel that has historically had serious challenges with contaminants. Recent reports indicate that, although there have been challenges associated with construction, maintenance, and monitoring efforts at the sites, these projects have successfully attracted foraging and migratory salmonids, birds, and other wildlife (Burgdorf and Gearns 2004).

5.4.6.2 Impervious Surfaces

Scientific studies indicate there is a strong relationship between the amount of forest cover, levels of impervious and compacted surfaces in a basin, and the degradation of aquatic systems (Klein 1979; Booth et al. 2002). Impervious surface associated with residential development and urbanization creates one of the most-lasting impacts to stream systems. Changes to hydrology (increased peak flows, increased flow duration, reduced base flows) as a result of loss of forest cover and increases in impervious surfaces are typically the most-common outcomes of intensive development in watersheds (May et al. 1997; Booth et al. 2002). Increased peak flows and flow duration often lead to the need to engineer channels to address flooding, erosion, and sediment-transport concerns.

Stormwater runoff continues to be a significant contributor of non-point source water pollution in core spawning and rearing areas and foraging, migration, and overwintering habitat areas for salmonids (WSCC 1999a; WSCC 1999b; KCDNR and WSCC 2000). Although not typically a direct measure of the influence of development, basin imperviousness is commonly used as an indicator of basin degradation

(Booth et al. 2002). Reduction in forest cover and conversion to impervious surfaces can change the hydrological regime of a basin by altering the duration and frequency of runoff, and by decreasing evapotranspiration and groundwater infiltration (May et al. 1998, Booth et al. 2001). Such changes can be detected when the total percentage of impervious surface in the watershed is as low as 5 to 10 percent (Booth et al. 2002). Watershed degradation, however, likely occurs with incremental increases in impervious surfaces below these levels, and is exacerbated by other factors such as reduced riparian cover and pollution (Booth 2000; Karr and Chu 2000; Booth et al. 2002). Booth et al. 2002 state, "[t]he most commonly chosen thresholds, maximum 10 percent effective impervious area and minimum 65 percent forest cover, mark an observed transition in the downstream channels from minimally to severely degraded stream conditions." They further assert, "Development that minimizes the damage to aquatic resources cannot rely on structural best management practices (BMP) because there is no evidence that they can mitigate anything but the most egregious consequences of urbanization. Instead, control of watershed land cover changes, including limits to both imperviousness and clearing, must be incorporated."

The amount of new impervious surfaces has increased significantly in recent history, and this trend will likely continue this trend in the future. Nonetheless, actions have been implemented by several entities to begin to counter the effects of impervious surface water and stormwater runoff on natural resources. Projects using low-impact development technologies have been planned or constructed in Whatcom, Thurston, Pierce, Island, Kitsap, and King Counties (PSAT 2001). Projects in various areas have included the construction of swales, rain gardens, and narrower roads, and the installation of permeable pavement, among other technologies. Some jurisdictions have provided guidance for region-wide planning. A technical guidance manual was recently released by the Puget Sound Action Team (Hinman 2005), outlining low-impact development strategies and tools for development in the state.

5.4.6.3 Loss of Riparian Buffers

The riparian zone along a stream is a transitional area between the stream and uplands, and performs a variety of functions in the ecosystem (WDNR 2000a). Trees and shrubs along the bank provide shade and cover for fish and other aquatic biota, while their roots provide bank stabilization and help to control erosion and sedimentation into the stream. The riparian zone also contributes nutrients, detritus, and fallout insects into a stream, which supports aquatic life. Vegetation and soils in the riparian zone protect the stream against excess sediments and pollutants. The riparian zone contributes to the reduction of peak stream flows during floods, and acts as a holding area for water, which is released back into the stream during times of low flow. The trees in the riparian zone serve the ecosystem even after they fall, many of them altering flow and creating habitat features (e.g., pools, riffles, slack areas and off-channel habitats) which benefit fish and other aquatic biota at various life stages. WDNR (2000) reports that approximately 85 percent of wildlife species in Washington depend on riparian habitats.

Since the early 1800s, over 50 percent of Washington's riparian habitats have been modified or lost (WDNR 2000a). Many different kinds of human activities have impacted riparian zones along streams in Washington. These activities include, but are not limited to, urbanization, agriculture, grazing, mining, channelization and damming of streams, logging, and recreational activities (Bolton and Shellberg 2001). In both eastern and western Washington, the riparian areas along streams are often converted to agricultural uses: croplands, pastures, dairies, and fields. These uses are often preceded by logging (Kauffman et al. 2001).

While human-related activities conducted within the riparian zone can damage the integrity of a riparian system, activities that occur outside the riparian zone can also create impacts (Kauffman et al. 2001). Riparian zones are often relatively flat and/or are situated at low elevations when compared to adjacent upland topography within a watershed; as a result, sediment and soils, nutrients, water, and substances carried by these vectors from upslope or upstream activities are often deposited by gravity within riparian zones. While the riparian zone helps to buffer streams against these materials, too large a volume can impact the riparian zone's ability to properly function in either the short- or long-term. The buffering ability of a riparian zone can be affected by landslides, erosion, altered flow regimes, degraded water quality, contaminant inputs, or other sources. Logging, agriculture and grazing, road construction, or other activities can generate these impacts, if appropriate safeguards are not in place.

Several efforts have been made to restore and/or protect riparian buffers along Washington streams. The Salmon Recovery Funding Board (2005) funded restoration or enhancement projects along 96 miles of streams between 2000 and 2004. Some activities have been designed to improve conditions along streams adjacent to farmland (Canty and Wiley 2004). Incentive programs, such as the Conservation Reserve Enhancement Program, encourage the maintenance of riparian buffers to protect water quality and habitat. By 2003, 216 farms in the Puget Sound area were participating in the Conservation Reserve Enhancement Program, resulting in the protection of almost 2,000 acres of stream. By the end of the same year, 80 percent of almost 600 registered dairy farms in Washington had implemented nutrient-management plans for their facilities. Riparian planting projects are sometimes done in conjunction with the removal of invasive, non-native species. For example, in a Thurston County project, Scots broom (*Cytisus scoparius*) and Himalayan blackberry (*Rubus discolor*) plants were removed and replaced with approximately 3,000 native riparian plants on 15 acres of conserved land along the Nisqually River and maintained by the Nisqually Land Trust (Carlson, Personal Communication, 2005c). Some groups are working to restore stream structure and function, and these characteristics are often related to functions that are normally provided by the riparian zone. For example, the Nisqually Tribe and the Northwest Indian Fisheries Commission have implemented a project to add LWD to a tributary to the Nisqually River (Mashel River), with associated monitoring of the effectiveness of the project (SPSSEG 2002).

Although recent changes have been made to most regional and local development regulations to provide protection (i.e., buffer zones) for riparian areas, the integrity of these areas is frequently compromised by encroachment (May et al. 1997). There is no prescribed buffer size to protect a stream or other water body from all potential impacts. Different buffer widths are required depending on the characteristics of each potential pollutant and the integrity and/or quality of a particular riparian zone; therefore, unless riparian zone buffers are carefully evaluated based on adjacent land use and threats, the success of the riparian zone in adequately buffering pollutants is uncertain at best. For many small stream systems, riparian areas are highly degraded or no longer exist, and their restoration is precluded by existing development. Although functional riparian areas have the capacity to mitigate for some of the adverse impacts of development (Morley and Karr 2002), they cannot effectively address significant impacts from changes to stream hydrology resulting from significant losses of forest cover (May et al. 1997; Booth i.e., 2002).

5.4.6.4 Loss of Wetlands

Wetlands provide habitat and perform functions that contribute to the health of ecosystems used by many species within Washington. There are many different kinds of wetlands (e.g., bogs, fens, estuaries, marshes, etc.), each of which has different characteristics and functions. Wetlands are found in diverse landscapes, including forests, prairies, deserts, and within floodplains of streams (WDNR 2000a).

Wetlands help maintain cool water temperatures, retain sediments, store and desynchronize flood flows, maintain base flows, and provide food and cover for fish and other aquatic organisms (Beechie et al. 1994, Mitsch and Gosselink 1993; WDOE 1998). Wetlands also can improve water quality through nutrient and toxic-chemical removal and/or transformation (Hammer 1989; Mitsch and Gosselink 1993).

Since the time of colonization, Washington State has lost between 30 to 50 percent of its wetlands through various efforts to modify or "reclaim" them for human uses (USFWS 1999a, WDNR 2000a). Certain types of wetlands have been particularly affected by development and modification. For example, WDNR (1998a) reports that by 1979, Washington had lost about 70 percent of estuarine wetlands that existed prior to 1800; some important river delta and estuarine areas, particularly those on the eastern shores of Puget Sound, have lost up to 99 percent of their wetland areas (WDNR 1998a, WDNR 2000a). Additionally, the functions of existing wetlands have been reduced. Various factors have contributed to wetland loss and wetland function reduction including agricultural development, urbanization, timber harvest, road construction, and other land-management activities. It is difficult to assess the current condition of wetlands in forested lands and other areas across the entire State. However, some wetlands on lands subject to the Washington Forest Practices Rules were altered in the past due to timber harvest and road building. These actions can affect wetland sites directly through vegetation alteration, soil compaction, changes in hydrologic regime, and degradation of water quality; or indirectly through sedimentation from adjacent land-management practices. Increases in impervious surface within a watershed have also been shown to affect wetlands (WDNR 2000a). Additionally, harvest of trees in or adjacent to wetland sites can affect the associated microclimate (Brosofske et al. 1997; Chen et al. 1995, 1999). Other impacts to wetlands have likely occurred from fires and other natural disturbances.

5.5 AGRICULTURE AND GRAZING

Agriculture is one of the principal industries in the State, with all production, processing, distribution, and marketing operations comprising $29 billion of the total economy of the State (Canty and Wiley 2004). Green et al. (2000) reports the existence of over 15,000 operations in Washington State, covering over 15,000,000 acres. Agriculture operations, which in this Opinion will address both farming and animal operations, exist in both western and eastern Washington, but there are differences between the kinds and sizes of operations between the two regions (Canty and Wiley 2004). In western Washington, individual farms are relatively small, with the primary products including dairy, poultry, and berries. In the eastern part of the state, large farms are common, producing wheat, barley, potatoes, fruit, and vegetables.

Many animal husbandry operations exist in Washington. Large operations in the State include cattle (beef and dairy) and poultry (Green et al. 2000). Other smaller operations raise horses, pigs, sheep, geese and ducks, dairy goats, rabbits, and exotic animals (e.g., llamas, emus, alpacas, ostriches). About one-third of the state is grazed by livestock, according to a study by the Washington Rangeland Committee and the Conservation Commission (in Green et al. 2000). The study indicates that rangeland acreage in the state totals approximately 7 million acres, while an additional 5.5 million acres of forested habitats have the potential to support grazing.

With the steady increase in urbanization and population growth in Puget Sound, agricultural lands are steadily being converted to residential and urban developments. Canty and Wiley (2004) report that more than one million acres of farmland was converted for other uses between 1982 and 1997, and with 20 percent of the Puget Sound-area farmland converted during this period. Conversion of farmland results in the fragmentation of surrounding farmlands (Canty and Wiley 2004), and displacement of new farmland development and/or expansion to marginal growing areas, in which lower yields may require conversion of a greater amount of forested habitats. These factors have also resulted in a net decrease in agricultural areas.

5.5.1 History

Many natural habitats were converted in both eastern and western Washington to support agricultural operations, with such conversions beginning in earnest by the mid-1800s, and continuing into the 1950s (Edge 2001). Many of the areas deemed suitable for agriculture were converted by the 1930s and were located in floodplains, estuaries and other wetlands, and prairies. West of the Cascades, farmlands are generally found in low-elevation, low-gradient areas, and most conversion to agricultural lands has occurred along lower elevations of the watersheds, estuarine and nearshore areas, or along floodplains of mainstem river reaches. For example, the Estuarine Research Federation estimates that 93 percent of the historical wetlands in the lower Skagit have been converted by agricultural activities over the past 150 years (Dean et al. 2000). In the Snohomish River estuary, approximately 74 percent of the wetlands were diked and drained for agricultural purposes (WSCC 2002b) and in the lower Stillaguamish, tidal marsh and wetland habitats within the anadromous zone have been reduced by 96 percent of historical levels (WSCC 1999a). Most of the major effects occurred in the early part of the century but construction of revetments and water-control structures continued into the 1960's in some areas.

East of the Cascades, deep arable soils and water availability have historically been significant determinants of agricultural lands. In these areas, agriculture began in the 1800s, with some of the first major modifications of habitat occurring with the construction of irrigation ditches to provide water for small areas of rangeland (WDNR 2000a). Other modifications soon followed. Before the 1930s, the majority of agricultural lands in eastern Washington were located in the grasslands of the Palouse Prairie area, which did not rely on irrigation to raise the main crops of grain, corn, and dry peas (WDNR 1998a). However, by the early 1900s, over 100,000 acres were being irrigated in the Yakima River Basin, with the water in the river already over-appropriated (WDNR 2000a). Flood-control dikes were constructed to prevent damaging floods, but resulted in habitat destruction and floodplain disconnection (WDNR 2000a). Beginning in the 1930s, dams and irrigation projects, including the Yakima Basin Irrigation Project, were constructed by Federal Bureau of Reclamation projects to increase the area in which crops could be grown (WDNR 1998a, WDNR 2000a). Complex systems of dams and irrigation canals (previously described in this section of the Opinion) were constructed, permanently affecting water quality, water quantity, and habitat.

Grazing began in Washington in the mid 1800s, with sheep and cattle herds initially using the lush grasses that covered many parts of eastern Washington (Oliver et al. 1994). Sheep grazing peaked in the 1930s, and then rapidly declined, while cattle grazing increased steadily in most areas (Oliver et al. 1994). In the early 1900s, livestock grazing was authorized on National Forest lands (Oliver et al. 1994). Grazing fees and regulations were implemented in 1906, with grazing allotments initiated the following year, although enforcement efforts were not substantial enough to prevent trespass by unregulated livestock. Grazing resulted in a number of effects, including: a general decline in range conditions; excessive use of available forage and resulting conflicts between livestock owners; removal of highly flammable fuels and reduction in ground fires; purposeful setting of fires (by livestock owners) leading to uncontrolled fires; establishment of invasive, non-native vegetation; and increase in siltation of water bodies.

As a result, the Bureau of Land Management began regulating grazing on public rangelands in the 1930s. Asian grasses were introduced as stabilizing vegetation for the erosion caused by overgrazing and other practices. The reduction in the number of sheep and localized declines in grazing pressure by cattle in some areas allowed recovery of some of the rangelands (which included forestlands) (Oliver et al. 1994). By the 1960s and 1970s, legislation allowed for monitoring, improvements, and better stewardship of rangeland (including those in National Forests).

5.5.2 Effects to Natural Resources

Agricultural lands provide some benefit for fish and wildlife species in comparison with certain other land uses. For example, there is generally less impervious surface associated with agricultural lands than in urbanized or industrial areas. However, there are a number of impacts associated with farms and animal operations. Agricultural practices have contributed to the loss of side-channel areas and riparian vegetation in the floodplain. The effects of livestock grazing, dairy operations, and crop production often extend many miles upriver and into areas managed primarily for timber. In the Skagit Valley, farms and pastures extend approximately 112 kilometers (70 miles) upriver to the community of Concrete. In the northern Puget Sound area, agriculture is most pronounced in the Nooksack River, where farming activities comprise almost 12 percent of the entire watershed and extend at least 69 kilometers (43 miles) up the mainstem and another 16 kilometers (10 miles) up the South Fork Nooksack River. In the Stillaguamish, the construction of dikes and revetments has resulted in a loss of over 31 percent of the historical side-channel habitat and the combined impact of agriculture and residential development has reduced the riparian vegetation in these areas by nearly 90 percent.

Agricultural operations also result in the degradation of water quality due to contaminants, such as excess nutrients, fertilizers, pesticides, and other chemicals. Livestock production often degrades water quality with the addition of excess nutrients, while pesticides are often applied to crops which can leach into the water table and enter streams from surface water runoff (Rao and Hornsby 2001; Spence et al. 1996). A number of pesticides have been detected in small streams and sloughs within agricultural and urban sites tested within Puget Sound (Bortleson and Davis 1997). In addition, elevated nutrient concentrations from animal manures and agricultural fertilizer application can contribute to excessive growth of aquatic plants and reduced levels of dissolved oxygen in Puget Sound and other waterbodies in the State, which can adversely affect fish (Embrey and Inkpen 1998) and other aquatic organisms.

Water quality can also be affected by increases in temperature and sediment loading from agricultural operations. As described previously, irrigation systems often result in warmer water temperatures in canals and streams. Warmer temperatures can result from the clearing of shade-providing riparian areas along streams or other waterways, and from solar heating of water flowing across fields or in shallow waterways. Sediment loading is a significant contribution of dryland agriculture in eastern Washington, and results from storms and rain and snow runoff (Palmisano et al. 1993).

Effects from livestock grazing can be considerable if management practices are not sufficient to protect habitat functions (WDNR 1998a, Wissmar et al. 1994, Belsky et al. 1999). Livestock grazing is currently the primary land use in existing eastern Washington shrub-steppe habitats; this grazing, together with fire suppression, has altered the nature of the habitat in several ways (WDNR 1998a). Shrubs are more numerous because many are not eaten by livestock, while bunchgrasses are less common because they are consumed or trampled by livestock. Trampling also damages the fragile moss and lichen layer that protects the soil against erosion and non-native invasive vegetation colonization (e.g., cheatgrass) and provides nutrients to the soil. Additional impacts may result from other practices, including: (1) improper spreading, of manure; and (2) increased surface runoff from overgrazed pastureland or other areas in which large numbers of animals are confined (Green et al. 2000).

A number of different kinds of habitats can be affected by grazing. Riparian and wetland habitats and stream water quality is often degraded by grazing, resulting in cascading effects to fish and riparian habitat in both eastern and western Washington (Wissmar et al. 1994). Kauffman et al. (2001) reported that livestock grazing is probably the most-extensive land use in the Pacific Northwest, significantly influencing the structure of riparian areas. Overstocking and overgrazing in eastern Washington since the 19th century were slowly recognized to be damaging to rangeland, resulting in changes in grazing practices; however, the adaptations in management have not fully addressed the problems created by grazing. Wissmer et al. (1994) notes that recent changes in grazing practices have resulted in additional concerns about damage to sensitive riparian and wetland habitats. For example, the grazing of cattle instead of sheep often leads to increased damage to riparian habitats (which cattle, especially bulls often seem to prefer) if they are not excluded from these areas. Many grazing operations have adopted limits to the amount of current annual vegetative growth removed to protect riparian shrubs that decrease under heavy grazing pressure. Instream restoration is used to try to reverse stream down-cutting and dropping water tables, alternate water supplies are developed on slopes to encourage use of secondary range, and sensitive reaches of streams are sometimes precluded from cattle use. Reintroduction of beaver to watersheds where they were extirpated is being considered in some cases to help reverse stream down-cutting and dropping water tables. Typical impacts to forested habitat includes removal of native vegetation, change in vegetative species composition, introduction of invasive non-native species, degradation of water quality, and erosion of stream banks and springs.

Other impacts result from the maintenance of grazing lands. Fence construction, reconstruction, and maintenance activities require transport of materials, digging of holes, and stringing or re-stringing wires or fences. Treated-wood posts are often used at corners with braces, with interspersed metal posts, wooden posts, or live trees. On flat terrain, power equipment may be used to auger holes and construct fence. On steep terrain, hand tools and chain saws become more common. Rock cribs are often used when crossing areas of bedrock.

Attempts have been made to begin correcting some of the past impacts on the State's ecosystems from agricultural operations. In 1988, the EPA implemented the Federal Insecticide, Fungicide, and Rodenticide Act to regulate the acceptance and use of chemical pesticides, although some authors note challenges associated with use of the Federal Insecticide, Fungicide, and Rodenticide Act (Edge 2001). Additionally, State and Federal landowner-assistance programs have been organized to aid landowners in voluntarily managing their properties to improve water and habitat quality (Edge 2001). In western Washington, Puget Sound was selected for inclusion in the National Water Quality Assessment program to begin addressing these issues. Certain actions have been specifically implemented to reduce impacts from grazing. Fords have been created by adding rock to streams beds that have been muddied by livestock use, fencing and guzzlers are often installed to reduce livestock disturbance to riparian areas.

5.6 MINING AND MINERAL PRODUCTION

Mining and mineral production includes sales of rock, gravel, and sand; prospecting and mining contracts; and oil and gas leases. Washington State (2005) indicates that the value of mineral production has steadily increased since 1975, despite the fact that data are not always available for all categories due to disclosure laws. It is likely that additional mineral deposit discoveries will lead to further activities in mining (with development possibly preceded by timber harvest) and mineral processing in the action area. Potential effects from such activities include loss of habitats, displacement during activities, harassment, and decreases in habitat quality.

As of 1998, there were 1,173 active rock, sand, and gravel mines over three acres in size permitted in the State (WDNR 1998a). Of these, 30 were over 200 acres in size. Some unknown number of pits are less than three acres in size and thousands of pits (averaging at least one per square mile) are used for construction and maintenance of commercial forest roads. During 1995, Washington produced over 41 million tons of sand and gravel and over 17 million tons of rock. On average, each person in the State is responsible for the consumption of over three tons of stone and over seven tons of sand and gravel each year. This average annual use of almost 11 tons would be about 16 tons if the production from smaller pits, such as forest roads, was also considered. Continued population growth is rapidly depleting the larger mineral deposits in Washington (WDNR 1998a).

Mining activities in eastern Washington can be described in terms of locatable, leaseable, and salable minerals. Much of the mining industry east of the Cascades has focused on metals (gold, silver, copper, nickel, and chromium), gravel, and stone (Wissmer 1994). While exploration for locatable minerals (e.g., copper, gold, silver, iron, etc.) is fairly common where the geology suggests they may be present, large-scale extraction is relatively uncommon. Current large-scale commercial mining occurs primarily in Okanogan and Ferry Counties, but smaller operations are relatively widespread. Larger operations are regulated by State and Federal agencies, so effects can be assessed and minimized through the permitting process. Smaller-scale mining operations are not generally analyzed individually, but rather can result in lesser impacts to ecosystems if appropriate guidance is followed (e.g., "Gold and Fish pamphlet; WDFW 1999a). Leasable minerals (e.g., oil, natural gas, coal, and geothermal mining) are relatively uncommon in eastern Washington or are not in sufficient amounts to be considered profitable. Notable exceptions include coal in the Cle Elum area, and natural gas in the Tieton River and Tri-cities area. Salable minerals (e.g., sand, stone, gravel, cinder, and clay) are widespread and typically abundant, but are of low relative value. They are generally used for construction purposes, but may be used for decoration and landscaping as well.

5.6.1 History

Historical operations occurred primarily in north-central and northeast Washington in the late 1800s and in the Yakima and Grande Ronde River basins in the early 1900s (Oliver et al. 1994). Many of the early mining activities targeted coal (initially in Bellingham Bay and King, Pierce, and Kittitas Counties) and gold (eastern and western Washington) (Palmisano et al. 1993). Other products included metals (zinc, copper, lead, silver, gold), which peaked in production between 1940 and 1970, and industrial mineral mining. The latter group includes a number of materials (e.g., sand, gravel, clay, diatomite, gypsum, peat, barite, dolomite, talc, etc.), and has experienced a rapid increase in production since the mid-1900s.

As of 1994, mining activities were relatively uncontrolled in National Forests (Oliver et al. 1994). Oliver et al. (1994) reports that from 1967 to 1992, there were 1,105 active claims in the Yakima Drainage Basin, covering just under 20,000 acres (compared to 112 claims over 2,012 acres from 1946 to 1966).

5.6.2 Effects to Natural Resources

Past mining for minerals has had a range of effects in eastern Washington from relatively minor, to qualifying for EPA's Superfund status. Impacts from historical operations included effects to stream and riparian ecosystems through habitat modification (including ditching and diversion operations), erosion/siltation, leaching, and dredging. Recent effects of mining include contaminants from leach mining (e.g., resulting in releases of cyanide or other chemicals) and excavation of stream channels and floodplains from sand and gravel operations (Wissmer et al. 1994; Oliver et al. 1994, Martin and Platts 1981).

Recreational mining and commercial mining can significantly alter the physical structure and stability of instream habitat (Spence et al. 1996). In-channel gravel mining can result in both upstream and downstream channel incision, which further destabilizes stream banks, leads to channel simplification, changes bed-load movements, and alters groundwater hydrology, which may reduce summer base flows (Spence et al. 1996). Although there have been recent revisions to the State rules and regulations for mineral prospecting and placer mining to be more protective of aquatic species ("Gold and Fish" pamphlet; WDFW 1999a), habitat impacts (especially cumulative and frequency impacts) from ongoing recreational mining are still a concern in salmonid spawning and rearing streams.

The negative effects of small-scale dredge mining may be minor and localized if the extent of the dredging is small (area or length of stream) and operations are timed to avoid direct excavation of salmonid eggs and fry. Effects can also be reduced if operators do not disturb or destabilize stream banks, vegetation, LWD, or boulders, and the reconfigured streambed does not reduce the stability of interstitial spawning and rearing habitats during subsequent peak-flow events (MBTSG 1998).

Wissmer et al. (1994) notes that, although some limitations have been placed on the method and extent of gravel excavation, habitat impacts are still likely to occur. Overall, mining effects in the past have resulted in substantial degradation of stream habitats and associated fisheries. Some of these effects continue to occur, degrading baseline conditions; actions are on-going in some areas in an attempt to restore ecosystem function. Current mining operations are generally better regulated, and should therefore result in comparatively fewer effects; however, attempts to determine long-lasting changes would be premature.

5.7 FORESTRY

The State encompasses 42,613,000 acres (66,582 square miles), including 21,892,000 acres, (51.4 percent) of public and private forests (Table 5-4 below). Government entities own about 13,350,000 acres of forestlands, with approximately 9,000,320 acres under Federal management. The remaining forestlands, approximately 8,542,000 acres, are private- and/or corporate-owned (i.e., not Federal and not WDNR) forestland in Washington (WDNR: 1991-1993 The Rate of Timber Harvest in Washington State (August 1997) in WFPA 2001; WFPA 2001).

The forest products industry in Washington is the second-largest manufacturing sector in the State after transportation (primarily aircraft production). The industry directly employed 50,060 workers in 2000, or 13 percent of total manufacturing employment. Lumber, plywood, paper, and other forest-products industries account for more than 15 percent of the total manufacturing income in the State. Foreign export of raw logs and lumber as a percent of total timber harvest has sharply declined from a high of 49 percent in 1989 to just under 15 percent in 2000 (WFPA 2001, page 11).

Approximately 4.1 million acres of forests in western Washington and 2.3 million acres of forests in eastern Washington are closed to harvest, due to some form of protected status (e.g., National Parks). Forestlands in western Washington account for about 57 percent of the forestland in the State, but have historically provided over 80 percent of the total timber harvest (Adams et al. 1992).

Table 5-4. Forest Land Ownership in Washington State. (WFPA 2001).

Forest Land Ownership	Subgroup	Acres
Government		**13,350,000**
Federal		9,541,000
	National Forest - Non-Wilderness	5,272,000
	National Forest - Wilderness	2,576,000
	National Forest - Scenic and Recreation	189,000
	National Parks	1,451,000
	National Wildlife Refuge	3,000
	Bureau of Land Management	50,000
State Trust		2,270,000
Native American		1,269,000
County and Municipal		270,000
Private		**8,542,000**
Industrial		4,305,000
Nonindustrial		4,237,000
Totals		**21,892,000**

5.7.1 History

The first report of timber harvest in Washington was the 1827 activity by the Hudson Bay Company near Vancouver, Washington (Palmisano 1993). By the mid-1850s, a series of mill towns had been established along Puget Sound, with steam sawmills operating in a number of areas in Puget Sound (Palmisano 1993). As with western Washington, forestry activities in eastern Washington originally occurred in areas that were easily accessible, such as near settlements, mines, and railways (Oliver et al. 1994). Forested areas that were considered unsuitable for agriculture were managed for timber harvest. Selective cutting, high grading, and overstory removal were harvest systems that were used in eastern Washington, with relatively low volumes harvested due to inaccessibility and costs.

Pioneers used Washington’s river systems to transport logs and other goods. Trees were felled directly into streams, rivers, and salt water and floated to their destinations, or pulled to streams and trapped behind splash dams, which were dynamited or pulled away, causing logs to sluice downstream. Roads for oxen, then railroads, followed transportation by water. In railroad logging, powerful steam-powered “donkey” engines pulled logs across great distances on the ground, crossing streams and anything else in the way. Following World War II, truck road systems replaced railroads, but smaller streams continued to be used as transportation corridors (CH2MHill 2000).

After 1930, the introduction of motorized trucks and chainsaws allowed for substantial increases in harvest. Fueled by the demand for new housing and development after World War II, harvest increased dramatically. Harvest initially focused on large-diameter trees; smaller trees were then harvested, ultimately reducing the number of large-diameter trees. Harvest of uneven-aged trees was practiced until 1940; by the 1950s, even-aged management was practiced.

Much of the lowlands initially harvested for timber were subsequently cleared for agriculture and residential development. Early riparian and stream clearing and the construction of splash dams to facilitate water transport of logs were common practices in western Washington streams (Sedell et al. 1991). Repeated splash damming resulted in major long-term damage to fish habitat, as the practice caused severe scouring of stream channels, often down to bedrock (Murphy 1995). In tributaries too small for splash dams, trees were typically yarded downstream, degrading stream channels and banks in the process. Railroad systems were also constructed for transporting timber to mills in many watersheds. Although these forest-management practices improved by the 1950s, clearcutting to the stream banks remained a common practice until the 1980s. Many of the destructive effects of these practices were usually the result of a lack of awareness, but sometimes even well-intended practices resulted in negative effects. For example, as recently as the 1970s, fish biologists were advising (and agencies requiring) foresters to “clean” log jams and other LWD from streams, in the mistaken belief that it would improve fish habitat or serve other values (SRGC 1983; Cited in CH2MHill 2000; Murphy 1995). Stream cleaning was common, affecting 58 percent of watersheds surveyed in a recent summary of watershed analyses completed to date (Beak 1998; Cited in CH2MHill 2000). Until recently, State forest practices allowed timber harvest to occur within 7.6 meters (25 feet) of salmon-bearing streams; these minimum widths were often insufficient to fully protect riparian ecosystems.

Forestry practices on the Olympic Peninsula have included instream salvage, stream cleaning, and the conversion of old-growth coniferous riparian forests to young stands of deciduous species. These practices have altered both the abundance and recruitment of LWD, especially decay-resistant conifers, such as western red cedar, in Olympic Peninsula streams. The LWD in many streams is now dominated by smaller diameter alder that tends to decay quickly and exert less influence on channel-forming processes. Such wood is often too small to influence river channel hydraulics, especially the formation of pools in large mainstem rivers. The rapid loss of large wood from streams may also be related to increased flooding and sediment in channels modified by intense logging (McHenry et al. 1998).

While timber harvest continues to occur in Washington, conversion of forestland to other uses has become more common as the population of Washington has grown. Comprehensive tracking of forestland conversion rates began in the late 1970s, with the Forest Service Forest Inventory and Analysis data (Bolsinger et al. 1997). These data, combined with limited data from the 1930s to the 1970s, indicate general trends in forestland conversion. The earliest data indicates there were approximately 26.5 million acres of forestlands in Washington State during the 1930s, with 25.2 million acres available for harvest; 15.2 million (60 percent) acres were found in western Washington , and 10 million (40 percent) in eastern Washington. By 2004, a net loss of approximately 3.5 million acres of forestland was reported, with 80 percent of this loss occurring in western Washington. The data indicate that reductions in the amount of privately owned forestland accounted for the majority of this loss.

During the period of 1945 to 1970, approximately 630,000 acres of commercial forestlands were converted to non-forest uses (e.g., urban-industrial, agriculture, and road use) in Washington (Bolsinger et al. 1997). By 1970, there were an estimated 23.1 million acres of forestland in Washington, with 4.7 million acres in reserve status or not considered capable of growing commercial timber. Between 1978 and 1991, Bolsinger et al. (1997) estimated that lands available for timber production in Washington outside of the National Forests decreased by 488,000 acres. This includes approximately 117,000 net acres of private timberlands that were transferred to the National Forest System, and an additional 92,000 acres (mostly tribal) that were reclassified to reserve status (i.e., forested, but not available for timber harvest). Conversions to other uses, such as urban development and rights-of-way for roads, pipelines, and other uses, accounted for approximately 279,000 acres.

5.7.2 Effects to Forests

Forestlands in Washington have experienced effects related to many different changes, which often vary by area. These changes, which disrupt natural processes that influence forest health, are produced by direct and/or indirect human activities that have occurred in the past and present (WDNR 1998a). These activities include timber harvest, grazing, fire suppression, road construction, and management practices and other influences that have resulted in increases in disease and pests. The impacts of grazing have been discussed previously, and will not be addressed in this section.

Intensive forest management generally results in adverse effects such as loss of older forest habitats and habitat structures, increased fragmentation of forest age classes, loss of large contiguous and interior forest habitats, decreased water quality, degradation of riparian and aquatic habitats, and increased displacement of individual species members.

Intensive forest management on most private lands generally maintain these lands in an early seral stage (e.g., 40 to 50 years of age) with relatively few structures such as snags, down logs, large trees, variable vertical layers, and endemic levels of forest “pests” and “diseases,” when compared to what was historically present prior to intensive management.

5.7.2.1 Timber Harvest

Washington boasts some of the most-productive forests in the world, with harvest on many private ownerships occurring at intervals of 40 to 60 years. The rate of timber harvest from commercial forestland in Washington State is about 1.1 percent (WDNR: 1991-1993 The Rate of Timber Harvest in Washington State (August 1997) as cited in WFPA 2001). Patterns of timber harvesting are influenced by natural events (fire, ice, insects, and disease), management practices, public policies, and market conditions. The average size of harvest units depends on harvesting methods. Clearcutting is a common harvesting method in forests dominated by Douglas-fir. Clearcut size is limited by State law to 120 acres, without special review. Actual sizes of clearcut areas vary by region of the State, but regional averages are generally between 20 and 40 acres on the Westside and 50 to 60 acres on the eastside (WFPA 2004). Where it previously occurred on steep slopes, clearcutting often resulted in slope instability, mass wasting (landslides), high silt loads, and reduced water quality.

There are many different kinds of activities associated with timber harvest, with varying degrees or types of impacts associated with each activity. Timber harvest and associated activities, such as road construction and skidding, can increase sediment delivery to streams, clogging substrate interstices and decreasing stream channel stability and formation. Harvest in riparian areas decreases woody debris recruitment and negatively affects the stream’s response to runoff patterns. Stream temperatures may rise with decreases in the forest canopy and riparian zone shading. Runoff timing and magnitude can also change delivering more water to streams in a shorter period, which causes increased stream energy and scour and reduces base flows during summer months.

Other impacts from logging practices include modifications to forest composition. For example, prior to Euro-American settlement of Washington in early 1800's, the different forest age classes were well represented across the State (WDNR 1998a). Since that time, declines in old-growth forests have occurred on both Federal and non-Federal lands. For example, since World War II, old growth in the Olympic National Forest has declined by 76 percent (Morrison 1990).

Much of the old-growth in western Washington (~54 percent) in the mid 1930s was on private lands (WDNR 1997); by 1992, only about 8 percent of that amount remained on private lands. Approximately 50 years ago, there were more than 9 million acres of old growth (WDNR 1997). By 1999, old growth was limited to 2.6 million acres and occurred mostly on Federal lands and at higher elevations where they were less available (or unavailable) for harvest. Today, old growth is found on less than 3 percent of non-

Federal lands in western Washington, and most forests outside of the National Parks and National Forests are younger than 50 years old (Spies and Franklin 1991).

In addition, studies have shown that large trees in temperate coastal rainforests collect moisture from fog, and this collection of moisture may contribute an estimated 35 percent of the annual precipitation (Quinault Indian Nation and USDA 1999). Significant reductions in large trees in these habitats may result in less moisture retention, affecting future runoff and/or precipitation patterns.

In eastern Washington, specific impacts from timber-harvest management have included the removal of LWD, reduction in riparian areas, increases in water temperatures, increases in erosion and simplification of stream channels (Quigley and Arbelbide 1997). Past timber harvest practices include the use of heavy equipment in channels, skidding logs across hill slopes, splash damming to transport logs downstream to mills, and road construction (USFWS 2002). Improvements in methodologies have reduced some of the effects from these practices (Oliver et al. 1994). Harvest units have been restricted in size, and greater consideration has been given to the health and appearance of forest landscapes and the biotic communities that depend on them. In some cases, equipment is used and/or engineered in ways to minimize soil disturbance and other habitat impacts. In other cases, however, the methods used may result in increased soil disturbance and extreme fire hazards (e.g., machine piling and burning, accumulation of dead slash from thinning activities, etc.) (Oliver et al. 1994).

5.7.2.2 Fire Suppression

Under historical fire regimes, natural disturbance to streams from forest fires resulted in a mosaic of diverse habitats. However, forest management and fire suppression over the past century have increased the likelihood of large, intense forest fires in some areas.

Prior to European settlement, both natural and human-initiated fires are believed to have affected the forests in eastern Washington (Oliver et al. 1994). Eastern Washington forests consisted of open, park-like areas with fire-resistant trees in the lowlands, and Douglas-fir/western larch and true fir forests in the middle and high elevations, respectively (Oliver et al. 1994). In the lowlands, most fires were frequent, and not highly destructive, primarily burning off revegetation; at higher elevations, and in cooler areas, fires were less frequent, and highly destructive. Fire suppression began in the late 1800s when a forestry commission was convened to begin studying the conditions of Forest Reserves (precursors of National Forests), which were created in 1891. Although fire suppression was viewed as necessary to protect resources and private property, some advocated the use of prescribed fire to reduce fuels and protect stands against damaging fires.

From 1930 to 1960, forest management began in earnest on National Forest lands, and many rural settlers moved to urban areas. Grazing occurred in previously burned areas, while other areas developed into dense stands. Fire-suppression efforts were intensified, with additional funding and crews made available to respond effectively to fight fires. The buildup of fuels likely led to larger, more-destructive fires. From the 1960s to the 1990s, fire prevention allowed the development of dense, closed stands of trees, which varies significantly from pre-management times. Oliver et al. (1994) report that this growth pattern makes stands increasing susceptible to disease and pests. In the 1960s, attitudes towards burning began to change, and the beneficial role of fire was recognized. The use of prescribed fire in certain environments was also encouraged, with certain precautionary measures. However, since the 1960s, fire frequencies in eastern Washington have been relatively low, as a result of either fire suppression, or the absence of fuels from previous severe burns.

Although scientists have recognized the value of prescribed burning as one of many tools to help return landscapes to natural conditions, managers have been slow to embrace prescribed burning partially due to the issues surrounding liability. There are also other constraints upon prescribed burning including short-term expenses and air-quality regulations.

5.7.2.3 Disease and Pests

Pests and disease were present in Washington's forestlands prior to European settlement. Several kinds of defoliating insects have been documented, including, but not limited to, Tussock moths, pine butterflies, and bark beetles (Oliver et al. 1994). Starting in the 1930s, pest surveys and control were used to combat these pests. Pest control included selective harvesting/or salvage harvest to remove infested trees, the spraying of pesticides (e.g., ethylene dibromide, DDT, and other insecticides), and removal of host plants (e.g., currant [*Ribes* spp.], host of white pine blister rust).

Since the 1960s, integrated pest management (IMP) has been used to control insect outbreaks. With IPM, several different management and pest-control alternatives are rated against cost/benefit analyses, alternative strategies, ecological considerations, and other concerns to determine the best recourse against the target pest(s). Examples of IPM alternatives include: favoring resistant stand structures and/or species in thinning and planting activities; fire prescription; selective use of pesticides; and salvage logging (Oliver et al. 1994).

5.7.2.4 Roads

Road construction in watersheds can promote simplification and channelization of streams, which reduce the connectivity of surface water and groundwater. Activities associated with road construction, maintenance, and use can also result in loss or damage to riparian areas, sedimentation, high erosion and slope hazards, installation of undersized culverts, and reduction or elimination in the ability of salmonids to access upstream reaches of a stream. Palmisano et al. (1993) reports that a substantial percentage of roads and railroads in the State are along streams or floodplains, and many have been placed within streams' riparian zones.

Historical methods of road construction were destructive to stream habitats (Palmisano et al. (1993). Stream gravel and cobbles were often used as fill, and excess excavation materials were pushed over the side of the road bank, where it frequently entered streams. Riparian vegetation and stream banks were damaged by the use of heavy equipment adjacent to and in streams. Side channels were often cutoff or eliminated, and stream channels were confined, resulting in increased bank erosion in certain areas. Lack of adequate drainage led to saturation of roadside soils. Constriction of floodplains resulted in increased flooding, which continues today in certain areas.

Little specific information is available on the historical origins and use of roads in forested areas outside of the Forest Service lands. Within the Forest Service lands, most forest roads were originally constructed by harvesters for access to forested areas, who then deducted the costs of road construction from final payments to the Forest Service (Oliver et al. 1994). Oliver et al. (1994) reports that less than 150 miles of road existed in Washington National Forests in 1907; by 1920, this number had increased with 176 miles of road per million acres in the Yakima River Basin (Washington), and 287 miles per million acres in the Grand Ronde River Basin (Washington and Oregon). Beginning in the 1950s, the Forest Service began to assert more direct control over the road network on Forest Service lands, and the network increased. In the Yakima Drainage Basin, road totals increased from 99 miles per million acres (before 1900) to 2,251 miles per million acres in 1992[11].

Road decommission and removal is one way in which the impacts from roads are being reduced. Between 2000 and 2004, the Salmon Recovery Funding Board[12] funded projects to repair or abandon 222 miles of road to reduce sediment input into streams (SRF 2005). In Pacific County, 5,800 feet of road was removed in the Ellsworth Creek watershed, including ripping of the surface, relocation of sidecast to restore the natural slope, revegetation of the area, and removal of several culverts and crossdrains (Carlson, Personal Communication, 2005b).

5.7.3 History of the Washington Forest Practices Rules

Hydraulics Code Guidelines, administered by WDFW, were established in 1949; but it was not until 1974 that the Forest Practices Act, administered by WDNR through the Forest Practices Board, was passed. The Forest Practices Act was designed to protect public resources (e.g., water, fish, wildlife, and capital improvements of the State or its political subdivisions), and created the Forest Practices Board. One of the Board's duties is to promulgate the Washington Forest Practices Rules (Chapter 222 WAC) necessary to implement the purposes, policies, and provisions of the Washington Forest Practices Act. These rules provide minimum standards for forest practices such as road construction, timber harvest, pre-commercial thinning, reforestation, fertilization, and brush control.

In 1987, Federal and state agencies, environmental groups, Native American Tribes, industrial and non-industrial forest landowners entered in the Timber, Fish, and Wildlife (TFW) Agreement. The TFW Agreement has five common goals: (1) Wildlife; (2) Fisheries; (3) Archeological and Cultural; (4) Water Quality and Quantity; and (5) Timber. For instance, the wildlife goal is to provide the greatest habitat diversity (particularly riparian, wetlands, and old growth) and assure the greatest species diversity within those habitats for the survival and reproduction of enough individuals to maintain the native wildlife of Washington's forestlands. On the other hand, the timber goal is to assure the continued growth and development of the State's forest-products industry, which has a vital stake in the long-term productivity of both the public and private forestland base. While TFW has numerous goals, the need to balance these goals serves as an important directive to the participants.

Advisory Groups under the TFW Agreement have been in place for almost 20 years under different names (i.e., Wildlife Steering Committee), and are organized under the Cooperative, Monitoring, Evaluation, and Research committee (CMER). For instance, the Wildlife Steering Committee (now know as Landscape Wildlife Advisory Group, or LWAG) is tasked with addressing wildlife research and monitoring issues associated with the Forest Practices Act on State and private lands. Wildlife biologists from Federal and State agencies, Native American Tribes, Environmental Groups, and the timber industry voluntarily participate to provide technical guidance to CMER.

The result of this cooperative approach to continuous improvement has been a proactive yet changing set of Washington Forest Practices Rules. For instance, prior to 1974, there was no requirement to retain wildlife reserve trees (including snags) or green recruitment trees. The Washington Forest Practices

[11] During this same period, railroad transportation in the basin increased from 26 miles/million acres before 1900, up to 53 miles/million acres beginning in the early 1900s, then 0 miles/million acres from 1967 to 1992 (Oliver et al. 1994).

[12] The SRF board statistics did not specifically denote roads associated with forestry. The reported projects (abandonment or repair of roads) were intended to reduce sedimentation into streams.

Rules have been amended and strengthened 13 times since they were established in 1975. As a result of rule changes and changes in common practices, many stands bear characteristics that are indicative of the era in which they were last harvested.

5.7.3.1 Northwest Forest Plan

In 1994, the Northwest Forest Plan (NWFP) was implemented. The total area of Federal lands covered under the NWFP in Washington State is approximately 8,839,040 acres 913,811 square miles). Several areas of research were instituted under the NWFP, including, but not limited to wildlife conservation and population viability issues, aquatic conservation strategy, adaptive management areas, ecological processes and function, and the creation of new stand development strategies for the Douglas-fir region covered under the plan (Snow and Perez 2001).

5.7.3.2 Conclusion

Over the last 25 years, forest management of Washington's forestlands has changed. Changes have resulted from revisions to the Washington Forest Practices Rules, restrictions due to federally listed species, voluntary efforts on private lands, new planning efforts on Federal and municipal forests, and increased efforts to preserve unique forested habitat through local, State, and Federal conservation programs and exchanges. These changes will influence the spatial array of habitat conditions.

The current Washington Forest Practices Rules are the rules that are contemplated in the proposed action of this Opinion. The State began implementation of the current Washington Forest Practices Rules contained in the FPHCP prior to receiving any incidental take authorization that might be needed from the Federal Services. These rules are described in greater detail within this document and the FPHCP, but are contained in their entirety within the Washington Forest Practices Rules: Title 222 of the WAC. Those rules are supplemented with guidance known as the Forest Practices Board Manual, which provides additional guidance to assist land managers in complying with the rules.

Major changes in the Washington Forest Practices Rules which were incorporated between November 1998 and the early implementation of the FPHCP (began in January 1999), are summarized later in this Opinion. The adverse effects and beneficial changes which have occurred between November 1998 and the date of the preparation of this document are part of the environmental baseline.

5.7.4 HCPs

In 1982, the ESA was amended to authorize the incidental taking of endangered and threatened species by private landowners and other non-Federal entities, provided they develop HCPs that minimize and mitigate the taking. In the first 10 years after the HCP process was established, only 14 permits were issued. Since 1992, the number soared to more than 400 HCPs nationwide.

In Washington, the FWS has completed HCPs for over 2 million acres. As of November 2005, there are 13 HCPs in the State of Washington that have been approved by the Services. Two HCPs were completed by NMFS only (Tagshinny Tree Farm and the Mid-Columbia Public Utilities District), and one was combined and then sold (Native Fish HCP with Plum Creek Timber Company.) Although the specific activities covered under each HCP and their mitigation requirements vary, depending on the interests of the landowners, most were developed for forest-management activities. The only exception to this is the Daybreak Mine HCP (Stordahl), which covers flood-plain adjacent mining. The HCPs for the State are listed in Table 5-5.

Table 5-5. Washington Habitat Conservation Plans and Similar Agreements as of March 2006.

Applicant/Name	Contribution	Incidental Take Permit Issuance Date
Scofield Corporation (Chelan County)	Low-effect, single species HCP for 40 acres in a scenic area; one-time selective timber harvest. The permit was issued for 1 year.	04/03/1996
Day Break Mine/J.L. Storedahl & Sons, Inc. (Clark County)	Multi-species HCP on a 300-acre gravel mining operation on the East Fork Lewis River; includes coverage for the anadromous fish and the Oregon spotted frog.	04/16/2004
Western Pacific Timberlands (Boise Cascade) (Klickitat County)	Low-effect, single-species HCP for ~620 acres of Spruce-budworm-damaged forests.	09/14/2001
Washington Department of Natural Resources (various areas in Washington)	Multi-species HCP for 1.6 million acres throughout Washington.	01/30/1997
City of Seattle, (Cedar River Watershed)	Multi-species HCP to enhance second growth for northern spotted owl and marbled murrelet conservation. No commercial timber harvesting; a 90,500-acre watershed will be in LS/old growth reserves; fish passage will be built at Landsburg Dam. Instream flows in Cedar River will be maintained for salmon and steelhead.	04/21/2000
City of Tacoma, Tacoma Water (Green River watershed)	Multi-species HCP for 14,888 acres of forested lands.	07/09/2001
Plum Creek Timber (I-90 corridor, King and Kittitas Counties)	Multi-species HCP across 130,000 acres. Riparian protection and management in addition to watershed analyses.	06/27/1996
Port Blakely/Robert B. Eddy Tree Farm (Grays Harbor and Pacific Counties)	Multi-species HCP over 11,334 acres.	07/19/1996
Green Diamond Resource (Simpson Timber) Company (Grays Harbor, Mason, and Thurston Counties)	Multi-species HCP for 214,000 acres.	10/13/2002
West Fork Timber Company/Murray Pacific Corporation (Lewis County)	Multi-species HCP with ≥18-20% reserves primarily in riparian habitat through 53,000 acres.	06/1995
Tagshinney Tree Farm (Lewis Co.)	This plan covers 133 acres with respect to effects from forestry regarding 17 species for 80 years. It serves as an HCP per section 10 (a)(1)(B) for NMFS; and a Safe harbor and candidate conservation agreement with assurances for FWS per section 10(a)(1)(A). Covers spotted owl, marbled murrelet, bald eagle, steelhead, coho, and a number of unlisted species.	09/2004
Mid-Columbia PUD HCPs	These HCPs with NMFS cover salmon and hydroelectric operations on Wells Dam (Douglas PUD), as well as Rock Island and Rock Reach Dams (Chelan PUD).	04/2005
Native Fish HCP with Plum Creek Timber Co. (Multiple Counties)	This multi-state HCP covered 1.5 million acres in parts of Washington, Idaho, and Montana with respect to native fish species and effects from forestry and grazing. It no longer applies to Washington State: lands in the Lewis, Tieton, and Ahtanum watersheds.	10/ 2000
White River Habitat Management Agreement (King and Pierce Counties)	This plan covers owls on 12,279 acres in the Green and Green River Watersheds for about 50 years. Authorization for take is based upon section 7 consultation in association with Huckleberry Land Exchange.	05/02/1997

Forestlands covered by existing federally approved HCPs are generally not considered part of FPHCP covered lands; however, there are two exceptions. The Western Pacific Timberlands (*nee* Boise Cascade Corporation) HCP encompasses 620 acres and provides coverage for a single species (Northern spotted owl); this HCP does not include coverage for bull trout or other aquatic species. The other exception is approximately 228,000 acres of WDNR managed land on the east side of the Cascade Crest. The WDNR State Lands HCP provides coverage for terrestrial species in this area, but does not include coverage for aquatic species. The WDNR HCP is the largest HCP in Washington, which covers approximately 1.6 million acres of state trust lands managed by the agency. The forestlands contained within the Boise HCP and the east side of the WDNR HCP are considered covered lands under the Forest Practices HCP.

The development of HCPs and other wildlife-management plans has altered the basic management of forestlands in western Washington. Conservation measures included in the HCPs are designed and expected to adequately minimize and mitigate the effects of the taking to the maximum extent practicable. The FWS acknowledges that the HCP process is complex, often difficult, and relatively new on the landscape (in terms of natural history); therefore, while we expect that HCPs will provide substantial benefits to species and their habitats, attempts to evaluate the full ecological success of these plans would be premature.

5.8 LAND ACQUISITION

During the period from 2000 through 2005, the State of Washington received over $61 million through the U.S. Fish and Wildlife Service's Cooperative Endangered Species Conservation Fund for land acquisition to benefit federally listed species and their recovery. Two grant programs under this fund, HCP Land Acquisition and Recovery Land Acquisition, have resulted in the purchase and permanent protection of more than 40,000 acres of old-growth forests, oak woodlands, shrub-steppe, coastal bluffs, prairie, riparian, and wetland habitats.

5.9 OTHER FACTORS AFFECTING THE ENVIRONMENTAL BASELINE

5.9.1 Fisheries

There are three major categories of fish harvest in Washington: commercial, recreational, and subsistence. These activities are supported by State and tribal management of fisheries, including hatcheries, aquaculture, designation of marine reserves, and other actions.

Fisheries management has contributed to habitat degradation and impacts to species. Managers from the 1950s to 1970s promoted the removal of LWD and log jams from streams because they were perceived to hinder fish migration (Murphy 1995). This practice eliminated or greatly reduced the habitat complexity in many streams. Overfishing has been considered a major cause of decline in certain salmon runs since the late 1800s, with closures noted as early as 1915 in the Columbia River (GSRO 1999). Harvest rates of adult salmon can sometimes reach 50 to 80 percent of the population, an amount that is not sustainable for all salmon stocks, particularly those that are struggling with poor productivity or unfavorable ocean conditions (GSRO 1999).

5.9.1.1 Commercial Fishing

The principal commercial and subsistence species categories in the region are salmon, tuna, groundfish, crab, and shrimp. The effects of commercial harvest on fisheries are difficult to determine fully;

however, reported catches over time may offer limited insight into these effects. Although fish canneries have existed in Washington since 1866, the first commercial salmon fishing records were not reported until the 1890s. During this time, the largest annual production occurred in the Columbia River (20 million pounds). From 1899 to 1935, fishing technology improved, and fisheries in Puget Sound increased substantially over the Columbia River production.

Although the volume and value of commercial seafood landed in Pacific Northwest ports fell substantially from 1989 to 1991, the most-significant decline occurred in salmon catch (FEMAT 1993). A variety of factors contributed to this including depressed fish prices, unfavorable ocean conditions, decreased habitat, and increased competition. However, due to the complex relationship between ocean conditions, quality of freshwater and estuarine habitat, and size of fish populations, short-term changes in abundance of fish cannot be extrapolated to determine long-term projections for potential harvest.

Another imperfect indicator of commercial fisheries is the number of licensed fishing boats in the state. The number of licensed fishing vessels under 50 tons has generally decreased over time, from 7,500 in 1980, to approximately 2,000 in 1998 (WDFW in WDNR 2000a). Vessels under 5 tons have decreased from 4,504 in 1980 to 947 in 1998 and vessels between 5 and 50 tons have decreased from 3,006 in 1980 to 1,115 in 1998. However, vessels over 50 tons have remained relatively stable (379 in 1980 and 432 in 1998). During the last 15 years, the volumes of catch for salmon have generally declined. The volume of catch for other marine fish has also decreased.

Commercial fisheries operations have had effects on various aquatic species (Morishima and Henry 2000). Certain methods or types of equipment used (e.g., trawls) capture large quantities of non-target organisms or life stages. Individual stocks or species can be over-fished.

Other aquatic species are harvested commercially in Washington. For example, wild stocks of sand shrimp are harvested as bait for steelhead, salmon, bottom fish, and other types of sport fish. Harvesters obtain sand shrimp onsite, generally at low tide in a small boat, using a hydraulic pump connected to a long hose, at the end of which is a three-foot rigid pipe often called a “wand.” The wand is hand-held and instills the hydraulic pressure into the sand shrimp burrows in the substrate, pushing sand shrimp to the surface where they are picked up by hand and placed in buckets. The whole operation involves one or two harvesters and a small boat (approximately 18 feet). The sand shrimp are then sold as bait.

During the 1950s, United States Navy divers in Puget Sound observed vast populations of sub-tidal geoducks throughout the region. The commercial harvest of wild geoduck began in 1970 following this discovery, but at that time, market demand was limited. Demand grew significantly, however, with the establishment of a major new market in Japan. Today the geoduck fishery is the largest and most-economically important clam fishery on the west coast of North America (WDNR 2001). To harvest geoducks commercially, harvesters use water-jets to loosen the substrate and allow the clams to be removed. After the diver locates a clam by its siphon (which extends out of the substrate) or by locating the depressions left by a burrowing clam, the nozzle is inserted next to the exposed geoduck siphon (or in the hole which is left when the siphon is retracted). A short burst of water, with a pressure of 40 to 60 pounds per square inch, liquefies the sediment allowing individual geoducks to be easily removed. A diver using this method can harvest 1,500 pounds per day (approximately 800 clams) on a productive tract (WDNR 2001).

5.9.1.2 Recreational Fishing in Washington

Recreational fishing is an important activity in Washington, especially in Puget Sound, the Olympic Peninsula, lakes, and many of the streams throughout the state. USFWS and U.S. Census Bureau (2003) report that approximately 938,000 Washington residents fished the waters in this State. Freshwater and marine recreational fisheries in Washington are managed by WDFW using specific quotas by species and catch areas (GSRO 1999).

5.9.1.3 Subsistence fishing

In addition to commercial and recreational fisheries, Native American Tribes in the Pacific Northwest also participate in fishing activities to procure salmon and other fish for ceremonial and subsistence purposes. Although the manner, volume, and extent of such subsistence fishing vary among tribal members and regions, subsistence harvest is used to provide basic nutritional benefits to Tribal members and to maintain essential cultural values that are intrinsic to the community through their traditional fishing practices (GSRO 1999).

5.9.1.4 Hatcheries

Many salmonid fisheries are supported by Federal, State, and Tribal hatcheries. Hatcheries have been used in the Pacific Northwest since the late 1800s as a means to compensate for the effects of overfishing and the declining numbers of salmonids (Burger 2000). Current hatcheries are operated for a variety of goals, including production for harvest and/or to strengthen depressed fish populations. There are 11 Federal hatcheries in Washington, designed to mitigate fishery losses, create fishing opportunities, and as one part of an integrated approach for the management and restoration of aquatic species and their habitats. As of 2000, WDFW operated 91 hatcheries in the State for the purposes of providing fisheries opportunities, fulfill State tribal treaty obligations, and to help recover and conserve naturally spawning salmon populations (WDFW 2000).

Burger (2000) reports that approximately 80 percent of the current anadromous salmonid production is believed to be of hatchery origin. A number of effects to species and habitats from the release of hatchery fish have been reported in the literature (Booker 2000). Hatchery-produced fish may compete with wild fish for limited food resources, or may prey on smaller wild juveniles. Hatchery and wild fish stocks may intermingle in streams or marine habitats; commercial or recreational harvest targeted towards hatchery-raised fish may result in disproportionately high impacts to limited wild fish stocks. Intermingling of hatchery and wild stocks may also affect the genetic integrity of the wild stocks, affecting the survival of future generations. Finally, abundance of hatchery fish can mask declines in numbers of wild fish.

The need for improved hatchery management has been recognized by Congress, with the funding of the Western Washington Hatchery Reform Project (Mobrand et al. 2005). This project was initiated to identify solutions to problems with hatchery management so that facilities could more-effectively meet their dual goals of supporting sustainable fisheries and assisting with the conservation of wild fish populations. Various other entities have also developed plans or recommendations for reducing ecological effects of hatchery-reared fish on wild fish and their habitats (e.g., McMichael et al. 2000; MacDonald et al. 2000). While these efforts are expected to result in positive resolutions to sometimes-controversial issues, the process is ongoing. Therefore, any attempts to gage their success would be premature at this time.

5.9.1.5 Aquaculture

The WDNR (2000) reports that aquaculture, the production of aquatic plants, shellfish, and fish, is currently the fastest-growing sector of the world food economy. In Washington, aquaculture operations are generally in marine habitats, and predominantly focus on penned salmonids, clams, and oysters, although other species are also produced.

Aquaculture has both direct and indirect effects on the benthic habitats and organisms near and/or under both harvest and production sites. Organisms may suffer lethal or sublethal impacts from increased sedimentation, decreases in dissolved oxygen, decreases or increases in nutrients, or mechanical harvest. They may also be indirectly affected by the chemicals or practices associated with the site. Other potential negative impacts of aquaculture include:

- Alteration of marine and/or nearshore bird nesting, feeding and migratory habitats
- Disruption of intertidal water and substrate movement through diking or other habitat modifications
- Depletion of microorganisms in the water column
- Decreased biodiversity from cultivation of a single species
- Introduction of target or non-target non-native species and their parasites
- Synergistic effects from the preceding impacts

The predominant type of fish aquaculture in Washington (Pacific and Atlantic salmon) is generally pen-based aquaculture, concentrating large groups of salmonids in relatively small areas. Pen-rearing of salmonids has existed in Washington since 1969 (Sylvia et al. 2000); although pen-rearing operations previously existed in both Oregon and California, Washington is currently the sole producer of pen-reared salmon within the western United States (Sylvia et al. 2000; Toba and Chew 2001). From 1990 to 1999, there was a marked increase in Atlantic salmon production in Washington. In 1990, less than 4 million pounds of Atlantic salmon was produced; however, in all but two of the following 7 years, annual production was over 8 million pounds, reaching 12 million pounds in both 1997 and 1999 (WDNR 2000a; Toba and Chew 2001).

Chinook and coho salmon have also recently been cultured in Washington, with production of these species decreasing significantly in the late 1990s (Toba and Chew 2001); Toba and Chew (2001) predicted that production of coho would reach 9,000 pounds in 2004 (down from 72,000 in 1996), while no Chinook would be produced in 1999 (from 44,000 pounds in 1997, when production of Chinook began).

Other fish that are raised in Washington include rainbow trout, channel catfish, arctic char, and largemouth bass (Toba and Chew 2001). Rainbow trout production reached 2.5 million pounds in 1999, and was projected to reach 3.5 million pounds by 2004. Annual production of catfish production is relatively low (2,000 to 3,000 pounds during the 1990s), and was expected to remain at these levels through 2004. Arctic char production was estimated at 131,000 pounds in 1999, with an expected increase of 250,000 pounds by 2004. Largemouth bass production was relatively minor (less than 500 pounds), with production not expected to increase significantly. While the tilapia has not yet been commercially cultured in Washington, Toba and Chew (2001) indicated that there is commercial interest in production, and reported the development of an experimental farm to explore this aquaculture opportunity.

In addition to foodfish operations, aquaculture operations generate other products. The aquaculture industry supplies eggs and juveniles of several salmonids, including Chinook, coho, Atlantic salmon, and rainbow trout (Toba and Chew 2001). Toba and Chew (2001) also noted that Washington is the largest producer of rainbow trout eggs in the world. Other non-foodfish products include baitfish and fish for the aquarium trade. In Washington, much of the non-foodfish production has consisted of koi (1,000 pounds in 1999) (Toba and Chew 2001).

The import and culture of fish species may result in several of the impacts listed above. For example, aquaculture of the non-native Atlantic salmon may result in the accidental introduction of parasites of Atlantic salmon, which may also affect Pacific salmon or other native fish species. Cultured Atlantic salmon may also occasionally escape aquaculture operations into nearshore or riverine habitats, competing with or displacing Pacific salmon from foraging, rearing, and spawning areas. Furthermore, operations may influence the behavior of cultured fish. For example, Toba and Chew (2001) indicated that delayed release of pen-reared smolt Chinook and coho salmon results in the fish often remaining in Puget Sound, instead of migrating to the ocean.

The shellfish industry has been particularly lucrative in parts of Washington. The state dominates the West Coast shellfish industry with extensive culture of a variety of species. Washington produces over 82 percent of the shellfish in the West Coast (Toba and Chew 2003), and there are currently 338 licensed shellfish companies and approximately 690 identified growing areas in Washington State[13]. Traditionally, shellfish aquaculture occurs in or on naturally occurring substrates, with the harvest done by hand. More recently, growers throughout the area have been using rafts similar to finfish net pens to increase production densities and minimize predation. Washington State does allow harvest by hydraulic escalator for commercial operations, provided they are 500 feet away from residential zones (Chapter 79.96.030 RCW).

The majority of the Washington shellfish production targets oysters. Pacific oysters (*Crassotrea gigas)* were originally introduced to Washington State from Japan in the 1920s and 1930s in order to replace diminishing populations of the native Olympia oyster (*Ostrea lurida*) (Washington Sea Grant, 2002). Two types of methods are used to culture oysters: bottom and off-bottom culture methods. Bottom culture is the most-common method of oyster farming: natural or hatchery produced seed are spread over the beds and then harvested when they reach an appropriate size. Off-bottom methods have been developed to expand the areas that are cultured, or used to culture single oysters for the half-shell trade. Oysters can be raised on intertidal longlines or in bags placed in the intertidal area. Oysters can also be suspended from longlines or rafts utilizing beds in navigable waters. Unlike the fishery for the eastern oyster (*Crassotrea virginica*) on the East and Gulf coasts of the United States, which is based almost entirely upon wild stock harvest, Washington's oyster industry has developed into a complete farming operation from larval rearing to planting and product harvest (Dumbauld et al. 2001). Other varieties of "specialty" oysters, such as Kumamoto oysters (*Crassostrea sikamea*), the Eastern oyster, European flat oysters (*O. edulis*) and the native Olympia oyster, are also produced (PCSGA 2002).

Intertidal clam production is the second largest type of shellfish aquaculture, and includes Manila clams (*Tapes philippinarum)*. Manila clams were accidentally introduced along with the Pacific oyster seed from Japan, and soon became established throughout Puget Sound. Manila clams have become the dominant intertidal clam cultured in the area. Intertidal clams are grown most commonly using bottom culture and can utilize predator exclusion methods. These range from lightweight plastic netting to

[13] Washington State Department of Health (www://doh.wa.gov/ehp/sf/commercial.htm).

heavyweight bags placed in the ground. Other culture methods include substrate modification, which creates suitable habitat for the growth and survival of Manila clams. Gravel, or a combination of gravel and crushed oyster shell, is added to mud and sand substrate. This increases the amount of area capable of producing Manila clams.

Mussel aquaculture began in the mid-1970s, with mussel rafts in Penn Cove, off Whidbey Island. Two species are commonly cultured, the native Puget Sound blue mussel (*Mytilius trossulus*) and the introduced Mediterranean mussel (*M. galloprovinicialis*). There is an increasing trend to use the non-native species, because of a naturally occurring disease that causes high mortalities that affects the native mussels. While the vast majority of the commercial mussel production is from floating rafts, there is some intertidal culture using bags.

The harvest of wild geoduck is now complemented by significant investments and advances in intertidal geoduck aquaculture by Washington shellfish growers. Geoduck aquaculture is not currently authorized on State-owned aquatic lands; however, an on-going pilot project is evaluating the feasibility of intertidal and subtidal geoduck aquaculture on State-owned aquatic lands.

5.9.1.6 Marine Protected Areas

In recent years, marine protected areas have been used or planned as conservation or preservation areas for fisheries or habitats that have been over-exploited (PSAT 2002). Marine and ecological reserves created by WDFW are found in the San Juan Islands, near Edmons, Des Moines, Steilacoom, and in Hood Canal, among other areas. Their effectiveness has not been fully documented, but studies are being conducted on rockfish and other species.

5.9.2 Non-native Species

A variety of human activities accelerate the process of introduction and spread of aquatic nuisance species that can cause extensive ecological damage. Many non-native, invasive species of plants and animals have been documented in Washington. While most non-native species are unable to survive in habitats that are very different from the ones in which they evolved, other introduced species thrive in the absence of their natural competitors, predators, parasites, and diseases. These species often become invasive, affecting native species and habitats through competition, predation, hybridization, and/or other mechanisms.

Some non-native animals have been introduced purposefully, as game species (e.g., bass, sunfish, non-native trout species, pheasants), through the aquarium trade (e.g., goldfish), for aquaculture (e.g., Manila clam, Pacific oyster), or for a variety of other purposes. Other species, particularly small or secretive species, are often transported unnoticed in packing materials, ballast water, as parasites of other species, or in other ways. Some non-native animal species (e.g., European starlings) were introduced in other parts of the continent and slowly spread to Washington. Non-native animal species can greatly impact native species populations. For example, introduced piscivores such as largemouth and smallmouth bass increase the predation pressure on outmigrating juvenile salmonids. Atlantic salmon (*Salmo salar*) have escaped from aquaculture operations, and natural spawning of these escapees has been documented in British Columbia (Volpe et al. 2005). Goodwin et al. (2004) note that non-native viruses can be introduced into habitats where native species have limited resistance.

Non-native plant introductions are an emerging threat to ecosystems. Non-native plants have been introduced both intentionally and unintentionally in the past through agriculture practices, erosion control, development, and for ornamental purposes, and non-native plants are slowly replacing less-aggressive native species. Cordgrass (*Spartina* spp.) has invaded nearshore habitats in north Puget Sound and threatens to exclude native fish species and reduce intertidal acreage (WSCC 1999a). WDNR (2000) reports that the amount of Spartina in Willapa Bay is predicted to grow from 3,200 acres in 1997 to 30,000 acres by 2030 (covering most of the intertidal zone). Intertidal areas provide critical foraging habitats for anadromous salmonids and their prey species. In a number of areas, invasive plant species are invading disturbed riparian areas and stream channels. Invasive species are altering and impairing these habitats and impeding the restoration and natural recovery of these areas by out competing native vegetation, including trees, which provide more important habitat benefits such as increased shade and LWD. All regions of Washington are probably affected by one or more of these species.

Although the control of non-native species is challenging, many attempts are being made to reduce the impacts or extent of invasive species. For example, in Thurston and King Counties, the respective removal of Scots broom and Japanese knotweed has been performed using Integrated Pest Management (Carlson, Personal Communication, 2005b). The removal of Scots broom was done in concert with re-vegetation in certain areas with grasses, forbs, and conifers. Western Washington prairie conservation activities often include control of Scots broom.

5.9.3 Recreational Activities

Washington supports many different types of outdoor recreation activities, including but not limited to skiing, hiking, mountain biking and other off-road vehicle use, climbing, fishing, camping, hunting, boating, and wildlife viewing. The Interagency Committee for Outdoor Recreation (IAC) (2002) estimates that over half of the state's population engages in some form of outdoor recreation. Recreational settings and experiences range from primitive areas (such as remote hiking trails or campsites) to sites that have vehicle access and associated development (such as campgrounds and summer homes), although the majority of developed recreation sites occurs in roaded settings.

There is evidence of an existing surplus of venues for highly developed and/or motorized forms of recreation, with a significant and increasing demand for recreational settings with minimal development and/or management activities, and with no motorized access (FEMAT et al. 1993). WDNR (2000) reports that the demand for water-related recreation increased by 32 percent from 1987 to 2000.

Hunting activities fluctuate in response to game population levels, weather, and regulation by WDFW. The number of deer and elk licenses sold has decreased from around 230,000 and 104,000, respectively, in 1975 to 190,000 and 85,000 in 1994. Numbers of resident small game harvested have also declined steadily from nearly 1.48 million in 1975 to around 0.43 million in 1994 (Washington State 1995). Carlson (2005) reported that in 2001, 227,000 Washington residents hunted. Generally, adverse impacts to wildlife are minor and include displacement during hunting activities.

There are many recreation destinations for the public in the State. Washington has approximately 10 million acres of public land that is managed at least in part for outdoor recreation and habitat (IAC 2002). The IAC (2002) notes that approximately 648,498 acres of State lands are available for outdoor recreation. The Washington State Parks system is comprised of approximately 260,000 acres (IAC 2002). Visits to Washington State Parks increased 300 percent between 1965 (12.9 million visitors) and 1997 (50.9 million visitors), with an increase of more than 10 million from 1987 to 1996 alone (Washington State Data Book 2000; WDNR 1998a, 2000). State trust lands are managed by WDNR and are comprised of approximately five million acres of forest, range, agricultural and aquatic/submerged lands. Examples of trust forest lands that are highly used include (by county): Capitol Forest (Thurston), Tahuya Forest (Mason), Yacolt Burn (Skamania), Tiger Mountain (King), and Loomis State Forest (Okanogan). State Wildlife Recreation Lands (WRL) are used primarily for hunting and fishing. Large WRLs are generally found in eastern Washington (e.g., L.T. Murray Wildlife Area), while small, scattered WRLs are found in western Washington.

National Parks, National Forests, and National Monuments in Washington State also receive heavy visitation. The National Park Service manages three National Parks (Mt. Rainier, Olympic, and North Cascades National Parks) and three significant National Recreation Areas (Ross Lake, Lake Chelan, Lake Roosevelt) (IAC 2002). Approximately nine million acres of National Forests exist in Washington. The State has seven National Forests (Colville, Umatilla, Gifford-Pinchot, Mt. Baker-Snoqualmie, Okanogan, Olympic, and Wenatchee), and one National Monument (Mt. St. Helens). National Forestlands include developed or undeveloped facilities for visitors. The IAC (2002) reports that 38 percent of recreation activities in National Forests occurs in conjunction with road use.

Private lands are also used for outdoor recreation, from parks on private timberlands to developed access areas (e.g., RV parks, resorts, ski areas, etc.) (IAC 2002). Private landowners often offer recreational opportunities for the public for hiking, hunting, and/or other consumptive or non-consumptive uses. The IAC (2002) also reports that certain landowners have habitat-access agreements with entities such as WDFW for restoration purposes.

Recreational activities in forested areas include many of the uses described above. Additionally, visitors in certain areas may also engage in permitted or opportunistic gathering of resources, such as fruits, wood, mushrooms, or other natural products. Some activities, such as camping, trail use, off-road vehicle use, or other activities have caused significant localized impacts. These are typically associated with riparian vegetation removal and degradation, sedimentation, and degradation of stream banks and channels.

5.9.4 Climatic Effects

Climatic effects on Washington species and habitats can be divided into two broad categories. The North Pacific environment is governed in part by decadal or multi-decadal cycles with changes in pressure and wind patterns, which affect ocean currents and water temperatures (Anderson 2000). The cycles (e.g., El Niño/La Niña years) are relatively short-term. Ocean conditions created by these cycles affect numbers and distributions of fish and other oceanic species. For example, it appears that during years when the climate regime in the Pacific Northwest is warm and dry, ocean conditions for some of the Columbia River salmon are poor, while Alaska salmon experience good conditions. When the climate regime is dominated by cool and wet years, the opposite is true, with the Columbia River salmon generally experiencing better conditions than Alaska salmon (Anderson 2000). The success or failure of management (e.g., of fisheries), restoration, enhancement and other actions has not always been considered in context with climate cycles, and the cycles may mask success or failure if they are not carefully evaluated (Anderson 2000).

Although the existence of these cycles is a natural phenomenon, anthropogenic factors also appear to be driving climate patterns (Mote et al. 2005). Increases in globally-averaged temperatures during the last three to five decades appears to be related to increasing levels of greenhouse gases in the atmosphere. The effects from this phenomenon include, but are not limited to, changes in air and ocean temperatures, amount and distribution of precipitation, changes in sea level and associated coastline impacts, and water quality. Mote et al. (2005) indicated that Puget Sound and Washington habitats have been and will continue to be directly affected by these effects. During the past 50 years, there have been hydrologic changes that are consistent with warming of the atmosphere. These changes include a reduction in the amount of spring snowpack in high elevations, earlier snowmelt runoff, and changes in seasonal stream flows (i.e., winter flow increases/summer flow decreases). Sea levels are rising, with local sea levels rising in southern Puget Sound up to twice the global average. Other parameters, such as water temperatures, dissolved oxygen, nutrient levels are currently being evaluated, as are the potential effects of atmospheric warming to sensitive habitats (e.g., salt marshes, eelgrass beds) and biota (Mote et al. 2005).

5.9.5 Wind Generation

Wind-power generation is becoming more common in eastern Washington as the industry's potential is being developed. The Bureau of Land Management recently completed an analysis of its lands in the western United States, identifying only 60 acres in central Washington as suitable for power generation (J. Krupka, Personal Communication, 2005). However, several existing and proposed wind-power-generation projects occur (or are proposed) on non-Federal lands. For example, four projects are currently online in eastern Washington (near the Tri-cities and Walla Walla), while four future projects have been proposed[14] (Tri-cities area, Walla Walla, Skamania County, and Klickitat County). The Wild Horse Wind Power Project has proposed the construction of 158 turbines in eastern Kittitas County in 2004; the application of the site certification for this project is in progress and is being assessed through State and Federal permitting processes. The second project, the Hopkins Ridge Wind Project, is currently under construction in Columbia County.

Potential impacts from wind-power generation to biota include direct effects, such as mortality to birds and bats, or indirect effects, such as habitat alteration (Government Accountability Office [GAO] 2005). Based on existing studies[15] evaluated by the GAO (2005), direct mortality to birds appeared to be correlated with both the location of wind-power facilities in relation to their migratory flyways as well as various designs of the turbines.

5.10 SUMMARY

The current baseline status for the state of Washington is complex and dynamic. It is impossible to analyze the environmental baseline as a moment in time because past regional and larger-scale development and its associated effects are ongoing and will continue to impact natural resources in the future. Actions, such as urban development, road building, and recreation, on private and public lands have and will continue to contribute to habitat degradation and loss, which have impacted habitat structure and function for many species of fish and wildlife. Increasing development and sprawl in Washington State have fragmented and destroyed habitats, and will continue to contribute to the decline of many species and their habitats. The development of private lands and associated loss of fish and wildlife habitat is anticipated to continue, although certain plans and guidance (e.g., HCPs, Salmon

[14] According to the American Wind Energy Association Website, accessed November 22, 2005. (www.awea.org/projects/washington.html), and L. Wedemeyer (pers. comm. 2005)

[15] The facilities studied in GAO's (2005) report were located in Oregon, California, Pennsylvania, West Virginia, Minnesota, and New York; no facilities in Washington were included in this report. GAO noted that information regarding impacts to species was limited or nonexistent in many areas of the country, as was data on how to minimize these impacts.

Recovery Funding Board) have been produced to help reduce the impacts. Habitat loss and habitat degradation are expected to continue as development creates a demand for new public services and facilities. Disturbances caused by human development in low-elevation areas, as well as recreation at all elevations, have, and will continue to have, a cumulative impact on some species through loss of habitat and displacement of individuals.

Lingering effects of past pollution and ongoing delivery of pollutants affect species and habitats, and the effects are expected to continue. Certain previously-banned chemicals continue to be found at elevated levels in many top predators such as orcas (*Orcinus orca*). Poor air and water quality, as well as hazardous wastes and oil spills have diminished the quality and usability of fish and wildlife habitats. Potential impacts include displacement and loss of individuals of some species, as well as decreased habitat quality. Recovery of fully-functioning habitat conditions in many areas, if possible, will take much time and effort, and new problem areas will certainly be detected in the near-term future.

Agriculture, mining operations, timber harvest, and other industries and their associated infrastructure (dams, canals, impervious surfaces, etc.) have impacted and will continue to impact natural resources. Certain actions are being implemented to reverse or reduce these impacts through the removal of dams, use of low-impact-development technologies, restoration and enhancement projects, and other activities.

Shoreline development has affected and will continue to impact coastal processes. Shipping, bulkheads, and other shoreline developments have contributed to the reduction in eelgrass beds and other spawning and rearing areas for forage fish such as herring. To counter these impacts, certain rules and guidance (e.g., Shoreline Management Act) have been enacted and adopted by some jurisdictions.

Within Washington, a significant amount of the forestlands are federally managed. Much State land and some private lands are already being managed under HCPs or similar agreements. This management is part of the environmental baseline. Any change from the current rate of protection for Federal forestlands would require separate section 7 consultation under the ESA.

6. COMPREHENSIVE CUMULATIVE EFFECTS

Cumulative effects, as defined in 50 CFR 402.02, include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this Opinion. Future Federal actions that are unrelated to the proposed action are not considered because they require separate consultation pursuant to section 7 of the ESA. Some of the activities described below are already addressed in the Comprehensive Environmental Baseline, but because they are ongoing and anticipated to continue in the future, they are also addressed herein.

Cumulative effects can result from individually minor but collectively substantial actions taking place over a period of time. Numerous non-Federal actions that could affect listed and covered species are reasonably certain to occur within the action area. These will typically include: (1) rural and residential development; (2) transportation improvements and expansion; (3) mining; (4) agricultural activities; (5) grazing; (6) changes in road density; (7) timber harvest on FPHCP covered lands that occurs outside the Riparian Zone; and (8) timber harvest on private lands conducted under four counties and one city (Thurston, King, Spokane, and Clark Counties and Port Townsend) that WDNR has transferred authority to regulate Class IV-General forest practices that are likely to be converted to non-forest uses. Each of these future activities could contribute to cumulative effects on listed and covered species or their habitats in the action area.

6.1 ACTIVITY-SPECIFIC ASSESSMENTS

6.1.1 Population and Development

Population growth and development is likely to continue to increase in Washington. The Washington State Office of Financial Management (WSOFM 2001) indicates that several assumptions can be made about growth patterns in Washington. First, future growth will probably occur near existing population centers, such as Seattle, Tacoma, Vancouver, Spokane, Wenatchee, Yakima, and the Tri-cities area in Washington; while limited developable space is available within the cities themselves, growth around their peripheries is likely to be high. While much of the population growth and development in eastern Washington will likely be limited to these metropolitan areas, developed areas in western Washington are expected to continue to expand east toward the Cascade foothills and passes, west toward the Kitsap Peninsula, and north and south along the I-5 corridor.

Another assumption regarding growth is that although much of the growth would likely occur along existing transportation corridors (such as highways), other off-corridor areas would likely see some growth through immigration of telecommuters and retired persons, among others (WSOFM 2001). Recent advances in technology have allowed settlement of more-rural areas throughout Washington, and development of support services often follows, leading to development in areas and distribution of development that were previously not feasible. Finally, rural counties with relatively small populations are less likely to experience substantial growth in the future.

Areas may experience different levels of future growth based on local conditions. According to the Puget Sound Action Team (PSAT 2005), all of the counties in western Washington surrounding the Puget Sound and the Strait of Juan de Fuca will experience at least 20 percent in population growth by 2025, with some counties expected to have population growth levels of over 50 percent (Jefferson, Mason, Thurston, Snohomish, Skagit, and Island Counties). In the 12 counties bordering Puget Sound alone, the Puget Sound Action Team (2004) reports that the population will increase by over 1 million people by 2025. The expected increase in population is likely to result in substantial effects to the natural resources of Washington State (WDNR 1998a).

Washington's Growth Management Act was enacted to help communities plan for growth and address growth effects on the natural environment. Under the Growth Management Act, many counties have enacted critical-area ordinances that impose a variety of restrictions on development. These critical-areas ordinances, while having variable environmental protection value, should continue to address a number of natural-resource issues.

Natural fish and wildlife habitat outside of protected lands will likely decline in both quantity and quality as a result of increases in population and development. As the population increases, there is likely to be an increase in demand for space for new homes, businesses, associated infrastructure, and other facilities. Production of solid and human waste is also likely to increase with the population. As the demand for water continues to increase, it will exacerbate water shortages and result in effects to habitat (Wissmer et al. 1994). New construction will result in the conversion of forested, agricultural, and other rural-land uses into residential, commercial, and industrial uses. In the 5-year period between 1992 and 1997, rural lands in Washington were developed at the average rate of 48,200 acres per year. About half (48 percent) of converted land was forested land (WFPA 2001). Many areas of non-industrial private forestlands in Washington were converted from primary forestland to non-primary forest use (e.g., residential development) between 1979 and 1989 at a rate of almost 100 acres per day (WDNR 1998a). We anticipate that the conversion of forestland to other uses will continue to accelerate as the population increases. Increased development will also likely place increased demands on the existing infrastructure, such as transportation, natural-resource extraction and manufacture (e.g., timber harvest, mining), and agricultural production.

Development is expected to continue to place pressure on the marine environment, as well as large lakes and rivers. For instance, Puget Sound has the highest per capita boat usage in the Nation (WDOE 2006). Docks are expected to continue reducing the light that reaches important habitats such as eelgrass meadows, which provide critical support for a variety of fish species. While each dock and boat may be small, the combined effect of many over-water structures can add up. Bulkheads (i.e., seawalls) are expected to continue damaging beaches. Shoreline armoring, landfill, and over-water structures continue to reduce both sediment supplies and transport from sources along the shore as well as sources further up the beach. Over time, seawalls constructed to protect property along retreating beaches often exacerbate beach erosion. They confine the wave energy and intensify the erosion by concentrating the sediment-transport processes in an increasingly narrow zone. Eventually, the beach disappears, leaving the seawall directly exposed to the full force of the waves.

Dumping of human waste and discharge of engine waste are expected to continue. Cleaning and repainting of boats are expected to release toxic chemicals into the environment. Stormwater and wastewater discharges increase nutrient inputs. The decomposition of these nutrients utilizes oxygen and lowers dissolved oxygen levels. During periods of thermal stratification, when layers of water develop with different temperatures and densities that resist mixing, layers of low dissolved oxygen can develop and can result in fish kills. Contaminants from wastewater and stormwater discharges will continue to accumulate in tissues of marine organisms. Habitat loss, degradation, contamination, and, in some cases, over-utilization have contributed to the decline of many marine species. Habitat loss, degradation, and contamination are influenced by population size and are expected to continue.

6.1.2 Transportation

Highway expansion and upgrading of the current road system will likely continue to be emphasized over new highway construction, although new construction may also occur. Beginning in 2000, seaports were expected to grow an average of 4 to 5 percent each year for the next 15 to 20 years, with shipping-container traffic expected to more than double by 2020 (WDNR 2000a). As the ports expand in size and capacity, other development to support these facilities will also increase. Increases in shipping and the use of larger ships will likely lead to increases and deeper dredging (WDNR 2000a). Because dredging requires a Federal permit, and thus would be subject to section 7 consultation, it is not discussed herein. Removal of large wood by the USCOE from rivers and marine waters will also not be addressed as these actions would be subject to future section 7 consultations.

Utility rights-of-way will increase for power, water, and petroleum transport and for phone, cable, and other communications. Many of these corridors will be addressed through future section 7 consultations with the respective Federal agencies. Other effects expected to increase as a result of these corridors include off road vehicle access and associated habitat destruction and contamination, illegal dumping of solid and liquid waste, and continued effects from poorly constructed and poorly maintained access roads.

6.1.3 Mining

Increases in construction and development related to population growth will require the increased extraction and use of natural materials such as sand, gravel, and rock. Mining effects in the past have resulted in substantial degradation of stream habitats and associated fisheries. Some of these effects are still degrading the environmental baseline conditions, but some restoration activities have been implemented to restore ecosystem function. Most mining activities without a future Federal nexus are currently more regulated than they were in the past and are generally expected to result in relatively fewer effects; however, locations of sand and gravel extraction relative to streams and rivers may determine the level of effects experienced.

6.1.4 Pollution

The cycling of contaminants delivered to waters in the past is expected to continue. High concentrations of polychlorinated biphenyls (PCBs) and other chemicals in marine mammals indicate that the food chain continues to bio-accumulate environmental contaminants. For some chemicals, such as polybrominated diphenyl ethers (PBDEs), the effects are not just lasting effects from past use, but their concentrations in the environment are still increasing. Although environmental regulations may continue to restrict use of these chemicals, the growing human population and existing infrastructures may exacerbate problems associated with reducing delivery of chemicals to the aquatic environment.

FWS anticipates that chemicals such as pesticides, herbicides, fertilizers, and fire retardants will continue to be used within the action area. Chemical application is under the jurisdiction of several Federal, State, and local agencies and their use is expected to be conducted under applicable laws.

6.1.5 Agriculture

Agricultural activities within the action area include dairy farming and crop cultivation. Effects to water quality from manure, fertilizer, and other chemicals are likely to continue, although these issues are being addressed in some areas of the State, as described in the Comprehensive Environmental Baseline section of this Opinion. Water diversion and irrigation associated with agricultural activities are expected to continue, contributing to water-quality and water-quantity effects. The construction and use of dikes to reduce flooding is common in agricultural lands, and has historically caused a significant loss of secondary channels in major valley floodplains. Confined channels create high-energy, peak-flow events that remove smaller substrates and LWD, a condition likely to persist into the future in any diked system. The loss of side-channels, oxbow lakes, and backwater habitats in the action area will continue.

Crop conversion (i.e., converting from one crop species to a new crop species) can have environmental effects on streams that can either benefit or degrade habitat function. For example, pasture lands and row crops in eastern Washington are increasingly being converted to intensively managed orchards and vineyards in Washington State in response to market pressure. Orchards and vineyards require more-intensive applications of insecticides and fungicides than do pasture lands or row crops. The statewide trend of converting farmland to other uses, such as development, has a far greater environmental effect than the possible beneficial and/or detrimental effects of changing from one agricultural practice to another. One reason the loss of farmland is occurring is because of an increasing demand for residential and commercial development as the population of the State grows.

The negative effects from agricultural operations are continuing to decline from historical levels, due in part to improved practices and coordinated resource-management plans between State and Federal agencies. County extension staff, Universities, and State and Federal agencies are cooperatively conducting a number of programs to provide incentives and assist landowners in improving management and conservation actions. As described previously in the Comprehensive Environmental Baseline section, some private landowners are including protective measures (e.g., riparian fencing, grassed swales) in the management of their lands to reduce the effects to stream habitats and other ecosystems.

6.1.6 Grazing

Grazing activities currently permitted by Federal agencies are governed by the Aquatic Conservation Strategy of the Northwest Forest Plan or the PACFISH / INFISH (i.e., aquatic management strategy for U.S. Forest Service and Bureau of Land Management lands outside the Northwest Forest Plan area). Grazing on State lands is conducted in conjunction with the guidelines provided by Washington House Bill 1309 (1994) and codified in 1996 in RCW 79.13.600, 610, and 620. Future grazing leases on Federal lands are not part of this cumulative effects analysis because they would be subject to future ESA section 7 consultations. Grazing on private lands has fewer restrictions, and thus potentially greater negative effects on forestlands and adjacent streams.

Livestock grazing in riparian areas is a controversial issue because the effects of grazing on fish populations are not well understood (Platts 1991; Mosley et al. 1997; Rinne 1999). Although extensive information exists on the direct effects of grazing on certain components of fish habitat and stream conditions, the effects of grazing (i.e., of grazing-induced habitat alterations) on the fish themselves is less easily demonstrated (Rinne 1999). Also, less information is available on the relationship between grazing and fish populations in forested environments compared to open rangeland environments.

Platts (1991) summarized 21 studies and stated that, generally, salmonid populations in streams passing through grazed areas are reduced compared to ungrazed areas because of more fine sediment in stream channels, more unstable and fewer undercut stream banks, and higher summer water temperatures. Changes to naturally-occurring, stream-system processes and associated riparian structure and functions have been implicated in the decline of fish abundance (Platts 1991). However, the effects of grazing on fish populations are directly related to how grazing is managed, in that well-managed grazing can be compatible with healthy, functioning riparian ecosystems (Mosley et al. 1997; Ehrhart and Hansen 1997; Ehrhart and Hansen 1998).

In summary, numerous studies have shown that improper livestock grazing can damage streams and degrade fish habitat (see review by Platts 1991). However, less is known about grazing effects in riparian forest environments which may be more resilient than rangeland riparian environments. There is evidence that certain livestock grazing practices can be employed that will protect stream fisheries (Platts 1982; Rinne 1999). Management of cattle stocking rates and distribution, vigor of riparian vegetation, and protective measures for stream banks and channels are important considerations in maintaining the environment where grazing occurs.

6.1.7 Water Diversion and Storage

Potential negative effects associated with water diversions include: (1) the delivery to streams of agricultural chemicals and silt present in irrigation return flows; (2) the diversion of water from streams, making streams unusable at certain times of the year for certain life stages of fish; (3) the reduction in a stream's capacity to transport sediment; and (4) the exacerbation of water temperature problems because of low stream flows. Reservoirs used to store irrigation water and subsequent releases will continue to create stream flows that are much higher than natural when water is being released from reservoirs and much lower than natural when reservoirs are being filled. As a result, fish spawning, migration, and rearing can be disrupted by either high flow or low flow events. Potential effects to fish of substantial water diversions are expected to include entrapment and impingement of younger life stages; localized de-watering of reaches; and depleted flows necessary for spawning, migration, rearing, flushing of sediment from the spawning gravels, gravel recruitment, and transport of LWD. Water impoundments also contribute to the introduction and spread of invasive species.

6.1.8 Aquaculture

Aquaculture activities in the State are expected to increase with associated degradation of water quality. Some harvest and hatchery practices may have diminished the genetic diversity of salmonids (reviewed in Allendorf and Waples 1996; NRC 1996 as cited in IMST 2004), potentially limiting their ability to cope with climate fluctuations. The ongoing Puget Sound and Coastal Washington Hatchery Reform Project is multi-stakeholder supported effort in western Washington that is expected to address some of these effects. Under this new model of hatchery reform, productive, available habitat is essential to an effective hatchery program. In addition, managers have to consider whether a hatchery program is the best means to help achieve the stated resource goal, once the risks and benefits from the program are considered.

6.1.9 Fishing

Recreational fishing within the action area is expected to continue, subject to WDFW regulations. The level of harvest of covered species within the action area from angling is not precisely known, but is expected to be managed at long-term sustainable levels. Subsistence fishing will also continue subject to regulations by specific Native American Tribes and tribal organizations.

6.1.10 Motorized Recreation

The effects of motorized recreation (e.g., motorcycles, off-road vehicles) are numerous. Lawfully constructed trails may introduce sediment to streams. Unauthorized trails compact wetland and riparian soils, degrade and remove vegetation from sensitive sites, collapse stream banks, and create ruts which can accelerate delivery of sediment to waters. Motorized recreation that crosses stream channels can have direct adverse effects such as destroying fish spawning redds in streams and indirect adverse effects such as leaking fuel when crossing streams. Off-Road Vehicles (ORVs) provide access to remote areas thereby facilitating activities in locations where effects may be greater. ORVs create water and air pollution through poor combustion of gasoline and oil.

ORV use has been shown to reduce species of amphibians, likely through a combination of direct crushing of individuals and also damage to habitat (Maxell and Hokit 1999). Snowmobiles may result in snow compaction that can affect subsequent run-off. Personal water craft and small outboard engines on boats can have a variety of effects. Nearly all personal water craft equipment has a 2-stroke engine. Out of every 10 gallons ingested, as much as 3 gallons are discharged unburned by personal water craft equipment, and as much as 4 gallons are discharged unburned by outboard engines. A typical 2-hour ride on personal water craft equipment may discharge 3 gallons of a gas-oil mixture into the water. Such engines also release oil and can depress dissolved oxygen levels in the water. The combustion process discharges additional toxic compounds into water. Concentrations of polycyclic aromatic hydrocarbons (PAH) in lakes and reservoirs with high motorboat activity have been found at levels dangerous to aquatic organisms and human health (Joslin and Youmans 1999).

6.1.11 Habitat Restoration

The State of Washington has various strategies and programs designed to improve the habitat of listed species of fish and wildlife and assist in recovery planning, including the Salmon Recovery Planning Act. Other restoration programs funded, permitted, or carried out by the Federal Government are not considered in this cumulative effects analysis, as they would be addressed in the future under ESA section 7. A variety of non-governmental (e.g., land trusts and conservation groups) and psuedo-governmental (e.g., lead entities) organizations are cooperating with the State and Federal agencies in restoring habitat.

Instream and riparian restoration activities (e.g., large wood placement, dam removal) typically cause temporary effects on the quality of fish habitat, during construction. These effects include increases in turbidity, altered channel dynamics and stability, and temporary isolation of work areas displacing fish. Properly constructed stream-restoration projects are likely to increase habitat complexity, stabilize channels and streambanks, increase spawning gravels, decrease sedimentation, and increase shade and cover. Upland restoration projects that benefit riparian and instream habitat will continue to occur in the future. These projects often focus on identifying source problems in an area (i.e., road-associated problem areas) and apply corrective measures to eliminate or minimize the adverse effects to aquatic resources.

6.1.12 Other Activities

Other activities, including those described earlier in the Comprehensive Environmental Baseline section, will continue to degrade Washington's ecosystems. Lands and waters used for recreation will become more crowded, and stress on native species and habitats will likely intensify, further affecting species and their habitats. Increasing trends in modification to and/or conversion of lands for pipelines, aqueducts, power lines, rail system transportation, and other facilities are likely to occur; construction, maintenance, and operations of these facilities may affect species and their habitats through modification of habitat, disturbance, or mortality to species and/or their forage base.

6.1.13 Timber Harvest

WDNR has transferred authority for Class IV-General forest practices, for Thurston, King, Spokane, and Clark Counties and Port Townsend, where the forestland is likely to be converted to non-forest uses. In other parts of the State, WDNR addresses Class IV-General forest practices, although other counties are actively working on obtaining authority from WDNR in the near future. These activities could affect aquatic resources and would not be considered FPHCP covered activities or lands. Also, timber harvest under the 20-acre exemption rule that is outside of the proposed FPHCP permit coverage (e.g., conversions) would have a cumulative effect on listed and covered species.

Upland timber harvest on FPHCP covered lands, and the associated location of additional roads, is anticipated to continue as it has in the past, and in a manner that is not influenced by issuance of a Permit for incidental take. Upland timber harvest may affect stream flows. Most studies conducted on flows have indicated that summer low flows and annual water yield are generally increased by timber harvest.

Peak flows may be increased as well. Increased peak flows have been recorded during small to moderate events, usually during spring and fall. Larger peak flows from winter storms and/or rain-on-snow events are generally not known to be affected by timber harvest (Austin 1999; MacDonald et al. 1997; Scherer 2001).

Upland harvest may accelerate surface erosion. Forest soils are generally characterized by low rates of surface erosion. When erosion occurs, most soil particles that are mobilized remain on the slope (Reid 1993). Vegetated buffers, including the litter, duff, and soils of those buffers, are effective at filtering particles above approximately 40 microns (0.0016 inches) in size. According to Gharataghi et al. (2005), almost all of the aggregates larger than 40 microns in diameter were captured within the first 16 feet (5 meters) of a vegetated buffer strip. However, the remaining, small-size aggregates are very difficult for a buffer to capture before delivering a stream. Therefore, while surface erosion may be increased by timber harvest several-fold, it is not common for delivery of sediment to streams to be substantially increased. In some cases, delivery may be increased (e.g., along unbuffered Np streams). Upland timber harvest conducted according to the Washington Forest Practices Rules would have little potential to increase the rate or magnitude of mass-wasting events. The FWS anticipates that delivery of some sediment and turbidity to streams may continue as a result of upland timber harvest.

Increased roading has allowed greater access for forest management and some types of recreation, and has both contributed to the ability to protect forests from the spread of fires as well as provided human access that may contribute to ignitions. The decision, of where and when to build roads, depends on the logistics of timber harvesting. As the density of roads increases, the adverse effects on riparian areas will potentially increase (Knutson and Naef 1997).

Even the most cautious road-construction methods are likely to yield some degree of effect. Increased road densities provide additional opportunities for hydrologic interception and increased sediment discharge. Road densities alone do not cause sediment delivery. Outcomes of a number of Watershed Analyses in Washington State and Montana have indicated that application of high-quality road-management standards can substantially reduce the production and delivery of road-generated sediment to streams. However, within a given watershed, increasing the density of roads, with all other factors being held constant, may result in additional adverse effects to streams and covered species.

Following timber harvest and both prior to and following planting, herbicides may be used to ensure forest regeneration by controlling competing vegetation. Chemicals used, application rates, and application methods depend on a number of variables such as characteristics of target plants versus desired vegetation, treatment objective (containment versus eradication), accessibility, topography, size of treatment area, location of sensitive areas in immediate vicinity, anticipated costs, equipment limitations, and weather and vegetative conditions at time of treatment. We anticipate that all applications will be consistent with requirements of specific herbicide labels, State laws, and other applicable laws. Even when properly applied, chemicals such as herbicides, insecticides, and fertilizers can have a variety of negative effects on water quality and aquatic life.

6.1.14 Fire Suppression

Fires (naturally- and accidentally-caused) in Washington range from frequent, low-intensity events to infrequent, stand-replacing events. The amount of land burned is variable between years. For instance, 23,511 acres under WDNR jurisdiction burned in 1998, but only 4,649 acres burned in 1997 (WDNR, Resource Protection Division, 2001-2003 Annual Fire Statistics as cited in WFPA 2001; 2004). In most years, less than 25,000 acres of forest burn. The number of fires does not change much from year to year, but generally only 1,000 to 2,000 acres of forest burn each year. In most years, lightning is the leading cause of fires (by acreage) but during some years slash debris burns and other causes may result in more acres burned.

Some believe that severe fire years are inevitable based on past forest-management practices which limited the role of natural fires in ecosystem maintenance. Recent efforts at fire suppression, especially in the Eastern Cascades, and selective timber-harvesting practices have resulted in shifts in tree species composition and forest structure in some areas. These shifts have moved from open stands of shade-intolerant ponderosa pine and towards higher density stands with more shade-tolerant species such as grand fir and Douglas-fir. Forests east of the Cascade crest have become increasingly susceptible to catastrophic fires and epidemic attacks of insects and disease. Historic "natural" fire patterns also vary from the fire patterns observed within the last 100 years as a result of forest management and fire suppression that has occurred since. The result of highly intense fires, is that soils may become hydrophobic and subject to surface erosion, as less infiltration will result in greater surface flow.

WDNR is responsible for suppressing fires on private lands, in addition to State and some Federal lands – about 12 million acres in total. Landowners share the fire-supression costs. Negative effects can emanate from fire suppression. Fire camps established in forest openings and meadows can result in destruction of vegetation, compaction of soil, generation of sediment, and introduction of waste to the environment. Sites for maintenance and fueling of equipment, including heliports, may also affect environmental conditions. Within the burn area, hazard trees may need to be felled. Fire-lines and equipment trails will be constructed and soil compaction may result. Fire-lines and trails may act as conduits for sediment transport. Bringing equipment onto a site with substantial soil disturbance and removed vegetation can facilitate introduction and the spread of noxious weeds. Activities designed to reduce post-fire surface erosion may also introduce weeds.

6.1.15 Natural-disturbance Regimes

Fires tend to burn variably across landscapes leaving patterns of severely and lightly burned areas as well as unburned areas. Fires can remove shade and can both remove and recruit large wood to forestlands and adjacent streams. Fires can temporarily reduce vegetation on side slopes which can contribute to surface erosion and sediment delivery to streams.

Other natural disturbance regimes expected to continue include high-flow events, flooding, avalanches, mass-wasting events, soil creep, sediment delivery and transport, channel migration, bank erosion, windthrow, forest insects and disease, log-jam formation, and construction of beaver dams. These natural processes are considered cumulative effects as well as habitat-forming processes/events.

6.1.16 Ocean Cycles

The ocean habitat fluctuates and is dynamic, changing over several time scales. There are inter-decadal variations in climate, as well as shorter-term variations, that affect ocean productivity for salmonids and other fish. A major assumption is that improved conditions of freshwater and estuary habitat are buffers to years with low productivity ocean conditions. Without improvement of the condition of these habitats, the years with low productivity ocean conditions, in the future, will be more devastating to anadromous and marine fish than what was experienced in the early 1990s (Lawson 1993).

6.1.17 Climate Change

Recent precipitation patterns in the Pacific Northwest appear to be changing from historical patterns. Depending on the region, more or less precipitation is occurring, and the seasons of precipitation are shifting (Mote et al. 2003). Researchers have projected the Cascade Mountain (Oregon and Washington) snowpack to decrease by as much as 60 percent based on changes occurring in the snowpack since the 1950s (Service 2004). The decrease in snowpack could significantly decrease summer stream discharges. Over the last 100 years in the Northern Hemisphere, scientists have measured a general air temperature increase of less than 1.0 degree Celsius superimposed on the natural variability of climate (Diaz and Bradley 1995; Mote et al. 2003). However, there is no evidence that the effect of slight variations in climate on stream temperatures would be equal to or greater than the documented effects that land-use impacts have had on stream temperatures (IMST 2004).

6.1.18 Invasive Species

Effects from invasive, non-native species are expected to continue through future introductions associated with aquaculture, hatcheries (e.g., Atlantic salmon), transportation (e.g., ballast water from ships), water impoundments, and other activities, affecting native species and their habitats. The introduction of non-native fish species has contributed to declines in native fish; one example is brook trout. Brook trout mature at an earlier age than bull trout and have higher reproductive rates. These differences may favor brook trout over bull trout when they occur together; often leading to the replacement of bull trout with brook trout. Brook trout also appear to adapt better to degraded habitats than bull trout.

A number of authors have suggested some correlation between stream temperature and interactions of bull trout and brook trout. Given that brook trout have a wide optimum temperature range and that they seek groundwater upwelling sites for spawning, it may be that brook trout can displace bull trout even at cold temperatures that bull trout prefer (Cavallo 1997). Brook trout have demonstrated higher individual growth rates than bull trout across even the coldest temperatures. The FWS expects that negative effects as a result of introduced fish and other invasive species will continue.

6.2 RELATIONSHIP OF CUMULATIVE EFFECTS TO FPHCP

In the following discussion, we describe relationships between the FPHCP and additional contributions to any of the cumulative effects.

The timber industry and supporting industries make up only a part of Washington’s economy. However, some small rural communities are dependant in large part on the timber industry. Any difference as a result of Permit issuance is not likely to make a difference at a regional scale. The level of certainty brought by Permit issuance is expected to increase the likelihood that a forest landowner would retain their lands in forestry rather than converting those lands to other uses. However, many other factors (e.g., current land market values) would affect a landowner’s decision of whether to convert their land.

Transportation corridors outside the forested environment are not dependent on traffic harvesting timber. Even if they were, the small differences imparted by the FPHCP regarding outgoing wood or incoming rock would not be significant. The FPHCP also would not affect hydroelectric facilities; water withdrawals for agriculture, industry, or human consumption; flood control; and the overall pattern of commercial, industrial, and residential development. Few, if any, industries would be affected by the difference resulting from the proposed Permit issuance. Fish hatcheries may eventually be affected in the long-term as the recovery of anadromous fish is facilitated by improved conditions in the forested environment, along with other regional salmon recovery efforts in the State. But other habitats, especially low-elevation habitats have been so badly degraded and have affected fish populations to such a degree that any short-term influences of the FPHCP on hatchery programs are mostly speculative.

The FPHCP is not expected to significantly affect recreation. The FPHCP is expected to result in better maintenance of roads that may facilitate access by some for recreation, but may result in reduced access in some cases to avoid excessive wear on roads during wetter conditions. Increased riparian buffer widths may make their experiences somewhat more aesthetic, but will not likely change the overall distribution and types of recreation on FPHCP covered lands.

The FPHCP does not include Native American tribal lands. However, it does affect Native American trust resources (e.g., fish populations). The FPHCP should enhance and not diminish their ability to harvest fish. The FWS does not expect that other tribal resources (e.g., bark, berries, medicinal plants) or access to FPHCP covered lands will be significantly altered by the FPHCP.

6.3 CONCLUSION

In general, many of the activities described in the comprehensive environmental baseline are expected to continue in Washington in the future. Many timber-harvest, mining, and agricultural practices have improved over time, and are not anticipated to result in the extreme effects that occurred in the past. Enhancement and restoration projects and other corrective activities are in the planning and/or implementation process. These actions are expected to improve natural-resource conditions in the future. However, the effects from increased population and development, if not sufficiently mitigated, have the potential to overwhelm the benefits of these activities.

7. EFFECTS OF THE ACTION

The effects of the action include an analysis of direct and indirect effects, together with the effects of the interdependent and interrelated activities. Direct effects are those impacts from the action that immediately affect the species or its habitat. Indirect effects are those impacts from the action that are later in time and may occur outside of the area directly affected by the action. Indirect effects must be reasonably certain to occur before they can be considered as an effect of the action. An interrelated activity is an activity that is part of the “larger” proposed action and depends on the proposed action for its justification. An interdependent activity is an activity that has no independent utility apart from the proposed action. At times, there are other activities that are interrelated or interdependent with the proposed action under consideration that result in additional effects to the species or its habitat that must be considered along with the proposed action.

In determining whether an action is likely to jeopardize a species or destroy or adversely modify critical habitat, the FWS analyzes the effect of the action, and the effect of other activities that are interrelated or interdependent with the action, in the context of the environmental baseline and cumulative effects. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone consultation under section 7, and the impacts of State or private actions which are contemporaneous with the consultation in process. Cumulative effects are those of future State or private activities, not involving Federal actions that are reasonably certain to occur within the action area of the Federal action subject to consultation.

7.1 FRAMEWORK FOR ANALYSIS

Section 7 of the ESA requires the Services to consult (regarding their respective species) on Federal actions which “may affect” listed species. For Federal actions which are likely to affect listed species, the consultation culminates in the preparation of a written Opinion. An Opinion must detail how the agency action affects the species or its critical habitat, in consideration of the species status, environmental baseline, and cumulative effects. The following information describes the framework used by the FWS in this Opinion to identify the effects of the agency’s action.

The proposed Federal action in this instance is to issue a Permit for the FPHCP that addresses forest practices on non-Federal, non-tribal, lands in Washington. This Permit would authorize incidental take, but would not permit or authorize the underlying activities. The permittee would be the State and the underlying activities would be a specific set of rules regarding the regulation of forest practices, such as timber harvest and road management, in Washington State. The State promulgated the current Washington Forest Practices Rules partly in anticipation of applying for a Permit and with the assumption that such changes would be necessary for the Services to issue Permits. Therefore, those rule changes are considered effects of the contemplated permit issuance. The incidental take that would be authorized by the Permit would be associated with the set of activities that are described in the FPHCP. It should be noted that the Permit would not constitute an authorization for the Covered Activities themselves, but only for take that may result from those activities. The take which would be authorized by the Permit would be incidental take, which is take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity (50 CFR 17.3). The term “take” means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in such conduct (ESA Section 3(18)). “Harass” in the definition of take in the ESA means an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. “Harm” in the definition of take in the ESA means an act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3).

Therefore, incidental take may include harm or harassment so long as the harm or harassment is not the purpose of the activity, and the activity resulting in harm or harassment is an otherwise lawful activity. In other words, the activities addressed by the proposed Permit must be in compliance with Federal, State, and local laws. The Permit proposed in this instance would authorize incidental take of native fish and several species of stream-associated amphibians, where such take is anticipated to be caused by Covered Activities. Should an activity be determined to result in take of a listed species that is not included in the Permit, and for which there is no other take authorization, that activity would violate ESA Section 9 and hence would not be an “otherwise lawful” activity. Consequently, it would not be a Covered Activity. Such activities will not be addressed by the incidental take statement in this Opinion; as such activities are not an effect of the proposed action.

Next, we determined how the proposed Federal action (issuance of the Permit) would change or alter the status quo for listed species, and for unlisted species covered under the Permit (native fish and stream-associated amphibians). There are two potential ways in which the issuance of the Permit could effect a change in forest practices over the course of the Permit period of 50 years: (1) some forest practices activities were changed as a direct result of Washington Forest Practices Rules, based on the Forests and Fish Report negotiations – such as riparian management zones, and therefore resulted in a distinct modification in the implementation of forest practices (whether or not take of any covered species would result); and (2) some forest practices that remained the same (i.e., were unchanged by the Forests and Fish Report negotiations) may, over the life of the Permit, result in the take of covered (listed or unlisted) species. In either case, these are the activities ("primary activities") which would be effects of the Permit and these activities will be directly addressed in the action-related analysis in this Opinion.

In order to determine if the specific rules governing forest practices changed as a result of negotiating the FPHCP, the FWS examined the November 1998 Forest Practices Rules as these were the most recent Rules prior to implementation of the requirements of the current Washington Forest Practices Rules (adopted permanently in 2001) that are also in the FPHCP. The FWS also considered the Watershed Analysis Process which was in effect under the November 1998 Forest Practices Rules and is acknowledging that many watershed analyses were completed and essentially became legally binding for those watersheds prior to 1998. Since then, a number of these efforts have continued where they were already initiated, but few new analyses were initiated after the current Washington Forest Practices Rules were developed, thereby minimizing the emphasis on watershed analysis. The FWS also recognized and considered that many protective aspects of the Washington Forest Practices Rules, such as those pertaining to unstable slopes, were already in the process of improvement through efforts such as education and training, and this trajectory of improvement is part of the environmental baseline. If those activities are ongoing or expected to occur in the future, the impacts emanating from them will be addressed under the Cumulative Effects section.

In addition, other activities (whether or not they may be listed as covered activities within the FPHCP) may occur solely because of the "primary" activities resulting from the Permit issuance. In situations where these activities would not have independent utility they are considered either interrelated or interdependent to the primary activities. They will also be addressed in the action-related analysis in this Opinion. Interrelated activities that were listed as covered activities will be referred to as "related activities" within this Opinion.

For all activities addressed in the action-related analysis, the FWS will assess the direct and indirect effects emanating from these activities in relation to any listed plant or animal species (and designated critical habitat) that may be affected, as well as the unlisted covered species. Other activities which have occurred and are occurring, regardless of permit issuance, are addressed in this Opinion under the Comprehensive Environmental Baseline section. Therefore, activities conducted between November 1998 and the date of this Opinion are considered within the Comprehensive Environmental Baseline.

7.1.1 Summary of Framework for Analysis

The effect of the Permit consists of the effects of all activities that are anticipated to occur under the FPHCP that were: (1) changed in the Washington Forest Practices Rules because of the Forests and Fish Report negotiations; and (2) unchanged by the Forests and Fish Report negotiations but that we expect to result in take of covered species during the 50-year proposed Permit term. Most forest-management activities on the 9.3 million acres of land covered by the Permits will occur outside of riparian areas and road corridors and, while they fall within the definition of FPHCP "Covered Activities," are not reasonably expected to take aquatic species and have not changed in recent rule revisions. Because a Permit is not required for those activities for coverage of aquatic, covered species, any impact that those activities might have would not be an effect of the Permit.

The effects of the Permit is constrained by the ability of the FWS to reasonable anticipate "take" of covered species. Forestry activities that occur near streams and that affect aquatic habitat will not necessarily cause take of listed species. "Take" under the ESA involves more than just adverse impacts on habitat. To prove take, the FWS must prove that a person committed an act that actually killed or injured wildlife, such as through habitat modification that significantly impaired essential behavioral patterns such as breeding, feeding, or sheltering. For aquatic species, habitat impairment typically is not attributable to a single act or person. More often, it is the result of the continuing effects of past land-management activities, combined with the effects of numerous current activities by multiple landowners within a watershed. Under these circumstances, it may be difficult to show that the incremental effect of an individual landowner's actions causes take, even if the aggregate effects of many actions harm the species.

Moreover, the likelihood that any activity will cause take depends on a number of site-specific factors, such as whether the species occupies the area, whether the habitat in question is already degraded, the season in which the activity occurs, and soil conditions and slope stability. Consequently, it is very difficult at the broad scale to determine with confidence whether certain classes of activities can be expected to cause take in all or even most instances.

Nonetheless, for purposes of analysis in this Opinion, we expect that certain Covered Activities cause take in some circumstances. The effect of the Permit, therefore, is the direct and indirect effect of those activities that are expected to cause take, as well as those activities that were modified through changes to the Washington Forest Practices Rules. This analytical approach is necessarily conservative, in that it overstates the actual effect of the Permit by including many activities that could proceed without a permit.

7.2 INCREMENT OF EFFECTS – BASES FOR COMPARISONS

Once we identified the activities which are effects of the proposed permit issuance (as described above), we determined how to analyze the effects of those activities. Typically, we would analyze (where possible) the incremental effects of activities that are conducted in a modified manner. However, in this Opinion, we do not use that approach, and instead, analyze the effects of those activities as they are proposed to be conducted.

Activities to be conducted under the Washington Forest Practices Rules and the FPHCP are in many cases improved in comparison to the November 1998 Forest Practices Rules. The development of the FPHCP resulted in changes (often substantive changes) to some, specific Washington Forest Practices Rules, and also allowed some rules (that may result in "take" of covered species) to remain unchanged in the face of current and future ESA listings of covered species because of the minimization and mitigation provided. The FWS herein analyzes both types of rules discussed above as "primary activities." We also analyze activities that do not have independent utility. These are either covered "related activities" or those activities which are not covered, but are nonetheless interrelated and interdependent to the "primary" activities. Other activities whether they are "covered activities" in the FPHCP or not, are analyzed in the Environmental Baseline and/or Cumulative Effects, as appropriate. For more detailed information, see Framework for Analysis above.

Throughout this assessment, the effects are often discussed through a comparison with a scenario in which the activities do not occur. The FPHCP, as is commonly done in HCPs with aquatic systems affected by forestry, relies on avoidance and minimization measures. Because of this, we can attempt to view the effects in a comparison to an absence of these activities.

The determination about how effects under this proposed Federal action relate to effects that would occur in the absence of a Permit is difficult at best, due to uncertainty about defining the bases for comparison. On one hand, the November 1998 Forest Practices Rules existed before any changes were made as a result of the proposed FPHCP. Then, beginning in 1999, rule changes were made which, under different circumstances, might be considered part of the current environmental baseline. Under the circumstances here, however, it would not make sense to consider the rule changes from 1999 to present as part of the baseline, because the current Washington Forest Practices Rules were adopted expressly for the purpose of seeking Permits. Two other possible approaches to defining the baseline would be: (1) assuming that covered activities are conducted in a manner that would be certain to avoid take of covered species statewide, even where listed fish were not known to occur; and (2) assuming that covered activities are conducted in a manner that would be certain to avoid take of covered species, in consideration of site-specific factors relevant to whether any risk of take exists. The former is probably unrealistic as the State would have difficulty in justifying a basis for such inclusive Washington Forest Practices Rules. The latter could be employed in conjunction with either the current Washington Forest Practices or the November 1998 Forest Practices Rules in locations where listed fish were not known to occur. In all cases, speculation is required.

It is difficult to anticipate how the activities would be conducted in adherence to a take-avoidance strategy depending on the presence of listed species now and in the future. Not only would the presence of currently listed species be difficult to identify with certainty, but additional listings might occur during the 50-year period. For listed species, land managers/owners would be expected to conduct site-specific risk assessments. For instance, riparian buffers required to avoid take might be larger in some geographic areas or at a local scale. References to what would be required to avoid take are occasionally used in the Opinion as examples to clarify the actual effect of the permit issuance. It is important to remember that no single prescription can describe take-avoidance across a broad landscape with varying existing conditions, management strategies, and varying site-specific conditions. Additionally, conducting an activity under a take-avoidance scenario may still result in adverse effects. However, we intend to use a variety of comparisons as we attempt to identify the additional effects and benefits that may result from the proposed FPHCP. Many of the effects that will manifest themselves over the next 50 years will emanate from activities that pre-date the FPHCP, and also pre-date the development of the current Washington Forest Practices Rules, and therefore would not be effects of permit issuance, but continuing effects of past actions and part of the baseline. We are attempting to conduct this analysis in full consideration of the baseline and the role of management in improving habitat conditions (e.g., required culvert upgrading, allowed thinning of densely stocked riparian areas), as well as the negative effects of management. We also assess the effects of the action in the context of natural disturbance regimes. Even unmanaged forests, within which the covered species evolved, were prone to, and dependant upon, natural disturbance regimes.

Comparing the current Washington Forest Practices Rules with the November 1998 Forest Practices Rules or other scenarios would just confuse the analysis. The purpose of this Opinion is not to determine whether the current Washington Forest Practices Rules included in the FPHCP are better than what existed before, but to analyze the effects of the Federal action. This requires making some assumptions about what activities would be changed by permit issuance, and comparing (a) a world with those activities to (b) a world without those activities. Therefore, we focus on the effects of those changed activities, rather than some increment of difference that would be difficult to articulate. However, only as needed, our discussion of effects may at times incorporate comparisons of the changes made to the current Washington Forest Practices Rules under the FPHCP to the November 1998 Forest Practices

Rules, and, only as appropriate, comparisons with a site-specific, take-avoidance scenario. These comparisons are not simple. For instance, some of the current Washington Forest Practices Rules regarding road construction and maintenance changed slightly. There were minor changes in guidelines regarding placement of fill and water-crossings.

A similar situation exists with respect to riparian buffers. In general, the Washington Forest Practices Rules, included in the FPHCP, requiring buffers on fish-bearing streams were developed with the objective to provide for the growth and development of a properly functioning riparian zone, that will provide over the life of the FPHCP the following riparian functions - suitable substrates, sufficient shade, bank stability, litter inputs for healthy nutrient supply, and a continual source of large wood for instream structural elements important to fish. These buffers are improved over those in place previously. In addition, buffers are now placed on many segments of perennial streams without fish, whereas previously these were rare. The overall buffering of streams is a considerable change above the November 1998 Forest Practices Rules.

The FPHCP riparian buffering prescriptions are aimed at minimizing take, but are not designed to avoid all possible take. A take-avoidance strategy likely would have to be implemented on a site-specific basis, to avoid ESA section 9 take prohibitions, and is therefore difficult to describe. In some cases, buffers equivalent to or less than those under the FPHCP might be sufficient to avoid take. However, where listed fish are present, a take-avoidance strategy would most likely equal or exceed the buffering requirements of the FPHCP. On the other hand, a take-avoidance strategy would not likely be employed where listed fish are not known to be present. In those situations, the FPHCP buffering likely exceeds that of a take-avoidance strategy.

Still, there could be effects that would emanate from activities conducted in accordance with a take-avoidance strategy, as such a strategy would seek to avoid take of covered species that were listed at the time the activities would be conducted, but would not likely seek to avoid all impacts to all covered species. Similarly, effects would also emanate from activities conducted under the November 1998 Forest Practices.

For these reasons described above, the FWS has chosen to conduct the majority of its analysis at the "gross" level rather than the "net" comparison level. Each basis for comparison has its own disadvantages. Descriptions of effects in this document often use the words "reduced," "enhanced," "decreased," "increased," etc. These terms are meant to be relative to pre-activity conditions. Those terms should only be interpreted by the reader to be comparative to other alternate prescriptions (e.g., November 1998 Forest Practices Rules or take-avoidance) when explicitly stated.

7.3 ASSUMPTIONS

A number of assumptions are made for the analyses in this Opinion and will often be stated within the appropriate sections. For clarity, we have listed these assumptions as follows:

- There will be no take of listed species which are not covered by the permit. Such take would invalidate the Permit with respect to all listed species for that forest practices application and activity.
- Limited salvage will occur within buffers retained in 20-acre exempt parcels. This assumption is based on the fact that salvage must be conducted in compliance with WAC

222-30-45; therefore, unless additional trees were originally retained when the 20-acre exempt parcel was harvested, there would not likely be any available wood to salvage.

- Alternate plans will be processed and approved as intended, with protection of the aquatic and riparian resources equal in overall effectiveness to the current Washington Forest Practices.
- Road crossings will require major repair, replacement, or renewal at least once during the 50-year Permit term. This assumption is based upon the fact that the Permit term is longer than the average lifespan of road crossing structures.
- Chemicals will be used in some cases to control competing vegetation resulting from hardwood conversion and other timber harvest within the riparian zone before and after subsequent planting of conifers. This assumption is based on the fact that chemical use to control competing vegetation is a common practice especially where aggressive understory vegetation exists. Chemical use is not a covered activity, and use of some of these chemicals could injure or kill fish. Therefore, we only analyze the use of glyphosate (e.g., in the form of Rodeo®), with the least-toxic surfactants available (e.g., Agridex®). Glyphosate applied as anticipated is not likely to kill or injure fish. See Effects of the Action – Instream Responses – Water Quality – Chemicals for more discussion on glyphosate. **Note**: the use of Trademark (™) names, registered names (®), or brand- or vendor-specific terms is not intended to imply endorsement. Our choice of terms merely refers to commonly identified materials, but should also be interpreted to apply to similar materials used for the same purposes.
- We assume that: 1) forest managers will assess potential conversion sites carefully as successful planting with conifers would be extremely costly in areas that are likely to release significant amounts of shrubs; 2) foresters will promptly plant high-quality stock in converted areas; 3) riparian zones are narrow and therefore are not as difficult to address through manual non-chemical control; and 4) when chemical use is necessary, single or repeated use of glyphosate should be sufficient to address competing vegetation in conjunction with additional non-chemical control.
- Glyphosate will not be applied to typed waters as part of a forest practices application. This assumption is based upon the fact that application of glyphosate directly to the aquatic environment is not addressed by the Washington Forest Practice Rules, even though Rodeo® and Agridex® are licensed for aquatic use. It is noted that hardwood conversions will be limited to areas farther than 30 feet (eastside) and 50 feet (westside) from such waters. Additionally, it is assumed that managers will maximize efficacy and minimize economic costs and therefore avoid costly spraying in areas and situations where the chemicals will be wasted. The FWS has no evidence of over-spraying with hand application.
- Failure to identify features requiring buffers or avoidance (e.g., seeps, streams, and wetlands) will be rare. This assumption is based upon the fact that harvest units are generally visited numerous times in the assessment/cruising stage, harvest-unit layout, as well as during harvest unit review by landowners and managers, WDNR forest practices foresters, and others (e.g., interdisciplinary teams).
- The FWS assumes that Class IV Special forest practices applications, including SEPA review, will result in activities that are consistent with the biological goals and objectives of the FPHCP. This assumption is based upon the fact that, following SEPA review, WDNR may approve, deny, or approve an FPA with conditions. Those conditions can include minimization and mitigation measures. These measures are expected to achieve the

biological goals and objectives of the FPHCP. In addition to SEPA policies that must be implemented, specific guidance is contained within the Washington Forest Practices Rules, such as WAC 222-10-030 (SEPA policies for potentially unstable slopes and landforms), which would further ensure these expectations.

- Failure to identify unstable features will be infrequent for smaller features and rare for larger features, and will generally be limited to situations where the risk of failure and consequences if failure occurs would both be low. This assumption is based upon the fact that the Washington Forest Practices Rules provide clear guidance on which features may be unstable, training is provided to foresters, and the State has additional procedures in place to screen applications and review them for potential instability. It is also expected that gradual improvement in identifying the recharge zones of deep-seated landslides within glacial deposits will continue.

- Failure to correctly identify fish-bearing waters will occur and is assumed to lessen over time. It is assumed that any methods used to map or delineate such waters will have an approximately equal probability of identifying waters as fish-bearing where fish do not actually occur or the reverse, identifying waters as non-fish-bearing where fish actually do occur. It is further assumed that such errors will be relatively small and largely offset at the landscape scale. This assumption is based upon the fact that this concept of equal error probabilities was inherent to the FPHCP.

- When Riparian Management Option 1 (thinning) is used for riparian harvest in western Washington, the stand-level requirement to retain 57 trees per acre within the inner zone will exceed the requirements for Desired Future Condition under the current basal area targets. This assumption is based upon preliminary calculations performed by the FWS, as well as information provided by Steve McConnell (Personal Communication, January 9, 2006) from sampling western Washington stands, that the 57 trees per acre was sufficient to meet or exceed the requirements of the Desired Future Condition in 144 of 150 stands that were sampled.

- Forest practices are conducted to the maximum extent allowed by the FPHCP and the Washington Forest Practices Rules. Although information is available that indicates some forest practices are typically conducted in a manner more conservative than would be allowed under the FPHCP, the assumption of "maximum extent" is based on the possibility that conditions may change as a result or market conditions, education, improved technology, lower operating costs, or changes in other constraining factors.

- The FWS recognizes the substantial effort that the State of Washington and other stakeholders are conducting with respect to Adaptive Management. Both Federal Services are participating and supporting that effort and believe it is an important component of the FPHCP. However, the FWS cannot predict which aspects of the FPHCP may be modified through adaptive management in the future, nor can we anticipate the manner in which, or degree to which, these changes may occur. For those reasons, this Opinion analyzes only the existing prescriptions and requirements of the current Washington Forest Practices Rules and does not rely on Adaptive Management in reach the conclusions contained herein.

- Summaries or descriptions of the applicable rules within this Opinion do not supplant or supercede the operating conservation program as described in the FPHCP, nor the contents of the applicable Washington Forest Practices Rules. In matters where such documents are in disagreement, the reader should consult the FPHCP and/or the Washington Forest Practices Rules.

7.4 DESCRIPTION OF ACTIVITIES THAT ARE EFFECTS OF THE PERMIT

Throughout this description, we use the term Riparian Zone of Influence (Riparian Zone) to describe the zone surrounding streams that is under riparian influence. Here the stream influences the surrounding vegetation and, in turn, the surrounding vegetation influences characteristics of the stream. This is not the same area as the buffers required by the Washington State Forest Practices Rules.

For this analysis, we generally consider the width of the Riparian Zone on most perennial streams as a site potential tree height (not a 100-year index tree height). Site potential tree heights commonly range from 200 to 300 feet on the westside of the Cascades, and are often less than 160 feet on the eastside of the Cascades. As described earlier in the Framework for Analysis, we expect that its action of issuing a Permit may influence and facilitate actions within this Riparian Zone, as well as along roads outside the Riparian Zone. Therefore, this Riparian Zone has relevance throughout the discussion of the effects of the action. It is important to remember that the term "Riparian Zone" does not refer to any specific regulatory guideline or buffer prescription. We describe the Riparian Zone here merely to help clarify the area in which permit issuance could have certain results. Please note that although some actions within this Riparian Zone may have adverse effects that rise to the level of take, we do not consider this distance from streams to represent the best distance to use in estimating take of covered species. See Extent and Amount of Take for additional information regarding estimates of anticipated take.

This section of the Opinion describes the activities resulting from the issuance of the Permit in detail, including interrelated and interdependent actions. Regulations implementing section 7 of the ESA require the FWS to consider the effects of activities that are interrelated with and interdependent on the proposed Federal Action (50 CFR 402.02). The ESA regulations define *interrelated activities* as those activities which are part of a larger action and depend upon the larger action for their justification. The ESA regulations define *interdependent activities* as those activities which have no independent utility apart from the action that is under consideration. Both interdependent and interrelated activities are assessed by applying the "but-for test," which asks whether any action and its associated impact would occur "but for" the proposed action.

The activities directly affected by the permit issuance are the "primary activities" considered in this analysis in this Opinion. The following discussion of activities would differentiate between the primary activities and the interrelated and interdependent activities, as appropriate. Interdependent and interrelated actions may also occur on adjacent lands, and may include the actions of hauling materials across roads outside, but adjacent to the FPHCP covered lands.

The Washington Forest Practices Rules are complex and have already been summarized earlier in the Description of the Rules and are not repeated below, except as necessary for clarity.

7.4.1 Permit Condition Limiting the Effects of the 20-acre Exemption Rule

During our section 7(a)(2) consultation process, we determined the need for a permit condition for the 20-acre Exemption Rule. We did not have enough information to complete our analysis on the 20-acre Exemption Rule, as it might be applied to future land divisions, for the proposed 50-year Permit term. Additionally, we determined the need for protection of covered species on Type Np streams in association with 20-acre exempt parcels. Therefore, if a Permit is issued, we would condition the Permit to limit the 20-acre Exemption Rule and provide conservation measures on Type Np streams, as follows:

- The Permit shall only apply to the following:

A. Forestlands owned by a person who affirms in writing on a forest practices application of qualifying as an eligible person under the "20-acre exemption" as of and since the date of Permit issuance.

B. Forestlands that are purchased, inherited, or otherwise lawfully obtained by a person who affirms in writing on a forest practices application of qualifying at the time that person takes possession of the forestlands under the following provisions:

   i. the forestlands have continually been qualified for the "20-acre exemption" since the date of Permit issuance; or,

   ii. the forestlands have not been subject to commercial harvest under the jurisdiction of the Washington Forest Practices Act since the date of Permit issuance and are being converted to forestland from another land use.

C. Forestlands subject to a Class IV General Forest Practices Application only when the otherwise-qualifying applicant indicates on the application that he or she is not converting those forestlands to another use within three years.

D. Forestlands in any Wastershed Administrative Unit (WAU) for which the permittee has previously established, with the review and approval by the Service, an estimate of the length of streams on FPHCP Covered Lands. The permittee shall establish, with review and approval of the Service, a method to reasonably estimate post-harvest the length of classified streams on a 20-acre exempt site and the proportion of riparian function as measured by recruitable LWD from the site when compared to that which would have been provided under the standard riparian strategies. The permittee shall monitor 20-acre exempt timber harvest activities and maintain a reasonable estimate of the cumulative change in riparian function provided by FPHCP Covered Lands as measured by recruitable LWD in each WAU that results from 20-acre exempt forest practices covered by this Permit.

   i. The Permit shall not apply to forestlands subject to subsequent 20-acre exempt forest practices applications when the permittee anticipates that forest practices on those forestlands will result in a cumulative reduction in riparian function as measured by recruitable LWD greater than 10 percent of what would have been provided under the standard riparian strategies.

   ii. The Permit shall not apply to forestlands subject to subsequent 20-acre exempt forest practices applications in a WRIA once the WAUs within the WRIA exceeding the "10 percent limit" (above) represent more than 15 percent of the total stream length on FPHCP Covered Lands in the WRIA.

   iii. The Permit shall not apply to 20-acre exempt forestlands in any WAU where there is found the spawning and rearing habitat of bull trout populations identified in Table 3-51 of the Opinion until the permittee has established, with review and approval of the Service, that forest practices under the 20-acre exempt provisions will not measurably diminish the level of riparian function provided by FPHCP Covered Lands in the WAU as measured by recruitable LWD when compared to that which would have been provided under the standard riparian strategies.

- The permittee shall require trees to be left along Type Np waters under the 20-acre exemption unless it is determined that such leave trees are not necessary to protect covered species and their habitats. Unless determined by WDNR to be unnecessary, leave at least 29 conifer or deciduous trees, 6 inches in diameter or larger, on each side of every 1,000 feet of stream length within 29 feet of the stream. These leave trees may be arranged to accommodate the forest practices operation.

7.4.2 Timber Harvest

7.4.2.1 Riparian Timber Harvest

The Washington Forest Practices Rules address areas close to the stream within the Riparian Zone with required riparian management zones (also called buffers). The Rules generally treat areas not included within these buffers as uplands, by default. The Washington Forest Practices Rules regarding riparian harvest, including buffer retention and management, were substantially changed from the November 1998 Forest Practices Rules. Timber harvest in the Riparian Zone under the current Washington Forest Practices Rules has some potential to result in effects that may rise to the level of "take" of listed fish and/or other covered species. Therefore, we presume that such timber harvest would result from permit issuance and that the effects of such harvest are also the effects of permit issuance.

Limited riparian timber harvest (e.g., consistent with Desired Future Conditions and minimum tree-density and basal-area requirements) may occur within the Riparian Zone and inside the buffered areas of fish-bearing streams. In addition, some harvest of trees may occur within the Riparian Zone that may be outside of the buffer. Timber harvest could also occur within the Riparian Zone of perennial streams without fish and along seasonal streams. The above-described harvest activities must be consistent with the FPHCP. The activity of riparian timber harvest and its effects are described separately, below for fish-bearing streams and for streams without fish.

Fish-bearing Streams

Fish-bearing streams include all streams with fish, including seasonal streams. Buffers would be applied along streams with fish (Type S or F streams) as directed by the FPHCP. Within the buffers, tree removal would occur consistent with the guidelines in the FPHCP and as dictated by current stand conditions and the Desired Future Condition. No timber harvest would occur within the 30- to 50-foot Core Zone (nearest the stream) although as discussed below, some trees may be felled and left in yarding corridors, and for road construction. Harvest within the Inner Zone (between the Core Zone and the Outer Zone) must be consistent with the stand requirements to achieve the Desired Future Condition (DFC) as well as leave-tree requirements.

The combination of stand-level DFC and leave-tree requirements establishes minimum requirements for post-harvest Inner Zone conditions that keep the stand on trajectory for meeting the DFC. This also serves to minimize the amount of timber removed and reduces effects of the current harvest.

For example, in a 2003 Washington Forest Protection Association member survey (Pete Heide, WFPA, Olympia, Washington, *in litt.*, November 30, 2004), WFPA assessed 834 FPAs submitted by its members between April 2000 and August 2003. For 376 FPAs (or 45 percent) which included 222 miles of stream buffers, they assessed types of harvest along fish-bearing streams on a stream-mileage basis. Most of the Inner Zones (58 percent) were not entered. When entry did occur within the Inner Zone (only 93 miles of the 222 miles), thinning from below (i.e., Option 1) occurred on 17 percent of the entries and harvest under option 2 (packing) occurred on 83 percent of the entries. When packing was used, approximately half of the entries retained more than the required “floor” widths of 80 or 100 feet, depending on stream width.

McConnell et al. (2005) assessed a number of FPAs as part of an evaluation of the DFC strategy. During that study, McConnell and others analyzed FPAs on which landowners did some Inner Zone management and were working on sites where either thinning or packing were permitted (site class 1 and 2, and site class 3 along small streams). When given such a choice, landowners used packing 102 out of 108 times (94.4 percent) (Steve McConnell, NWIFC, Lacey, Washington, *in litt.*, December 20, 2005). In all of the FPAs McConnell et al. (2005) evaluated, thinning was used 48 out of 150 times (32 percent), but 42 of those instances occurred when thinning was the only choice available (i.e., site class 4, 5 and 3 along large streams). McConnell et al. (2005) noted that packing was used 68 percent of the time when Inner Zone harvest occurred; this is similar to the 83 percent reported by Heide. McConnell et al. (2005) did not tabulate information on how often landowners chose to do no Inner Zone management as compared to conducting Inner Zone harvest. The FPAs he selected for this study had at least one stream reach in which Inner Zone management was implemented. Yet, McConnell et al. (2005) noted that FPAs with at least a single reach in which the Inner Zone was entered, often had several reaches in which no Inner Zone harvest occurred (Steve McConnell, NWIFC, Personal Communications, December 20, 2005).

The WDNR Compliance Monitoring Preliminary Assessment for Riparian Zone Management (WDNR 2005) yielded additional information regarding variability of harvest options selected. WDNR reported that of 43 FPAs including western Washington Type F RMZs, 5 percent conducted no harvest and 65 percent conducted only Outer Zone harvest, for a total of 70 percent conducting no Inner Zone harvest. This is similar to the 58 percent reported by Heide (2004). Inner zone harvests were evenly split between thinning (16 percent) and packing (14 percent), which implies greater use of thinning than reported by Heide (2004) or McConnell et al. (2005). In eastern Washington, 35 FPAs were examined and 51 percent conducted no RMZ harvest (Inner or Outer Zone) and 11 percent conducted only Outer Zone harvest, for a total of 62 percent conducting no Inner Zone harvest.

It should be emphasized that the WDNR compliance monitoring data was collected during a preliminary assessment phase of the program. The main focus of this effort was to determine the best way to collect and analyze data for the program. In 2006, the WDNR would be starting another round of collecting field data for Type F RMZ compliance monitoring and this information would be added to the data collected during the preliminary assessment phase.

We do not expect timber harvest within the Core Zone. Only under certain circumstances (e.g., yarding corridors where trees may interfere with lowering and raising of cables or may fall upon cables) would trees be felled and then they must be retained on site. Timber harvest within the Inner Zone (managed for Desired Future Condition) would result in only minor to moderate levels of tree removal. Additionally, Inner Zone harvest may occur where trees closest to the water are generally retained. In all cases, tree removal may result in temporary openings in the canopy.

For instance, in a Douglas-fir dominated stand that is about 45 years-old, that has been pre-commercially thinned, most trees would likely be between 16 and 20 inches in diameter at breast height (dbh). There might be around 120 to 200 trees per acre. These trees would currently provide about 240 to 270 square feet of basal area. The rules for Inner Zone harvest would require retention of the 57 largest trees, which would result in retention of about 124 square feet or more of basal area, roughly half the existing basal area. Those 57 trees, even with 10 percent mortality, would be expected to exceed the DFC target by year 140 (as defined under the Inner Zone harvest rules) in the vast majority of cases. Even though DFC requirements may specify a basal area target that must be retained, the 57 trees per acre requirement would usually result in a greater number of trees being retained than the requirements to meet DFC. Based upon experiences from sampling western Washington stands, the 57 trees per acre would be sufficient to meet or exceed requirements of DFC in 95 to 98 percent of stands (Steve McConnell, Personal Communication, January 9, 2006).

Generally, within the Outer Zone, the required number of conifer trees (WAC 222-30-021(1)(c) and WAC 222-30-022(1)(c)) must be retained per acre in a dispersed or clumped manner. The required number of trees may be reduced for situations where large-wood placement is planned or where special features require buffering. Within those portions of the Riparian Zone that are outside the Outer Zone, timber harvest may occur according to Washington Forest Practices Rules pertaining to upland areas.

Harvest within the Riparian Zone may affect the wind-firmness of remaining trees. In some cases, this might lead to windthrow of trees within the riparian buffer; in other cases, it may alter wind paths such that wind pressure is alleviated resulting in more wind-firm trees within the buffer. Some landowners, depending on their goals, may choose to retain windbuffers and in some cases may count windbuffers as part of their upland leave-tree requirement. Wind-firmness varies greatly by species of trees, characteristics of the soil, and positioning on the landscape relative to prevailing storm patterns. In most cases, it is expected that the integrity of the buffer would be maintained, even if some windthrow occurs. Minor amounts of salvage may occur and would be conducted consistent with the requirements for downed wood retention within the buffers and according to the descriptions for bucking, limbing, and yarding activities. However, the requirement for downed wood would most often preclude any salvage within the Inner Zone.

Harvest within the Riparian Zone of Type S or F streams would likely lead to the removal of some snags or cavity trees (when defined as hazard trees by State Labor and Industry guidelines) from within the buffer when operations within the immediate vicinity are planned (WDLI 1992) (**see Interrelated and Interdependent Activities–Hazard Tree Removal)**. Removal of suppressed or stressed trees may be a component of riparian harvests depending on the management option chosen. Landowners often choose wildlife reserve trees and/or green recruitment trees from trees located within the riparian buffers, either due to logistical considerations and a desire to not leave trees in upland areas, or because there are better wildlife reserve trees within riparian areas as a result of a) past logging practices, or b) differences in growing site. In cases where the upland leave-tree requirements would be met for that harvest unit by the trees retained in the riparian buffers, harvest outside the Outer Zone may not retain many, if any, standing trees so long as the spacing requirements for leave trees can be met.

Felling of trees by cutting with a chainsaw or with mechanized cutters may impact surrounding trees and understory vegetation. Rarely would trees be felled into Type S or F Core Zones. Yet, the Washington Forest Practices Rules do allow for this if trees cannot be practically and safely felled outside these areas. Limbing and bucking (cutting tree into merchantable log lengths) by chainsaw would likely have no effect to the habitat. However, limbing and bucking of the timber with heavy equipment and movement of heavy equipment may affect the surrounding buffer. Forest managers are expected to exercise great care to avoid damage to potential future crop trees within the mid-story and overstory. For instance, landowners and operators may armor trees next to yarding corridors to avoid bark rubbing when operating in conifer stands during the spring sap-flow period.

Movement of heavy equipment within the Riparian Zone would be limited and would generally not occur within the Core Zone without prior approval from the WDNR. Heavy equipment is rarely used in the

Core Zone and infrequently in the Inner Zone of Type F waters because many of these areas are inaccessible due to topography. Best Management Practices (such as reduction of pressure from tires and tracks) would be used to minimize rutting and other soil disturbance. Such equipment would generally operate on top of logging slash and downed vegetation. Established skid trails would be used to avoid multiple-passes where soil compaction is an issue. Only a minor amount of felling and bucking is expected to occur within the inner and outer riparian buffers of fish-bearing streams, and as such, the need for equipment to access these areas would be very limited. Felled trees within the Core Zone would be left on-site and a limited number of trees are expected to be removed from the Inner Zone. Generally, directional felling would be used to fall trees away from streams, which would further distance bucking and other timber-harvest activities from streams.

The Washington Forest Practices Rules in the FPHCP regarding slope stability have not changed in their goals, or their trajectory of continuous improvement and refinement, since the November 1998 Forest Practices Rules. The intent of the current slope stability rules remains that of prevention or avoidance of management-induced delivery of slope failures to typed waters. While these slope stability rules themselves are not viewed as an activity that would be changed by permit issuance, other rules that would be effects of permit issuance (e.g., RMZs) may affect activities which can influence the delivery of slope failures to typed waters. Timber harvest within the Riparian Zone along fish-bearing streams may occur on unstable slopes when existing processes fail to identify unstable slopes and unstable features, or because incorrect prescriptions are applied to identified areas. Timber harvest within the Inner Zone would seldom accelerate any instability because very few trees would generally be removed, root strength would generally be retained, and unstable features should be identified and addressed. Timber harvest in the Outer Zone or outside the riparian buffer may, on occasion, result in accelerated slope failure to the local area and result in delivery to typed waters. Failure to identify such areas is expected to be rare and would most likely occur only in marginal cases. These marginal cases would include situations where the unstable feature is too small to be easily identified, and where the feature would represent a low risk of failure.

The minimum Type F requirements under the FPHCP apply to all Type S waters regardless of less-restrictive Shoreline Management Act regulations developed by individual counties. If county regulations are more restrictive than the FPHCP, the county regulations would apply. In counties with no regulations, the default 200-foot buffers would apply. Some counties may have adopted regulations which are less restrictive than the FPHCP, in those cases, timber harvest conducted under the FPHCP must apply the more-restrictive prescriptions. Activities conducted under the less-restrictive county regulations (e.g., development) are not addressed by the proposed permit issuance.

On some 20-acre parcels (those where a landowner’s total ownership is less than 80 forested acres), harvest may occur under the Washington Forest Practices Rules specific to 20-acre parcels (WAC 222-30-023) known generally as the 20-acre exemption. Buffers would be retained according to November 1998 Forest Practices Rules plus 15 percent of the volume. In addition, shade requirements must still be met on Type S and F streams. The FPHCP reported that in a statewide sample of 37 RMZs established on 20-acre exempt parcels during 2002/20033, 32 (or 86 percent) were treated as no-harvest areas and only two had 15 percent or more of the trees removed from the RMZ. Further analysis of an additional 39 RMZs established on 20-acre exempt parcels during 2004/2005 showed the same trend. The FPHCP attributes the low frequency of RMZ harvest to shade-retention requirements and shade-analysis requirements. Buffers on Type S and F streams are measured from the bankfull width for 20-acre exempt parcels (as opposed to the outside of the CMZ for standard Washington Forest Practices Rules).

Generally, the requirements of the 20-acre exemption (in the absence of the shade rule) could be met with retention of about 20 trees per acre dispersed within the first 50 feet of the stream, or clumped retention on less than 1 percent of the buffer width area. We assume there would be limited salvage of windthrown trees from buffers under the 20-acre exemption because salvage is only allowed where the Inner Zone stand requirements, Outer Zone stand requirements, and downed wood requirements can be met. Timber harvest conducted to the specifications of the 20-acre exemption would not typically retain a sufficient number of trees to allow salvage consistent with the rules. Salvage may not occur within typed waters, CMZs, or Core Zones, even if trees fell from outside these zones. Under the 20-acre exemption, yarding in riparian areas would occur closer to streams than under standard Washington Forest Practices Rules.

Under the 20-acre exemptions on fish-bearing streams, shade requirements must be met; but 20-acre exemptions would not account for CMZs as the 75-foot distance for shade is measured from the Ordinary High Water Mark only. Due to the combination of reduced buffer width, density, and point of measurement, it is expected that the Riparian Zone would receive less large woody debris recruitment than would occur under the standard Washington Forest Practices Rules. Operation under the 20-acre exemption should generally maintain root strength, bank integrity, and detrital inputs to fish-bearing streams at or near the same level as the standard Washington Forest Practices Rules. RMZs would be narrower and would not provide the same amount of habitat to forest wildlife species. In addition, reductions in windfirmness, microclimate buffering, and recruitment of downed logs to the Riparian Zone are expected. The level of effects assessed in this Opinion assumes there would be limited salvage of windthrown trees from buffers under the 20-acre exemption. There would likely be slightly greater effects from windthrow and greater effects from yarding in riparian areas under the 20-acre exemption as logs would be closer to the stream than under the standard Washington Forest Practices Rules.

It is difficult to quantify the proportion of small landowners who are eligible for the 20-acre exemption within a watershed. In 2004, a report was prepared to provide riparian ownership statistics for forestland parcels that would be eligible for the 20-acre exemption (Rogers 2003). The most critical step in the analysis involved identifying those 20-acre parcels using county GIS data and tax-assessor records that would allow an adequate analysis. Although the report provided a detailed and thorough look at the geographies of potentially exempt 20-acre parcels in Washington, the report acknowledges that the percentages of small forest landowners that would be eligible is likely underestimated due to lack of adequate data for a statewide analysis. The estimate of small forestland ownership based on the available information ranges from 0.5 percent to 5.8 percent. Where small forestland ownership is proportionally high or concentrated along a stream there would be an increased risk of adverse effects to riparian and aquatic resources.

Alternate Plans

Alternate plans for timber harvest along fish-bearing streams would be developed to address situations where landowners can meet riparian and aquatic functions at least equal in overall effectiveness as provided by the Forest Practices Act and the Washington Forest Practices Rules. Alternate plans would better meet landowners' operational needs. Over time, the FWS expects the use of alternate plans to increase as landowners become more familiar with developing them. Alternate plans would address site-specific considerations and would therefore be difficult to describe in a programmatic manner. Alternate plans must, by definition, accomplish the same biological goals with respect to riparian and aquatic functions as the standard Washington Forest Practices Rules. Because of this, it is expected that the impacts to the aquatic and riparian environment would be essentially the same as what would occur under the standard Washington Forest Practices Rules. In addition, alternate plans may allow activities within the Core Zone, such as hardwood conversion, as long as the benefits to aquatic and riparian functions outweigh the short-term effects to functions, such as shade.

Harvest under alternate plans may occur under templates for common situations for small forest landowners. One example of an alternate plan is the overstocked-stand template. A Core Zone of 14 to 30 feet (equal to the average crown radius) would be retained and large wood placement would occur (see description of large wood placement and its impacts and benefits). Stand-density minimum requirements would be applied outside the Core Zone according to tree size.

Management of overstocked stands is expected to provide a long-term benefit by reducing competition among trees and improving the health of the remainder of the stand. Trees that would have succumbed to suppression mortality would be harvested; however, it is expected that few of these trees would have fallen into the stream or provided meaningful value to the stream or riparian area. Smaller suppressed trees are less likely to provide key piece size and they are more likely to rot in place (rather than falling intact) while being held up by branches of surrounding trees. Larger trees that develop over time through management are expected to provide better value in the future to stream and riparian areas when they eventually fall. Understory vegetation would often respond and re-establish itself in a short period of time.

Equipment Use

Timber harvest activities may include the use of chainsaws, heavy equipment, and in some cases, blasting, which would cause noise and vibration. Equipment would require refueling and maintenance, which would most often be accomplished at designated sites (S**ee Interrelated and Interdependent Actions–Refueling and Maintenance**). As mentioned earlier, heavy equipment is rarely used in the Core Zone and infrequently in the Inner Zone of Type S and F waters because many of these areas are inaccessible due to topography.

Streams without Fish

Harvest may occur along unbuffered reaches of perennial streams without fish (Type Np), along buffered reaches of Type Np streams outside of the 50-foot Core Zone, or along seasonal streams without fish (Type Ns). Generally, in western Washington, there would be no timber harvest within a 50-foot buffer along the first 300 to 500 feet of stream length, upstream of a confluence with a fish-bearing stream. In eastern Washington, limited harvest under the partial-cut option may occur within 500 feet of a confluence with a fish-bearing stream. Due to required buffers on Type S and F streams, it is expected that little to no harvest would occur within 100 feet or more of intersecting Type Np or Ns segments.

For Type Np streams less than 1,000 feet in total length in western Washington, the lower 300- to 500-foot reach may comprise the entire buffered portion of the stream. For longer streams, beyond the 300- to 500-foot lower reaches, a variable percentage of the stream may be buffered. The Washington Forest Practices Rules guide the percentage of stream buffered and the placement of the buffered reaches. In eastern Washington, up to 30 percent of Type Np length may go unbuffered; however, these segments would not occur within 500 feet of a confluence with a fish-bearing stream.

For Type Ns streams, any buffering required would be provided through prescriptions to address slope instability or other resources. In many landscapes where there is steep and unstable topography, it is expected that up to 50 percent of the seasonal streams without fish may receive a convergent headwall or inner gorge classification and receive buffers accordingly. The FWS bases this assessment upon the outcomes typically observed from Watershed Analyses completed within western Washington, such as those completed in the Green River Watershed. On other landscapes, seasonal streams without fish may not be buffered. All seasonal streams with fish are treated as fish-bearing streams. In all cases, a 30-foot ELZ would be maintained.

Felling and bucking in riparian areas along seasonal streams and unbuffered segments of perennial streams without fish may occur in proximity to the stream, but directional felling may increase the distance from the stream where most bucking activities would occur. Felling and bucking adjacent to buffers on perennial streams should occur outside of, and at some distance from the 50-foot buffer due to the use of directional felling. Partial-cut buffers in eastern Washington may be entered for harvest and some felling and bucking may occur within those buffers.

Timber harvest may occur on unstable slopes within the Riparian Zone of streams without fish (e.g., convergent headwalls, inner gorges) when existing processes fail to identify unstable slopes and features or because incorrect prescriptions are applied to identified areas. This may result in accelerated slope failure to the local area and may result in delivery to aquatic resources. Failure to identify such areas is expected to be rare and would most likely occur in marginal cases. These would include cases where the degree of instability is small, features are not readily apparent, and effects of failure would likely be smaller than more obvious cases.

On some 20-acre parcels (those where total ownership is less than 80 acres), harvest may occur under rules specific to 20-acre parcels (WAC 222-30-023) known generally as the 20-acre exemption. Trees would be required to be retained along Type Np streams where such practices are necessary to protect public resources including FPHCP covered species and their habitat. Where such practices are necessary, the FPA shall be conditioned by WDNR to require at least 29 conifer or deciduous trees, 6-inch diameter or larger, be retained within 29 feet of the stream on each side of the stream for every 1,000 feet of stream length. The leave trees may be arranged to accommodate operations. Retaining 29 trees per acre in a 29-foot wide zone along a 1,000-foot stream reach is equivalent to about 44 trees per acre.

Alternate plans for timber harvest along streams without fish would be written with site-specific considerations to address situations where landowners can meet riparian and aquatic functions at least equal in overall effectiveness to the standard Washington Forest Practices Rules, while better meeting their operational needs. However, because of the effort by the landowner to develop a site-specific alternate plan and the less-onerous buffer requirements for Type Np and Ns streams, the FWS does not expect many alternate plans to be submitted for Type Np streams and very few for Type Ns streams.

Timber harvest activities may include the use of chainsaws, heavy equipment, and in some cases, blasting, which would cause noise and vibration. Equipment would require refueling and maintenance, which would most often be accomplished at designated sites (WAC) (**see Interrelated and Interdependent Actions–Refueling and Maintenance)**.

7.4.2.2 Yarding in Riparian Areas

Yarding is the process where logs are transferred to a loading site. This often involves the movement of heavy equipment over the understory vegetation, logging slash, and soil. The Washington Forest Practices Rules for yarding timber have changed regarding yarding corridors across streams, when compared to the November 1998 Forest Practices Rules. In addition, yarding within the Riparian Zone has potential to result in effects that might rise to the level of “take” of covered species. Yarding may occur within and adjacent to buffers on streams with and without fish. Yarding is expected to occur closer to streams without fish than to streams with fish because of the wider buffer requirements on streams with fish.

Logs may be removed from the Riparian Zone by a number of methods. Various types of equipment may be used with the Riparian Zone. The manner in which yarding would be conducted would be heavily influenced by slope and soil characteristics. Impacts from yarding include soil compaction, collapsing interstitial spaces in soil, collapsing burrows, and crushing downed wood which may be habitat to a number of animal species.

Low-impact equipment is required when soils are saturated or otherwise subject to rutting. Low-impact equipment includes equipment with low pressure tires or shallow tread, and those that are not prone to spinning, grinding, or scraping soil. Soil disturbance and compaction are expected to be avoided and/or minimized by the use of Best Management Practices applied to the handling and moving of the logs within the Riparian Zone. Tractor yarding and skid trails may occur within the Riparian Zone, however, they would not be expected in the Core Zone on buffered portions. Additionally, within unbuffered portions of Type Np streams, tractor yarding and skid trails would only occur infrequently due to the ELZ requirement. The FPHCP states that "On-site mitigation is required if any of the following activities exposes the soil on more than 10 percent of the surface area of the (ELZ) zone: ground-based equipment; skid trails; stream crossings (other than existing roads); or cabled logs that are partially suspended." Mitigation, such as waterbars, grass seeding, and mulching would be used to address such damage. Skid trails are expected to be minimized due to BMPs in the Washington Forest Practices Rules, such as repeated use of established skid trails.

No logs are expected to be ground-yarded across Type S or F streams and equipment may only be used within the Core Zone of Type F or S water if WDNR grants approval. Directional felling is anticipated to be used so that felled trees may be reached by ground-based equipment from the same side of the stream from which they were felled.

Few entries are expected into the buffered portions of the Riparian Zone in any given location. However, multiple entries with heavy equipment may occur along unbuffered portions of streams without fish where most would be harvested. Movement of heavy equipment is expected to occur during yarding and would generally move over understory vegetation, logging slash, and soil. Heavy equipment is rarely used in the Core Zone and infrequently in the Inner Zone of Type F waters. Ground-based equipment is seldom used on slopes greater than 35 percent, especially within the Riparian Zone.

In addition to ground-based yarding, there are two other options. Helicopter yarding may be used on occasion but is often expensive and is used only when other yarding methods are not feasible. Helicopter yarding can produce noise and wind that may disturb certain wildlife species. Cable yarding is much more common and can be done in a variety of ways. High-lead yarding raises one end of the log off the ground (i.e., partial suspension) while sky-line yarding raises the entire log off the ground (i.e., full suspension). Logs are generally attached to cables (i.e., chokers) and are attached to a carriage which runs along the mainline. In some operations, the carriage is motorized and provides additional flexibility in extracting timber during thinnings or around interspersed clumps of retained trees. In some cases, logistical difficulties in extracting logs may be overcome by a complex series of pulleys and cables, or by utilizing ground-based equipment in association with cable systems.

Cable yarding is used when topography precludes ground-based equipment. Logs are expected to be directionally felled away from riparian buffers or exposed segments of stream. Only a minimal amount of the distance over which the logs would be yarded would be within the Riparian Zone. Partial suspension is expected on most logs being yarded across upland areas. Full suspension would most often be expected when yarding across typed waters. On Type S or F waters, an exception must be addressed in an HPA. On a Type N waters, an exception could be approved in the FPA, but would seldom be provided on flowing waters as that exception would only be allowed if an HPA were to authorize it.

In some situations, yarding corridors may be placed across streams. When trees are felled to construct yarding corridors they would generally be left in place and are unavailable for harvest. Where sufficient deflection exists, logs would be yarded above the riparian buffer or through the upper portion of the riparian canopy. In almost all cases, full suspension would be used when crossing streams unless an HPA or FPA approves of other options. Yarding through these corridors may result in some scarring of retained trees. Hazard trees may be required to be felled when they could interfere with cable lines (**see Interrelated and Interdependent Activities–Hazard tree Removal)**.

Trees within the Riparian Zone may be used as tailhold trees for yarding logs. This entails stringing a small cable across the harvest unit and riparian buffer, and then using this cable to pull a lead cable across the riparian buffer. Once the lead cable is in place, it is tightened and raised. When the cables are tightened during installation, or slackened and tightened during use, they may rub some trees and remove some branches. This damage may resemble a lightning scar. In extreme cases, a tree or several trees may need to be cut. Such trees would be unavailable for harvest.

Under the 20-acre exemption, yarding would occur closer to perennial streams without fish than yarding along Type S and F stream segments. In general, yarding adjacent to Type Np streams under the 20-acre exemptions would be the same or similar to these activities along unbuffered Type Np stream segments under the standard Washington Forest Practices Rules.

Sorting logs for transport may occur in several locations. Usually, logs are piled according to species, size, grade, and/or other characteristics. Most sorting would occur at or near landings. Loading of logs is expected to occur at roads or landings and not otherwise expected to occur within the Riparian Zone.

7.4.2.3 Special Activities in Riparian Zone

Hardwood Conversion

The Washington Forest Practices Rules addressing hardwood conversions have changed. Effects that may rise to the level of "take" of covered species may occur from these actions, and therefore we consider that this activity may result from issuance of the Permit.

Stand conversion may be employed to restore riparian management zones to more natural or historical conditions. Hardwood (i.e., red alder) or brush stands often resulted from logging over the past century, especially those stands that were naturally regenerated instead of planted. Conversion of riparian hardwood or brush stands to conifer stands is often conducted with the intent of creating a stand of mature conifers that can provide large woody debris that would be more persistent, once delivered to the stream, than large woody debris derived from hardwood species. Generally, stand conversion from hardwood to conifer is only attempted on sites where evidence exists that such sites naturally supported mature conifers prior to previous management. Lands that are best-suited for hardwoods are generally retained as hardwood stands because they are difficult to convert, biologically inappropriate to convert, or may bring higher economic returns as hardwood stands. In western Washington, red alder has proliferated in stands once dominated by conifer, and conversion back to conifer is often considered desirable. In contrast, hardwoods are often a preferred species for retention in eastside riparian forests, recognized for their benefits to wildlife. Therefore, hardwood conversion is less common on the eastside than it is on the westside.

In older hardwood stands, some yarding, as described previously, may occur. In younger stands, hardwoods may be slashed and left. Hardwood conversion would often include running chainsaws and heavy equipment. During hardwood conversion the no-harvest Core Zone would be retained adjacent to the stream. The no-harvest Core Zone would help retain bank stability, shade, and detrital inputs, as well as diversity of tree species for wildlife habitat.

Reduction in canopy cover outside the Core Zone may allow some additional sunlight to reach the stream but is unlikely to affect summer time temperatures in the immediate reach or increase autochthonous primary production within the stream. Stream-side shade would continue to be provided by the Core Zone. Canopy reduction or removal would increase the amount of sun reaching the ground in the Riparian Zone during the growing season and would stimulate understory vegetation. However, shading of the Riparian Zone would return relatively quickly as the canopy of retained trees closes, tall shrubs become established, and young trees grow quickly in height. Reduction of hardwood canopy may result in some loss of detrital production from hardwoods (i.e., alder) outside the Core Zone. Conversion may result in some reduction in detrital input to the riparian zone and eventual reduction of nutrient inputs from hardwood trees into the stream.

Removal of hardwood boles would result in a short-term loss of wood recruitment and eventual reduction in short-lived hardwood on the forest floor and within the stream. This would also reduce the number of cavities within hardwoods and number of hardwood snags, as well as a general reduction in forest structure in some cases. Loss of existing snags would occur due to harvest, logistical needs, and felling and bucking activities. Hazard trees may need to be removed during hardwood conversion (**see Interrelated and Interdependent Activities–Hazard Tree Removal**).

Resulting conditions following hardwood conversion would differ depending on the level of removal. In some cases, hardwoods may be the only overstory trees and hardwood conversion would result in a stem-initiation condition, with conifer seedlings. In other cases, a number of conifers may be retained and represent a variety of species and sizes. Reduction in the hardwood canopy would only result in minor increases in wind-throw vulnerability of the Core Zone as hardwoods decrease in ability to deflect wind in the winter because they lose their leaves during this time of year.

When stream segments adjacent to hardwood conversion activities are depauperate in large wood, trees with root wads attached may be added to the stream if equipment can do so without damaging public resources. In other cases, trees may be cut and felled into the stream. Placement of this wood in the stream may require an HPA. See next section for more detail.

Log Placement

Large wood placement in streams is generally done to benefit fish and their habitat. However, adverse effects that may rise to the level of “take” may result in the short-term (e.g., during log placement and until winter rains commence). Occasionally, riparian restoration in the form of placement of large wood would be proposed as part of an FPA. Placement of large wood requires approval from the WDNR to work in the Core Zone and an HPA from WDFW to work within the wetted portion of the stream. Board Manual section 26 contains guidelines including limiting log placement to fish-bearing streams, minimum log length and width criteria, and other specifications. Root wads must be placed entirely within the bankfull width. HPAs are required for all in-channel placements and may result in additional restrictions and guidelines. For instance, public-safety issues such as downstream bridge or culvert crossings that could be damaged may necessitate anchoring of placed wood. Anchoring is generally accomplished either by placing large boulders on top of the log, burying one end of the log in the bank (sometimes in conjunction with boulder placement), or cabling the log to an anchor (such as a boulder, buried ecology block, screw anchor, or driven anchor bar).

Placement would generally be accomplished in one of two ways: equipment would be used to place the bole with attached root wad into the stream; and/or the bole would be anchored to the bank or bed. Placement of a bole without an attached root-wad would generally require (through HPA restrictions) other methods to secure the piece within the stream as described above. Work using heavy equipment may take one or more days and may result in some soil exposure. It is only expected that such placement activities would occur once per rotation. According to Chapter 26 of the Washington Forest Practices Board Manual, ground disturbance must be less than 5 percent of the stream reach within the harvest unit. Crawler tractors and rubber tired skidders are discouraged.

While placement of wood with attached root-wad would provide better stability of large wood, it would also increase the probability of sediment delivery and may generate a short-term sediment pulse or turbidity. Placement of a bole without an attached root wad would generally require other methods to anchor the piece within the stream. This is generally less desirable from a stream-dynamics standpoint, but may result in less short-term sediment delivery.

Within the stream, substrate may be disrupted by movement and positioning of logs. Following placement, large wood may shift and may migrate downstream, having positive and/or negative effects lower in the stream system. This potential for movement is especially true for large wood placed without an attached root wad, and may be true even if anchored in other ways. Large wood that remains in place is expected to alter the stream dynamics by creating pools, increasing the amount of local sediment deposition resulting in a temporary storage of that sediment, and acting as a host site for aquatic invertebrates. Large-wood placement occurs at limited spatial scales, and therefore would provide limited abundance at the watershed scale.

Longevity of wood-placement projects is relatively short (5 to 25 years) and expensive (Cederholm et al. 1997). It is generally believed that artificially added wood pieces are more likely to move than naturally occurring pieces. The limited lifespan of wood-placement projects is frequently a result of artificially placed wood being "blownout" or washed downstream during high flow events.

7.4.2.4 Related Covered Activities in the Riparian Zone

The Washington Forest Practices Rules regarding regeneration, site-preparation, vegetation control, and clearing of slash from streams have not been changed from the November 1998 Forest Practices Rules. However, these activities would accompany other activities (e.g., riparian Inner Zone harvest) which would be facilitated and influenced by the Permit.

Regeneration

Riparian Zone harvest, including hardwood conversion, would be followed by replanting the stand. Artificial regeneration (planting) would generally be done in the winter and spring months and most stands would be replanted within 12 months or less of harvest. Regeneration would utilize a variety of seedling types (bare root, plug, transplants, and wild seedlings) and a variety of species to meet resource objectives. Even where natural seeding is expected, some naturally seeded areas would be supplemented with planted stock to meet reforestation objectives and requirements. Generally, crews of individual planters would conduct planting in riparian areas, disturbing surface vegetation or duff, and digging and cutting roots with hand tools to create plantable spaces. Use of mechanical augers may occur on rare occasions.

Special precautions may be necessary when conifers, especially western red cedars, are planted so that browsing by ungulates can be reduced. These may include wire or plastic cages, bud caps, and repellants. All species other than Sitka spruce may require protection. Other tree species may be protected as well through a variety of methods collectively known as browse control or animal damage control (**see Interrelated and Interdependent Activities–Browse Control**).

In some situations where there is insufficient natural shade provided by stumps, logs, etc., artificial shade materials, such as cards or mesh shade cloth, would be secured next to seedlings with wire pins to protect planted seedlings from the mid-day sun.

Vegetation Control

A description of the application of herbicides outside the Riparian Zone is not considered part of this action according to our framework for analysis, but is addressed in the Comprehensive Environmental Baseline.

Within the Riparian Zone, timber harvest that significantly removes some of the riparian canopy may occur within riparian buffers subjected to hardwood conversion. Hardwood conversions may occur within the Inner and Outer Zone of buffers on fish-bearing streams, or outside buffers but within the riparian zone.

Vegetation management is used for site preparation and to control competing vegetation in order to increase survival, growth, and health of planted stock. Vegetation control may occur within the Riparian Zone, including hardwood conversions. The goal is to reduce or control, not eliminate, competing vegetation. Various methods can be used. Site-specific conditions and management objectives are considered when choosing a control method. However, aerial application of herbicide is not permitted within riparian areas and application of chemicals is not a covered activity under the FPHCP. Hand slashing or cutting of unwanted vegetation, pulling or grubbing with hand tools, ground application or injection of herbicides, or a combination of these methods may be used to control competing vegetation. Mowing, tilling, disking, and plowing competing vegetation are not expected in the Riparian Zone. All noxious weed material would be disposed in a manner that would prevent its spread.

Young alder competing with conifer seedlings are often hand-slashed, while big-leaf maple coppicing (production of new shoots from stumps or roots) is usually controlled by fine stem spraying or injection with herbicides. Ground application of herbicide is more likely to control salmonberry (*Rubus spectabilis*). Control of broadleaf plants often involves the use of a variety of chemicals. Regardless of application type, multiple applications may be necessary in some situations until seedlings are “free to grow,” usually a period of less than 10 years.

In contrast, control of broadleaf plants within the Riparian Zone would be more limited. The FWS assumes that landowners would try to avoid the use of chemicals by careful harvest planning. For instance, some sites considered for hardwood conversion may be deemed likely to generate problems for regeneration due to existing abundance of salmonberry which would likely thrive following harvest. Landowners would also consider the planting of superior and advanced planting stock in these areas.

Because these riparian areas are narrow and involve relatively smaller areas than upland harvest areas, they would be easier to address through mechanical and manual means. We assume that manual treatments would be sufficient in most cases, but in other cases chemicals may be used to control competing vegetation resulting from hardwood conversion and other timber harvest activities within the Riparian Zone, before and after subsequent planting of conifers. This assumption is based on the fact that chemical use to control competing vegetation is a common practice especially where aggressive understory vegetation exists.

However, chemical use is not a covered activity, and use of some of these chemicals could injure or kill covered species. Therefore, we only analyze the use of glyphosate (e.g., in the form of Rodeo®), with the least-toxic surfactants available (e.g., Agridex®). Glyphosate applied as anticipated is not likely to kill or injure fish.

Application of chemicals when applied as described above is considered an interrelated and interdependent activity. Because application of chemicals is not a covered activity, it would be subject to the section 9 prohibition if it were to result in the take of species protected under the ESA (**see Interrelated and Interdependent Activities–Herbicide Application**).

Slash Clearing

Following timber harvest or hardwood conversion in riparian areas, clearing excessive slash and fine debris from streams occasionally may occur. Slash clearing is most likely upstream (50 to 100 feet) of culverts where potential exists for debris to plug culverts. Slash clearing would generally be done by hand unless equipment is necessary. Avoidance of soil compaction, rutting, and destabilizing banks is a primary consideration in designing slash clearing activities. HPAs would be required to do this work in a Type S or F stream, and may also be required in Type Np or Ns waters. During clearing, workers may walk in the stream and churn substrates or have direct impacts to species. Running power tools over and adjacent to stream is occasionally allowed and would be conditioned on a site-specific basis by WDNR. Use of heavy equipment in the Riparian Zone, as well as power tools, may lead to contamination from exhaust and leakage during operation.

Site Preparation

Harvestable areas within the Riparian Zone may be subject to even-aged harvesting (clear cutting) and subsequently site preparation to prepare the area for the next stand of trees. Uneven-aged harvest techniques may also require some site preparation and slash disposal or management. Various methods of site preparation are used to control competing vegetation, reduce fuels, and ensure seedling establishment and survival.

Cutting and slashing was once a common technique to remove trees from a clear-cut which were too small to be marketable, and were perceived to interfere with regenerating the next stand. Previously, cutting and slashing were followed by broadcast burning to prepare stands for replanting. When cutting and slashing were not followed by burning, the slashed smaller trees contributed to the downed wood on the forest floor.

Current forest managers recognize the value of slash as a ground cover that makes the harvest areas more suitable for reforestation activities. However, excessive amounts of downed wood (slash) are not desirable for reforestation purposes. Such slash may be treated in a variety of methods. Piling is a common practice where excessive slash is placed in a number of piles distributed across the harvest unit.

This is generally done by using ground-based heavy equipment. However, in those cases where heavy equipment is used to conduct site preparation activities, the slopes are generally less than 35 percent. Piles are almost always associated with cable-yarding or helicopter-yarding landings as there is usually some waste that is yarded to the landing, but not loaded for hauling. They may also be associated with shovel logging, especially with stands that have a lot of brush or non-merchantable trees. Piles may either be burned or left intact to provide wildlife habitat in the short-term and eventually decompose.

In addition to piling, other mechanical treatment may include lopping and scattering, chopping (roller chopping), shredding, and mulching slash. Impacts to the environment from mechanical slash treatment would generally be limited to the impacts of the equipment used. All equipment would be used away from surface waters and in locations where any leaks would not contaminate water bodies (**see Interrelated and Interdependent Activities–Maintenance and Fueling of Heavy Equipment**). Operators would use equipment with treads or tires appropriate for soil conditions to minimize rutting and compaction.

Soil scarification is a technique used to aid in artificial planting as well as natural seeding. Scarification involves the removal of organic matter to expose mineral soil for planting. This generally is done with equipment, with a variety of blades or rakes, to remove plants and roots and to rip the topsoil and sod, exposing the mineral soil. Some machines are designed to scarify patches, while others do more extensive soil disturbance. Chaining is another mechanical treatment used to remove or destroy vegetation in areas with dense shrubs or small trees. Various levels of scraping, plowing, and tilling may also occur, but are used less frequently. The FWS expects that only minor site preparation would occur within the Riparian Zone because most areas would retain adequate understory trees on the site and also would not accommodate access for mechanized equipment. Most site preparation would likely occur at least 80 feet from the stream.

Scarifying planting sites may lead to soil compaction and rutting as a result of heavy equipment use. Scarification also disturbs the understory layer, duff, and debris layer. Conifers become established more quickly after site-preparation and eventually shade out much of the understory vegetation.

7.4.3 Road Management

The aspects of road construction and maintenance in the Washington Forest Practices Rules, that are effects of permit issuance, are discussed in this section. For example, some of these rules changed slightly; there were minor changes in guidelines regarding placement of fill and water-crossings. Other aspects of these rules that represent a moderate to high risk of take of covered species, even though the rules did not change, are also considered to be a “result” of permit issuance. Therefore, the following aspects of road Management are expected to result from permit issuance:

1. Increased emphasis on existing water-crossing structures to improve fish, flood, wood, and bedload passage.
2. Utilization of additional BMPs to reduce or eliminate the delivery of road-generated sediment.
3. Improved hydrological connectivity from repair of existing road problems and improvement in design of new roads. Landowners are now required to inventory roads and identify maintenance needs and schedule work to correct them to prevent or curtail impacts to public resources. The requirements regarding the completion of Road Management and Abandonment Plans (RMAP)

by 2006 and subsequent road improvements by 2016 is a substantial change from the November 1998 Forest Practices Rules.

4. Some additional road maintenance activities would occur. Road maintenance was already required under the November 1998 Forest Practices Rules. Road surfaces were maintained in specified conditions to prevent accelerated erosion, interruption of water movement within wetlands, mass wasting, or direct delivery of water or sediment to typed water. Although the November 1998 Forest Practices Rules generally addressed these same factors, the new road-maintenance measures are more-specifically and more-frequently articulated in the Washington Forest Practices Rules and the FPHCP.

5. Construction of some roads slightly closer to streams may occur under FPHCP because there would be take authorization, however, the FPHCP severely limits the ability of road building within 200 feet of streams.

7.4.3.1 Types of Roads

There are various kinds of roads within the forest that are subject to the Washington Forest Practices Rules. Many are closed for long periods of time and opened only for specific forest practice activities. Although most roads have rocked surfaces, some have no surfacing and are composed of native soils. These roads may be difficult for many vehicles to maneuver and may even require re-installation of stream crossing structures prior to use. Some roads are opened seasonally or intermittently and may have gates. Hard, structurally-competent rock is often required west of the Cascade Crest because of the amount of precipitation. Therefore, more roads on the eastside of the State are composed of native soils. Many forest roads require high-clearance vehicles. However, a number of forest roads are open to passenger vehicles. Some of these roads are single lanes with turnouts and surfaced with aggregate material or pavement. All of these roads are subject to the FPHCP. Also, the effects of rock quarries and borrow pits, which functionally may result in similar effects as roads, are discussed in this section.

7.4.3.2 Road Construction Standards

Issuance of the incidental take permit would not affect the number and geographic location of roads; however, the standards to which roads are constructed would be altered. The maintenance and construction standards have improved the way roads are constructed and maintained, but may still result in some level of impact to the physical environment and may result in take of covered species.

Regardless of the permit issuance, the construction and maintenance of road systems would be expected to continue. Road construction is expected to take three forms: new road construction, re-construction of an inactive road, or an active road being altered so substantially that it cannot be categorized as just maintenance. Re-construction is expected as orphaned roads are upgraded or new roads are constructed at previous locations to accommodate future timber harvest.

Road re-opening and reconstruction would occur under normal and emergency situations. During emergency situations, closed roads may be re-opened to allow for emergency vehicles and personnel access. Re-opening closed roads may require removing barriers, knocking down excessively tall water bars, clearing vegetation and downed trees in the right-of-way, snow-plowing, and/or reconditioning other roadway features. Temporary culvert crossings of streams may be installed. Closed roads that have been re-opened may then need to be closed after use. Re-construction is often needed when old roads were primarily composed of uncompacted cut-and-fill slopes (side cast) and used only native soils as surface materials under inappropriate situations (e.g., over culverts with no addition of rock). Reconstruction must meet the road-construction standards in the current Washington Forest Practices Rules.

New road construction would be expected to decrease in amount (number of miles and density per unit area) over the life of the 50-year Permit as the need for new roads decreases. New road construction would also include the construction of temporary roads, spurs, and landings. Permit issuance is not expected to change the number, density, or general placement of these roads, only the standards to which they are built and maintained.

Road construction requires a variety of activities depending on the type of road being constructed. These may include removal of surface vegetation and soil, potential blasting of rock, excavation of slopes, placement of fill material (cut-and-fill), excavation of slopes and removal (and disposal -- endhaul) of excavated material (full-bench), grading and compacting of sub-grade, rock placement, installation of drainage and structural features, placement and finishing of road surface, marking of roads, installation of signs, and installation or construction of other safety features.

Vegetation Removal

Road construction would likely involve the removal of individual trees, or swaths of trees, resulting in the creation of linear forest openings which may vary from 20 to 60 feet in width. Openings may expand as a result of windthrow, depending on site-specific conditions. Hazard trees along constructed roads may also need to be removed to provide a safe work environment and travel corridor. Merchantable trees are often cut, bucked, and stored to the side of the road until loaded onto a log truck. Where the road right-of-way only supports small trees and brush, there may be no need for cutting and the area can be cleared by machine. Trees, brush, and all other vegetative materials are cleared from the area so that roadbed construction can begin. Vegetation removal may occur at anytime of the year and often with the use of power tools, including chainsaws. Where heavy equipment is used, seasonal restrictions may apply to protect soils and prevent erosion. Bulldozers, graders, backhoes, and power tools such as chainsaws and roadside brushers may all be used. Vegetation is seldom cleared beyond the immediate top of a cut slope, or toe of a fill slope. Sometimes vegetation is left in the lower section of the fill area on temporary roads.

Establishing Road Grade

The excavation of material to make a level road surface, hauling of material, and filling across drainages and depressions may be necessary to establish a road grade. Machinery such as a bulldozer would be used to establish the topographic subgrade that would serve as the road foundation. Machinery would be used to scrape off vegetative remnants (e.g., stumps, roots, and brush) and remove top soil to prepare the base surface. In some situations, rock features may need to be removed or reduced. Drilling and subsequent blasting may be used. Diameter and depth of drilled holes would be related to distance between holes and desired diameter of resulting rubble. Following blasting, rock may be removed or left on-site. Slopes would be excavated and excavated material would be removed and disposed off-site (**see Interrelated and Interdependent Activities–Hauling and Spoil Disposal),** side-cast, or end-hauled, or left on-site. Such excavation would require heavy machinery and may be seasonally limited.

Road construction on steep slopes is limited to full-bench construction with end hauling of spoils to limit side-casting. Road integrity is expected to be maintained because all roads on side slopes exceeding 60 percent slope with potential to deliver sediment must utilize full-bench construction. Side-casting of fill is prohibited on all slopes greater than 60 percent unless specifically approved by WDNR. In all cases where used, cut-and-fill roads must be designed and constructed in a manner that would remain stable throughout the life of the road.

Control of road-generated sediment is an integral part of the road construction design standards and includes requirements for cross drain culverts. Roads would be either out-sloped or ditched on the uphill side. Road BMPs focus on a number of items including keeping water in its natural drainage, dissipating the flow on the cross-drain outlet side with rock or allowing the water once diverted onto the forest floor to infiltrate the ground minimizing sediment delivery to streams. Structures for flowing waters (e.g., culverts) are usually installed during road excavation activities. See Feature Installation below.

Fill

Where fill is needed in constructing a road, it is often excavated from on-site sources. In some cases, additional fill or a different type of fill may be needed that is not available on-site. This may result in additional hauling and delivery of fill by dump trucks. Clean, structurally competent rock is a valuable commodity and is often unavailable regionally. This requires trucking from quarries outside the covered lands **(see Interrelated and Interdependent Activities–Hauling)**. In most cases where additional fill is delivered to streams, it would be clean and structurally competent rock material.

Fill and other exposed surfaces must be treated as necessary to avoid erosion or failure. Measures to minimize sediment delivery from recently filled areas during and following construction may include sediment-control fences, slash-filter windrows, or other techniques.

Finish Sub-grade

Once excavation and placement of fill are complete, the base road surface would be coarsely graded and may be further compacted. Drainage features such as Geotextile material, or structural features such as culverts and cross-drainage structures, may also be added at this time. In some cases, this may complete the road construction process, especially in drier areas on acceptable soil types (see Feature Installation below).

Ballast/Base Course

The base course (road base) would be created by dumping and spreading rock. The size of rock would vary. In some cases, smaller crushed rock would be placed upon or within the larger rock to increase stability. Smaller rock may be hauled to the site **(see Interrelated and Interdependent Activities–Hauling)** or may be crushed on site. Surface material from rock pits or quarries would likely be used during this phase of operations.

Surface Course

The road surface would be designed to meet anticipated road use. Native surfacing would generally be used on low traffic roads. On occasion, aggregate rock material would be used to help stabilize moisture-sensitive sub-grades and protect against erosion. Materials for the surface course may be brought in by truck **(see Interrelated and Interdependent Activities–Hauling)** and composed of small diameter rock. Once the road construction is complete, it may be allowed to “set-up” for up to a year. Surface preparation may include paving. Paving involves spreading of gravel and asphalt and may include sealing. Trucks and paving equipment may drip or leak asphalt, but it is expected that this equipment would be used and maintained in locations where such leakage would be containable and not reach the stream system **(see Interrelated and Interdependent Activities–Fueling and Maintenance)**.

Feature Installation

Geotextile fabric may be used to prevent soil or water movement within the road prism. Water stops (i.e., barriers to movement of water within the ballast and fill) may be installed during construction to prevent "pipelining" of water within the road prism. This also allows the road construction to proceed using less rock for ballast and surface material.

Depending on the design of the road, the road would be either in-sloped, out-sloped, or crowned. Each surface profile would be designed to direct water would be done in association with features to control water drainage.

A variety of cross-drainage structures are available for consideration in road construction. Cross-drain structures are designed to intercept flows from road surfaces and divert flows onto the forest floor, away from stream channels. The Washington Forest Practices Rules provide guidelines for the number and placement of cross-drain structures depending on site-specific features. Cross-drainage features are designed to reduce road-surface erosion and minimize the potential for sediment delivery to streams. Frequent cross drains avoid accumulation of large amounts of water running down the road-side ditch with increased energy and allow diversion on to the forest floor away from streams.

Control of road-generated sediment is an integral part of the design standards including requirements for cross drains. Roads would be out-sloped or ditched on the uphill side. A variety of surface drainage may be used that would ensure water is removed from the road prism and delivered to the forest floor to disperse the flow. Rock armoring may be used as needed to protect headwall inlets at stream crossings, at cross-drainage structure headwalls, and on fill slopes above stream crossings. Slash-filter windrows may be used on road sides.

Construction of stream crossings generally requires diversion of stream water during installation of culverts and during in-stream work to prevent excessive sediment delivery and turbidity. Water would either be diverted or pumped around the work site. This may require installation of block dams and may include fish salvage (discussed later). A small portion of the stream would therefore be "de-watered" (short-term loss of stream-flow from a channel segment). Water may be diverted from a work site by constructing a temporary dam across the stream to divert flow through a bypass pipe. Dams are typically constructed by hand using sandbags and/or fabric barriers and dirt. Dams are usually in place for a few days and generally would be required only once per stream crossing for the effective life of the crossing structure. Following completion of the project, water flow would be returned. This work is generally restricted to summer months to comply with in-water-work windows required by HPAs or other seasonal restrictions. Impacts include short-term desiccation of a segment of streambed (generally less than 100 feet total) and short-term disruption to passage of water, stream materials, and fish.

Features (e.g., culvert and bridge features) would be installed. For culverts, the culvert must be properly positioned in the stream, including any armoring at the head or tail end. This would be followed by placement of rock bedding and fill. Clean "drain rock" bedding and backfill (at least halfway up on culvert) are common practices. Countersinking is also a common practice on fish passable culverts and involves burying about 20 percent of the bottom of a culvert and filing it with pea gravel or similar stream substrate.

In the case of bridges, it may be necessary to construct abutments. In some cases, support features may require drilling and/or blasting. This would result in creation of debris, sediment, and slurry. Drilling procedures would be established to manage slurry waste from drilling. Some bridges may be able to span the floodplain and can be permanent or temporary. Temporary bridges that would be removed prior to high water events may be placed at a lower level across the channel. When bridges cannot span the floodplain, abutments and other support may be necessary.

Erosion control

Erosion control may be needed to reduce sedimentation in streams during construction, as well as avoid erosion after construction. Erosion control may include placing sediment fencing, straw or straw bales, debris (e.g., tree tops and limbs), or mulch on recently filled areas and on exposed surfaces. It may also include prompt revegetation. These actions are designed to dissipate the energy of falling rain and surface flow, and retain soil on the slope thus minimizing delivery to streams and decreasing the loss of soil from slopes. Project timing may be modified to ensure minimum surface erosion from exposed slopes and fill deposits. Proper timing would allow sufficient time for germination and growth of ground-covering vegetation so that effective revegetation can be accomplished prior to the rainy season.

Finishing

Finishing the road construction project may involve a number of smaller tasks such as the marking of the road course with reflective posts and installation of signs or other needed safety features. It may also include paving and painting of pavement. Monitoring and follow-up activities may also be required with regard to exposed slopes and fills and the progress of revegetation and efficacy of erosion-control measures.

Summary of Road Construction Activities

The activities and impacts described herein include construction activities and standards. They do not include general placement or location of roads on the landscape (i.e., within a watershed), as that aspect of road management is not influenced by the issuance of the Permit.

7.4.3.3 Road Maintenance

Road maintenance includes the activities that are needed to protect water quality and aquatic resources, meet access needs, provide safe and efficient road operations, and protect the capitol investment of the road itself. Road maintenance consists of a variety of activities that contribute to the preservation of the existing road and public resource protection.

The number and location of roads would not be affected by the issuance of the incidental take permit; however, the standards to which roads are maintained would be altered by permit issuance. The maintenance standards have improved the way roads are maintained, but may still result in some level of impact to the physical environment and may result in take of covered species. In this section, we discuss the activities and tasks used to maintain, repair, remove, and replace portions of roads and their features.

Many forest roads were built at a time when aquatic ecology was not well-understood, and primary objectives in road design and construction were focused on diverting water away from and off roads as efficiently as possible. Water on roads can damage them and lead to failure of roads–an expensive investment. Road grades, ditches, and cross-drains were designed to collect water and divert water away from the road. Often, this meant that water collected from roads, as well as sediment, would be delivered directly to nearby streams. Many early roads were built on old railroad grades which generally followed streams due to the gentle grade. Many early roads on side slopes utilized side casting during road construction. Roads were often built with stream crossings that were not constructed to handle flood events. Because of this legacy, many of the repair and maintenance issues on today's roads can be particularly challenging.

Slopes and Road Bed

Cut slopes along roads may be subject to excessive raveling, rilling, and slumping which may block the ditch. This may require flattening the cut slope, widening the ditch, and re-vegetating exposed soils. Ravel barriers, rip-rap, or retaining structures may be needed on the slope. Fill slopes may settle and movement may occur. Armoring may be attempted to stabilize such slopes. Excavating unstable fill slopes and replacing with stable material may be needed. Sometimes, addition of features to address water movement may be needed. These activities would often require the use of heavy equipment.

Slide Removal

Cut banks along roads may slump and block the ditch. Ditches may be cleared with a variety of equipment types, a grader, loader, backhoe, excavator, or bulldozer. On aggregate-surfaced roads, the waste material is loaded into a dump truck and hauled to a designated stable waste area. Waste sites would not be located on slopes greater than 60 percent. However, material could be placed on stable slopes adjacent to a slide if found to be suitable and thus approved by WDNR.

Emergency Storm Repair and Patrol

Emergency storm repair may involve the placement of fill, wash-out repair, establishing new crossings, etc. The removal of material caused by a large slide generally requires the construction of some type of structure to re-stabilize the roadway. Re-vegetation or other erosion control measures are often taken to reduce future erosion from the site.

Environmental consequences from fires can put additional pressure on structures and other road features needed for a properly functioning road. Vegetation can be burned off stabilized slopes and banks, increasing the probability of erosion and mass-wasting events; very hot burns can cause soils to become hydrophobic. Water yield can be magnified in these instances and can put increased stress on culverts and drainage capacity. Woody debris can become mobilized, causing culverts to become plugged. Wind storms can cause branches and other debris to fall and excessive rains can mobilize branches and other material which may plug cross-drainage features. Timely maintenance required under the FPHCP can prevent major damage.

Road Surface Maintenance

Snow and Ice Removal – Plowing snow is often necessary to gain access for harvest activities or planting. In the spring, the majority of the snow blocking the road is often in drifts. In these cases, drifts may be plowed. Runoff may continue to wet the road surface as snow melt continues from roadside areas. Sometimes when snow is deep, most of the snow is plowed leaving several inches to melt and the road to dry before vehicle use. Snow plowing can result in some sediment mobilization. De-icing agents are not commonly applied on forest roads.

Surface Treatments – Driving on upland roads, especially when dry, disturbs the road surface material and creates loose layers of soil and rock powder (dust). These are loose materials that can then erode and flow into ditches. Dust abatement methods are used to help control dust on heavily used forest roads not having a hardened or paved surface. This is especially needed when the volume and frequency of use keeps the surface stirred and fines become separated and airborne in the form of dust. Water dust abatement is generally accomplished by spreading water on roads with a truck carrying a water tank and a spreader bar attached to the back of the truck. Only approved sources of water can be used for abatement, and sometimes this may require water-source development, which would be subject to applicable laws and regulations. We do not anticipate any increase in dust abatement as a result of the proposed Permit.

Road Surface Grading – Road surface material eventually breaks down or is moved through the action of water and traffic. Grading restores the shape of the road, redistributes aggregate material evenly on the roadbed, and eliminates potholes, tire-wear ruts, and other surface features that tend to concentrate water and accelerate erosion. Grading would reduce rutting and ponding, making the surface of the roadbed more even, and the substrate more drainable. Surface grading is important to prevent the road from channelizing water, which would increase the damage to the road, and is important to maintain a safe driving surface. Grading cuts into the road surface are used to loosen material that would re-mix, compact, and bind with underlying materials. Graders are used to redistribute rock/gravel by pulling it back to the middle of the road, and then spreading it back over the road. Blading can be implemented to ensure road materials do not get too far off the roadbed which otherwise can widen the road surface. A roller may be used to compact the road surface following the final grading passes to prevent further sedimentation.

Road grading is done to maintain the integrity of the road surface and associated drainage features. Grading is avoided during excessively wet or dry conditions. Grading that results in a berm along the edge of the road can redirect flow and cause road surface erosion. Routine grading is expected to occur on bridge approaches to keep road surface materials from accumulating at bridges. Fine sediments mobilized by road grading may be delivered to stream channels. Road sediments may contain traces of oil, gasoline, hydraulic fluid, or other compounds. Grading can re-mobilize this source of water-quality contamination and hasten its delivery to the stream system. However, due to the low-level of traffic associated with forest management on most forest roads, such contamination is expected to be negligible. In addition, no increase in such contaminants is expected to result from proposed permit issuance.

Road Surface Re-shaping – Road surfaces would need to be reshaped from time-to-time. Eventually, road surfacing materials would break down and are inadvertently moved off to the side of the road. When this material can no longer be retrieved, this can result in the need to resurface the road bed. The road bed would then be ripped and new rock would be spread, mixed, and compacted into the existing materials. Surface reshaping is most likely to occur during periods of heavy traffic or truck hauling and is avoided during excessively wet or dry conditions.

Road Surface Patching (rock replacement) – This is commonly needed for road maintenance. Over time and from a multitude of uses, original surface rock becomes washed, bladed, worn off, and pushed into muddy sub-grade soil. Eventually surface rock needs to be replaced. This is accomplished by loading a dump truck at a commercial source or landowner stockpile with surface rock, hauling the rock to a designated site, then dumping the rock onto the road. Moving the truck forward distributes the rock over the road, and a grader is used to further spread the rock. Subsequently, a roller may be used to compact and harden the road surface. When the aggregate is dry, it is particularly important to add water prior to blading to prevent segregation and facilitate compaction. Spot surfacing is a type of surface rocking and is limited to a dump truck spreading the rock at specific spots and is followed by grading.

Ditches

Ditch maintenance is necessary to ensure that road surface runoff is intercepted and diverted onto the forest floor. Occasionally ditches would become plugged or filled with material. Ditch cleaning is necessary when ditches no longer meet the objective of transporting water to the next cross drain or away from a road or stream culvert. Water running down the road can increase road surface generated sedimentation, and may overload the next drainage structure, causing a fill failure. A bulldozer or grader cleans ditches by dropping a corner of the blade into the ditch and pushing the material along the ditch. Occasionally an excavator is used to clean out (pull) ditches that have been filled in by large amounts material and/or vegetation. This re-establishes designed road drainages. When possible, grass, brush, and minor debris is left in place to stabilize the surface, trap sediment, and slow the velocity of water, as long as the ditch adequately handles the expected flow without scour damage. Excess material pulled from ditches is loaded on a dump truck and hauled to pre-approved disposal sites **(see Interrelated and Interdependent Activities–Spoil Disposal)**. Sometimes suitable fines are used to replace lost ones in the aggregate surface of the road. Sediment traps may need to be cleared on a frequent basis. This work may occur in the spring and summer, but should cease in time to allow re-vegetation of ditches.

Roadside brushing is done to prevent vegetative growth in the roadbed which may damage the roadbed or interfere with functioning of ditches, and to improve sight distance. Most roadside brushing is done by mechanical removal of trees, branches, and brush. Occasionally, hand tools such as chain saws with standard bars or brushing bars are used. Mechanical brushing is generally done with a road brushing machine that may use a bar or rotating brush head. A number of passes may be made on each side of the road and generally the uphill side takes more passes. Sometimes a pole saw may be needed to reach limbs on the lower side of the road. Chainsaws are used to cut and remove fallen logs from the roadway and roadsides. Ditch maintenance sometimes may include use of herbicides to control ditch-line vegetation; however, chemical application is not a covered activity.

Cross drainage Structures

Cross drainage structures are designed to capture and divert flows off of road surfaces and onto the forest floor, away from stream channels. The Washington Forest Practices Rules provide guidelines for the number and placement of cross drain structures depending on site-specific features. Cross drainage features are designed to reduce road surface erosion and minimize the potential for sediment delivery to streams. Accumulation of large amounts of water running down the road-side ditch with increased energy can be avoided by frequent cross drains that allow diversion of intercepted water onto the forest floor and away from streams. Debris may plug cross drains and other features and require removal. Regular maintenance results in reduced risk for road fill failures, wash-outs, and mass wasting. Short-term mobilization and deposition of sediment and turbidity associated with cleaning debris from drainage structures may occur. Cross drainage is important to maintain because insufficient drainage could result in road failures or mass wasting.

Existing roads may have inadequate or poorly located cross-drainage features that deliver road and ditch-line runoff directly to streams. This situation requires existing features be repaired or adjusted and/or the installation of additional cross drains. Cross drain culverts are added to areas where water would otherwise travel through excessively long ditches. Depending on the size of the cross drain culvert, a backhoe with rubber tires or metal tracks may be used for installation. Depending on the topography and site characteristics, catch basins may also need to be installed. Culverts are installed with a certain amount of fill placed over the top of the culvert. Much of this should be addressed early in the RMAP process through relocation or improvement of cross-drainage features. Therefore, the FWS expects a pulse of such work within the next decade. Some of this work has already occurred.

Stream-crossing Culverts

Occasionally culverts would become plugged or filled with material. Culverts may become plugged on their own or through the action of beavers. Culverts plugged by beavers may need to be cleared on a frequent basis. Beaver-exclusion devices may need to be installed and beaver removal may become necessary (**see Interrelated and Interdependent Activity–Beaver Control).** Culverts on streams with heavy sediment loads or moveable woody debris may also be more likely to plug. Plugged culverts may require removal or relocation of large wood.

Stream crossings may become plugged or may fail and result in diversion of streams. Plugged stream crossings may cause streams to flow across roads increasing road-surface erosion and sediment transport and delivery. When diverted across roads, streams are shallow and mostly impassable. The FWS expects that the FPHCP would better protect against such failures than the November 1998 Forest Practices Rules. The FPHCP construction standards are expected to improve passage for fish, allowing access to almost all available habitat, with few exceptions. The standards should also provide better transport of water and large wood than under the November 1998 Forest Practices Rules. The FWS expects a reduced potential for mass-wasting of roads and hill slopes due to culvert blockage or failures under the current Washington Forest Practices Rules and the FPHCP.

Culverts may require repair when struck by large woody debris or equipment. Outlets and headwalls may require additional rock or energy dissipaters. Such repairs may vary in extent from hand-clearing of slash and debris from the culvert, to major repair with heavy equipment. In some cases, access to conduct repairs may need to be constructed or reconstructed to complete work.

Culverts may also be replaced when they can no longer effectively handle expected water and storm events, and can be improved to better facilitate the passage of fish (**see Road Upgrading below**). Sometimes when replacing a temporary culvert in a flowing stream, backfill such as drain rock is used. This allows for culvert installation directly in the water with no additional compaction needed for the backfill.

Removal and/or replacement of stream-crossing structures, such as culverts may require diversion of stream water during instream work to prevent excessive sediment delivery and turbidity. Water would either be diverted or pumped. This may require installation of block dams and may include fish salvage (**see Interrelated and Interdependent Activity–Fish Salvage)**. A small segment of the streambed (generally less than 100 feet total) would therefore be "de-watered" (short-term loss of streamflow from a channel segment). Water may be diverted from a work site by constructing a temporary dam across the stream to divert flow through a bypass pipe. Dams are typically constructed by hand using sandbags and/or fabric barriers and dirt. Dams are usually in place for a few days and generally would be required only once per stream crossing for the effective life of the crossing structure. Following completion of the project, water flow would be returned. This work would generally be restricted to summer months to comply with in-water-work windows required by HPAs or other seasonal considerations. Following culvert installation or replacement, follow-up remedial treatments may be needed within 1 to 2 years. These remedial treatments may be in response to unexpected bedload movement or other unexpected circumstances.

Replacement of improper crossings with improved crossings may reverse some of the negative effects to the aquatic system over time. Culverts that were insufficient for the stream have in some cases impounded water and created a wetland with significant amounts of stored sediment. Once the crossing is retrofitted, the stored sediment may be mobilized and transported downstream. This process may take many years, during which the downstream channel is subject to increased sediment transport and/or delivery. However, the stream should eventually return to a natural sediment-routing regime and existing problems should dissipate. Fish passage at stream crossings, as well as passage of flows and wood, would be improved by better stream-crossing standards and the requirements and schedule requirements of the RMAP program.

Bridges

Woody debris may need to be extracted by chainsaw and/or heavy machinery if it is obstructing flow under a bridge or causing damage to the bridge itself. Riprap maintenance, deck cleaning, guardrail repair, or abutment repair may be needed. This may occur on decks and guardrails, abutments and sills, protecting riprap, bridge approaches, ramps, and wing walls when needed. Many of these activities would require the use of mechanical tools and heavy equipment. Bridges may occasionally require stabilization of banks or construction or maintenance of abutments. If these have an influence on fish-bearing waters, as they usually do, they are regulated by WDFW and would require an HPA. Such work on Type N streams may be permitted through WDNR on individual FPAs.

7.4.3.4 Road Upgrading

Road upgrading often requires components used for both maintenance and reconstruction. Generally, the function of road upgrading is to improve road drainage capacity and to add a margin of safety for increased water flow. Upgrading can reduce the need for recurrent road maintenance. Adding more cross drains, rolling dips, or culverts would reduce existing load on roadside ditches. Replacing existing culverts with larger culverts; and/or changing the inlet structure to better handle flows and debris are common upgrading measures.

Storm-proofing – This involves the implementation of management practices that substantially reduce the potential for erosion, sedimentation, and mass wasting, while still allowing road use. Storm-proofing for road upgrading may require constructing drivable dips or waterbars, installing additional culverts, and/or upgrading existing culverts with larger or newer culverts, or with special inlet sections and/or debris racks. It may also involve reshaping the roadway, disconnecting ditches (diverting flow to the forest floor–not relying on ditch flow) and surfacing the roadway. Slope stability can be restored with re-vegetating efforts such as seeding, fertilizing, mulching, vegetation mats, or sediment filters.

Bridge Replacement – Bridges are replaced when they are damaged or have become too old to function safely. Bridges are also replaced when they cannot provide access and mobility as needed (e.g., updating from single to double lane), and/or when the original design cannot pass anticipated flood events. Bridge replacement can range from replacing the decking to replacing the entire bridge including the abutments. Bridge replacement procedures would vary according to the design, size, type, and configuration of the bridge. Large cranes and other heavy equipment are used to remove and install bridges. Minor impacts to water quality are likely to occur. For instance, small pieces of chemically-treated wood may fall into streams when an old bridge is being removed, or old bridge decking and/or stringers are being replaced.

Installation of Drainage Dips and Waterbars – For most road types, roadbed drainage features, such as dips and waterbars, are preferred to facilitate roadbed drainage. Dips or waterbars are not as "maintenance dependent" as culverts or cross drain culverts and work almost indefinitely, even with minor slumping of cut banks into the roadbed. They have the added benefit of helping to storm-proof the road, or providing an added measure of safety for storm events in the event of overtopping. Installing water bars and dips usually requires the use of mechanical tools and heavy equipment.

Culvert Installation and Upgrade – Culverts are installed where they are needed to reduce soil erosion and run-off. Installation requires implementation of procedures that would minimize sedimentation and turbidity during the installation of in-channel structures, properly accommodate stream discharge, bedload, and debris to reduce road failure risk, provide for stream function (by installing a buffering device that intercepts road surface erosion), and provide fish passage if needed. All culverts must be sized to accommodate 100-year flood events. Culvert installation usually requires the use of mechanical tools and heavy equipment such as backhoes, bulldozers, and dump trucks. After a trench to accommodate a culvert is dug, rock may be placed where the culvert would lie in the trench. Fill is placed on top of the culvert in layers that are compacted. In some cases, access to install and upgrade culverts may be constructed or reconstructed to be able to complete work.

Recent experience in western Washington has shown that about 25 percent of fish-passage barriers at culverts have required full replacement of the culvert (WDFW 2003–Design of Road Culverts for Fish Passage). About 5 percent have required replacement of the culvert with a bridge or abandonment of the roadway. These percentages may vary by topographical areas, between low-gradient and higher gradient streams, and between forested and non-forested land uses.

Surface Shaping and Draining – On high-traffic roads, surface shaping and drainage are needed to keep the road dry. Simply grading the road usually completes shaping the surface and allows for proper drainage.

Surface Material Processing – Processing surface materials at a rock/gravel pit or on-site at a harvest operation can be accomplished many different ways, from crushing operations to blading and re-distributing rock on the road. Binding substance may be added to an aggregate being used to surface the road, and this can be re-mixed while it is being graded on the road surface. Rock pit plans are designed to minimize adverse effects of excavation and processing of rock materials. The pit plans cover erosion-control measures needed during and after pit preparation.

7.4.3.5 Road Re-location

Relocation means that a segment of old road would be discontinued and a new segment of road would be constructed and would be linked at both ends to an existing road system. The new road bed would follow an alternate and separate route from that of the old road. This would most commonly occur where a road currently parallels a stream or crosses a sensitive site or unstable slope. Generally, relocation would move a road from within the Riparian Zone to adjacent upland areas.

A road in a riparian area which would no longer be used may be abandoned according to the applicable Washington Forest Practices Rules. The new segment of road would also be constructed according to the Washington Forest Practices Rules. In some cases, a portion of this road construction may need to occur within or across a riparian area and, as such, an interdisciplinary team would be convened if the road would parallel the stream or did not cross using a direct route.

The road corridor that remains following abandonment may be 20 to 60 feet wide initially, would likely be replanted with suitable tree species, and the forest gap would eventually close. The new road location would be cleared of existing vegetation and that corridor may initially be 20 to 60 feet wide, closing to 20 to 40 feet or less over time. Where the new road would merge with the old road, the two corridors would meet and may result in a temporary opening of up to 120 feet, which again would eventually close to 20 to 40 feet or less.

The construction of the new segments of road may require preparing the bed including cut-and-fill or full-bench construction. This may necessitate the removal of individual trees or swaths of trees. Some of these trees may constitute wildlife habitat. Standing dead trees along such roads may need to be removed to provide a safe work environment and travel corridor. Suitable material would be brought to the site to create the road prism and would be hauled over adjacent covered and non-covered FPHCP forestland roads.

Preparing the road bed (subgrade) and building the road prism are expected to expose bare ground along slopes and in areas of deposited fill. The road prism would be constructed of clean and structurally competent material (often rock). Revegetation activities would likely occur.

In addition, in order to connect the old and new roads, portions of the old road would need to be excavated and cleared from the work area. This would generate some fill that would either be used in new road construction or may require disposal at an appropriate site.

7.4.3.6 Road Re-alignment

Road re-alignment means that only minor changes in road location would result. In some cases, improvements to stream crossings or installation or expansion of other features contributing to sediment abatement or road stability may require that the road be re-aligned. An approach to a bridge may require a different type than that which had been previously used for a culvert crossing. Road re-alignment work may occur through widening of the road prism on one side and removing the road prism on the other, or in some cases, a new road prism would be constructed adjacent to or in immediate proximity to the existing prism.

The effects of these re-alignments are very similar to the construction of a short segment of road. The prism bed would need to be created or modified and the road prism would need to be established. This may necessitate the removal of individual trees or swaths of trees. Some of these trees may constitute wildlife habitat. However, unlike new road construction or relocation, removal of vegetation is usually expected to expand existing forest openings rather than create new and separate openings. In rare situations, a new corridor through the forest might be created with a narrow band of trees separating the old prism from the new prism. In such situations, the potential for windthrow of the narrow band of trees may be substantial, depending on site-specific conditions and the number and juxtaposition of trees to be retained. In some cases, in anticipation of wind-throw, trees may be removed rather than retained. Standing dead trees or hazard trees along such roads may need to be removed to provide a safe work environment and travel corridor (**see Interrelated and Interdependent Activities–Hazard Tree Removal**).

Preparing the road bed and laying the road prism are expected to expose bare ground along slopes and in areas of deposited fill. The road prism would be constructed of clean and structurally competent material. Material would be brought to the site to create the road prism and would be hauled over adjacent covered and non-covered FPHCP forestland roads (**see Interrelated and Interdependent Activities–Hauling**).

7.4.3.7 Road Prism Widening

Road prisms may need to be widened for a variety of reasons, including creating turn-outs, to increase visibility. In some cases, the prism could merely be widened to accomplish needed re-alignment. This could be the case when a cut-and-fill, constructed road required conversion to a full bench construction road. The prism would be widened by cutting further into the slope and then removing the previously deposited fill. Additional excavation may require the removal of trees. This may expand the openings in the forest canopy on a temporary basis from about 20 to 60 feet, up to approximately 80 to 100 feet. Over time it is expected that the forest canopy would partially return to its previous width. Removal of fill, as well as cutting of the slope, would expose slopes and fill surfaces as previously discussed above.

7.4.3.8 Road Abandonment

Abandoning roads would involve different combinations of activities, from closing active roads to full road obliteration. Roads chosen for abandonment are those no longer needed for transportation purposes. Such roads may be in poor locations, causing unacceptable sediment loads, disturbance to wildlife, or may involve unacceptable maintenance costs. Abandonment may require the use of bulldozers or other heavy machinery. The most-noteworthy activity associated with road abandonment is any associated restoration of hydrological functions. Generally, abandonment is done at a terminal point of the road. Necessary work is completed as the equipment is moved toward the beginning point.

Culvert Removal – In many cases, culverts and their associated fills are completely removed to return the stream channel to its original width, gradient, and function (s**ee Interrelated and Interdependent Activities–Hydraulic Modification**). Culvert removal requires the use of mechanical equipment. In some cases, access for heavy equipment may be needed above or below the culvert and road. Small culverts can be removed with rubber-tired backhoes but large culverts may require the use of larger backhoes with metal tracks. Culverts are removed from the site for salvage and re-use, or disposal. Appropriate re-vegetation and temporary erosion control measures are generally needed at culvert removal sites.

Culvert removal includes removal of fill and other supporting structures, and may include stabilization of slopes, steps to address run-off and erosion control, and re-vegetation. Slopes are pulled back to match the natural contour so that the stream channel can return to its original form and function.

Effects of stream-crossing structure removal are generally short-term (i.e., generally about 12 to 18 months). Sediment mobilization and turbidity associated with structure removal and site contouring are short-term (i.e., during construction and again during first rains) and localized. Removal can be followed by ongoing surface erosion of exposed surfaces for one or more years until surfaces are revegetated. Scouring of unconsolidated materials may occur during flood events. Potential loss of downed wood and riparian vegetation may occur at crossing and access sites. Long-term benefits include restoration of natural stream gradient, channel width, and aquatic habitat connectivity as well as restoration of the natural riparian vegetation. Removal of such structures can alleviate the risk of mass-wasting of road fill due to culvert blockages or failures.

Side-Cast Pullback – This operation requires the use of an excavator to pull the side-casted material away from a fill slope and is often restricted to summer months to comply with seasonal restrictions. Heavy equipment is used to excavate road side-cast material and reposition it against cut slope areas, or end-haul it via dump truck to a waste disposal site. Work may be confined to road segments that have a potential of failing and delivering to streams and wetlands. When only those areas with potential for delivery are treated, caution is usually exercised in selection of segments to be left untreated—once work is complete, access is unavailable for future additional pullback work.

Re-contouring –Road abandonment may involve re-contouring the road surface to restore the original slope angle. Side-cast material or replacement material is placed back onto the road surface using a large backhoe. Heavy equipment such as excavators are used to re-contour the abandoned road surfaces. Re-contouring helps disperse runoff and reduce potential for failure, and is generally restricted to summer months to comply with regulations and other seasonal considerations.

Roadbed Ripping – Roadbed ripping can be accomplished with a bulldozer pulling a bar with teeth, or by using an excavator to scarify the roadbed with a toothed bucket. Ripping helps restore water infiltration and facilitates vegetative growth. Prior to actual ripping, cross-drains and other structures are removed, as is the excessive overburden, running surface, and base. Tank traps (barriers) may also be installed at this time.

Water Barring – Water barring is the excavation of troughs or trenches from abandoned road surfaces. Waterbars prevent erosion and decrease sediment distribution by intercepting and forcibly interrupting surface water flow that would otherwise have followed the road bed. It is accomplished by using a bulldozer or excavator to dig a trench across the road surface. They are usually placed at 30- to 40-degree angle to road direction. Water bar spacing are more frequent on steeper roads or where substantial surface water is expected to accumulate. Water barring is usually accompanied with road surface out-sloping, as appropriate, to reduce potential for cut slope erosion. Water-barring is generally restricted to summer months to comply with seasonal restrictions.

Erosion Control – Controlling erosion includes excavating excessive fill, re-contouring surfaces, installing slope-stabilization features, straw or straw bales, debris, or mulch on surfaces. It also includes prompt revegetation. These actions are designed to dissipate energy of falling rain and surface flow, and retain soil on slope thus minimizing delivery to streams. When decommissioning roads, rock or woody debris may be placed in streams to restore the channel, dissipate energy, or prevent erosion. An HPA would likely be required for these activities. Project timing for erosion control may be modified to ensure sufficient time for germination and growth of ground-cover so that effective revegetation can be accomplished prior to the rainy season. This would minimize surface erosion from exposed slopes and fill deposits (see Revegetation section below).

Berm/Barrier Construction **–** A berm is a barricade placed to restrict road access and is generally composed of natural material such as mounded soil, either alone or in combination with ditches, logs, rocks, vegetation, boulders, logs, root wads, gates, guard-rail barriers, or other constructed barriers. Potential sources of soil for construction of a berm include side cast, road surface, or the adjacent ditches. Berm construction is generally done with a small bulldozer, excavator, or backhoe. More elaborate berms may require excavation, digging post-holes, pouring cement, welding, and may also include a minor amount of clearing vegetation to accommodate construction of barrier. Dump trucks may be used to haul material to the site. Rehabilitation of the area with revegetation may be needed.

Revegetation – Re-vegetating areas is important for re-establishing soil and slope stability, and reducing surface erosion of exposed materials. Re-vegetating activities may be accomplished by mechanical or manual means, and by planting or distributing seeds (or seed mixes) or planting seedlings or other vegetative propagules (such as cuttings). Exposed erodible surfaces are often revegetated using hydro-mulching, hay, or bio-matting to protect the soil surface during revegetation and to facilitate sprouting and establishment of vegetation. Mulching and fertilizing are also common practices. Vegetation mats and sediment filters may all be used during re-vegetation. In most cases, non-invasive species are used to re-vegetate and stabilize exposed slopes to the extent possible. Perennial rye grass, creeping fescues, timothy, orchard grass, or bluegrasses are commonly used.

Native seed mixes, or other acceptable mixes, should contain no invasive species and may be spread over the disturbed areas. Also, the area may be replanted with native or nursery stock plants. In some cases, heavy equipment may be used to rip road surfaces to facilitate revegetation.

Management – Monitoring of site for signs of use or misuse, or for effectiveness and progress of restoration may be needed. Trash removal, alteration and enhancement of traffic barriers, noxious weed control, and other appropriate responses may result from this monitoring.

7.4.3.9 Exceptions for Road Maintenance

Small forest (non-industrial) landowners must replace fish passage barriers only as the need arises or as otherwise identified through proposed FPAs. Small forest landowners may submit an RMAP checklist in lieu of a complete RMAP. In Watershed Administrative Units where watershed analysis has been conducted and approved, small forest landowners may elect to follow the watershed's road maintenance plan rather than development an RMAP. WDNR maintains authority to regulate road impacts associated with individual forest practices activities so that public resources are not damaged. Owners of 20-acre exempt parcels are not required to complete RMAPs or RMAP checklists, but must abide by the road construction and maintenance requirements and would be required to address repairs needed to protect public resources.

Based on the RMAP exceptions, barriers would be replaced at a slower pace than industrial landowners and, then, only based upon State priorities and funding availability. Some small landowners are choosing to replace fish passage barriers at their own expense and others are pursuing non-State sources (for example, private and tribal restoration groups) for replacement and cost-share assistance. Non-industrial landowners with a barrier on their land have three options at the time they submit an FPA: 1) fix it during the term of the FPA, 2) develop an RMAP checklist and schedule its repair, or 3) enroll in the Family Forest Fish-Passage Program (FFFPP). However, landowners may also sign-up for the FFFPP on a voluntary basis in the absence of an FPA. Approximately 70 to 80 percent of the current enrollment was derived from voluntary sign-up (Kirk Hanson, Personal Communication, January 13, 2006). The FFFPP was developed to help small landowners with the often high cost of correcting fish-passage barriers. This cost-share program was developed cooperatively between the WDNR and WDFW. The Interagency Committee for Outdoor Recreation is responsible for managing grant funds allocated to projects. The State legislature allocated $2 million for the FFFPP in the 2004-05 biennium and $4 million for the 2006-07 biennium.

Landowners who submitted an FPA for timber harvest on or after May 14, 2003, may be required to provide a limited share (match) of the overall cost of the barrier correction. The most a landowner must pay is 25 percent of project costs, or $5,000, whichever is less. The cost-share program provides 75 to 100 percent of the cost of correcting the barrier and also provides technical assistance. The State would pay 100 percent of project costs under two scenarios:

1. A Forest Practices Application or Hydraulic Project Approval was previously provided for the existing barrier.
2. A Forest Practices Application for timber harvest has not been submitted by the landowner between May, 14, 2003, and the time the project has been selected for funding.

The second item serves as an incentive for landowners to repair passage barriers now rather than waiting until a future date. If a landowner corrects more than one barrier in a calendar year, the maximum required match per year varies according to the average annual timber volume harvested from the landowner's lands in this State during the three preceding calendar years, and whether the barrier is in eastern or western Washington. In addition, a number of conservation groups are involved in identifying, prioritizing, and funding correction of fish-passage barriers and would often sponsor such projects, including providing engineering and logistical experience and providing the matching funding for the landowner. The FFFPP helps link local project sponsors experienced in implementing fish-passage projects with landowners in need of technical assistance and project management.

Because many small landowners are located lower in the stream system, passage often becomes an issue affecting a considerable amount of potential habitat. Such culverts would be prioritized for replacement or upgrading. Fish-passage barriers are ranked within each WRIA. Projects are prioritized based on the number and location of other upstream and downstream barriers, amount and quality of fish habitat addressed, the number of species benefiting, and project cost. In the first year of the FFFPP (2004), over 58 miles of habitat were opened to access as part of 36 projects. In comparison, as of the end of 2004, Statewide RMAPs had removed or replaced 1,217 structures and had opened 647 miles of fish habitat to passage.

FFFPP is utilizing county data and satellite imagery, in association with fish databases to identify existing barriers. They are working with local groups to contact landowners and encourage participation. In addition, FFFPP is advertising in newspapers and setting up public meetings to inform landowners about the program. On-the-ground inventories are ongoing and are being done in cooperation with the Lead Entity organizations (quasi-governmental planning groups under the State's Salmon Recovery Act), but completion of a statewide inventory is not expected for several years. In the meantime, annual ranking and repair of barriers is ongoing.

It is likely that high-priority, fish-passage barriers would receive State cost-share funding and would be replaced on non-industrial lands if the barrier occurs in conjunction with a proposed FPA. There is also a likelihood that other high-priority barriers would be identified through a number of other processes and that such potential projects would be addressed through a number of other funding sources (e.g., Salmon Recovery Funding Board). Lower-priority barriers (e.g., those that access very little upstream habitat) that occur in conjunction with a proposed FPA and those projects not associated with a proposed FPA may be replaced at any time, but non-industrial forest landowners are not required to replace these culverts prior to the same 2016 deadline that applies to industrial landowners. However, the State legislation on the FFFPP program requires legislative reports on the status of fish-passage barriers and replacements on small forest landowner forestlands in 2008 and 2013.

Orphaned roads are roads constructed prior to 1974 that have not been used for forest practices since that time (WAC 222-24-052*(4)). Such roads are typically not maintained, and many were constructed without a requirement to consider public resource and channel impacts. The mileage of orphaned roads in Washington is unknown; however, the associated hazards have been identified. The concern with orphaned roads is the lack of knowledge about their location and potential for failure and initiation of debris avalanches, debris flows, and debris torrents. Although the FPHCP would require landowners to inventory and assess orphaned roads, their repair or abandonment is not required. However, landowners may voluntarily fix problems identified during the inventory and assessment of orphaned roads.

7.4.4 Other Related Activities

7.4.4.1 Spoil Disposal

Activities such as excavation, grading, cleaning culverts, and cleaning ditches can all generate spoils. These spoils would generally be hauled to an approved local disposal site (an area that is stable and distant from typed water and has a minimal potential of delivery to typed water) where disposal material is placed or held until a later date. These sites must be located on stable ground, free of sensitive plants and animals, usually out of view of recreation areas, above the 100-year flood level of typed waters, outside Type A and B wetlands and wetland management zones, and otherwise suitable for the purpose. Disposal sites would be carefully selected and may be prepared prior to use. This preparation may include the removal of trees. Disposal sites would be designed to ensure run-off is dispersed. Disposal material may be buried or piled and may consist of soil, tree stumps, slash, brush, or other items such as old culverts. Piled soil may be stabilized with mulch and vegetation. When disposal sites are located off the project site, spoils would be hauled by dump truck and may be hauled by other machinery when nearby. During and following deposition, the site would be maintained by re-vegetating and/or mulching spoils and checking and addressing channelization and potential delivery to typed water.

7.4.4.2 Timber, Rock, and Spoil Hauling on FPHCP Covered Lands

Harvest units would potentially produce a different amount of harvestable wood as an effect of the Permit (more in some cases and less in others, also depending on the baseline used for comparison). This would change the amount and distribution of wood being hauled across FPHCP covered lands. Also, additional attention to road maintenance, adequate cross drainage, and sediment abatement may increase the use of rock on forest road surfaces, in cross-drainage structures and at their headwalls and outfalls, and in sediment-abatement and slope-stabilization structures. This would increase the amount of rock hauled onto FPHCP covered lands and may also result in larger and/or more rock pits or quarries in use on forestlands covered by the FPHCP. Also, there would be additional spoils from excavated roads as more roads are built to full-bench construction standards or the amount of fill incorporated into road design and construction is reduced. As more fill in road constructions comes from off-site rock sources, this would replace, to some degree, the use of native fill and increase the amount of native fill that becomes spoil instead. The combination of these factors would likely increase the amount of spoils that are hauled across FPHCP covered lands.

Additional traffic on FPHCP covered forestland roads due to increased hauling of rock and spoils may result in some additional margin of wear-and-tear on roads and may create some additional sediment from roads. The large amount of traffic experienced by most roads managed to the standards of the Highway Safety Act (i.e., mainlines and public roads) would likely obscure the marginal effects resulting from the FPHCP covered activities.

7.4.4.3 Hazard Tree Removal

Hazard trees are defined as trees that may pose a danger to workers, the public, or equipment. Washington Department of Labor and Industries regulates when such hazard trees must be removed. Common situations requiring removal of hazard trees include:

1. Sawyers operating within a distance equal to 1.5 times the height of a hazard tree.
2. Trees that may fall on cables, guy wires, or equipment at landings.

3. Trees that may interfere with safe operations at landings or in the slacking and tightening of cables in corridors.

4. Trees which may fall across roads or endanger the public.

Generally, Type 3 or 4 wildlife reserve trees (i.e., moderate to heavy decay) are those with potential to be a hazard tree; Type 1 and 2 reserve trees are most often not considered hazard trees. Hazard trees may often be avoided during operations by retaining a buffer surrounding the hazard tree. Hazard trees may be felled using chainsaws, heavy equipment, or blasting, and such removal may occur at any time of the year. The Washington Forest Practices Rules regarding felling assist landowners to avoid disturbing spotted owls or marbled murrelets.

7.4.4.4 Blasting

The method in which blasting is conducted and the potential for disturbance is dependent on the situation. Generally, the smallest charge that would work effectively is used to reduce cost. Drilling in rock may often need to precede blasting for the desired effect. The Washington Forest Practices Rules regarding blasting and road construction assist landowners to avoid disturbing spotted owls or marbled murrelets.

7.4.4.5 Hill slope and Exposed Slope Erosion Control

Erosion control may be achieved by trenching, terracing, or placement of logs, straw bales, silt fences, erosion-control blankets, or mulch. Erosion control may also involve contour felling (following fires) of trees to slow surface run-off. Other more-extreme measures may be needed, but would be subject to necessary protections for public resources.

7.4.5 Interrelated and Interdependent Activities

Regulations implementing section 7 of the ESA require the FWS to consider the effects of activities that are interrelated with and interdependent on the proposed Federal Action (50 CFR 402.02). The regulations define interrelated activities as those projects which are part of a larger action and depend upon the larger action for their justification, and interdependent activities as those projects which have no independent utility apart from the action that is under consideration. Both interdependent and interrelated activities are assessed by applying the "but-for test," which asks whether any action and its associated impact would occur "but for" the proposed action.

Interrelated and interdependent actions may occur on adjacent lands and may also be actions which are not covered by the FPHCP, but occur on FPHCP covered lands. Interrelated and interdependent activities include timber, rock, and spoil hauling on adjacent non-forested lands; hydraulic modification (in-stream road and stream-crossing work); beaver-exclusion devices or beaver removal; riparian application of glyphosate; milling on site (small kerf band saws or “chain saw mills”); monitoring and research; and fish salvage.

7.4.5.1 Timber, Rock, and Spoil Hauling on FFR-adjacent Lands

A few roads located adjacent to FPHCP covered lands on non-forested ownerships may be affected by the marginal increase in hauling discussed above in the **Timber, Rock, and Spoil Hauling on FPHCP Covered Lands** section. The only roads affected to a measurable degree would be small arterial roads located on non-forested lands designed specifically for local access. On larger roads with more-frequent traffic, any marginal increase in hauling of timber, rock, or spoils would be an insignificant change and would not result in measurable effects. A number of road-access agreements, cooperative agreements, and road-use permits already exist and are part of the environmental baseline. New agreements regarding Federal roads or lands would be future Federal projects subject to Federal discretion at the time such agreements would be requested. These agreements as well as new agreements with non-Federal landowners are not contingent on the proposed issuance of the Permit, as access would be needed for upland harvest as well. As a result, such agreements are not considered further herein.

7.4.5.2 Hydraulic Modification (in-stream "road & stream-crossing" related work)

A number of actions may require an HPA from WDFW but are also related to and part of covered activities resulting from the Permit. As part of such a process for new crossings, it is common to address the question of whether the crossing is needed, or whether there are alternative routing options that would be less damaging to public resources (e.g., a road-use agreement with a neighboring landowner). It is also common that these activities address replacement of poor-quality road crossings with improved crossing structures. Sometimes, structures may be retrofitted. For example, a weir may be used near the outlet to slow velocity and raise water levels. In some cases, fords may be a preferred method of crossing where traffic levels are small, such as a gated road. This may be especially true on streams with intermittent flows. Less frequently, these activities may also involve regrading of a stream segment or the placement of grade-control features, such as large wood. Projects designed to remove fish-passage barriers would avoid and minimize long- and short-term impacts to stream and riparian habitat. Such projects would be implemented with the oversight of WDFW through an HPA. However, landowners would be required to follow the requirements in the Washington Forest Practices Rules and the State guidelines for stream-crossing design and installation.

Instream Bypass Procedures

The instream work area would be isolated from stream flow by temporarily diverting the flow from the work area or bypassing the work area altogether. Flow would be diverted using structures such as cofferdams or aqua barriers. Where fish are present in the isolated work area, they would be removed prior to the start of construction and actions would be taken to minimize effects on fish adjacent to the work area (s**ee Fish Removal Procedures)**.

Diversion may be accomplished by constructing a temporary channel, piping, pumping, or utilizing existing culverts during portions of the construction. When pumping stream water to an area downstream of the fish-exclusion reach, bypass pumping shall occur only in the stream reach isolated by upstream and downstream block nets, but not from within the work area. Sometimes a combination of methods would be used, such as pumping the stream flow downstream during work hours and piping it through the work area during off-hours.

Temporary bypasses are sized large enough to accommodate the predicted peak flow rate during construction. Dissipation of flow at the outfall of the bypass system (e.g., splash protection, sediment traps) diffuses the erosive energy of the flow. Steps would be taken to ensure that the water quality below the bypass outfall would be protected to minimize effects on habitat and associated fish downstream of the bypass. Water removed from the de-watered work area would be pumped to upland areas and treated as necessary to ensure it retains water quality upon re-entering any wetland, stream, or any other water body. To ensure that the work area is not exposed to flowing water (i.e., due to unexpected rain during the work period), bypass requirements may also be applied to seasonally dry streams as well as streams with perennial flow.

7.4.5.3 Herbicide Application

Hardwood conversion would be allowed within the Inner Zone riparian buffers and other timber harvest would be allowed within the Riparian Zone. As a result, conifer planting would occur within these areas and it would be necessary to ensure adequate survival of those young trees. Chemical application is therefore anticipated as an interrelated or interdependent activity even though it is not covered by the FPHCP. However, if these activities were to result in the take of species protected under the ESA, they would be subject to ESA section 9 take prohibitions.

There are limitations on broadcast spraying within the Riparian Zone such as prohibiting drift that may damage plants in the Inner and Core Zone. Broadcast spraying is defined by the State as any chemical application other than by a hand-operated wand for individual plant treatment. Manual or mechanical treatment would be utilized whenever feasible with sufficient efficacy.

Glyphosate (e.g., in the form of Rodeo®) may be used when it has sufficient efficacy for the target plants. In order to help the efficacy of glyphosate, surfactants are used because they increase the absorption of the active ingredient across the plant's surface membrane. Toxicity of surfactants and formulations are expected to be major considerations within the Riparian Zone and all steps to minimize delivery of toxic chemicals are expected to be used even if they result in a slight reduction of efficacy. The economic incentives of managing conifers for rapid growth are more limited than in upland areas. Several surfactants have been approved in Washington State. We expect that only the least toxic surfactants, and those producing the least toxic break-down products, would be used. At this time, we expect that only a surfactant such as Agridex® may be used. Rodeo® and Agridex® are licensed for aquatic application. We assume, however, that land managers would want to maximize efficacy and minimize economic costs and therefore would avoid allowing spray to reach water surface. As addressed earlier, although application of glyphosate directly to the aquatic environment is not addressed by the Washington Forest Practices Rules, Rodeo® and Agridex® are licensed for aquatic use.

Hardwood conversion would not occur within the first 50 feet of Type S and F streams. Forest managers would generally apply the lowest application rate consistent with the intended purpose using a low-pressure back-pack sprayer for spot treatments. When feasible, a spray hood would be used to direct chemicals at the immediate vicinity of the planted tree. All applications would be made in accordance with label instructions to ensure proper timing, correct rate of application, and appropriate application methodology. Application would not be made when rain is anticipated within 24 hours.

We expect a limited portion of the planted area would be sprayed. Other areas would not be sprayed at all. Application may need to be repeated. We expect permit issuance would not result in a need for other chemicals and have determined that the use of glyphosate (e.g., Rodeo® and Agridex®) as described above is not likely to adversely affect covered fish or amphibian species.

7.4.5.4 Maintenance and Fueling of Equipment

Backhoes, bulldozers, tractors, feller-bunchers, forwarders, and other road-related and yarding-related equipment would require maintenance and refueling in the field. All such work on heavy equipment should occur in staging areas to contain any leaking fuel, oil, and cleaning solvents and prevent contamination of adjacent streams and riparian areas. At times, repair or refueling may be required to occur in the work area. Chainsaws and other hand-held power tools require fueling, oil, sharpening, and other maintenance that may occur at the worksite.

7.4.5.5 Worker Camping

Crews working on harvest units, tree planting, or other forest activities may camp near the work site to reduce travel time. Such crews are usually responsible for their own clean-up and are held responsible by the respective landowners. Campgrounds on Federal, State, or other lands may also be used; but, any effects from camping in these campgrounds would be indistinguishable from effects resulting for recreational camping which are already addressed in the environmental baseline.

7.4.5.6 Livestock

Where livestock such as horses or oxen are used to pack in materials or for yarding, corals or hobble areas would be used and may be trampled, resulting in soil compaction. Some localized grazing pressure may result. Feed, including hay, would usually be provided. Because landowners can be held responsible for control and eradication of noxious weeds, caution is generally used to avoid introduction of weeds through hay, transport trailers, or on coat of animals. The FWS expects the use of livestock, to aid in conducting forest practices, to occur infrequently.

7.4.5.7 Browse Control

Special precautions may be necessary to reduce animal damage to replanted areas. The many methods available are collectively known as browse control or animal damage control. Western red cedars are particularly vulnerable to browsing by ungulates. Protection against ungulates includes applying wire cages, bud caps, and repellants to young trees. For protection from other animals, stems may also need to be wrapped to prevent girdling by rodents, especially in grassy environments. Fencing or other barriers protect plants from both ungulates and rodents. Co-planting cedars with spruce creates a successful barrier in some cases.

Some animal damage control methods come with risks. Fencing and barrier material (e.g., netting or Vexar® tubing) may be pulled off and may find its way into a stream. Also, repellants may wash off and eventually reach a stream. Most repellants are naturally occurring organic solutions such as putrescent egg solids, dog or coyote urine, or organic chemicals mimicking the scent of predators or decay.

7.4.5.8 Monitoring and Research

Issuance of the Permit is also expected to result in a variety of CMER-approved monitoring, evaluation, survey, and research efforts. These activities are intended to support the monitoring and adaptive management components of the FPHCP and attendant reporting requirements. The monitoring of stream conditions, riparian conditions, performance and efficacy of road standards, baseline condition monitoring, and compliance monitoring are not expected to result in effects to covered species. General categories of monitoring and research expected to have the potential for adverse effects to covered species are addressed below:

<u>Habitat Manipulations</u> – reductions in RMZ prescriptions may occur in order to test the effectiveness of various buffer designs. The FWS expects that habitat manipulations would likely occur on less than 0.1 percent of RMZ buffers. The range of treatments may vary. The most-aggressive experiments anticipated may result in some Type Np streams receiving no buffer. Type F streams may receive reduced buffers. These treatments may result in reduced large wood delivery, shade, nutrient input, and bank stability; treatments that involve enhanced buffers may locally provide additional function beyond that provided by the Washington Forest Practices Rules. These impacts are expected to occur along a

very small percentage of streams, be localized, and have minor impacts at a watershed scale. Two specific CMER projects are described below.

One example of an ongoing, adaptive-management research project with alternative riparian-management prescriptions is the Eastside Riparian Shade and Temperature Effectiveness Project (CMER FY 2006 Work Plan). This project is designed to evaluate the effectiveness of both the "all available shade" prescription (required within the mapped, bull trout overlay) and the standard eastside riparian prescription. The primary objective of the project is to determine if a difference exists between shade and stream temperature provided by the "all available shade" prescription and the standard eastside riparian prescription. The two riparian harvest treatments were assigned randomly among study sites and are as follows: (1) the "all available shade" prescription that requires all shade trees remain unharvested within 75 feet of fish-bearing streams within the bull trout overlay; and (2) the standard eastside riparian prescription. In some of treatment assignments, the standard eastside riparian prescription was randomly assigned to a study site that occurred within the bull trout overlay, which would require the "all available shade" prescription if harvest were to occur under normal circumstances (i.e., outside of an adaptive-management research project). This is an example of an alternative prescription under adaptive management.

Another example of an experimental riparian-management prescription, under the adaptive management program, is the Type N Experimental Buffer Treatment Project (CMER FY 2006 Work Plan). This project is currently in the site-selection phase. The project is designed to compare the effect, on a variety of riparian and aquatic resources, of three different Type N riparian buffer treatments with an untreated riparian control. One of the treatments is a clearcut prescription along Type Np streams. Outside of an adaptive-management research project, at least 50 percent of Type Np streams would receive 50-foot no-harvest buffers. So, the clearcut treatment is an example of an experimental prescription under adaptive management.

Species Handling – a variety of methods may be used to handle fish and wildlife species. Amphibians may be collected by hand or net. Fish may be captured by net alone or in conjunction with electrofishing (s**ee Electrofishing)**. However, species may be subject to handling stress, injury, and/or mortality as well as directly or indirectly contributing to transmission and increased susceptibility to disease. Species handling may occur as an activity authorized by the proposed Permit during studies proposed as part of the CMER process. Such studies may require repeated sampling to determine habitat use, growth rates, or other response variables. The FWS would continue to participate in CMER and guide such studies to reduce unnecessary effects to listed and at-risk species.

Additional specific features of sampling are expected to include:

A written description of the year's sampling and reporting plans would be sent to the FWS prior to each field season which would include estimates of the amount of work to be conducted and the names and qualifications of all personnel that would be supervising the field operations. They would sample at times and locations that avoid disturbing spawning native salmonids, incubating eggs, or newly emerged fry. If WDNR used electrofishing activities for these purposes, such use would comport with appropriate requirements (**see Electrofishing**). Sampling activities that would involve extensive shocking or handling of fish would likely be conducted at times or in locations (e.g., cold, groundwater-dominated streams) that avoid temperature stress of fish.

Live specimens would typically be released as soon as possible, and as close as possible to the point of capture. Fish would be held in live wells in the natural stream environment during measuring and weighing. The fish would be inspected periodically to ensure they are not being crowded or stressed. Holding time would usually be minimized. Water-to-water transfers, the use of shaded, dark containers, and supplemental oxygen would all be considered in designing fish-handling operations. Prior to conducting activities that may involve handling fish, researchers would ensure that hands are free of sunscreen, lotion, and insect repellent.

Fry and larger individuals would be held separately to prevent predation. All incidental mortalities would be preserved in a fashion to best provide maximum scientific information. Any specimen killed would be kept whole and put on ice or frozen as soon as possible. As requested by the FWS following review of study plans, additional information may be collected from incidental mortalities. For instance, in specific cases, a small tissue sample (e.g., fin clip of 0.2 square inch (1 square centimeter) would be preserved in a vial of 95 percent ethanol and sent to the Western Washington Fish and Wildlife Office for storage or processing.

Following such work, results of the year's surveys would be reported to the FWS on an annual basis. Reports of incidental injury or killing would include the date, time, location of the injured animal or carcass, and any other pertinent information such as the cause of death or injury. Such reports would generally include the following information:

i. A summary of the findings relevant to listed species and their recovery in the context of the FPHCP.

ii. Maps and descriptions of locations sampled where listed species were encountered.

iii. Estimates of the fish populations in the sampled reaches, if possible.

iv. Estimated quantification of take, including numbers of fish incidentally killed or injured, and the locations where this take occurred. The report should also include any insight derived from this work that may contribute to minimizing sources of injury or mortality in the future.

v. Other pertinent observations relevant to the status and ecology of listed species, including size and presumed life-history form.

Determining Fish Presence – Electrofishing to validate and update the water-typing model would be covered by the proposed Permit. Effects may occur to headwater fish and amphibians when electro-fishing is used to validate and update the water-typing model (extent of fish use). The FWS expects that electrofishing associated with model validation is expected to affect less than 0.1 percent of streams. When fish are discovered, electrofishing is expected to occur on those streams only once during the life of the Permit (50 years). When fish are not discovered, model validation or updating may occur at 5-year increments. Electro-fishing does not usually kill fish or amphibians, but disrupts their movements and behaviors at the time of shocking (**see Electrofishing)**. However, in some circumstances, electrofishing may cause injury and mortality. Electrofishing to determine fish presence on a given stream as an elective activity by a landowner is not related to the proposed permit issuance and is not a covered activity.

7.4.5.9 Fish Removal Procedures (Salvage)

Fish-removal, as may be authorized through a section 10(a)(1)(A) permit, may occur during stream crossing construction or maintenance. A site-specific assessment usually informs decisions about when diversion and fish salvage are necessary. During diversion, fish would be removed from the work area using a variety of methods. First, the work area is isolated by installing block nets at up and downstream locations to isolate the entire affected stream reach. This is done to prevent fish and other aquatic wildlife from moving into the work area. Block nets require leaf and debris removal to ensure proper function. Block nets are installed securely along both banks and in channel to prevent failure during unforeseen rain events or debris accumulation and are checked frequently to ensure they remain functional. Some locations may require additional block net support. Block nets are normally left in place throughout the fish removal activity and not removed until flow has been bypassed around the work area.

Drag netting or seining is a technique to remove fish from the isolated area with less potential for adverse effects to fish compared to electroshocking. Other possible techniques include collecting aquatic life by hand or with dip nets as the site is slowly de-watered, trapping using minnow traps, or by electrofishing. Electrofishing in stream channels is normally done only where other means of fish exclusion and removal are not feasible (s**ee Electrofishing**).

When removing fish out of the isolated stream reach, attempts would be made to remove fish from of the existing stream-crossing structure. Often, a connecting rod snake is inserted and wiggled through the pipe or other structure, creating noise and turbulence to get the fish to move out so they can be captured and removed out of the stream reach.

Pumps used to temporarily bypass water around work sites are normally fitted with mesh screens to prevent aquatic life from entering the pump hose. The mesh screens are installed as a precautionary measure to exclude any fish and other wildlife which may have been missed in the fish exclusion process, or may have entered the work area through a failed block net. Screens are generally located several feet from the inlet of the pump hose to avoid subjecting fish to the suction of the pump.

Captured fish are immediately either released or put in dark colored 5-gallon buckets or other suitable containers filled with clean stream water. Frequent monitoring of container temperature and well-being of the specimens ensures that specimens are released unharmed. Any injuries or mortalities to ESA-listed species usually require the event to be documented and reported to the one of the Federal Services (e.g., NMFS or USFWS); and, any listed fish that are inadvertently killed are provided to the appropriate Service. Captured fish would be released upstream of the isolated stream reach in a pool or area which provides some cover and flow refuge.

7.4.5.10 Electrofishing

Backpack electrofishing surveys are used to gather fish distribution and abundance data to inform operational decisions and for the aquatic monitoring and adaptive management commitments in the FPHCP. The surveys are used for three main purposes.

The first and most-widespread use is for verification of fish presence or absence in streams to test the water typing model. This use of electrofishing would be covered by the proposed Permit and typically involves electrofishing in smaller headwater streams, at or near the upstream limit of fish distribution. Standard methods would be used with any supplementary protocols described in the appropriate CMER Project Description and provided to the FWS for approval. When electrofishing is used for this purpose, it is applied in consideration of likely fish habitat and it ceases upon the first identified fish and as a result, only a small fraction of the stream is surveyed by electrofishing. Electrofishing is only used as needed and fish are not often encountered when it is used. The need for these surveys has diminished due to historical surveys. Use of electrofishing merely to determine fish presence on a given stream as an elective activity by a landowner is not related to the proposed permit issuance and is not a covered activity.

The second purpose of electrofishing surveys covered by the Permit is to conduct monitoring and research. For instance, in conjunction with certain other investigations (e.g., fish-passage effectiveness), it may be necessary to collect information about covered species. Such work may be conducted annually during certain years or may be conducted only periodically (e.g., every 10 years). Surveys may be conducted using standard multiple-pass removal electrofishing techniques, with block nets, or using modified procedures provided by the Services. Habitat surveys generally would be conducted concurrently.

The third purpose for electrofishing is to move fish during stream-channel diversion projects. This use of eletrofishing would be addressed through section 10(a)(1)(A) of the ESA and may require individual permits when bull trout are present. These types of projects are not very frequent, but may occur during culvert replacements and in-channel work (**see Fish Salvage**).

7.5 EFFECTS OF THE ACTION

7.5.1 Introduction

The activities that are the effects of this Federal action have been discussed earlier in the section entitled **Description of Activities that are Effects of the Permit**. In this section of the Opinion, we assess those primary activities (as well as related, interrelated, and interdependent activities) and their effects on aquatic and riparian resources. These activities would affect aquatic and riparian resources directly and indirectly. Indirect effects "are caused by or result from the proposed action, are later in time, and are reasonably certain to occur". These activities could affect inputs to streams directly, or indirectly, through the effects to riparian conditions. Lisle (1999) identified five types of inputs to watersheds: wood, sediment, water, heat, and detritus. Activities could also affect how inputs are transported and the level of connectivity within the fluvial system. For each of the resource topics regarding aquatic inputs and transport, we discuss the sources of effects, and discuss the level of effects. Changes to inputs and transport processes would also manifest themselves as changes to instream habitat which is discussed. The conditions that are expected to occur from these potential changes in riparian conditions, aquatic inputs, transport factors, and instream responses are compared to the range of variability expected under natural-disturbance regimes. Finally, some activities would affect habitat or animals in ways that are not readily captured within the above framework. We discuss the effects to individuals (of the collective covered species) that would be expected from activities such as work-site-isolation techniques (fish salvage), related to road-stream crossings, designed to minimize effects on fish; handling associated with fish salvage, monitoring, or research; and other sources of potential injury not stemming from habitat alteration.

Fish habitat includes the physical, chemical, and biological components of riverine, lacustrine, and estuarine/near-shore environments. Spence et al. (1996) suggested four general principles for consideration when determining habitat requirements for salmonids, and presumably for other aquatic species as well: (1) watersheds and streams differ in their flow, temperature, sedimentation, nutrients, physical structure, and biological components; (2) fish populations adapt and have adapted – biochemically, physiologically, morphologically, and behaviorally – to the natural environmental fluctuations that they experience and to the biota with which they share the stream, lake, or estuary; (3)

specific habitat requirements of salmonids differ among species and life-history types, and these requirements change with season, life stage, and the presence of other biota; and (4) aquatic ecosystems change over evolutionary time.

Consequently, there are no simple definitions of fish habitat requirements, and the goal of conservation should be to maintain habitat elements within the natural range for the particular system (Spence et al. 1996). Fish habitat is the product of many components, including water quality, hydrology / flows, channel structure, sediment supply, access or connectivity throughout the watershed / floodplain, riparian areas, and estuarine / near-shore environments. When properly functioning, these components are closely intertwined to form habitat conditions favorable to healthy populations of fish and other aquatic species. Key processes regulating the condition of aquatic habitats are the delivery and routing of water, sediment, and wood.

This section describes the factors affecting habitat, status, reproduction, and distribution of covered fish and amphibian species. Much of the information cited in the following text is specifically referring to salmonids. This is because there has been more research conducted on salmonids in the Pacific Northwest than on the other species. However, much of the information and many of the limiting factors apply to other fish species, as well as amphibians.

7.5.2 Riparian Features and Conditions

In this section, we discuss the existing and expected characteristics of the riparian forest that form the riparian buffers, the integrity expected from those buffers and the streambanks they are designed to protect, and some of the functions these areas provide in terms of soil protection, sediment filtering, and microclimate stabilization.

7.5.2.1 Riparian Forest Characteristics

Riparian forests occupy the areas adjacent to streams, lakes, and wetlands, and both influence those waters and are influenced by them. Because they are in the ecotone between streams and uplands, are subject to a variety of disturbance factors, and have strong gradients in microclimate, these forests often have distinct vegetation and wildlife communities, and tend to be more diverse than the surrounding upland areas. Riparian forests are often more structurally complex than surrounding upland stands.

Typical species composition of riparian stands in eastern and western Washington is described in Franklin and Dyrness (1973). Upland species are often dominant along small and confined streams. Valley-bottom riparian areas, subject to flooding and other effects, are generally characterized by species that can tolerate moist soils and riparian processes.

Riparian forests often are subject to disturbance regimes that are distinct from the surrounding uplands. Riparian forests are often more prone to flooding or debris flows. Flood frequency in riparian areas is a primary driver of vegetation composition and dynamics. Riparian forests tend to burn less frequently, but are generally more prone to stand-replacing fires when they do burn than their surrounding upland forests. Wind also plays a role in riparian forests, especially within the Sitka spruce (*Picea sitchensis*) / western hemlock (*Tsuga heterophylla*) coastal zones and Pacific silver fir (*Abies amabilis*) zone in higher elevations. These are also areas where moisture has limited the role of fire. Riparian forests tend to be long and narrow and edge effects are commonly associated with them, although the cool and moist microclimate of intact riparian forests can be similar to interior forests.

Baseline

Current riparian conditions on State and private lands are mostly a function of past forest-management practices, but natural phenomenon such as wildfire, windthrow, landslides, and disease have also contributed to conditions in many areas. The majority of riparian forests on State, private, and some Federal lands have been logged at least once. Today it is believed that red alder (*Alnus rubra*) dominates more riparian sites in western Washington than was "typical" under natural disturbance regimes (Washington Forest Practices Board 2001a; McHenry et al. 1998).

In-stream woody debris presence and recruitment potential are related to the extent of decay of in-stream wood and seral stage of current riparian vegetation. The most-durable wood pieces in streams are large sizes of conifer heartwood; conifer sapwood and softwood are less durable. The largest sizes and most-durable wood are from riparian forests upwards of 60 to 200 years old (Abbe and Montgomery 1996). Seral stage provides a general picture of riparian condition and quality, and potential large-wood recruitment. See **Effects of Activities by Resource Topic – Large Wood** section of this Opinion.

A Washington Forest Practices Board study concluded that unnaturally high levels of early seral stage vegetation existed in riparian areas on private forestland, primarily as a result of timber-management activities and, to a lesser extent, from fire, windthrow, and other natural processes in riparian areas (Washington Forest Practices Board 2001a). In general, early seral stages produce riparian vegetation that provides lower riparian values for aquatic and terrestrial biota. In contrast, later seral stages that are typically more diverse in species composition and stand structure can more fully provide for riparian functions. However, early seral (tree size less than 12 inches in diameter at breast height) hardwood riparian forests provide large amounts of high-quality detrital inputs from nitrogen-rich leaves. Data regarding seral stages of riparian areas indicate that within the lands subject to Washington Forest Practices Rules up to 2001, approximately 78 percent of western Washington stream miles and 61 percent of eastern Washington stream miles flow through riparian areas in early seral stages, while about 1 percent of western Washington miles and 5 percent of eastern Washington miles are late seral. Though natural variability is expected in riparian areas, the level of alteration due to past logging and road building is apparent.

Lunetta et al. (1997) used digital-elevation modeling of stream channels to determine channel gradient, and then characterized riparian seral stage by gradient category. The analysis looked at forest vegetation in 179 watersheds across western Washington. Stream channels were classified into three categories based on channel slope: response reach, transport reach, and source reach. The response-reach, seral-stage data are the only raw data still available from this study and are, thus, the only data reported here. Response reaches were defined as channel reaches with less than 4 percent slope, and were considered the area where most anadromous fish production occurs. The most-common seral stage was early seral, ranging from 52 percent in the West Puget Sound Region to 72 percent in the Lower Columbia Region. Late seral made up the lowest percentage, ranging from 5 percent in the Southwest and South Puget Sound Regions to 19 percent in the North Puget Sound Region. Riparian condition and function (e.g., floodplain condition, bank stability, large wood, shade, stream temperature, and water quality) vary from good to poor within each region, depending on site scale and location.

Beak (1998) conducted an assessment of 1,426 miles of streams in 28 Watershed Administrative Units (WAUs). They reported that nearly 55 percent of forest lands along fish-bearing waters have good to fair recruitment potential for riparian large wood. They also noted that the near-term potential for large-wood recruitment in eastern Washington is greater than the recruitment potential along western Washington streams. The shade assessment covered 1,637 miles of streams in 29 WAUs. They reported that 57 percent complied with the temperature/ elevation screen and should meet water-quality standards. They also noted that 17 percent were assessed as being streams naturally low in shade regardless of potential canopy condition, such as large, wide Type 1 waters of the State.

Many riparian stands in eastern Washington are currently stocked with an abnormally high density of trees and the species composition is dominated by shade-tolerant species. Historically, forest stands consisted of the more fire-resistant species such as ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Psuedotsuga menzesii*), and western larch (*Larix occidentalis*)(Agee 1994). Fire suppression over the last 100 years has greatly altered forest conditions. Since the early 1900s, fire suppression has resulted in an increase in the number of trees and fuel on the forest floor. It has also resulted in a shift to less-fire-resistant tree species (Kauffman 1990), for instance, grand fir (*Abies grandis*). These conditions can put stands at additional risk from stress, insects, disease, and eventually more-intense and destructive fires. Many forested riparian areas in eastern Washington have also been subject to grazing, which also has reduced streamside vegetation.

Many riparian forests within the FPHCP Action Area are either early- or mid-seral. In some cases, riparian forests have been subject to repeated timber harvest and resemble the surrounding uplands in terms of stand age and simplification. In other cases, riparian areas were not harvested as intensively due to logistical considerations and contain residual trees and stands offering significant ecological value to the surrounding landscapes.

A review of the baseline for each Water Resource Inventory Area (WRIA) (See USFWS and NMFS 2006 Appendix A) shows that many Washington rivers have altered riparian forests due to previous timber harvest and other land uses. Specific information on these past and ongoing effects is provided in the **Comprehensive Environmental Baseline** section and **Comprehensive Cumulative Effects** section of this Opinion.

Importance of Riparian Forest Characteristics

In addition to being highly diverse, riparian forests perform important functions in controlling stream-channel form, microclimate, biodiversity, and water and nutrient cycling. Large wood originating in riparian forests influences routing of water and sediment in stream channels and modifies the channel form. Riparian areas are especially important as the source of large wood input to streams, a phenomenon that directly influences several habitat attributes important to fish such as pool formation and maintenance, food sources (such as capture and retention of adult salmon carcasses), and sediment storage (FEMAT 1993; Spence et al. 1996). Riparian areas along larger rivers also serve as storage areas for large woody debris until transported by fluvial processes.

Riparian vegetation enhances bank stability, captures suspended particles from receding floods, and buffers the movement of nutrients. Forest canopies provide shade above stream channels and contribute organic matter to aquatic systems. Riparian vegetation produces insects that fall into the stream and supplement the diet of fish (Murphy and Meehan 1991).

Hardwoods play a variety of ecological roles in riparian forests. Red alder is a nitrogen-fixing species. Alders within a stand can contribute to the soil-nitrogen pool and may in some cases improve general tree growth. Alder are also resistant to certain tree diseases. Big-leaf maple (*Acer macrophylum*) and other hardwoods have been implicated in improved nutrient cycling in conifer forests. The easily decomposed litter of these species mixes with and hastens the decomposition of conifer litter, thus increasing the rate of nutrient cycling. Hardwood stands often support a different understory community compared to conifer stands. The Core Zones of RMZs in western Washington are variable, but tend to have species composition with about 10 percent greater hardwood component than adjacent Inner Zones. Fox (2003) noted that species diversity in the first 5 meters was attributable to hardwoods. He also noted that most of the species richness in riparian areas came from the first 35 meters and dropped abruptly in the next two 15-meter intervals.

Large trees by virtue of their size, age, and resistance to fire, floods, and decomposition play a central role in shaping the physical and chemical conditions within aquatic areas and, thereby, strongly affect the aquatic community. Tall trees cast long shadows and can shade even wide streams. Large trees that enter streams due to blowdown, bank undercutting, or mass-wasting can remain for decades or even centuries, functioning as stream features that rival bedrock sills or outcrops in regulating channel processes. Large wood creates habitat for a wide range of terrestrial species and is important in cycling nutrients (Harmon et al. 1986). Riparian areas of large rivers function not only as sources of most very large wood, but also as storage locations for organic material and substrate until redistributed during future flood events.

The direct influence of the riparian areas on streams and rivers declines with increasing distance from the channel, and is strongly related to dominant tree species and height, stream size, and drainage-basin morphology. A natural riparian zone includes a composite of tree stands of different age, size, and species (Spence et al. 1996; National Research Council 1996).

Effects of FPHCP on Riparian Forest Characteristics

Riparian timber harvest

Timber harvest within Riparian Zone of Influence of Type S or F streams would likely result in loss of some existing snags and cavity-capable trees. Washington State Department of Labor and Industry guidelines may require removal of some snags from within the buffer when operations within the immediate vicinity are necessary (WDLI 1992). These guidelines may also require removal of hazard trees from buffers when operations occur outside the buffer, but within the hazard zone of such trees. Snags and downed wood are one of the most-critical factors influencing the presence and abundance of wildlife species in Washington forests.

Timber harvest within fish-bearing stream buffers would not only result in the loss of some existing snags and cavity-capable trees, but may also retard the recruitment of future snags and downed logs. When buffers would be harvested under the thinning option, removal of suppressed or stressed trees during harvest would result in loss of some potential future snags, as well as some loss of future downed logs. However, thinning would remove smaller trees and would accelerate diameter growth on remaining trees, thus having some positive effect on the quality of future snags. Thinning can promote development of structural characteristics that are found in older forests (Barbour et al. 1997; Hayes et al. 1997). Short-term influences of thinning are negligible or positive for many species. Although the long-term effects of thinning on wildlife are less clear, current information suggests that the influences of thinning would be positive for species associated with older forest stands (Hayes et al. 1997).

In some cases, when stand conditions allow, trees may be removed from the Inner Zone while retaining a specified number of the largest trees. For instance, on the Westside, 57 of the largest trees would be retained following a thinning. The 57 trees would be a minimum number of trees that would be retained whether the pre-harvest stand contained 100 or 400 trees per acre. In a high basal area ponderosa pine stand, 21 of the largest trees per acre would be retained, as well as another 29 trees per acre over 10 inches dbh. However, the Core Zones would remain in tact for a distance of 50 and 30 feet, respectively.

When buffers would be harvested under the “packing” option, riparian forests would remain intact within the buffer but would be narrower than under the thinning option. Such stands would not benefit from the positive effects of thinning. However, in a number of situations, windthrow of a portion of the trees would simulate the effects of thinning. See **Effects of Activities by Resource Topic – Windthrow** section. Harvests outside the Outer Zone, but within the Riparian Zone of Influence, may not retain standing trees to contribute to future snags or downed logs.

Felling of timber and movement of heavy equipment may also result in degradation of existing downed wood. Pre-harvest downed wood may have debris piles accidentally placed upon them, but should not be relocated to debris piles or to landings.

Timber harvest along Type F and Type S streams and resulting reduction in canopy cover should result in some additional sunlight reaching the forest floor and should generally stimulate understory plants. It is expected that there would be minimal effects to understory vegetation in most cases because the amount of removal from the Core and Inner Zones would be minor, location of removal would be primarily from the Outer Zone or at least the outer portion of the Inner Zone, and branches and leaves of remaining trees composing the riparian canopy would generally respond quickly to available light.

Harvest under Alternate Plans may occur in a modified manner according to individual or grouped alternate plans. Landowners may create an alternate plan to harvest timber so long as it is deemed by WDNR to be at least equal in overall effectiveness at addressing the riparian functions as the standard rules. No significant or measurable physical effects to the stream are expected due to the “equal in overall effectiveness” provisions of alternate plans with respect to aquatic and riparian function. However, there may frequently be a reduction in wildlife habitat in both quantity and quality at the local level, so long as the Alternate Plan does not violate the “equal in overall effectiveness” provision. The standard of “equal in overall effectiveness” applies to “aquatic and riparian functions” and does not guarantee the same level of function for wildlife habitat. In other cases, effects may be neutral or beneficial.

For instance, some alternate plans, such as those that address young over-stocked stands, may provide enhanced forest structure. Young, dense stands that are not managed would be subject to suppression mortality, but much of this mortality would occur to trees that are substantially smaller than those trees that would result following thinning treatment. Thinning from below would retain the largest trees and they would grow in diameter faster as a result of thinning. Under the overstocked stand template for nonindustrial forest landowners, some trees could be removed as close as 14 to 30 feet from the stream. This removal would benefit the remaining stand in terms of growth, diameter increase, and increasing windfirmness. In addition, such treatments would provide sunlight for improved understory development. Young, dense stands are a relatively common part of the environmental baseline.

Due to felling of trees, yarding of logs, and movement of equipment, understory vegetation would be damaged including the breakage of taller shrubs and some understory trees. Damage would also occur to some existing hardwoods and conifers in the overstory or mid-story. Harrington et al. (2005) in observing effects of variable-density thinning operations on the Olympic Peninsula noted that some advanced regeneration and understory plants were damaged by equipment. Some understory shrubs were killed and others re-sprouted. Harrington et al. (2005) stated that, overall, logging damage to the residual timber and soils was low. Activities were halted when soils became too wet to continue without risking rutting or compaction. The usual breakage and occasional stem scarring associated with timber falling and extraction were observed, but few trees were affected overall. Removal of bark on the lower bole and exposure or damage to shallow roots were the most common forms of damage observed. Falling branches from overstory trees also damaged some residual understory and mid-story trees, resulting in top or branch breakage or stem scarring.

Only rarely would trees be felled into Type S or F Core Zones, and then they may only be removed under an HPA. Forest managers typically exercise great care to avoid damage to future crop trees within the mid-story and overstory. Special precautions (e.g., avoidance of bark rubbing and armoring some trees next to yarding corridors) are often used when operating in conifer stands during the spring sap-flow period.

Yarding through corridors may result in some scarring of retained trees. Scarring of retained trees may hasten the development of snags or other defect. Yarding-caused injuries and damage would likely increase the probability for formation of cavities or other structures in the riparian zone. Trees felled in the Core Zone to create yarding corridors would result in a localized pulse of downed wood for the stream and riparian area as such trees would be retained on the forest floor. Snags and "hazard trees" may be required to be felled when they could reach cable lines, but should be retained on site. Yarding may damage taller shrubs and understory trees. Yarding corridors may increase diversity of riparian forest by introducing areas of defect, directly or indirectly creating snags, or creating small openings. Trees required to be left on site in corridor creation would be left as downed logs.

Effects from tailholds and tailhold cable corridors are expected to be negligible. When the cables are tightened they may rub some trees and remove some branches. This damage may resemble a lightning scar. In extreme cases, a tree or several trees may need to be felled. Such trees would generally remain within the riparian zone as downed wood, because they are required to be retained within the Core Zone and must be retained if they were needed to meet DFC within the Inner Zone. The effects from this activity would generally be indistinguishable from an individual downed tree, pocket of windthrow, or root-rot pocket, with the exception of the presence of a cut stump. Usually straps are used to attach tailhold lines to trees. Sometimes, tailhold trees would be notched, but minimal lasting damage is expected.

Canopy reduction or removal as a result of hardwood conversion would increase the amount of sun reaching the ground in the riparian zone during the growing season and would stimulate understory vegetation. Eventually, removal of hardwoods and replacement with conifers would restore the riparian forest to its historical species composition and functioning. However, in the interim, removal of alder boles would mean a decline in structure, cavities, downed logs, and nutrient inputs. Declines in structure, cavities, downed logs may last for several decades. Hardwood conversion would also reduce the number of cavities within alders and number of alder snags, as well as a general reduction in forest structure in some cases. Loss of existing snags would occur due to implementation of safety standards, logistical needs, and accidental felling and bucking activities, and there would be a loss of cavity-capable hardwood trees. Hardwood conversion may on occasion remove more than just dominant alder, therefore removing species important for mast and bio-diversity, such as bitter cherry, beaked hazelnut, cascara, etc. However, hardwood conversions would eventually re-establish a natural conifer stand capable of providing durable large wood and other functions.

Long-term benefits are expected from hardwood conversion, but shorter-term effects are also expected. Replacement of alder by conifer as a component of the riparian forest may take several decades. Short-term effects are expected to be minimized by the Core Zone; but, long-term benefits may also be reduced by retention of the Core Zone. Core Zones that are presently under-stocked, hardwood-dominated stands as the result of operations under previous regulatory regimes might not attain shade levels typical of an old-growth conifer forest (Washington Forest Practices Board 2001a). Past logging practices caused these conditions and effects, and they are common in the environmental baseline in the action area. A large portion of forest land in the action area is under-stocked, or in early- to mid-seral stages as the result of historical fires (Bisson et al.1997**)**. The legacy effects of past logging practices are measurable, as are the effects of other historical processes. Hardwood conversions may assist in the restoration of properly functioning riparian zones, relative to how conditions would have developed under natural occurrences. However, hardwood conversions under standard rules may not provide rapid benefits, or may not be deemed effective at achieving desired future condition. Some landowners may not be able to meet other constraints of those standard rules. Alternate plans may be utilized where the standard hardwood-conversion rules are not sufficient or flexible enough to meet restoration objectives.

Hand-slashing competing vegetation in the Riparian Zone and possible use of herbicides (e.g., glyphosate) would reduce the amount and diversity of riparian vegetation for a short time period. Hand slashing would primarily reduce the height of target species such as salmonberry (*Rubus spectabilis*), big-leaf maple, for a very short time period (e.g., less than 2 to 3 years). Vegetative control would enhance conifer survival and accelerate development of conifer-dominated stand. As a result of site-preparation, planting, and subsequent husbandry, conifers would be established more quickly, and the conifers would eventually shade out much of the understory in an accelerated time-frame.

Timber-stand improvement within the Riparian Zone may improve the health and vigor of remaining trees and therefore the stand as a whole. However, it may reduce the bio-diversity through simplification of the species composition and therefore also affect stand structure. Nonetheless, the effects of timber-stand improvement are considered as a consequence of riparian timber harvest and need not be separately addressed.

Timber harvest along fish-bearing streams under 20-acre exemptions would result in a local reduction in riparian function. Riparian areas would be narrower and would not provide the same amount of habitat to forest wildlife species. Recruitment of downed logs to the Riparian Zone would be substantially less than under standard rules. Mature stages of forested riparian habitat retained along Type Np streams under 20-acre exemptions would be minimal. With respect to streams without fish, those riparian areas managed under standard rules would provide some narrow forested corridors (e.g., along half or more Type Np streams where 50-foot or wider buffers would be retained, and Type Ns streams buffered for slope stability). These corridors could provide refugia and would function at a higher level when surrounding stand reaches height and condition to help provide interior forest condition as well as provide connectivity between refugia.

Roads

Effects associated with road construction include the creation of a road corridor. When roads are constructed or relocated within or across riparian areas, this activity removes trees which otherwise would have contributed to habitat or riparian downed wood. At time of installation of stream-crossing structures, there may be loss of downed wood and riparian vegetation at the crossing site and at any required access sites. Riparian vegetation would generally regrow within several years outside of road prisms and ditches. Construction and retention of stream-adjacent parallel roads has the potential to impede large wood from recruiting into the riparian area and has the potential to introduce other effects to the riparian forest. Road corridors in riparian stands can influence the rate of windthrow. Roads adjacent to and within riparian areas may reduce the delivery of downed wood directly by removing trees which would have eventually fallen. They may also alter the delivery of downed wood by increasing windthrow potential, replacing long-term delivery with a short-term pulse. Maintenance, repair, and road upgrading may also have minor effects to adjacent riparian stands by increasing sediment or removing trees adjacent to roads. The presence of roads may result in requirement to remove hazard trees, thereby reducing the number of snags. Cutting of hazard trees along roads will not necessarily result in additional downed logs as roadside areas are convenient places to cut firewood.

Unused roads often are naturally revegetated by red alder and scattered conifer. Abandonment may remove some young vegetation (most likely less than 10 to 20 year old alder with understory conifer less than 6 to 10 feet tall) resulting in a short-term setback to secondary succession, but would usually result in long-term benefits as the area returns to a natural forest.

Research

Effects associated with habitat manipulations for research purposes are expected to occur along a very small percentage of riparian areas, be localized, and have negligible effects at a watershed scale. Habitat manipulations may locally reduce the amount of canopy for a short time period and may reduce downed wood and potential future downed wood. For instance, where thinning was employed, canopy cover would usually be expected to recover to near pre-treatment levels in less than a decade. Stand-level recovery of suppression-mortality rates would follow.

Summary of FPHCP Effects to Riparian Forest Characteristics

Riparian forests along Type F and Type S streams managed according to the standard Washington Forest Practices Rules or alternate plans would generally continue to improve in condition, although short-term effects may be realized on a site-specific basis. Where thinning occurs, it typically would be beneficial in the long term (decades) to the development of late-seral characteristics with only minor short-term (generally less than 2 to 5 years) effects in most cases. Where harvest occurs under the “packing” option, riparian forest would be left intact and composed of a more-narrow arrangement of trees. Lack of thinning within the 80 to 100 foot RMZ under the packing option may forestall the improvements expected in RMZs. Riparian forests along perennial streams without fish often could be fragmented by intervening harvests and, as such, would not provide as much riparian forest connectivity until the intervening areas regrow. Some intervening functions would recover in 2 to 5 years (such as shade and cover) while other functions may take decades (wood recruitment). Hardwood conversion would return riparian forests to their natural condition; however, no conversion would occur within 50 feet of the stream under standard hardwood-conversion rules. Alternate plans may frequently address hardwood conversion on a site-specific basis and would ensure “equal in overall effectiveness” protection of riparian and aquatic function. Riparian forest in CMZs would be maintained, except on 20-acre exempt parcels.

Roads would interrupt connectivity of riparian forests and may create a source of additional effects, such as windthrow, but FPHCP would minimize roads within RMZs and would remove some existing roads. Harvest conducted under the 20-acre exempt parcel rule would result in a reduction in riparian forests and function along both streams with fish and streams without fish.

7.5.2.2 Windthrow

Windthrow is an important consideration in evaluating buffer integrity. Strong winds can uproot trees, disturbing the soil, reducing the stabilizing influence of tree roots on steep slopes and substantially increasing the potential for mass soil movements. Windthrow (as well as stem breakage) can be chronic (endemic), episodic, or catastrophic. Catastrophic windthrow occurs infrequently and affects both stable and unstable areas. Chronic windthrow is mostly found in less-stable stands (Miller 1985). Windthrow frequently occurs along streams because winds tend to follow the natural pathways provided by the drainage system, but is also common elsewhere where trees are exposed to winds and/or high water tables. Windthrow is also influenced by harvest patterns.

Windthrow is a significant disturbance process in many parts of Washington, especially in coastal areas, Southwest Washington, and in certain elevated areas. Windthrow can include trees that are blown down as well as boles that are broken in the wind. Most windthrow occurs during the winter months when soils are saturated and winter storms bring sustained and high-velocity winds. Generally, windthrow has an increased probability of occurrence and severity in areas dominated by shallow-rooted species such as western hemlock, Sitka spruce, or Pacific silver fir; in areas with and at times of high water tables; and on slopes or topographic features exposed to prevailing or storm winds.

Some soils are more susceptible than others, for instance, some soils lack sufficient rock to provide strength while others are too rocky to allow good root penetration or too close to bedrock. Depth of organic layer is positively correlated with vulnerability. Increasing damage with site quality was observed by Fleming and Crossfield (1983) in boreal forests and Harris (1989) in southern Alaska.

Increased damage with higher stocking is a function of slenderness and lower stability of individual trees (Becquey and Riou-Nivert 1987; Mitchell 2000). Stem taper may be an important factor affecting susceptibility to stem breakage. The height-to-diameter ratio of dominant trees in even-aged stands has been found to be a good indicator of risk of stem breakage (Stathers et al. 1994).

Root and bole rots have been found to be associated with high frequencies of both windthrow and stembreak, because of their effects on root anchorage and bole strength. Surveys of windthrow in high elevation Engelmann spruce (*Picea engelmannii*) – subalpine fir (*Abies lasiocarpa*) forests have found root or bole rots associated with about one-third of the wind damage. Other studies have shown that 20 to 50 percent of wind-damaged trees have evidence of infection by various types of rot (Stathers et al. 1994).

Relevant Issues

Windthrow can also be influenced by management. Harvest within the RMZ can affect the wind-firmness of remaining trees. Generally, clearcutting adjacent to riparian sites increases the windthrow risk. Rollerson and McGourlick (2001) noted that windthrow in riparian reserves on northern Vancouver island was chronic and varied from individual trees to occasional areas where all trees are windthrown.

Selection of windfirm leave trees, pre-harvest thinnings designed to increase windfirmness of remaining stands, and pruning and topping are a few techniques that may reduce windthrow risk. In addition to increasing diameter growth, thinning has also been shown to influence wind firmness in residual trees. The ability of a tree to resist being blown down during high winds is related to root architecture, soil characteristics, and the ratio of height to diameter (Ruth and Harris 1979). Even if a tree has a well-developed root system and is growing in well-drained soils, the bole of the tree may snap under high winds if the tree is tall relative to its diameter.

Thinning from above removes dominant overstory trees, leaves trees which are about as tall but much more narrow, and can significantly increase wind damage of residual trees. Rollerson and McGourlick (2001) noted that strips with only smaller merchantable trees retained experienced substantially higher windthrow and that windthrow penetrated further in these stands. Trees with slender boles are less stiff and thus are more likely to move widely in wind. In taller stands, wide movement of trees in a windstorm can result in violent collisions with neighboring trees; this results in crown abrasion and narrow crowns with unoccupied space between crowns (Lieffers and Silins 2005).

On the other hand, thinning from below does tend to retain the most-windfirm trees within a stand and generally decreases the risk of wind damage as the stand develops (Ruth and Harris 1979). Thinning opens up growing space within the stand and increases photosynthate production in residual trees. This additional production is allocated to fine-root growth and diameter growth (Oliver and Larson 1996). While wind firmness may be lower immediately following thinning, the increased growth of roots and diameter eventually increases windfirmness as the stand develops. Jull (2001) found that trees with height-to-diameter ratios of less than 50 (i.e., a tree one foot in diameter would be less than 50 feet tall) had a loss rate of 3.9 percent, while trees with height-to-diameter ratios of over 90 had loss rates over 20 percent.

Brown (1971) cautioned that buffer strips were susceptible to wind damage, and other specific characteristics of the buffer must be used in determining proper widths. Narrow riparian buffer strips exposed to storm winds are highly susceptible to windthrow for 5 to 10 years after their formation (Steinblums et al. 1984). In a study pertaining to windthrow in forested buffers strips on Type 4 streams (roughly equivalent to current Type Np streams) in northeast Washington, it was noted that trees within small stream buffers (adjacent to clearcut harvest units) are subject to increased wind exposure (Grizzel and Wolff 1998). Because of this increased wind exposure, windthrow is often the primary mechanism of wood delivery in managed forests (Grizzel et al. 2000). If too much of the riparian vegetation blows down at once over a long distance, some of the target buffer functions can be impaired (Grizzel and Wolff 1998). The short-term benefits to the stream can be followed by a long-term shortage of instream wood once the current debris washes away or decays.

Grizzel and Wolff (1998) studied buffer strips on small streams without fish in northwestern Washington and reported there was a prevalence of RMZs along the studied streams even though the regulations in effect at the time did not require them. About 33 percent of buffer trees were affected by windthrow. However, only 3 of 40 sites had more than two-thirds of the trees windthrown. The level of windthrow varies among trees species. Western hemlock, Sitka spruce, and Pacific silver fir tend to be more vulnerable. Pacific silver fir and western hemlock experienced the highest levels of windthrow reported by Grizzel and Wolff (1998). Grizzel and Wolff (1998) reported windthrow occurrence by species: Pacific silver fir 37.3, western hemlock 36.0, western red cedar (*Thuja plicata*) 21.8, Douglas-fir 20.2, red alder 17.2, and big-leaf maple 7.5 percent.

To reduce windthrow when operating in dense hemlock stands in situations that may be vulnerable to windthrow, foresters often use a “rule-of-thumb” to remove no more than one-third of the basal area at one time. Lancaster (1985) recommended that no more than one-third of the total basal area should be removed at one time when thinning heavily stocked stands of eastern hemlock (*Tsuga canadensis*). Excessive cutting results in reduced growth and increased mortality, and contributes to windthrow. Stathers et al. (1994) recommended removal of no more than 15 to 20 percent of basal area during initial harvest when operating on high-hazard sites in British Columbia, and they further stated that amount of canopy removal should reflect the windfirmness of the original stand. They further recommended retaining opportunity for branch-to-branch contact between trees so that sway is dampened in stands of high initial density.

Measured windthrow rates are a factor of the geography and geology in which the research is conducted, prevalent species of trees and soils, as well as timing relative to strong storms. Windthrow rates in Washington and Oregon are variable and have been reported to average 5 percent (Mobbs and Jones 1995; Hobbs and Hallbach 1981 *as cited in* Grizzel and Wolf 1998), 10 percent (TFW 1994), 12 percent (Sherwood 1993), 22 percent (Andrus and Froehlich 1988), and 29 percent (Steinblums 1978). In a study by Rollerson and McGourlick (2001), riparian windthrow averaged about 21 percent of the standing timber along stream edges. They note there were a large number of plots with only a minor amount of windthrow and conversely only a limited number of areas with substantial amounts of windthrow. The average distance of penetration into standing timber was about 12 m (40 feet). They also noted that buffers exposed on both sides were more vulnerable and that "feathered edges" had lower amounts of windthrow.

Harrington et al. (2005) in a study of variable-density thinning on the Olympic Peninsula noted that wind-related damage differed substantially from plot-to-plot. In terms of total number of wind-damaged stems, only 1 of the 14 thinned plots had moderate to heavy damage (>50 trees damaged per hectare), 2 of the thinned plots had minor to moderate damage (20 to 25 trees per hectare), and damage at the other 11 thinned plots and the 4 control plots was very minor (fewer than 5 trees per hectare). Only two plots had more than 10 trees per hectare greater than 20 cm in diameter damaged by wind following thinning. Height-to-diameter ratios appeared to play a role in predisposing stands to wind damage. Most of wind-damaged trees were western hemlock.

Harrington et al. (2005) also noted that even the 3 stands that lost more than 10 trees per hectare, retain adequate stocking to meet the original management objectives. Greater loading of coarse woody debris and increased spatial variability of tree distribution resulting from windthrow are both characteristics consistent with the objectives.

Effects of FPHCP on Windthrow

Riparian timber harvest

Timber harvest within the Riparian Zone of Influence and adjacent to, or within, regulatory buffers has the potential to increase windthrow. Pollock and Kennard (1998) state that buffers less than 75 feet are more susceptible to windthrow. Type F and S buffers would not be as likely to be subject to intensive windthrow. Type Np streams with discontinuous buffers of 50 feet are anticipated to experience a greater proportion of windthrow than buffers of fish-bearing streams.

Windthrow has a higher possibility of occurring with harvest along fish-bearing streams under 20-acre exemptions, as well as 20-acre exemptions on streams without fish. Because fewer trees would be retained and buffers would be narrower, there is an increased probability of windthrow occurrence and an increased possibility of deleterious effects, depending on geography and other factors. Also, the minimum requirements for size and type of leave trees may not result in retention of the most-windfirm trees.

Due to the "equal in overall effectiveness" constraints of Alternate Plans, it is expected that the effects to the aquatic and riparian environment would be essentially the same or less than what would occur under the standard rules. No significant or measurable physical effects from windthrow (in comparison to standard rules) are expected due to the "equal in overall effectiveness" provisions of alternate plans with respect to aquatic and riparian function. Due to the age of trees and type of thinning to occur under the over-stocked template, we do not anticipate a short-term increased risk of windthrow. In the long term, thinning can increase tree stability in stands which are not differentiating well, so long as the thinning occurs before the trees become too unstable. As a result of harvest conducted under the overstocked stand template, windfirmness should be improved in the long term and would strengthen trees within 14 to 30 feet of the bank, as well as retained trees along the streambank.

Reduction in alder canopy from hardwood conversion would only result in minor increases in windthrow vulnerability of the Core Zone as alder decrease in ability to deflect wind in the winter. Core Zones in areas subjected to hardwood conversion are also likely to be composed of hardwoods which are generally more resistant to windthrow.

In most cases, it is expected that the integrity of fish-bearing buffers would be maintained because the width of these buffers and the density and type of retained trees would generally pose little risk of windthrow. Additionally, the greater retention of trees in proximity to streams would reduce the possibility of windthrow penetrating the buffer and compromising the integrity of trees contributing root strength to stream banks. However, in less-frequent cases, riparian areas would experience substantial windthrow that would reduce the density of trees, increase downed wood, and alter understory vegetation. Such cases of more-intense windthrow often increase the spatial diversity of riparian areas.

Roads

Effects associated with road construction, re-alignment, or reconstruction include the creation or re-establishment of a road corridor. Existing stream-adjacent parallel roads are also associated with road corridors in riparian areas. Relocation and re-alignment may increase openings beyond the standard right-of-way widths. Removing trees from within the Riparian Zone can increase windthrow concerns for remaining trees, but the contribution of a road corridor to catastrophic windthrow that would compromise the riparian buffers would be very infrequent and localized.

Research

Effects associated with habitat manipulations for research purposes are expected to occur along a very small percentage of riparian areas, be localized, and have negligible effects at a watershed scale. Habitat manipulations may locally reduce the density of stands for a short time period but are not expected to substantially affect windthrow risk beyond the effect of standard rules.

Summary of FPHCP Effects to Windthrow

Windthrow is one of the processes by which large wood is recruited to the stream and riparian floor. Downed wood contributes to shade of stream and a variety of riparian and instream functions, such as sediment storage. Windthrow is one of the natural habitat-forming processes. Loss of some scattered trees within a buffer to windthrow, as well as loss of small segments of buffers (pockets), to windthrow does not compromise the integrity of the buffering system. Remaining trees would generally respond by retaining a higher live-crown ratio, more-expansive root systems, increased epicormic branching in some cases, and increased diameter growth and vigor, thus accelerating development of late-seral characteristics. Yet, in a few cases, trees that don’t blow down during an episodic event, would have their root systems compromised by uprooting of adjacent trees and would also fall or blow down within a few years. This would be most common where trees have not differentiated much and are composed of shallow-rooted species. Lack of differentiation implies that individual trees are actively competing with each other, resulting in taller, narrow boles, shallow and narrow live crowns, and correspondingly narrow root systems. Stands composed primarily of shallow-rooted species are common in Coastal regions –

such as western hemlock and Sitka spruce, as well as within the Pacific silver fir or true-fir zone in the Cascades and Olympic Mountains. In most cases, it is expected that the integrity of the stream buffers under FPHCP would be maintained, even if some windthrow occurs; because, the majority of stands experience little if any windthrow, severe windthrow is quite infrequent, and downed wood in riparian zones serves multiple functions including sediment storage and shade.

7.5.2.3 Other Damage

Felling in riparian areas adjacent to buffers on perennial streams should result in minimal damage to the buffers due to the use of directional felling. Limbing and bucking of the timber and movement of heavy equipment may also result in damage to smaller existing conifers and hardwood trees in the overstory or mid-story; however, it is anticipated that integrity of dominant and co-dominant conifers (potential future crop trees) would be protected. However, a certain amount of damage is expected to occur to leave trees. These trees would then be susceptible to insects and pathogens that may further introduce risks to the tree, but may also increase defect and abnormal characteristics which are valued as wildlife habitat (e.g., broken and regrown tops, hollow boles). A discussion of some damage expected within buffers from thinning was discussed with respect to felling, bucking, and yarding under the **Effects of Activities by Resource Topic -- Riparian Forest Characteristics** section of this Opinion.

Forest health of riparian buffers is a major concern, especially in portions of eastern Washington. Many riparian stands in eastern Washington are currently stocked with abnormally high densities of trees and the species composition is dominated by shade-tolerant species. These conditions can put the stand at additional risk from moisture stress, insects, disease, and eventually more-intense and destructive fires. In some situations, buffer integrity may benefit from silvicultural treatment to control species composition and stocking density, as well as addressing ladder fuels. However, dynamics of snags, downed wood, and large-wood recruitment to streams, may, in some areas, be more dependent on episodic and catastrophic events, rather than on chronic processes. Insects, disease, and fire are integral parts of a natural process of riparian development and large-wood recruitment. The standard Washington Forest Practices Rules for riparian areas attempt to address these considerations; and, through the “equal in overall effectiveness” provisions of the alternate plans, development of future alternate plans is expected to adequately address these considerations as well.

7.5.2.4 Bank and Channel Integrity

Erosion and weathering of the landscape naturally contribute to sedimentation in streams; however, unstable banks may produce an excessive, chronic source of fines. Bank stability varies with channel and forest types (Newton 1993). Roots of vegetation help to develop soil structure, stabilize streambanks by binding soil in place, and provide resistance to erosive forces of flowing waters (Beschta 1991), especially the root masses of live trees, shrubs, and herbs nearest the channel (Swanson et al. 1982a). Soil is strong in compression, but weak in tension. Plant roots are weak in compression, but strong in tension. When combined, the soil-root matrix produces a type of reinforced earth which is much stronger than the soil or roots separately. Roots are effective in both adding tensile strength to the soil and, through their elasticity, distributing stresses through the soil, thereby avoiding local stress development and progressive failures (Thorne 1990; Simon and Collison 2002).

Mass failure of non-cohesive banks occurs by shearing along shallow, planar or slightly curved surfaces. The motivating force is shear stress on the potential failure plane due to the downslope component of weight (Thorne 1990). Most mass failures of cohesive banks occur following rather than during high flows in the channel. This is because the switch from submerged to saturated conditions that accompanies drawdown in the channel approximately doubles the bulk weight of the bank material, while simultaneously reducing the soil strength by means of increased pre-water pressure (Thorne 1990).

The amount of bank stability provided by roots is influenced by fine root abundance and density (Thorne and Tovey 1981). Factors that appear to influence root strength are soil productivity, hydroperiod, species composition, and frequency and intensity of disturbances. Roots of all plant species increase soil strength to varying degrees (Castelle and Johnson 1995). Diverse assemblages of woody and herbaceous plants may be more effective in maintaining bank stability than single species assemblages (Spence et al. 1996). This implies that mature forest with diverse understory, developed naturally or though thinning, may provide better, more-effective, root strength than stem-exclusion stage forest. In general, the deeper the penetration of roots, the more effective they are in enhancing soil strength. Thus, trees tend to enhance bank stability greater than woody shrubs, which are in turn better than grasses and forbs. Woody roots, once exposed, are also more effective at armoring the soil against hydraulic forces, and contribute to overall reduction in near-bank shear stress. Roots also stabilize banks by means of their hydrologic effect, increasing the cohesion of the soil particles by their effect on water content (Simon et al., 2000), although this effect is only significant during the conditions when transpiration is active.

Root-stabilized banks may facilitate bank building during high flow events by slowing stream velocities, which in turn helps to filter sediment and debris from suspension (Swanston 1991; Spence et al. 1996). This combing action allows existing channels to narrow and deepen (Elmore 1992). Vegetated stream banks can reduce stormflow damage by increasing channel roughness and reducing velocity of flows (Spence et al. 1996). Root systems allow undercut banks to provide fish shelter (Beschta 1991; Murphy and Meehan 1991), and contribute to the dynamic stream-channel morphology and the diversity of fish habitats (Swanston 1991). In larger, lower-gradient streams, undercut banks in forest and meadow riparian areas can provide high-quality resident habitat as well as cover for migrating fish. The margins or banks of streams, estuaries, marine waters, and river channels provide important habitats for both aquatic and riparian-dependent species.

High-velocity flows can undercut vegetated banks, dropping trees into the water, which can redirect flow against the banks and cause further erosion. Soil exposed at root wads of fallen trees may be transported to the stream channel, increasing sedimentation (Spence et al. 1996). Streambank erosion is a natural process that delivers sediment to streams, affecting many stream-channel features. Accelerated bank erosion contributes a great deal of fine material to downstream reaches (CH2MHill 2000).

Root strength is only one of numerous factors contributing to streambank stability (Castelle and Johnson 1995). Factors other than root strength, such as sediment load and large wood, generally have a greater effect on stream-morphology characteristics (Kleinfelder et al. 1992).

Buffer distance to maintain the effectiveness of root strength for bank stability probably does not extend beyond 30 to 50 feet (Newton 1993; Newton et al. 1996), or one-half a tree crown diameter (Wu 1986 as cited in CH2MHill 2000). However, these buffer distances may not allow for natural channel migration and bank erosion processes in the long term. In wide valleys where stream channels are braided, meandering, or highly mobile, the zone of influence of root structure is substantially greater, especially over long time periods (Spence et al. 1996). Data quantifying the effective zone of influence relative to root strength is scarce (Spence et al. 1996).

Effects of FPHCP on Bank and Channel Integrity

Riparian Timber Harvest

In assessing bank and channel integrity, we consider that activities that cut streambank trees or result in areas of exposed streambank soil can adversely affect these habitats by altering the character of stream banks and perhaps diminishing large-wood recruitment. However, forest practices prescriptions in the FPHCP require that activities in the RMZ Core Zone for Type S and Type F waters and in RMZs for Type Np waters must ensure streambank integrity is maintained. Retention of trees closest to the streambank would help protect streambanks and channels. Where necessary, high stumps near the streambank must be left to prevent felled and bucked timber from entering the water. Trees with large root systems embedded in the streambank must also be left. In addition to these requirements, activities that affect streambank integrity such as road construction or log yarding would require an HPA permit from WDFW. Activities that require an HPA are subject to additional conditions under the State's Hydraulic Code (WAC 220-110-030(17)). Streambank-protection measures require operators to avoid disturbing stumps, root systems, and logs embedded in the stream bank, as well as brush and other understory vegetation rooted in the stream bank. Light et al. (1999) concluded that if enough trees or other vegetation are maintained after harvest to sustain an interlocking root network, then bank integrity should be protected, but also that the strip of vegetation retained should be wide enough to anticipate channel movement.

Root strength and bank stability would generally be maintained during riparian timber harvest through conservative treatment within buffers along fish-bearing streams and ELZs on other streams. However, some reduction in stream-bank integrity may be expected along unbuffered segments of streams without fish, especially between 5 to 20 years following harvest when roots of harvested trees have decayed and new plantations are still developing their root systems. In most cases, it is expected that greater tree retention in proximity to fish-bearing streams and buffered Type Np streams would ensure that root strength is retained at functional levels.

Due to the "equal in overall effectiveness" constraints of Alternate Plans, it is expected that the effects to the aquatic and riparian environment would be essentially the same or less than what would occur under the standard rules. No significant or measurable physical effects to the streambank integrity are expected due to the "equal in overall effectiveness" provisions of alternate plans with respect to aquatic and riparian function. Under the over-stocked stand template, maintenance of 14 to 30 feet of untreated stand (based upon crown diameter) should maintain one rooting diameter and help protect root strength and streambank integrity. Hardwood conversions under standard rules would retain 30 to 50 feet untreated in the Core Zone.

Operation under the 20-acre exemption along fish-bearing streams should generally maintain root strength and bank integrity, so long as the stream-adjacent trees are retained in consideration of the shade rule. However, there is no requirement for distribution of the leave trees in the 20-acre exemption except for the shade rule measured from the bankfull width. Where few trees are retained along banks and additional equipment traffic occurs, root strength and bank integrity may be compromised. Where CMZs exist, streambank protection may not be provided for migrating channels.

Buffers would be required for Type Np streams on 20-acre exempt parcels where covered species may be affected; however, due to the small number of required trees and ability to clump these trees, these buffers would provide less function. In cases where covered species would not be affected, these streams may not receive any buffer. Streambank stability would likely decrease for a number of years, and may not return to previous levels for several decades.

Equipment limitation zones may not fully protect bank integrity on unbuffered Type Np streams. However, ELZs requiring on-site mitigation for any damage exceeding 10 percent of the area would also apply to 20-acre exempt parcels, as would requirements for HPAs. As a result of the increased harvest along the Type Np streams, it is more likely that effects such as soil compaction, rutting, and scraping could occur. There are also additional effects expected to understory vegetation. Mitigation would be applied when more than 10 percent of the area is disturbed, however, not all aspects of this level of activity would be mitigated by actions such as mulching and seeding. Greater traffic within near-stream areas are expected to contribute to potential bank collapse in some cases, which may result in introduction of fine and coarse sediment.

It should be noted that while 20-acre exempt parcel distribution has not been conclusively determined, we presume that these parcels are far-more common in low-elevation areas near rapidly expanding development centers. In these landscapes, fish would likely be present in a greater proportion of streams partly due to the low gradient of streams. This means that Type Np streams likely comprise a smaller proportion of the total stream network in these landscapes; and, therefore, a smaller portion of the stream network would be exposed to effects associated with 20-acre exempt treatments for Type Np streams. There is a high proportion of such streams which are low-gradient, low-energy streams where delivered sediment may not be efficiently transported. Such streams may also occur in proximity to streams with land uses other than forestry, may be degraded, and may be poorly equipped to receive additional sediment. These are also areas where soil compaction may be a particular concern, due to lack of frost heaves and soil vulnerability.

Roads

Existing stream-adjacent parallel roads may be sufficiently close to streams to compromise bank stability in rare occasions. These roads should be high priority candidates for abandonment if feasible. Stream crossings when improperly installed or maintained may contribute to local scour and destabilization of streambanks.

Research

Effects associated with habitat manipulations for research purposes are expected to occur along a very small percentage of riparian areas, be localized, and have negligible effects at a watershed scale. Habitat manipulations that would affect vegetation within a rooting diameter of steams with fish would likely be rare. Some effects may be realized on perennial streams without fish, but effects similar to those experienced under the standard rules are expected.

Summary of FPHCP Effects to Bank and Channel Integrity

Because of the retention along banks, limited yarding along most fish-bearing streams, and the preclusion of equipment from the stream channel, few direct effects are expected to the channel integrity of most fish-bearing streams. Some effects may occur along unbuffered Type Np and Ns streams, but damage within ELZs would be subject to on-site mitigation under Washington Forest Practices Rules if the damage exceeds specified limits. Effects along 20-acre exempt parcels may be more intense locally, but would still be subject to ELZs which should help reduce those effects or at least provide remediation when those effects do occur.

7.5.2.5 Soil Compaction

Much of the following discussion is derived from Technical Note 4: Soil Biology and Land Management (NRCS 2004).

Forest soils of the Pacific Northwest have very high infiltration rates due to their high porosity. Porosities ranging from 50 to 75 percent of soil volume and infiltration rates of over 200 inches per hour in the upper soil horizons are common in some soil types (Dryness 1969). Because of these conditions, overland flow and associated surface-erosion processes are not common on forest lands. High organic-matter properties make many Pacific Northwest forest soils generally low in bulk density, high in porosity, but low in strength. As a consequence, these soils are often susceptible to compaction by machines. Site preparation, harvest, yarding, and other activities that utilize heavy equipment can increase soil compaction (Spence et al. 1996). The effects of compaction are especially important because of the potential long-term consequence (on the scale of decades and centuries) of the hydrologic characteristics of soils and site productivity of second growth forests (Everest et al. 1987). In many cases, natural ameliorative processes do not rapidly loosen compacted soil, and where it remains compacted, stand growth losses can be measurable for many years.

Forest soils in Washington State are variable with their respect to vulnerability to compaction and erosion. Ideally, soils are approximately 50 to 60 percent pore space comprising a variety of pore sizes and lengths. Pressure placed upon the surface of the soil (e.g., from wheels of heavy vehicles) can compact the soil. Compaction created under roads, skid trails, and landings compresses soil particles together and reduces pore sizes. Compaction increases in severity and extends deeper into the soil profile with increased pressure and with moister/wetter soil conditions. Approximately 80 percent of soil compaction occurs on the first pass of equipment. The use of designated skid trails and restoration of landings after harvest minimizes the amount of forest land affected.

Soil compaction reduces air spaces; limits gas exchange with atmosphere; slows water movement in soil; increases ponding; slows infiltration; increases surface run-off which leads to increases in surface erosion; increases splash erosion; reduces water-holding capacity; lengthens periods of saturation; causes anaerobic conditions and can cause a shift from aerobic to more anaerobic organisms; increases denitrification (increases losses of nitrogen to the atmosphere); decreases rate of root growth and may limit rooting-depth in highly compacted soils; and reduces vegetative cover which can also lead to increases in erosion. Compaction changes the movement of air and water through soil, and can have direct effects of increasing erosion and direct discharge to streams.

Compaction can reduce infiltration of water (Tackle 1962) impede root penetration (Heilman 1981; Minore et al 1969; Taylor and Gessel 1956); therefore, compaction can effect seedling growth. It has been reported that the major effects appear to occur during the first 10 to 30 years (Power 1974), but that severely affected soils may not recover for 30 to 40 years or longer (Perry 1964; Oiwer 1974; Wert and Thomas 1981). However, Heninger et al. (2004) found that effects of compaction and rutting on seedling Douglas-fir lasted about 7 years in the Oregon Cascades, compared with about 2 years in coastal Washington, and noted that generalizations about negative effects of skid trails on tree growth have limited geographic scope. Heninger et al. (2004) noted that slightly shorter trees on skid trails represent an accumulation of small deficits in annual growth, but that annual growth was increasingly similar once seedlings exceeded breast height (about 4.5 feet).

In eastern Oregon and Washington, sites logged 14 to 23 years earlier on volcanic ash soils were measured to have 19 percent of the logged area had bulk densities which were at least 20 percent higher than unlogged areas (Geist et al. 1989). In Central Washington, average soil bulk density was 15 percent greater on skid trails than on undisturbed soils on a ponderosa pine site 23 years after logging and 28 percent greater on a lodgepole pine site 14 years after logging (Froehlich et al, 1986). Compacted volcanic and granitic soils were slow to recover on skid trails in western Idaho, and after 23 years, only the bulk density of the granitic soil's top 5 cm had returned to undisturbed values (Froehlich et al. 1985). Page-Dumroese et al. (1998) noted that stump removal to control *Armillaria* root disease increased soil bulk density by 15 to 20 percent to a depth of 30 cm.; and noted that volcanic ash soils are apparently particularly susceptible to vibrational compaction. Douglas-fir seedlings in the soil compaction treatment had lower root volumes, lower height, and smaller root collar diameters than seedlings in other areas. However, western white pine seedling root volumes were not affected and they had smaller root collar diameters but greater height in the compaction treatment.

Although trees planted on skid trails and landings are subjected to the most-severely disturbed soil (Froehich and McNabb 1984; Helms and Hipkin 1986), altered soil properties do not always result in poorer survival or tree growth (Greacen and Sands 1980; Firth and Murphy 1989; Miller et al. 1996; Senyk and Craigdallie 1997b). In some coarse-textured soils, seedling performance can be better on compacted than on undisturbed soils (Powers et al. 1999). Heninger et al (2004) found that the percentage of trees surviving two growing seasons after planting averaged slightly greater in ruts of skid trails than in nearby logged areas, in spite of increased bulk densities. Others (Youngberg 1959; Miller et al 1996) also report that survival of Douglas-fir planted on primary skid trails in clearcuts is similar to that on adjacent logged areas. For naturally seeded areas, however, Steinbrenner and Gessel (1955) and Wert and Thomas (1981) report about 20 percent less stocking on skid trails compared with adjacent areas. Trees that grow on persistent compacted surfaces may be more prone to windthrow due to shallow rooting systems. Froehlich et al. (1981 as cited in Poff 1997) indicate that modern harvesting equipment, such as cut-to-length processors and forwarders, does not compact soil, even when operating on moist soils. Compaction can also be reduced to acceptable levels using conventional ground-based equipment if designated skid trails and end-hauling are used. However, with repeated entires under uneven-aged management, skid trails may increase from the typical 8 to 10 percent of the area with each subsequent entry (Poff 1997).

Commonly used site-preparation treatments are almost as variable as the sites on which they are applied (Minore 1986). Although severely burned sites can be difficult to regenerate (Stewart 1978) and poor seedling growth has been associated with severely burned soils (Baker 1968), the effects of slash burning do not seem to last as long as soil compaction (Minore 1986). Burning can decrease the subsequent number of mycorrhizae on Douglas-fir seedlings (Wright 1971), but the resulting ash can act like a slow-release fertilizer. The direct effects of burning logging slash are usually confined to the top 2 inches of soil depth (Austin and Baisinger 1955), but this may depend on burn severity and duration, soil type, and soil moisture. Minore (1986) found that in southwestern Oregon, piling and burning slash tends to be associated with less seedling growth in 5-year old seedlings than does broadcast burning, but other factors such as equipment used in piling slash may have contributed.

Machine or hand-piling of slash also concentrates nutrient-rich branches, foliage, and sometimes topsoil. This can increase soil organism populations and activity locally. Excessive nutrient leaching can occur in areas where microbial activity increases (NRCS 2004).

Soil compaction occurs during several site-preparation treatments. Compaction may sometimes be beneficial where moisture is limiting and aeration is adequate (Lull 1959), and moderate compaction may not seriously affect plant nutrient status where moisture conditions remain satisfactory in fertile soils

(Kemper et al. 1971). Soil compaction is detrimental under most conditions, however, and the compaction that occurs during logging and slash disposal generally has a negative effect on most sites.

Effects of Soil Compaction to Soil Organisms

Soil organisms play an important role in forming and stabilizing soil structure. Fungal filaments and exudates from microbes and earthworms help bind soil particles together into stable aggregates that improve water infiltration, and protect soil from erosion, crusting, and compaction. Macropores formed by earthworms and other burrowing creatures facilitate the movement of water into and through soil. Good soil structure enhances root development, which further improves soil. By improving or stabilizing soil structure, soil organism dynamics help reduce runoff and improve the infiltration and filtering capacity of soil. Compaction reduces the diversity of pore sizes and the amount of space and pathways available for larger organisms to move through the soil. Poorly drained soils have a high level of anaerobic microsites and therefore a higher rate of dentrification (conversion of nitrate to gaseous nitrogen – which is then lost to the atmosphere) compared to well-drained soils. Ground cover at or near the surface moderates soil temperature and moisture; provides food and habitat for fungi, bacteria, and arthropods; and prevents the destruction of microbial habitat by erosion.

Reducing /Reversing Effects of Soil Compaction

Approximately 80 percent of soil compaction occurs on the first pass of equipment so repeated passes should utilize established trails whenever possible to minimize the area affected. Recovery from soil compaction may occur naturally through freeze-thaw cycles or through alternating wet and dry cycles. In severe cases, tillage (as well as ripping and subsoiling) can break-up compacted soils. Tillage of compacted soil can be effective with properly designed and used implements, but can introduce a host of other negative effects.

Prohibiting the use of tractive machines on soils most susceptible to compaction, suspending operations above specified soil-moisture content levels, or requiring the use of low-ground-pressure machines do not always reduce soil compaction. Reducing the area of compacted soil by designating skid trails may be the most economical means to maintain site productivity in the Pacific Northwest.

Effects of FPHCP on Soil Compaction

Riparian Timber Harvest

Vehicle traffic across forest soils or on heavily used trails can create ruts that compact soil and channel water. The resulting accelerated erosion, rills, and gullies can strip or bury topsoil and can have a negative effect on soil organisms. Erosion associated with vegetation shifts often results in the redistribution of top soil, organic matter, resources, and habitat across short distances. Compaction that negatively affects ground cover can lead to more erosion.

Compaction may occur whenever heavy equipment is used, including log placement, slash treatment, site preparation, road construction, road abandonment and decommissioning, etc. Equipment used in logging and yarding generally operates on top of logging slash and downed vegetation that generally forms a protective cover on much of the ground during logging operations. Ground-based logging over snow and frozen ground also can reduce the effects to the soil. Movement of heavy equipment may result in some level of soil compaction within the uppermost layers of the soil profile.

The level of compaction should be minimized by exclusion from the Core Zone. Movement of heavy equipment during timber harvest in buffers of fish-bearing streams may result in some level of soil compaction in the Inner Zone, and perhaps some additional level of compaction within the Outer Zone. Soil compaction is expected to be minimized during tractor yarding through the use of a variety of BMPs. A number of Washington Forest Practices Rules require reasonable care to minimize soil disturbance and protection of public resources. Specifically, WAC 222-30-070(5)(b) addresses high soil moisture and minimizes soil compaction.

When timber harvest occurs in proximity to streams, wetlands, and saturated soils, the potential for soil compaction is increased. Because buffered areas preclude the need for equipment to a large degree, risk of soil compaction adjacent to streams is minimal along fish-bearing streams, buffered wetlands, and buffered segments of perennial streams without fish. Soil compaction may occur within 30 feet from perennial streams without fish in unbuffered sections and from seasonal streams without slope-stability retention. Within 30 feet of streams in unbuffered stream reaches, equipment may operate under the provisions of the ELZs, but would also be subject to the mitigation requirements of those ELZ rules.

Only a minor amount of felling and bucking is expected to occur within riparian buffers of fish-bearing streams, and as such, the need for equipment to penetrate these areas would be very limited. Felled trees within the Core Zone would be left and few trees are expected to be removed from the Inner Zone. Felling and bucking within the Outer Zone and adjacent to buffers should result in minimal effects due to the use of directional felling.

Felling and bucking in riparian areas along seasonal streams and unbuffered segments of perennial streams may occur in proximity to the stream, but directional felling may increase the distance from the stream where most bucking activities would occur, and would also distance equipment needed for yarding from the stream. Provisions of the ELZ would require on-site mitigation if more than 10 percent of the area is effected. However, affecting 10 percent of the riparian zone can result in negative effects to stream habitat as well as riparian habitat. In some cases, damage may exceed 10 percent.

Skid trails are expected to be minimized as specified in the Washington Forest Practices Rules. Repeated use of designated skid trails and minimizing the number of trails reduces soil compaction providing better opportunities for replanting. Because few trips are expected into the buffered portions of riparian areas in any given location, repeated compaction should not occur. Additional trips may occur along unbuffered portions of streams where larger numbers of trees are cut. Minor rutting and soil compaction from skidding of logs may result in localized run-off and erosion, and thus to an increase in sediment delivery. Within areas being logged by the use of cable-yarding systems, soil compaction is not expected outside of landing areas. Landing areas are located at some distance from streams, usually in an elevated area alongside a road.

Minor amounts of soil compaction and rutting may occur as a result of use of heavy equipment to scarify planting sites. Understory disturbance and disturbance of duff and debris layer would be expected as a direct result of scarification.

Due to the “equal in overall effectiveness” constraints of Alternate Plans, it is expected that the effects to the aquatic and riparian environment would be essentially the same or less than what would occur under the standard rules. No substantial or measurable physical effects to soil compaction are expected due to the “equal in overall effectiveness” provisions of alternate plans with respect to aquatic and riparian function. Hardwood conversion and harvests conducted under the over-stocked template may include the use of equipment within the Inner Zone and as close as 14 to 30 feet from the streambank. Use of heavy equipment close to the streambank may result in soil compaction, especially if equipment must travel to the end of the management zone.

There would likely be slightly greater effects from yarding in riparian areas along fish-bearing streams under the 20-acre exemption as logs would be closer to stream than under standard rules. Yarding may also occur closer to streams without fish under the 20-acre exemption, especially in situations where trees are clumped for logistical convenience. Equipment limitation zones would be provided along 20-acre exempt parcels. The 20-acre exemptions are most-likely to occur at lower elevations at the urban interface. Many low-elevation areas that do not experience frost heaves during the winter may be more-susceptible to compaction. Minor rutting and soil compaction from skidding of logs may result in increased run-off and erosion

Roads

In addition, heavy equipment used for road repair and upgrading that may need to operate outside of the road prism may cause localized soil damage and compaction. This may occur in order to access fill at road crossings, for instance.

Research

Research involving habitat manipulation may at times require equipment with riparian buffers. This is expected to occur infrequently and soil compaction would typically be avoided. Nonetheless, some soil compaction may result from research activities.

Summary of FPHCP Effects to Soil Compaction

Where soil compaction occurs, it typically results in retarded soil functions until it is reversed, by frost heaves or repeated wetting and drying cycles. This recovery can take from several years to several decades to be completed. Soil compaction can result in direct effects to ground-dwelling and burrowing vertebrates and invertebrates, destruction and closing of animal burrows, and increased run-off from the soil surface that can lead to erosion. Soil compaction can change the chemical processes of the soil by reducing porous space and thus changing an aerobic environment to an anaerobic environment. This can alter the microbial composition of the soil and contribute to a loss of permeability. Heavy equipment passing over the soil can affect the surface crust of the soil, the organic-rich topsoil layer (A-horizon), and deeper layers depending on the effect of the equipment and soil conditions. A combination of rutting and soil compaction which reduces the infiltration capacity of the soil can accelerate erosion from splash erosion and channelized runoff. If left untreated, ruts from heavy equipment can provide a conduit for erosion and sediment delivery to the stream channel.

The BMPs and Washington Forest Practices Rules are expected to minimize soil compaction and rutting by requiring operators to reduce pressure of tires and tracks and to minimize rutting and other soil disturbances. Damage is also expected to be lessened due to the presence of logging slash and residual downed vegetation that generally forms a protective cover on much of the ground during logging operations. Designated skid trails would be used to manage multiple-passes where compaction is an issue. Where damage within ELZs affects more than 10 percent of the area, damage to soil would be mitigated. Some short-term effects are expected in high-elevation areas where frost heaves regularly occur. However, concern is high for some low-elevation areas, especially where frost heaves are less common. Concern is particularly high regarding susceptible soil types where significant harvest would occur in streamside areas, such as 20-acre exempt parcels. Many of these parcels may not be harvested by operators with the proper equipment and knowledge of techniques to minimize soil damage. Operators selected by small landowners can be variable in their abilities, as well as in their access to specialized equipment.

7.5.2.6 Diffuse Sediment Filtering

We examine a number of studies, including those that address routing of sediment from roads and under influences of culverts, to examine relationships between routing and filtering in consideration of all available information. We also examine specific travel distances of sediment as a result of surface erosion of harvested areas in an attempt to discern the differences.

Source of Diffuse Sediment

Erosion is the detachment and movement of soil particles whether individually, in small aggregates, or in large masses (Brooks et al. 1991). The two dominant processes of erosion on forest lands are surface erosion and mass wasting. Surface erosion is the detachment and subsequent removal of soil particles and small aggregates from land surfaces by wind or water and generally occurs gradually. Sediment-particle detachment and transport can be initiated by a variety of mechanisms including raindrop splash and/or overland flow of water. The amount of erosion generally increases with rain intensity, overland flow of water, and hillslope gradient (CH2MHill 1999). Diffuse sediment can be delivered to streams through processes such as soil creep and surface erosion. Surface erosion in Washington forest lands commonly occurs during run-off when the rainfall and/or snowmelt exceed the soil's infiltration capacity and excess water flows across the soil surface.

The role of the protective surface residue layer on the forest floor is critical in controlling erosion (Elliot et al. 1999). Loss or disturbance of this litter and duff layer through mechanical means can significantly increase erosion. Further, the decomposing root system reduces infiltration capacity resulting in increased surface runoff with the potential for increased sediment delivery to stream channels.

Not all hillside surface erosion reaches stream channels, but conduits such as roads, ditches, and skid trails increase this probability, particularly if buffer strips are not left between treated areas and stream channels (Chamberlin et al. 1991). The potential for surface erosion is directly related to the amount of bare compacted soil exposed to rain and runoff, and timber harvesting tends to compact the soil (Chamberlin et al. 1991). Skidding logs to landing sites compacts and scarifies the soil. Skid trails are responsible for most of the erosion on timber harvest units because of the removal or disturbance of the surface organic layers (Elliot et al. 1999) and the reduced infiltration rates as a result of compaction of the forest soil (Everest et al. 1987).

Some yarding activities, such as tractor yarding, can cause extensive soil disturbance and compaction that can increase splash erosion and channelize overland flow. If this occurs within riparian areas, the potential for fine-sediment delivery to streams significantly increases. Cable yarding and helicopter systems that suspend logs usually cause less soil disturbance (Murphy 1995). Site preparation and other actions which result in loss of the protective organic layer can also increase the potential for surface erosion (Hicks et al. 1991).

Soil compaction caused by heavy equipment and yarding can decrease infiltration capabilities, increasing surface runoff. Forest-management activities that substantially disturb the soil, such as yarding, burning, or road and skid trail construction, can alter both surface and subsurface pathways that transport water to streams (Thomas et al. 1993, Murphy 1995, Keppeler and Brown 1998). Logging can also alter the internal soil structure. As tree roots die, soil “macropores” collapse or are filled in with sediment. These subsurface pathways are important for water transmission and filtration. When subsurface flow pathways are destroyed over a sizable area of steep slope, the flow can be routed to the surface and increase gully erosion and sediment delivery (Keppeler and Brown 1998).

Piling and burning debris may have localized effects. Burning organic cover decreases interception capability and exposes the soil to the direct effect of raindrops, which can detach the soil and lead to increased erosion. Burning also reduces litter and vegetation that obstruct overland flow and disrupt sediment transport. Another effect fire can be the formation of a hydrophobic layer. Hydrophobic layers form when organic compounds volatilized in the surface litter are driven into the soil and condense on the underlying, cooler soil particles. This can create a water-repellent coating that may restrict, or in some cases completely impede, water movement into the soil, substantially increasing the runoff and erosion hazard on the site. The amount of water repellency that occurs is a complex interaction that depends upon fire intensity, soil texture, soil-moisture content, and the type and amount of organic matter. Water repellency does not occur as a result of fires which are too hot or not hot enough. Shrubs with waxy coatings or high oil content may be particularly prone to contributing to this phenomenon. Strongly hydrophobic layers create an effectively very shallow soil, making the wettable surface soil very vulnerable to erosion. Hydrophobic layers may also form at the surface if soils are moist or clayey, or where fire intensity is low. Surface hydrophobicity protects the soil from erosion but can greatly increase channel scour by causing rapidly accelerated runoff. Poff (1997) stated that the formation of hydrophobic layers under prescribed burning is probably rare. Hester et al. (1997) noted decreases in infiltration from prescribed burning in oak juniper types, but infiltration was still higher than adjacent unburned grassland.

Megahan et al. (1995) found accelerated soil erosion in a study where forest was clearcut and broadcast burned. The accelerated surface erosion noted by Megahan et al. (1995) occurred primarily as a result of the prescribed burning. The detailed plant surveys showed that percent bare soil and length of bare soil openings were considerably greater on burned areas of the cutting units. In addition, the prescribed burning consumed much of the litter and killed most of the residual understory vegetation. Thus, there was no long-term source of litter to protect the soil surface. They further noted that only 50 percent of the logged area was burned; the remainder had less bare soil than surrounding unlogged areas because of accumulations of logging slash. Megahan et al. stated that “Thus, it is reasonable to assume that the accelerated surface erosion occurred on the burned portions of the area logged.” They also pointed out that erosion rates need to be adjusted for delivery; and, based upon sediment budgets prepared in nearby watersheds; they used an average of 7 percent for a sediment-delivery ratio.

Travel of Diffuse Sediment

Factors affecting travel distances include hillslope gradient (Benoit 1978; Brake et al. 1997; Megahan and Ketcheson 1996; Packer 1967), density of hillside obstructions (Brake et al. 1997; Megahan and Ketcheson 1996; Packer 1967), and total eroded volume (CH2MHill 1999). Benoit’s (1978) data indicate that sediment-filtration effectiveness decreases with increasing gradient in an approximately linear fashion. Brake et al (1997) showed a positive linear relationship between sediment travel distance below culverts and hillslope gradient, while Megahan and Ketcheson (1996) found that sediment travel distance below culverts was proportional to square root of the gradient.

Several studies have demonstrated that sediment travel distances below culverts decreases with increasing obstruction density (Brake et al. 1997; Megahan and Ketcheson 1996; Packer 1967; Burroughs and King 1989), with the exact nature of the relationship varying between different studies.

Megahan and Ketcheson (1996) and King (1979) both found that sediment travel distance increases with increasing volume of eroded material. Similarly, Brake et al. (1997) and Packer (1967) demonstrated positive linear relationships between sediment travel distance and contributing road length between culverts, the trend most likely due at least in part to increased sediment volume from longer road lengths (CH2MHill 1999).

In the Oregon Coast Range, Brake et al. (1997) found mean travel distances of 16.7 and 30.6 feet from culverts draining old and new roads, respectively. In highly erodible granitic soils of Idaho, Megahan and Ketcheson (1996) found mean sediment travel distances of 173, 39, and 21 feet for culverts, rock drains, and fillslopes respectively. Also in Idaho, Burroughs and King (1989) found average sediment travel distances ranging from 26 to 80 feet for fillslopes with varying amounts of flow contribution from culverts.

Adding logging slash barriers to the fillslopes significantly reduced average sediment travel distance to 4 feet (Burroughs and King 1989). Burroughs and King (1989) stated that although the initial rate of fillslope erosion can be high compared to erosion rates on other road components; it is the transport of eroded material below the fillslopes that determines the degree to which streams are affected by fill erosion. For most mid-slope forest roads, only those fillslopes near stream crossings have a high potential to contribute eroded material to streams.

Packer (1967) found that hillslope obstructions explained one-third of the variability in sediment travel distances below roads. Obstructions on the ground clearly play a large role in sediment interception. Heatherington (1976) also found that a buffer strip prevented sediment transport to streams, whereas nearby streams without buffers had sediment delivered where soils were disturbed. In Montana, Pfister and Sherwood (1991) determined that a streamside management zone of 50 feet would suffice for sediment interception except where wetlands, steep slopes, or erodible soils occurred. The most-effective strategy for reducing management-related inputs of sediment to streams is to stop erosion at the source (McGreer et al. 1998).

Forest Roads are considered the most-detrimental forest-management operation to forest soil and water quality, perhaps accounting for 90 percent of sediment yield for forest lands (Megahan 1972a, 1974; as cited in Grace 2002). Megahan and Ketcheson (1996), Ketcheson and Megahan (1996), King (1979), and many others have studied sediment delivery to streams that originated from road surfaces. Other studies have also reported similar findings from road-diverted water (e.g., ditch-relief culverts). Travel distances from roads and ditch-relief culverts would be expected to be greater due to the additional volume of eroded material and the influence of concentrated water.

The degree of surface roughness and vegetation may be more important than distance (CH2MHill 1999). In a study of grass seeding and soil erosion, Helvey and Fowler (1979) concluded that grass seeding had little or no effect on soil surface changes in the clearcut. Their conclusion was based on their measurements, as well as observations of places where overland flow occurred. The maximum soil movement was 240 cm downslope in a severely disturbed skid trail. They observed evidence of overland flow only in the deep skid trails; and even there, soil movement was limited to a few meters. According to Gharataghi et al. (2005), almost all of the aggregates larger than 40 microns in diameter were captured within the first 5 meters of a vegetated filter strip. However, the remaining, smaller-size aggregates are very difficult to remove by filtering.

Many factors influence the ability of the buffer to remove sediments from land run-off, including the sediment size and loads, slope, type and density of riparian vegetation, presence or absence of a surface litter layer, soil structure, subsurface drainage patterns, and frequency and force of storm events (Osborne and Kovacic 1993).

Role of Riparian Zone and Vegetation in Filtering Diffuse Sediment

Streamside buffers can substantially reduce fine sediment that is transported overland (Rashin et al. 1999). The capacity of riparian buffers to control sediment inputs from surface erosion depends on several site characteristics including the presence of vegetation or organic litter, slope, soil type, and drainage characteristics. Additionally, the filtering capacity is affected by timber-harvest activities within the buffer. Although soil disturbance generally increases the sediment delivery potential, the addition of obstructions on the forest floor from tree limbs and boles associated with partial logging can offset diminished filtration (Burroughs and King 1989; Benoit 1979). These factors influence the ability of buffers to trap sediment by controlling the infiltration rate of water and the velocity of overland flow.

After evaluating the effectiveness of previous Washington Forest Practices Rules in controlling sediment-related, water-quality effects, Rashin et al. (1999) recommend that buffers "of at least ten meters should be maintained on all streams in order to avoid chronic sediment delivery and direct physical disturbance of streams from harvest-related erosion." Five relevant studies examined by CH2MHill (1999) suggest that sediment filtration typically is about 80 percent effective within 80 feet of the stream, and approaches 100 percent within 150 feet of the stream. Effectiveness depends on whether the sediment source is concentrated (road drainage, landslide scars) or diffuse (road fills, harvest activity). The inclusion of road fills and road drainage in these studies likely overestimates travel distances of sediment particles from harvest activities because total eroded volume and water concentration are likely important factors.

Effects of Proposed FPHCP on Diffuse Sediment Filtering

Obstructions on the ground, ground vegetation, duff, and litter clearly play a large role in sediment interception, as does soil-infiltration capacity, slope, aspect, and patterns of precipitation. Timber harvest measures within the RMZs of Type F or S streams, as well as buffered portions of Type Np streams would minimize ground disturbance, thus allowing natural roughness elements and intact duff on the forest floor to capture most of the fine sediment generated and delivered from upslope areas. With respect to unbuffered Type Np streams, sediment from outside the Riparian Zone would likely be filtered within the ELZ, but additional sediment generated within the Riparian Zone, especially when generated and mobilized in proximity to the stream, is likely to result in sediment delivery. Harvests under the 20-acre exemption along Type F streams should maintain sediment filtering capacity as a result of additional retention to meet the shade rule, so long as channel migration does not occur. Where the channels migrate, sediment filtering may be reduced or eliminated. Minimal buffers are expected to be retained on 20-acre exempt parcels with respect to Type Np streams where covered species may be affected. Equipment limitation zones should generally help maintain soil infiltration, duff, litter, and ground vegetation to assist with sediment filtering, yet because equipment may operate in proximity to stream, some additional sediment may be mobilized and delivered. In highly degraded reaches, this additional amount of sediment, in conjunction with reduced wood recruitment, may have detrimental instream effects – see **Effects of Activities by Resource Topic – Sediment** section.

Use of machines to construct piles has similar effects as using machines for yarding or site preparation. Burn piles may result in local changes to soil including development of hydrophobic conditions leading to small-scale increases in surface flow and erosion. Landings must be located according to WAC 222-24-035(1) and landings are essentially extensions of the road system. Broadcast burning may result in some increased surface erosion and sediment production, as well as reduced filtering. Broadcast burning requires a separate permit and does not need to be addressed on an FPA. Broadcast burning is allowed per the Washington Forest Practices Rules (WAC 220-30-100), but is becoming exceedingly rare. Over the last 5 years, approximately 2,000 acres on State and private land have been permitted. According to Darrel Johnston (WDNR, Resource Protection Division - the permit authority for this type of burning), they have issued one burn permit for broadcast burning in the last three years. WAC 222-30-100(2)(a) states that any conventional method of slash disposal may be used except in certain situations. Those exceptions include where WDNR determines that a particular method would cause unreasonable risk to public resources or site productivity. Permittees are required to follow WAC 332-24 (Forest Protection Regulations) and the State Smoke Management Plan for both broadcast and slash-pile burning. WDNR reserves the authority to impose additional requirements through the use of written burning permits and the smoke management plan (WAC 332-24-205 (13)).

7.5.2.7 Microclimate

Microclimate is a general term used to define local, fine-scale conditions. These conditions are often influenced by topography, vegetation, or presence of water (Knutson and Naef 1997). Factors that are often measured when assessing microclimate include ambient air temperature, relative humidity, wind speed, short-wave radiation, surface temperature, and soil temperature and moisture content. Riparian microclimate may differ from the surrounding macroclimate.

Generally, water, topography, and vegetation combine to make riparian areas more moist and mild, with higher humidity, higher rates of plant transpiration, and less air movement than upland areas (Knutson and Naef 1997). However, Risenhoover (Personal Communication, March 15 and 17, 2006) found that relative humidity was higher in upland areas during nights. It should also be noted that while streamside areas are often viewed as having interior forest conditions provided by riparian buffers; streamside areas are often edges of forests and streams, often resulting in various influences depending on channel width, gradient, discharge, confinement, and other factors. Risenhoover et al. (2004) reported on observed differences between 55 to 65 year old mature stands, riparian areas, and clearcuts. He found that soil moisture was highly variable and showed no consistent trend in relation to distance from streams. Soil moisture was higher in clearcuts than in forested areas. He noted that the range in microhabitat conditions in clearcuts did not differ greatly from those found in riparian buffers or mature forest stands. Diel patterns of ambient temperature and relative humidity suggested that microclimate conditions in clearcut and unharvested forests were similar except during 4 to 6 hours of the mid-afternoon. Clearcuts exhibited greater variation in temperature and humidity, being slightly cooler and wetter at night.

Riparian microclimate is reported to influence productivity, abundance, and richness of plant, invertebrate, and vertebrate communities (Hicks et al. 1991; Cummins 1975); as well as incidence of windthrow and wood delivery to streams. Changes in microclimate within riparian areas resulting from removal of adjacent vegetation can influence a variety of ecological processes that may affect the long-term integrity of riparian ecosystems (Spence et al. 1996). Microclimate affects water temperature (Geiger 1965; Beschta et al. 1987); however, riparian buffer width had no effect on stream temperature, except in the case of almost complete absence of streamside trees (Brosofske et al. 1997). See discussion under the **Effects of Activities by Resource Topic -- Water Temperature** section.

Microclimate is believed to be important to stream/riparian species such as amphibians and fish. However, microclimate effects on aquatic conditions are not well understood. No know relationships exist between microclimate and stream temperature; dissolved oxygen; production of instream organisms;

or fish species composition, production, and health (Hicks et al. 1991; Murphy et al 1986; Bisson et al. 1988; Reeves et al 1987; Magnuson et al 1979). Brosofske et al. (1997) showed little or no relationship between buffer width and air temperature or wind speed; and only weak relationships between buffer width and solar radiation or relative humidity. They found that soil temperatures, to the extent they are influenced by buffer width, appear to exert a strong influence on shallow soil-water temperature. The effects of incremental changes in microclimate on riparian and aquatic areas are essentially unknown (Ledwith 1996).

Although elevated ambient air temperatures have been an area of concern, evidence from studies of microclimate in clearcuts strongly suggests that air temperatures do not provide a good indicator of available conditions on the ground. Although temperatures and relative humidity showed larger diel fluctuations in clearcuts, soil temperatures and soil moisture remained well within the normal range found in adjacent mature forest and buffered areas along streams. A study of microclimate conditions in southwestern Washington found that air temperature at 15 cm above the ground varied more widely in clearcut areas than within forested areas (K. Risenhoover, Port Blakely Tree Farms, Personal Communication on unpublished data, January 4, 2006). The study also found that soil temperature at 15 cm below the soil-surface were extremely constant, at approximately 15 degrees C, both in clearcut areas and forested areas. Risenhoover's data indicated that air temperature was warmer in clearcut areas during the day and cooler during the nights compared to forested areas. The data also showed that clearcut areas exhibited greater diel variation in humidity and were actually more humid than forested areas during the night. Available cover conditions in clearcut areas were measured and less than 90 percent of these areas were composed of exposed soil or herbaceous cover (areas that may be more susceptible to increases in soil-surface temperatures through direct exposure to solar radiation). The majority of areas were covered with litter, organic duff, woody debris, or shaded by shrubs and that both soil moisture and soil-surface temperature were maintained by this cover. Risenhoover's study also indicated that the distribution of suitable cover typically found in clearcuts was adequate to maintain cool and humid conditions were available to amphibians. Amphibians are generally in the soil, under the duff layer or beneath some debris and living in an environment that remains pretty much constant with respect to soil temperature and soil moisture

The extent to which microclimate effects may act additively or synergistically is unknown (Brosofske et al 1997). We note that advances in technology that can be used to measure aspects of microclimate in real-time situations in multiple locations are expected to add to our knowledge of these factors in the near future. This should be especially true as investigations are designed to explore microclimate relationships in ways that are relevant to the species of interest.

Effects of FPHCP upon Microclimate

Vegetation removal causes riparian areas to become drier and hotter in the summer, colder in the winter, and accumulate more snow and ice (Knutson and Naef 1997; Geiger 1965; Beschta et al 1987). These changes occur as a result of loss of shading vegetation, loss of fog drip and sources of humidity, increased evaporation due to exposure and wind, reduced or lost interception of snowfall by forest canopies, and loss of heat- and cold-moderating forest canopy and interior microclimate.

However, substantial vegetated areas would be retained surrounding streams with fish in the FPHCP. On stable seasonal streams and perennial streams without fish, buffers would be intermittent depending on location of sensitive sites and unstable areas. Microclimate changes are expected to occur in areas that are not buffered. To the extent that these changes can affect stream temperature, and to the extent that stream temperature changes can propagate downstream, these effects are discussed under the **Effects of Activities by Resource Topic -- Water Temperature** section. To the extent that microclimate changes along streams without fish can affect amphibians, these effects are further discussed in the **Effects to the Headwater Habitat Association** section. However, it should be noted that not all changes in microclimate are directly relevant to amphibians. For instance, air temperature 6 feet above the ground may be relevant to arboreal lichens and other bryophytes, arthropods, and even nesting vertebrates. The primary determinants of suitable habitat for amphibians are likely soil temperature and moisture, both near the surface and further under the soil and/or logs and vegetation.

In general, we expect minor changes to microclimate within Type F and S buffers, including small changes in situations where roads cross such buffers. Moderate microclimate effects may occur within 50-foot buffers on Type Np streams or within de facto buffers left to address instability. Buffers on features such as inner gorges would be expected to be no larger than 50 feet from the edge of the feature because that is the most likely distance needed to avoid accelerating failure and providing root strength to the edge of the feature. We expect greater effects, especially in the short term, where no buffers would be retained or where only scattered trees are retained. Retention of shrubs and downed logs would moderate conditions at the surface and within the first few inches of soil for ground-dwelling amphibians. On the eastside, many areas are naturally drier and warmer during the summer. Where the shrub layer and understory vegetation is sparse, additional effects may occur.

7.5.3 Wood

The term "large wood" includes entire trees, rootwads, and larger branches that enter the stream system. "Functional" large wood is large enough to influence hydraulics and form a pool (Bilby and Ward 1989). "Key pieces" of large wood are larger than merely functional and are considered large enough to be effective at trapping other smaller, more-mobile pieces of large wood (Abbe and Montgomery 1996).

7.5.3.1 Baseline

Historically, there were significant amounts of wood in Washington streams and rivers. Many riparian zones were dominated by large old-growth trees that eventually served as key pieces. These riparian zones, in many cases, were not burned during successive fires as were the upland areas. Current conditions are variable; riparian conditions vary be ownership and land-use, which in turn determine streamside recruitment. Currently, large wood is often reduced in abundance and quality, especially within larger rivers. Smaller streams do not require key pieces of wood as large as those required by larger streams and rivers, and pieces of wood in small streams are subject to fewer depletion processes; therefore, because functions such as sediment storage and channel morphology can be met by smaller wood (Bilby 1995), smaller streams generally do not have as degraded a baseline condition as larger rivers.

Several recent studies have found that streams flowing through second-growth forests have reduced amounts of large wood compared with pre-timber harvest levels (Reeves et al. 2003). Past management practices and regulations tended to only address the riparian zone along fish-bearing streams and not streams without fish, which resulted in a greater proportion of wood being removed from headwater stream riparian areas and less wood being available for recruitment to these streams.

Beginning over 150 years ago, trees were often felled directly into streams, rivers, and salt water and floated to their destinations. Wood was removed from stream channels, especially larger streams and rivers, for a variety of reasons, including transportation and travel. Because many riparian areas along rivers are degraded and it takes many years to grow very large trees, large wood in rivers may continue to decrease through decomposition and transport, for some time before large key-piece wood can again be routinely recruited. Due to various land-use practices in non-forested areas, many riparian areas do not currently contribute large wood. Within forested areas west of the Cascade Mountains, many riparian areas are dominated by red alder where very large conifers once grew.

In 36 percent of the stream reaches surveyed by Beak (1998), the abundance of in-channel large wood was either fair or good for fish habitat; in 64 percent the abundance was rated poor. Results were similar for both western and eastern Washington. Approximately 55 percent of the forestlands measured had good to fair near-term, large-wood-recruitment potential in riparian zones along fish-bearing streams. Six percent were naturally poor, and 39 percent were rated poor. TFW Ambient Monitoring (Ralph et al. 1991) reported that wood loading was relatively low for flat channels with only 13 of 40 examined (32 percent) having more than 40 pieces per 1,000 feet. They also found that steeper, more-confined segments had higher counts.

Large deep pools in many areas of the Columbia River Basin had been reduced by about 58 percent on National Forests and by about 80 percent on private lands according to Sedell and Everest (1991) as referenced in FEMAT (1993). FEMAT (1993) describes this reduction in pools as being related to the loss of pool-forming structures such as large wood and refers to Bryant (1980) and Sullivan et al. (1987).

In managed forests, the past and present supply of large wood may restrict pool development in Washington streams. However, Bilby and Ward (1991) reported that the average abundance of residual large wood in streams flowing through 40-year-old second growth is 102 pieces / 1,000 feet (0.34/m), and that large-wood abundance recovers much more rapidly in small streams than larger streams. Bilby and Ward (1991) found that frequency of large wood in clear-cut and second-growth sites for steams 50 feet wide (15 m) was 50 percent and 59 percent, respectively of that found in old-growth streams of the same width. In channels 16.5 feet wide (5 m), this relationship was found to increase to 56 percent and 77 percent, respectively. The length of time needed for riparian areas to produce functional large wood after harvest depends upon the size of the stream, residual stand composition, and site potential.

Large streams that are deficient in large wood and have adjacent and upstream riparian areas bordered by riparian stands in early seral stages are likely to remain deficient in large wood longer than smaller streams because of their requirement to have large key pieces (MacDonald et al. 1991; Abbe and Montgomery 2003). However, if numerous key-piece-size wood were available in these wide stream reaches, and because wood transport distance increases with stream size, these large streams may be able to increase large wood locally by capturing downstream-transported large wood in jams developed by key pieces (Abbe and Montgomery 2003; Martin and Benda 2001; Collins et al. 2002). However, the development of key pieces of large wood is infrequent in most early-seral forests.

Although existing levels of wood might currently provide functional habitat elements in some streams, as the existing instream wood load gradually decays or washes from the watershed, existing riparian stands in many managed forests might not be of sufficient size and quantity to maintain wood loadings. In the estuarine and near-shore marine areas, the historical amount of large wood was much greater than it is today (Gonor et al. 1988). Since the mid- to late-1880s, much of the large wood has been lost to human-related activities, including timber harvest and removal of large wood to establish and maintain safe navigation channels (Gonor et al. 1988).

Large-wood enhancement has recently become a more common method for improving large-wood content in stream reaches and estuarine and marine shorelines with insufficient large wood. Large-wood placement can provide benefits to these systems by providing bank stabilization, a more-complex habitat structure, nutrient input, and substrate for invertebrate colonization, all of which would benefit fish habitat. However, it is important to note that studies regarding addition of wood have not shown consistent results, especially over the long-term. Although estuaries and marine habitats might benefit from the increased input of large wood, much of the large wood entering rivers and marine waters is removed to provide safe navigation, thereby reducing the benefits of wood placement and wider buffers to some lower reaches of major rivers and marine areas.

7.5.3.2 Importance of and Variation in Distribution of Large Wood

Large wood is one of the most important components of stream habitat for fish populations, of stream hydrology, and of stream-channel morphology (USFWS 2000). Native fish species evolved in streams that were often wood-rich. Large wood physically alters stream-flow patterns and channel characteristics, stores sediment and food, provides cover, and represents a long-term food source for aquatic organisms.

The importance of large wood varies within watersheds, within individual streams, and within individual areas or reaches of streams. Some streams are less sensitive to large wood inputs than others. The locations and principal roles of large wood change throughout the river system. In general, the influence of large wood on stream channel-forming processes and sediment storage is thought to decrease in a downstream direction. In steep headwater streams where logs span the channel, debris creates a stepped longitudinal profile that governs the storage and release of sediment and detritus. When the stream channel becomes too wide for spanning by large logs, wood is often found deposited along the channel margins. In these wider channels, large wood related fish habitat is primarily found near the stream margin and in secondary channel systems of the floodplain (Bisson et al. 1987). Some studies in western Washington suggest that as the width of the stream increases so do the diameter, length, and volume of large wood (Bilby and Ward 1989). In most fish-bearing streams, there is some degree of clumping, and the magnitude and spacing of debris clumps generally increase progressively in a downstream direction (Bisson et al. 1987). Some channels contain boulders that provide channel roughness and pool formation; other channels are dependent on large wood to form pools, store and sort sediment, and form important habitat features for fish and amphibians.

There are number of factors that may contribute to variation in large wood recruitment and channel responses. Changes in tree species composition, abundance, and input rates to streams resulting from forest management practices have differed according to location in the watershed (Bisson et al. 1987). Not all riparian areas contribute the same types and quantities of large wood. For example, some stream reaches flow through riparian areas where large-wood contributions are not possible, e.g., meadows. Not all channels respond in the same manner to large wood (Montgomery and Buffington 1997); and different channels support different amounts and quality of fish habitat. In comparing 12 studies, Light et al. (1999) found that these relationships of frequency and volume of wood changing with channel width did not hold true for Interior Columbia Basin streams.

Although large wood in streams can be very dynamic, stability of large wood pieces is important. If large wood is too unstable, its functions are diminished. Tree form may also contribute to stability; deciduous trees with broadly branching, large limbs may be less susceptible to transport than conifers of similar volume. Relatively few of the wood structures delivered to streams actually contribute significantly to aquatic function (Martin et al. 1998). Tree tops just reaching the edge of large streams do not introduce large durable wood. Structures composed of sapwood and branches are more temporary than heartwood and large pieces. Braudrick and Grant (2000) stated that large wood pieces with rootwads attached were more stable in streams.

Large-wood aggregates (log-jams) can impound gravel and water. Aggregates may be more successful at forming large pools than all but the largest individual pieces of wood. Larger pools formed by aggregates may be important habitat during low-flow periods. Wood from upstream/upslope may be important in forming aggregates, but so are key pieces.

Channel Morphology

By dissipating stream energy and creating local channel scour and deposition, large wood is a determining factor in channel morphology of many streams. Large wood of appropriate size forms and maintains a variety of structures within the stream by modifying the flow of the stream. Large wood increases the hydraulic roughness of a channel and tends to locally influence the time-rate dissipation of potential energy of flowing water. Roughness also depends on other factors such as particle sizes of bed and bank materials, stream sinuosity, bank characteristics, and streamside vegetation (Light et al. 1999). Features such as large wood are particularly important for low-gradient, unconstrained streams because they dissipate energy, stabilize banks and channels, and influence meander. Bisson et al. (1987) describe in detail how pools are formed or their geometry is modified by scour and deposition associated with stream flow over, under, and around large wood. They also describe how large wood can increase pool frequency and variability in pool depths. “Steps” in the longitudinal profile are created where a large log or accumulations of large wood form a dam that traps a wedge of sediment (Bisson et al. 1987).

The effects of large wood on channel profile decrease with increasing stream order (Harmon et al. 1986). For example, Bilby (1981) reported that channel drop formed by large wood decreased from 52 percent to 46 percent to 10 percent from small first-order streams to larger third-order streams in New Hampshire. The degree to which large wood controls stream profile is related to abundance and size of large wood and the ability of channels to bypass obstructions (Harmon et al. 1986).

Trees that fall directly onto the bank and large wood that drifts on to the shoreline can provide protection for unstable and erodible banks and beaches. Large wood also acts as a barrier to wind-transported sand and can form the nucleus for a temporary accumulation of sand (Gonor et al. 1988). Additionally, large wood can contribute moisture and nutrients necessary for the establishment of woody vegetation (Stembridge 1979, as cited in Gonor et al. 1988). Forage fish may use woody debris for spawning substrate in estuaries and near-shore areas.

Storage of Sediment and Organic Matter

The role of large wood in forming pools and storing sediment varies in relation to channel type, size, and position in the network (Swanson and Lienkaemper 1978; Montgomery and Buffington 1993; Martin et al. 1998). Large rivers sediment storage sites tend to be located on point bars and floodplains. These sites tend to be absent in steep low-order streams and large wood may account for a much greater portion of the total sediment storage in these streams (May and Gresswell 2003). In headwater streams, instream large wood influences channel morphology, sediment transport, the retention and processing of organic matter, and invertebrate communities.

Large wood creates a temporary storage of inorganic sediment and organic matter in stream channels. In these small headwater channels, large wood creates a stepped-bed profile that influences sediment storage, channel morphology, and organic-matter processing (Beschta et al. 1987). In bedrock channels where solid rock is exposed, pools may be formed by large wood, but there is no clear relationship between pool frequency and large-wood loading (Montgomery et al. 1995). On the other hand, large-wood loading can have a large influence on sediment storage and the formation of alluvial segments in bedrock channels, especially in moderate-gradient (3 to 10 percent) bedrock channels, where sediment is deposited and transported (Montgomery et al. 1996). Sediment storage by large wood also is influenced by channel size, with storage declining as channel width increases downstream (Bilby and Ward 1989).

Fish and Amphibian Habitat

Woody debris presence/absence and features of woody debris, such as surface area and cover complexity, were the dominant factors influencing distribution and abundance of summer rearing juvenile coho salmon in the relatively large river channel sampled by Peters et al. (In Prep.). Results from Peters et al. (In Prep.) suggest that river-management activities should attempt to maintain or restore complex woody debris in large river channels. In the short term, the greatest challenge for restoring woody debris is adding woody debris that will remain stable in the higher discharges associated with these larger channels. In the longer term, restoration of natural riparian trees, which gradually contribute large wood to streams, will provide optimal large-wood-based coho salmon rearing habitat, among other benefits (Berg et al. 2003).

A number of wood-removal studies are summarized in Light et al. (1999) and Rentmeester (2004). These studies showed decreased number and average size of salmonids following wood removal. The studies described indicate that a decreased supply of large wood can change the quality of salmonid habitat by reducing cover, pool habitat, protection from high flows, storage of gravels and organic matter, and hydraulic complexity. The potential consequences for salmonid growth and survival include increased vulnerability to predation and reduced winter survival, rearing and spawning habitat, food production, and species diversity (Hicks et al. 1991). In the long term, the loss of large wood in the stream channel reduces the retention of spawning gravels, the frequency of pools, the habitat complexity necessary for cover and productivity and the structure necessary for natural energy dissipation to maintain stream-channel function (USFWS 2000). However, studies regarding addition of wood have not shown consistent results.

Characteristics important for stream-associated amphibians include hydrology, the level of downed woody debris, suitable substrates, and, for some species' adults, riparian microclimate.

Some important microclimatic parameters that can be influenced by large wood include maintenance of cool soil and air temperatures, soil moisture, and air humidity, as well as reductions of solar radiation and wind velocity. Increased sedimentation in headwater streams is thought to negatively affect some amphibian species by filling interstitial spaces in the stream substrate that are important for movement and larval development (Corn and Bury 1989; Diller and Wallace 1996). Large wood forms pools, sorts gravels, and provides substrates for primary production such as diatoms and algae upon which other organisms, including amphibian larvae feed. Large wood forms habitat complexity and hydraulic complexity within the channel. Large wood also creates cover and substrates for egg deposition.

7.5.3.3 Channel Sensitivity to Large Wood

Although there is general consensus that large wood contributes to diversity within stream channels, which is beneficial to fish and other aquatic organisms, there is less agreement on the minimal amount of large wood that is necessary to support viable fish populations.

Channel reaches located where debris flows deposit are expected to have very high wood loading and fine sediments, while reaches located in the scour and run-out phase of a debris flow are expected to be devoid of wood and alluvium. Headwater segments have greater wood abundance, volume, and more key pieces than mainstem channels (Rentmeester 2004).

Large wood in alluvial streams may be the most-important component of the environment for forming salmonid habitat, particularly in coastal streams (NRC 1996). Light et al. (1999) provides a discussion regarding the channel classes (Montgomery et al. 1995) most used by salmonids and the channel classes most sensitive to large wood loading with respect to formation of fish habitat. In addition to the relationships between channel morphology and sensitivity to large wood discussed above, a channel's propensity to migrate laterally across its valley bottom may influence channel sensitivity to large wood. CMZs can have a range of channel migration potential, as well as a range of sensitivity to inputs of coarse sediment and large wood.

7.5.3.4 Sources of Large Wood

Large-wood recruitment originates from a variety of processes including tree mortality, windthrow, undercutting of streambanks, debris avalanches, snow avalanches, deep-seated mass soil movements, and redistribution from upstream. Natural wood recruitment to streams is governed by a relatively small set of landscape disturbance factors, which can be categorized as: Near-stream Riparian (bank erosion, windthrow, chronic or acute mortality), Upstream and/or Upslope (mass-wasting from landslides, debris flows, and snow avalanches), and Upstream Transport (flotation from floods and high flows). Van Sickle and Gregory (1990) suggested that, although sliding and rolling may indeed result in significant downslope movement of large wood, it may not add a significant number of new pieces of instream large wood.

Studies of large-wood recruitment processes have provided insight into the proportion of wood from various sources. Taken as a whole, these studies indicate that recruitment processes vary across landscapes. Wood enters streams via chronic and episodic processes. Chronic process, such as tree mortality and bank undercutting (Murhpy and Koski 1989) generally deliver single pieces or small numbers of trees at frequent intervals from nearstream riparian areas. When episodic processes occur, they typically add large amounts of wood to a stream rapidly in large but infrequent events, such as severe floods, landslides, and debris flows, which may originate upslope or within riparian areas (Reeves et al. 2003).

Near-Stream Riparian: Until recently many studies on wood sources in streams have focused on chronic input from the adjacent riparian zones. Such studies often found that most of the wood found in streams was derived from within a distance of about 100 feet (Reeves 2006). Such studies have acknowledged the potential role of other sources, especially in watersheds where topographic features influence the relative contribution of upslope sources of wood.

Light et al. (1999) report that Martin et al. (1998) found that 42 percent of large wood came from within 3 feet of the bank, that Long (1987) found 18 percent from that distance, and Benda and Sias (1998) found a significant percentage came from within 3 feet of the bank even where bank-erosion rates are low; possibly overwhelming all other sources where bank erosion is rapid. In some streams, especially in alluvial channels, natural stream bank erosion provides a disproportionately high degree of recruitment from the near-stream (less than 3 feet) riparian area.

Murphy and Koski (1989) report that, in a southeastern Alaska study, bank erosion was the dominant wood-recruitment mechanism in alluvial channels, and windthrow was the dominant mechanism in bedrock channels. Mass-wasting was the least-important process across all channel types and gradients studied. Martin et al. (1998 as cited in Light et al. 1999) reported that 65 percent of the trees in 1 to 7 percent gradient channels were recruited by bank erosion. In steeper, small (first- to third-order) channels, McDade et al. (1990) reported that only 11 percent of the large wood whose source could be identified reached the stream by bank erosion as evidenced by attachment to the bank, and 89 percent was derived from windthrow and other processes. They stated that although many of the specific delivery mechanisms were unknown, much of the wood probably was derived from pieces that floated in from upstream, and many probably were recruited by upstream bank erosion. Long (1987) studied large-wood recruitment mechanisms for an entire fourth-order basin in the Oregon Coast range with a history of active mass wasting, logging, and fire. Near-stream riparian sources contributed 41 percent of large-wood pieces by windthrow and 19 percent by bank cutting, while landslides contributed only 2 percent.

Upstream/Upslope: In mountainous environments, shallow and deep-seated landslides and debris flows can recruit large wood to channels and valley floors (Swanson and Lienkaemper 1978; Keller and Swanson 1979; Reeves et al. 1995). The primary recruitment zones for large wood from mass wasting include inner-gorge landforms along streams of all orders (sizes) and debris flows that start in headwalls and scour first-and second-order streams. Inner gorges can occur along both fish-habitat streams and non-fish-habitat streams. The large-wood source areas of unstable slopes vary in width, depending on the geologic hazard and travel distance of soil material.

Colluvial channels (as defined by Montgomery and Buffington, 1997) receive wood from further upslope than alluvial channels. Colluvial channels lack the capacity to transport wood by fluvial redistribution, and therefore, small streams often store large volumes of wood that can be episodically transported by debris flows (May and Gresswell 2003). Accumulated sediment and wood may be episodically evacuated by debris flows and transported to larger channels (Benda et al. 2005).

In steep terrain, landslides and debris flows are potentially important mechanisms. Stream-side-derived pieces tend to be more evenly distributed among reaches within the stream system. Upslope-derived pieces tend to be located primarily in the middle stream reaches, often located in aggregates at or near tributary junctions, and were often broken and debarked (Reeves et al. 2003). Stream-side-derived pieces were predominantly in the influence zones (per Robison and Beschta 1990) that had least contact with the low-flow channel and upslope-derived pieces were predominantly in the zones of influence that had the most contact with the low-flow channel (Reeves et al. 2003). Topographic features of a watershed influence the relative contribution of upslope sources. Steeper, more-dissected watersheds will likely have a greater portion of wood from upslope sources. Stream-side-derived pieces were on average 3-times the volume of upslope-derived pieces. The combined volume derived from streamside sources was twice the combined volume of upslope sources in pool and glide habitat, although the volume of upslope derived pieces was approximately equal in riffle habitat. Reeves et al. (2003) stated that in this instance the difference between the mean volumes of the pieces of wood from each source was likely a result of the fire history of the studied watershed.

Debris flows scour sediment and organic matter from steep 1st-order and 2nd-order channels and create deposits (debris fans) at tributary junctions in higher-order streams (Benda et al. 2003). Debris flows are known to originate in reaches with slopes of 20 percent or greater and to deposit in reaches with slopes ranging from 3 to 11 percent (Swanson and Lienkaemper 1978; Benda and Cundy 1990). Additional material may be entrained in intervening areas. Typically, landslide deposits function as fans or terraces, causing the entrained pieces of large wood to become accessible to the stream channel only gradually over many years (Swanson and Lienkaemper 1978; Benda 1990). However, debris flows may deposit at tributary junctions or along main-stem channels. Landslides are more likely to deliver large wood to non-fish-habitat and small, steep, mountain streams than to fish-habitat and alluvial streams due to steeper topography surrounding the former. Debris flow deposits at confluences act as sources of increased morphological heterogeneity depending on volume of deposit and energy of receiving channel. In small channels, high wood storage may persist for a century or more following a debris flow (Benda et al. 2003).

Mass-wasting can be locally important, especially when a landslide event occurs above a fish-habitat reach. However, the long-term recruitment of large wood to 1^{st}- and 2^{nd}-order channels from debris flows on a 500-year cycle was estimated to be a relatively low 12 percent (Swanson et al. 1982b; Benda and Dunne 1997; Benda and Sias 1998). Hence, landslides and debris flows may create the highest point loading of wood in streams, but the long-term contribution will be less important. It will usually be a fraction of the contribution from bank erosion and windthrow.

In the steep, forested terrain of the Pacific Northwest the contribution of large wood delivered by landslides or debris flow from the upslope may account for more than half of the wood in a stream (Reeves et al. 2003; May and Gresswell 2003). In Coastal Oregon, preliminary results suggested large-wood recruitment from upstream sources ranged between 11 and 59 percent (Gresswell and May 2000). Murphy and Koski (1989) found landslides accounted for 4 percent. Wood delivered by landslides and debris flows may be higher in V-shaped valleys than in broad U-shaped valleys, because V-shaped valleys have high connectivity between hillslopes and channels and between headwater streams and larger rivers (Martin and Benda 2000). Reeves et al. (2003) found that the amount of upslope-derived wood was greatest in reaches with narrow valley floors.

Landslides and debris flows are capable of forming large accumulations of wood at locations in the network where fluvial processes may not be competent to transport large quantities of wood. In channels that are narrow or have a small drainage area, it may not be possible to transport large wood by flotation during high flows (Swanson and Lienkaemper 1978; Martin and Benda 2001). Even in watersheds where the potential contribution from upslope sources of wood is high, the ability of individual upslope sources to contribute wood to fish-bearing streams can differ widely.

Wood can be transported from upstream during high-flow events, avalanches, and from debris torrents, which includes dam-break floods and debris flows (Swanson and Lienkaemper 1978). However, movement of wood in high-flow events are more common in third- to fifth-order streams because much of the wood that falls into streams is too large to float in smaller streams (Swanson and Lienkaemper 1978). Although less frequent than high-flow events, debris torrents can introduce and move large amounts of large wood (Lamberti et al. 1991). The majority of debris flows and dam-break floods are initiated in low order streams, primarily second-order streams (Coho and Burges 1991). Transported wood, although individually small, is important to the formation of aggregates, which are important habitat features in larger rivers.

Flotation from upstream reaches increases in importance as stream size, order, and upstream watershed area increase. During high-flow events, logs are moved downstream resulting in depletion from one channel reach and recruitment to another. Depletion of wood from a given reach occurs through downstream transport, decay, and fragmentation (Bilby and Bisson 1998).

Debris torrents contribute only relatively minor quantities of large wood to downstream channels over time and across the landscape (Benda and Sias 1998). The channel gradient and degree of channel migration also are key variables that affect wood delivery from upstream. Long (1987) recognized upstream processes (flotation and debris torrents) as potential, but less-important, delivery sources. Long (1987) found flotation contributed only 28 percent and debris torrents contributed only 2 percent. Clearly, the percentage of large wood contributed by flotation decreases with increasing distance upstream, as stream size and hydraulic energy decrease.

The transport of large wood in headwater streams may be even more restricted than transport of sediment. Numerous studies have documented that wood longer than the BFW is less likely to be transported by streamflow. Because headwater streams commonly have widths of only a few meters and contain wood that is substantially longer, transport in them of large wood by streamflow would be very rare. This leads to large buildups of wood in headwater streams. However, in certain topographies, debris flows are an effective agent for scouring stored wood from headwater channels and transporting it downstream to larger channels (Benda et al. 2005).

Comparison of Coastal and Interior Large Wood Relationships

Compared to equivalent situations on the westside, Light et al. (1999) found that large wood frequency is generally lower and volume was generally smaller. Light et al. (1999) found that frequency of pieces increased as stream gradient increases. They also examined whether pieces per channel width in unmanaged interior streams was related to pool spacing or percent pool area and found no consistent relationship. Examination of the studies did not support the hypothesis that, in managed stands, frequency of large wood was lower, size was smaller, or pool spacing or pool area were lower. Light et al. (1999) found that some studies indicated a lower volume of large wood in managed stands while other studies did not.

Although most large-wood studies were conducted in coastal forests of the Pacific Northwest, the role of large wood in Rocky Mountain streams appears to be quite similar. Richmond and Fausch (1995; Cited in Light et al. 1999) found that although large wood in Rocky Mountain streams had smaller diameter, length, and volume than in coastal Pacific Northwest streams, its abundance and function were similar. They concluded that the function of large wood in forming fish habitat in small Rocky Mountain streams was strongly influenced by the stream's location within the watershed. Stream size and gradient appeared to exert significant influence on the characteristics and function of large wood in the studied streams.

Eastside riparian forests and functions differ from those on the westside. Differences include the size and density of riparian stands, species compositions, mortality factors and rates, large-wood-recruitment processes, and lack of large wood/channel width relationships as reported for westside streams (Bilby and Wasserman 1989; Knight 1990).

For example, mass-wasting is a more important mechanism in steep, highly dissected topography receiving significant amounts of rain or rain-on-snow, such as is commonly found on the westside. Tree heights on the eastside are generally shorter. The tree-diameter distributions for unmanaged, mature eastside forests tend to have a wider range of diameters and be skewed towards smaller trees; whereas westside forests have very high timber volumes associated with a narrower range of diameter trees (Powell et al. 1994). Tree densities in eastside riparian forests often are lower. Naturally-open meadows, willow thickets, other hardwood stands, and riparian areas lacking trees are more common in the eastside (Beschta 1997). eastside tree mortality more often is caused by fire, insects, and disease, and less often by windthrow. Fire would be more prevalent if not controlled by fire-suppression efforts. Insect and disease are responsible for about 40 percent of tree mortality in ponderosa pine forests (Harmon et al. 1986). Relatively low depletion and transport rates may be likely for large wood in Interior/eastside streams as evidenced by the lack of a relationship between channel size and characteristics of large wood (Light et al. 1999).

Consequently, large-wood recruitment mechanisms for trees to the stream channel are unique for the eastside. Stream capture and deadfall are the most-common recruitment mechanisms; and mass wasting, windthrow, and transport from upstream are the least-common mechanisms cited by watershed analyses (Light et al. 1999). Also, slower growth and different or changing mortality agents suggest unique mechanisms for eastside forests. These differences contribute to important differences in the frequency and volume of in-channel large-wood loading levels, which are naturally lower in eastside streams (Knight 1990; Overton et al. 1994; Bilby and Ward 1989; Bilby and Wasserman 1989; Bilby 1996).

Summary of Sources and Mechanism of Recruitment

The field studies cited above describe a limited time frame for large-wood recruitment. It remains difficult to assess the relative importance of recruitment processes over decades or centuries. These studies indicate that delivery processes vary substantially by stream segment. Stream size and topographic setting strongly influence processes that deliver wood to the channel network (May and Gresswell 2003). Bank erosion is limited in steeper channels (i.e., first- and second-order non-fish-habitat streams), and more prevalent in flatter channels (i.e., third-and fourth-order fish-habitat streams). Steeper, more-highly dissected watersheds will likely have a greater proportion of wood coming from upslope sources than will watersheds that are less dissected or steep (Reeves et al. 2003).

Quantity of large wood in streams is variable in space and time because wood recruitment and transport are driven by episodic disturbances. Relative importance of recruitment mechanisms varies with time and space. Variables in recruitment include riparian stand conditions (height, species composition, density, etc.), relative importance of streambank erosion, and landscape processes (debris flows and floods). Relative contributions of near-stream riparian zones and upstream/upslope processes vary by geographic area and remain a subject of scientific discussion. However, adjacent riparian areas are perhaps the better predictors of the larger LWD pieces (i.e., key pieces), which are less easily entrained and thus more readily remain in close proximity to their origin (Fox 2003). Yet, forest management that relies primarily on recruitment of wood from riparian buffers along the larger fish-bearing streams may result in much lower levels of wood recruitment than the historical range of conditions (IMST 1999).

7.5.3.5 Source - Distance Relationships

CH2MHill (1999) compares a number of studies regarding source-distance relationships. Primary factors in determining probability of delivery are distribution of tree fall directions, height of tree, and distance from stream. Often a uniform distribution of fall directions is assumed in modeling, which under estimates the number of trees that fall towards the stream. Probability of tree fall intersecting stream is related to distance to stream, height of tree, taper, diameter, slope, wind direction during storms, bank erosion, mortality rates, soils, etc. McGreer and Andrus (1992) report that windthrown conifer trees in the Oregon Coast Range had an 83 percent probability of falling into the channel when located within 10 feet, but only a 19 percent probability when located at 100 feet. Recent studies in western Washington and Oregon demonstrate some effect of slope on tree-fall direction (Minor 1997, Andrus 1998; as cited in Light et al. 1999). To determine the probability that a tree will deliver functional large wood, height of tree to “effective” size should be substituted for total height. Unpublished data by Beschta (referenced in

Robison and Beschta 1990) suggest that on hillslopes of 17 percent to 70 percent slope, the probability of a tree falling downhill is 75 percent.

While a portion of a tree may fall and land within the stream, it may not be a piece of sufficient size for formation of pools, thus, even large trees may not produce large wood (key piece) if located far from the stream. Gehringer (2004) modeled mean cumulative percent of volume for various stream classes with distance from stream. Depending on bankfull width, between 94 and 98 percent of the functional large wood volume was recruited within 70 feet from the stream. For larger streams (75 feet bankfull width), 95 percent of the functional volume was recruited within 50 feet. For smaller streams, 3 feet to 33 feet bankfull width, 85 percent to 87 percent of the functional volume was recruited within 50 feet of the stream. McKinley (1997 Cited in HCP) found that 95 percent of large wood originated within 50 feet of the streambank for small streams bordered by second growth in northwestern Washington.

7.5.3.6 Wood-Loading Levels

Wood loading is controlled by channel size, riparian forest condition, channel type, landscape type, and frequency of catastrophic events. As channel size increases, so does the ability of the stream to move increasingly larger logs. Wood loading is a function of existing wood, wood recruitment, and wood depletion. Abundance of wood at a given time is likely to affect future abundance for 50 to 100 years, with the effect decreasing over time.

Martin et al. (1998) suggested that maximum pool development in alluvial channels occurs at about 3 channel widths per pool, and under a load of approximately 120 pieces per 1,000 feet. This hypothesis is generally supported by Montgomery et al. (1995) and Beechie and Sibley (1997). The effectiveness of large wood for forming pools declines with an increase in large wood load, and the relationship varies by geomorphic channel type. Montgomery et al. (1995) and Beechie and Sibley (1997) provided a geomorphic context (i.e., gradient, channel confinement, channel width, and substrate size composition) for interpreting the differences in large-wood relationships. Both studies showed that the relationship between pool formation and large wood was stronger in moderate-gradient (2 to 5 percent) plane-bed channels than in low-gradient (less than 2 percent) pool-riffle channels. Montgomery et al. (1995) examined higher-gradient (step-pool) channels and did not find a significant relationship between large wood and pool formation. None of the studies explicitly address the amount of large wood needed to form habitat, though the Montgomery et al. (1995) data showed a clear reduction in channel response (i.e., pool formation) to increased large wood load when large wood was greater than about 91 pieces/1,000 feet of stream length. Beechie and Sibley (1997) concluded that when the number of large wood pieces (greater than 8 inches in diameter) reaches about 122 pieces/1,000 feet of stream length, pool formation is less sensitive to further increases in loading of large wood.

In small- to moderate-sized alluvial streams, pool frequency increases with increasing large wood load. At higher loads, the effectiveness of large wood to influence pool frequency diminishes.

The influence of large wood on pool frequency is less effective in low-gradient channels (less than 1.5 percent, with a pool-riffle morphology) compared to moderate-gradient channels (1.5 to 3 percent, with a plane-bed or forced pool-riffle morphology) (Montgomery and Buffington 1993; Montgomery et al. 1995; Beechie and Sibley 1997).

Headwater Streams

In steep and bedrock channels, pool formation is not closely related to the large-wood load. The primary function of large wood in these channels is for debris dams and sediment storage, not pool formation. Debris dams formed by large wood can influence sediment storage, local channel gradient, substrate size, and the creation of alluvial habitat (Keller and Swanson 1979; O'Connor and Harr 1994; Montgomery et al. 1996).

Data from the TFW small streams study (TFW and Sullivan 1999) show that the size of logs that form steps equals the size mix in the channel (Dieu 1999). Therefore, all sizes of wood, not just large wood, function to form debris steps and provide sediment storage in small streams. Bilby (1995) projected that the amount of large wood in the channel would range from 86 to 125 pieces/1,000 feet over two 40-year rotations after clearcutting under then current Oregon forest practices rules, with a slowly increasing trend over time. The amounts of large wood at their peak would be similar to the median large wood loads reported for old-growth forests (i.e., 76 to 88 pieces/1,000 feet of stream length (Bilby and Ward 1989; Ralph et al. 1994). Importantly, Bilby (1995) found that large wood delivered from regrowth would exceed the amount lost by depletion over the rotation period. Based on the TFW small streams study, nearly all of the large wood would be large enough to function in debris jams and sediment storage sites (TFW and Sullivan 1999).

It is difficult to predict the actual large wood yield of proposed prescriptions without site-specific modeling or empirical data. Forest growth models are available to predict ingrowth and mortality, and the size and timing of large-wood delivery (e.g., Andrus 1998; Welty and Sullivan 2000), but none can anticipate all of the reach-specific conditions and processes found across the landscape. Short- and long-term large-wood recruitment would depend on actual large wood delivery by riparian areas relative to the depletion of large wood in the stream (Bilby and Wasserman 1989). For the short term, functional wood loads would depend on the current status of riparian forest, wood-delivery processes, and individual tree growth and mortality rates.

In general, over the long term, functional large-wood loads decrease as stands approach maturity (Bisson et al. 1987). Stem exclusion processes provide large initial inputs of wood over the first 150 years (Fox 2003). Fox (2003) also reports that mortality of trees is again high in stands approximately 550 years of age. Huff (1995) illustrates that significant mortality of Douglas-fir occurs around 400 to 500 years. The amount of large wood declines as stands mature because tree input decreases with decreasing stand density. Therefore, mid-succession stands provide for production of large-wood pieces and maintaining aquatic habitat, at least along smaller confined streams where size of large wood is less important. Delivery of large wood continues to exhibit cyclical pulses timed to forest growth and tree harvest and, perhaps, natural-disturbance events in some regions (Agee 1993; Everett et al.1994).

Large wood in channels with boulder and bedrock material contributes relatively little to pool formation. However, some bedrock channels were formerly forced pool-riffle systems which lost their ability to retain sediment deposits due to reductions in large wood presence (Montgomery and Buffington, 1997). In constrained channels, about 10 percent of large wood pieces function to affect spawning gravel retention. In alluvial channels, about 40 percent of large wood pieces functioned to influence gravel bar stability (Martin et al. 1998). Loading in streams is heavily influenced by both chronic and episodic recruitment, and chronic and episodic depletion. Wood loading is therefore difficult to predict.

7.5.3.7 Effects to Large Wood Resource

To predict the amount of potential recruitment provided during the 50-year permit term, FWS believes it is appropriate to use the 100-year site index tree height for estimates of stand height in association with streamside source-recruitment distance curves. Most existing stands are less than 50 years old and would achieve an age of 100 or less during the permit term. However, to assess long-term effects that may continue beyond the 50-year permit term, it is more appropriate to use the 250-year site potential tree height estimates for stand height.

As an example, a tree that is currently 50 years old might be harvested 30 years from now in 2036 when it might be 150 feet tall. If this tree is 120 feet from the channel, it may have had a small probability of reaching the stream had it fallen naturally, and even then would have had limited ability to contribute functional size wood (e.g., only the upper 30 feet would have reached the stream). However, in 2136, that tree might have grown to exceed 200 feet tall and had a higher probability of delivering large wood to the channel if it had fallen naturally. The FWS considers these longer-term conditions and effects in this analysis. Estimates will also vary by Site Class – values presented in this analysis are generally for site class II, unless otherwise indicated.

Potential Effects from Forestry

Forest practices can have positive or negative effects on the rate and magnitude of large-wood recruitment. They affect the rate of large-wood delivery through silvicultural treatments that influence forest and individual tree health and that influence a forest's susceptibility to catastrophic disturbance events such as wildfire. Thinning and partial harvest influence the growth rates of residual trees and the rates at which trees attain functional sizes for large-wood recruitment. Also, forest practices can influence the future composition of large wood by favoring certain species; for example, treating alder-dominated riparian forests to favor longer-lasting conifers. Woody debris produced by deciduous trees tends to be smaller, more-mobile, and shorter-lived in streams when compared to conifers. Practices that remove trees from riparian areas (harvest, thinning, and salvage) can have the potential to directly and indirectly affect delivery of large wood. Trees damaged during logging may die soon afterwards and be recruited quickly, as opposed to surviving longer and growing to a larger size prior to recruiting. As an indirect result, a pulse of mortality may occur following harvest in adjacent areas from causes such as logging or yarding damage, sun scald, or windthrow.

The following assessment is based primarily on expected harvest upon attainment of economic maturity (stand age about 50 years) and upon watersheds composed of lands under FPHCP jurisdiction. We attempt to project effects through and beyond the proposed 50-year permit term. We recognize that the common practice of uneven-aged management east of the Cascade crest will alter the timing and nature of harvests.

7.5.3.8 Effects of the Proposed Action on Large Wood

Fish-bearing Streams

Riparian Management Zones: There will be no timber harvest within Core Zones of fish-bearing streams, and post-harvest Inner Zones must meet DFC as well as specified retention levels, which will limit the removal of recruitable large wood. Management in the Inner Zone would be allowed only if growth projections for Core Zone and Inner Zone indicate that the stands would be retained on a trajectory toward DFC. Moderate levels of removal may occur within the Inner Zone during westside thinning as only 57 trees per acre need be retained and DFC is unlikely to require a greater number of trees. Substantial removal of trees could occur from the Outer Zone and beyond, but this is an area where the probability of delivery is less likely and the size of wood delivered would also be smaller (e.g., only tops).

The combination of the zones is expected to provide over 90 percent of the recruitable wood expected during the permit term regardless of which management option is chosen. Beyond the permit term, the effects may persist through time. When assessed against the 250-year estimate of the SPTH, 80 to 85 percent of the recruitable wood is expected to be retained as a result of thinnings along small and large streams respectively. However, this estimate does not account for the off-setting accelerated growth of retained trees following thinning. Using the 250-year SPTH, 90 percent of the recruitable wood would be retained as a result of harvests under the packing option.

The majority of the large wood delivered to the channel originates within 50 feet of the channel. The benefit of each additional increment of buffer width decreases precipitously beyond the first 50 feet. Only a small portion of the large wood delivered to the stream is derived from beyond 100 feet. The Core Zone would supply the majority of wood that could be recruited during the next 50 years. The Core Zone may supply about half of the wood that could be recruited in the next 200 to 250 years. Together with additional no-harvest areas or partial-harvest options within the Inner Zone, the majority of recruitable wood is expected to be retained. The timber harvest in the Outer Zone would affect only a small portion of the recruitable wood supply. These relationships developed for large wood are even more pronounced for functional wood or key-piece-sized wood. A greater portion of the key-piece-sized wood will be recruited from closer to the stream.

However, as stated above, timber harvest would not be allowed in the Inner Zone until sufficient trees could be retained in the Core Zone and Inner Zone to meet DFC. The thinning option would only be used to remove the smallest trees and the proportion of trees that are conifer would be retained. When harvest would be permissible under FPHCP, the requirement to retain 57 trees per acre in the Inner Zone is expected to be more restrictive than DFC requirements.

The thinning option would accelerate the diameter growth of the leave trees within the Inner Zone by removing competition. This makes it more likely that when trees eventually fall into the stream, the tree bole reaching the stream will be large enough to provide functional habitat attributes. However, thinning would inhibit suppression mortality even though most of these trees were unlikely to reach the stream or be large enough to function in many streams. Suppression mortality affects the smaller, weaker trees in a stand which often fall apart in place rather than fall intact. The largest trees within the Inner Zone would be retained and thinning would promote faster tree growth. Thinning would produce a larger proportion of functional-sized trees at an accelerated pace that would compensate for the loss of smaller, thinned trees.

The thinning option is expected to maintain 91 to 96 percent of recruitable wood during the permit term (along small and large streams respectively), based upon estimates of typical amounts of tree removal during thinning. In some cases, such as stands with dense, smaller-diameter trees, the actual amount of removal may be higher resulting in decreased potential recruitment. Even under the worst-case scenario, the FWS expects retention of more than 80 percent of the potential recruitable wood. In these situations, the retained trees should grow at an accelerated rate.

In contrast, the packing option, concentrates retained trees where competition will be higher and growth rates diminished. The packing option does retain trees closer to the stream where they will have a high probability of recruitment. One effect of no-harvest options within the Inner Zone is that there will be no opportunity to accelerate diameter growth. Only a small portion of the recruitable large wood is derived from the Outer Zone, and the portion of these trees that could reach the stream would consist mainly of tops. Therefore, production of functional and key-piece wood is dependent on the condition of the Core and Inner Zones. Yet, clumping leave trees around sensitive areas and minimum tree-retention requirements (i.e., 10 to 20 trees per acre) in Outer Zones would maintain some of the large-wood supply for those sites.

On the eastside, the FPHCP would allow management of RMZs in a manner that can address forest-health concerns. A Core Zone of 30 feet would retain about two-thirds of the recruitable wood during the 50-year permit term. The remainder of the RMZ could be managed, but only in a manner that would retain the largest trees. This will allow managers to managed species composition and stocking density in the face of current forest-health issues. However, removal of suppressed and off-site species will still influence the recruitment of large wood. Management under the various categories of treatment (based on basal area and species composition) would retain approximately 90 percent of the recruitable wood during the permit term. Using the 250-year SPTH, it is estimated that management would retain over 80 percent of the recruitable wood.

Retention of potential large wood recruitment does not include all potentially recruitable wood. Some of the potential recruitment will be removed during harvest along Type F and S streams. However, due to diminishing return of additional large wood in terms of pool formation and sediment storage, retaining the majority of potential wood recruitment should provide the vast majority of potential function. In addition, wood closer to the stream channel (that most likely to be retained) is the most likely to provide higher-quality pieces. In spite of this, some adverse effects to instream habitat may result from less than natural rates of large-wood recruitment.

Alternate Plans: Timber harvest within fish-bearing stream buffers under alternate plans is expected to provide similar levels of potential large-wood recruitment. However, some alternate plans may provide enhanced large-wood recruitment such as those Alternate Plans that addressed young over-stocked stands. Young, dense stands will be subject to suppression mortality, but this mortality would be smaller than functional or key-piece size for most streams, and such smaller trees will decay upright rather than deliver (due to small size of dead tree and support from branches of adjacent trees). However, following treatment, density of stands will be reduced and allow accelerated growth of boles to functional or key-piece size. Due to the “equal in overall effectiveness” constraints of Alternate Plans, it is expected that the effects to the aquatic and riparian environment will be essentially the same or less than what would occur under the standard Washington Forest Practices Rules. No significant or measurable physical effects to large-wood recruitment are expected due to the “equal in overall effectiveness” provisions of alternate plans with respect to aquatic and riparian function.

20-acre Exempt Parcels: Where the 20-acre exemption would be applied to timber harvest along fish-bearing streams, there may be a substantially higher level of harvest than discussed above for standard RMZs, resulting in a substantial reduction in potential large-wood recruitment. WDNR (2005) (Appendix J, part 2, Exempt 20-acre parcel riparian management zones: an assessment of riparian function) reported that in a statewide sample of 37 RMZs established on 20-acre exempt parcels during 2003, 32 (or 86 percent) were treated as no-harvest areas and only two had 15 percent or more of the trees removed from the RMZ. This assessment attributes the low frequency of RMZ harvest to shade-retention requirements and shade-analysis requirements. According to the assessment, potential large-wood recruitment from 20-acre exempt riparian buffers would range from 45 to 95 percent and 75 to 100 percent for mature conifer and mature hardwood forests, respectively. In the worst of these reported conditions, recruitment of conifer could be reduced up to 55 percent if there were no other factors involved.

However, 20-acre exempt buffers are only measured from the bankfull width and not the outside of the CMZ, even if that distance is greater. As a result, large-wood recruitment may be reduced even further in riparian areas associated with CMZs. Additional trees within the RMZ may need to be retained to meet the Shade Rules, but a reduction in potential large-wood recruitment is nonetheless expected along fish-bearing streams, especially those with CMZs. Additional effects to large wood recruitment could result if harvests were conducted more aggressively than assessed in WDNR (2005) (Appendix J, part 2). Harvests per the 20-acre exemption will reduce instream functions as a result of less large-wood recruitment.

Species Control and Hardwood Conversion: Red alder is a common species in RMZs of western Washington. Stands of alder often begin to senesce at about 60- to 80-years of age. Some RMZs are dominated by red alder and there is little or no conifer understory. Conifers and some hardwoods are relatively resistant to decay and abrasion in the stream channel, other hardwoods, such as red alder, decay and break up more rapidly after falling into channels (Harmon et al. 1986; Newton et al.1996). A recent study reported that 30 to 52 percent of the riparian forests along westside streams currently supporting fish are dominated by red alder (Washington Hardwood Commission 2000).

Hardwood conversions would remove a source of large wood (harvested deciduous trees) that would have been available in the short term, but would not have been very persistent once delivered. Removal of alder and planting conifer would eventually result in conifer of key-piece size with potential to deliver to stream and to persist as large wood for extended periods of time. When adjacent stream segments are large-wood depauperate, hardwoods with root wads attached may be added to the stream, but large-wood placement is limited and often is not persistent. Large wood from conifers will take longer to recruit than if alder were retained, but conifer will eventually provide more-persistent large wood. The effects resulting from hardwood conversion will be ameliorated by a no-harvest Core Zone adjacent to the stream which will help retain some recruitable wood during the interim period which may last several decades.

Controlling species composition is often a silvicultural objective on the eastside, along with management of ladder fuels, to address forest health and risk of catastrophic fire. When timber-stand-improvement activities are conducted within RMZs some eventual reduction in large wood may result. However, these effects are generally negligible as only very small trees are slashed and the remaining riparian forest is alleviated from some moisture stress. These activities are not expected to change the assessment of post-harvest RMZs in eastside stands.

Channel Migration Zones: CMZs will not be subject to timber harvest. Wherever CMZs occur, with the exception of 20-acre exempt parcels, RMZs are measured from the outer edge of the CMZ. Therefore, along streams with CMZs, there will be a much higher level of large wood retained than assessed for fish-bearing streams in general. All of the wood available to streams from within the CMZ is expected to be retained under the standard Washington Forest Practices Rules.

Yarding Corridors: Although they are not common, yarding corridors will be placed across fish-bearing streams in some situations. The number and size of clearings in RMZs are to be minimized. Total openings must not exceed 20 percent of the stream length associated with the harvest unit. Trees cut to create yarding corridors within the Core Zone must be retained as downed logs. When trees are felled to construct yarding corridors, those trees will remain in place as downed wood, or may be recruited into the streams. Trees felled to create yarding corridors will result in a localized pulse of downed wood for the stream and riparian area. Where yarding corridors are used in association with Type Np streams, additional trees would be required elsewhere to account for lost basal area.

Downed Wood Retention: The removal of downed logs from RMZs could have an indirect effect on current and future in-stream large wood. Removal of downed wood in riparian areas may affect reestablishment of some conifers, such as western hemlock and spruce because they may rely on decomposing nurse logs elevated above the forest floor (Spence et al. 1996).

On the eastside, 12 to 30 tons/acre of down wood in specified material sizes must be retained in the Inner Zone following harvest, if initially present, depending on the forest-habitat type. Down wood retention is intended to provide surface roughness and detain overland flow. Retaining downed wood under FPHCP would provide a balance between retention of woody debris and reduction of fire hazard. Retained downed wood within RMZs may be recruited during high flows.

Large-Wood Placement: Large-wood placement is an available option to reduce the number of leave trees in the outer RMZ. Placement of large wood in Type F or S waters would be conducted under an HPA. Wood placement guidelines are contained in the WFPB manual. Even assuming that all guidelines are followed and that appropriate sites are selected, these activities are unlikely to be very effective at the landscape scale. The persistence of such large-wood-placement projects may be short, and these activities are limited in number and can therefore only affect a small area. However, when such activities are conducted, they are more likely to contribute to aquatic habitat than trees in the outer RMZ that were replaced.

Streams without Fish

There will be some reduction in large-wood recruitment from riparian timber harvest with retention of 50-foot buffers along Type Np streams. It is estimated that about 70 percent of the recruitable wood during the permit term may be retained by 50-foot buffers. Partial harvest buffers on the east side along Type Np streams will be subject to some wood removal, but must meet the basal requirements for that forest zone. It is expected that 24 percent to 36 percent of the wood that could be recruited during the permit term would be retained in partial harvest buffers. On the eastside, no more than 30 percent of the stream length within a harvest unit would be left without a buffer. The portions of perennial and seasonal streams without fish that are left unbuffered (either through standard Washington Forest Practices Rules or the 20-acre exemption) will result in a more-acute reduction in large-wood recruitment as a result of elimination of standing potential recruitment trees.

For perennial non-fish-habitat streams on the westside, the prescriptions are designed to protect sensitive sites (e.g., headwall seeps, springs, alluvial fans, and stream junctions) by requiring 50-foot buffers along at least 50 percent of the unit length. Where buffers are located, the prescriptions would maintain unmanaged timber stands supplying about 70 percent of the potential large wood available in the next 50 years.

Using the 250-year SPTH, we estimate that only about half of the wood that could be recruited in the long term would be retained along Type Np streams. The amounts estimated without considering unstable slopes or sensitive sites are 38 percent in eastern Washington and 44 percent in western Washington. Recruitment will vary depending on stream length and special sites (e.g., factors affecting the resultant percentage of stream buffered), but recruitment should be about 40 percent or more of the potential recruitment. Additional wood, albeit smaller pieces of wood, would be recruited during typical harvest rotations and this smaller-sized wood may often function in smaller streams with respect to pool formation and sediment storage. It is unclear whether such smaller wood would meet the needs of stream-associated amphibians.

In harvested reaches of units, clearcut harvest would typically eliminate recruitable wood in the short term. On the westside, cleared areas along these streams would be expected to produce functionally sized pieces of large wood from stands as young as 25 years old (Hall et al. 1985). By the end of a 40-year rotation in a typical Douglas-fir stand, about 23 pieces of wood (greater than 6 inches diameter) per acre would be produced by natural suppression (Hall et al. 1985). Assuming that trees within 70 feet of the channel are close enough to contribute large wood, and allowing for the probability of trees hitting the stream channel after falling (Andrus et al. 1993), about 44 pieces of large wood per 1,000 feet of channel could be delivered to the stream from in-growth within 40 years after harvest (Bilby 1995).

Wood suitable for sediment storage in small confined channels is likely to result from normal mortality of the managed stand during its growth cycle. The ability of large wood to affect many channel forms in Type Np streams is relatively limited. Pool frequency and depth are relatively insensitive to wood abundance and size in headwater streams. Steps created by large wood are a relatively small fraction of the step population, and step size is only weakly related to the size of key wood (Liquori and Jackson 2003). In larger perennial streams without fish, smaller wood may not be as functional in formation of pools and storage of sediment. In addition, when such unbuffered reaches occur on steeper topography, mass-wasting events originating from upslope would not include the wood from these channels that they might otherwise include indirectly through downstream run-out of debris flows.

Generally, minimal buffers will be required on Type Np streams on 20-acre exempt parcels which will reduce the amount of large-wood recruitment. When such harvests occur on steeper topography, mass-wasting events originating from upslope would not include the wood from these channels that they might otherwise include either directly through failures or indirectly through downstream run-out of debris flows. However, most 20-acre exempt parcels will occur in lower elevations, flatter topography, with less mass-wasting, and with a greater proportion of fish-bearing streams. The greater proportion of fish-bearing streams will reduce the frequency and/or amount of 20-acre exempt harvests on Type Np streams. Application of 20-acre exemption to Type Np streams will retain buffers in situations where covered species may be affected. These buffers will consist of at least 29 trees per 1,000 feet. If all these trees were retained within the first 25 feet from the bank, it would represent only about 50 trees per acre, as small as 6 inches in diameter, only half of which must be conifer. The Shade Rules would not apply, so no additional trees would be required to be retained. In watersheds where 20-acre exemptions are common, this may substantially affect the recruitment of large wood. Retention of 50 trees per acre may represent less than 20 percent of the potential wood recruitment within 25 feet of the bank. Additional trees would not likely be retained within a 100-year site index tree height for large wood recruitment. The persistence of these buffers may be questionable and the size of retained trees may only be minimally effective as large wood within these streams.

For seasonal streams without fish, timber harvest would not be restricted except where potentially unstable slopes occur near the channel. In reaches with stable side slopes, nearly all timber would be removed from potential large-wood source areas. In reaches with potentially unstable side slopes, a portion or majority of the timber probably would be retained within and adjacent to unstable features. Seasonal streams may receive large wood from several sources. On the eastside, where selective harvest is a common practice, the FWS and NMFS estimated that 18 percent of the recruitable wood may be retained along Type Ns streams. In steep and often unstable terrain, the FWS experience with watershed analyses suggests that as much as 50 percent or more of Type Ns streams may require buffers of 50 feet or more to address instability from inner gorges. Additional areas may be left unharvested to address convergent headwalls and other features. FWS is not relying on these estimates of instability within this analysis and total percentages for large wood retained do not reflect protection for unstable features.

Unstable Slopes: Practices that affect mass-wasting can affect the delivery or stability of areas, as well as the opportunities these and downslope/downstream areas have to develop standing large trees prior to episodic events. The objective of the FPHCP for unstable slopes is to limit management-induced increases in the rates and magnitudes of landslides, and provide tree retention in areas most likely to fail. More-rigorous environmental analysis and review are required where potentially unstable slopes or landforms are identified. The current Washington Forest Practices Rules require forest practices that minimize the probability that slope movement would threaten public safety and maximize the probability of natural rates and magnitudes of landslides. Leaving trees on and around at-risk landforms would ensure wood recruitment to streams from mass wasting, if the potentially unstable areas fail. In cases where it can be demonstrated to be prudent through geotechnical review, partial harvest might be applied. If a slope would be partially harvested, large-wood recruitment would be less than 100 percent if the slope failed, and if the slide reached a stream channel. However, it should be noted that most landslides fail to reach or contribute large wood to fish-bearing streams due to topographic barriers. Protection of features such as steep bedrock hollows, convergent headwalls, and inner gorges is expected to provide essentially the full amount of large wood that would be delivered through failures, and is expected to maintain a natural rate of failures. The maintenance of a natural rate of failures will not influence other large wood relationships in downstream areas.

Salvage Logging: On the westside and eastside, removal of large wood from fish-bearing streams, CMZs, or Core Zones would not be permitted during salvage logging. Salvage of wood embedded in the banks of Type Np steams is restricted. Salvage logging in Inner Zones and Outer Zones is permitted only if specified minimum numbers of down logs are retained. Salvage of trees from the Inner Zone required to meet DFC targets or eastside basal area or tree-count requirements would be prohibited. As a result, buffers retained to minimum 20-acre exempt parcel standards are unlikely to be eligible for salvage logging.

Forest Road Management: Effects associated with road construction include the creation of a road corridor. When roads are constructed within or across riparian areas, this activity removes trees which otherwise would have become large wood. Road construction adjacent to and within riparian areas may reduce the delivery of large wood directly by removing trees which would have eventually been recruited. It may also alter the wood-recruitment regime by increasing windthrow potential, replacing long-term recruitment with a short-term pulse depending on wind direction, tree size, etc. Stream-adjacent parallel roads can disrupt the recruitment and transport of large wood. Removal of road-side hazard trees can affect large-wood recruitment depending upon the road location.

Where the presence of stream-adjacent parallel roads influences the potential to recruit large wood to streams or meet the leave tree requirements for Inner Zones or Outer Zones, harvest within RMZs is additionally restricted to make up for or replace the shortfall. Prescriptions address the potential passage of large wood across roads and the future supply of large wood from abandoned orphan roads. Requirements for off-setting retention of trees to compensate for lost potential delivery due to stream-adjacent parallel roads provide an incentive for abandonment or relocation of these roads.

At the time stream-crossing structures are installed, there may be some loss of downed wood at the crossing site and any needed access sites. Large-wood recruitment lost due to activities at stream crossings, whether construction, repair, or abandonment, are expected to be minimal. Realignment, prism widening, and road re-location are also expected to result in negligible impacts to large-wood recruitment at a watershed level.

Where adequate drainage patterns are not provided and culverts or bridges do not accommodate extreme flood events, large-wood transport can be interrupted. Under the FPHCP, road upgrading is expected to improve passage of floods and associated large wood. Standards for road maintenance and construction provide for increased sizes of hydraulic openings for stream conveyance. Abandoning roads would increase large wood delivery in the long term.

Wetland Protection: Landowners would be encouraged to maximize large-wood functions in the Outer Zone of riparian areas by clumping retained trees around forested wetlands. Nonforested wetlands would be buffered according to Washington Forest Practices Rules, which have not changed substantially since the November 1998 Forest Practices Rules.

Research: Habitat manipulations may be conducted for research purposes and are expected to occur along a very small percentage of streams, be localized, and have minor effects on large wood recruitment at a watershed scale. Such research proposals that deviate from the prescriptions within the FPHCP would be reviewed by the FWS. As a result, we expect negligible effects to the large wood resource as a result of research activities associated with the Adaptive Management Program.

Stream Typing: In situations where fish distribution is under-estimated, fish-bearing streams may receive less wood than otherwise anticipated. This may occur if fish distribution extends into the 300- to 500-foot sensitive site at the confluence of Type F and Np streams, or if fish distribution extends into unbuffered stream reaches. The FWS anticipates that such under-estimations of fish distribution will only occur in a small number of situations (e.g., less than 5 percent of stream reaches) and will be somewhat off-set by over-estimations of fish distribution in other cases.

7.5.3.9 Large-Wood Summary

Baseline

The large wood baseline has been degraded by past actions within streams, rivers, riparian zones, and on unstable slopes. Many of Washington's streams presently are low in habitat-forming large wood. Functional loading of large wood in smaller streams is generally quicker to recover due to the generally smaller size of wood required for a functional or key piece. Steeper, more-confined stream segments are expected to have better conditions than low-gradient streams of larger size. Many larger rivers remain deficient in key-pieces of wood. Large streams that are deficient in large wood, and have adjacent and upstream riparian areas bordered by early seral stage riparian stands, are likely to remain deficient longer than smaller streams because of their requirement to have large key pieces. Most wood, and the vast majority of key-piece-sized wood, along major streams and rivers is expected to be recruited from stream-side riparian zones.

The current Washington Forest Practices Rules regarding retention of large wood have changed significantly since the November 1998 Forest Practices Rules. A number of years of improved protection for large wood are therefore already part of the baseline. Regardless of such improvements, large wood conditions in some reaches (i.e., larger streams and rivers) may continue to decline while riparian areas are growing wood large enough to become key-piece size. Regulations can do little to change those situations.

Summary of FPHCP Effects

Removal of trees that might have contributed to large-wood recruitment is expected along fish-bearing streams as a result of timber harvest and related activities, but this is expected to only represent a small portion of the total potential recruitment. Due to a diminishing return of additional wood with respect to pool formation and sediment storage, the portion of large wood (standing trees) retained for future delivery should exceed the amount needed for responsive channel conditions. Some short-term loss of hardwood debris may occur as a result of hardwood conversion, but will be offset by long-term recruitment of larger and more-persistent conifer large wood. However, in the interim, large wood would continue to be recruited, as available, from the Core Zone.

Many of Washington's streams presently are low in habitat-forming large wood. Forest practices may affect the amount and timing of large-wood recruitment to streams from riparian areas and unstable hillslopes, but cannot reverse past actions in the near term. Most large wood delivered to alluvial fish-habitat streams comes from bank erosion and windthrow. Landslides and debris flows may create local wood loading in streams, but their long-term contribution is less important than the other processes.

Where riparian areas already have been altered by human activity, the long-term prospects for recovery of large conifers may be limited without active manipulation of riparian vegetation. Conditions in riparian areas may not improve quickly unless active management is used to increase current and future large wood for floodplain and stream-channel complexity. Even so, during this period of riparian recovery, instream depletion may continue, especially within larger streams and rivers.

Loss of large-wood recruitment along Type Np streams as a result of FPHCP is expected to be greater than reductions along Type F and S streams. Approximately half of the streams will receive a 50-foot buffer and up to another 30 to 50 percent may receive no buffer. Effects will vary by stream type.

As a result of timber harvest, it is expected that large-wood delivery to Type Np and stable Type Ns streams will be diminished. Large wood does not function similarly in all streams. In some streams, boulders provide channel roughness, create pools, and facilitate the sorting of substrates. In some lower-gradient, low-energy streams, large wood may not enhance the ability of the stream to store sediment. However, decreased delivery of large wood will decrease the number and quality of pools in streams sensitive to large wood input and, in turn, would decrease the sediment-storage capacity of such streams. Yet Type Np streams are generally small and smaller wood can function within small streams. Therefore, functional wood may be replenished during typical harvest rotations in many cases.

Reduced recruitment of large wood to Type Np and Ns streams may also reduce the amount of wood delivered downstream to fish-bearing streams through episodic events. Fish habitats most likely to be effected by such reductions are those in steep tributary streams, closest to the affected reaches. Reduction in large-wood loading may occur at tributary junctions and upstream portions of response reaches due to smaller or less wood being included from debris flows as they pass through Type Np and stable Type Ns areas. This reduction would most likely occur in steep topographic watersheds and would most-likely affect steep tributaries of fish-bearing waters. However, delivery points of debris flows are still expected to be concentration points of large wood.

Reduced recruitment of large wood to Type Np and Ns streams may directly impact amphibian habitat, to the extent that larger wood is needed to meet their life-history requirements. This may be a substantial effect upon Plethodon salamanders that may rely on large wood to meet certain life-history requirements.

Seasonal streams without fish (Type Ns) will not normally be provided with buffers unless they are required to address mass-wasting concerns. In many mountainous areas, up to 50 percent of Type Ns stream segments may require inner-gorge protection. As a result of unstable-slope protections, delivery to downstream fish-bearing waters that would occur through episodic events is not anticipated to be diminished. Reduction in large-wood delivery to stable Type Ns stream segments may result in diminished sediment-storage capacity. Yet such streams are generally small and smaller wood can function within small streams. Therefore, functional wood may be replenished during typical harvest rotations in many cases. Where amphibian habitat occurs within stable Type Ns streams, it may be diminished in quality by the reduction in large wood.

Marine and estuarine areas that receive discharge directly from Type Np or Ns streams may receive less wood as a result of portions of Type Np and Ns streams not being buffered. Delivery of such wood may be through debris flows that, should they occur, would contain less wood than if those Type Np and Ns streams had not been harvested. We do not anticipate changes in wood delivery to marine and estuarine areas through Type F and S waters.

Large-wood recruitment along fish-bearing streams under the 20-acre exemption could be reduced up to 55 percent or more. The effects assessed in this plan assume there would be limited salvage of windthrown trees from buffers under the 20-acre exemption. Application of 20-acre exemption to Type Np streams will retain a buffer when covered species may be affected. These buffers would contain at least 29 trees (6 inches or larger) per 1,000 feet. Only half of these trees would be required to be conifer. Salvage must be conducted in compliance with WAC 222-30-45; therefore, unless additional trees were originally retained when the 20-acre exempt parcel was harvested, there would not likely be any available wood to salvage.

Road-management provisions are designed to address the effects of roads on the recruitment and transport of large wood. The effects of road management are therefore expected to be minor.

7.5.3.10 Conclusion

Stream size and topographic setting strongly influence processes that deliver wood to the channel network (May and Gresswell 2003). In larger alluvial channels the majority of the functional large wood along fish-bearing streams comes from near-stream processes (streambank erosion, wind throw, and near-bank tree mortality), with the remainder coming from channelized landslides or debris flows, and stream-adjacent hillslope landslides (Murphy and Koski 1989; Pollack and Kennard 1998). Riparian buffers adjacent to fish-bearing streams prescribed in the FPHCP are expected to maintain 91 to 100 percent of the potential large wood that originates adjacent to these streams during the 50-year permit term. This percentage would be substantially less along 20-acre exempt parcels bordering fish-bearing streams. In small colluvial channels draining steep hillslopes, processes associated with slope instability can dominate large-wood recruitment.

Due to the portions of many of Type Np or Ns streams without buffers, there will be some reduction in large-wood recruitment to fish-bearing streams. The portions of Np and Ns streams that are left unbuffered will result in a reduction in large-wood recruitment to fish-bearing streams, especially fish-bearing streams nearer headwaters. When debris flows occur, we expect initiation points to provide some wood in most cases. Debris flows will entrain additional wood as they travel downstream. Due to the presence of harvested reaches, a lesser amount of wood would be entrained. Additional wood may also be delivered in the run-out reach in lower segments. Not all debris flows will deliver to fish-bearing streams. When debris flows do deliver to fish-bearing streams, a lesser amount of wood may be delivered due to riparian timber harvest along Type Np and Ns streams. However, wood delivered through debris flows may be damaged and broken as a result of the transport mechanism and may not be as effective at retaining sediment as larger whole pieces recruited lower in the stream reaches affected by these processes. For instance, wood recruited by debris flows or other mechanisms within the 300 to 500 foot sensitive site at the confluence of Type F and Np streams may be longer and less broken, less transportable by fluvial processes, and may be more important for retaining sediment. Regardless of these considerations, the FWS expects that some negative effects will result for the incremental difference in wood delivered at these points. As a result, at these delivery points and in downstream reaches, there may be fewer deep pools, reduced stability of streambanks, channel widening, and additional bedload movement.

This assessment indicates that the standard prescriptions (and alternate plans) proposed in the FPHCP have a high probability of delivering functional levels of large wood and protecting and restoring fish habitat where buffers are retained. Although the amounts of large wood that would be delivered under the FPHCP would be less than the maximum possible, the amount delivered would approach, or be similar to, the amounts of wood that commonly occur under natural circumstances, or at least the amount that would be available for recruitment with site-potential tree height, no-harvest buffers. There should still be enough large wood recruited for maximum pool formation in most cases. The amount of large wood needed in a stream is not a function of recruitment potential; instead, it is dependent on channel sensitivity to large wood and on the site-specific role that large wood performs. Therefore, it appears that the proposed prescriptions would contribute less than the full large-wood recruitment potential, but an amount likely to be functionally effective for forming fish habitat.

Buffers would be provided along fish-bearing streams and many perennial streams without fish. Potentially unstable slopes would be avoided or managed to maintain a supply of large wood. Alternate plans would also be expected to provide equivalent or improved levels of large-wood recruitment, in comparison to the standard Washington Forest Practices Rules.

Major points in this consideration include: (1) Delineation of CMZs and potential fish habitat, in association with buffers for Type F and S waters will substantially minimize the effects of timber harvest along fish-bearing waters; (2) Reduction of potential large-wood recruitment along harvested sections of Type Np and stable Type Ns streams; (3) Protection of large-wood sources where they appear most needed and at locations where large wood could be most effective (e.g., along fish-bearing streams, and on perennial streams prior to confluence with fish-bearing streams, at confluences with other perennial streams, low-gradient reaches, initiation points, side-slope seeps, etc.); (4) Protection of potentially unstable slopes to maintain large-wood supply should they fail, and to avoid increasing the rate or magnitude of slope failures; (5) Gradual improvement in hydraulic passage of large wood through bridges and culverts; and (6) Reduction in potential large-wood recruitment along fish streams within 20-acre exempt parcels, and retention of only minimal large-wood recruitment along streams without fish within 20-acre exempt parcels.

Therefore, FPHCP should provide an amount of large wood within the natural range of variability, and likely to be effective for forming fish, amphibian, and riparian habitat. Headwater species and habitats would be affected to a greater degree than species and habitats lower in watersheds.

However, fish and amphibians found in association with 20-acre exempt parcels may be exposed to effects due to habitat degradation at a local level. Unless 20-acre exempt parcels are concentrated, we would not anticipate negative effects at a watershed level. Yet, most 20-acre exempt parcels are expected to occur in and adjacent to areas already exposed to habitat degradation from conversion and development and may occur in local concentrations. In these contexts, 20-acre exempt parcels will not likely contribute substantially to further degradation of habitat conditions, as habitat conditions in many of these areas (e.g., urban and rural residential areas) are already degraded. We expect that proportionately few 20-acre exempt parcels occur in concentrations within the general forest-practices landscape at higher and middle elevations.

7.5.4 Sediment

Sediment is generally divided into two broad categories when its effects are addressed in relationship to the aquatic environment. These are divided based on particle size into the two categories of coarse and fine sediments. Fine sediments are typically described as sand- and silt-sized particles, while coarse sediments are essentially categorized as all larger particle sizes. Sediments are naturally recruited to the aquatic environment through processes collectively referred to as erosion. The three dominant processes of natural sediment recruitment on forestlands are surface erosion, erosion of stream channel boundaries and mass wasting.

Much of the following discussion of baseline conditions, importance of sediments, and the issues surrounding sources, amounts, and function of sediments in streams was adapted from discussions in the Review of the Scientific Foundations of the Forests and Fish Plan (CH2MHill 2000); and the Final EIS for the Forest Practices HCP (USFWS and NMFS 2006).

7.5.4.1 Baseline Summary

Riparian and stream clearing, and the construction of splash dams to facilitate water transport of harvested logs, was common practice in Washington streams (Sedell et al. 1991). Early logging used rivers and streams to transport logs. Trees were often felled directly into streams and rivers and were floated or yarded down these channels to their destinations. Sometimes, logs were pulled to streams and trapped behind splash dams, which were dynamited or pulled away, causing logs and sediment to sluice downstream. Repeated splash damming resulted in major long-term damage to fish habitat as the practice caused severe scouring of stream channels, often down to bedrock (Murphy 1995). With the advent of railroad logging, grades were cleared along large channels, and logs were yarded down the small tributaries to the rail bed which resulted in additional sediment impacts. In this way, impacts extended up to the headwater channels. Whole watersheds were logged as convenience. Logs were yarded downhill, moving debris and sediment into stream channels. Later, trucks and road systems replaced railroads, requiring additional clearing of forest vegetation and frequently resulting in substantial mass wasting and sediment runoff due to construction techniques or the placement of roads on unstable slopes. For more than 100 years, wood was removed from stream channels in the United States to facilitate boat traffic, floating of logs or log drives downstream, for protection of property, bridges, and roadways, and for improving fish migrations (Murphy 1995; Spence et al. 1996). Although forest management practices were improved somewhat by the 1950's, clearcutting to the streambank remained a common practice on fish bearing streams until at least the mid-1970's, and clearcut harvesting of unstable landforms having delivery potential was common until the late 1980's.

These forest activities have significantly altered natural recruitment rates, storage, and transport (routing) of sediments within aquatic systems. Large networks of forest haul roads, skid trails/roads, and yarding corridors now exist in the majority of watersheds. In many watersheds, the road networks are so large that much of it cannot be maintained to current regulatory standards until sometime in the future. Many of these road networks cross or parallel stream channels, leaving a legacy of problems such as chronic bank erosion, debris flows, chronic delivery of fine sediments, stream channel capture, crossing roadfill washout and slope failures.

According to CH2MHill (2000), there is no systematic assessment of current stream-habitat conditions on forestlands in Washington. Beak (1998) collected data from completed Watershed Analyses including certain types of data that were collected under a defined set of protocols (See Baseline – Large Wood for additional details). In 44 percent of the stream reaches surveyed across Washington State, the substrate quality was rated as fair (12-17 percent fines) to poor condition (>17 percent fines). Results were poorer for eastern Washington than for western Washington (Beak 1998). This may be a result of a higher proportion of weathered granitics and ash-derived soils on the east side. However, the results of the Beak review should be used with caution, because they do not reflect a statistically sound or unbiased monitoring program.

Over short time scales (i.e., a few years to a few decades), landscapes may appear static and tranquil. However, sediment budgets have consistently shown that mass wasting (e.g., shallow and deep landslides, debris flows, and earthflows) is a major source of sediment to stream channels in the Pacific Northwest in managed and unmanaged basins (Dietrich and Dunne 1978; Reid 1981; Swanson et al. 1982; Lehre 1982; Roberts and Church 1986; Benda and Dunne 1987 cited in CH2MHill 2000).

Over longer time periods (i.e., decades to centuries), periodic fires and windstorms create a changing mosaic of vegetation (Spies and Franklin 1988; Agee 1993 cited in CH2MHill 2000). Wildfires, which were an important part of most landscapes in the region prior to European settlement (Agee 1993 cited in CH2MHill 2000), probably played an important role in triggering episodes of increased landsliding (Benda et al. 1998 cited in CH2MHill 2000). Wildfires are presently suppressed in the region, and suppression has resulted in significantly fewer large fires (Agee and Flewelling 1983 cited in CH2MHill 2000). Infrequent large storms, sometimes occurring in conjunction with wildfires, trigger mass wasting, sheetwash, and gullying (the latter two surface erosion processes being more prevalent in eastern Washington). Episodic cycles of increased erosion followed by a relatively quiescent recovery period is characteristic of many landscapes in the Pacific Northwest region, including eastern Washington (Klock and Helvey 1976 cited in CH2MHill 2000), the more humid portions of the Cascade mountains (Swanson et al. 1982 cited in CH2MHill 2000), and the Pacific coastal rainforests (Dietrich and Dunne 1978; Benda et al. 1998 cited in CH2MHill 2000).

7.5.4.2 Importance of Sediment

Overview

Coarse sediment is an important component of aquatic habitats. It creates channel complexity and physical structure (cover), and provides substrate for spawning and the development of a hyporheic zone. It comprises the streambed and governs channel morphology (cross sectional shape, planform pattern, and longitudinal profile) in segments of the stream system most biologically important to salmonid fishes. The streambed substrate characteristics, including particle size distribution, bedforms, and the frequency, magnitude and depth of sediment mobility, depend on the watershed flow regime (pattern, duration and magnitude of peak flows), the modes and source characteristics of sediment input, and interactions with large wood and other hydraulic roughness elements that retain sediment. Thus, the response of a channel to an altered coarse sediment input regime may depend on its initial condition, reflecting the timing since the last episodic sediment input, presence or absence of chronic sediment sources, legacy of past management actions (e.g., removal of large wood, channel destabilization by streambed or riparian disturbance, etc.), and watershed hydrologic condition. For example, a landslide delivering coarse debris to a channel with a low supply of sediment and wood (e.g., a bedrock channel) may bring about the return of mobile, alluvial streambed features and habitat complexity, provided the channel can retain these deposits. Such retention is more likely if the deposits contain large wood in the mix, since bedrock channels tend to be hydraulically smooth and thus non-retentive. On the other hand, landslide deposits delivered to a sediment-rich channel may result in aggradation (increase in streambed elevation) with associated channel destabilization (e.g., accelerated bank erosion or avulsion), shifts in channel type (such as evolution into a braided reach), increase in streambed mobility and scour, a decrease in average grain size of the channel bed, and a decrease in bed porosity and permeability. Episodic large-scale sediment input such as from landslides initiates a cycle of recovery towards pre-disturbance conditions which may take a decade or more. Alteration of the frequency of mass wasting thus shifts the stream morphology and substrate characteristics towards earlier phases in this recovery cycle.

In cases where sediment supply is very low, a streambed consisting of coarse, seldomly-mobile particles may develop. Such channels tend to form poor spawning habitat. Channel complexity created by obstructions such as large woody debris, boulders, channel meanders, and bedrock outcrops dissipates hydraulic energy, thus increasing the sediment retentiveness of the system. This allows stable depositional features to develop and plays a key role in the formation of clean, well-sorted gravel deposits. There is an equilibrium between sediment input and sediment routing that must be maintained to have a geomorphically stable stream system, conducive to salmonid productivity and healthy riparian-aquatic interactions (Everest et al. 1987 as cited in FPHCP).

Fine sediment typically has negative impacts to the aquatic environment either while suspended (turbidity) or when deposited (siltation). Siltation and turbidity adversely affect fish at every stage of their life cycle (Iwamoto et al. 1978 cited in Spence et al. 1996). In streams, turbidity is usually a result of suspended particles of silts and clay, but may also include organic matter, colored organic compounds, plankton, and microorganisms. Suspended sediment is the portion of the sediment load suspended in the water column. The grain size of suspended sediment is usually less than 1 to 2 mm (Sullivan et al. 1987); however most suspended sediment in typical streams is probably less than 0.5 mm in diameter. Ecological effects of increased turbidity may include a decrease in primary productivity of algae and periphyton due to the decrease in light penetration. Declines in primary productivity can adversely affect the productivity of higher trophic levels such as macroinvertebrates and fish (Gregory et al. 1987).

If present in amounts large enough to dominate the streambed composition, fine sediment in the sand particle size classes (0.0625 – 2 mm) can dissipate stream energy through bed-form roughness (dunes, ripples) and the effects of suspended sediment in transport on increased effective dynamic viscosity. In sufficient volumes, fine sediment can cause channel shoaling, further reducing sediment transport capacity and channel competence. Fine sediment is an important component of overbank deposition, and thus is essential in floodplain development processes and riparian zone dynamics (CH2MHill 2000). Fine sediment may also bind with some particulates and dissolved chemical solids that are harmful to salmonids. However, this reduction in water-column bioavailability is counteracted by increased concentrations in the bed sediments, which are subject to periodic re-mobilization during scour events. Organisms dwelling within interstitial gravels, including salmonid eggs and juvenile stages, may be disproportionately exposed to toxic sediments. The toxicity of some dissolved chemicals may increase because of interactions with suspended sediments (Spence et al. 1996). In general, deposited sediments tend to have a greater overall impact on fish than do suspended sediments, with spawning and incubation habitats being the most directly affected (Spence et al. 1996). However, suspended sediment can settle out of suspension in the water column and become part of the bedload (i.e., sediment carried along the bed of the stream). Fine sediments are recruited to aquatic systems through the same processes as coarse sediments, but are more easily recruited through surface erosion (such as road wash, rilling and gullying) than are coarse sediments.

High concentrations of suspended sediments may physically abrade and mechanically disrupt respiratory structures (e.g., fish gills) or surfaces (e.g., respiratory epithelia of benthic macroinvertebrates), modify or delay migration in fish, and impair foraging behavior (Spence et al. 1996). Potential sublethal effects of chronic suspended sediment to fish include reduced growth rate, greater susceptibility to disease, and reduced competitive ability for space and food with larger cohorts (Everest et al. 1987).

Siltation results when fine sediments settle out of suspension, cover intergravel crevices, and fill flow pathways within the gravel layers. This may degrade or reduce the amount of available spawning habitat for fish by embedding spawning substrates; reduce fry and embryo survival by entrapping eggs within the streambed and reducing intergravel flow and oxygen availability; decrease carrying capacity of streams by eliminating interstitial spaces used as shelter (cover) and foraging habitat by juvenile fish and amphibians; reduce or eliminate available forage base by filling habitats required by macroinvertebrates; and reduce the quality of pool habitats by filling pools (Everest et al. 1987; Spence et al 1996).

Role of Sediment in Aquatic Habitat Formation

Sediment, especially coarse sediment, is an important component of aquatic habitats. It both directly and indirectly creates habitat used by fish, amphibians, and their prey. The level of habitat use is ultimately influenced by the composition, quantity, and distribution of these sediments within the waterbody. Fish require sufficient substrate (e.g., gravel, sand, cobbles) of the appropriate size and mixture for spawning and rearing, but this varies among species.

Generally, coarse sediments play a key role in forming interstitial spaces which are used as concealment from predators, shelter from fast currents, and habitat for foraging (Bjornn and Reiser 1991; Spence et al. 1996). Populations of tailed frogs can be severely reduced or eliminated by increased sediment (Corn and Bury 1989; Welsh 1990) presumably because of their dependence on unembedded interstitial areas in the stream substrate where they hide and overwinter (Daugherty and Sheldon 1982a; Brown 1975). Coarse substrates are also used by a variety of fish for spawning. Fish may use coarse substrates to bury their eggs (e.g., lamprey, salmon, and trout), broadcast their eggs over (e.g., mountain whitefish), or as a surface to lay there eggs upon (e.g., sculpins and dace) (Wydowski and Whitney 2003).

Sediments that are delivered to the stream channel also work in combination with natural geomorphic features, flowing water, riparian vegetation, and large wood to create habitat structure (Spence et al. 1996). This structure is composed of macro- and microhabitat attributes that are used by fish (especially salmonids) at various stages of their life history. Macro-habitat features include pools, glides, and riffles, while microhabitat attributes include feature characteristics such as substrate type, cover, depth, hydraulic complexity, and current velocity.

At the watershed or landscape scale, coarse sediments enter the aquatic system mainly through mass wasting processes and erosion of stream-adjacent unconsolidated deposits such as terraces. The long-term budget of coarse sediment input is governed by the spatial patterns and density of mass wasting and debris flows, their frequency of occurrence and timing, and the nature of the sediment and wood involved (e.g., particle and wood size distribution, rock and soil type). This coarse sediment input is then routed through the fluvial system, stored in various places in the system (e.g., floodplains, terraces, and alluvial fans), and eventually weathered and abraded to finer particles which become deposited and stored in long-term accumulations such as coastal valley floodplains, depositional fans, deltas and estuarine mudflats over geologically-significant time scales. A long-term sediment budget exists, which determines the overall system characteristics (e.g., source, transport, and depositional response zones), as well as the channel morphology of river segments. Reach morphology (channel form, pattern, profile and streambed texture) adjusts to create a quasi-equilibrium between sediment input, output and storage over intermediate time scales (e.g., years to decades).

Landslides and debris flows represent episodic disturbances which are followed by recovery of quasi-equilibrium conditions over years to decades or even centuries. The rate and form of the recovery process depends on factors such as the timing and magnitude of peak flows and the abundance and persistence of large wood. Increases or decreases in the frequency or magnitude of episodic mass wasting alters this recovery cycle, pushing the system towards either an earlier or later phase in the process, respectively. Early phases are characterized by sediment-rich systems with greater rates of channel migration and evolution. Later phases are more coarse-sediment poor, with lower rates of channel migration and stable channel types. Thus, long-term patterns of mass wasting on a landscape scale create a cumulative morphologic legacy of coarse sediment deposits which dictate the types, diversity, and distribution of many of the channel and riparian environments found within watersheds (Swanson et al. 1988; Benda et al. 1998 cited in CH2MHill 2000).

Mechanism of Recruitment

In forested mountain basins, sediment enters stream channels from natural mass-wasting events (landslides and debris torrents), channel bank erosion (including localized mass wasting), surface erosion, and soil creep. Channel bank erosion, surface erosion, and soil creep tend to occur regularly, as a part of ongoing erosion processes, whereas landslides and debris torrents are more episodic in nature, and tend to occur during rain-on-snow and extreme rainfall events.

Mass Wasting: Across much of the landscape, mass wasting is the principal mechanism by which coarse sediment enters stream channels, when viewed over long temporal scales. Mass wasting can be classified into several processes according to the mechanism of movement (flowing versus sliding), the temporal behavior (slow and continuous versus rapid and discontinuous), and the type of material involved (Schuster and Krizek 1988; Easterbrook 1993). In the Pacific Northwest, it is common to classify mass wasting as shallow-rapid landslides (including debris flows), and deep-seated landslides and earthflows (CH2MHill, 2000).

Landslides and debris flows have an extremely low probability of occurrence at any particular site or point in time, but over a broad landscape (i.e., areas more than 200 km^2) they are more common, and their pattern and frequency are related to lithology and geomorphology. The rate of landsliding can be considered for a single site, referred to as a recurrence interval, or a rate can be described for a specific area containing a population of slide areas (e.g., number/area/time). Along with topography, lithology, and geomorphic position, vegetation, and climate cause landslide rates to vary across the region (Benda and Dunne 1997 cited in CH2MHill 2000). Landsliding cannot be represented as a single rate, but only as a distribution of rates, with each landslide rate (number of slides per specified time period per area) associated with a particular likelihood or probability of occurrence (Benda and Dunne 1997 cited in CH2MHill 2000).

Surface Erosion: Surface erosion and fine sediment delivery to streams are natural processes that occur to various degrees in every watershed. As described in the Review of the Scientific Foundations of the Forests and Fish Plan (CH2MHill 2000), surface erosion can be differentiated into two component processes (fine sediment generation and fine sediment transport), both discussed below in more detail.

Fine Sediment Generation. The potential for surface erosion is a function of climate, topography, vegetation, and other organic cover and soil characteristics. Fine sediment can be generated naturally from on-site processes, such as physical and chemical weathering of rocks and bedrock. Raindrop splash, expansion and contraction of soil from freeze and thaw cycles, wind, and overland flow can detach soil particles. Loss of vegetation or organic duff from fire or ground disturbance can increase surface erosion. Finally, the effects of all of these causes of surface erosion are more pronounced on steep slopes, on bare managed surfaces such as roadbeds and fill, and wherever local microtopography allows water to concentrate into rills or channels (also see **Soil Compaction** section).

Fine Sediment Transport. Fine sediment can be transported off-site by wind (e.g., volcanic ash) or surface water runoff (e.g., seeps, rills, gullies, and streams). Most undisturbed forest soils in Washington State have little potential for sediment transport by surface water because runoff is deterred by a thick, protective layer of organic material (duff layer), relatively low intensity rainfall, and relatively high soil infiltration rates (Bennett 1982; Dunne and Leopold 1978 cited in CH2MHill 2000). In forested environments, ground surface disturbances from natural events such as wildfire can increase the potential for surface erosion and delivery of fine sediment to streams (Swanson 1981 cited in CH2MHill 2000). Where human activities leave soils bare, rills can develop and transport fine sediments in places where compaction has reduced infiltration capacity or where saturation develops due to subsurface water originating upslope.

Erosion of Stream Channel Boundaries: Streambank erosion and avulsion associated with channel migration dynamics is another important source of fine and coarse sediments. The rate of bank erosion can vary depending on a number of factors including flood discharge, soil saturation, bank material type and stratification, and vegetation type, density and maturity. Most bank erosion occurs during larger floods where saturated soils are easily washed away. More-cohesive soil types and soil containing a healthy root network of riparian trees will have reduced rates of bank erosion (Hooke 1980 cited in CH2MHill 2000). Channel incision can increase bank erosion rates by concentrating hydraulic forces within the channel boundaries and creating bank heights greater than soil stability thresholds. Aggradation can result in rapid channel migration rates, also increasing bank erosion. Erosion of the edges of high terraces, particularly glacial deposits, is a major source of sediment to some stream reaches.

Where geomorphic instability occurs, streambank erosion can temporarily overshadow other sediment sources. However, accelerated streambank erosion is unsustainable over long time periods, resulting in shifts in channel type (morphology) which tend to restore sediment equilibrium over years to decades. In the geomorphic sense, streambank erosion represents a re-mobilization of sediment in storage.

Transport and Storage of Sediments within Streams

The timing, frequency, and type of precipitation influence the hydrologic patterns, which in turn govern the rate at which sediment is mobilized, transported and deposited within streams. Topography (slope steepness, length, elevation, and aspect) further influences runoff energy, which determines the volume and velocity of water moving downslope and the energy it has to transport coarse sediments downstream. Stream gradient and retentive in-channel structures are also important in determining whether sediments are deposited locally or transported further downstream (Spence et al. 1996). Any sediment not too coarse in particle size to be mobilized by a stream would be routed downstream over a time period that depends on the system. Instream features such as large boulders and large woody debris result in complex velocity and depositional patterns, creating pools and riffles, scour and fill zones, coarse-sediment bedforms and undercut banks. Woody debris-dams buffer downstream reaches from rapid changes in sediment loading. Large woody debris also retains coarse sediments that are essential for spawning salmonids (Spence et al. 1996).

Large pulses of sediment can be be propagated downstream over a temporal scale of years to decades. Recent studies have shown that these sediment pulses take the form of a wedge, lengthening and thinning as it translates downstream over time (Cui et al. 2003). Sediment pulses create associated changes in channel form and bed texture (Miller and Benda 2000). The onset of a sediment wave may result in aggradation and braiding of the channel, reduction in average grain size of sediment making up the surface of the channel bed, and burial of riparian zones. The pulse's passage may leave a channel incised to a coarse, immobile bed (lag deposit) inset between terraces cut by numerous, shallow side channels.

Fine-sediment transport and deposition within streams can be extremely variable. Some silt and smaller-sized particles are rapidly transported downstream as suspended sediment. However, some become embedded on and within the streambed gravels. Once fine sediments are drawn into inter-gravel-flow pathways, they readily settle out. These embedded fines are typically routed on though the system only by scour and fill events that cause major streambed disruption. These are generally the larger peak-flow events (i.e., those greater than bankfull discharge). Sand-sized particles can also be transported during a flood event. As a flood recedes, sand, along with some finer material, is deposited on floodplains and channels where still water occurs (e.g., in the bottoms of pools in low-gradient reaches and in side channel and slough environments). Larger woody debris-dams store fine sediment and organic materials, reducing their rate of transport downstream (see additional discussion on sediment storage under **Wood** section).

7.5.4.3 Classification of Sediment Effects to Aquatic Species and Habitats

Specific effects of sediment on fish and their habitat can be put into three classes that include (Newcombe and MacDonald 1991; Waters 1995; Bash et al. 2001):

Lethal: Direct mortality to any life stage, reduction in egg-to-fry survival, and loss of spawning or rearing habitat. These effects damage the capacity of the ecosystem to produce fish and future populations.

Sublethal: Reduction in feeding and growth rates, decrease in habitat quality, reduced tolerance to disease and toxicants, respiratory impairment, and physiological stress. While not leading to immediate death, may produce mortalities and population decline over time.

Behavioral: Avoidance and distribution, homing and migration, and foraging and predation. Behavioral effects change the activity patterns or alter the kinds of activity usually associated with an unperturbed environment. Behavior effects may lead to immediate death or population decline or mortality over time.

Aquatic systems are complex interactive systems, and isolating the effects of sediment on fish is difficult (Castro and Reckendorf 1995). Environmental factors affecting direct sedimentation impacts on salmonids include duration of exposure, frequency of exposure, toxicity, temperature, life stage of fish, angularity and size of particle, severity/magnitude of pulse, time of occurrence, general condition of biota, and availability of and access to refugia (Bash et al. 2001). The difficulty in determining which environmental variables act as limiting factors has made it difficult to establish the specific effects of sediment impacts on fish (Chapman 1988). For example, reduction in suitable spawning habitat as a result of excess fines in the spawning gravels may not lead to smaller populations of adults if the amount of naturally occurring juvenile winter habitat limits the number of juveniles that reach adulthood. Often there are multiple independent variables with complex inter-relationships that can influence population size. For some species of fish, it has been suggested that there is no threshold below which exacerbation of fine-sediment delivery and storage in gravel bedded rivers will be harmless (Rieman and McIntyre 1993; Suttle 1995).

Direct Effects

Gill Trauma: High levels of suspended sediment and turbidity can cause fish mortality by damaging and clogging gills. Fish gills are delicate and easily damaged by abrasive silt particles (Bash et al. 2001). As sediment begins to accumulate in the gill filaments, fish excessively open and close their gills to expunge the silt. If irritation continues, mucus is produced to protect the gill surface, which may impede the circulation of water over the gills and interfere with fish respiration (Bash et al. 2001). Gill flaring or coughing abruptly changes buccal cavity pressure and is a means of clearing the buccal cavity of sediment. Gill sediment accumulation may result when fish become too fatigued to continue clearing particles via the cough reflex (Servizi and Martens 1991).

Spawning, Redds, Eggs, and Alevins: The effects of suspended sediment deposited in a redd may include reduction in water flow, smothering of eggs or alevins, and/or impeding fry emergence. These effects are related to sediment particle sizes of the spawning habitat (Bjornn and Reiser 1991). Sediment particle size determines the pore openings in the redd gravel. With small pore openings, more suspended sediments are deposited and water flow is reduced compared to large pore openings.

Egg survival depends on a continuous supply of well-oxygenated water through the streambed gravels (Cederholm and Reid 1987). Eggs and alevins are generally more susceptible than adults to stress from suspended solids. Accelerated sedimentation can reduce the flow of water and, therefore, oxygen to eggs and alevins which can decrease egg survival, decrease fry emergence rates (Cederholm and Reid 1987; Chapman 1988; Bash et al. 2001), delay development of alevins (Everest et al. 1987), reduce growth, and cause premature hatching and emergence (Birtwell 1999). Fry delayed in their timing of emergence are less able to compete for environmental resources than other fish that have undergone normal development and emergence (intra- or interspecific competition) (Everest et al. 1987).

For example, several studies have documented that fine sediment can reduce the reproductive success of salmonids. Natural egg-to-fry survival of coho salmon, sockeye salmon and kokanee has been measured at 23 percent, 23 percent, and 12 percent, respectively (Slaney et al. 1977). Substrates containing 20 percent fines can reduce emergence success by 30-40 percent (MacDonald et al. 1991). A decrease of 30 percent in mean egg-to-fry survival can be expected to reduce salmonid fry production to extremely low levels (Slaney et al. 1977).

Individuals: Resultant large influxes of sediment (both coarse and fine) into streams has the potential for direct fish kills through burial, an increase in the potential for dam-break floods (Coho and Burges 1993), and influx of excess fine sediment (Beschta 1981). Fish species (e.g., cottids) that dwell within or close to the substrate are more likely to be buried by large influxes of sediment.

Indirect Effects

Macroinvertebrates: Turbidity and suspended solids can affect macroinvertebrates in multiple ways through increased invertebrate drift, feeding impacts, respiratory problems, and loss of habitat (Cederholm and Reid 1987). Certain groups of macroinvertebrates are favored by salmonids as food items. These include mayflies, caddisflies, and stoneflies. These species prefer large substrate particles in riffles and are negatively affected by fine sediment (Everest et al. 1987; Waters 1995).

The effect of light reduction from turbidity has been well documented and results in increased invertebrate drift (Waters 1995; Birtwell 1999). This may be a behavioral response associated with the night-active diel drift patterns of macroinvertebrates. While increased turbidity results in increased macroinvertebrate drift, it is thought that the overall invertebrate populations would not fall below the point of severe depletion (Waters 1995). Increased turbidity due to suspended sediments may also include a decrease in primary productivity of algae and periphyton due to a decrease in light penetration. Declines in primary production can adversely affect the productivity of higher trophic levels such as macroinvertebrates and fish (Gregory et al. 1987), as well as amphibians.

Increased suspended sediment can affect macroinvertebrates by abrasion of respiratory surface and interference with food uptake for filter-feeders (Birtwell 1999). Increased suspended sediment levels tend to clog feeding structures and reduce feeding efficiencies, which results in reduced growth rates, increased stress, or death of the invertebrates (Newcombe and MacDonald 1991). Invertebrates living in the substrate are also subject to scouring or abrasion which can damage respiratory organs (Bash et al. 2001).

Benthic invertebrates inhabit the stream bottom. Therefore, any modification of the streambed by deposited sediment will most likely have a profound effect upon the benthic invertebrate community (Waters 1995). Increased sediment can affect macroinvertebrate habitat by filling of interstitial space and rendering attachment sites unsuitable. This may cause invertebrates to seek a more-favorable habitat (Rosenberg and Snow 1975). The degree to which substrate particles are surrounded by fine material was found to have a strong correlation with macroinvertebrate abundance and composition (Birtwell 1999). Increased fines can shift invertebrate assemblages from available prey organisms to unavailable burrowing taxa, lowering food availability for salmonids (Suttle et al. 2005). At an embeddedness of one-third, insect abundance can decline by about 50 percent, especially for riffle-inhabiting taxa (Waters 1995).

Feeding Efficiency: Increased turbidity and suspended sediment can affect a number of factors related to the feeding efficiencies of salmonids, including feeding rates, reaction distance, and prey selection (Bash et al. 2001). Changes in feeding behavior are primarily related to the reduction in visibility that occurs in turbid water. Effects on feeding ability and prey availability are important as salmonids must meet energy demands to compete with other fishes for resources and to avoid predators.

Distance of prey capture and prey capture success both were found to decrease significantly when turbidity was increased (Berg and Northcote 1985). Waters (1995) states that the loss of visual capability, leading to reduced feeding, is one of the major sublethal effects of high suspended sediment. Increases in turbidity was reported to decrease the percentage of prey captured (Bash et al. 2001). At 0 NTUs, 100 percent of the prey items were consumed; at 10 NTUs, fish frequently were unable to capture prey species; at 60 NTUs, only 35 percent of the prey items were captured. At 20 to 60 NTUs, significant delay in the response of fish to prey was observed. Loss of visual capability and the ability to capture of prey leads to depressed growth and reproductive capability. While most effects of elevated suspended sediment (or turbidity) are negative, in some cases turbidity can enhance juvenile fish cover from predatory fish (Gregory and Levings 1998).

Sigler et al. (1984) found that a reduction in growth occurred in steelhead and coho salmon when turbidity was as little as 25 NTUs. The slower growth was presumed to be from a reduced ability to feed; however, more-complex mechanisms such as the quality of light may also affect feeding success rates. Redding et al. (1987) found that suspended sediment may inhibit normal feeding activity, as a result of a loss of visual ability or as an indirect consequence of increased stress. Suttle et al. (2005) found that juvenile steelhead growth declined steeply and generally linearly with increasing concentrations of fine-sediment in habitat substrates, which was consistent with the effects they observed of sedimentation on macroinvertebrate prey availability.

Physiological Effects: Sublethal levels of suspended sediment may cause undue physiological stress on fish, which may reduce the ability of the fish to perform vital functions (Cederholm and Reid 1987). At the individual fish level, stress may affect physiological systems, reduce growth, increase disease, and reduce its ability to tolerate additional stress (Bash et al. 2001). At the population level, the effects of stress may include reduced spawning success, increased larval mortality, and reduced recruitment to succeeding life stages resulting in overall population declines (Bash et al. 2001).

Tolerance to suspended sediment may be the net result of a combination of physical and physiological factors related to oxygen availability and uptake by fish (Servizi and Martens 1991). The energy needed to perform repeated coughing (see Gill trauma section) increases metabolic oxygen demand. Metabolic oxygen demand is related to water temperature. As temperatures increase, so does metabolic oxygen demand, but concentrations of oxygen available in the water decreases. Therefore the fish's tolerance to suspended sediment may be primarily related to the capacity of the fish to perform work associated with the cough reflex. However, as sediment increases, fish have less capability to do work, and therefore less tolerance for suspended sediment (Serizi and Martens 1991).

Turbidity can adversely affect fishes at every stage of their life cycle. Auld and Schubel (1978) found that larval survival in American shad (*Alossa sappidissima*), a clupeid fish, was reduced under conditions of elevated suspended sediment, but hatching was not. Redding *el al*. (1987) observed higher mortality in young steelhead trout exposed to a combination of suspended sediment (2500 mg/l) and a bacteria pathogen, than when exposed to the bacteria alone. Physiological stress in fishes may decrease immunological competence, growth, and reproductive success (Bash et al. 2001).

Behavioral Effects: Increased turbidity and suspended sediment may result in behavior changes in salmonids. This may include changes in avoidance, distribution, homing, and migration. Many behavioral effects result from changes in stream habitat. As suspended sediment concentration increases, habitat may be degraded which results in abandonment and avoidance of previously preferred habitat. Stream-reach emigration is a bioenergetic demand that may affect the growth or reproductive success of the individual fish (Bash et al. 2001). Pulses of sediment result in downstream migration of fish, which disrupts social structures, and causes downstream displacement of other fish (McLeay et al. 1987; Bash et al. 2001). Loss of territoriality and the breakdown of social structure can lead to secondary effects of decreased growth and feed rates, which may lead to mortality (Berg and Northcote 1985; Bash et al. 2001).

High turbidity may delay migration back to spawning sites, although turbidity alone does not seem to affect homing (Murphy 1995). Delays in spawning migration and associated energy expenditure may reduce spawning success and, therefore, population size (Bash et al. 2001).

Habitat Effects: High inputs of both coarse and fine sediments to aquatic habitats will lead to aggradation within streams. When substantial erosion occurs in a watershed, pool habitats diminish by aggradation (net accumulation of sediment on the streambed) (Madej 1984). Increases in sediment supply from mass movements or surface erosion, bank destabilization, or in-stream storage losses can cause aggradation, pool filling, and a reduction in gravel quality. Typically, if sediment delivery to the channel is increased, it is expected that the channel would become wider, shallower, and less stable (Spence et al. 1996). Aggradation often triggers a shift in channel type, as from a single-thread to a braided type, or from a relatively straight plane-bed system with few bars to a deposit-rich pool-riffle system with high channel migration rates (Thorne, 1997). Such changes can be unstable, evolving rapidly as the system recovers.

Increases in sediment supply to the channel can have a major influence on in-stream biological conditions. For instance, increased sediment supply can result in reduced fish rearing and overwintering habitats (loss of pools and undercut bank areas), decreased juvenile fish survival and smolt production, and impaired spawning and incubation environments (degraded riffle sites) (Waters 1995). It may also result in modification of habitats to such an extent as to be no longer used by some fish species. For example, cottids typically require well-oxygenated rubble to rubble-gravel substrate and are absent or rare in areas where fine-grained substrate or highly embedded cobble substrate predominate (Mebane et al. 2003). The Pacific, river, and brook lampreys, in their larval stage (ammocoetes), prefer small substrates in coldwater streams for rearing such as mud and fine-silt deposits (Kostow 2002; Moyle 2002; Wydoski and Whitney 2003). These conditions are generally located in backwaters and quiet eddies along the banks of streams and rivers (Wydoski and Whitney 2003). Although typically associated with fine sediments, lamprey do require gravel habitats (for spawning) as adults, and pool habitats as ammocoetes (rearing) and as adults (overwintering) (Kostow 2002; Wydoski and Whitney 2003). Torgersen and Close (2004) found that larvae selected pools over riffles because the morphology of pool margins was more conducive to sediment deposition than riffle margins. Native fish species within the region have evolved with a range of sediment conditions (i.e., different habitats). Therefore, they and their habitats are best conserved in freshwater environments by supporting the natural occurring levels of sediment input, transport, delivery, and storage.

Although large inputs of sediment (e.g., mass-wasting events) represent disturbances that have negative impacts on aquatic habitats, new channel habitats and riparian plant communities are established as the system recovers from the disturbance by transporting and sorting the deposits, and as the channel evolves into a stable morphology. Episodic, large disturbances of this nature initiate a cycle of recovery towards pre-disturbance conditions which may take a decade or more. Increasing the frequency of mass wasting thus shifts the stream morphology and substrate characteristics towards earlier phases in this recovery cycle. These earlier phases are generally characterized by sediment-rich channels, less channel stability, and finer substrates. However, the natural disturbance regime, which included mass wasting events, is responsible for the mosaic of habitat types to which the aquatic species are adapted, and for the continued functioning of processes which maintain the channel morphology and streambed characteristics.

Regardless of the source, past management-related mass wasting has caused persistent changes to stream habitats throughout the Pacific Northwest. Reeves et al. (1995, as cited in NMFS 2005a) observed that the frequency and pattern of watershed disturbances (e.g., mass wasting with large wood) strongly influenced the quality and distribution of salmonid habitat on the Oregon Coast. While channelized landslides cause short-term adverse changes in aquatic habitats, and many stream channels have segments that receive excessive sediments or scour, some streams would become sites of good-quality habitat as landslide-deposited boulders and wood become stable channel features and mobile sediments were processed by peak flows.

In estuarine and marine waters, substrate grain-size has been shown to be a determining factor in habitat selection by a variety of species that are either covered by the FPHCP, or are similar to those that are covered (Becker 1988; Howell et al. 1999; McConnaughey and Smith 2000; Stein et al. 2004). Storm-induced siltation of a previously-sandy lagoon in California has been blamed for the significant reduction in numbers of shiner surfperch (Onuf and Quamment 1983). Spawning habitat for surfsmelt and sandlance is particularly vulnerable. These species utilize sandy/gravelly upper intertidal beaches for spawning (Pentilla 1997) and could be susceptible to degradation should large amounts of fine sediment be delivered to these beaches. Upstream sources of sediment are controlling factors for accretion or erosion in the estuary. Excess sedimentation can result from timber harvest in the catchment (Levings and Northcote 2004). Therefore, a range of potential impacts to the habitat of covered species in the estuarine and marine waters from sediment delivered by mass-wasting events is possible. These changes include increased rates of sedimentation leading to reduced rearing capacity (Tschaplinski 1987) and changes in grain-size composition in areas where some covered species spawn and rear.

7.5.4.4 Effects of the Proposed Action on Sediment Resource

FPHCP Effects on Sediment

Covered activities under the FPHCP that are expected to generate sediment that could directly and indirectly affect aquatic life as described above, can be grouped into one of two general categories. These categories include 1) riparian timber-harvest activities, and 2) road system management (i.e., construction, upgrading, maintenance, and abandonment activities). In watersheds containing potentially unstable slopes, some increase in the frequency of slope failures due to timber harvest is anticipated. Slope failure, although dependent on soil conditions, lithology, slope angle and geomorphic position, is generally initiated by elevated pore-water pressures in the soil during storm events. Timber harvest can result in a short-term increase in soil moisture due to reduced evapotranspiration and interception. This may result in an earlier and later persistence of soil water conditions conducive to slope failure during which storms could trigger a failure event. Soil condition during the rainy season would likely be unaffected.

Mass wasting can be an effect of forestry when unstable areas are not properly identified or categorized (e.g., likelihood of delivery). Some portion of such events may occur from outside the channel system, and some portion of those events may deliver to Type Np or F streams. The Services believe that those features likely to be misidentified are those smaller in size and less apparent. Where accidental misidentification of features is likely, we are analyzing those possibilities including the adverse effects that would emanate from such misidentification. We believe larger, more obvious features, with a high probability of delivery to public resources, are less likely to be misidentified. Mass wasting events are controlled by multiple factors, and we also note that uncertainties concerning causal mechanisms make it difficult to attribute these events to a specific FPHCP activity. When such events would occur, it is generally difficult to attribute specific adverse effects that rise to the level of harm to such events.

In addition, potentially unstable landforms may not be avoided during harvest if the delivery zone is predicted to lie outside of typed streams. These predictions can sometimes be erroneous, as they are made without the benefit of a geotechnical report or SEPA review. Thus, some opportunities to reduce mass wasting hazard or reduce potential resource impacts are missed if mass wasting should exceed anticipated runout distance or severity. The degree to which these unanticipated effects occur is not expected to change as a result of the FPHCP.

Riparian Timber Harvest: Timber-harvest activities in the Riparian Zone can cause soil erosion and can cause sediment generation, mobilization, and delivery. Timber harvest and associated activities such as yarding can be a significant source of sediment if improperly conducted. Rashin et al. (1999) identified several timber harvest activities permitted by the State of Washington's previous forest practices rules that contributed significant amounts of sediment to adjacent streams. Riparian buffers of at least 10 meters, 10-meter equipment-exclusion zones (no ground disturbing activity except directional tree falling), and directional falling of trees away from typed water are all measures identified by Rashin et al. (1991) as effective means to avoid chronic sediment delivery and direct disturbance of streams from harvested-related erosion. The FPHCP protective measures are designed to minimize soil disturbance, reduce the potential for erosion, and minimize the amount of sediments reaching typed streams and wetlands where it could be harmful to fish and fish habitat. Generally, the amount of sediment created from riparian timber-harvest activities is related to the amount of bare and compacted soils exposed to rainfall and runoff, and the degree to which streambank disturbance or loss or footing strength affects bank stability. Measures in the FPHCP that regulate aforementioned timber harvest practices are designed to minimize the amount of exposed and compacted soils (see additional discuss in **Soil Compaction** section) close to the stream channel or wetlands. In addition, the FPHCP includes measures to regulate timber harvesting on all high-hazard unstable-slopes. However, even with these minimization measures in place, sediment is expected to be generated by timber harvest activities and will enter streams in a number of cases. This is a result of entries by equipment into riparian zones and ELZs, equipment crossing Type Np and Ns streams, partial suspension yarding across Type Np and Ns streams, and harvest within 10-meters of Type Np and Ns streams. Occasional failure to detect and appropriately regulate high-hazard unstable slopes, and naturally occurring slope failures, are addressed within the baseline and cumulative effects sections.

Under the FPHCP, there would be no timber harvest within the Core Zone of fishbearing streams, and the post-harvest Inner Zone must meet Desired Future Condition as well as specified retention levels, which would limit the amount of ground disturbance and vegetation removal near streams. Substantial removal of trees is permitted from within the Outer Zone and beyond, but this is an area of the buffer where the probability of delivery of sediment is less, as long as core and Inner Zone buffer strips remain in place. Riparian protection is extended from the outer edge of channel migration zones associated with fish-bearing streams. This ensures that as streams actively move within valleys due to natural processes, riparian buffer areas are retained to prevent sediment generated from harvest-related ground disturbance and forest roads from entering streams. Riparian prescriptions on Type S and F streams are thought to be adequate to prevent excessive (above natural levels) amounts of streambank erosion that could increase the amount of sediment delivery downstream. Trees in the 50 foot (westside) and the 30 foot (eastside) no-harvest Core Zone of Type S and F streams and along the buffered portions of Type Np streams are intended to provide the majority of stability to stream banks. According to FEMAT (1993), trees within one-third of a tree height from the channel provide the rooting strength important for maintaining the integrity of the streambank. In most instances, all buffered portions of typed streams meet or exceed this criterion (see **Streambank Stability**).

Timber harvest within Type S and F stream buffers under alternate plans is expected to provide similar levels of protection for aquatic habitats. Due to the "equal in overall effectiveness" constraints of Alternate Plans, it is expected that the impacts to the aquatic and riparian environment would be essentially the same or less than what would occur under the standard rules. No significant or measurable differences in effects to sediment recruitment are expected due to the “equal in overall effectiveness” provisions of alternate plans with respect to aquatic and riparian function.

Where the 20-acre exemption would be applied to timber harvest along fishbearing streams, there may be a higher level of harvest, resulting in an increase in the level of ground disturbance near streams. Unlike the standard prescription, requirements for 20-acre exempt buffers are only measured from the bankfull width and not the outside of the channel migration zone, even if that distance is greater. As a result, timber harvest and ground disturbance may occur within riparian areas associated with channel migration zones, which would facilitate sediment inputs to streams. This is particularly problematic in cases where a stream would reoccupy the inner boundary of a channel migration zone after harvest, and would result in the loss of the riparian buffer which was intended to ameliorate harvest related sediment impacts generated outside of the buffer. Additional trees within the RMZs of 20-acre exempt parcels may need to be retained to meet the shade rules, but an increase in ground disturbance is nonetheless expected along fishbearing streams with channel migration zones.

There would be some harvest-related sediment impacts along perennial streams without fish (Type Np streams) and seasonal streams without fish (Type Ns streams). A 50-foot riparian buffer is required along at least 50 percent of the Type Np on the westside, and on the eastside, only 30 percent of the stream can be left unbuffered (with a corresponding length in no-harvest buffer). A provision also exists for potential to use partial harvest within 50-feet of the stream on the eastside. Partial harvest buffers along Type Np streams would be subject to some tree removal, but must meet the basal requirements for that forest zone. The portions of perennial and seasonal streams without fish that are left unbuffered (no more than 50 percent of Type Np streams on the west side and 30 percent on the east side, and up to 100 percent of stable Ns streams) would result in more-acute, sediment-related effects to streams as a result of more-intense harvest activities and ground disturbance near or across these waterbodies. Harvest adjacent to all non-fishbearing streams are subject to the 30-foot ELZ.

Generally, minimal buffers would be required on Type Np and Ns streams on 20-acre exempt parcels which would increase the amount of harvest-related streambed and streambank disturbance, as well as ground disturbance adjacent to these streams, and would significantly reduce the amount of large wood recruitment in these areas. Although sediment would not directly enter fish bearing streams, it would eventually be routed to Type S and F streams. When such harvests occur on steeper topography, sediments from mass-wasting events may be routed more-rapidly downstream, because large wood, which tends to increase sediment retention, would be present in reduced supply. However, most 20-acre exempt parcels generally occur in lower elevations, flatter topography, proportionally fewer areas with mass-wasting potential, and with a greater proportion of fishbearing streams, and therefore a smaller proportion of their stream system will be composed of Type Np streams. In addition, timber harvest along streams under the 20-acres exception rule is still subject to the 30-foot ELZ rule. Application of 20-acre exemption to Type Np streams would retain buffers of at least 29 trees per 1,000 feet when covered species could be affected. The shade rules would not apply on Type Np streams. For a more complete discussion of riparian buffer widths, refer to **Description of the Rules** Section.

Riparian vegetation aids in maintaining stream-channel dimensions and bank stability, and affects where erosion and sedimentation of channels and floodplains occurs (IMST 2004). The reduction of riparian vegetation on portions of Type Np and Ns streams can lead to the instability and eventual failure of the streambanks, resulting in delivery of sediment to the stream channel (see **Streambank Stability** section). Sediment from streambank erosion is more likely to originate from the unbuffered portions of Type Np streams and the unbuffered Type Ns streams. These stream segments have a 30-foot ELZ and harvest activities must avoid disturbing stumps, root systems, and any logs embedded in the stream bank, as well as brush and similar understory vegetation. However, where no riparian buffers are required, harvest can occur up to the edge of the stream. A decrease in riparian vegetation may destabilize the streambank, resulting in an increase in sediments being deposited downstream. In turn, the deposition of sediments can cause the channel to widen increasing the amount of solar radiation reaching the stream. As a result, some habitat impairment within the unbuffered stream segments from sedimentation is expected to occur. In addition, the routing of sediment through non-fish-bearing streams into fish bearing streams will also occur over time, circumventing the effectiveness of riparian buffers on other typed streams (Rashin et al. 1999).

Felling and Bucking. The felling of trees and bucking of logs in or adjacent to typed streams and RMZs must be conducted in a manner that protects riparian and in-stream habitat and water quality. Under the FPHCP, application of the following measures when harvesting in or adjacent to typed water, RMZs, and WMZs, are designed to minimize soil disturbance, damage to residual trees, and the delivery of excessive slash to typed streams.

Only a minor amount of felling and bucking is expected to occur within inner portions (80 to 100 feet) of riparian buffers of fishbearing streams, and as such, the need for equipment to penetrate these areas will be very limited (see expected effects from Ground-based Equipment Use and Cable Yarding below). Felled trees that fall within the Core Zone are required to be left and few trees are expected to be removed from the Inner Zone. In some cases, when stand conditions allow, the majority of trees may be removed from the Inner Zone while retaining a specified number of the largest trees. For instance, on the westside, 57 of the largest trees would be retained following a thinning. In a high basal area Ponderosa pine stand, 21 of the largest trees would be retained, as well as another 29 trees over 10 inch dbh. However, even with this removal, the Core Zone (30 ft eastside and 50 ft westside) should ameliorate the small amount of sediment generated by felling and bucking. Felling and bucking within the Outer Zone and adjacent to buffers should result in minimal effects due to the use of directional felling. Directional feeling away from Type S and F streams is not expected to contribute sediment to streams, especially since it maintains the integrity of the riparian buffers which would likely prevent any sediment generated from this activity from reaching the stream. Effects including the introduction of sediment from felling and bucking adjacent to buffered reaches of Type Np streams are also expected to be minor.

Felling and bucking along unbuffered portions of Type Np streams and Type Ns streams may result in the direct delivery of some sediment to these waters, but is likely to be minor to insignificant amounts. Some of this sediment could reach fish-bearing streams. The more-significant levels of sediment delivered from timber-harvest activities to Type Np streams would be from stream bed and bank disturbance (i.e., if equipment were allowed to cross streams) and ground disturbance associated with the actual removal of felled trees.

Ground-Based Equipment Use. Ground-based equipment is commonly used to fell and yard timber, and to construct, maintain, and abandon skid trails used during timber-harvest activities. Under the FPHCP, ground-based equipment is regulated to limit physical impact to typed streams and wetlands and to minimize indirect effects such as soil disturbance and associated erosion and sedimentation that could impact typed streams and wetlands. Measures regulating ground-based equipment vary with local conditions and address typed streams, wetlands, RMZs, WMZs, soil-moisture conditions, residual trees, skid trails, and slope conditions. Low-impact equipment would be used when soils are saturated or otherwise subject to rutting. Soil disturbance and compaction are expected to be avoided or minimized by the use of Best Management Practices applied to the handling and moving of the logs within the RMZ.

FPHCP states that on-site mitigation “is required if equipment use exposes soil on more than 10 percent of the surface area of the ELZ. These activities include operating ground-based equipment, constructing and using skid trails and stream crossings, and yarding partially suspended, cabled logs” (WDNR 2004a). The FPHCP further states, “Mitigation must be designed to replace the equivalent of lost function, particularly as it relates to the prevention of sediment delivery”. Mitigation, such as waterbars, grass seeding, and mulching would be used to address such damage, however, damage of less than 10 percent could go unmitigated. Although no width is specified, Washington Forest Practices states that, “Skid trails shall be kept to the minimum width” (WFPB 2002). For the purposes of this assessment we assume the width of skid trails will typically be no wider that that of the width of the equipment used at a particular site. However, equipment will not always follow its previous trail exactly, so there may be a small increment of width added with additional passes. In some locations, equipment will need to maneuver and turn, increasing some trail width at these particular portions of the trail.

Sediment may be mobilized during yarding by ground-based and cable equipment. Rutting and soil compaction (See additional discussion in **Soil Compaction** section) from skidding of logs may result in increased run-off and erosion rates, and thus may lead to an insignificant to small increase in sediment delivery where streams have intact riparian buffers of 10 meters or more. Where yarding is permitted across streams or equipment enters the ELZ, delivery of sediment becomes more probable. Rashin et al. (1999) in evaluating timber harvest best management practices in place during the summers of 1992 to 1995 in Washington, found that based on the extent of exposed soil associated with erosion features that delivered sediment to streams, the main causes of erosion at harvest sites were skid trails and other timber-yarding activities. Based on observations of erosion and sediment routing from several different harvest practices (including skid trails) over a range of topographic conditions in both eastern and western Washington, Rashin et al. (1999) also expected that a 10–meter setback for ground disturbance would prevent sediment delivery to streams from about 95 percent of harvest-related erosion features. Gomi et al. (2005) found that streams with buffers ranging from 10 to 30 meters wide had relatively small increases in sediment yield from physical disturbances (i.e., tractor yarding). Based on these findings, in most cases riparian prescriptions for Type S and F streams and buffered portions of Type N streams under the FPHCP are expected to sufficiently minimize the amount of sediment that would otherwise be delivered from disturbance caused by ground-based equipment (see **Sediment Filtering** section).

There will likely be greater sediment yields from yarding in riparian areas under the 20-acre exemption as harvestable timber will be closer to the stream than under standard rules. Greater effects from yarding in riparian areas under the 20-acre exemption would be likely since timber can be harvested along Type Np streams, more-frequent entry into the ELZ is expected, and more numerous yarding corridors within 20-acre-exempt riparian zones would be expected. Type Np stream channel crossings will also result in significant disturbance and compaction to stream beds. Although mitigation will be required in cases where soil exposure exceeds 10 percent, these mitigation measures will typically be effective in alleviating or preventing chronic sediment input from surface erosion, and not necessarily the episodic input of sediment that will result from any streambank disturbance. Waters (1995) suggested that the erosion of streambanks, as a result of cutting or skidding directly in the riparian zone, may be second in importance only to roads in producing excessive sediment. Waters (1995) further pointed out that the only way to eliminate this source of sediment appeared to be by avoiding working in the riparian zone altogether.

Cable Yarding. According to Rashin et al. (1999), cable yarding, although a less-frequently used yarding technique, actually produces more relative amounts of erosion than ground-based yarding. Erosion features at cable-yarding sites had a higher frequency of delivery to streams. Under previous forest practices rules, cable yarding without buffers resulted in sediment routing to the stream. Substantial disturbance of stream channels, valley walls, and steep inner gorge areas by cable-yarding practices were observed resulting in chronic sediment delivery and extensive fine-sediment deposition on streambeds. This is largely because cable yarding tends to be used in steeper sites relative to ground-based yarding.

The FPHCP limitations on cable yarding in and across typed streams and wetlands are intended to minimize soil disturbance and impacts to their beds and banks. Cable yarding in or across Type S and F streams is not allowed, except where logs will not materially damage the stream bed, banks, sensitive sites, or the riparian management zones. Yarding over Type S and F streams also requires a HPA from WDFW that may carry additional restrictions to protect fish and fish habitat. If permitted, yarding is usually limited to cable or other aerial logging methods that suspend the logs above the riparian zones.

When it is necessary to create yarding corridors through the RMZ of Type S or F streams, the corridors must be no wider than or more numerous than necessary to accommodate safe and efficient transport of logs. Total openings resulting from yarding corridors must not exceed 20 percent of the stream length associated with the forest practices application. When trees within the Core Zone are felled to construct yarding corridors they will remain in place as downed wood, or may be recruited into the streams. Where logs are yarded from or across RMZs, WMZs, and sensitive sites, reasonable care must be taken to minimize damage to vegetation that provides shade and to understory vegetation, stumps, and root systems. When practical and safe, logs must be yarded uphill, in the direction in which they lay, and away from RMZs, WMZs, and sensitive sites. Where downhill yarding is necessary, reasonable care must be taken to lift the leading end of the log to minimize downhill movement of slash and soils. When yarding is parallel to Type S or F streams, below the 100-year flood level, or within the RMZ, reasonable care must be taken to minimize soil disturbance and to prevent logs from rolling into the water or RMZs.

Even with these protections, cable yarding will result in the delivery of some sediment to Type S, F, and N streams. However, as with ground-based equipment use, there will likely be greater sediment yields from cable yarding in riparian areas under the 20-acre exemption as harvestable timber will be closer to the stream than under standard rules. Greater effects from cable yarding in riparian areas under the 20-acre exemption would be likely since timber can be harvested closer to Type Np streams, more-frequent entry into the ELZ is expected, and more-numerous cable crossings (settings) across Type Np streams are expected. Although mitigation will be required in cases where soil exposure exceeds 10 percent, mitigation measures will generally be effective in alleviating or preventing chronic sediment input due to surface erosion, but may not necessarily be effective in preventing episodic input related to ground or stream bank disturbance within the ELZ.

Clearing of Slash and Debris. Large accumulations of slash may contribute to the initiation or exacerbation of mass-wasting events (e.g., debris slides and debris torrents). Conventional methods of slash disposal include pile or windrow and burn; pile or windrow without burning; mechanical scatter and compaction; scarification; chip, mulch, or lop and scatter; burying; and physical removal from the forest lands. Controlled broadcast burning is used less often due to air-quality concerns and fire risk. Forest practices rules prohibit slash disposal methods that employ machine piling, mechanical scatter and/or compaction, scarification, or other techniques that result in soil disturbance within ELZs. In addition, limbing and bucking (activities that usually generate slash) is prohibited within the bankfull channel of Type S, F, Np streams, in RMZ Core Zones, sensitive sites, or open water areas of Type A wetlands.

Where slash and debris is expected to plug culverts on Type Np and Ns streams, it must be cleared from the channel for a distance of 50 feet upstream. Site preparation through scarification will result in a range of soil disturbance, but will typically be minor (See **Soil Compaction** section).

There are some benefits to retaining slash and debris. Small woody debris provides cover for juvenile fish, amphibians, and prey species and may trap leaf litter and other detritus important to aquatic insects. Slash and debris left on flood plains also traps leaf litter and detritus, which subsequently decomposes and enriches the soil. Accumulations of small woody debris and slash may also help moderate fine-sediment transport from the forest floor to downstream habitats. Larger woody debris provides important structural components to stream channels, trapping gravels used for spawning and providing habitat for fish and aquatic insects. While Type Np and Ns streams do not support fish, woody debris in these streams helps prevent excessive erosion during peak flows. To prevent the removal of beneficial woody debris, forest practices rules limit the type and amount of material that can be removed. HPAs are required to remove harvest-related slash or debris from Type S and F streams (e.g., material removed upstream of culverts to prevent culverts from plugging) and, depending on the circumstances, may be required for Type Np and Ns streams.

Small woody debris is more easily transportable than large wood, and tends to form small, relatively unstable debris jams. Large wedges of sediment can temporarily accumulate behind these debris jams. This sets the stage for "dam-outburst" sediment dynamics, in which the jam breaks apart, suddenly releasing its wood and sediment, which is transported downstream until caught in another jam nucleation point, initiating another jam and sediment wedge. In this manner, large pulses of sediment can move downstream, far exceeding the transport rates normally associated with the given hydraulic conditions (Bryant 1980; O'Connor and Harr 1994). Small debris jams and their movement damage and destabilize channels and habitat, and can block road crossing culverts. Some of the debris generated from harvest activities on Type Np and Ns streams is expected to become incorporated in small debris jams of this sort, possibly increasing their occurrence over natural levels. The effects of small debris jam formation and outburst events on habitat and channel stability has not been well studied.

Only a minor amount of clearing of slash and debris is expected to occur within riparian buffers of fishbearing streams, and as such, the need for equipment to penetrate these areas will be very limited. Impacts including the introduction of sediment from clearing of slash and debris adjacent to buffered portions of Type Np streams are also expected to be minor. Although machine piling, mechanical scatter and compaction, scarification, chip, mulch or lop and scatter, and burying is not allowed within 30 ft of unbuffered Type Np and Ns streams, clearing of slash and debris may result in the direct delivery of some sediment to nonfish bearing streams. The amount of sediment reaching these unbuffered streams depends on the level of ground disturbance from activities within this zone. Some of this sediment will eventually reach fish-bearing streams.

<u>Large Woody Debris In-Channel Placement Strategy</u>. Occasionally, riparian restoration in the form of placement of large woody debris may be proposed as part of an FPA, but this currently appears to be rare (C. Rodgers, WDNR, pers. comm. 2006). Placement of large wood requires approval from the WDNR to work in the Core Zone and an HPA from WDFW to work within the wetted portion of the stream. Root wads must be placed entirely within the bankfull width. HPAs are required for all in-channel placements and may result in additional restrictions and guidelines. For instance, public-safety issues such as downstream bridge or culvert crossings that could reasonably be assumed to be endangered by stream-borne logs may necessitate anchoring of placed wood. Where unavoidable, anchoring is generally accomplished either by placing large boulders on top of the log, burying one end of the log in the bank

(sometimes in conjunction with boulder placement), or cabling the log to an anchor (such as a boulder, buried ecology block, screw anchor, or driven anchor bar).

While large-wood placement in streams is generally done to benefit the aquatic system as well as the fish species which depend upon those habitats, sediment effects as well as other effects (e.g., modification of existing habitat) may result in the short term. For example, while placement of wood with attached root-wad will provide better stability of large wood, it will also increase the probability of sediment delivery and may generate a short-term sediment pulse or turbidity. Placement of a bole without an attached root-wad will generally require other methods to secure the piece within the stream, is less desirable from a stream-dynamics standpoint, and may result in more short-term sediment delivery depending on the amount of bank and ground disturbance required to anchor the piece within the stream.

Within the stream, substrate may be disrupted by movement and positioning of logs. Following placement, large wood may not remain in place and may migrate downstream, causing additional sediment mobilization and/or sediment storage lower down in the stream system, but adding to the channel habitat complexity. This potential for movement is especially true for large wood placed without attached root wad, and may be true even if secured in other ways. Large wood that remains in place is expected to increase the amount of local sediment deposition and result in a temporary storage of that sediment. The amounts of sediment mobilized due to large wood placement are expected to be small and temporary in nature.

Road Construction, Upgrading, Maintenance, and Abandonment

Logging roads and their designs are particularly important factors affecting surface erosion and subsequent stream sedimentation. Surface drainage concentrated within roadside ditches, that is not dissipated or redirected to reduce its effects can lead to erosive cuts (resulting in soil erosion and stream sedimentation) and concentrated water flow onto slopes that may exceed a slope's capacity to hold the weight (resulting in mass soil movements or landslides). Surface erosion on gravel roads also can lead to high levels of suspended sediment moved into streams. Inadequate road designs, such as inappropriate placement of backfill, undersized culverts, and other factors, can lead to mass-wasting events such as land slides or debris torrents. During periods of heavy rainfall, roads and ditches can become temporary stream systems, speeding water runoff and reducing water absorption into forest soils.

Everest et al. (1987) found that logging roads, not the tree-harvesting practices themselves (unless both sides of a stream bank were clear-cut), were responsible for a majority of the sediment that enters an aquatic system. Roads can modify natural drainage networks and accelerate erosion processes. These changes can alter physical processes in streams, leading to changes in streamflow regimes, sediment transport and storage, channel bank and bed configurations, substrate composition, and stability of slopes adjacent to streams. These changes can have important biological consequences, and they can affect all stream ecosystem components (Furniss et al. 1991). Road construction can also cause the stream channel network to increase, because the roads act as tributaries, creating a more-efficient, sediment-delivery system (Castro and Reckendorf 1995). McCashion and Rice (1983) found that logging roads were responsible for 61 percent of the soil volume displaced by erosion in northwestern California. Reid and Dunne (1984) found that gravel forest roads generated up to 300 tons of sediment/mile/year from surface erosion in the Olympic Mountains of Washington. They found sediment loss was found to be related to traffic intensity and was highest on heavy-use gravel roads compared to unused roads or paved roads. Sediment yield from cutbanks and ditches alongside paved roads was less than 1 percent of that from gravel roads in their study. Heavily used roads were calculated to produce 300 tons of sediment/mile/year over the period of study, compared to lightly used roads with 2.6 tons/mile/year and paved roads with 1.4 tons/mile/year.

Severe erosion is almost inevitable if roads are not properly constructed and regularly maintained. Road construction and maintenance associated with timber harvest typically increases the amount of sediment delivered to streams through surface erosion, as compared to natural delivery rates. Roads can rarely be constructed that do not have adverse effects to streams (Furniss et al. 1991). Roads constructed within riparian areas and parallel to streams typically have pronounced adverse effects to aquatic systems, compared to roads built in other locations. In particular, stream crossings pose the greatest risk to fish habitats of any road feature. When culverts are plugged by debris or overtopped by high flows, road damage, channel realignment, and severe sedimentation can occur (Furniss et al. 1991). Wash-out of a road crossing fill can input large volumes of sediment directly to the channel. Even greater inputs result when a plugged culvert diverts the stream out of its channel and into the road ditch. As the diverted stream seeks a new path down the hillslope, it can carve a substantial gully (Furniss et al. 1998). Failure to properly maintain road drainage can also result in large sediment inputs to streams (Furniss et al. 1991). “Roads, which are the major source of management-related sedimentation in streams associated with logging regionally, continue to have adverse effects to stream communities even when not actively utilized”, and they continue to contribute high sediment loads until they are stabilized and abandoned (Cederholm and Reid 1987). Furniss et al. (1991) found soil erosion rates were 30 to 300 times higher on forests with roads than undisturbed forest. Roads can also alter streamflow rates and volumes, which along with increased sedimentation, can result in altered stream channel geometry (Furniss et al. 1991). Acting as new flowpaths for water, roads can increase the channel network over watersheds, increasing the drainage density. By increasing the frequency, magnitude, and altering the composition of debris flows, road-caused erosion and delivery can affect the long-term potential for developing complex channel morphology and aquatic habitat (Jones et al. 2000).

The premise behind the road construction and maintenance program in the forest practices rules and the FPHCP is that a well-designed, located, constructed, and maintained system of forest roads is essential to forest management as well as the protection of public resources. To protect public resources such as fish habitat and water quality, roads must be constructed and maintained in a manner that will prevent potential and actual damage. This will be accomplished by constructing and maintaining roads so as not to result in the delivery of sediment and surface water to any typed water in amounts, at times, or by means that preclude achieving desired fish-habitat and water-quality goals. These goals are to be achieved by eight objectives: 1) providing for fish passage at all life stages; 2) preventing mass wasting; 3) limiting delivery of sediment and surface runoff to all typed streams; 4) avoiding capture and redirection of surface or ground waters; 5) diverting most road runoff to the forest floor; 6) providing for the passage of some woody debris; 7) protecting streambank stability; and 8) minimizing the construction of new roads and abandoning old roads.

Road-generated sediment may be delivered to streams unless prevented by active management. FPHCP road maintenance and design standards are expected to address the delivery to road-generated sediment to a high degree, however, a number of road maintenance tasks are also expected to generate and/or mobilize sediment (e.g., flattening cut slopes, widening ditches, ditch maintenance). FPHCP road construction, grading (including cutting into existing slope), and placement of fill will result in exposed, un-vegetated surfaces that may be subject to erosion. Most of this work usually will be done in the drier summer months and revegetated or addressed in alternate ways prior to the wetter winter season. Installation of drainage features may result in additional mobilization during construction, but will reduce potential for mobilization and delivery during the life of the road. During stream-crossing structure installation there maybe short-term mobilization and deposition of sediment and turbidity, and erosion at improperly armored culvert inlets. Road construction, as well as re-construction, repair, upgrading, and installation or improvement of stream crossings may require drilling which will create debris, sediment, and slurry. Drilling procedures will be established to manage slurry waste from drilling. Excavation, grading, cleaning culverts, pulling ditches, and other activities can generate spoils, however, spoil disposal is not expected to result in sediment run-off that would enter the stream system (see **Spoil Disposal** section for description of activity).

Obliteration of abandoned roads adjacent to streams can also result in adverse effects to fish, amphibians, and their habitat through sedimentation of spawning and rearing habitat, degraded water quality (turbidity/contaminants), and direct injury to fish and amphibians from heavy equipment used for instream work (e.g., culvert removal). If properly done, road obliteration or full decommissioning will ultimately reduce the potential for excess sediment delivery to streams from roads and would eliminate further effects of road use. On that basis, road obliteration or full decommissioning is generally considered to have long-term beneficial effects to fish, amphibians, and their habitat.

RMAPs. Forest practices rules require all forest landowners to develop road maintenance and abandonment plans (RMAPs) to prevent sediment and hydrology related impacts to public resources including aquatic habitats utilized by fish and amphibians. Road maintenance and abandonment work carried out under approved RMAPs must meet forest practices standards. These standards require landowners to: 1) keep drainage structures functional; 2) divert captured groundwater from ditchlines onto stable portions of the forest floor; 3) maintain road surfaces to minimize erosion and the delivery of sediment to typed streams; and 4) slope and waterbar road surfaces to prevent water accumulation. Large landowners are required to have all roads within their ownership covered by an approved RMAP by July 1, 2006. The RMAP process is intended to bring all roads owned by large landowners into compliance with forest practices standards by July 1, 2016.

Implementation of the FPHCP is intended to substantially reduce road-related erosion and sediment delivery from current and future roads, both in the near-term (< 10 years) and over the long-term (10 to 40 years) relative to current levels of sediment delivery. Near-term reductions from existing sources are expected to result largely from implementation of RMAPs. These standards require that roads be disconnected from the stream network through the installation of drainage structures, that road fills susceptible to mass wasting be removed, and that stream-adjacent parallel roads be repaired and maintained, or abandoned. Sediment reductions from small forest landowner lands will occur in a different manner and on a different schedule (see Exceptions to Road Maintenance in **Description of Activities that are Effects of the Permit** section). FPA approval by WDNR will include a requirement for improving roads to the new forest practices standards as part of timber harvest operations, or small forest landowners must enroll in the FFFPP. Therefore, sediment reductions accrued from small landowner lands will likely be distributed over a longer timeframe. In cases where roads on lands of small forest landowners are causing or have the potential to cause damage to public resources, WDNR can, at any time, require the landowner to take corrective actions to minimize and mitigate the impacts. Approximately 40 percent of covered lands are owned by small forest lands owners.

Forest practices rules also require large forest landowners to prioritize road maintenance and abandonment planning based on a "worst first" principle. This means that road systems or watersheds where RMAPs implementation would produce the greatest benefit for public resources receives the highest priority. The highest-priority areas identified in the FPHCP are areas where listed and vulnerable species occur. This is likely to benefit listed salmonids, other fish, and amphibians, as roads in or near their habitat will be addressed first, minimizing the time that the most-severe sediment impacts from roads will continue into the future. Small forest landowners have two options for meeting RMAP requirements: 1) They may follow the RMAP process for larger landowners or they can submit a checklist RMAP with each forest practices application or notification, or 2) The can fix any road-related problems at the time they conduct the FPA. With respect to fish passage barriers, they have a third option of enrolling in the FFFPP. This may mean that road-related sediment on some lands owned by small forest landowner will not be corrected as timely as a similar situation on land owned by large forest landowners. The effects of this schedule to fish and amphibians will vary depending on the species, its distribution, and the option selected by each particular small landowner. Delayed repair will mean that the benefits of improved passage may be delayed. Impacts are likely greatest for sensitive species such as bull trout and tailed frogs in watersheds where a significant number of small landowners choose to submit a checklist RMAP with each application, or where such a small landowner is located on a particularly important piece of habitat within the watershed. However, WDNR retains the authority to require any landowner to address road-related impacts where the road has affected or could potentially affect public resources. As of December of 2005, approximately 89.8 percent of the required RMAPs had been completed, with an expected 8.8 percent to be completed by June of 2006.

The FPHCP area currently has over 60,000 miles of mapped roads, which yields an average road density of 4.1 miles per square miles on FPHCP lands (Appendix G). According to our GIS analysis, about 9 percent of these roads occur within the riparian zones (100-year site-index tree height) of Type S, F, or Np streams. In addition, there are over 130,000 road-stream crossings in the FPHCP, including over 18,000 crossings on fish-bearing streams. Stream-adjacent parallel roads (those roads with in a 100-year site-index tree height) and stream crossing are the likely the two features on FPHCP covered lands that will deliver the greatest amount of sediment to streams.

Orphan roads are roads constructed prior to 1974 that have not been used for forest practices since that time (WAC 222-24-052*(4)). Such roads are typically not maintained, and many were constructed without a requirement to consider public resource and channel impacts. The mileage of orphan roads in Washington is unknown; however, the associated hazards have been identified. The concern with orphan roads is the lack of knowledge about their location and potential for failure and initiation of debris avalanches, debris flows, and debris torrents. Although FPHCP would require landowners to inventory and assess orphaned roads, their repair or abandonment is not required. However, landowners may voluntarily fix problems identified during the orphaned road inventory and assessment.

Some cases will occur where unused or seldom used roads are not maintained to FPHCP standards. This is more likely to happen on small landholder parcels, where reporting requirements do not occur until filing of an FPA, which could be many years into the future. Such roads are vulnerable to the various failure mechanisms discussed previously which can result in sediment input to stream channels. In addition, some roads may be abandoned without full implementation of specified sediment reduction measures if it is believed that the likelihood of delivery to water is small. In some cases, these determinations may be in error, resulting in inadvertent sediment delivery. In the past, efforts to stabilize abandoned roads have sometimes not been successful, and have resulted in unintentional sediment delivery.

Road Construction. The first step toward limiting the delivery of sediment from forest roads to the aquatic environment is to properly locate news roads. FPHCP requires that roads be fit to the topography to minimize alteration of natural features. This includes avoidance of aquatic features such as surface waters, wetlands, channel migration zones, riparian management zones, and sensitive sites such as seeps, springs, and initiation points of perennial flow. Road and landing construction are also regulated on all high-hazard unstable slopes.

Conceivably the most-important mitigation measure related to sediment delivery from road erosion to streams depends on the location of the road with respect to the stream. The closer the road to the stream the more the mitigation should focus on the road ditch or traveled way (Elliot and Tysdal 1999). Some have observed that sediments discharged from the road do not reach streams due to the filtering and sediment trapping effects of intervening buffer strips (Ketcheson and Megahan 1996; Megahan and Ketcheson 1996; WFPB 1997).

Drainage near a stream crossing (whether the crossing is a culvert or bridge) is important. It has been assumed that 100 percent of the sediment carried by road ditches which discharge into streams at stream crossings will be delivered to the stream (WFPB 1997). Miller et al. (1995 as cited in USFWS and NMFS 2000) observed that when runoff was discharged directly to stream channels, 50 percent of the deposited sediment and 100 percent of the suspended sediment reached the stream, in contrast to only 1 percent of road sediment reaching the stream channel when runoff was directed to the forest floor. At least 10 percent sediment delivery can be expected when culvert outflow occurs within 200 feet of a stream, so hydrologic decoupling would only be possible for portions of the road located more than 200 feet from a stream (WFPB 1997).

Design standards included in the FPHCP are mainly related to construction techniques and water-management requirements to minimize or prevent sediment delivery to aquatic habitats. In general, forest practices rules encourage road designs that utilize balanced cut-and-fill construction to avoid side-casting of excess fill materials. Specifically, in steep terrain (> 60 percent slopes), forest practices rules require full-bench designs in which no fill material is used to construct the road prism and waste material is end-hauled or over-hauled to stable locations where sediment would not enter the aquatic environment. In addition, no fills will be placed within the 100-year flood plain. Water-management requirements under the FPHCP focus on maintaining hydrological flow paths and minimizing sediment delivery by limiting road-induced rerouting of water. This includes design standards for culvert sizing and the spacing of drainage structures and requirements that roads be designed so that ditch water is routed onto the forest floor to facilitate infiltration and prevent or minimize sediment delivery to the stream network.

Placement of relief culverts is considered effective as long as discharge and sediment are not delivered to surface waters. Because of this, road location relative to stream location becomes the over-riding factor determining the effectiveness of drainage relief practices (Rashin et al. 1999). The further a road is located from a stream the less likely that road will deliver sediment to the stream. Rashin et al. (1999) found that the observed range of sediment transport from road to stream was 160 meters. Within that distance, adequate road-design measures where key to disconnecting road sediment from the stream channel.

FPHCP road-construction requirements focus on maintaining a stable road prism and water-crossing structures, and on minimizing sediment delivery to streams and wetlands. Road prism-related measures include limiting the volume of organic matter that can be incorporated into the road prism, compacting fills, removing construction-related slash and debris from culvert inlets, installing ditches and drainage structures concurrent with construction, depositing waste materials in stable locations, and preventing side-casting of excess fill materials on steep slopes.

FPHCP rules are also designed to minimize sediment delivery from new roads during and after construction. Measures include limiting construction to periods of low soil moisture, end-hauling or over-hauling waste material when side-casting would potentially result in delivery of sediment to streams, sloping roads and landings to prevent water accumulation, and stabilizing exposed soil. Other construction-related measures under the FPHCP minimize sediment delivery from new roads both during and following construction. Sediment can be delivered to streams and wetlands during road construction from exposed cut and fill surfaces and newly constructed roadbed surfaces and drainage ditches; even though special precautions are expected during construction, including the use of silt fencing, hay bales, etc. Sediment delivery may occur during construction and repair, but chronic sediment delivery may persist for long periods of time depending on location and design of road. Inadequate or poorly located cross-drain features may deliver road and ditch-line runoff directly to streams. However, we expect roads and their drainage features that would be designed and built according to the HCP standards should greatly minimize the delivery of road-generated sediment to the stream system. A study by Toth (1998) indicated that sediment delivery in the Chehalis, Stillman, and Taneum watersheds was reduced by 48, 34, and 44 percent, respectively, within 5 years. Although each watershed is unique and road maintenance and abandonment plans varied, the results provide a reasonable indication of the expected benefits from implementing such road plans.

The majority of roads that will be needed for timber harvest and related activities, especially mainline roads during the permit term, have already been constructed. Because road density has been linked to fine-sediment effects to streams (Cederholm and Reid 1987; Opperman et al. 2005), road densities will be addressed in **Cumulative Effects** section. Additional roads are expected to be constructed during the next 50 years whether or not the proposed permit is issued. The amount of new roads that can be constructed during the permit term is not limited by the FPHCP, nor is the FPHCP expected to substantially change the number or location of such roads. Current road density averages approximately 4.1 miles of road per square mile statewide (Appendix G). As a result of changes in equipment (i.e., generally shorter yarding towers), smaller harvest units, more-intricate harvest-unit design, and the need for access to currently inaccessible areas, additional roads would continue to be built. Obliteration or abandonment of many roads may reduce roads, but may also create the need for alternate routes.

<u>Road Maintenance and Use</u>. Road surface grading and re-shaping may re-mobilize fine sediments. Fine sediments mobilized by road grading may be delivered to stream channels. Road sediments may contain traces of oil, gasoline, hydraulic fluid, or other compounds (see **Water Quality** section). Road surface re-shaping and grading can re-mobilize sediment and hasten its delivery to the stream system, resulting in increased fine sediment loading in the stream substrates above natural levels. Sediments delivered to wetland areas can alter water quality and the wetland character by increasing eutrophication processes. Surface blading can temporarily increase sediment production and delivery can ensue during intense rains or through movement of dust.

Stream crossings may become plugged or may fail and result in diversion of streams. Plugged stream crossings may cause streams to flow across roads increasing road-surface erosion and sediment transport and delivery into downstream reaches. When diverted across roads, streams are shallow and mostly impassable. Debris may jam ditches and result in road failures or mass wasting. However, regular maintenance results in reduced risk for failures of road fill and mass wasting. Short-term mobilization, delivery, and deposition of sediments and turbidity may occur with cleaning debris from ditches or from culverts.

Timing of road use affects the generation of sediment from roads (Reid and Dunne 1984; Mills et al. 2003). Wet-season road use is a significant source of chronic turbidity and fine sediment in streams (Reid and Dunne 1984). Although the FPHCP does not specify seasonal restrictions, landowners will, in practice, minimize sediment production associated with the various road-related measures by conducting many construction activities in the dryer months (WAC 222-24-030). This will also serve to reduce the traffic of trucks hauling rock during wet periods. Landowners will often manage public traffic on their roads to ensure road surface degradation from public traffic does not interfere with their ability to haul over those roads.

A recent study in the Oregon Coast Range indicated that detectable turbidity increases at stream crossings during wet-weather hauling were limited to approximately 10 percent of the sites when road surfaces were adequately treated (Mills et al. 2003). The limited number of sites that delivered fine material to streams also displayed rapid dilution as turbid water moved into larger receiving tributaries, rendering effects undetectable (Mills et al. 2003). However, turbidity increases were noted where roads paralleled streams. The quality of aggregate used to surface roads is a key predictor of potential sediment yield from rocked roads (Foltz and Truebe 1995). Results from Oregon and Washington suggest that hauling on roads surfaced with high-quality aggregate can reduce sediment delivery by several orders of magnitude (Reid and Dunne 1984; Bilby et al. 1989; Foltz and Truebe 1995). By engaging in more activity in dryer months, FPHCP participants will significantly reduce the volume of chronic sedimentation that occurs from roads, relative to the historical practices that inform the present environmental baseline conditions.

<u>Road Upgrading (Fish Barrier Removal)</u>. Road upgrading may be done for a variety of reasons including to reduce sediment delivery, decrease maintenance requirements, reduce potential for road damage, and improve passage of fish, water, wood, or bedload. Fish-passage barriers at culverted crossings are created by several conditions. Improperly designed or placed culverts do not have the roughness and natural variability of stream channels and therefore do not dissipate energy as readily. In many instances high water velocities amplified by undersized culverts have created large scour pools at the culvert discharge point, altering the stream elevation below the natural gradient (i.e., downcutting). Over time, culverts become elevated or perched above the stream and create a physical barrier to fish passage. In other cases, water also drains under and around culverts, and migrating fish attempting to follow these flows can become stranded or impinged against the culvert or road fill.

Under the FPHCP roads must be constructed and maintained in such a manner that provides for fish passage at all life stages. In addition to striving for fish passage for all age classes of fish, the replacement or removal of fish-blocking culverts should result in more-naturally maintained stream hydraulics, including bedload movement, sediment transport, and passage of moderately-sized woody debris, leading to more-natural stream dynamics and stream geometry. The overall impact of this requirement of the FPHCP on fish and fish habitat is expected to be beneficial because it will restore spatial and temporal connectivity of waterways within and between watersheds where movement of fish and habitat elements are currently obstructed. Although the long-term impact of restoring fish passage and more of the natural stream dynamics to stream systems statewide is beneficial, the on-the-ground construction activities employed to correct fish-passage barriers can typically result in short-term adverse sediment impacts to a number of fish species and all life-history stages.

Sedimentation and turbidity will occur from heavy equipment operation on access roads, excavation areas, and fill locations by exposing, destabilizing, and/or compacting streambanks, streambeds, and riparian soils. Additional sedimentation may occur from excavating the roadfill, backfilling, bank armoring, clearing and restoring the riparian area, culvert maintenance, and restoration of streambeds following high-flow events, as needed. Sediment can be expected to be generated as the existing culvert is excavated, the work area is enlarged, and the new structure is installed and buried. Sediment generation downstream of the site is also expected after initial redirection of a stream back into its channel after construction. In addition, sediment may be generated during the installation of grade controls, large wood, boulders, spawning gravels, or other mitigation as required by the FPHCP or other permits. The effects of sediment to fish, amphibians, and their aquatic habitat are expected to be minimal during construction if it occurs in dewatered streams and if other BMPs are being implemented at each construction site. However, rain events during and after the construction period will likely mobilize sediment into the stream, even with sediment control measures in place, as sediment control measures are not always effective at precluding sediment deposition into streams (Rashin et al. 1999). Therefore, sediment effects may occur to fish and amphibians inhabiting stream reaches during initial rain events following construction. Sediment generated at these sites will typically have short-term impacts to aquatic habitat downstream of the construction site. Effects to individual fish from dewatering and fish-salvage activities are addressed under the **Fish Salvage** section.

As a result of changes in gradient, sediment stored behind the old culvert may also be mobilized and transported downstream. Several rain events may be necessary before all the sediment is mobilized and redistributed downstream of the culvert. In some cases, a culvert that was insufficient sized for a stream may impound water and create a wetland upstream with significant amounts of stored sediment. Once the crossing is retrofitted, the stored sediment may be mobilized and transported downstream. This process may take many years, during which the downstream channel is subject to increased sediment transport and/or delivery.

The removal or replacement of culverts can also result in head cutting upstream of the project. Culverts may be acting as a stable nick point, preventing the upstream migration of reach-scale channel incision. Should head cutting occur, this could result in loss of instream and riparian habitat due to channel instability, accelerated streambank failure, and increased sedimentation which can cause localized channel braiding and instability of streambanks (Castro 2003). Such impacts are likely to occur until new channel equilibrium is reached. Although removal and replacement designs will typically incorporate measures to limit headcutting in cases where regrade is over 1 foot (WDFW, in litt. 2003), it is currently unknown how frequently headcutting will occur in cases where regrade is less than this threshold, and how frequently grade controls may fail. Where breaks in grade are $\leq$ 0.6 feet, the risk of channel incision is considered low (USFWS 2004c). We are unable to cumulatively estimate the extent of such headcutting (i.e., amount of stream impacted) for culvert removal and replacement projects addressed under the FPHCP. However, where it does occur we expect localized effects to fish and amphibian habitat. We anticipate that fish and amphibian habitat may either be permanently lost or made unsuitable (e.g., for spawning, for cover, for foraging) for a period of time until it naturally recovers after a new channel equilibrium is reached.

There is generally a low probability of direct mortality to fish and amphibians from sediment generated during the actual removal of fish barriers. Outside of an emergency (see Emergency Road Work), the work will most likely be performed when ESA-listed fish species are least likely to be present based on in-water timing restrictions. However, ESA-listed, non-listed fish species, and amphibian species, are found in some locations at all times of the year and therefore, in some situations they will be directly affected by an increase in suspended sediments. Due to in-water timing restrictions, any major input of sediment generated during project construction would generally not occur during the actual spawning period for salmonids. However, spawning and rearing habitat for salmonids and other fish species and amphibians may still be degraded as a result of sediment generated during construction activities. Spawning and rearing habitat, and potentially redds, could be affected by post-construction sediment releases that could enter the stream during subsequent high flows from either areas disturbed during construction or from sediment that has accumulated behind the fish barrier. This could result in the mortalities of a range of life stages (from eggs to adults) depending on fish species immediately below the construction site. In the cases of headcutting, fish (Erman et al. 1988) and possibly amphibian mortalities are likely to occur immediately upstream of the construction site as a result of channel instability and bedload movement. The magnitude of the impact will depend on the severity of head-cutting and the abundance of susceptible fish and amphibian species in the affected reaches. As disturbed areas and the channel itself begin to stabilize, the amount of sediment generated during high flow events is expected to subside to background levels. With most sites, this is expected to occur within the first couple of years following construction (removal and/or replacement).

<u>Road Abandonment</u>. Sediment effects to streams are likely to result from road abandonment, since they may involve removal of culverts and associated fill, ripping the road for revegetation, or full obliteration (return to natural slope). Removal of culverts and any associated fill can temporarily increase sediment loads to streams. Heavy equipment used to rip road surfaces to facilitate revegetation will expose sediment to surface erosion. However, this activity is generally restricted to summer months to comply with regulations and other seasonal restrictions. Sediment effects of fill pullback and re-contouring are generally short term. On roads that are water-barred, some surface erosion may also occur. Some of this work may need to occur within riparian areas and may generate some additional sediment which could be delivered to adjacent streams if BMPs employed are not fully effective. All these activities may result in exposure of cut slopes and fill areas and may mobilize sediment, with some short-term surface erosion continuing until exposed surfaces at these sites are revegetated.

Sediment effects of crossing-structure removal are generally short term, but in some cases may be long term (also see <u>Road Upgrading</u> section). Mobilized sediment and turbidity associated with project implementation (structure removal and site contouring), may be followed by ongoing surface erosion of exposed surfaces for one or more years until surfaces are revegetated. Scouring of unconsolidated materials may occur during flood events. Long-term sediment benefits include restoration of natural stream gradient, channel width, and sediment transport, and also the elimination of risk from mass-wasting of road fill due to culvert blockage or failures.

<u>Emergency Road Work</u>. Heavy equipment might be used in the stream for emergency activities (e.g., unblocking culverts, brushing, spot rocking). In-water equipment use could temporarily affect fish, amphibians, and their habitat, including effects on redds, smothered or crushed eggs and alevins, crushed amphibians, increased turbidity and sediment deposition, blocked migration, and disrupted or disturbed overwintering behavior. Many fish are particularly vulnerable during the fall and winter, when adults are migrating and spawning, and the spring, when eggs and fry are still present in the substrate. Emergency work could move juveniles out of overwintering habitats such as side channels and deep pools, into inferior habitats or high-velocity waters. The effects of sediment mobilized by emergency activities during the winter and spring are likely to be localized and short-term, but can be locally intense, especially if redds are destroyed. Additionally, such emergency activities could deliver fine sediments to estuarine and marine waters, causing degradation of the habitats used by covered species in those environments. With the assessment and stabilization schedules established under the RMAPs, the frequency of occurrence for such extensive emergency stabilization treatments will be low. Also, over

time, as roads and stream crossings are upgraded to the specifications required in the FPHCP, the necessity for emergency stabilization work will decline. The short-term impacts would be further offset by the immediate and long-term benefits provided from stabilizing fill, preventing culvert blowouts, and minimizing erosion problems.

Research. Under the FPHCP, habitat manipulations may be conducted for research purposes and are expected to occur along a very small percentage of streams, be localized, and have minor sediment effects at a watershed scale. Localized effects to listed species (e.g., bull trout spawning and rearing areas) are expected to be limited due to screening and coordination with the Services in the site selection process for studies.

Screening and coordination with the Services in the site-selection process for studies should ensure that sensitive areas are avoided and that status of covered species is considered so as to avoid unnecessary population effects.

7.5.4.5 Conclusion

The FPHCP is expected to provide moderate to high levels of protection from sediment impacts to fish, amphibians, and their habitats. However, it is not expected to completely eliminate sediment impacts to fish, amphibians, or their habitat. FPHCP would result in stream-bed aggradation, a risk of habitat degradation from pool filling and modified channel capacity, and risk of direct impacts to fish from turbidity and suspended sediments.

Sediment impacts from activities covered under the FPHCP are expected to have direct and indirect adverse effects to fish and amphibians ranging from mortality to sublethal effects. Adverse effects to fish and amphibian habitat will range from short-term impairment to long-term change or degradation. However, any long-term degradation effects are expected to be infrequent and highly localized in nature (i.e., individual stream reaches) due to the types and locations of FPHCP activities. For example, a gravel spawning or rearing habitat could scour to bedrock during head-cutting.

Sediment effects that will have adverse effects to fish and amphibians will most likely result from the following forest practice activities: road construction/reconstruction and abandonment, and yarding. Sediment effects of a much lesser magnitude may also be generated from clearing of slash and debris, and large woody debris in-channel placement. Clearing of slash and debris may generate sediment effects, as will small woody debris jams that may form as a result of debris made accessible to Type Np and Ns streams, but the likelihood of impact is variable and site specific. It is highly dependent on the level of riparian buffering left on Type Np and Ns streams and the degree of ground disturbance (both mitigated and unmitigated) that occurs from other allowed activities within ELZs. Large woody debris in-channel placement is expected to be an infrequently implemented option due to the specificity in site condition that must be met before it is applied. As a result, the potential short-term sediment effects of large woody debris in-channel placement are projected to be highly localized and limited in nature. The most-acute sediment effects from timber harvest activities will be on Type Np and Ns streams, particularly on private forest lands with 20-acre exemptions. However, sediment effects from these actions are generally not expected to be chronic in nature due to the minimization and mitigation measures outlined in the FPHCP to minimize or avoid such effects. Any sediment effects from riparian timber-harvest activities are also expected to be tempered, since harvest will be spread out over the life of the FPHCP (i.e., 50 years), and across the State. Therefore cumulative effects from forest-practice activities are unlikely to be concentrated at a particular time (e.g., year) or within a particular watershed(s). This will likely allow some of the sediment reaching streams within a watershed to be processed through the aquatic system prior to receiving additional timber-harvest sediment effects. However, 20-acre exempt parcels are often on the edge of development (and agricultural lands) and sediment baselines may already be degraded on these lands immediately downstream and adjacent to forested parcels.

Depending on the time of year, sufficient germination and growth of ground-covering vegetation may be accomplished prior to the rainy season to minimize surface erosion from exposed slopes, fill deposits, and ground disturbance, which should help minimize the generation and delivery of sediment. Other methods to minimize sediment generation and delivery may include sediment-control fences, slash-filter windrows, mulching, etc. At other times, ground-covering vegetation may not be adequately developed, and short-term inputs of sediment will still result.

Road management may occasionally result in sediment effects from mass-wasting events on unstable slopes. However, these events triggered by road construction or management under the FPHCP are anticipated to be uncommon across private forest lands due to the existing unstable-slopes protection measures. FPHCP has not changed the States emphasis on unstable slope protection and supports its continuation. Effects from any mass wasting events will be most severe after the initial event, and then decrease overtime as slopes stabilize and sediment is transported through the stream system. Mass-wasting events that occur in the near future at a frequency or severity beyond the natural background will likely be caused by roads constructed and harvests performed under previous rules. For instance, root strength may decrease for 15 to 20 years following harvest as the roots from the previous stand rot, until the new stand develops its root system. Mass-wasting events are not uncommon in stands of this age where unstable features were not identified at the time of harvest.

Chronic sediment effects will still be seen on private timber lands, but will typically be legacy effects from past timber harvest and road construction activities conducted under previous Forest Practices Rules, as well as from existing roads. These legacy sediment effects (e.g., mass-wasting events, ongoing road effects, culvert failures) are not the direct result of the FPHCP, but in some cases (i.e., roads or culverts) the effect or the risk of effect may persist over the life of the agreement until corrected. Without permit issuance, there may be no requirement to fix these legacy problems unless it could be proven that omission of actions were causing adverse effects to listed species that rose to the level of harm. However, severe and chronic sediment effects are not expected to continue for this period of time since WDNR retains the authority to require any landowner to address road-related effects where the road has affected or could potentially affect public resources. We expect WDNR will be using this authority to significantly reduce the period of time that ongoing, chronic effects remain uncorrected.

7.5.5 Hydrology

Surface waters may consist of perennial and seasonal streams, lakes, ponds, and wetlands. Subsurface (soil) waters consist of water that is stored in or transported shallowly through hillslope soils or colluvium. Groundwater is water moving through, or stored in rock, or deep unconsolidated strata called aquifers. Groundwater is often connected directly or indirectly to rivers, streams, lakes, and other surface water bodies, with exchange and mixing occurring between the sources. Depending on the geologic and hydrologic conditions, water entering the groundwater system may again reach surface waters within days or may take hundreds or even thousands of years (Domenico and Schwartz 1990).

Streamflow results from precipitation on a watershed, with water entering the stream channel by precipitation falling into the channel, surface runoff of rain or snowmelt, or sub-surface flow. The sum of these is often called stormflow or runoff. Additionally, groundwater and any long-term sub-surface drainage from uplands sustain streamflows year around in perennial streams, particularly between periods of snowmelt and rainfall. Often called baseflow, such flows are common in the summer months when high stream temperatures typically occur. Subsurface flow is shallow lateral flow below the soil surface but above an impermeable or slowly permeable layer above the groundwater table. Subsurface flows occur early during storms and contribute to stormflow. Groundwater is recharged by infiltration from portions of the landscape called recharge areas. Recharge areas for a particular aquifer may be extensive or more narrowly distributed, depending on topography, climate, and soil permeability. The boundary layers between aquifers and overlying unsaturated soils is the watertable. Baseflow is the typical flow rate for a given stream at a particular time of year and is sustained by groundwater inputs, which may be localized as springs or distributed across the entire stream reach.

The amount of water provided to aquatic ecosystems at critical times is important for sustaining fish and other aquatic species. Soil water and groundwater provide cool, clean water to streams and help to maintain adequate water quantities and temperatures for aquatic organisms. The outflow of soil water and groundwater, especially at perennial seeps and springs, can be important for amphibians and aquatic insects (Petranka et al. 1993; Kelsey 1995; Bury and Corn 1988). Fish adapt to natural flow cycles for feeding, spawning, migration, and survival needs. The timing, magnitude, and duration of peak and low flows must be sufficient to create and maintain riparian and aquatic habitat. Flooding and sediment transport are normal events critical for formation and development of streams and floodplains (Waring and Schlesinger 1985). However, hydrologic regimes outside of the normal range of variability can cause excessive erosion and result in channel alteration.

Rain-on-snow events are a common reason for flooding and streambed scour in parts of the State where snow or a transient snow zone exists. In some watersheds, extreme low flows there can be detrimental to water quality and habitat availability during the summertime.

Regional differences in runoff patterns, ranging from rain-dominated to snow-melt dominated systems (Swanston 1991), affect how land-management practices can affect basin hydrology and stream habitat (Chamberlin et al. 1991). For example, in rain-dominated coastal systems, frequent high winter floods elevate the importance of maintaining and protecting side channels. In interior snow-dominated watersheds, management practices to augment low late-summer rearing flows are important. These regional streamflow differences also influence management practices related to sedimentation. Spring flows related to snowmelt-dominated systems are responsible for most road erosion and channel-sediment movement, but within rain-dominated areas, frequent rains provide sufficient energy to transport sediments during many months of the year.

Although high- or low-flow events may affect fish and amphibian populations, dynamic flows are also needed to perform essential functions important for the long-term persistence of these populations. High-flow events redistribute sediments in streams, flushing fine sediments from spawning gravels and allowing recruitment of gravels in downstream reaches. In addition, extreme flow events are essential in the development and maintenance of healthy floodplain systems through deposition of sediments, recharge of groundwater aquifers, recruitment and transport of large wood, and creation of side channels. Low flows and the timing of low-flow recession may also be important for establishing riparian vegetation on gravel bars and along stream banks (Spence et al. 1996).

In general, low- or base-level stream flows that occur during the late summer often limit habitat and survival for rearing juvenile salmon and trout. They can also negatively affect migration and access to habitat and food resources, as well as disrupting spawning behavior. Such conditions can occur naturally during this period due to lack of precipitation. However, low flows can be exacerbated by water withdrawals, silting (which can decrease pool depth), and stream widening resulting from unstable banks. Decreased base flows, especially at critical low-flow periods in late summer, can diminish available fish habitat and increase stream temperatures (Chamberlain et al. 1991; Murphy 1995). Low summer flows can be a problem for juvenile fish due to reduced available habitat, increased stranding, decreased dissolved oxygen, increased water temperature, concentrated toxic materials and increased predation. Low summer flows may also affect upstream migration for spawning fish.

High winter flows and floods that scour the streambed can be detrimental to eggs or young fish that may be incubating in the stream gravels (Thorne and Ames 1987). Fish need suitable stream flows, particularly for migration, spawning, and rearing. Increases in peak flow magnitudes or timing can be as much of a problem as reduced summer baseflow. Increases in peak flows beyond natural levels may cause increased channel bedload movement and bank erosion. The resulting scouring of spawning gravels reduces egg-to-fry survival. In addition, movement of large wood decreases bed and bank stability, which can, in turn, increase egg-to-fry mortalities.

7.5.5.1 Hydrologic Processes

Processes that control water movement in forests include: evaporation, transpiration, snowmelt, infiltration, percolation, lateral flow, and capillary rise (Waring and Schlesinger 1985). Surface water is mainly controlled by precipitation, topography, vegetation, evaporation, and soil characteristics (Hewlett and Nutter 1970; Dunne and Black 1970). The three primary factors affecting surface-water quantity in forested watersheds are climate, vegetation, and transport pathways. Precipitation amount and form (snow or rain) determine the rates of delivery of water to a watershed. The rate and volume of surface water flow is largely controlled by seasonal precipitation patterns and the timing of individual storms.

Vegetation primarily influences flow through interception (collection of rain and snow by the canopy), evapotransporation (water lost back to the atmosphere), condensation, and canopy snowmelt. These processes influence delivery of water to the forest floor and are controlled mainly by vegetation. On an average annual basis, forests lose more water to the atmosphere than any other vegetative cover or land-use type (Dunne and Leopold 1978). Canopy cover also alters the amount (Troendle and Olsen 1993), frequency, and intensity of precipitation delivery to forest floors.

Water-transport pathways (surface and subsurface) determine runoff from the forest floor to the streams. These pathways are controlled by the interaction of condensation, precipitation, evapotranspiration, interception, snowmelt, and other physical and biological factors.

Streams draining forestland are fed almost entirely by drainage through (not across the surface of) soils. Over most of the forested landscape, overland flow does not occur. Rain ordinarily infiltrates as fast as it falls, the exceptions being compacted soils or soils saturated by subsurface water originating upslope, which function as variable source areas (see below). Furthermore, the incessant tug of gravity gradually pulls enough water from upslope soils to supply streams between storms, with some augmentation from regional groundwater input (Patric 1994).

Streamflow between storms, or baseflow, results largely from the slow migration of water as unsaturated flow from drying soils upslope (Patric 1994). At the onset of a storm, rain falling directly into channels increases streamflow immediately. With continuing rain, water infiltrating riparian soils along the channel soon percolates to the depth of streamside soil saturation. The level of saturation in riparian soil rises, water begins to drain more rapidly into the stream, and stormflow begins. The longer the rain continues, the farther upslope the streamside areas of saturation extend, the faster soil water drains to streams, and the greater the volume of stormflow produced. In effect, the source area providing water immediately to the stream extends farther into riparian areas and upslope, laterally and longitudinally as rain continues (Hewlett and Hibbert 1967; Dunne and Black 1970; Troendle and Leaf 1980).

Watershed features can influence the magnitude and timing of storm discharge. The physiography of watersheds influences storm flow by affecting the timing of runoff arriving from the various parts of the watershed. Large watersheds exhibit proportionately smaller, but longer duration peakflows than small watersheds on a per area basis, if precipitation is similar. Watersheds with steeper channels, or higher densities of channels, route water to the main channel faster. Natural wetlands and lakes retain water and dampen the storm hydrographs. Climatic variation can influence the magnitude and duration of floods within a basin, thus flood hydrographs are highly variable.

Increases in flow volume result from successively greater storms and expanding zones of saturated soil (termed variable source areas) within individual watersheds (Hewlett 1982). Floods occur when bankfull stage of channels is exceeded, and overbank flow occurs. The magnitude of floods is determined by the amount of rainfall, the rate of snowmelt, and soil antecedent conditions. Rain-on-snow events have generated some of the largest floods on record in western and eastern Washington (Coffin and Harr 1992; MacDonald and Hoffman 1995). The highest flows (of rare occurrence) produce the greatest sediment discharges and increases in habitat complexity, in part because streambanks erode and large-woody-debris jams are created. Flows with higher recurrence intervals, and enough power to transport bedload (bankfull flows), tend to be the dominant force in shaping a stream or river.

Headwater riverine and depressional wetlands can delay discharge of peak run-off into streams and impede passage of over-bank flow downstream during storm events, thus reducing the potential for downstream flooding (Winter 1988; Roth et al. 1993). Depressional wetlands can help maintain minimum stream base flow by naturally regulating the release of groundwater discharge into streams and by recharging aquifers that discharge groundwater to streams (Dinicola 1990; Hidaka 1973; O'Brien 1988; Mitsch and Gossselink 1993).

7.5.5.2 Management Influence

Human activities also influence the magnitude and timing of peak flows. Road building, drainage ditches, channel simplification, compaction of soil surfaces, channelization, levees and dykes, and impervious surfaces and buildings route water more quickly, increase peak flows, and cause them to occur more frequently. Man-made reservoirs can detain water and dampen peak flows. Widespread canopy openings can increase water yield and summer low flows temporarily by decreasing the interception of precipitation by trees and evapotranspiration loss of soil water (Dunne and Leopold 1978).

In forested areas, the vegetative cover plays a key role in rainfall/runoff relationships and snowmelt processes affecting basin yields and flow characteristics. Densely vegetated areas generally lose more water to evapotranspiration than areas with sparse vegetation and, therefore, densely vegetated areas may generate less runoff during the growing season. Removal of vegetation typically reduces water loss to evapotranspiration, resulting in increased water yield from the watershed. Precipitation is intercepted by vegetation and either evaporated directly or transported to the forest floor through stem flow. As vegetated surfaces become saturated, more precipitation reaches the forest floor through stem flow and through fall. A similar process of interception and evaporation occurs on the forest floor, with saturation ultimately resulting in infiltration to groundwater and overland flow to surface water. Uptake and use of precipitation by vegetation can also factor into the amount of water running off and reaching surface water. The amount of precipitation intercepted, evaporated, transpired and infiltrated varies depending upon factors such as antecedent moisture conditions, temperature, the intensity and duration of precipitation, slope of the land, as well as the age and composition of vegetation. Dense vegetation also tends to create a lag effect on the runoff resulting from any given precipitation event—runoff tends to be delayed from reaching surface water bodies by all the mechanisms described above. Some precipitation events in heavily forested areas result in little or no measurable runoff due to these effects (Dunne and Leopold 1978).

Presumably, forests that are abnormally highly stocked (i.e., forests overstocked because of decades of fire suppression) have reduced water yields. These conditions may result in lower water yields and reduced low flows. It is logical that historical fire suppression and the build up of abnormal quantities of biomass in riparian areas have altered forest hydrology and its associated ecological processes to create conditions outside the natural ranges of variability, particularly in many Eastside forest locations (WFPB 1995).

Stocking and species control can make more water available to residual trees, increasing their vigor and the health of forest stands. Certainly, stocking control can reduce evapotranspiration on a landscape scale, resulting in greater soil moisture and an increase in water available for aquifer recharge.

Also, decreases in water yield and summer low flows may be associated with establishment of hardwoods in riparian areas (WFPB 1995), because hardwoods transpire more than conifer. Water yield can increase following logging, but the extent of increase depends on the type and amount of forest vegetation removed, climatic conditions, and the percentage of land area harvested and roaded. In mountainous watersheds, the soil and bedrock are key storage areas for water (Hewlett and Hibbert 1963; Anderson et al. 1997). Where present, lakes, ponds, and wetlands may also play a significant role in moderating the extremes in high and low flows. Soil and bedrock storage can sustain summer flows even through droughts of many months.

Water Yield

Water yield is the amount of water that is transported from a watershed, usually discussed as an annual water yield. Various studies (Helvey 1980; Bosch and Hewlett 1982; Harr 1983; Kattlemann et al. 1983; Troendle 1983; King and Tennyson 1984; Trimble and Weirich 1987; Keppeler and Ziemer 1990) have shown short-term increases in water yields following timber harvest. Much of this increased water yield appears as increased baseflow during the growing season, and increases in small peak discharges, especially those occurring at the beginning and end of the wet season (i.e., transitional between wet season and growing season). Forested lands, compared to other land uses, also tend to reduce peak flow magnitude while increasing flow duration. This is because forested lands tend to have better infiltration capacity and a high capacity to retain water than nonforested lands (Jones and Grant 1996; Intergovernmental Panel on Climate Change 2003), and because forest vegetation slows the routing of precipitation into the ground. Soils on agricultural and urban lands have lower percolation rates due to compaction or pavement. Overland flows during peak storm events occur often on those lands. Increases in peak flows and more-frequent bankfull flows are more common there than in managed forestlands with the same topography and precipitation (Knutson and Naef 1997).

Removal of substantial amounts of vegetation can be so great as to reduce evapotranspiration for several years following clearcutting, which can increase the amount of water that infiltrates the soil and ultimately reaches the stream. Therefore, streams draining recently logged areas generally see increased summer base flows (Keppeler 1998, Lewis et al. 2001). However, in some cases, removing trees can also result in less delivery of water to streams. In one study, researchers found that about half the yearly water inputs to a higher elevation conifer forest came from fog-drip, i.e., cloud water that condenses on tree limbs (Lovett et al. 1982). Cutting trees in a coastal and mountainous fog-drip zone could remove a large fraction of annual water inputs, and significantly reduce summer baseflows (Harr 1982).

Several researchers found increases in annual water yield proportional to the amount of timber harvest in western Oregon (Rothacher 1970; Harris 1973; Harr et al. 1979). In general, the increase in water yield is directly proportional to the area harvested (Spence et al. 1996). Small patch cuts probably result in less water yield than large clear-cuts, and selective thinning or selective harvest may also have minimal effect on water yield (Beschta et al. 1995). Bosch and Hewlett (1982, as cited in Spence et al. 1996) after reviewing over 90 studies concluded that water yield usually increases after 20-30 percent of the watershed has been harvested. These effects may persist until revegetation approaches recovery, which can take 30 to 40 years assuming no further disturbance (Spence et al. 1996). Higher yields in logged watersheds can occur in the spring in snow-dominated systems; and in rain-dominated systems, the greatest flows can occur in the fall with the onset of fall rains (Spence et al. 1996). In some cases, however, harvest intensity alone was not found to be a good indicator of harvest effects on water yield (Connelly and Cundy 1992; Fowler et al. 1987).

Another potential pathway of effects for altered hydrology is when a substantial area of forest ground cover is disturbed from felling and yarding, resulting in less infiltration and perhaps more surface flows.

Low Flows

Low flows are often referred to as base flows, dry-weather flows, and groundwater flows. Low flows are the flows provided by groundwater to the streams during the lowest precipitation months of the year. In western Oregon, increases in low flow are generally short-term (5 years) following clearcut timber harvest (Rothacher 1970; Harr et al. 1982). In a northern California study, summer low flows were increased following selection harvest and then declined irregularly for 5 years until they were indistinguishable from low flows prior to harvest (Keppeler and Ziemer 1990). Base flows typically increases after timber harvest, benefiting aquatic species by maintaining higher water levels, but benefits can be short-lived as vegetation recovers. Small volumetric increases may provide improved habitat conditions (lower stream temperature, increased instream wetted area and volume) and survivability of aquatic species.

Scherer and Pike (2003) summarized eight research studies relevant to the Okanogan basin that addressed low flows. Four studies identified increased volume of flow subsequent to timber harvest and four studies document no significant changes in low flows. None documented a reduction of water volume during low flows. These findings are consistent with Austin (1999) who reviewed almost 350 international studies concerned with low flows and peak flows. Twenty-eight of the studies evaluated by Austin examined changes in low flows related to timber harvesting. In summary, 16 of the studies identified an increase in volume, 10 studies identified no changes, and only 2 studies identified a decrease in water quantity during low flows. This demonstrated that in the majority of forest types, forest harvesting causes no change or an increase in streamflow during the low flow period subsequent to timber harvesting. Austin (1999) concluded that: (1) low flows typically increase after harvesting; (2) changes in low flows are highly variable and difficult to analyze statistically, and (3) low flows rarely decrease in quantity. These results are intuitive from the fact that reductions in evapotranspiration following timber harvest will occur and will be greatest during the summer and autumn.

It is important to note that two studies reported lower water quantity in low flows after forest harvesting. These studies were both from the coastal forests in northwestern Oregon. In the first study, Harr (1982) attributed reductions in low flow volumes to a reduction in fog drip. Prior to timber harvesting, summer fog intercepted by the forest canopy subsequently dripped onto the forest floor. The water that was intercepted by the forest canopy contributed to the low flow volume. Even without substantial amounts of water entering the soil through this mechanism, the fog condensation augmented the dry season water budget, presumably reducing the amount of water taken up from deeper soil strata by trees to support transpiration. Upon removal of the forest canopy, the process of fog drip was greatly reduced, thereby reducing low flow volumes. In the second study, Hicks et al (1991) identified reductions in low flow volumes 8 and 15 years after timber harvesting. Reductions in this case were attributed to changes in riparian vegetation, from coniferous to deciduous. Because deciduous tree species transpire more water than conifers, lower water quantities were observed. It is important to note that this study involved riparian harvest. Both of the exceptions occurred in the coastal area of northwest Oregon. In the first case, fog-drip interception was offered up as a plausible explanation of the unexpected results. In the second example, the exception was due to harvest, and subsequent regrowth, of the riparian zone.

Peak Flows

Peak flow is the maximum instantaneous discharge measured in stream channels during high flow periods. Management activities can affect peak flows based upon their site-specific effect, elevational location within a watershed, and proportion of basin forest that has been altered by timber-related activities, such as roads and timber harvest (Bauer and Mastin 1997).

Although several mechanisms for alteration of peak flows by forest practices have been identified, changes in peak flow hydrology resulting from forest practices are difficult to interpret due to the numerous confounding factors present. Research into the effects of forest practices on peak flows in the Pacific Northwest has shown varying results. Some studies have documented increased peak flows following timber harvest (Harr et al. 1975; Ziemer 1981; Heatherington 1987), while others have observed decreased peak flows (Rothacher 1973; Cheng et al. 1975) or no change (Harr et al. 1975; Wright et al. 1990).

In Washington, it is commonly thought that the greatest potential for forest practices effects on peak flows is through the influence of clearcut timber harvest on snow accumulation and melt rates (DNR 1997). In general, harvested openings have greater snow accumulations and higher wind speeds than adjacent forested areas, leading to potentially faster melt rates and more water available for runoff (Coffin and Harr 1992). How this increased water delivery to the soil is routed to the stream network ultimately determines the effect on peak flows. The physical characteristics of a watershed—including the topography, soils, geology and vegetation—all influence water routing. Therefore, peak flow responses to timber harvesting are likely to be watershed-specific and may vary widely within and among different regions of the state.

Western Washington (and some of eastern Washington) receives moderate to high precipitation and is influenced by rain-on-snow events. The significance of rain-on-snow events is the increase in water delivered to the stream system during these events compared to rainfall alone. When warm air and rain occur on areas with a snowpack, rapid melting of the snow can occur, resulting in a pulse of water into the drainage network. Rain-on-snow events can occur on mountain slopes in the transient snow zone, which extends from altitudes of approximately 1,000 feet to 3,000 feet above sea level (Harr 1986), but can shift upward or downward during any given storm due to varying meteorological conditions.

Peak-flow events associated with rain-on-snow can be of greater magnitude than rain-only events because the rainfall is augmented by snowmelt. The direct effects of substantially increased peak flows include stream-channel alteration, bank erosion, redistribution of sediment and large organic debris, and flooding. Peak flows can be as great as to have direct effects on salmon when the resulting increased stream power can scour stream channels, killing incubating eggs (Murphy 1995), changing pool volume and frequency (Sullivan et al. 1987), and displacing juvenile salmon from winter cover (McNeil 1964, Tschaplinski and Hartman 1983). Increased freshwater flows into estuaries may result in reduced penetration of the salt wedge upstream into the lower reaches of rivers (Allanson and Barid 1999, as cited in Levings and Northcote 2004). In addition to the direct effect of peak flows, rain-on-snow events generate large inputs of water to the soils and can generate unstable conditions on hillslopes by increasing the pore-water pressure, which decreases the strength of the soil (Sidle et al. 1985); a reduction in soil strength increases the potential for slope failure.

In eastern Washington, the buildup of snowpack over winter contributes to large amounts of spring runoff. Rain-on-snow events are less common, but do occur, and are responsible for some of the largest floods. In forested areas east of the Cascades, snowmelt is the dominant mechanism for producing peak flows, most commonly in February to July depending upon location and elevation. Snowpack depths are often greater in forest openings in eastern Washington forests (Kattlemann et al. 1983; Troendle 1983). Peak flows are predominantly generated by snowmelt and may account for most of the 2- to 10-year peak flows. The timing of snowmelt runoff is important for many eastern Washington watersheds because this runoff is vital for irrigation supplies and fish habitat. Snowmelt-generated peak flows tend to be of longer duration and with less rapid variations than rain-generated or rain-on-snow peak flows. This is due to the fairly consistent energy input from full sunlight.

Timber Harvest Influences on Peak Flows: Increased peak flows can occur in the winter, when a warm, wet storm brings rain after a cold storm deposits substantial amounts of snow. Many floods in Washington, mostly on the westside of the Cascades, have occurred as a result of rain-on-snow events. The rain-on-snow zone in western Washington typically occurs between 1,200 and 4,000 feet in elevation (WDNR 1997a), depending on geographic area (WDNR 1991: September 26, 1991, Memorandum on Implementation of the Rain-on-snow Rule WAC 222-16-046(7))(WDNR 2006: Appendix M). Forest openings are conducive to increased snow pack accumulations because more snow reaches the ground as a result of less snow interception by the tree canopy, which is also a source of long-wave infrared radiation and shielding from the thermal effects of night sky exposure.

Extremely high flows can be detrimental to salmonids and their habitat. However, information about increased peak flows and forest cover removal is highly variable. One line of reasoning states that timber harvest can influence peak flows. Some authors have reported that while rain-on-snow events are a natural occurrence, their effects can be exacerbated when a watershed has been logged in a short amount of time (25 to 30 years) (Coffin and Harr 1992; Troendle and Leaf 1981). It has been said that the two most-important watershed variables that affect rain-on-snow events are elevation and extent of timber harvest. Timber harvest has the potential to alter snow accumulation and melt rates in any portion of a watershed, but predominantly in the "rain-on-snow" zone. Once rainfall associated with a storm occurs, the forest openings are believed to be more conducive to higher rates of melting of the snow pack than the surrounding forest. The combination of greater snow accumulation and potential increased melt rates can lead to a greater rate of moisture available at the soil surface in forest openings during a rain-on-snow event than occurs in the adjacent forest (Coffin and Harr 1992). The net result is that an increase in runoff is expected from forest clearcuts in areas where rain-on-snow is prevalent.

Because timber harvest can cause increased snow accumulation in openings, areas where runoff is dominated by snowmelt can theoretically experience increased peak flows. However, research in the Pacific Northwest has not consistently demonstrated this effect. Cheng (1989) found as much as a 35 percent increase in peak flows with 30 percent clearcuts in British Columbia. Anderson and Hobba (1959) found an 11 percent increase in spring peak flows across 21 watersheds in eastern Oregon. However, Fowler et al. (1987) found no effect in small watersheds in Oregon.

Extensive reviews of the literature on the response of peak flows to forest harvesting have been completed by Moore and Wondzell (2005), MacDonald et al. (1997), Austin (1999), and Scherer (2001). MacDonald et al. (1997) reported no consistent relationship between the percent of a basin that had been harvested and the percent change in peak flows. MacDonald et al. also noted that increases in peak flows greater than 150 percent generally occurred in the growing season as a result of rainfall and wetter antecedent soil-moisture conditions following forest harvesting; and further noted that peak flows are generally much smaller during the growing season and this means that a small increase in absolute discharge can yield very large increases in terms of a percentage change. Austin (1999) concluded that large peak flows increased only a small amount. The smaller increases in the larger peak flows may be attributed to their occurrence when soil moisture levels are high regardless of the forest cover.

Largest peak flows in the action area likely result from rain-on-snow events. The assumption by many people is that, because snow accumulates to greater depths on the ground in clearcuts, and because greater exposure to moist, turbulent winds occurs in openings, that clearcutting must result in higher volume of flows during rain-on-snow events. However, in cases where rain-on-snow occurs during a time when substantial amounts of snow still clings to tree branches, the increased surface area of that snow relative to the snow pack on the ground can facilitate greater melt rates within the trees than in clearings (Harr and McCorison 1979). Peak flows may increase due to harvest for events with substantial antecedent ground snowpack, whereas events with a smaller snowpack may show a decrease (Harr 1986). Another confounding factor that plays a part in the inconsistent field observations is the effect of timing of water routed from different parts of the watershed. Synchronization of peaks due to watershed physiography and clearcut distribution could produce enhanced peaks, while de-synchronization would have the opposite effect (Moore and Wondzell 2005). Timing and synchronization issues make it difficult to extrapolate the results of small watershed studies or stand-scale mechanisms to larger watersheds.

Rain-dominated watersheds, such as those along the coast, may also be subject to increased peak flows, but for different reasons. Studies that have shown peak-flow increases in rain-dominated watersheds (Harr et al. 1975; Harr 1986), but have correlated the increases with soil compaction, rather than timber harvest. Yet other studies indicate no change in peak flow after harvest (Benda et al. 1998). Smaller peak flows at the beginning or end of the wet season (i.e., transitional periods between the wet and growing season) may be expected to increase due to the influence of reduced evapotranspiration rates on antecedent soil moisture.

Road Management Influences on Peak Flows: Roads can alter runoff by collecting subsurface and road-surface water and routing it efficiently and directly to stream channels (Chamberlin et al. 1991, McIntosh et al. 1994). These road effects potentially can increase peak flows during rainstorms (Ziemer 1998).

The design, construction, and maintenance of roads interact with watershed characteristics of soil, topography, and geology and natural disturbances (such as large storms) to determine the effects of roads on the hydrology of a particular watershed. The interception of surface runoff during storms and interception of shallow groundwater flow by a road prism and associated ditches can affect the routing of surface water, extend the channel network (Wemple et al. 1996), increase the potential for higher peak flows, and increase the potential for mass wasting (Montgomery 1994). In a general sense, roads can act as extensions of the drainage network if the roads drain to streams. Road-influenced peak flows have been demonstrated in small watersheds (Ziemer and Lisle 1998); however, the effects of roads on a river basin scale are less consistent (Jones and Grant 1996; Beschta and Boyle 1995). Logging in large drainages generally results in proportionally smaller effects to the hydrology than in smaller drainages, probably due to the spatial distribution and timing issues discussed earlier (Duncan 1986).

Two summaries of recent research studies on roads in forested areas demonstrate that roads can have significant effects on peak flows if roads are improperly constructed and if their drainage networks are allowed to become connected to the stream network through improper construction or inadequate maintenance or abandonment procedures (USDA Forest Service 2001; CMER 2004). CMER (2004) has issued a draft review of published literature that suggests that roads alter runoff processes by the production of overland flow, by interception of subsurface stormwater flow, and by piracy of streams by road ditches. Road runoff may create additional channels in the stream network by incision (Montgomery 1994), potentially leading to adverse consequences for both hydrology and slope stability, depending on the road location.

A road-maintenance survey conducted by the WDNR (1999) indicated that in 36 subbasins surveyed, the majority were out of compliance with road-maintenance objectives for road-surface drainage, ditch drainage, and water-crossing structures. The authors stated that the rules in effect on January 1, 1999 were "subjective and inadequate," and recommended that outsloping or water dips would be the first priority in improving performance of road drainage on forest roads. Based on recent research and modeling studies, the USDA Forest Service (2001) made the following recommendations on a national scale: that forest-road locations should be carefully chosen based on a geologic study; that road design should minimize interception, diversion, and concentration of water using out-sloping and drainage structures; that crossings should be designed to pass all stream materials (including water, fish, debris, and sediment); that design and removal of roads should take into account the sensitivity and orientation of the road; and that roads should be designed with failure in mind.

Rashin et al. (1999) recommended a variety of improvements to road BMPs. Those that apply to reduction of peak flows and direct input of road runoff to streams include: minimization of road location within 485 feet (150 meters) of streams, revised spacing of relief culverts, adequate sediment traps, and spreading or dissipation measures to prevent incision from runoff. They also recommended against the use of ambiguous language in BMPs.

Roads can affect hydrologic regimes by interrupting hillslope drainage patterns, which can alter the magnitude and timing of peak flows and change base flows of streams (Quigley and Arbelbide 1997). Changes in peak flows from roads have been observed in some studies (Harr et al. 1975; Harr 1979; King and Tennyson 1984; Jones and Grant 1996). However, similar research in other Pacific Northwest watersheds found no significant difference or a decrease in peak flows following substantial soil compaction from roads and skid trails (Rothacher 1970; Ziemer 1981; King and Tennyson 1984; Wright et al. 1990). Still others have found different effects depending on the relative size of the peak flow, and have emphasized the difficulty in making statistically-valid conclusions (Thomas and Megahan 1998). The variability in these results suggests that watershed-specific factors influence the effects of timber harvest and road construction on peak flows.

7.5.5.3 Discussion

Historical road routing and construction practices have, at times, led to substantial effects on riparian systems, and in turn, on hydrology. Roads were often built along flat floodplains, which resulted in the removal of riparian vegetation. In narrow canyons with limited floodplains, roads were commonly located on the sideslope within the riparian zone or encroached on the stream channel; some roads even used the actual stream channels. Even in the absence of these longitudinal effects, the continuity of the riparian corridor has been interrupted at each bridge and culvert crossing (Kondolph et al. 1996).

Stream-adjacent roads can cause the degradation of some or all riparian functions, including hydrologic processes, within riparian lands depending on where road construction has occurred. One example is the loss of large-wood recruitment potential from trees on the upland side of roads within riparian areas. Most of the trees on the upland side are not be recruited as large wood because they are typically removed when the tree falls onto the road. Major changes to the aquatic system have also occurred from riparian land modifications due to road development, including the straightening or simplification of the stream channel system (Knutson and Naef 1997; Oregon Department of Forestry 1999a).

Consideration of elevation, aspect, stand age, and hydrologic response improves the predictions of harvest effects on stream flows (Connelly and Cundy 1992). Increases in peak flows have been noted for areas of the Pacific Northwest after timber harvest and road construction (Harr et al. 1975; Harr et al. 1979; Thomas and Megahan 1998). However, other researchers have found either no effects or even decreased and delayed peak flows following harvest and road construction (Duncan 1986; Harr 1976; Harr 1980; Cheng et al. 1975; Harr and McCorison 1979). Rothacher (1965, 1973) reported that peak flows showed little or no increase from timber harvesting, but low flows showed a modest increase.

Concentrated flows from any source can exacerbate potentially unstable conditions on hillslopes by increasing the pore-water pressure, which decreases the strength of the soil (Sidle et al. 1985); a reduction in soil strength increases the potential for shallow-rapid slope failure. Where peakflows increase and the spatial pattern within a basin is synchronous or additive to peak flows downstream, channel erosion in lower-order channels could increase; resulting in an increased volume of sediment and perhaps woody debris transported to downstream fish-bearing reaches. In some watersheds, peak flow increases might be undetectable or asynchronous and not measurable downstream. Forest practices may affect hydrologic processes through the alteration of vegetation characteristics and soil properties. However, detectable changes may be difficult to demonstrate except in cases where large portions of a watershed are harvested over a short period of time.

It has been surmised that because harvested areas have reduced evapotranspiration, and soils in these areas are subsequently wetter, they may potentially reach saturation sooner during a rain storm. This accelerated saturation point may result in attainment of surface flow somewhat quicker than on a site that was not harvested. This seems to be the case during the growing season (e.g., summer and fall). Reduced evapotranspiration may cause wet antecedent soil conditions, conducive to small peakflows, to occur earlier in the year, and later into the spring. The extent to which timber harvest alone has triggered substantially increased peak flows is unknown and likely limited to smaller peaks (Storck et al 1995). Most recent research suggests that peak flow changes due to forest practices are difficult to detect on large river systems; effects of peak flow changes due to forest practices in small basins are highly variable, but small peaks are apparently affected more than large peaks (e.g., Thomas and Megahan 1998; Beschta et al. 2000).

Disruption of subsurface flow could, potentially, affect freshwater seeps along the shorelines of estuaries and the marine near-shore. Inside Puget Sound, spawning of certain forage fish is thought to be associated with freshwater seepage, where the water keeps the spawning gravel moist (WDFW 2005a). Disruption of these seeps could potentially cause reduced spawning success, and reduced available forage for certain marine and anadromous fish.

7.5.5.4 Effects of FPHCP on Hydrology

Introduction

The old forest practices rules (i.e., in place November 1998) reduced the potential for significant hydrologic effects from timber harvest and road construction. The November 1998 rules limited a contiguous clearcut area to 120 acres. Areas under the same ownership adjacent to existing clearcuts could not be harvested until young trees were reestablished (green-up rules). Proposed forest practices in the rain-on-snow zone were screened for potential to affect peak flows if the area contained hydrologically immature vegetation. Hydrologically immature vegetation was defined as young forest stands that did not hold significant snowfall in the tree canopy and did not moderate the effects of wind and rain on the snow pack at ground level. Furthermore, the November 1998 rules provided for voluntary watershed analysis that included a hydrologic assessment of the past and current effects of timber harvest within the basin. Watershed analysis resulted in binding, site-specific prescriptions to address any effects revealed in the assessment, particularly those related to rain-on-snow peak flows. See the **Comprehensive Cumulative Effects** section of this Opinion. Many watershed analyses were completed prior to the proposed FPHCP and are considered part of the environmental baseline.

The November 1998 rules reduced the potential for significant hydrologic effects from timber harvest and road construction by:

1. Limiting clearcut size and distribution (green-up rules).
2. Using a rain-on-snow rule to help control peak flows.
3. Identifying wetlands and limiting harvest operations.
4. Establishing best management practices (BMPs) for road construction and maintenance.
5. Road Maintenance and Abandonment Plans (albeit, not on an established schedule).
6. Promoting voluntary watershed analysis.

The November 1998 Forest Practices Rules addressed timber harvest effects on rain-on-snow peak flows directly through watershed analysis and the rain-on-snow rule, and indirectly through the green-up rule. Each of these regulatory mechanisms includes provisions that reduce the potential for harvest-related increases in rain-on-snow peak flows. Watershed analysis addresses peak flow increases through the development of watershed-specific management prescriptions that typically restrict clearcut timber harvesting by requiring the retention of minimum levels of “hydrologically mature” forest cover. “Hydrologically mature” generally means forests with canopy structures that are effective at intercepting and retaining snow above the forest floor. The sum experience with the modeling approach in the Watershed Analysis Hydrology Module (over 60 watershed analyses) indicates that rain-on-snow was rarely a concern relative to the WDNR conditioning guidelines. Outside areas where watershed analysis has been performed, the rain-on-snow rule gives the WDNR authority to limit clearcut timber harvesting in the significant rain-on-snow zone in order to reduce peak flow effects, although as currently implemented, the rain-on-snow rule is not used often. This appears to be largely due to two considerations. First, the implementation criteria of both a significant portion of a watershed being within the rain-on-snow zone and a significant portion of the watershed being in hydrologically immature vegetation are seldom triggered. The prevailing patterns of harvest in these areas do not result in large clearcuts dominating, or being concentrated in, a single watershed. Second, there is a stipulation that evidence of in-channel damage due to excessive peak flows must be readily apparent prior to imposing these rain-on-snow rules. While channels may be degraded due to a combination of factors, it is difficult to identify whether observed degradation may result from increases in peak flows or from other factors. WDNR-issued guidance for implementing the rule includes a risk-assessment method and conditioning strategies for minimizing peak flow increases. While not specifically designed to address rain-on-snow, the green-up rule minimizes its effects by limiting the size and timing of clearcut timber harvesting within the rain-on-snow zone as well as other portions of the State, provided that adjacent parcels fall under the same ownership. In cases where ownership is mixed or small landowners dominate, however, the green-up rule would not apply.

The Forest and Fish Report (1999) set an objective to “maintain surface and groundwater hydrologic regimes (magnitude, frequency, timing, and routing of stream flows) by disconnecting road drainage from the stream network, preventing increases in peak flows from causing scour, and maintaining hydrologic continuity of wetlands.” In addition to the improvements discussed below, the FPHCP would continue to apply protection to unstable slopes and would continue applying the “green-up” and “rain-on-snow” rules, and the other protective measures discussed above.

Compared to the November 1998 rules alone, the FPHCP further reduces the potential for management-related effects on hydrologic processes on covered forestlands. The FPHCP provides additional provisions (see below) to further reduce the effect of forest practices on hydrologic processes. FPHCP is expected to reduce soil disturbance and compaction at areas with significant shallow subsurface flow and reduce the amount of concentrated road drainage flowing directly to streams.

Riparian Timber Harvest

Improved wetland mapping, combined with rules for operations within wetlands, should protect the hydrologic functions of these sensitive systems. Protection of the hydrologic continuity of forested and non-forested wetlands would be continued. Buffers would continue to be retained around non-forested wetlands.

Prescriptions are designed to maintain the hydrologic functions of wetlands. All road and landing construction within wetlands would have to employ a mitigation plan to avoid, minimize, and restore, reduce, or replace affected areas. Small wetlands within an RMZ would be identified and mapped. The threshold for mapping forested wetlands outside RMZs would be lowered to 3 acres. WDNR would be required to maintain a map record of wetlands identified in FPAs. However, hydrology may be adversely affected when forested wetlands are harvested. Forested wetlands may have saturated soils or small amounts of surface water during significant portions of the growing season.

No-harvest buffers on Type S and F streams, including CMZs, would retain vegetation and downed wood and would protect the shallow subsurface flows beneath and adjacent to these riparian areas. Channel migration zones are recognized as part of the channel, and therefore are included within the no-harvest portion of the RMZ. These measures protect shallow subsurface flows beneath and adjacent to these streams, which are important for supporting a variety of aquatic organisms.

Type Np streams would receive buffers on strategic areas including thermal recovery zone and sensitive sites. These buffers would also protect the shallow subsurface flows beneath and adjacent to these streams. Type Ns streams on unstable slopes would also be protected. Equipment limitation zones would be established along Np and Ns stream channels and would further reduce soil disturbance and compaction at areas likely to have significant shallow subsurface flow.

Sensitive-site RMZs emphasize tree retention around seeps, and springs, which may be hydrologically sensitive. These measures protect shallow, subsurface flows beneath and adjacent to these streams, which are important for supporting a variety of aquatic organisms. Sensitive sites receive 50- to 56-foot, no-harvest buffers on the westside and partial harvest buffers on the eastside. There would be no harvest within alluvial fans on the westside.

Riparian activities involving heavy equipment can cause soil compaction and rutting which can reroute water and alter ability of water to infiltrate soils. Skid trails and ruts may also enlarge the drainage system routing water to the stream system more quickly. No-harvest buffers and ELZs that prevent or minimize disturbances to the riparian forest floor would help maintain water infiltration rates and subsurface flow through riparian soils. Also, retention of down wood in RMZs after harvest would help maintain normal patterns of surface roughness and overland flow when it occurs (Megahan and Ketcheson 1996; McGreer 1981; Benoit 1979).

Hardwood conversion would not occur within the Core Zone and would have little if any effect on hydrology. Changing the Inner Zone from a deciduous canopy to a coniferous canopy would have little effect when the magnitude of affected stream length and incremental evapotranspiration rates are considered. No significant or measurable physical effects to stream hydrology are expected due to the "equal in overall effectiveness" provisions of alternate plans with respect to aquatic and riparian function. The overstocked template would retain trees within an approximate rooting diameter of the streambank and is not expected to greatly influence evapotranspiration of remaining stand over time.

Ground-based yarding would generally be conducted outside the Core Zone and may result in some localized compaction or rutting. This may lead to minor changes in infiltration and surface flow. Equipment would operate closer to streams and would operate across a greater portion of the ground within riparian areas on 20-acre exempt parcels, increasing the potential for soil compaction and other effects that could alter the local hydrology. However, the shade rule would assist in reducing some of these effects. The retention of small buffers on Type Np streams within 20-acre exempt parcels would result in some effects to hydrology. The effects on these Type Np streams may be more severe in cases where trees would be excessively clumped to accommodate operations.

Road Management

Road surfaces can alter natural infiltration rates and can result in the interception and diversion of near-surface flow to the surface. The interception and diversion can increase the area of a watershed that is composed of small streams and increase the short-term water yield to the stream system. These factors may potentially influence the frequency and amplitude of small to moderate peak flows, especially in small watersheds. There could be some increased potential for higher peak flows during mild to moderate rain or rain-on-snow events when surface / subsurface flows are captured by the roads and redirected to streams via roadside ditches. Large rain-on-snow events or large flood events are unlikely to be modified by forest roads or harvest units.

The FPHCP would considerably reduce the potential for road-related delivery of water to streams by restoring the natural flow paths of surface and shallow subsurface water when roads are abandoned, disconnecting road drainage from directly entering streams, and minimizing the length of forest roads that deliver water directly to streams, as well as improving road crossings so they do not impede natural flow. These practices address the water-delivery mechanisms with the greatest potential for changing water-routing patterns and increasing peak flows. These would be accomplished through both new road standards and RMAPs. BMPs for road maintenance and construction would continue to disconnect ditches from streams and minimize effects of routing intercepted water, and would provide higher standards for passage of wood, sediment, debris, and fish. RMAPs would be accelerated beyond the potential requirements of the previous (November 1998) rules, thereby correcting existing problem areas and providing for passage of wood, sediment, debris, and fish.

Other important effects are the rate at which the road maintenance and abandonment plans would be implemented and the prioritization of watersheds with listed species. The condition of all roads (including orphan roads) would be inventoried and assessed to address direct delivery of water from roads to streams. Road systems or basins potentially affecting listed fish species would be given highest priority, generally starting at the mouth of the basin and working upstream.

The FPHCP would necessitate a much more-rapid rate of road-condition assessment and improvement than would be done under the existing watershed-analysis process. Since the Washington Forest Practices Board adopted watershed analysis into regulation in 1992, original assessments have been completed for only 56 of the 754 (7 percent) of the forested watershed analysis units (WDNR 2000b). That translates to approximately eight units (WAUs) per year. At that rate, it would take about 87 years to complete original watershed analyses on all forested watersheds in Washington.

Watershed analyses contain a requirement for review 5 years following implementation. Five-year reviews of surface erosion in several watersheds estimated a 34 to 48 percent reduction in delivery of sediment to streams following implementation of road maintenance and abandonment plans (Baitis 1999; Toth 1997). It is reasonable to expect a proportionate increasing trend toward the normal delivery of surface waters to streams as a result of implementing the plan. Management measures for forest roads would reduce the potential disruption of hydrologic regimes by requiring landowners to minimize construction of new roads in riparian areas, upgrade existing roads to reduce disturbances of water-routing patterns, and construct new roads to higher standards.

Coffer dams (for culvert replacement) are usually in place for 1 to 2 days and generally required only once per stream crossing for the effective life of the crossing structure. Most often, such structures are not required for culvert replacement. When they are used, effects include short-term desiccation of a segment of streambed (generally less than 100 feet total) and short-term disruption to passage.

Under FPHCP, intercepted water from direct rainfall and exposure of hillslope soil in roadcuts is expected to be re-directed onto the downslope forest floor in a diffuse manner. Such change as a result of road interception of water may still concentrate surface flow in a manner that could increase the amount of stream system and could contribute to some increase in the frequency and amplitude of peak flows. However, these effects depend on watershed size and the relative size of the peak flows in question.

Research

Habitat manipulation research within RMZs may later the hydrology of smaller streams. This may occur through deviations from standard timber-harvest rules that result in soil compaction or alterations of riparian vegetation. This may also occur as a result of instream measurements involving measurement weirs or other structures that may affect stream flow in individual small streams for a short timer period (during measurement activities). Such changes in stream flow would be subtle and would only occur on a very small number of streams. Effects would be indistinguishable from addition of a large tree to the stream.

Conclusions

Based on several studies in Washington (Coffin and Harr 1992, O'Connor and Harr 1994, Storck et al, 1995, and Bowling and Lettenmaier 2000, Moore and Wondzell 2005), we expect that peak flow increases during small to moderate peak-flow events might occur as a result of timber harvest, particularly in small watersheds, during the beginning and end of the wet season. In watersheds comprised of elevations falling dominantly within the rain-on-snow zone, peak flow increases may occur if the proportion of the watershed in recently harvested condition is substantial. Due to difficulties in detectability, presence of cumulative and confounding effects, and a lack of ability to determine causation, it is extremely difficult to link a contribution to a peak-flow event, or incremental effects of such an event, with any single harvest unit.

Small and moderate peak flows may be increased, however, due to water interception and routing by road networks, which may be independent of season, except in the zone of permanent snowpack. Increases in peak flows as a result of the road network may cause premature scour of redds.

The FPHCP proposes a number of measures that would reduce the potential effects of forest practices on hydrologic processes. The FPHCP prescriptions should reduce undesirable effects on the surface-water network by requiring road maintenance and abandonment plans, upgrading existing roads, and constructing new roads to minimize effects on water routing. The FPHCP proposes substantive measures to disconnect road drainage from the stream network, reducing the possible effects of road runoff on peak flows and their potential effects on channel scouring.

These factors should reduce ability of road system to contribute to frequency or amplitude of peak flows or their ability to scour. New roads and newly repaired roads might cause localized, increases in small to moderate peak flows and in sediment delivery, but the net effect over longer time periods, across the action area, would be an overall decrease in road-related peak flow increases when other proposed measures (i.e., road upgrading and removal) are considered, with little detectable effect on redd stability and overall habitat conditions. Similarly, in estuarine habitats, there would be little detectable difference in the location of the estuarine salt wedge, or area of maximum turbidity; nor would there be substantial effects on the covered species that use these areas.

Summary: While an increase in peak flows from timber harvest is possible, it is likely to be confined to smaller watersheds and small to moderate, early and late season peak flows, or possibly to watersheds lying in the rain-on-snow zone where substantial portions of the watershed are cut within a short time period. Some increases in summer low flows would occur in sub-watersheds that drain recently harvested areas. However, we expect increases in low flows will generally be a benefit or neutral during periods of low flow. In some small coastal streams, reduced flow may occur from removal of trees contributing to fog drip. Any increases in peak flows would generally occur in the summer or at the beginning or end of the wet season and be of little measurable consequence for covered species. Influences on larger peak flows (storm flows) resulting from timber harvest are expected to be inconsequential.

While an increase in peak flows from forest roads is possible, it is likely to be confined to smaller watersheds and small to moderate peak flow events, or to watersheds lying in the rain-on-snow zone. Fishes are more likely to be affected by the effects of altered inputs and routing of sediment than the effects of altered flows. Some increases in peak flows and summer low flows may occur in sub-watersheds that drain areas with many road crossings and stream-adjacent parallel roads.

Hydrologic regimes that occur within the range of natural variation are presumed to maintain cool clean water with natural flow rates and adequate aquatic habitat for covered species. Baseline conditions should continue to improve as a result of the proposed FPHCP.

7.5.6 Water Temperature (Heat)

Water temperature is a product of complex interactions between geomorphology, soil, hydrology, vegetation, climate, elevation, and aspect of the watershed. The relative influence of these factors can vary spatially across the landscape and over time. Water temperature can vary along the length of a stream as a result of local topographical and geological factors. Thermal heterogeneity within streams and rivers and can be affected by local energy inputs and outputs (IMST 2004).

Temperature influences many biological and ecological processes in a stream, including nutrient cycling and productivity. Temperature is also important because it influences the metabolic rates and physiology of aquatic organisms, including fish. Cold water is able to absorb more oxygen than warmer water; therefore, oxygen-richness of water is directly linked to water temperature. Likewise, many processes influence temperature. For example, elevated temperatures are often linked with other signs of stream degradation including loss of riparian vegetation and wider than expected stream channels (IMST 2004).

Many of the FPHCP covered species require relatively cold water throughout their life-history stages. Overly warm, oxygen-poor waters are detrimental to these species and their ecosystems. Most of the native fish species in Washington are classified as cold- or cool-water species. Native aquatic species that are sensitive to warm temperatures include bull trout, shorthead sculpin, and Dolly Varden, and a number of other fish species. In fact, due to bull trout's required lower temperature than other salmonids, specific temperature standards to protect this species are needed within the species known historical distribution (IMST 2004). The stream-associated, FPHCP covered amphibians are also sensitive to water temperature, especially tailed frogs tadpoles. Small, headwater streams are particularly important to amphibians, in part because they are free from competition and predation by fish.

The survival of cold-water fish is dependent on water temperatures, and increases in temperature have been linked to fish mortality, sub-lethal effects such as increased presence of disease, and distributional or habitat preferences (Johnson and Jones 2000). Temperature directly and indirectly affects physiology, development, growth, and behavior of fish, as well as food-web dynamics, predator-prey relationships, and the incidence of parasitism and disease (Spence et al. 1996, McMahon et al. 1999, Sullivan et al. 2000).

Although lethal temperatures do occur in streams and can be locally problematic, sub-lethal effects of temperature determine the over-all well-being of our native fish. Sub-lethal and chronic effects may include reduced growth, disease, and interrupted smoltification. Responses by fish to changes in stream temperature occur through physiological and behavioral adjustments that depend on the magnitude and duration of temperature exposure (Sullivan et al. 2000).

7.5.6.1 Baseline

Several historical documents provide data on stream temperatures in the Columbia River Basin (Stone 1878; McDonald 1895; Gilbert and Evermann 1895; Evermann 1896). Sullivan et al. (1990) and Caldwell et al. (1991) reported on stream conditions on small streams in western Washington.

A 1998 review of shade inventories conducted through watershed analysis found that more than half (57 percent) of fish-habitat streams complied with the riparian shade requirements (Shade Rule) of the Washington Forest Practices Board Manual and would result in streams that meet the current numeric temperature criteria (16 or 18 degrees Celsius) in the State water-quality standards (Beak 1998). In consideration of more than a century of logging combined with the relatively recent requirement of riparian buffers when harvesting timber, this majority of streams was considered to be "good" according to Beak (1998). However, streams that meet this standard may not meet the needs of some cold water fish. Westside and eastside streams were similar in their capacities to comply with the Shade Rule.

Beak (1998) reported that about 17 percent of streams had riparian areas that are naturally low in their capacity to provide shade (e.g., low-productivity sites, rocky slopes, and wet meadows). Under these circumstances, many of these streams may not achieve the numeric temperature criteria, regardless of forest practices (Beak 1998). Most of these situations occurred in large and wide Type 1 waters of the State (currently referred to as Type S waters) (Beak 1998). In these streams, natural temperatures will likely define the water-quality standards.

The remaining streams (26 percent of the total) had the potential for riparian canopy conditions to meet the State temperature criteria, but had shade levels below that predicted to meet the standard. The majority of these low-shade situations were legacy conditions resulting from shade removal prior to adoption of the Washington Forest Practices Act in 1974 or the Shade Rule in 1992. The 1998 report was a compilation of information from completed Watershed Analyses, so the actual data had been collected across the 53 watershed administrative units during some time previous to 1998. The level of improvement in shade conditions between the time of data collection and the current time is uncertain, but we expect that shade conditions have improved during this interval because requirements on riparian buffers have increased since the data was collected for the 1998 report.

7.5.6.2 Physical and Behavioral Adjustments

There are numerous reasons why fish may be present in waters where temperature exceeds the predicted suitable range. According to the IMST (2004), they may do so: (1) with physiological or genetic adaptations to survive brief exposures to high temperatures; (2) as transient fish, not members of healthy populations resident in the warm stream reach; (3) with impaired performance (e.g., earlier emergence, faster growth, changes in migration timing, increased susceptibility to disease, altered response to competition and predation), the effects of which could be cumulative or obviated at some later life stage; (4) because they are utilizing cold-water refugia in these warm streams; (5) because variations in stream temperatures over the course of a day or week might allow fish to survive short-term unexpectedly hot conditions; or (6) because the upper extreme of temperatures that fish populations can tolerate may be higher than scientists assume. Acclimation and seasonal acclimatization to temperature changes are important in the ecology of fish. Behavioral mechanisms allow organisms to tolerate short-term extreme temperatures (McCollough et al. 2001). Some evidence suggests that fish can cope with high temperatures if the daily highs do not persist too long and/or the daily lows are sufficiently low or there are adequate thermal refugia available; however, the ways fish adapt to or cope with fluctuating temperatures are not yet well understood.

Summer

A rise in stream temperature increases the metabolic rate of aquatic species. Consequently, more energy is required, even during periods of low activity. In addition, dissolved oxygen decreases as water temperature increases, potentially increasing stress on fish. Water temperatures in the range of 21 degrees Celsius or greater can cause death in cold-water species such as salmon and trout within hours or days (ODEQ 1995). Long-term sub-lethal effects as well as short-term acute effects of warm water temperatures can be detrimental to the overall health of aquatic species. Heat stress may accumulate such that increased exposure for juvenile fish increases their susceptibility to disease, reduces swim speed, and reduces growth, especially when food is limiting as it is in many northwest streams (ODEQ 1995). Since the timing of life history events, such as migration from natal rearing streams to larger tributaries or rivers is an adaptation to local conditions, changes in those environmental conditions such as to stream temperatures, may reduce the fitness of affected populations of fish (Beschta et al. 1987).

There are numerous conditions that can result in summer temperature increases in streams. These conditions include: 1) reduced canopy cover; 2) increased coarse and fine sediment delivery to stream channels, which can lead to channel widening and loss of pools; 3) reduced large wood recruitment, which results in reduced number of pools, reduced channel capacity, and loss of thermal buffering and cold-water refugia; 4) interception of shallow groundwater by road systems; 5) increased air temperature over streams by loss of microclimate buffering; 6) riparian roads, which reduce the interaction of the floodplain with the channel; 7) loss of off-channel wetlands; 8) loss of streambank stability leading to increased sediment delivery and channel widening; 9) increased in sediment delivery due to forest-related road systems, leading to pool loss and channel widening (Beschta et al. 1987; Brosofske et al. 1997; Johnson and Jones 2000; IMST 2004).

Winter

Sugden et al. (1998) provides an overview of salmonid biology and habitat use during the winter, including habitat changes and sources of mortality from formation of ice within streams, especially anchor ice. Cunjak (1996) provides additional information on this topic.

In the winter, riparian canopy cover may help moderate water temperatures by inhibiting energy losses through evapo-transpiration, convection, and long-wave radiation. Channel width and depth also affect stream temperatures in the winter. Wide, shallow streams are more likely to become super-cooled than deep, narrow streams (Chisholm et al. 1987; Swanston 1991). Chisholm et al. (1987) also reported that snow bridging was more likely to occur on deep, narrow streams and would prevent surface and anchor ice from forming by insulating the stream.

7.5.6.3 Factors Controlling Stream and River Temperatures

Stream temperatures are affected by many environmental factors including, but not limited to, direct and indirect solar radiation, watershed elevation, aspect and topography, regional and seasonal climate, local climate (air temperature, vapor pressure, humidity, wind, cloud cover, etc.), time of year (day length and sun angles), precipitation amounts and timing, channel dimension, streambank entrenchment, streamflow (water quantity), groundwater inputs, and riparian vegetation. Although shade does not physically cool a stream down, it can help reduce further heating of the stream and therefore it can maintain the cool temperature associated with groundwater inputs and tributaries (Beschta et al. 1987). Water temperatures decrease when heat energy is transferred from the water to the surrounding environment via convection (mass movement of heat within a liquid or gas) and conduction (heat transfer by substances coming in direct contact with each other). Temperature indicates the direction heat energy will move; heat will move from the warmest to the coolest substance. Temperatures will also decrease when heat in the water is diluted by cool water inputs from groundwater, tributary inputs, or precipitation.

The major source of heat added to streams is from solar radiation. Shade blocks radiation from reaching the surface of the stream and decreases the amount of heat added to the water. With increasing amounts of heat blocked and not allowed to reach the water's surface, cooling via evaporation, convection, conduction, and possibly hyporheic exchange will be more effective. However, water temperature may remain relatively unchanged in shaded reaches until it mixes with other cooler water within the reach (Beschta et al. 1987).

Average daily stream temperatures are regulated by many factors: ambient air temperature, relative humidity, groundwater influx, stream channel morphology (including discharge rate), and substrate composition (Bryam and Jemison 1943; Brown 1969; Patton 1974 as cited in Cross 2002; Adams and Sullivan 1989; NCASI 2000). Solar radiation has a relatively small impact on daily mean stream temperatures (Adams and Sullivan 1989). However, solar radiation is most responsible for deviations from average daily temperatures (Adams and Sullivan 1989; Ice 2001), and is almost the only factor that can be directly controlled by (active or passive) forest management. Increases in direct solar radiation due to reduction of riparian vegetation are most responsible for high stream temperatures (Brown and Krygiers 1970; Barton et al. 1985; Ice 2001).

It is well established that riparian timber harvesting can increase maximum stream temperatures (see review by Beschta et al. 1987) and diurnal fluctuations (Beschta et al. 1987; Spence et al. 1996). The primary mechanism for this stream warming is an increase in direct-beam solar radiation that reaches the stream surface when shading is removed (Brown 1969). Because direct-beam solar radiation is a principal source of heat energy inputs to streams (Brown 1969), it follows that vegetation immediately adjacent to streams provides the greatest relative benefits for intercepting solar radiation. Vegetation farther from the stream may increase the density of the canopy and thereby help reduce solar inputs, but these benefits diminish with increasing distance from the channel (Light et al. 1999).

Small streams that are wide and shallow with low discharge rates are at the highest risk of temperature problems (Welch et al. 1998). Low-order, narrow stream channels are more likely to be well-shaded in comparison to wide stream channels that can be expected to have lower levels of shade simply due to their geometric relationship between vegetation height and channel width. On large streams and rivers, riparian shade may be present only along bank edges or secondary channels.

Riparian vegetation can regulate temperatures by blocking incoming solar radiation, and maintaining channel morphology, and floodplains. The amount of influence riparian vegetation may have on stream temperatures is dependant on multiple factors including the size of the stream, water depth, groundwater and tributary inputs, riparian vegetative community, length of stream channel shaded, slope, aspect, and region.

The primary factors influencing shade, and therefore solar input, are: (1) density of vegetation – buffer width alone is not a good predictor of canopy characteristics, shade, or solar energy transmitted to the stream (Brazier and Brown 1973; Newton and Zwieniecki 1996); (2) height of vegetation – site-potential tree height varies physiographically, trees that lean over streams provide more-effective shade than their height suggests (Cross 2002); (3) stream width – effective shade generally decreases as stream width increases, and less sunlight is blocked by the adjacent canopy (Betscha et al 1987; Sullivan and Adams 1991), small streams can be effectively shaded by understory vegetation (Lorensen et al. 1994); (4)

stream-reach orientation – interception of solar radiation is dependent on location of vegetation relative to the stream and solar path (i.e., the amount of sunlight that is blocked) (Cross 2002); (5) latitude and time of year. – the angle of the sun decreases with increasing latitude which causes more potential shade, low winter sun angles maximize reflection at the water surface and shading effects of riparian vegetation, while high summer sun angles maximize direct-beam solar radiation (Beschta et al. 1987); (6) time of day – the angle of the sun increases in the morning and decreases in the afternoon, low morning and afternoon sun angles maximize reflection at the water surface and shading effects of riparian vegetation, while high midday sun angles maximize direct-beam solar radiation.

Air temperature is cited in some studies as strongly influencing stream temperatures (e.g., Edinger et al. 1968; Smith and Lavis 1975; Sullivan and Adams 1991; Larson and Larson 1996). Bartholow (2005) attributes long-term changes in water temperatures within the Klamath Basin to changes in air temperatures. However, when describing cumulative effects of clearcutting on stream temperatures, Bartholow (2003) states that stream shading is important because general air temperature did not appear to be as important in governing the increase in maximum daily water temperature as direct solar radiation. Johnson (2003) points out that the relationship between air and stream temperatures can be misleading because air temperatures are strongly correlated with stream temperatures. Correlations have been reported by several researchers (e.g., Pilgrim et al 1998; Mohseni and Stephan 1999) with very good results obtained at monthly and weekly time-scales (Mohseni et al. 1998). Strong correlations do not indicate a cause and effect relationship; such a relationship can only be determined under completely randomized experimentation, not with observational or case studies (Ramsey and Schafer 1997). Since solar radiation strongly influences both air and stream temperatures, the correlations are understandable. Hagan (2000a) reiterated that when air temperature is greater than water temperature, water temperature will rise at a rate governed by physics. Hagan (2000b) also pointed out that cold water naturally warms faster than warmer water when in contact with warmer air. Bartholow (2003) concluded that although air temperature is influential in increasing maximum water temperatures, it is less influential than both solar radiation and the effect of stream widening.

In summary, correlations have been documented between summer air temperatures and summer water temperatures. However, these correlations do not indicate a single cause-and-effect relationship. Long-term and multi-seasonal studies show that air-water temperature relationships vary and that other environmental factors also influence the relationship.

7.5.6.4 Variability in Conditions

Stream temperatures inherently and naturally increase in a downstream direction (Dent and Walsh 1997). Caldwell et al. (1991) noted that maximum stream temperatures are strongly influenced by elevation with warmer temperatures observed at lower elevations. The majority of researchers has found relationships between stream temperature and either basin size or distance from divide, as well as canopy cover. Many people have speculated about the role of air temperature as a determining factor and have discussed whether air temperature is causative or merely correlated with stream temperatures. Yet, there is good agreement that stream temperatures tend to increase in a downstream direction and that riparian shade is not as effective in preventing heating in larger streams and rivers as it is in smaller streams.

As stream order increases, so usually does stream width, stream discharge, and number of tributaries. As width increases, surface area exposed to solar radiation usually increases because riparian vegetation may shade less of the stream surface. During the summer when stream temperatures are the highest, the combination of increased direct solar radiation, warmer air temperatures, and decreased stream flows are the major factors affecting stream temperature (Beschta et al. 1987). Of these three factors, forest management can have the greatest effect on direct solar radiation by reducing shade. In several studies, the largest increases in stream temperature after riparian removal occurred not in the late summer, the usual time of maximum stream temperatures, but in early summer, which coincides with the timing of maximum solar inputs (Johnson and Jones 2000).

Beschta et al. (1987) reported that daily temperature fluctuations in lower stream sections are more pronounced because of increased exposure to solar warming – a function of wider, less-confined channels. Temperatures at the bottom of pools may be 5 to 10 degrees Celsius cooler than surface layers. Sullivan et al. (1991) discuss what is known about stream temperatures at the basin or watershed level. Temperatures tend to increase in stream reaches as water flows from headwaters to lower elevations. They state that this appears to be caused by several factors: air temperature tends to increase as elevation decreases, groundwater inflow is less in proportion to in-channel flow, and wider stream channels result in decreased shading from riparian vegetation (Beschta et al. 1987).

7.5.6.5 Shade

A number of studies have been conducted to describe the relationship between buffer width and amount of shade provided. These studies are described in CH2MHill (1999, 2000), Castelle and Johnson (2000), and in other publications. These authors have generally found that incremental shade effectiveness diminishes with distance from the stream (Brazier and Brown 1973; Steinblums et al. 1984; Brosofske et al. 1997). Relationship of shade and distance from stream developed by Brosofske et al (1997) for western Washington were similar to Steinblums et al. (1984) despite measured differences in total solar radiation related to buffer width. In Oregon, it appears that riparian buffers of 30 meters or more in width along small streams provide approximately the same level of shading as an old-growth forest (Beschta et al. 1987).

Steinblums et al. (1984) identified that shade could be delivered to streams from beyond 75 feet and potentially out to 140 feet. In some site-specific cases, forest practices between 75 and 140 feet from the channel have the potential to reduce shade delivery by up to 25 percent of maximum. However, any reduction in shade beyond 75 feet would likely be relatively low on the horizon, and the impact on stream heating would be low or negligible because direct-beam radiation declines in effectiveness as the angle approaches the horizon, according to Lambert’s Law (the law that the illumination of a surface by a light ray varies as the cosine of the angle of incidence between the normal to the surface and the incident ray) (CH2MHill 2000). Only direct solar radiation is thought to affect stream temperatures (Ice 2001).

7.5.6.6 Channel Morphology, Discharge, and Water Source

Channel characteristics, particularly width and depth, influence the amount of heat gained or lost from a stream. As streams widen, the more stream surface area increases, providing more surface area for heat energy exchange with the atmosphere (Boyd 1996). Streams with a well-defined pool/riffle sequence may have more water forced into the hyporheic zone due to hydraulic pressure. Floodplain roughness is increased by riparian vegetation which slows stream velocities and increases retention time of water on the floodplain while reducing local shear stresses and bank erosion. Channel morphology can be as important as shade in moderating summer temperatures (Blann et al. 2002 as cited in Cristea 2005). The temperature increase in a stream is directly proportional to the area exposed to sunlight and inversely proportional to the volume of water in the stream. The effect of canopy removal on stream temperatures is greatest for small streams and diminishes as streams get wider (Sugden et al. 1998). Consequently, small streams respond faster to changes in canopy cover than larger streams (Sugden et al. 1998).

In Oregon, most summer flow out of the high Cascade Mountains is not due to snow melt (USDA 2002). Instead, the Cascades form a vast hydrologic sponge that stores many decades worth of water as deep groundwater. At the point of stream initiation, the temperature of water entering a forest stream system typically resembles that of the watershed's subsoil environment. Black and Bolton (1996) found that groundwater (spring) temperatures were very cool and remained constant, but that wetland source temperatures tended to follow air temperature. Mellina et al. (2002) found that streams headed by small lakes or swamps cool as they flow downstream during the summer, and that headwater streams warmed, regardless of whether they were harvested or not. They concluded that lentic water bodies and groundwater inflows are important determinants of stream-temperature patterns in sub-boreal forests. Stream flow is a significant parameter leading to temperature changes, and low-flow streams are very sensitive to temperature changes (Boyd 1996). Stream temperatures may be greatly influenced by the thermal characteristics of the dominant water source (e.g., snow melt, rain fall, or groundwater).

7.5.6.7 Floodplains and Wetlands

Local water temperatures can change where cooler or warmer tributary waters, or groundwater, enter a stream channel. The magnitude of change is in proportion to the temperatures and amounts of flow in each source (Brown et al. 1971). Natural riparian and floodplain wetlands collect and distribute flood flows, recharge groundwater aquifers, and store water for slower releases. Wetlands play an important role in storing water from winter floods, making water available for recharging groundwater aquifers, and later providing water to surface streams during summer low flows. Normally, wetland soils store water from winter rains, and slowly release the water over longer periods of time. Loss of wetlands has reduced the potential recharge of groundwater aquifers and reduced their ability to provide flow during dry summer and fall months (IMST 2002). Streams that have well-connected terraces and large amounts of deep gravel will typically have cooler water temperatures. Alluvial gravel in both large and small floodplains store cold water from periods of high runoff and releases the water gradually during periods of low runoff (Coutant 1999). Adequate recharge of alluvial gravels depends on high spring peaks in river elevation (Coutant 1999). Stream reaches with sloughs and side-channels can also supply large amounts of subsurface flow to the main channel.

7.5.6.8 Small Streams

Shade in clearcuts and heating following harvest

Riparian timber harvest has been shown to produce increases in stream temperatures, and the magnitude of these increases varies among sites and regions (Johnson and Jones 2000). Sites where only overstory riparian vegetation was removed generally had smaller increases in stream temperature than where the understory was also removed. Mellina et al. (2002) noted that streams in harvested areas had 40 percent to 60 percent shade during post-harvest years (i.e., 1-3 years). Robison and Runyon (2003) found shade from understory and slash and narrow channels provided 50 percent shade and noted that the areas without buffers were reduced from 87 to 52 percent shade cover. Chan et al. (2005) found that a narrow vegetated buffer of trees or dense shrubs along headwater streams in clearcuts lowered insolation to the stream. Caldwell et al. (1991) stated that logging debris and brush provided substantial shade, as did ravine steepness, immediately after harvest. On the Coast Range of Oregon, however, it took about 5 years before 50 percent of a stream was shaded following harvesting and in the higher elevations of the

Cascades it took up to 25 years to reach 50 percent stream shading (Beschta et al. 1987). In a study by Johnson and Jones (2000) in the western Cascades, it took 15 to 20 years for summer maximum temperatures to return to normal following clear-cutting and burning.

Johnson and Jones (2000) found that maximum stream temperatures increased 7 degrees Celsius and occurred earlier in the summer after clearcutting and burning in one basin, and after debris flows and patch cutting in another. Diurnal fluctuations in June increased from approximately 2 to 8 degrees Celsius. Mellina et al. (2002) reported minor changes (averaging 0.05 to 1.1 degrees Celsius) following harvest. Results from a cooperative temperature study in Washington State, covering 92 sites in several ecoregions, found an average 5 degrees Celsius increase in maximum water temperatures as shading decreased from 75-100 percent to 0-25 percent (Sullivan et al. 1990). For small streams, complete shade removal can increase water temperature as much as 3 to 10 Celsius, but the actual change will be determined by local conditions (Beschta et al. 1987). The IMST (2004) reviewed 49 studies on the influence of riparian vegetation on shade. In 44 of these studies, the stream temperatures increased from as little as 1.09 degrees Celsius to as much as 12.7 degrees Celsius after vegetation was removed. Macdonald et al. (2003 as cited in Cristea 2005 and IMST 2004) recorded increases in daily stream temperature fluctuations from 1.0 to 1.3 degrees Celsius before harvesting to 2.0 to 3.0 degrees Celsius after harvesting. They also observed increases in maximum mean weekly temperatures of 4 degrees Celsius (from 8 to 12 degrees Celsius).

In another study, Summers (1983) found that small streams that had been clearcut and burned at various times in the past to assess the recovery of shade. On average, 50 percent of a stream was shaded within 5 years of harvesting and burning in the Coast Range of Oregon, and within 15 years at lower elevations in the Cascade Range. Caldwell et al. (1991) made similar observations and concluded that shade reduction along small clearcut streams in western Washington would recover within 5 years. Since nearly all Type Np streams are small (i.e., <20 feet BFW), shade reductions and any associated temperature increases are not likely to persist for long periods. Much of the early recovery in shade levels is attributable to the rapid growth of understory vegetation, which can almost completely shade small streams with a few years after harvest (Summers 1983).

Gravelle and Link (2005) found that water temperature maximum in the streams without fish increased by 1.4 to 3.6 degrees Celsius in clearcut first-order watersheds, probably due to increased solar radiation from decreased canopy cover. There was also an apparent, yet slight, increase in the year immediately following harvest at the selective cut sites when compared to the control tributaries. Chan et al. (2003), in Oregon, found that thinning had minimal effects on temperature in streams and soils at depths of 5 cm. However, Beschta et al. (1987) found that the effect of partial canopy removal is directly proportional to the reduction of canopy providing shade to the stream. Chan et al. (2005) in studying streams in clearcut, thinned, and unthinned areas found the percentage of radiation penetrating the forest canopy at stream center averaged 57, 10, and 3 percent respectively. Maximum streambed temperatures were similar for streams flowing through thinned and unthinned areas, and were about 2 degrees Celsius higher in streams flowing through clearcuts.

There has been less research on the effects of riparian canopy removal on winter water temperature, and its connection to habitat alteration or changes in fish behavior. Holtby (1987), summarized changes associated with timber harvest in a Vancouver Island stream and found monthly average temperature increases in the February-April period of 1 to 2 degrees Celsius. Sullivan et al. (1990), looking at eight monitoring sites mostly in Western Washington, noted temperatures decreased with increasing elevation, and noted a 0.5 degrees Celsius difference in average February temperatures between two neighboring streams with similar elevation, and aspect and different shading levels. Both Holtby and Sullivan et al. found the greatest temperature differences between shaded and unshaded sites occurred in April (i.e., early spring).

Cunjak (1996) reports that the most-prevalent effects on winter habitat in northern-latitude streams are reductions in streamflow, which increase ice formation and decrease available space. He also notes that removal of riparian trees can change the amount of shallow edge habitat, scoured channel areas, and can reduce winter habitat.

Heat budgets

The main components of a heat budget (physics of stream heating and cooling) are discussed in Sullivan et al. (1991), Beschta et al. (1987) and IMST (2004). There are several factors that make up the heat balance of water, including: solar radiation, air temperature, evaporation, convection, conduction, and advection (Brown 1983; Adams and Sullivan 1989). Water temperatures at a given location are a function of a balance between heat inputs and heat loss. Heat inputs are driven by solar radiation, which varies daily and seasonally, and are affected by shading from riparian vegetation and topography. There is some disagreement among studies whether or not water warmed in streams with no riparian canopy will decrease in temperature when it flows into and through shaded sections of stream. Although there are some differences of opinion about the relative contribution of factors, heat loss appears to be largely the result of groundwater inflow, hyporheic exchange, and conduction of heat to the stream bed (Story et al. 2003; Beschta et al. 1987; Johnson and Jones 2000; IMST 2004). Johnson (2004) states that “heat budget analyses show that convection, or the transfer of heat energy from warmer air to cool stream water is, in fact, only a small portion of the energy exchange influencing stream temperature. Therefore, air temperature is a relatively weak determinant of stream temperature. The major factor influencing both air and stream temperature is incoming solar radiation.” IMST (2004) emphasizes that although correlations have been documented between summer air temperatures and summer water temperatures, these correlations do not indicate a cause-and-effect relationship.

In an experimental shading study on a second-order stream in the west slopes of the Oregon Cascade Range, Johnson (2004) reported that maximum water temperatures declined significantly in an artificially shaded reach, but minimum and mean temperatures did not change. Heat budgets calculated prior to adding artificial shade indicated that solar energy was the dominant factor influencing temperatures in the stream. In a similar heat budget for a shaded reach, convection became the dominant source of heat even though its overall magnitude changed little. Evaporation decreased in the shaded area, but other losses of heat remained similar. A net loss of heat occurred within the shaded reach. During shading, energy fluxes other than direct solar input showed little change, although their relative importance increased. Johnson (2004) also reported that under the artificial shade, the largest energy fluxes were evaporation and net long-wave radiation. Johnson (2004) reiterated that “Convective fluxes are determined by temperature differences between the water and air” and that “the heat budget also showed that convective or sensible heat exchanges between warm air and cooler streams comprise a relatively small portion of the heat flux.” However, Johnson cautioned that several factors in this experiment, such as the type of material used for shading or that shading only covered the wetted portion of the stream channel, may not have functioned in a similar manner to the influence of riparian vegetation on stream temperatures.

Equilibration

Water warmed in streams with no riparian canopy may decrease in temperature after entering fully shaded sections. IMST (2004) refers to a number of authors that have documented stream temperature decreases after streams flow through a shaded reach. The cooling reported by these authors, is not necessarily a direct result of shading. Heat in a stream is lost through convection, conduction, and evaporation. Evaporation can be a major cooling agent for streams when temperature gradients, vapor pressure gradients, and winds are high enough and humidity is low enough to transfer heat from the water to the air. The riparian canopy will intercept direct solar radiation and slow down the rate of heating. The riparian canopy can lower local daytime air temperatures over the stream channel and change the rate of evaporation, although the rate of evaporation is dependent upon a number of variables including humidity and wind speed. Heat energy can be lost to the air, stream channel, and streambank in shaded reaches until equilibrium occurs.

IMST (2004) identified other studies where no detectable change in temperature was seen once a stream entered a shaded stretch. For example, in a small western Oregon tributary Brown et al. (1971) reported stream temperatures approaching 80 degrees downstream from a large clearcut. No significant reduction in temperature was seen after the stream entered a 600-foot reach with a forested canopy. The authors found that there were insufficient wind speeds, temperature gradients, and vapor pressure gradients to cause either evaporative or convective cooling of water once the stream entered a shaded reach.

Cold groundwater or tributary inputs will also contribute to water temperature cooling in shaded sections (Brown et al. 1971; Story et al. 2003). A thermal-recovery zone is a reach with relatively similar riparian and channel conditions for a sufficient distance in order to allow the stream to reach equilibrium with surrounding conditions (Lewis et al. 2000). The length of stream reach required to reach equilibrium will depend on stream size (especially water depth) and morphology (TFW 1993). In some studies, the distance of similar riparian and channel conditions required to establish equilibrium with those conditions in fish-bearing streams is relatively short, in others, it was estimated to be approximately 1,000 feet (Lewis et al. 2000).

In some situations, no detectable change in temperature may be seen once a stream enters a shaded stretch as there may be insufficient wind speeds, temperature gradients, and vapor pressure gradients to cause either evaporative or convective cooling of water once the stream entered a shaded reach.

The magnitude of potential temperature change varies with stream size and elevation. Smaller streams will both heat and cool more quickly without shade than larger streams (Adams and Sullivan 1990). In an old-growth Douglas-fir stand in the Cascades, a temperature decrease of 4.5 degrees Celsius was observed after water flowed from an unshaded reach through 700 feet of shaded channel (Levno and Rothacher 1967). In one study, the distance of similar riparian and channel conditions required to establish equilibrium with the conditions in fish-bearing streams was estimated to be approximately 1000 feet (Lewis 2000). In another study in a small stream, temperatures decreased 6.6 degrees Celsius after the stream had crossed 400 feet of channel that was shaded (Swift and Messer 1971). Since small streams respond faster to changes in shading than larger streams, we would assume that small headwater streams would cool down in the shorter range of the distances if shading was present.

Dilution

The ability of a small stream to affect the temperature of a larger stream depends in part on the sizes of the contributing and receiving waters (Sugden et al. 1998). A small tributary will produce little change in the temperature of a larger river unless the small stream's temperature is greatly different (Beschta et al. 1987). When several tributaries flow into a large river their cumulative temperature contributions can affect the temperature of the larger river. In addition the confluences of these small tributaries with the larger rivers can provide important cold water refugia for salmonids.

Role of Substrate

Conduction between water and alluvial substrates is often underestimated as an important mechanism influencing stream temperature (Brown 1969; Beschta et al. 1987). Conduction from near-stream soils and alluvial substrates may account for more of the stream temperature dynamics than is generally recognized (Hondzo and Stefan 1994). Conduction can have a different magnitude of influence on stream temperature in bedrock versus alluvial reaches. Johnson and Wondzell (2005) found that gravel, as compared to bedrock, moderates peaks in temperature.

Role of Hyporheic Zones

Recent studies of dynamic thermal regimes in the hyporheic zone along with improved understanding of the hyporheic zone as an important flow path of surface water now suggest that the hyporheic zone may play an important role in influencing stream temperature in alluvial reaches (Johnson 2004). Johnson (2004) found temperatures changed over very short distances – as the stream flowed through a 656-foot (200-meter) bedrock reach, daily maximums increased several degrees; in the 1148-foot (350-meter) alluvial reach, daily maximums decreased by as much as 8.7 degrees Celsius and minimums increased by 3.9 degrees Celsius. Johnson (2004) found that, throughout the summer, diurnal fluctuations of stream temperature in the bedrock reach were much greater (higher maximums and lower minimums) than downstream in the alluvial reach.

Johnson (2004) stated that hyporheic flow could influence downstream temperature maximums and minimums by several possible mechanisms: (1) residence time is lengthened by hyporheic flow paths, which could lead to simple mixing of daytime water and nighttime water; (2) increased hydraulic retention and the large volume of subsurface storage could lead to simple mixing of warm daytime water and cooler nighttime water, thereby moderating downstream temperatures; and (3) conduction with substrate surfaces could transfer heat to substrates. However, substrate that has been impacted by increased sediment is less able to provide the porosity and connectivity required to maintain hyporheic flows.

In small streams, pool-step sequences were found to be the dominant feature driving the hyporheic exchange (Wondzell 2004 as cited in Cristea 2005). Pool-step sequences can influence the hyporheic exchange rates at a smaller time scale (hours) than the complexity of flow paths created by a meandering stream (days) (Wondzell 2004). Bilby (1996) described one of the roles of large wood in headwater streams as creating wedges of stored sediment, and causing subsurface flows, which forces interchange with the hyporheic zone and cools the stream. Debris-flow topography will tend to slow down water and accelerate mixing. Large wood tends to slow down water and accelerate mixing through formation of sediment wedges.

Johnson (2004) found that estimates of velocities between bedrock and alluvial reaches differed dramatically depending on methods used. Median retention time of water in the 656-foot 200-meter section of bedrock was 1.1hours but was 18 hours in the 1148-foot (300-meter) alluvial reach. Not only are bedrock channels more responsive to solar inputs, but they have shorter hydraulic retention times, and therefore less mixing and dampening. Gravel substrates provide opportunity for exchange with substrate.

She notes that the potential influence of alluvial substrates on surface temperature is related to the proportion of total stream flow passing through the hyporheic zone, which in the lower 328 feet (100 meters) of one of her experimental streams was the majority of stream flow. Johnson (2003) notes travel time of water through a reach is not a homogenous process. Characterizing the hydraulic retention time through a reach, and, therefore, the contact time during which energy exchanges can occur, requires understanding of potentially very complex surface and subsurface flow paths. Johnson (2003) stated that more research is needed on the effects of turbulence of water on evaporative fluxes and energy absorption, the influences of substrate type, hydraulic retention time, and stream flow paths on conduction.

Role of Groundwater

Groundwater is insulated from daily and seasonal warming and cooling, so groundwater temperatures fluctuate very little. Therefore, groundwater inflow to a stream usually has a cooling effect on warm summer water temperatures and a warming affect on colder winter water temperatures. As summarized in Moore and Wondzell (2005), forest harvesting was found to increase soil moisture and groundwater levels due to decreased interception losses and transpiration. All heat exchange processes are influenced by the volume of the flowing water (Poole and Berman 2000 as cited in Cristea 2005). Harr et al. (1982) found an increased water yield in two small central Oregon watersheds cut to varying degrees. Increased yield was substantial (20 cm to 40 cm), and the number of low-flow days during the summer, including drought years, decreased, perhaps due to reduced evapo-transpiration. Small perennial streams typically have a large proportion of groundwater inputs which tends to be very cool. Groundwater temperature typically mirrors soil temperature. These streams are thus typically cooler than downstream receiving waters.

Stream Variability

Stream temperature is a product of complex interactions between geomorphology, soil, hydrology, vegetation, climate, elevation, and aspect of the watershed. The relative influence of these factors can vary spatially and across the landscape and over time. Water temperature can vary along the length of a stream as a result of local topographcial and geological factors. Thermal heterogenity varies in streams and rivers and can be affected by local energy inputs and outputs (IMST 2004).

The magnitude of potential temperature change with streamside vegetation varies with stream size (Adams and Sullivan 1990). Stream temperatures are very reach-specific, and responsive to reach-level parameters such as shading and groundwater inflow rate. Thus, the potential exists for stream temperatures to increase or decrease in response to local conditions. Smaller streams will both heat and cool more quickly, in response to changes in environmental parameters, than larger streams.

Other Habitats

In the upper intertidal zone of estuarine and marine habitats, temperature is an important factor in the ecology of at least two species of forage fishes as well as for most salmonids. Although these two forage fish are not species under FWS jurisdiction, we note that surf smelt and Pacific sandlance may provide us with insight regarding other covered marine fish, as well as effects to covered marine and anadromous fish with respect to prey availability. These species spawn in upper intertidal beaches with substrates of sand and/or fine gravel (Pentilla 1997). Elevated temperatures on beaches have been linked to a significant reduction in the hatching success of surf smelt (Pentilla 2001). Rice (2006) recently linked this reduction in hatching success to the loss of riparian shade, which was responsible for significantly higher daily mean light intensity, air temperature, and substrate temperature, and significantly lower daily mean relative humidity on these altered intertidal beaches. Pacific sandlance are known to burrow into intertidal beaches during the winter (Quinn 1999). During periods of elevated temperatures and low tides, interstitial dissolved oxygen is depleted, and these fish may emerge from the sediment and either dry out thoroughly or become easy prey for a host of predators (Quinn and Schneider 1991). Loss of riparian shade could also contribute to the high substrate temperatures and low oxygen events that adversely affect Pacific sandlance. These effects may also be experienced by other marine fish. Reductions in forage fish may affect both marine and anadromous predatory fish.

7.5.6.9 Summary of Relevant Issues

Intact riparian vegetation traps sediments, influences watershed hydrology, maintains favorable width-to-depth ratios, maintains water table depth, reduces solar radiation, and allows for heat exchange with substrate, thereby indirectly influencing stream temperature. If riparian canopies are removed, increases in stream temperature may occur. The largest increases in stream temperatures after riparian canopies are removed can be expected to occur in small headwater streams. Small streams that flow though harvested areas (particularly unbuffered reaches) may have elevated temperatures. Shade alone cannot cool a stream, but it can prevent further warming from occurring (IMST 2004). Water temperatures decrease when heat energy is transferred from the surrounding environment. Depending on the length of shaded reaches and also site-specific conditions, the amount of heat leaving the stream may be greater than the amount entering the stream, causing water temperatures to decrease. The extent to which stream warming may transfer to downstream fish-bearing streams depends upon a number of site specific factors and can be affected by a number of features including substrate (bedrock versus alluvial channels), discharge of affected waters, discharge of receiving waters, coldwater inputs from hyporheic areas and tributaries, and the condition of riparian areas and other sensitive sites such as tributary junctions.

7.5.6.10 Effects of Proposed FPHCP on Water Temperature (Heat Input)

Human land-use activities typically affect stream temperature by altering one or more of the following factors: 1) the width and depth of a channel; 2) the amount of flow in the stream; 3) the exchange between the surface water in the stream and the water flowing through its streambed and banks; and 4) the shade and vegetation along a stream. These four factors are highly interrelated and the overall influence that individual factors may have on stream temperature will depend on stream size. Timber harvest has the potential to affect stream temperatures primarily through removing riparian vegetation. The potential for riparian vegetation to mediate stream temperatures is greatest for small to intermediate size streams and diminishes as streams increase in size lower in the floodplain (Spence et al. 1996).

Shorelines of the State

The influence of riparian timber harvest on stream temperatures in wider channels (i.e., greater than 30 feet) tends to be less than narrower channels, because the channel can only be partially shaded by riparian trees. Therefore, water temperatures are naturally higher. However, trees do affect water temperature on larger channels, meaning temperature recovery from riparian timber harvest can take longer than for small streams. In some areas, this problem is compounded by the fact that the majority of the riparian buffers affected by timber harvest have regenerated as hardwood-dominated stands (i.e., greater than 70 percent hardwood composition).

The RMZ prescriptions under the FPHCP protect most shade along Type S waters by requiring the retention of trees within a certain distance of the bankfull width or the CMZ. The size of the RMZ needed to meet shade requirements varies depending on whether the RMZ is located in western or eastern Washington and the specific provisions of the Shoreline Management Act.

Streams with Fish

In western Washington, the Core Zone provides the majority of the shade to streams. Tree retention in the Inner Zone would be dependent on pre-harvest stand conditions and the selected management option. Some stands would not contain sufficient tree density to qualify for any harvest in the Inner Zone. If harvest options are available, the conifer density in Core and Inner Zones would control the intensity of harvest.

The thinning option (Option 1) would not reduce shade substantially due primarily to retention of the Core Zone, but also because of the canopy that would be retained in the Inner Zone. Thinning is not being used as frequently as packing (Option 2). Applying the packing option would extend the no-harvest zone to 80 or 100 feet from the bankfull width or CMZ edge. The potential reduction in shade delivery under this option would be minimal because the rate of shade reduction decreases with increasing distance from the stream. For purposes of this analysis, we considered that the thinning option could be selected more often than is occurring currently. The thinning option provides more opportunity for shade reduction than the packing option. With the retention of the canopy associated with the 57 largest trees per acre in the thinned Inner Zone, we would expect that only solar radiation at indirect angles would reach the stream. Diffuse radiation has little effect on stream warming and because solar radiation at indirect angles has reduced intensity, and less effect on stream warming.

In addition, the Shade Rule will require that minimum levels of shade are retained, depending on elevation, in order to meet the 16 or 18 degree Celsius temperature standard. In Western Washington, the Shade Rule requires trees be retained within 75 feet of a Type S or F stream, or CMZ, to meet water-quality standards. The Shade Rule must be satisfied whether or not a stream-adjacent parallel road is present. Shade requirements must be met regardless of harvest opportunities provided in the Inner Zone. However, the Shade Rule may not be sufficient to achieve the objectives of cold water temperatures and may not ensure adequate shade where existing shade is below target levels.

In eastern Washington, riparian management prescriptions for tree retention depend on the existing basal area and forest vegetation zone. The intention is to address the forest health of residual stand while retaining the most-desirable species and largest trees within the stand. In all cases, the Core Zone is 30 feet wide and not subject to timber harvest. The Inner Zones are 45 or 70 feet, for small and large streams respectively. A minimum of 50 trees per acre must be left where basal areas are high and a minimum of 100 to 120 trees per acre must be retained where basal areas are low. Minimum basal-area targets are also required. The combination of the Core Zone and the Inner Zone (75 to 100 feet) provide for a majority of the available shade.

The Bull Trout Habitat Overlay includes portions of perennial, fish-bearing streams in eastern Washington. Within the Bull Trout Habitat Overlay, all available shade must be retained within 75 feet from the edge of the bankfull width or outer edge of the CMZ (whichever is greater) along Type S or F waters. Outside the bull trout habitat overlay in eastern Washington, the Shade Rule provides some level of shade for streams with fish, but is expected to provide less shade than provided by the Bull Trout Overlay or westside prescriptions. The effectiveness of eastside prescriptions in maintaining stream temperatures outside the Bull Trout Overlay is less certain.

Alternate Plans: Alternate plans may allow deviations from the standard Washington Forest Practices Rules as long as they are determined to be at least equal in overall effectiveness in meeting riparian and aquatic habitat protection as the standard rules. Short-term effects to shade may occur from operations that would enhance long-term shade, wood, or other functions. Depending on the level of canopy removal, stream temperature may increase locally in the short-term under alternate plans.

20-acre-Exemption Rule on Streams with Fish: Streams on 20-acre exempt parcels may be exposed to greater amounts of solar radiation. For instance, on a small, westside Type F stream, a landowner would be required to retain at least 29 trees along a 1,000-foot reach within an area that would be 29 feet wide. The distribution of those trees can accommodate operational considerations, so some clumping would be allowed. Provisions also would exist to leave as few as half of these trees when criteria of harvest unit size and overlapping wetlands are considered.

However, 20-acre-exempt parcels must still meet the Shade Rule in the current Washington Forest Practices Rules. Yet, these rules apply to RMZs which are measured from the outer edge of the bankfull width. Where such RMZs and the associated Shade Rule are applied on streams with CMZs, long-term loss of shade may occur with channel movement. In the absence of the 20-acre exemption, shade must be left on the outside of the CMZ. Our conclusion is that where small landownership is proportionally high or concentrated along streams, diminished shade may occur along streams, resulting in increased risk of elevated stream temperatures. This is especially true where CMZs exist. While shade is generally ineffective at controlling water temperature of an entire large stream or river, it may be effective at maintaining cold-water refugia important to FPHCP covered fish.

Streams without Fish

Perennial Streams without Fish: For Type Np streams in western Washington, a 50-foot, no-harvest riparian buffer is required for the first 500 feet if the Type Np water is 1,000 feet or greater; or at least 50 percent of its length or 300 feet, whichever is longer, if the Type Np water is less than 1,000 feet. The buffer starts at the confluence of the Type Np water to the Type S or F water. Along the portions of Type Np streams that receive a 50-foot no-harvest buffer, it is expected that approximately 65 to 90 percent of the maximum potential shade (ACD) would be left (Brazier and Brown 1973; Steinblums et al. 1984). For those areas of the stream without buffers, these reaches would be subject to heating from solar radiation. Natural topographic features will shade small streams in some situations. In some areas, protection measures for sensitive sites and unstable-slope protections will complement Type Np RMZ prescriptions resulting in buffers along Type Np streams exceeding 50 percent of their lengths. Given the large degree of variability in the occurrence of sensitive sites and unstable slopes throughout the State, it is difficult to quantify the degree of protection that would result from these features.

Within 50 feet of the Type Np waters in eastern Washington, three scenarios are possible: no-harvest buffers, partial-harvest buffers, and clearcut areas. Within the partial-harvest buffers, the basal-area requirements are the same as those for Type S and F waters and may not provide complete protection of shade, but run the total length of the Type Np stream. If timber harvest along Type Np streams is conducted, no-harvest buffers must be at least equal in length to the clearcut portion of the stream in the harvest unit. No more than 30 percent of a harvest unit's stream length or 300 continuous feet may be clearcut. Clearcut reaches cannot be within 500 feet of a confluence with a Type S or F stream and may not occur within 50 feet of sensitive sites.

Many Type Np streams will have spatially intermittent sections. Sections of Type Np streams which flow subsurface will reduce the effects of solar radiation. No harvest buffers may occur along 50 percent or more of stream reaches (west and eastside respectively), with other considerations (e.g., unstable slopes and mandatory leave areas) providing additional shade to the streams. As a result of these considerations, 50 percent or less of eastside and westside Type Np streams would remain unbuffered. Consideration of intermittent subsurface flow would result in estimates for unbuffered reaches being even less. Conversely, partial-harvest buffers on eastside streams would not necessarily provide complete retention of shade along Type Np streams, but would be buffered their entire length.

Unbuffered reaches may be subject to reduced effects of heating if the reach is subsurface during the late spring and early summer. However, all unbuffered reaches may be subject to some effects of elevated or reduced temperatures at other times of the year. In some areas, stochastic events such as severe debris torrents in steep channels can remove enough riparian trees to impact shade and water temperature as well, and also alter the sensitive site protection measures at the confluence of Type F and Np streams. Windthrow may occur within buffered reaches, potentially increasing the consequences of upstream unbuffered areas.

Type Np streams are more-easily shaded because of their relatively small size compared to other stream types. The 50-foot no-harvest buffers should address most direct-beam solar radiation. Windthrow along narrow buffers is likely to occur; however, these fallen trees and their boles could provide some shade, as well as insulation from solar radiation. In the unbuffered portion of the stream system, the amount of residual vegetation would vary by prescription and forest composition and structure. Slash, logs, bank, brush, and early seral vegetation have been found to provide up to 50 percent shade for small streams. Where discontinuous buffers or partial harvest is practiced, the riparian overstory would be at least partially removed and shade would be reduced. Natural topography would provide site-specific amounts of shade, depending on the physical setting and aspect, but localized effects to water temperature may occur within these Type Np streams.

Harvest along Type Np and Ns streams under the standard Washington Forest Practices Rules may also result in some reduction of large wood delivery to Type F streams in areas with steep topography – see Large Wood section. This may affect the delivery of large wood to Type F streams and the difference in amount of large wood could potentially result in changes in channel morphology at these sites and for some distance downstream, and could result in some stream warming in these areas.

In summary, 50-foot buffers (thinned or unthinned) would be provided on at least 50 percent of westside and 70 percent of eastside Type Np streams. However, many other previous harvest units in a watershed would be shaded due to recovery of shade since harvest. Assuming that at least partial shade would recover in 10 years, in a watershed that would be harvested evenly over the 50-year period, one-fifth of the stream reaches would be in past harvest units which may be young enough to contain Type Np streams not yet receiving shade. However, about half or more of the streams in those harvest units would be buffered. Thus, a total of 10 percent or less of the watershed would be unbuffered at any particular time. A watershed that was harvested more-aggressively in a short time, and had few sensitive sites, might theoretically have as much as 50 percent in an unbuffered condition at any particular time. As mentioned earlier, these unbuffered reaches would likely have some shade from understory vegetation, topography, and slash. These streams may experience adverse effects to water temperatures until shade was provided from regrowth.

Seasonal Streams without Fish: Operations near Type Ns streams will not likely affect temperature because these streams are typically dry during the warmest summer months, when the waters are most vulnerable to warming. However, the few Type Ns streams that have water present (including intermittently) during this time might not have adequate shade from overstory trees to maintain cool stream temperature as these streams generally receive no specified buffers under the FPHCP. Local topography, shrubs, and debris along the streams can provide some shade. On steeper topographies up to 50 percent or more of Type Ns stream reaches may be buffered. There is a high likelihood of water temperature increases in Type Ns streams where water is present during the early spring and summer months (June through September), when the sun is at its highest and temperatures are at their greatest. This may negatively affect some amphibian species present in Type Ns streams.

It is uncertain what the effects to downstream water temperatures are from unbuffered Type Ns streams. When Type Ns streams flow directly into Type F streams, in some cases they will have limited effect due to differences in discharge volume. Type Ns streams would likely contribute a small proportion to receiving Type F streams. When Type Ns streams flow into Type Np streams, the principles limiting potential delivery of heat (as discussed earlier and below for Type Np streams) would apply.

Delivery of Heat to Fish-bearing Streams: Because some headwater streams are very small, understory vegetation and younger age class coniferous forests can provide shade sufficient to influence water temperature. For small headwater streams, streams should be mostly reshaded within 10 years following riparian timber harvest. For larger Type F streams, recovery may take 25 years or more (Beschta et al. 1987). Therefore, a number of Type Np and Ns streams may experience warmer water temperatures for a number of years following timber harvest.

Research has shown that temperature increases in small headwater streams have a limited, localized effect on the temperature of downstream reaches, with the affected downstream distance influenced by stream size, water velocity, and amount of heating or cooling (Castelle and Johnson 2000).

For both the eastside and westside, water that may be warmed as it flows through unbuffered reaches of Type Np or Ns streams could potentially affect stream temperatures in fish-bearing streams. The degree to which temperature increases in Type Np streams would affect downstream fish streams is uncertain and could be influenced by a number of factors including hyporheic and groundwater input, volume of water in both in the Type Np waters and the receiving fish-bearing waters, substrate, condition of the buffered stream reaches, as well as adjacent land uses between FPHCP lands and receiving Type F waters (USFWS et al. 2001).

Conversely, Type Np and Ns streams may cool excessively during the winter when left unbuffered. This loss of heat may manifest itself in increased in-stream icing and therefore, reduced habitat availability and even injury or death of individual fish through gill abrasion, entrapment, or scouring and lifting of redds. These effects would generally be limited to high elevations and would tend to be more likely on the eastside. These effects are not well-understood, but are likely somewhat ameliorated by groundwater influx. While these effects are likely not common, they can have severe effects when they do occur.

20-acre-Exemption Rule on Streams without Fish: Under the 20-acre exemption rule, no buffer is required on Type Np streams unless required to protect public resources (e.g., covered species, shade). When such is required, at least 29 trees per 1,000 feet would be retained. These trees may be conifer or deciduous and may generally be 6 inches in diameter or the next largest available. Clumping is allowed to accommodate operations. In watersheds with a high proportion of small landowners that qualify for the 20-acre exemption, the lack of RMZs on both Type Np and Ns streams would diminish shade and produce a high probability of increased water temperatures. Reduced delivery of large wood from 20-acre exempt parcels may decrease the habitat complexity, reduce the formation of deep pools, destabilize streambanks, and widen channels. These habitat effects may also result in subsequent stream warming that could affect cold-water fish.

Wetlands: Maintenance of buffers on non-forested wetlands would be expected to maintain shade at moderate to high levels. Other requirements to protect hydrology within wetlands should also protect natural flows and avoid disruption of cooling flows. However, the FPHCP would allow forested wetlands (not connected to Typed waters) to be harvested without shade retention. Where such wetlands contain year-round water or are saturated near the surface during the summer, solar radiation may warm these areas and result in delivery of warmer water to fish-bearing streams or streams with amphibians.

Other Considerations: Landowners are also required, to the extent practical, to avoid creating yarding corridors and road crossings through sensitive sites and to avoid vegetation removal in perennially moist areas. Minimal impacts are expected to the hydrological regime (see Hydrology section). Effects from other activities and relationships with other habitat features (e.g., channel morphology) resulting from FPHCP are not expected to affect temperature beyond negligible levels. Reductions in shade created by openings in riparian areas for road crossings (typically only 25 to 50 feet of stream length), and yarding corridors (no more than 30 feet wide) should have little measurable effect on stream temperature. Identification of 30-foot ELZs, and associated BMPs and mitigation, as well as identification of and prescriptions for RMZs, are expected to protect near-bank areas and off-channel features that may contribute to groundwater influx.

Research: Habitat manipulation of riparian buffers for CMER research purposes may result in small and localized reductions of shade beyond that allowed under the standard Washington Forest Practices Rules and FPHCP. The effects of the research activities on water temperature are expected to be relatively small and only affect specific reaches of streams associated with study sites.

7.5.6.11 Summary of Water Temperature (Heat Input)

Prior to any harvest in Type S or F RMZs, the FPHCP would require assessment regarding existing conditions relative to DFC and the Shade Rule. If there are insufficient trees to meet basal area requirements, harvest opportunities would be limited or not allowed in the Inner Zone. Where harvest may occur, Core Zones would be retained, and Inner Zone requirements would add additional shade. Where the harvest option of packing trees (Option 2) is selected, it would increase the no-harvest buffers to at least 80 and 100 feet, for small and large streams, respectively. Where the thinning option is selected (Option 1), Inner Zones could be thinned to 57 trees per acre. Harvested eastside stands would retain at least 50 to 120 trees per acre depending on vegetation zone and existing basal area. However, additional trees might also be retained under the requirements of the Bull Trout Habitat Overlay or the Shade Rule. Therefore, the amount of shade produced along Type S and F streams under the FPHCP would be high and the amount of shade available across the extent of FPHCP covered lands would continue to increase relative to baseline conditions that resulted from past practices.

While the long-term landscape conditions are improving, short-term reductions in local shade may occur under the FPHCP. The likelihood of adverse temperature effects from reductions of shade along Type S and F streams is considered low for most Type S and F westside streams and marine and estuarine areas, including areas where thinning and partial harvest would be implemented. The likelihood of adverse temperature effects are also expected to be low in eastside Type S and F streams within the Bull Trout Habitat Overlay, which includes much of the action area on the eastside. In low-elevation basins where water temperatures are more sensitive to changes in shade and in eastside streams outside the Bull Trout Overlay, there may be adverse effects in some situations, depending on site-specific conditions.

Along Type Np streams, reductions in shade are likely to continue to occur in site-specific situations and water temperature may increase over limited distances as a result of these unbuffered Type Np reaches. In some unknown number of cases, increases in temperature may be delivered to downstream Type F waters. This is most likely in moderate-sized bedrock channels, where multiple streams converge in one area, where a single stream changes from Type Np to Type F, and where the sensitive site protections at the confluence of Type Np and F streams have been degraded. Within Type F streams, cool water sources usually result from a cold tributary stream or from groundwater input. When water delivered to Type F streams has not completely equilibrated, it may reduce the effectiveness of cold-water refugia at these tributaries for a period of years until shade recovers. The rate of shade recovery depends on streamside conditions and vegetation. Where warming of Type Np or Ns streams transmits heat downstream, warming may also disrupt the ability of cold-water fish to survive and/or reproduce within the delivery area. The degree to which temperature increases in Type Np streams would affect downstream fish-bearing streams could be influenced by a number of factors in addition to those stated above: distance of harvest unit from fish-bearing streams; past harvest; debris flows; windthrow; fire; intermixed land uses other than forestry; groundwater input; volume of water in both the Type Np and receiving fish-bearing waters; shade provided within the harvest unit; and the type of substrate and hyporheic exchange within the stream.

Riparian timber harvest on 20-acre exempt parcels could have adverse effects to the survival and reproduction of cold-water fish. The most-severe effects would likely occur to eggs, alevins, and fry, potentially resulting in the injury or death of individual eggs or small fish. Fortunately, 20-acre-exempt parcels do not represent a large proportion of covered lands in most basins. Ownerships meeting the 20-acre exemption are most likely to be concentrated in areas adjacent to other non-forestry land uses. In these areas, habitat conditions may already be degraded. Additionally, at lower elevations, water temperatures are more likely to be naturally warmer. Degraded and or naturally warmer conditions may mask or exacerbate temperature effects from 20-acre exempt harvests.

In the long-term, the FPHCP is expected to lower water temperatures from baseline conditions (where baseline conditions are elevated above natural conditions) through improved riparian management. Although the magnitude of changes in stream temperatures for any given stream is difficult to predict, improved canopy cover, increased streambank stability, increased amount and quality of large wood, and reduced sediment delivery to streams are anticipated to typically result in improvements to the temperature regime of most waters supporting fish. Sediment reduction as a result of improved road management is also expected to maintain or improve water temperatures (see **Sediment** section). Overall, the effects of potential temperature increases due to FPHCP activities are most likely to occur in headwater reaches of Type F streams, at confluences of Type F and Np streams, unbuffered Type Np and Ns streams, and in areas adjacent to 20-acre exempt parcels that are harvested.

7.5.7 Nutrient Input

Much of the following discussion of the issues surrounding nutrient input was adapted from discussions in Review of the Scientific Foundations of the Forests and Fish Plan (CH2MHill 2000) and the Final EIS for the Forest Practices HCP (USFWS and NMFS 2006).

Organic litter (Detritus) inputs to streams are important food and energy sources for a variety of organisms that, in turn, provide food and energy for fish and other aquatic organisms. The base of the aquatic food chain is supported by the combination of dissolved chemical nutrients and detrital materials. The chemical constituents such as nitrogen (usually in the form of nitrates and nitrites), phosphorus, and carbon can be derived from the breakdown of detritus and through leaching and runoff from surrounding soils (Gregory et al. 1987). Also, organic litter influences water quality and habitat quality in riparian areas. Forest practices have the potential to affect organic litter generation and transport from riparian forests to aquatic areas. In addition to surface inputs, dissolved nutrients may reach the stream through shallow groundwater or hyporheic flow paths. Little quantitative information is available to describe the relationship between cumulative inputs of these materials (Light et al. 1999).

There are two primary sources of organic matter within streams: Photosynthetic algae and other aquatic plants within the stream (i.e., autochthonous sources); and Terrestrial inputs from outside the stream (i.e., allochthonous sources). In forested ecosystems, terrestrial sources provide streams with most of their organic matter (Anderson and Sedell 1979; Gregory et al. 1987; Richardson 1992, 1991). For example, 98 percent of the organic material in a forest stream in the eastern U.S. came from terrestrial sources (Fisher and Likens 1973).

Organic litter includes leaves, needles, cones, twigs, bark, propagules, and other small plant materials. It also includes animal material, such as insects, that fall into or are delivered to the stream. Leaves and other organic matter entering streams contribute to nutrient cycling and support food chains and aquatic community structures. Stream microbial communities, algae, and invertebrates encrust fallen litter, and then the litter is slowly decomposed. These processes provide nutrient and energy sources to fish and other animals that ingest them. Terrestrial sources of organic matter compose the largest proportion of the energy base for many smaller streams. In addition to providing energy and nutrients to streams, fallen organic litter and partially decomposed humus in riparian areas may intercept muddied waters and catch silt (Knutson and Naef 1997), and may provide food and cover for aquatic insects.

Most litter is supplied by tree crowns, but important amounts come from understory vegetation. In deciduous riparian forests, about 80 percent of the organic material input to streams is derived from leaf litter. In coniferous riparian forests, needles contribute a major portion of the terrestrial input to streams (Bilby and Bisson 1992), and fallen cones or wood may account for 40 to 50 percent of the total terrestrial litter input (Naiman et al. 1992). Up to 90 percent of the organic matter that ultimately remains in small coniferous forest streams is composed of woody material (Naiman and Sedell 1979; Triska and Cromack 1980).

Most litterfall enters streams as a pulse in autumn, but species composition of forests affects the seasonality of inputs (Beschta et al. 1987). Hardwood litter provides short-term pulses during summer and fall (Naiman et al. 1992), and conifer litter provides a longer-lasting, year-round food source. When present in riparian areas, a mix of deciduous and conifer species should be maintained (Light et al. 1999). In southeastern Alaska, young-growth alder sites were documented to export significantly greater counts and biomass densities of macro-invertebrates than young conifer sites (Piccolo and Wipfli 2002). Floods and overland flows flush large quantities of organic materials into streams during large storms.

Litter production is related to canopy density, site productivity, and stand age. More-productive (higher site index) sites produce more forest biomass. There appears to be a relationship between stream order and litter production whereby litterfall volume is highest in first-order (headwater) streams, gradually diminishes along a stream size continuum, and is lowest in the largest-order streams (Conners and Naiman 1984). Generally, a relatively higher proportion of litter function is provided by near-stream vegetation as stream size decreases.

The nutrient values of litter and rates of decay vary by plant species and part. The complete decay process takes about one year for most high-quality materials such as leaves and herbaceous plants and may take several years or decades for low-quality materials such as cones and wood (Gregory et al. 1991). Instream large wood influences the retention and processing of organic matter, sediment transport, and invertebrate communities. Large wood creates a temporary storage of inorganic sediment and organic matter in stream channels that allows an opportunity for processing of the organic debris. Fallen limbs provide food and cover for aquatic invertebrates (Knutson and Naef 1997).

Food production for aquatic insects and fish is not necessarily maximized (i.e., fully effective) when litterfall is maximum. Site factors other than litterfall, such as instream photosynthesis, control food availability; and, instream photosynthesis is inversely related to forest canopy density. A dense canopy that provides abundant litterfall also blocks sunlight, a dense canopy therefore also reduces productivity of the stream.

Terrestrial organic litter may reach streams by direct fall or lateral movement (e.g., blowing or sliding down stream banks or steep slopes) (Benfield 1997). Although no known studies have been conducted to specifically determine the horizontal source distance within which terrestrial litter is input to streams, Rhoades and Binkley (1992) noted that very little of the nutrients and litterfall from red alder falls beyond the live crown.

It can be assumed that most litterfall to streams is generated close to the channel. The Forest Ecosystem Management Assessment Team (FEMAT) litterfall-effectiveness curve suggests that approximately 90 percent of the litterfall to streams originates within half a site-potential tree height from the stream (FEMAT 1993). However, reports by Newton et al. (1996) and Rhoades and Binkley (1992) suggest that the FEMAT litterfall relationship overemphasizes the contribution of litter from trees more than 0.2 site-potential tree height from the channel and underestimates contributions from trees within 0.2 site-potential tree height. Richardson (1992) estimated that 14 to 25 percent of the total litter input to a stream can originate from the banks due to wind action alone. Culp and Davies (1983 cited in Light et al. 1999) found that compared with complete clearcutting, a 10-m (33-foot) riparian buffer would provide leaf litter inputs to streams that were similar to pre-logging conditions.

Indirect evidence of litterfall effectiveness is suggested by benthic invertebrate communities. Several studies describe the role of various types of litter and associated processes to maintain aquatic macroinvertebrates and stream productivity (Hawkins et al. 1982; Meehan et al. 1977; Gregory et al. 1991). Studies in streams with managed riparian zones at least 100 feet (30 m) wide had benthic communities that were indistinguishable from streams flowing through unlogged watersheds (Erman et al. 1977; Newbold et al. 1980; Belt et al. 1992). However, maintenance of overhanging trees and shrubs within just 10 feet (3 m) of the bank maintains the source of most litterfall (Newton et al. 1996).

Although streamside litterfall is highly localized, stream transport systems readily move litter within streams from source areas to sink areas (Newton et al. 1996). Richardson (1992) estimated that 70 to 94 percent of all leaves that enter a stream segment are transported downstream until stored in a large pool or lake. Gregory et al. (1987) indicated that the greater the roughness elements (e.g., boulders, gravels, wood, roots) of a stream and the lower the hydraulic energy, the greater the retention of litter input. Thus, areas having large amounts of existing woody debris may retain more of the litter input.

Litter input to upstream headwater reaches contributes to downstream segments that support fish. Thus, within watersheds, upstream litter source areas tend to compensate for areas where litter inputs are low. The overall importance and magnitude of upstream contributions to litter input is not known, but they probably vary among watersheds with varying physiographic and biological conditions.

7.5.7.1 Management Implications

Forest practices that affect litterfall processes have the potential to modify the vegetation-stream relationship, including nutrient and energy sources to streams. More specifically, some forest practices can affect the productivity and quality of organic material, the timing of its delivery, and, to a lesser extent, litter transport processes. Silvicultural practices tend to improve biomass production over time, but can reduce litter production in localized, disturbed areas. Practices that alter the species composition and structure of riparian forests can change the quality of litter produced, as well as the timing of delivery.

Forestry effects that are within the historical ranges of natural disturbances are less likely to have a measurable effect on organic inputs. Practices that cause litter production and delivery processes to dramatically shift have the greatest potential to enhance or disrupt ecosystem processes and aquatic communities, particularly if their effects are cumulative over the watershed. However, cumulative effects remain relatively speculative for litterfall processes of riparian areas (Beschta 1998).

Among forest stands, the quantity and quality of organic inputs are related to forest development stage and structure. The type of silvicultural system (i.e., even- versus uneven-aged management) affects the annual pulsing of litter production, with uneven-aged forests providing more regular inputs over time. Total input of terrestrial litter to streams within old-growth forests was found to be approximately five times higher than in streams within clearcut forests (Bilby and Bisson 1992). Furthermore, Richardson (1992) found that terrestrial litter input was approximately twice as high in old-growth forests as compared to either 30- or 60-year-old forests.

On the other hand, forestry effects are considered temporary because many organic and nutrient inputs recover to pre-activity levels rapidly after a disturbance event (ODF 1994). Input of litter, especially to small channels, recovers rapidly following timber harvest. Studies indicate that nutrients from a variety of sources increase in the first few years following logging (Hicks *et al.* 1991). Where light is provided to the stream, these increases in primary productivity can enable increases in individual fish and amphibian growth. Increases in individual juvenile fish growth have been attributed to increases in primary productivity, but effects on overall production have not been detected related to these increases (Hicks *et al.* 1991). Canopy closure in planted stands typically occurs within 7 to 15 years (i.e., within approximately one-fifth of a 50-year rotation age). Input of all types of organic matter from terrestrial sources, except large wood, often returns approximately to pre-harvest levels within 20 to 25 years (i.e., within approximately two-fifths to one-half of a 50-year rotation age). Meehan (1996) found no overall change in macro-invertebrate inputs with canopy removal. Although he found some changes in the minor taxa significant, he found large amounts of *Ephemeroptera* and *Diptera* in both canopied and non-canopied reaches and determined that the differences overall did not appear to be of practical importance.

The potential effects of forest practices on litterfall processes are moderated by compensating factors, including in-stream photosynthesis, replacement of woody biomass by herbaceous and understory plants, and transport systems that move litter and detritus from source areas to deficient areas. Reduced forest canopy in the riparian zone leads to increased light levels in the aquatic zone, thereby increasing algae production in streams (Sedell and Swanson 1984; Bilby and Bisson 1992). Possible adverse effects of removing riparian vegetation often are outweighed by the increased primary production resulting from increased light levels, instream productivity, and nutrients (Beschta et al. 1987). In situations where the ability of riparian overstory trees to produce litter is reduced, shrubs and overhanging tree cover compensate for most of the litter production (Newton et al. 1996). Therefore, there probably is a broad range of riparian canopy conditions compatible with primary and secondary production needs of streams (Newton 1993).

A change in the origin of litter (allocthonous versus autochthonous sources) would have uncertain effects on community structure in streams. However, several studies have documented increases in aquatic insect production after canopy removal (Murphy and Hall 1981; Bisson and Sedell 1984; Gregory et al. 1987; Hicks et al. 1991). Also, aquatic community structure and function adjust to be in equilibrium with the physical stream conditions at each reach across the broad continuum of stream conditions (Vannote et al. 1980).

The river-continuum concept (Vannote et al. 1980; Minshall et al. 1983; Minshall et al. 1985, Minshall et al. 1992) indicates that natural stream communities undergo predictable changes from headwater areas to lower elevations in response to fluvial processes; changes in the relative contributions of riparian versus aquatic primary producers (plants); and the size and type of organic material being transported from upstream areas. Small, headwater streams have steep gradients, confined channels and cool temperatures when adequately shaded by riparian vegetation. Consequently, they obtain most of their organic material in the form of leaves, needles, branches and other plant parts from the riparian zone rather than from primary producers within the stream. Farther down the river continuum, stream channels are less confined and have more-extensive flood plains. Instream primary production increases in response to greater light penetration. Daily temperature fluctuations in these lower stream sections also are more pronounced because of increased exposure to solar warming (Beschta et al. 1987).

7.5.7.2 Effects of Proposed FPHCP on Nutrient Input

Timber harvest or tree cutting within the portion of the Core Zone (no harvest except for yarding corridors) and the Inner Zone (managed for desired future condition and stand-level requirements) would result in temporary openings in the canopy, at a localized level. As branches and leaves of remaining trees composing the riparian canopy would generally respond quickly to available light, amount of removal would be minor, and location of removal would be primarily from the outer portion of the Inner Zone, it is expected that there would be minimal effects to detrital inputs. The greater retention in proximity to the stream would ensure that detritus delivery is retained at functional levels.

Prescriptions protecting CMZs would maintain additional near-stream litter source areas important to fish-habitat streams. Most of the Type S and Type F streams maintain maximum litter input sources. Core and Inner Zones would provide most of the litter-producing potential of riparian areas. These buffers would supply over 90 percent of the normal litter recruitment to streams.

Early seral (tree size less than 12 inches in dbh) hardwood riparian forests provide large amounts of high-quality detrital inputs of nitrogen-rich leaves. Red alder is one of the most-important sources of detrital inputs to lower-order streams. Red alder, a common early-seral tree in RMZs (Murphy and Meehan 1991), fixes atmospheric nitrogen and the leaves rapidly decompose in the stream, providing a ready source of nitrogen for primary productivity.

Past harvest activities are believed to have reduced leaf and litter supply in some places throughout the action area. As forest practices regulations in the action area have required increasing conservation of streamside vegetation during operations, detrital inputs have likely increased. Before no-harvest zones were applied along streams, hardwood (i.e., red alder) or brush stands often replaced harvested conifers in the riparian zone, especially when natural regeneration was common practice. Currently, at least 50 percent of the riparian vegetation in western Washington is composed of hardwoods, largely red alder and bigleaf maple.

Under the FPHCP, landowners in western Washington have the option of converting hardwood-dominated riparian stands to conifer-dominated stands in the Inner Zone of the RMZ. Conversion of "artificial" stream-side hardwood or brush stands to conifer stands is often conducted with the intent of creating a stand of mature conifers that can provide large wood from conifers that is more persistent once delivered to the stream than wood derived from hardwood species. Hardwood-to-conifer stand conversion is only allowed on sites that naturally supported mature conifer before previous management. Lands that are best-suited for hardwoods are generally retained as hardwood stands because they are difficult to convert and biologically inappropriate to convert.

Hardwood-dominant riparian stands might also naturally convert to mixed hardwood-conifer stands. Over time, as alder trees age, die, and fall, already established conifers typically out-compete the next generation of red alder, resulting in a gradual reduction of red alder inputs to the stream and some change in detrital input to the riparian zone and stream.

During hardwood conversions, possible reductions in alder detrital inputs would be ameliorated by: (1) the untreated CMZ and the no-harvest Core Zone adjacent to Type S and F streams and portions of Type Np streams; and (2) the fact that few landowners (i.e., less than one percent of all forest practices applications) have converted riparian hardwood stands to conifer stands since the current Washington Forest Practices Rules went into effect in 2001. Given the prevalence of red alder across the action area, and the inherent patterns of riparian disturbance, alder would continue to be a significant source of allochthonous inputs.

Spraying glyphosate following hardwood conversion would have little effect on detritus. Even though application would temporarily reduce production of litter from shrubs such as salmonberry, these areas would be farther than 50 feet from the stream and only a small portion of this detritus would be delivered directly to streams. See the **Effects of Activities by Resource Topic -- Water Quality** section for a discussion on glyphosate use and invertebrates.

Due to the "equal in overall effectiveness" constraints of Alternate Plans, it is expected that the effects to the aquatic and riparian environment would be essentially the same or less than what would occur under the standard rules. No significant or measurable physical effects to stream detrital inputs are expected due to the "equal in overall effectiveness" provisions of alternate plans with respect to aquatic and riparian function. Implementation of the overstocked template would remove some trees as close as 14 to 30 feet from the streambank, but would retain a fully stocked stand of conifer.

Along fish streams, 20-acre exemptions would maintain a slightly reduced level of detrital input. It is anticipated that the majority of retained trees would be along the stream bank where most of the detritus input would originate. .

Litter from trees and understory vegetation along the channel is an important source of organic matter for headwater streams. Generally, a relatively higher proportion of litter function is provided by near-stream vegetation as stream size decreases. Many of the invertebrates living in these systems use this material as their primary food source. Removal of the overstory canopy would temporarily reduce the amount of material delivered to the channel and change its composition from a mixture of conifer needles, deciduous leaves, twigs, and other material to almost entirely deciduous leaves and herbaceous vegetation. The litter delivered to the stream after riparian area conifer harvest tends to be more nutritious for the invertebrates than material provided by older stands; albeit, less material comes from herbaceous material than came from the harvested stand.

Type Np streams would receive buffers at sensitive sites such as reaches near confluences with fish-habitat waters, and sensitive and priority areas. Buffered reaches would be expected to provide the majority of potential detritus input. Full-retention riparian areas would be left along at least 50 percent of the affected non-fish-habitat reaches to provide conditions for litter delivery. However, a much greater percentage of the reaches in upper watersheds typically would be fully vegetated because portions of watersheds would be in various stages of forest growth at any one time. Recovery of litter production along small channels occurs within 7 to 15 years (Summers 1983), riparian forests between 15 and 50 years of age would be delivering overstory litter, and forests less than 15 years of age would be in recovery, but providing some early seral litter as well.

Because headwater streams are net exporters of organic matter and nutrients, and compensating factors modify food and energy processes and distribution within the reach, it would be reasonable to assume that the amount of detritus would be adequate to maintain aquatic functions, and would vary over space and time. However, there are no studies that measure the total amount and timing of litter inputs required to maintain aquatic functions. Furthermore, there are no studies that indicate the desirable loadings of nutrients and organic matter downstream. The total litter input to a given reach probably would be reduced temporarily as a result of staggered harvest openings rather than continuous buffers along a harvest unit. The magnitude of the reduction would depend on the actual amount of canopy loss and on transport factors (e.g., steepness of slope, prevailing wind direction). But the reduction in litterfall may not be important or may be compensated by adjustments in instream photosynthesis, terrestrial vegetation, and aquatic communities that change in equilibrium with the physical stream conditions. Also, dense concentrations of fine woody and herbaceous material from logging may provide significant litter inputs to small perennial streams – but these would soon be depleted. Such inputs would likely be depleted within a few years, providing nutrients partly through the recovery period until overstory inputs are once again attained.

At sensitive sites (i.e., unstable slopes, wetlands, seeps, springs, the initiation point of perennial flow, and the intersection of two or more perennial non-fish-habitat streams) and priority areas (i.e., low-gradient areas, steep perennial stream reaches of non-sedimentary rock, hyporheic and groundwater influence areas, and downstream areas such as thermal recovery zones), the prescriptions for perennial streams would require that 50-foot-wide buffers be allocated. This would maintain litter and nutrient processes in habitat areas potentially important for amphibians and other aquatic fauna. Newton and others (1996) reported that a great proportion of the total litterfall to these small streams originates from trees and shrubs overhanging the stream and streambank.

Under standard rules, detrital inputs would remain intact for the lower 300 to 500 feet and the remaining buffered stream length of perennial streams. Detrital inputs should remain high in those sensitive sites and reaches receiving buffers, which may also be the reaches most important to amphibians.

Timber harvest along streams without fish under the 20-acre exemption would not necessarily maintain substantial overstory vegetation for detrital input. Where covered species could be affected, 29 trees per 1,000 feet would be retained as described earlier. These trees may be either deciduous or conifer. Trees may be distributed to accommodate operations, which may result in some streambank areas being subjected to vegetation removal and thereby reducing available litter.

Many Type Ns streams in steep topography would receive buffers to address potentially unstable slopes. These areas would provide approximately maximum amounts of detritus. Additionally as described above, effects of reduced overstory would be expected to be temporary and short term. Only a small portion of Type Ns streams would be less than 10 years old, especially in steep topography where potentially unstable slopes would require retention of trees on up to (or exceeding) 50 percent of seasonal streams (e.g., inner gorges).

Significant amounts of understory vegetation would be retained along unbuffered Type Np and Ns streams, and natural nutrient input processes should be protected by the ELZ requirements and mitigation. Although the probable amount of litter input would be less than the maximum in Type Np and Ns waters, the reduction in litter delivery may not be important for maintaining aquatic systems, or may be compensated by adjustments of instream photosynthesis, terrestrial vegetation, and aquatic communities that change in equilibrium with the physical stream conditions.

Road Management

Effects associated with road construction include the creation of a road corridor. When roads are constructed or relocated within or across riparian areas, this activity removes trees which otherwise would have provided detrital input. This amount of removal is minor, although some portion of this removal is a long-term effect.

Research

Habitat manipulations that might affect detrital inputs may be conducted for research purposes and are expected to occur along a very small percentage of streams, be localized, and have negligible effects at a watershed scale.

Summary

Maintenance of overhanging trees and shrubs near the stream channel would sustain the source of most litterfall. The potential effects of forest practices on litterfall processes would be moderated by compensating factors, including in-stream photosynthesis, replacement of terrestrial woody biomass by herbaceous and understory plants, and transport systems that move litter and detritus from source areas to deficient areas. Also, aquatic community structure and function would adjust to equilibrium levels with the physical stream conditions at each reach.

Hardwood conversion would result in reduced detrital inputs, especially detrital inputs from deciduous leaves, although this should be ameliorated by the “no-harvest zone”. Reduction of canopy may result in some loss of detrital production from alder outside the Core zone. Hardwood conversion may result in some reduction in detrital input to the riparian zone and eventual reduction of nutrient input into the stream. Detrital inputs from hardwood and deciduous shrubs are particularly important for aquatic life (Piccolo and Wipfli 2002). The ultimate result of hardwood conversion is a return to natural riparian conditions and amount and type of detrital inputs.

Areas subject to harvest under 20-acre exemptions would retain less input of detritus than those harvested under the standard rules. However, overall, the amount of detrital input would remain high, and benthic invertebrate production diverse, even in recently harvested riparian areas, mainly because of retention of detrital sources in CMZs and the no-harvest Core Zones of RMZs, conservative removals from inner zones, and maintenance of buffers along substantial portions of the Type Np streams, and the rapid recovery and compensating processes. Compared to baseline conditions, the amount of leaf and needle delivery is expected to improve as riparian stands grow into older mixed hardwoods and conifers.

Retained streamside vegetation would, over time, provide nutrient input levels that meet the biological requirements of covered species.

Therefore, covered activities should cause no detectable changes in production from changes in stream nutrient loads. The covered activities would contribute nearly, but perhaps somewhat less than, the maximum potential organic litter delivery, but an amount and quality likely to be functionally effective for fish and other aquatic resources. However, the persistent lack of other sources of nutrients, particularly those supplied from adult anadromous salmonid carcasses, which are already low because of presently low anadromous salmonid abundance in many areas, would remain low in those areas until local numbers are increased and improved passage is achieved.

7.5.8 Transport and Process Factors

7.5.8.1 Habitat and Process Connectivity

In this section we discuss the processes that may be affected by forest activities such as lateral processes of deposition, erosion, storage, and recharge associated with floodplains and off-channel habitats, as well as longitudinal processes of transport and delivery associated with other habitats. We use this opportunity to discuss anticipated effects of the FPHCP to these connected habitats (e.g., lakes, ponds, wetlands, and near-shore marine habitats).

Floodplains and Wetlands

Floodplains are low-elevation, low-gradient portions of a watershed that are periodically flooded by the lateral overflow of rivers and streams. They can contain a variety of aquatic habitats, such as side channels, sloughs, backwaters, oxbows, wetlands, and lakes. Some of these features have a permanent hydrologic connection to the main channel. However, many are connected only seasonally or during periods of higher flows.

Floodplains are focal points for growth of many riparian plant communities. Riparian habitat is often a product of dynamic processes that continually operate within a watershed. Aggradation may occur in one area and degradation may occur in another. The characteristics of riparian habitat and its interaction with the stream environment is mainly a function of stream size. The influence exerted by riparian areas on the aquatic stream environment is greater in small streams, and is less in larger streams. Large streams receive less shade from the riparian area. However, as stream size increases, its influence on the riparian forest increases. Riparian forests along large streams are often associated with floodplains and may be subject to periodic and prolonged flooding, lateral channel migration, meanders, oxbow lakes, and wetlands in old river channels. These areas often have a diverse vegetative and faunal community dependent on moist soils. Floodplains and riparian areas provide (1) natural storage of flood waters and hence amelioration of flood events; (2) settling of suspended matter and thus can clean muddied waters; (3) uptake of excess nutrients; and (4) recharge of hyporheic and sources of groundwater to provide later amelioration of low-flows.

Floodplains, wetlands, and other connected habitats have been altered in the past due to timber harvest and road building. These actions can affect these sites through vegetation alteration, soil compaction, changes in hydrologic regime, degradation of water quality, or sedimentation from adjacent or upstream activities. Other effects to floodplains, wetlands, and other connected habitats have likely occurred from floods, fires, and other natural disturbances, as well as often intense change from land-use activities (i.e., agricultural, residential, commercial, and industrial development). Floodplains and coastal wetlands and estuaries may comprise some of the most-altered aquatic-related habitats in Washington State.

Floodplains and off-channel areas are an important component of aquatic habitat as well as terrestrial plant community types. This habitat includes side channels, backwater alcoves, ponds, and wetlands. They provide important habitat seasonally to particular life stages as well as input of organic matter and large wood. Off channel habitats such as wetlands, may be a source of warmer water to stream temperatures, but they also provide fish habitat and a source of nutrients, and can provide cooling discharge through hyporheic influences. Seasonally flooded channels and ponds are particularly important for rearing coho salmon and other fish species during winter months. Physical and vegetative succession processes occur in these specialized riparian habitats. Side channels from via channel migration processes (e.g., avulsions, chute cut-offs), then gradually become blocked and filled with fine sediment, eventually becoming wetlands or forest unless reactivated by channel migration dynamics. Channel migration and overbank flow thus are part of a suite of processes that create and maintain elements of the riparian habitat mosaic, including functional off-channel habitat types.

Many wetlands provide habitat for resident and anadromous fish (including, but not limited to coho, cutthroat, steelhead and rainbow), depending on surface area, cover, water depth, food sources and other attributes necessary for overwintering (Peterson 1982). Wetlands also provide important habitat for many amphibians. Connection to sloughs, springfed seeps, and side channel habitat is critically important for salmonid rearing and overwintering (Spence et al. 1996).

Large floodplains can also function as filters for subsurface flows and maintenance of water quality (Gregory and Bisson 1997). Floodplains also provide for sediment storage, modulating the pulses of sediment from upstream sources to downstream habitat. Wetlands can improve water quality through nutrient removal and transformation (Hammer 1989). For example, wetlands can remove nitrate and phosphorus from agricultural runoff. Nutrient-rich sediments may also become trapped and removed from the water. Wetlands can reduce shoreline and bank erosion by binding soil substrates in wetland plant roots. Thus, wetlands protect upland habitats along streams and rivers from erosion, and protect downstream habitats from sedimentation and pollution.

Wetlands provide a vital role in watershed health as a whole, thereby benefiting fish, amphibians and other wildlife habitat. Water-quality benefits include conversion of inorganic nutrients to organic forms, primary productivity, and breakdown of pollutants and storage of sediments. Wetlands recharge groundwater by storing precipitation and surface flows, thereby increasing infiltration (Richardson 1994). Wetlands also help maintain minimum stream base flow by naturally regulating the release of groundwater discharge into streams and by recharging aquifers.

Floodplains help dissipate water energy during floods by allowing water to leave the channel and inundate the adjacent terrestrial landscape, thereby lessening the effect. Floodplains and their associated aquatic features play an important role in mediating flood flows by storing water and slowly releasing this storage back to the river during lower flows. Based on their morphology, wetlands have a greater storm-water holding capacity than typical upland environments. Wetlands, therefore, reduce peak flows on streams and rivers by slowing and storing overbank flow and by holding upslope stormwater runoff (Reinelt and Horner 1990). Wetlands are known for their high primary productivity and export of organic matter to adjacent aquatic ecosystems (Mitsch and Gosselink 2000).

Approximately 4.4 percent of the FPHCP lands are comprised of wetland habitats. Wetland areas comprise approximately 2 percent of the land base in eastern Washington and approximately 6 percent in western Washington (USFWS and NMFS 2006). Previous logging and road building has reduced the function of some wetlands by vegetation alteration, soil compaction, changes in hydrologic regime, and through sedimentation.

Some backwater alcoves and ponds result from groundwater seeps and may have shade levels higher than the main channel. These areas provide cool water refugia during high summertime temperatures. Off channel habitats such as wetlands, may also be a source of warmer water to stream temperatures. Major floodplains in the planning area generally are located in the lowest reaches of major rivers. Beavers can play a substantial role in the development of ponds and wetlands important as habitat for fish. By creating and maintaining deeper ponds with greater water volume, beaver activity modulates thermal fluctuations from off-channel water sources. Wetlands, which discharge cool groundwater, can help maintain desirable stream temperatures in the summer. Forested riparian and wetland areas serve an important role in shading streams from direct solar heating. Other wetlands, without cool groundwater discharge, may be a source of warmer water to stream temperatures, but they also provide fish habitat and a source of nutrients.

Rivers and their valleys are linked by exchanges of water between the true groundwater and hyporheic zones, and these linkages influence nearly all aspects of the physical and chemical habitat of aquatic organisms (Ward and Stanford 1989). Floodplains provide hyporheic connectivity through coarse beds of alluvial sediments that filter chemicals and ultimately regulate nutrient availability to primary producers in streams and rivers. These interchanges in groundwater are critical to maintaining productivity in rivers and streams and to maintaining healthy and productive fish habitat (NRC 1996).

In alluvial rivers, the hyporheic zones are one of the dominant links between riparian vegetation and the stream channel (Edwards 1998). Natural river floodplains can store cold water during high spring discharge events and can release this cooler water gradually to surface flow in the summer when discharge is reduced. During floods, riparian areas can temporarily store excess water which delays and attenuates the flood peak in downstream areas (NRC 2002). Bank storage occurs when surface waters move laterally from the channel into the subsurface areas when river stages are high and the water is released when the river stages go down. Bank storage in riparian areas can affect water storage, surface water temperatures, and riparian vegetation communities (NRC 2002).

Hyporheic zones (the saturated sediment region under and along streams) are often the connections between groundwater and surface water in these habitat areas and often supply substantial habitat for hyporheic organisms such as insects, bacteria, and fungi (Edwards 1998; Naiman et al. 2000). The presence of a hyporheic zone is most often associated with the alluvium below the stream and in the floodplain adjacent to streams. Nutrients and organic matter is processed in this zone by bacteria and other organisms (e.g., invertebrates, specialize insects, and crustaceans) (Boulton et al. 1998). Where this water surfaces it may be high in nutrients producing locally high primary production areas (Edwards 1998; Boulton et al. 1998). The overall exchange of organisms and effects on stream production is not well known, and in most systems may be relatively minor; however, it could be more important in some floodplain habitats (Boulton et al. 1998). In dry summer months or during floods this zone may provide a refuge for some aquatic organisms (Boulton et al. 1998). Substrate porosity may affect its function and size, but the relationship is not clear (Boulton et al. 1998).

Extensive valley floodplains with alluvial deposits and groundwater flows are extremely important where the upwelling of groundwater affects temperatures and reduces the probability that eggs or embryos would become dewatered and/or freeze (Weaver and Fraley 1991b). Habitats influenced by groundwater inflows can be critical thermal refugia for riverine species when river temperatures warm in the summer and when overwintering in deep pool habitat in winter (MBTSG 1998). Floodplains having hydraulic connectivity within channels can support flowing groundwater (hyporheic) habitats and serve as refugia for macroinvertebrate communities (Quigley and Arbelbide 1997).

Effects from logging and roading on wetlands may include removal of nutrients, reduction of soil productivity resulting from extraction methods (road construction, skid trails and staging areas), increased sedimentation, increased soil temperature, alteration in water yield and stream flow patterns and reductions in available habitat (Trettin et al. 1997). Results from studies outside the Pacific Northwest suggest that proper harvesting techniques can minimize effects to forested wetlands (Shepard 1994).

Channels can be disconnected laterally from their floodplains through the construction and placement of roads and flood-control structures within the floodplain. Roads parallel to streams isolate the stream system from the uplands, and can constrain the natural development of meanders, side channels, and attached wetlands (Everett et al. 1994). Forest harvesting can affect alluvial systems by weakening channel banks, removing the source of large wood, altering the frequency of channel-modifying flows and changing sediment supply. Off-channel fish habitats in the floodplain such as side and flood channels, ponds, and swamps also can be strongly influenced by forest harvesting (Chamberlin et al. 1991).

As river channels are simplified and constrained, connectivity of surface waters with the hyporheic zone is lost (Frissell 1999). These groundwater interchanges can also be strongly disrupted by activities that remove groundwater or inhibit the movement of water into or out of rivers and floodplains (National Research Council 1996).

Other Connected Habitats

Lakes and Reservoirs

Lakes and reservoirs provide areas for spawning, early rearing, and growth for many fish species. They also function as migratory pathways. The nearshore environment of lakes and reservoirs depends on riparian areas in many ways that are similar to streams, relying at least partly on input of large wood from shoreline areas (Harmon et al. 1986; Christensen et al. 1996) and on terrestrial nutrient input and leaf and litter input as an aquatic food base (Wetzel 1975). However, much of the production is based on autochthonous growth (e.g., algae) within the system, typically much more so than most flowing water systems (Wetzel 1975). Nearshore areas are often a sink for nutrients and organic matter entering from streams and rivers that enter these systems (Washington Department of Fish and Wildlife 1997a). Temperature and flow conditions in lakes and reservoirs influence suitability of these environments for various fish species (Washington Department of Fish and Wildlife 1997a). Habitat structure along shorelines influences species use, including species that may be prey on juvenile salmonids (Wedge and Anderson 1979; Savino and Stein 1989).

Lakes and reservoirs serve as an important habitat component during the life histories of many fish species. Fish exhibiting the “adfluvial” life history strategy (e.g., populations of bull trout, cutthroat and rainbow) use lakes and reservoirs for much of their juvenile and adult rearing, but spawn in tributaries. In addition to rearing in these waters, sockeye and kokanee both spawn within tributary streams, as well as along shorelines of lakes and reservoirs.

Because lakes and reservoirs often have more-abundant food availability (i.e., plankton and prey species), fish exhibiting the adfluvial life history strategy often reach the largest sizes (Goetz 1989). For instance, adfluvial bull trout have been reported to reach 40.5 inches and 32 pounds (Goetz 1989); whereas, the resident life history form may only reach 6 to 12 inches (Wydoski and Whitney 2003). Other fish such as coho often use lakes or reservoirs for rearing—especially winter rearing. Other fish species, such as pygmy whitefish, mountain whitefish, chiselmouth, minnow species (e.g., chubs, peamouth, redside shiner), suckers, burbot, stickleback and sculpin, use lakes and/or reservoirs for a large part of their life histories (Wydoski and Whitney 2003). It is important for connectivity to be maintained within inlet and outlet streams, so that fish are able to have free access during all seasons.

Literature is limited relating to effects of forest practices on lake and reservoir habitats. Watershed analyses, however, have been conducted on a number of watersheds including larger reservoirs and lakes (e.g., Lake Whatcom, Keechelus Lake and Thompson Creek). Causal Mechanism Reports have documented that coarse and fine sediment from mass-wasting and road-maintenance problems can directly deliver into lakes/reservoirs and/or into inlet channels, which then could be rapidly transported to the lake/reservoir. Very large, persistent increases of coarse and fine sediment could have negative effects on the stream habitat immediately upstream of the lake/reservoir margin, as aggradation may lead to channel dewatering, channel avulsion, and reduction of pool habitat. This aggradation and channel dewatering can disconnect access for adfluvial fish from the lake/reservoir to their spawning tributaries (Draft Keechelus Lake Watershed Analysis, DNR; Lake Whatcom, WDNR 1998b). The Thompson Creek Watershed Analysis (WDNR 1997b) notes that shallow eutrophic lakes, such as Newman Lake, could be vulnerable to filling with sediment. Lake filling is a natural geological process that may take thousands of years, but may be accelerated by human activity. The Lake Whatcom Watershed Analysis noted that fine sediment deposition can result in loss of lacustrine habitat, yet gaining wetland characteristics. In extreme cases, such as Mirrow Lake in the Anderson Creek drainage, unnatural prolonged periods of suspended sediments can cause unsuitable living conditions for salmonids. Also, excessive sedimentation in lakeshores has been found to adversely affect spawning sockeye salmon (McHenry et al. 1996).

Nearshore marine

Nearshore marine areas are generally the shallow portions of the marine environment. They may be shallow “open” water, or may contain estuaries. The habitat features contained within or influencing the near-shore marine may include bluffs, beaches, marshes, riparian vegetation, sandflats, mudflats, rock and gravel habitats, non-vegetated subtidal areas, kelp beds, inter-tidal algae, and eelgrass beds. It generally does not include deeper marine waters, but species associated with this habitat association may also use deeper water at times.

Estuaries are the zones in which fresh and saltwater mix, extending from the ocean to the uppermost extent of tidal influence. Estuaries support a variety of shallow and deep-water habitats and often include extensive areas of tidal fresh water and brackish and marine habitats (Shreffler and Thom 1993). Because of the physical, chemical, and biotic diversity of estuarine systems, they are among the most biologically diverse and richest systems found on earth (Castro and Reckendorf 1995).

There are 3 basic types of estuaries based on salinity classification: freshwater, brackish, and marine. Freshwater estuaries are dominated by inflow from the rivers, which keeps the salt water pushed out of the estuary. Brackish estuaries exhibit a mixing of salt water and fresh water. Marine estuaries are dominated by tidal action and can have salt levels very close to those of the offshore ocean. The relative mixing between fresh water and salt water in each of these types depends on relative salinity and temperature differences between the two sources of water. It is common to have a wedge effect. If two sources of water (one saline and the other fresh) of the same temperature converge, the salt water will wedge beneath the fresh water because the fresh water has a lower density than salt water. However, if the salt water is warmer, a thermohaline convection current may form causing vertical mixing (Dyer 1973 as cited in Castro and Reckendorf 1995). Estuaries can also be classified into 3 topographic or morphologic types: drowned river valley, fjords, and bar-built estuaries (Pritchard 1952 as cited in Castro and Reckendorf 1995).

A characteristic of estuaries is that their beds are constantly moving because of river inflow and tidal fluctuations. Transport prcesses in estuaries are often dominated by tida fluctuations rather than river peak flows. Thus, estuary morphology and physical evolution can be drastically altered by actions that change the volume of the tidal prism, such as dikes and levees or dredging. The bedload in estuaries is composed mainly of sand-sized particles which are easily entrained and moved for long distances. Depending on tidal influences, material may be moved up and down the channel. Fine silts and clays flocculate in the salt water and are deposited in tidal marshes (Castro and Reckendorf 1995).

Like lakes and reservoirs, estuaries are often considered a sink for a variety of upland and riverine processes. River flow and transported nutrients, sediment, and other organic matter including large wood are important to estuaries. Large wood provides structure and nutrients for marine habitats (Maser and Sedell 1994), although its relative importance and use by fish in these habitats is not clear (Simenstad et al. 2003).

Large wood generally accumulates in backshore areas at extreme high tides, and can help stabilize the shoreline (Zelo and Shipman 2000). Although not well documented in marine systems, large wood provides structurally complex roosting, nesting, refuge and foraging opportunities for wildlife; foraging, refuge and spawning substrate for fish; and foraging, refuge, spawning and attachment substrate for aquatic invertebrates. Logs embedded in beaches also provide a source of organic matter, moisture and nutrients that assist in the establishment and maintenance of dune and marsh plants (Williams and Thom 2001).

Historically, large wood was found in great abundance in some Pacific Northwest estuaries, influencing the formation and distribution of estuarine channels (Collins et al. 2002). In the estuarine and nearshore marine areas, the historical amount of large wood was much greater than it is today (Gonor et al. 1988). Since the mid- to late-1880s, much of the large wood has been lost to human-related activities, including timber harvest and removal of large wood to establish and maintain safe navigation channels (Gonor et al. 1988). Today, considerable large wood is cleared from marine waters to reduce interference with commercial and recreational transportation.

Large-wood enhancement has recently become a common method for improving large wood content in stream reaches and estuarine and marine shorelines lacking wood. Large-wood placement can provide benefits to these systems by providing bank stabilization, a more-complex habitat structure, nutrient input, and substrate for invertebrate colonization, all of which would benefit fish habitat. Expected beneficial changes in freshwater fish habitat include increased pool quality and quantity for juvenile rearing and adult holding, and a greater abundance of functional wood in smaller, non-fish bearing channels to ameliorate the effects of sediment inputs. Similarly, estuarine and marine habitats are expected to benefit from the increased input of woody debris. However, because much of the large wood entering the estuaries and marine water is removed by the U.S. Army Corps of Engineers to maintain safe navigation, the benefits of wider RMZs is expected to be less in these habitats than in the freshwater habitats.

Trees that fall directly onto the bank and large wood that drifts on to the shoreline can provide protection for unstable and erodible banks and beaches and can stabilize banks and beaches. Large wood also acts as a barrier to wind-transported sand and can form the nucleus for a temporary accumulation of sand (Gonor et al. 1988). Additionally, large wood can contribute moisture and nutrients necessary for the establishment of woody vegetation (Stembridge 1979, as cited in Gonor et al. 1988). Pacific herring may use woody debris for spawning substrate in estuaries and nearshore areas.

Estuaries are utilized by specialized organisms that have adapted to fine sediments, high sedimentation rates, and mobile substrate. The macroinvertebrates that are found in the substrate of estuaries are much smaller than those found in the streambeds with larger particle sizes. Common benthic organisms found in the estuaries tend to be opportunistic rather than an equilibrium type of species (Schaffner et al. 1987 as cited in Castro and Reckendorf 1995). Within the estuary, the density of fauna is commonly greater in the freshwater tidal areas than in other parts of the estuary. The species diversity of macroinvertebrates is usually lower in fine-sediment substrates than that in coarser-particle substrates. The diversity and eveness of species decline with an increasing percentage of silt/clay and organic matter (Junoy and Vietez 1990 as cited in Castro and Reckendorf 1995). However, fine-sediment beds are important for burrowing tube-making invertebrates and other burrowing species (Minshall 1984 as cited in Castro and Reckendorf 1995).

Nearshore obligates—including salmonid forage fish such as surf smelt, Pacific sand lance, and Pacific herring—are dependent upon beaches and intertidal areas for spawning. Abundant food supplies, wide salinity gradients, and diverse habitats make nearshore/estuarine areas particularly valuable to anadromous fish for rearing, feeding, and osmoregulatory acclimatization during the transition between fresh water and marine habitats (MacDonald et al. 1987). Near-shore marine areas have many similarities to that of lakes and reservoirs as they provide important rearing and migratory areas for many fish. Estuaries are often considered very important for development and growth of many salmonid species during outmigration (Simenstad et al. 1982, Groot and Margolis 1991); as well as for species known as “forage fish” (e.g., surf smelt, herring, sand lance, etc.) because they provide forage to a wide variety of fish and wildlife species. Some juvenile salmonids may spend more than a month rearing in estuaries prior to migrating to the open ocean.

Chum, coho, sockeye, pink, and chinook juveniles are known to utilize estuarine habitat, including salt marsh and tidal channels that are dewatered during normal low tides. Pink and chum rely heavily on estuaries for early growth. Chinook utilize salt marsh habitat, estuarine sloughs and tidal channels. Coho use estuaries primarily for interim food while they adjust physiologically to saltwater and prior to migrating offshore. The spawning of Pacific herring—an important forage fish for salmonids—has been documented in estuarine salt marshes. Eelgrass supports copepods, a favored food for juvenile chum salmon. Estuarine habitats are also important for anadromous Dolly Varden and bull trout, where their movement is believed to follow after the timing and behavior of forage fish (i.e., surf smelt, sand lance and herring) (C. Kraemer, Personal Communication 1999). The majority of searun coastal cutthroat migrate to the mouths of rivers and estuaries, where they remain for varying lengths of time (most remain an average of 90 days) and feed along beaches in water usually less than ten feet deep (Wydoski and Whitney 2003).

Estuaries provide ideal areas for rapid growth of juvenile salmonids because they contain abundant food sources (Healy 1982; Simenstad 1983). The food supply is supported by abundant detrital sources provided by eelgrass beds, kelp forests, salt marshes and terrestrial vegetation coupled with high levels of primary production in the shallow, nutrient-rich waters (Phillips 1984). Riparian areas bordering estuaries (i.e., bluffs, banks) are important for maintaining slope stability, shading, organic-matter delivery and large-wood recruitment.

The dynamics of sediment transport in and through estuaries is extremely complex due to the complex hydraulics associated with movement of water comprising the tidal prism across networks of branching and anastomosing channels. Philips (1991 as cited in Castro and Reckendorf 1995), in studying Atlantic estuaries, found that estuarine sediment is derived from fluvial sediment input, shoreline erosion, and migration of marine sediments inland. In many estuaries, fluvial sediments inputs are the dominant process affecting those estuaries. Increased fluvial sediment in estuaries may result in extended tidal marshes, shoaling, infilling of navigation channels, reduction of benthic and aquatic habitat, and reduced primary productivity due to turbulence and limited light penetration (Phillips 1991 as cited in Castro and Reckendorf 1995). Sediment quality is very important in estuaries because of the residence time of the sediment. Chemical bonding that occurs between many chemicals and fine sediments is important; these chemicals can remain stored in the estuary sediment and do not disappear. Similar sediment quality issues exist for all chemicals that enter estuaries and are bound to sediment. The sediment is stored on the bottom of the estuary until it is disturbed by natural processes or human activities. The effects of dredging become a critical issue when sediments are the storage reservoir for industrial and agricultural chemicals (Cunningham et al. 1987 as cited in Castro and Reckendorf 1995).

In estuarine and marine waters, substrate grain-size has been shown to be a determining factor in habitat selection by a variety of species that are either covered by the FPHCP, or are similar to those that are covered (Becker 1988; Howell et al. 1999; McConnaughey and Smith 2000; Stein et al. 2004). Storm-induced siltation of a previously-sandy lagoon in California has been blamed for the significant reduction in numbers of shiner surfperch (Onuf and Quamment 1983). Spawning habitat for surf smelt and sand lance is particularly vulnerable. These species utilize sandy/gravelly upper intertidal beaches for spawning (Pentilla 1997) and could be susceptible to degradation should large amounts of fine sediment be delivered to these beaches.

Turbidity can adversely affect fishes at every stage of their life cycle. For example, Auld and Schubel (1978) found that larval survival in American shad (*Alossa sappidissima*), was reduced under conditions of elevated suspended sediment, but hatching was not. Increased freshwater flows (from peak flows) into estuaries may result in reduced penetration of the salt wedge upstream into the lower reaches of rivers (Allanson and Barid 1999, as cited in Levings and Northcote 2004).

In the upper intertidal zone of estuarine and marine habitats, temperature is an important factor in the ecology of at least two species of forage fishes. Surf smelt and Pacific sandlance spawn in upper intertidal beaches with substrates of sand and/or fine gravel (Pentilla 1997). The loss of shade provided to the spawning beaches by riparian vegetation produces elevated substrate temperatures at low tide. Elevated temperatures on beaches have been linked to a significant reduction in the hatching success of surf smelt (Pentilla 2001).

Pacific sandlance are known to burrow into intertidal beaches during the winter (Quinn 1999). During periods of elevated temperatures and low tides, interstitial dissolved oxygen is depleted, and these fish may emerge from the sediment and either dry out thoroughly or become easy prey for a host of predators (Quinn and Schneider 1991). Loss of riparian shade could contribute to the high substrate temperatures and low oxygen events and adversely affect Pacific sandlance.

Shoreline armoring, over-water structures, landfill, and stormwater/wastewater discharge, lead to altered physical processes that affect habitat conditions and juvenile salmonid survival, as well as the survival of other near-shore obligates (i.e., fish species that are dependent upon nearshore habitats such as surf smelt, sand lance, herring, etc.). Trees along the shoreline provide shade, which moderates temperatures in littoral spawning habitats used by near-shore obligates. Trees and downed beach wood help to moderate the rate of beach erosion. Downed wood functions to hold substrate (i.e., pea gravel and sand) needed for spawning habitat, to provide organic matter and nutrients and to provide habitat complexity and cover for fish and wildlife.

The recruitment of large wood to all these areas contributes organic input to the system but also influences the development of habitat structure for potential fish rearing habitat. The rate and type of sediment accumulation in the shallows also influences habitat, foodwebs, and production (Simenstad et al. 1979). The maintenance of estuarine habitat through sediment and large-wood inputs is important. For example, Collins et al. (2002) reported that large-wood jams in major Puget Sound estuaries historically influenced intertidal channel formation, pool depth, and sediment distribution.

Effects of the Proposed FPHCP

Floodplains

Riparian Timber Harvest: Buffers on Type F and S streams would be placed beginning at the CMZ. Harvest inside the CMZ would be prohibited. Road construction inside the CMZ would likewise be prohibited. Retaining natural vegetation within and adjacent to the floodplains would protect their soils, hydrology, and riparian vegetation and should ensure their continuing function. Hardwood conversion and treatments for overstocked stands under the template would occur outside CMZs. Yarding activities would be limited to the creation of yarding corridors. Alternate plans would provide equivalent protection for aquatic and riparian functions; therefore, effects from implementation of alternate plans would be expected to be the same or less than operations under standard rules.

Riparian harvests associated with 20-acre exempt parcels may have negative effects upon floodplains as the buffers are only required to begin at the BFW and do not need to consider the CMZ. As a result, harvest of trees could begin immediately outside the CMZ, or in some cases harvest may occur within the CMZ. Provisions of the Hydraulic Code (WAC 222-110-160) may regulate harvest within CMZs but adverse effects may occur nonetheless. Roads would not be constructed within CMZ, except as needed for crossing streams, and then alternative crossing locations would likely be sought.

Increases in the frequency of mass wasting is minimized by protective measures of the FCHCP, although, some portions of the managed landscape have higher rates of mass wasting than during pre-management times. Mass-wasting events may deliver less wood as a result of FPHCP if they initiate above unbuffered or partially buffered Type Np or Ns reaches, and subsequently deliver to floodplains or channels of larger streams. Deposits from the latter mass-wasting events could be less retentive of transportable sediment and have less large wood available to downstream reaches during future events capable of re-mobilizing large wood and sediment. A reduced amount of wood may delay recovery from such events. Potentially unstable landforms may not be avoided during harvest if the delivery zone is predicted to lie outside of typed waters. These predictions can sometimes be erroneous, as they may be made without the benefit of a geotechnical report or SEPA review.

Wetlands

Where wetlands contain surface water occupied by fish, those wetlands would be treated as Type S or F waters. In those situations, the effects analyzed below are not appropriate and the actual effects would be the same as described earlier for fishbearing waters. Below is an assessment of effects to wetlands that do not contain fish.

Forested wetlands may be harvested. Retention of a buffer is not required and there is no retention requirement for trees within the wetlands. Voluntary retention is suggested, but trees left for other purposes may also be counted toward this voluntary goal. Harvest would reduce the large wood recruited to the wetland floor and would effect the understory. Soil compaction is a concern when equipment is used within forested wetlands. Activities in forested wetlands shall be limited to low-impact harvest or cable systems. However, partial suspension of logs is not required. Some potential exists for vegetation removal in forested wetlands to influence the temperature of surface and shallow subsurface water, which could then affect the temperature of nearby surface waters (Olson and Wissmar 2000) This effect is also possible where certain other hydrogeomorphic features result in emergence or near-emergence of the local or intermediate groundwater system (Wondzell and Swanson 1999; Frissel 1999). However, the occurrence of this effect is likely to be small, given the buffering provided by CMZs and riparian buffers on fish-bearing streams. Forested wetlands may be degraded by riparian timber harvest and associated activities under the proposed FPHCP. An incentive is provided in that the distribution requirement for leave trees within the unit may be adjusted if the voluntary targets for the forested wetland are met.

Nonforested wetlands above 0.5 acres (0.25 acres for bogs) are provided with wetland management zones (WMZs). WMZs are variable in size depending on wetland type and size. WMZ tree retention requirements of 75 trees (with specified numbers in size categories) would provide large wood, shade, and other functions to the wetlands. Because wetlands are areas of high water tables, retention of wetland buffers may be subject to windthrow. In some cases (e.g., clearcuts of less than 30 acres or partial harvest of less than 80 acres) when the WMZ comprises more than 10 percent of the harvest unit, the leave tree retention requirement may be reduced to no less than 50 percent (38 trees per acre) of what would otherwise be required (75 trees per acre). This would also reduce the number of larger trees required for retention. The wetland rules provide some additional protective features, addressing individual trees or small forested wetlands within non-forested wetlands. Other harvest of upland or forested wetlands which are surrounded by non-forested wetlands must be conducted in accordance to a plan approved by WDNR. No timber shall be felled into or cable yarded across non-forested wetlands without written approval by WDNR. No harvest is permitted within bogs.

Tractors, wheeled skidders, or other ground-based harvesting systems shall not be used within the minimum WMZ width (25 to 50 feet) without written permission of WDNR. Landings within forested wetlands would be minimized, but some adverse effects to hydrology may result where landings are placed within forested wetlands. Landings would not be placed within nonforested wetlands or their WMZs.

Road construction should avoid wetlands under the proposed FPHCP. When filling or draining more than 0.5 acre of wetland, 2-for-1 substitution /replacement would be required. Road construction may occur in proximity to wetlands and may deliver sediment to forested wetlands. Non-forested wetlands would have WMZs that should help filter sediment from roads. Altered hydrology may result from roads in proximity to wetlands. Small, isolated wetlands (e.g., less than 0.5 acres) may not be identified and may be subject to adverse effects associated with timber harvest and road system management.

Lakes and Reservoirs

Buffers for Type S waters would maintain a direct source of large wood for lakes and reservoirs. These buffers are also expected to provide the shoreline with shade and bank or bluff stability. Large wood that is delivered directly to shorelines would often remain in place due to anchoring by rootwads. Such wood has the ability to alter lateral movement of sediments and provide habitat diversity along beaches and shores. Increases in the frequency of mass-wasting is minimized by protective measures of the Washington Forest Practices Rules, although, some portions of the managed landscape likely has higher rates of mass-wasting than during pre-management times. Mass-wasting events may deliver less wood as a result of FPHCP if they initiate above unbuffered or partially buffered Type Np or Ns reaches, and these events may sometimes deliver deposits to Nearshore areas of lakes and reservoirs. In addition, potentially unstable landforms may not be avoided during harvest if the delivery zone is predicted to lie outside of typed waters. These predictions can sometimes be erroneous, as they may be made without the benefit of a geotechnical report or SEPA review. Erosion of lakes shores should be minimized by the protective measures of the FPHCP.

Indirect effects may occur to lake and reservoir habitat from implementation of the FPHCP. The measures to address roads and near-stream areas may reduce the elevated levels of sediment delivered from upstream. Buffers on streams should provide for maintenance of large wood delivered from upstream areas and should protect the temperatures of waters that flow into lakes and reservoirs. These cool waters should provide refugia where cooler waters flow into lakes. Where Type Np streams flow directly into lakes, there may be rare situations where water warmed in a clearcut harvest has not cooled prior to entering the lake or reservoir. In these infrequent situations, the effects are expected to be short-lived (e.g., 5 to 10 years at most) until stream-side shade is re-established. Sediment delivery through tributaries should be reduced by a combination of large wood storing sediment in streams and measures to reduce sediment delivery to those streams. Where Type Np streams flow directly into lakes, there may be situations where increased sediment input occurs, although these effects are expected to last only until hydrologic and riparian zone recovery have occurred (10 years at most). Upstream road crossings may deliver sediment that is eventually routed to lakes and reservoirs.

Near-shore Marine

Type S buffers are expected to provide shade to beaches, shorelines, and estuaries. Small streams flowing directly into estuaries are also expected to be protected as described earlier for Type F or Type N streams (as appropriate). Type S buffers should provide the natural rate of large-wood recruitment to estuaries and shorelines. We also expect maintenance of natural levels of sediment, nutrient, and detrital inputs. There may be some effect from small coastal Type N streams that deliver wood, nutrients, and sediment, and water to estuaries and to marine near-shore areas. However, most connecting waters are expected to be fishbearing and the lower 300 to 500 feet of perennial streams without fish would be protected as discussed earlier. In addition to stream effects and delivery, many such waters are influenced by tidal inputs as well. Tidal delivery further confounds our ability to predict effects and would likely mitigate and reduce effects that may otherwise have resulted.

Marine and estuarine areas that receive discharge directly from Type N streams may receive smaller amounts of wood from these sources, however, the Type N streams make up a smaller source, overall, than the Type F streams, which receive more substantial protective measures. The margins or banks of streams, estuaries, marine waters, and river channels provide important habitats for both aquatic and riparian-dependent species. Forest practices that cut streambank trees or result in areas of exposed streambank soil would adversely affect these habitats by altering the character of stream banks and perhaps diminishing large-wood recruitment.

Disruption of subsurface flow could, potentially, affect freshwater seeps along the shorelines of estuaries and the marine nearshore. Inside Puget Sound, some forage fish spawning is thought to be associated with freshwater seepage, where the water keeps the spawning gravel moist (WDFW 2005a). Disruption of these seeps could potentially cause reduced spawning success of forage fish species, which in turn could reduce the prey available for marine and anadromous predator species such as searun cutthroat trout.

New roads might cause localized, increases in peak flows and sediment delivery, but the net effect over longer time periods, across the action area, would be an overall decrease in road-related peak flow increases when other proposed measures (i.e., road upgrading and removal) are considered. Because FPHCP would not result in significant increases to large peak flow events, there would be no detectable difference in the location of the estuarine salt wedge in lower reaches of rivers, or area of maximum turbidity in estuarine habitats during large peak flow events. Some increases in small to moderate peak flows are expected, especially in estuaries of smaller watersheds. Likewise, some increases in growing season baseflows are anticipated, which could have small effects on the summer season estuarine water-quality dynamics, temperature, and salt content. These effects would likely be short-lived, becoming undetectable as hydrologic recovery occurs.

Overall, the likelihood of adverse temperature effects are considered low for most westside coastal streams and marine and estuarine areas, including areas where harvest Option 1 (thinning) would be implemented, and eastside streams within the bull trout overlay, which includes most of the action area on the eastside. In low-elevation basins where water temperatures are already elevated and eastside streams outside the bull trout overlay there are moderate probabilities of thermal effects. However, these effects would be less likely where Type S streams receive 200 foot buffers. Temperature conditions, and therefore protection of fish resources, are expected to improve relative to baseline conditions. Where Type Np or Ns streams enter directly into lakes or estuaries, it is unlikely that there would be sufficient discharge to influence the water temperatures of these larger water bodies if heating of these streams occurred and did not dissipate prior to delivery, except for a very small area at the mouth of the stream. In most cases, Type N streams would cool prior to entry into lakes or estuaries and provide areas of thermal refuge.

Passage of Water, Wood, and Sediment

Stream-crossing structure installation and maintenance must consider connectivity to floodplains, estuaries, and other stream-connected habitats, in terms of passing flows, sediment, and large wood. FPHCP construction standards are expected to provide better transport of water, sediment, and large wood than under previous regulations, and RMAPs are expected to address existing problems. While stream-adjacent parallel roads may disconnect large-wood delivery and overbank sediment deposition from the floodplain, and may also serve to constrict the floodplain in some situations, the FPHCP would result in fewer floodplain roads and would also result in the removal of many existing stream-adjacent roads. The FPHCP would require that a substantial component of current problem areas be addressed in the near future (many have already been addressed).

FPHCP road standards (Culverts and bridges at stream crossings designed to accommodate 100 year flood event) are expected to provide passage for fish, other covered species, large wood, sediment, and flood flows in excess of what was previously required and above what currently exists in many cases. However, there still remains a potential that inadequate stream crossings may restrict the natural channel and floodplain width. Not all stream crossings will be fixed in the short term. Those culverts meeting passage criteria (i.e., those that can pass 150 mm fish), existing on currently eligible 20-acre exempt parcels, and some proportion of culverts on non-industrial lands may not be fully upgraded in the short term so that meet the FPHCP standards for passage of floods and wood. Where inadequate crossings persist, they may result in changes to channel morphology, increased scouring at crossings, stream-bank erosion, and undermining of the crossing structures. There is the potential for long-term scouring downstream, upstream aggradation, channel constriction, and reduced capacity for instream large-wood transport. In addition, some stream crossings are at risk for upstream headcutting and channel incision when culvert replacement or removal is performed in cases where there is pre-existing reach-scale incision downstream (Castro 2003). Where this happens, it may result in channel destabilization and bank erosion for a distance upstream that depends on local soils, channel and valley topography and streambed characteristics. Proper culvert design should include examination of geomorphic factors which would indicate a risk of headcutting, and result in incorporation of grade control measures to prevent headcutting from occurring. However, under current practices, opportunities to prevent headcutting are sometimes missed or incorrectly mitigated, and we anticipate some continued occurrence of this problem. Flotation of large wood and importance of delivery from upstream was already discussed in the **Effects of Activities by Resource Topic – Large Wood** section.

7.5.9 Instream Responses

This section examines changes within the stream system that may occur from altered inputs and processes, which were discussed earlier.

7.5.9.1 Stream Channel Morphology

Baseline of Stream Channel Morphology

Large pools have been lost in many tributaries of the Columbia River in the past 50 years (Sedell and Everest 1991; McIntosh et al. 1994; USDA 1996). Overall, there has been a 58 percent reduction in the number of large, deep pools in resurveyed streams in National Forests within the range of the northern spotted owl in western and eastern Washington (FEMAT 1993). In western Washington, Bisson and Sedell (1984), reported a similar loss of pools in sub-basins with moderate to intensive levels of timber harvest. Historical grazing practices in some locations have contributed to degraded riparian zones with reduced summer flows in streams, unstable and eroding stream banks, and reduced productivity of fish. Reduction of wood in stream channels, from past activities, generally reduced pool frequency, habitat quality, and channel complexity (Bisson et al. 1987; House and Boehne 1987; Spence et al. 1996). Road construction and timber harvest on unstable slopes resulted in the loss of pools from mass-wasting events and sedimentation (Janda et al. 1975; Morrison 1975; Swanson and Dyrness 1975; Ziemer and Swanston 1977; Betcha 1978; Ketcheson and Froehlich 1978; Marion 1981; Swanson et al. 1981; Coats 1987; Kelsey et al. 1981; Madej 1984; Nolan and Marron 1985; Grant and Wolff 1991). Ralph et al. (1991) summarized the status and trends of instream habitat in forested lands of Washington.

Upslope activities (e.g., timber harvest, land clearing, and road development) can change channel morphology by altering the amount of sediment or water contributed to the streams. This, in turn, can disrupt the balance of sediment input, output, and storage in a stream (Sullivan et al. 1987). Stream habitat conditions in Washington are affected by a wide range of factors, including geophysical changes (e.g., volcanic eruptions, earthquakes, and associated uplifting), extremes of flow (e.g., flooding and low flow), existing geological conditions (e.g., erodible soils), and land-use practices (e.g., timber harvest, grazing, urban development, road construction and operation, and gravel mining). Many rivers and streams flowing through urban and agricultural areas have been channelized to facilitate rapid storm runoff and reduce local flooding. The effects of these combined factors result in the existing stream-habitat conditions.

Factors affecting Stream Morphology

Natural channels are complex and contain a mixture of habitats differing in depth, velocity, and cover (Bisson et al. 1987). Stream-channel morphology is often described in terms of width/depth ratios related to bankfull cross-section (Rosgen 1996). Bankfull, in this sense, refers to the edge of the floodplain or incipient floodplain surface adjacent to the channel, which is a depositional surface formed under the current sediment regime and climate, and inundated by commonly occurring peak flows (Leopold et al. 1964). Studies of watershed function have confirmed that changes in bankfull channel dimensions correspond to changes in the magnitude and frequency of bankfull discharge or changes in sediment load. Natural habitat features are often formed during storm events with associated flows that mobilize sediment in the channel bed (Murphy 1995). The hydrologic regime of a watershed, combined with its geology, hillslope characteristics, and riparian vegetation determines the nature of stream channel morphology (e.g., number and spacing of pools and width-to-depth ratio) (Beschta et al. 1995; Sullivan et al. 1987).

Channel condition and dynamics indicators of streams considered to be functioning appropriately are dependent on the stable or equilibrium stream type for the reach in question. For example, most meandering, single-thread “pool-riffle” channels are expected to have a bankfull width: depth ratio in the range from 13 to 29 (Rosgen, 1996). A ratio significantly larger than this could be indicative of instability. Here, “stability” means persistence of a particular stream type over time, not the absence of streambank erosion or channel migration. Criteria can also be developed for the amount of streambank erosion present at any one time, or the rate of channel migration, based on observations of similar stream types in undisturbed condition. Criteria for other processes important to stream function are also important, such as the frequency and duration of overbank flows that occur and maintain wetland function, riparian vegetation, and succession (USFWS 1998a [from NFHCP BO]).

In streams, channel morphology is largely influenced by geomorphic setting, sediment load, and riparian vegetation (Sullivan et al. 1987 cited in Murphy 1995), and by climate (Leopold 1994). Human factors influencing channel morphology are changes in sediment and streamflow regime, channelization, changes in riparian vegetation that can influence bank characteristics, and solid structures such as large wood, bedrock, and boulders (Murphy 1995; Rosgen 1996). Structurally diverse streams in watersheds unmodified by human activity typically have a great deal of buffering capacity to moderate the effects of floods on channel patterns and bed configuration (Cross and Everest 1995).

Off-channel areas should be hydrologically linked to the main channel, and overbank flows need to occur to maintain wetland function, riparian vegetation, and successional diversity. Riparian vegetation along streambanks ensures stability and minimizes sediment input. Intact off-channel areas that are functioning properly help dissipate the energy of water during high flow events and provide additional shoreline habitat at higher flows.

Habitat components representative of stream channels where channel morphology is considered stable and complex are: large and diverse pools; large woody debris; overhanging vegetation; undercut banks; areas of coarse substrate; diversity in water depth and turbulence; aquatic vegetation; diverse stream margins; side channels; groundwater-surface water linkages; and connectivity (Graham et al. 1981; Pratt 1984; Hoelscher and Bjornn 1989; Goetz 1991; Pratt 1992; Murphy 1995).

Riparian vegetation aids in maintaining stream-channel dimensions and bank stability, and affects where erosion and sedimentation of channels and floodplains occurs. Healthy riparian vegetation contributes to good root growth and root strength in streambanks. Riparian vegetation communities are critical in maintaining channel stability during high flow to allow maintenance of stream dimension, pattern, and profile (Kleinfelder et al. 1992; Cornwall 1998; Lyons et al. 2000; Toledo and Kauffman 2001; Liquori and Jackson 2001; Micheli and Kirchner 2002 as cited in IMST 2004). Millar (2000) reported that vegetation communities had significant influence in determining whether systems would become braided or single thread systems in gravel bed rivers. Beeson and Doyle (1995) reported that vegetated bends experienced significantly less erosion during high flow periods than channel bends without riparian vegetation.

Another mechanism by which riparian vegetation maintains the dimensions of a stream channel is by increasing the roughness of the banks and floodplain, thereby decreasing erosion and increasing sediment deposition. If the rooting strength of riparian vegetation and the surface roughness is sufficient, sediments will be deposited, not eroded. Reduction in root mass through removal of riparian vegetation can lead to increased bank erosion and sedimentation rates. During high discharge events, water naturally overtops stream banks and inundates stream floodplains. In healthy riparian communities, high floodplain roughness traps sediments on stream banks and floodplain surfaces during these floodplain inundations. Riparian communities in poor condition lose this ability to trap material, and sediments are actually eroded from the floodplain surface during high discharge events (IMST 2004).

Importance of Stream Channel Morphology

Some fish species are known to be associated with large pools, consisting of a wide range of water depths, velocities, substrates, and cover (Watson and Hillman 1997). Large wood in streams enhances the quality of habitat for salmonids and many other fish species and contributes to channel stability (Bisson et al. 1987). It creates pools and undercut banks, deflects streamflow, retains sediment, stabilizes the stream channel, increases hydraulic complexity, and improves feeding opportunities (Murphy 1995). By forming pools and retaining sediment, large wood also helps maintain water levels in small streams during periods of low stream flow (Lisle 1986a *cited in* Murphy 1995). Cover is a component of habitat complexity used by fish at all stages.

Some fish show strong affinity for stream bottoms and a preference for deep pools of cold water streams, lakes, and reservoirs (Goetz 1989). Cobble or fist-size stones provide the most-favorable streambed habitat for stream algae and invertebrates, in turn influencing the amount of benthic biomass available to sustain various fish species (Goldeman and Horne 1983). Stream channels that are either lacking cobble-sized substrate, have elevated cobble embeddedness, or are unstable in nature (shift or scour), generally have less-abundant aquatic insects and have decreased species diversity.

Groundwater-surface water linkages have also been shown to be important habitat components for a number of species. As channels are simplified, connectivity of surface waters with the floodplain and hyporheic zone is lost (Stanford and Ward 1992; Stanford and Ward 1993; Ward 1993 as cited in USFWS and NMFS 2000). Sedimentation appears to play an important role in decoupling groundwater and flow exchange processes, especially when chronic increases in fine sediment are experienced (Brunke and Gonser 1997 in Frissell 1999). It is possible for fine sediment to seal downwelling sites that could in turn reduce downstream up-welling.

Erosion within channels occurs naturally during high flows, but in a stable channel, erosion at one point is balanced by deposition at another location. Severe erosion of streambanks, at rates greater than the natural range, can cause channels to widen, while erosion of the bed can cause channels to incise, disconnecting the floodplain from the stream system.

Sedimentation, or sediment deposition, occurs when streamflows no longer have sufficient hydraulic shear stress to transport sediments. Hydraulic friction increases as the channel becomes wider and shallower, reducing available energy for transporting sediments. Riparian vegetation, large wood, or boulders can also decrease water velocities, causing deposition of sediments. Sediments that enter a stream can be deposited 1) directly into the streambed, 2) along the streambank, 3) along gravel bars, or 4) on the floodplain during flooding. Sediments may also remain suspended in the water column and be transported downstream. Excessive deposition in the stream channel can contribute to a decrease in stream channel depth. A large sediment supply may cause aggradation (i.e., filling and raising the streambed level by sediment deposition) and widening of the stream channel, pool filling, and a reduction in gravel quality (Madej 1982). Shifts in channel morphology and channel stability can be triggered by increases in sediment input rates, such as from increasing erosion in upland areas. Changes to the hydrology, either increasing or decreasing the hydraulic energy available to move sediment, can affect channel morphology and stability as well. Such changes may exhibit positive feedback behavior, as when increased sediment input causes shallowing, which in turn reduces hydraulic energy and induces more deposition.

Sedimentation also reduces pool depth, alters substrate composition, reduces interstitial space, and causes channels to braid, and increases the rate of channel migration (Rieman and McIntyre 1993 citing others). Impoundments and diversions have altered natural sediment-transport processes, causing deposition of fine sediments in slackwater areas, reducing flushing of sediments through moderation of extreme flows, and decreasing recruitment and increasing erosion of coarse material (including spawning gravels) downstream of the obstruction (Spence et al. 1996). Channel morphology can be affected indirectly by changing frequency and magnitude of scour and fill in the stream channel.

Many fish species are strongly associated with various components of habitat complexity, including cover, large wood, side channels, undercut banks, boulders, pools, and interstitial spaces in coarse substrates. Reductions in habitat complexity include decreases in: large wood; pool quality; channel stability; substrate quality; and groundwater inflows. Side channels, stream margins, and pools are sensitive to activities that directly or indirectly affect stream-channel stability and alter natural flow patterns. Some species are strongly associated with the habitat characteristics of stable stream channels. Increased bedload exacerbates the scouring effect of high water, increasing channel instability, leading to a loss of habitat diversity, especially pools (Henjum et al. 1994; McIntosh et al. 1994). Eggs and fry of fish species that utilize gravels likely survive such scouring at lower rates (Henjum et al. 1994). Reduced recruitment of large woody debris can reduce stream habitat complexity. Loss of riparian vegetation destabilizes streambanks and increases erosion and sediment delivery to streams. Road construction that involves channelizing streams may cause reduced habitat complexity and increased sediment delivery.

Persistence and sustainability of side-channel habitat depends on functioning channel-migration processes. Side channels go through a natural succession process in which they eventually fill in, become disconnected from the main channel and cease to function well as fish habitat. New side channels are generated by channel migration, including log-jam dynamics and avulsion at naturally sustainable rates. Thus, sustainability of side-channel habitat depends on having deformable (unhardened) stream-channel boundaries and water access to overbank areas during peak flows.

Highly variable stream flows, mobilization of streambed materials, and channel instability influence the survival of young fish. Substantial increases in size, duration, and frequency of peak flows can cause streambed scour and bank erosion. Low habitat complexity, the frequency of bed load scour, and the frequency of low flows (which may cause freezing within the substrate) may be aggravated by watershed disruption and problems of channel instability. Cover is another important component of habitat complexity. Cover can include woody debris, overhanging vegetation, undercut banks, cobble and boulder substrate, water depth and turbulence, and aquatic vegetation

All biota in streams are influenced by water-velocity distribution. The water velocities control the physical structure of the streambed and the amount of suspended material that is transported (Goldman and Horne 1983). When channel morphology/complexity is diminished, a greater proportion of the total hydraulic energy is available to scour the streambed. Greater levels of streambed disturbance can then occur during high flow events resulting in negative effects to benthic biota, which in turn, affect fish species at all life-stages through the loss of food sources.

Streams that lack a balance between pools and riffles are often less productive than streams that have more complex structure. Pools are used as holding and resting areas for adult fish prior to spawning, deep water cover for protection, and cool water refugia during low flow summer months. Riffles are important for re-oxygenation of water, habitat for food organisms such as aquatic macroinvertebrates, and as rearing areas for fish (Gregory and Bisson 1997).

Sediment eroded from headwater channels and debris flow deposits is transported to lower channel reaches (Cross and Everest 1995), which tend to be response zones, where channel morphology and channel migration rates are highly influenced by sediment input. Lower-elevation channel reaches historically constituted some of the most-important habitats for fish. These habitats are more-easily developed and have been exceedingly degraded by human activities.

Complex aquatic habitats are necessary to accommodate the diverse needs of various fish species (Murphy 1995; Spence et al. 1996). Complex habitats not only provide fish with critical habitat for all life-history stages in freshwater, but provide refuges from environmental variability (e.g., extreme flows) and stochastic events (e.g., catastrophic fires), buffering populations from the effects of environmental perturbations (Sedell et al. 1990; Rieman and McIntyre 1993). See the **Effects of Activities by Resource Topic -- Refugia and Movement** section.

Effects of proposed FPHCP on Channel Morphology

Riparian Timber Harvest

Riparian timber harvest would result in some reduction of large wood along Type Ns and Np streams. Decreased delivery of large wood could potentially decrease the number and quality of pools in some streams (such as forced-step-pool streams), and, in turn, could decrease the sediment-storage capacity of such streams. Downstream routed sediment might then affect downstream pool depth. In order to be effective at reducing pool depth in this manner, the amount of sediment input would necessarily be quite large. This amount of sediment would not commonly be associated with chronic sources (e.g., soil erosion due to riparian timber harvest or exposed slopes at road crossings), but would be indicative of episodic events such as slope or road failures, accelerated streambank erosion, or upstream channel incision.

Unbuffered Type Np streams may also reduce the amount of wood that could be incorporated into debris flows that originate further upstream. Where debris flows deposit at major junctions or at gradient changes, there may be some increment of reduced wood delivered to those locations. Decreased sediment stored upstream or decreased large wood delivered from upstream may have some effect to fishbearing streams. For instance, where two Type Np streams converge to form a fishbearing stream, reduced wood from above and/or increased sediment delivery may have effects to channel morphology. Direct effects to local channel morphology should be minor in most cases because debris flows would incorporate wood from other reaches, including the thermal-recovery reach, as they travel. However, reduction in wood content could affect the rate at which sediment in these accumulations is routed downstream. In general, smaller streams subject to loss of large wood can recover channel complexity more quickly than larger streams, since relatively smaller pieces of wood can store and processes sediment in small stream systems.

Slope failures may occur upstream and large sediment pulses may be delivered to the stream system. If woody debris is less available to store that sediment (either due to less wood within failure deposits, or less wood in headwater streams, it may have a moderate effect to the routing regime. Sediment may be more likely to fill pools, redirect streams, and/or cause shifting of substrate for a number of years. However, in most cases, FPHCP would avoid initiation of man-caused failures that deliver directly to fish-bearing streams, and would provide moderate amounts of wood on areas naturally prone to failures and debris-flow pathways. The magnitude of effects from mass-wasting events would likely mask the margin of difference from a reduced increment of wood recruitments from certain reaches of Type Np or Ns streams.

Retention of buffers along Type F and S streams within 20-acre exempt parcels (in conjunction with the Shade Rule) would provide some large wood but may not provide enough quality pieces of large wood to protect channel morphology. On 20-acre exempt parcels along Type Np streams, minimal buffers could be retained that would provide few pieces of functional large wood. Harvest along these Type Np streams may also result in increase in sediment delivery, thereby having an increased risk of affecting channel morphology.

Bank stability is influenced directly by root strength of trees in riparian forest and protection from ground-based equipment. Bank stability is also influenced by episodic events such as slope failures, debris flows, floods, windthrow, and fire. Activities that alter these episodic events could also influence bank stability. The combination of Core Zone retention on Type F and S streams, retention of buffers on sensitive sites, and retention of buffers for certain reaches of Type Np streams, in combination with ELZs, would help maintain root strength and would minimize disturbance from ground-based equipment. As discussed under the **Effects of Activities by Resource Topic -- Windthrow** section, windthrow is not expected to be increased at the catastrophic level by the proposed FPHCP. Minor amounts of windthrow are expected in association with riparian harvest, but the majority of this effect is anticipated to occur in the outer portions of riparian zones and would seldom affect trees contributing to bank stability.

Forest management cannot alone determine fire risk. Management of species composition and stocking density, as well as fuel type and loading, are the major management factors that can be controlled. The FPHCP provides for the ability of landowners to address forest health to a certain degree, but does not mandate such treatment. Fire is variable in its occurrence and effects, which contributes to its value as a landscape-level habitat-forming feature. It is not expected that the FPHCP would negatively affect bank stability due to altered fire risk.

Road Management

In-channel habitats can be affected in areas where peak flows increase (Chamberlain et al. 1991; Spence et al. 1996) resulting in changes to channel scour frequency and depth, which affects survival of incubating eggs (Murphy 1995), and in pool volume and pool frequency (Sullivan et al. 1987), which can displace juvenile salmonids from winter cover (Tschaplinski and Hartman 1983). Hydrologic changes that alter normal bedload movement and scour and fill patterns can excavate or bury redds. These effects to redds may expose eggs to stream flow and may trap or crush eggs or fry. The effects of road management on peak flows are variable, depending on watershed size and magnitude of peak flows. The potential exists for roads to intercept shallow subsurface flows and convert those to surface flows which are more efficiently and quickly routed to the stream system. More-rapid routing of road runoff to streams is addressed by the proposed FPHCP, yet some increase in this routing and resultant influence on timing and magnitude of peak flows is possible. In this way, some influence on channel morphology is possible as a result of road-system management that changes peak flows.

Stream-crossing structures can restrict the natural channel and floodplain width, which can change channel morphology, increase scouring at crossing sites (as well as increase scouring below crossings), increase stream-bank erosion, undermine stream-crossing structures and associated road fills, increase upstream aggradation, destabilize upstream channels through aggradation or interference with channel migration processes, and reduce the capacity for instream wood and bedload transport. Some replacements of road crossings result in unexpected channel incision upstream (Castro 2003). Culverts sometimes act as barriers to upstream progression of pre-existing reach-scale incision. If these barriers are removed without identifying the need for, and successfully establishing, grade-control elements, incision may migrate into the upstream reach causing channel destabilization and accelerated streambank erosion. Sediments mobilized during this period can then cause aggradation and pool infilling downstream.

Road management would result in sediment delivery despite measures to avoid delivery. Sediment is expected to result primarily from road crossings and stream-adjacent parallel roads. Channel morphology may be affected by road failures, instream road work, and exposed soil surfaces associated with stream crossings, and to a lesser degree by chronic road-related delivery. Channel morphology in streams with road crossings is expected to improve as culverts that constrict the channel would generally be replaced within the first 10 years of the Permit term. Stream-adjacent parallel roads that constrain the channel would be considered for abandonment. Stream and bank stability, both upstream and downstream, are affected by crossings and constrictions by stream-adjacent parallel roads. These conditions are expected to improve from the current baseline conditions.

7.5.9.2 Water Quality

The 1998 Washington State Water Quality Assessment, Section 305(b) Report (Butkus 1997) used a sampling approach to assess all streams in the State for use impairment under EPA guidelines. Although 65 percent of the streams in the State were found to be use impaired for at least one category, silviculture was a possible source for use impairment on only 4 percent of the State's streams. This is among the lowest effects identified, and was less than half of the number of possible natural sources for use impairment, which was 11 percent.

Chamberlain et al. (1991) reported the primary water-quality constituents that may be influenced by timber harvesting are temperature, suspended sediment, dissolved oxygen, and nutrients. Because temperature and fine sediment (including turbidity) have already been addressed separately as Aquatic

Inputs earlier in this Opinion, the topic of Water Quality included herein pertains to contaminants such as chemicals and excess nutrients as well as their effects such as lower dissolved oxygen levels.

Chemicals

Water quality and anadromous and resident fish species can be adversely affected by the accidental introduction of forest chemicals and petroleum products to drainages. Timber harvest and yarding along streams may involve chainsaws and heavy equipment, resulting in equipment exhaust and leakage of petroleum-based products such as gasoline, oil, hydraulic fluid, and anti-freeze. The same is true for large-wood placement, mechanical slash treatment, soil scarification and site preparation, road work, and other activities involving heavy equipment. Equipment would generally be staged and maintained at locations away from surface waters and in locations where any leaks would not deliver to the stream system or surface waters.

Water-quality contaminants (e.g., petroleum products) can severely impair aquatic ecosystems either by sublethal (e.g., reduced growth) or lethal effects (e.g., fish kills). Petroleum products are used in conducting forest practices, such as gasoline and lubricants. Chain-saws and other power tools are often inefficient in their gasoline consumption. These tools can discharge unburned gasoline. Such engines also release oil which can depress dissolved oxygen levels in the water. The combustion process discharges additional toxic compounds such as polycyclic aromatic hydrocarbons (PAH). EPA initiated control standards in 1995 (Tier 1) out of concern from hydrocarbon and oxides of nitrogen, and continued improvement in emissions is expected. Staging of large equipment away from waters during storage and maintenance would help reduce the probability (or severity) of any leaks or spills reaching typed waters.

Road grading and ditch cleaning may mobilize contaminants present in road surface material and may accelerate their transport and hasten their delivery. Fine sediments mobilized by road work may be delivered to stream channels and may contain traces of oil, gasoline, hydraulic fluid, or other compounds. Therefore, road work can re-mobilize this source of water-quality contamination and hasten its delivery to the stream system. Furniss et al. (1991) reported that wherever roads are near streams or road drainages enter streams, a potential chemical-spill hazard exists. Chemicals used to suppress dust, control or fertilize roadside vegetation, and stabilize or de-ice road surfaces also can enter streams directly or be transported by runoff. These are considered to be Cumulative Effects. There is similar potential for adversely affecting water quality, aquatic habitat, and aquatic organisms because of possible spills and leaks of petrochemical products (fuels, lubricants, hydraulic fluids) along roads or at activity sites near drainages.

Wetlands and floodplains can also remove toxic chemicals, such as pesticides, heavy metals, or excess nutrients from water (Mitshc and Gosselink 1993). Water-quality contaminants such as insecticides and fertilizers are addressed under Cumulative Effects, as are herbicides which are not interrelated or interdependent to the proposed issuance of the subject Permit.

As a result of timber harvest and hardwood conversion in the riparian zone, reforestation and attendant activities may be necessary. Of these, vegetation management through use of chemicals may provide a source of contamination. Active ingredients, surfactants, and adjuvants should be selected based on the least toxic available that still maintain efficacy for application. All BMPs and label restrictions should be strictly followed so that there would be no direct application to streams or wetlands. Due to tree-specific spraying and anticipated planting densities, we expect that less than 20 percent of an area would likely be sprayed when chemical application is necessary. We also expect that in most cases, alternate methods of control would be tried before resorting to chemical use. Herbicide use would have very reduced potential for introduction to water due to 50-foot Core Zone.

Herbicides

Herbicide use to control competing riparian vegetation would be an interrelated and interdependent activity associated with hardwood conversion on Type S and F streams and rivers. Similar activities may occur along Type Np streams; however, riparian areas along Type Np streams are more likely to transition quickly into upland conditions and are less likely to present conifer-regeneration challenges. The use of forest chemicals of any type is not an FPHCP covered activity.

A number of constraints currently apply to application of chemicals in forests. Only chemicals approved by the Washington Department of Agriculture may be used, and those chemicals must be used in accordance with label directions and the current Washington Forest Practices Rules. However, in this Opinion we are only analyzing the application of glyphosate that is factory-formulated with no carrier other than water and only surfactants that are very low in toxicity (e.g., Agri-Dex®). We are only analyzing this combination of herbicide and surfactants because we do not have enough information about other pesticides and combinations to conduct a rationale effects analysis. Many chemicals have potentially harmful by-products and the combination of chemicals and tank mixes may have potential synergistic effects. The number of potential chemicals available for use, multiplied by the potential combinations, preclude us from reasonably assessing effects to covered species. In addition, interrelated activities that are not covered activites are expected to be lawful activities. We are confident that use of glyphosate and a surfactant such as Agri-Dex® would not result in effects that would be expected to rise to the level of take for the covered species. We cannot be equally confident of this for other chemicals and combinations of chemicals.

Active Ingredients

Glyphosate is the common name for N-(phosphonomethyl) glycine. Trade names for aquatic products with glyphosate as the active ingredient include: Rodeo®, AquaMaster®, and AquaPro®, among others. Glyphosate is an herbicide that is used in the forest for conifer release, noxious-weed control, and site preparation. All commercial formulations of glyphosate that are used in forestry applications contain the isopropylamine salt of glyphosate. Some formulations contain only this salt of glyphosate as an aqueous solution. The EPA has determined that 92 percent of technical grade glyphosate contains an impurity, N-nitrosoglyphosate, at less than one part per million and that this amount is toxicologically insignificant. Several liquid formulations of glyphosate contain glyphosate alone in water (e.g., AquaMaster®, Glyfos Aquatic®, Roundup Custom®, and Rodeo®) (USDA 2003). Other glyphosate formulations generally contain surfactants. While surfactants are typically classified as “inert” ingredients in herbicides, these compounds may be more toxic than the herbicides with which they are used. Differences in acute toxicity among the various glyphosate formulations appear to be largely due to the use of surfactants that are toxic to fish and invertebrates (USDA 2003).

Action Mechanism

The herbicidal activity of glyphosate is due primarily to the inhibition of the shikimate pathway which is involved in the synthesis of aromatic amino acids in plants and microorganisms. This metabolic pathway does not occur in animals and thus this mechanism of action is not directly relevant to animal-health risk assessment. Studies on the mechanism of action of glyphosate are numerous and standard toxicity studies are available on seedling emergence and vegetative vigor in a number of different plant species (USDA

2003). This systemic, broad-spectrum herbicide is often used to control undesirable floating-leaved plants and shoreline plants. It is generally applied as a liquid to the leaves and does not work on underwater plants.

Application Method

All product labels and requirements of the Washington Department of Agriculture, and application requirements of WDOE and/or WDNR would be followed. We expect that only the minimum area necessary would be treated. Before application, applicators would thoroughly review the site to identify and mark, if necessary, buffer requirements. Application, as well as mixing, would only occur in places and at times specified by the manufacturer's label and other restrictions. All spill contingency planning and notification would be expected to conform to applicable restrictions and guidelines.

The most-common method of application for glyphosate is backpack-applied directed foliar spray. In directed foliar applications, the herbicide sprayer or container is carried by backpack and the herbicide is applied to targeted vegetation. Glyphosate may also be applied in hack and squirt applications, in which the bark and cambium of a standing tree is cut with a hatchet and the herbicide is then applied to the cut using a squirt bottle. This treatment is used to eliminate young trees during site preparation or conifer-release operations. Although glyphosate is a broad spectrum, non-selective herbicide, proper application can selectively remove targeted plants by focusing the spray only on the plants to be removed. Plants may take several weeks to die and a repeat application is often necessary to remove plants that were missed during the first application.

Surfactants are added to a spray tank to improve herbicide application by modifying the wetting and deposition characteristics of the spray solution resulting in a more even and uniform spray deposit. Surfactants and adjuvants can improve pesticide efficacy. Glyphosate would be mixed with water as a carrier and may contain surfactants or adjuvants to promote saturation and adherence. For instance, Agri-Dex® is a proprietary blend of heavy range, paraffin-based petroleum oil and non-ionic surfactants designed for use with a broad range of herbicides where a crop oil concentrate adjuvant is recommended.

Application Rate

The typical application rate is about 0.5 to 2 pounds of active ingredient per acre. The maximum label application rate is 3.75 pounds of active ingredient per acre. A typical dilution rate is taken as 10 gallons per acre. Glyphosate is absorbed primarily through the foliage, and the absorption is rapid. Approximately 33 percent of the applied glyphosate is absorbed within a few hours after application. The retention of glyphosate on foliage is affected by the use of adjuvants with a wash off of about 50 percent with adjuvants and 64 percent without adjuvants (Leung 1994). According to manufacturer's label instructions for ground application, Agri-Dex® would be mixed at the rate of about 1 to 4 pints per 20 to 100 gallons of spray solution.

Fate and By-Products

Glyphosate is very immobile in the soil and is rapidly rendered inactive over a period of several weeks. Glyphosate is not generally active in the soil and is not usually absorbed from the soil by plants. Glyphosate dissolves easily in water. The potential for leaching is low as glyphosate is strongly adsorbed to soil particles (USDA 2003), even those soils with lower organic and clay content (Extoxnet 1996). Glyphosate does not evaporate easily. Glyphosate remains unchanged in the soil for varying lengths of time, depending on soil texture and organic matter content. Glyphosate is moderately persistent in soil with an estimated average half-life of 47 days (Extoxnet 1996), with a range from 3 to 130 days; the half-life for glyphosate in water ranges from 35 to 63 days (USDA 2003).

Glyphosate quickly adheres to vegetation and other organic matter, adsorbs strongly to the soil, and is not expected to move vertically below the 6-inch soil layer. Residues are expected to be immobile in soil (USDA 2003). One estimate indicated that less than 2 percent of the applied chemical is lost to runoff. Microbes are primarily responsible for the breakdown of the product, and volatilization or photo-degradation losses will be negligible (Extoxnet 1996). Glyphosate is readily degraded by soil microbes to aminomethyl phosphonic acid, which is further degraded to carbon dioxide. Thus, it is highly unlikely that there could be movement to groundwater (U.S. EPA 1993b). Glyphosate may be translocated throughout the plant, including the roots. It is extensively metabolized by some plants, while remaining intact in others (Extoxnet 1996).

Herbicides can potentially enter streams through run-off, leaching, or percolation. However, adsorption onto soil particles reduces these potential pathways. Glyphosate though very soluble, binds well with organic matter in soils and therefore is not easily leached. Glyphosate does have the potential to contaminate surface water through erosion, as it adsorbs to soil particles which can then be suspended in runoff. The likelihood of delivery through surface erosion will be a function of soil-erosion risk. Because glyphosate binds tightly to soil particles, it is unlikely that toxic levels would occur in aquatic systems through erosion, especially where water is constantly moving. Glyphosate is rated as “very low” for herbicide movement (Vogue et al. 1994).

Acute Toxicity

Like all chemicals, glyphosate may be toxic at sufficiently high exposure levels. However, glyphosate is “practically non-toxic” to fish, aquatic invertebrates, and honeybees (U.S. EPA 1993). For instance, Rodeo®, with the low-level toxicity surfactant Agri-Dex®, has been determined to be practically non-toxic to rainbow trout and *Daphnia magna* (WSDA 2004). Available toxicity data suggest that amphibians are no more sensitive to glyphosate than fish (USDA 2003). See **Potential Direct Effects** section below.

Sub-lethal Effects

Studies do not indicate a basis for suggesting that glyphosate is an endocrine disruptor. Nonetheless, glyphosate has not undergone an extensive evaluation for its potential to interact or interfere with the estrogen, androgen, or thyroid hormone systems. Thus, the assessment of the potential endocrine effects of glyphosate cannot be overly interpreted (USDA 2003). The Re-registration Eligibility Decision document on glyphosate (U.S. EPA 1993b) indicates that glyphosate is classified as Group E: “Evidence of non-carcinogenicity for humans.”

Glyphosate produces reproductive changes in test animals very rarely and then only at very high doses. According to the USDA Forest Service (2003), glyphosate does not appear to be teratogenic (i.e., causing malformations of an embryo or fetus) and glyphosate mutagenicity (i.e., increase the frequency of mutation to an organism) and genotoxicity (i.e., result in mutations to genetic material) assays have been negative. USDA Forest Service (2003) summarizes several studies that noted some decreased body weight and decreased weight of several organs in studies of effects to mammals. Glyphosate has no significant potential to accumulate in animal tissue (Extoxnet 1996). There is a very low potential for the compound to build up in tissues of aquatic invertebrates or other aquatic organisms (Extoxnet 1996).

Potential Direct Effects

Amphibians: Available toxicity data suggest that amphibians are no more sensitive to glyphosate than fish (USDA 2003). Relyea (2005) in a test conducted in cattle tanks containing no sediment, found that Roundup (formulated with surfactants) application resulted in mortality of tadpoles from a number of amphibian species. However, Dr. Relyea has not yet analyzed the effects of unformulated glyphosate on amphibians (Relyea, Personal Communication, February, 14, 2006). A number of studies have concluded that technical glyphosate has little toxic effects on amphibians (Trumbo 2005; Howe et al. 2004; Wojtaszek et al. 2003; Thompson and Wojtaszek 2003). Mann and Bidwell (1999) found that technical glyphosate was "practically non-toxic," producing no mortality among tadpoles of any of the four species over 48 hours, at concentrations between 503 and 684 parts per million.

USDA (2003) noted that there are a number field studies that have assessed the effects of glyphosate on groups of terrestrial organisms, both animals and plants. These studies indicate that effects on terrestrial animals are likely to be secondary to the effects on vegetation when glyphosate is applied at application rates comparable to those considered in the studies. In some cases, the effects noted in field studies appeared to be beneficial to some species under study. In most cases, the effects noted were changes in population density that reflected changes in food availability or suitable habitat**.** For instance, Cole et al. (1997) reported no effect on populations of six species of amphibians (based on capture rates) among clearcut sites with and without glyphosate applications. Species included rough-skin newt (*Taricha granulose*), ensatina (*Ensatina eschscholtzii*), Pacific giant salamander (*Dicamptodon copei*), Dunn's salamander (*Plethodon dunni*), western redback salamander (*Plethodon vehiculum*), and red-legged frog (*Rana aurora*). However, Cole et al. (1997) noted that removal of red alder from the habitat reduced amphibian populations regardless of the method used to remove the alder.

Fish: USDA (2003) summarizes a number of studies regarding fish species. EPA (1993b) classified technical grade glyphosate as "practically non-toxic" in freshwater fish and concluded that: "technical glyphosate should not cause acute or chronic adverse effects to aquatic environments."

USDA (2003), in summarizing a number of studies, noted there is information indicating that some fish species, such as salmonids, are more sensitive to glyphosate than other species of fish. But the study also noted that the information is complicated by the fact that some surfactants are very toxic to fish as well as gaps in the available literature. Bioassays of the direct toxicity of herbicides suggest that glyphosate herbicides used at recommended rates pose little or no risk of acute toxicity to salmonids (Chapman 1989; Holtby and Baillie 1989; Morgan et al. 1989; Janz et al. 1991; Folmar 1976; Hildebrand et al. 1982; Morgan and Kiceniuk 1992).

Potential Indirect Effects

Based on reports summarized in USDA (2003), we conclude that it is unlikely that there would be indirect adverse effects on fish, amphibians, aquatic plants, soil microorganisms, and terrestrial or aquatic invertebrates.

FPHCP Effects

We anticipate glyphosate use, in the general form and application described above, to occur within the Inner Zone and Outer Zone of Type S and F streams and rivers. Further, the Washington Forest Practices Rules require a minimum 50-foot distance from unbuffered Type Np and Ns streams when applying forest chemicals. Since glyphosate is very immobile in the soil, we do not expect glyphosate to enter streams, except where the soil-erosion risk is high in localized areas. Thus, we expect that the fish and stream-associated amphibians would rarely be exposed to glyphosate. Even if they were exposed, we do not expect any fish or amphibian mortality or changes in growth rates or reproductive success because of the low toxicity to fish and amphibians from glyphosate. Application of glyphosate during dry conditions would reduce the possibility of migration from the application site to typed waters and hand application would further reduce the possibility of drift because spray nozzles would be in close proximity to target plant species and to the ground.

In summary, we do not expect covered or listed species and their habitat in the FPHCP Action Area to be adversely affected by the use of glyphosate as described in the above discussion.

Nutrients

Inorganic nutrients commonly associated with forest-practice activities, such as nitrogen or phosphorus, may show moderate increases following timber harvest although levels are typically limited to moderate amounts that persist no more than 10 years following harvest (Hicks et al. 1991; Chamberlin et al. 1991). Water-quality criteria for nitrogen are rarely exceeded, but the criteria are based on human health (nitrates) and fish toxicity (ammonia) rather than ecological disturbances (Anderson 2002). Algal response to additional nutrients could be greatest in downstream reaches (Anderson 2002). Excessive algal growth can lead to high pH from photosynthesis (Erickson 1999) and to low oxygen from decay of dead algae (Roberts et al. 2004). High pH and low dissolved oxygen can be harmful to salmon (Bell 1991). In nutrient-limited streams, large algal blooms triggered by the release of the limiting nutrient in the water column can potentially affect aquatic life if algal remnants settle into inter-gravel spaces and their decay reduces dissolved oxygen levels (Chamberlin et al. 1991).

The effect of nutrient input on surface waters as a function of land use is illustrated by the findings of a U.S. Geological Survey study of nutrient transport (U.S. Geological Survey 2000). This study reported that forested watersheds in the Puget Sound Region have much smaller yields of organic nitrogen and nutrients than do watersheds that are urbanized or have agricultural land uses, due to higher inputs from these developed areas. Phosphorous yields were not related to phosphorous inputs, however, because phosphorous adsorbs to soil particles.

Reduced large wood in headwater reaches could potential reduce the pattern of nutrient delivery downstream. Large and small wood pieces can store sediment and organic matter (detritus) in headwater streams which allow for organisms to process this detritus into usable size particles and useable forms for downstream organisms. Reduced large wood could result in minor disruption of these patters. Decreased shade in some headwater reaches may result in an increase in primary production having a mixture of negative and beneficial effects to nutrient and energy flow within the stream system. Improving fish passage may provide nutrients to the system as a result of anadromous fish access in the form of eggs and carcasses. Wetlands can improve water quality through nutrient removal and transformation (Hammer 1989). For example, wetlands can remove nitrate and phosphorus. Nutrient-rich sediments may also become trapped and removed from the water.

Dissolved Oxygen

Adequate dissolved oxygen levels are important for supporting fish, invertebrates, and other aquatic life. Salmonids are particularly sensitive to reduced dissolved oxygen (Oregon Department of Environmental Quality 1995). Inter-gravel dissolved oxygen has been recognized as crucial to the survival of salmonid embryos. Inter-gravel dissolved oxygen depends on several interrelated factors such as water temperature, surface-water concentrations, percentage of fine sediment and gravel in pores, and the oxygen demand of the eggs. Management-induced depletion of dissolved oxygen in stream water can occur from harvest activities, such as excessive amounts of logging debris left in a stream that can result in decreased dissolved oxygen (MacDonald et al. 1991). Critical levels of dissolved oxygen also depend on the velocity of the water passing over the eggs, as oxygen consumption would rapidly reduce oxygen supply to the egg without replenishment through adequate inter-gravel flow (velocity). Therefore, at lower velocities, higher initial oxygen concentrations are needed for proper egg development (Oregon Department of Environmental Quality 1995). Forest-management activities can exacerbate any inter-gravel dissolved oxygen problems through increases in fine sediment, which reduce inter-gravel water velocity (Bjornn and Reiser 1991; Ringler and Hall 1975; Moring 1975).

Dissolved oxygen levels in the water column also can be depressed during extreme low-flow periods, especially during warm summer months, and adversely affect aquatic organisms.

Chamberlin et al. (1991) noted that for dissolved oxygen, concentrations in intergravel spaces may be reduced if deposits of fine sediment restrict the flow of water through the streambed, potentially adversely affecting incubating or pre-emergent individuals.

High water temperatures can contribute to low dissolved oxygen because warm water cannot hold as much oxygen in solution as cold water can. Dissolved oxygen is often lower in surface waters that have a large percentage of their volume coming from poorly oxygenated groundwater, especially during summer low flows. Excess nutrients, especially phosphorus from sediments, fertilizers, or waste products, can stimulate algae and aquatic plant growth in surface water. When dead plant material decays, and when plants are taking up oxygen at night, dissolved oxygen levels decline. Fish and other aquatic life need sufficient levels of dissolved oxygen to survive. As temperature increases, metabolism increases and the demand for oxygen also increases. For maintenance of the health of fish and many other aquatic organisms, levels of dissolved oxygen concentrations in the water should approach saturation.

The primary water-quality problem on forestlands throughout the State is temperature, which also happens to be the most prominent water-quality problem for the State’s water bodies (USFWS and NMFS 2005, Appendix A). Some of these streams may be naturally elevated for temperature (USFWS and NMFS 2005). Stream temperature has already been addressed in this analysis. Increased heat and sediment and reduced flow can also lower dissolved oxygen. There are over 200 freshwater segments listed for dissolved oxygen. Many of the elevated values for dissolved oxygen can be linked to temperature effects (dissolved oxygen decreases with increasing temperature) (WDOE 2004a).

Minimizing fine organic loading (i.e., prevent slash and debris inputs) help to maintain the appropriate dissolved oxygen concentrations. While providing access to anadromous fish is desirable for a number of reasons (e.g., improved anadromous fish populations, nutrient source for resident fish), decaying salmon carcasses can also reduce the amount of dissolved oxygen in streams.

7.5.9.3 Aquatic Community Composition

The base of the aquatic food chain is supported by the combination of dissolved chemical nutrients and detrital materials. The chemical constituents such as nitrogen (usually in the form of nitrates and nitrites), phosphorus, and carbon can be derived from the breakdown of detritus and through leaching and runoff from surrounding soils (Gregory et al. 1987). Many bacterial and macroinvertebrate species rely directly on detrital material from leaf and needle litter, branches, and stems from the surrounding riparian zone vegetation. Some estimates indicate that leaf and needle recruitment may provide up to 60 percent of the total energy input to stream communities (Richardson 1992). Other macroinvertebrate species rely on aquatic algae that primarily use dissolved chemical nutrients and require solar radiation. In streams containing spawning habitat for Pacific salmon, substantial influxes of nutrients from the marine environment occur during the decomposition of carcasses (Bilby et al. 1996).

The abundance and diversity of macroinvertebrate food sources to fish and amphibians is dependent upon the primary algae and detrital food sources. Some amphibians at certain life stages depend directly upon algal food sources. Riparian timber harvest can affect the food chain by changing the relative macroinvertebrate production between herbivores and detritivores (Gregory et al. 1987). The magnitude and duration of the change is dependent upon a variety of factors, including stream size, gradient, location (headwater versus mainstem), and the type of riparian vegetation and management prescriptions. Gregory et al. (1987) suggest that tree harvest in riparian areas initially leads to higher total invertebrate abundance, but fewer invertebrate species, and that recovery of the macroinvertebrate community occurs over periods similar to recovery of riparian zones. Bilby and Bisson (1992) observed higher summer production of coho fry in a stream flowing through a clearcut area relative to a nearby stream reach in an old-growth riparian stand. However, no differences in coho production were present during fall censuses, and the high summer fish production was attributed to high algae production (Bilby and Bisson 1992). Bilby and Bisson (1992) and Spence et al. (1996) have noted that other changes in habitat features (e.g., numbers of pools) required by yearling and adult fish could likely offset any increases in sub-yearling production. Gregory et al. (1987) argued that short-term higher fish productivity might occur downstream of timber harvest units in some areas, but at the expense of long-term stability in the overall abundance and diversity of the aquatic community.

Turbidity and suspended solids can reduce nutrients for fish and amphibians by decreasing phytoplankton abundance. The diminished light penetration can also result in reductions in primary production of algae and periphyton. Particulate materials physically may abrade macroinvertebrates and their body parts. Suspended sediments usually consist of clays or silts. Suspended sediments are the portion of the sediment load suspended in the water column which can be measured by turbidity, although organic matter, plankton, and micro-organisms are also part of a turbidity measurement. Decreases in primary productivity can adversely affect the productivity of macroinvertebrates, amphibians, and fish.

As a result of past logging, it has been noted that nutrients can become more available to the stream immediately following harvest, resulting in part from addition of slash to the forest floor, accelerated decomposition of litter, and increased runoff and erosion (Spence et al. 1996). Increased sunlight immediately following harvest also contributes to higher algal primary productivity and a greater abundance of invertebrates, with an associated increase in abundance of predators (Salo and Cundy 1987; Murphy and Meehan 1991).

Meehan (1996) found no overall change in macro-invertebrate inputs with canopy removal. Although he found some changes in the minor taxa significant, he found large amounts of Ephemeroptera and Diptera in both canopied and non-canopied reaches and determined that the differences overall did not appear to be of practical importance.

Hardwood conversion may result in some reduction in detrital input to the riparian zone and eventual reduction of nutrient input into the stream. Detrital inputs from hardwood and deciduous shrubs are particularly important for aquatic life (Piccolo and Wipfli 2002). The ultimate result of hardwood conversion is a return to natural riparian conditions and amount and type of detrital inputs. Yet, in southeastern Alaska, young-growth alder sites were documented to export significantly greater counts and biomass densities of macro-invertebrates than young conifer sites (Piccolo and Wipfli 2002). Murphy et al. (1986) compared old-growth, buffered, and unbuffered riparian areas and the effects on juvenile salmonids. The buffered reaches did not differ consistently from the old-growth forest reaches. He did note that clear-cut reaches had more periphyton and increased fry abundance in the summer, but also noted that clearcutting without a buffer may reduce abundance of parr in winter, especially if debris is removed from channels. Wipfli (1997) found that a riparian overstory with more alder and denser shrub understory may increase abundance of terrestrial invertebrates in streams.

Improved passage can affect the aquatic community in several ways. Bilby et al. (1998) noted that the proportion of marine-derived nitrogen in the muscle tissue of juvenile salmonids increased as much as 39 percent following carcass placement, indicating that eggs and carcasses of adult salmon provide a very important resource during a period when other food items are often scarce. Densities of age 0+ coho salmon and age 0+ and age 1+ steelhead increased following carcass additions to treated steams.

Another potential effect of improved passage is access by invasive species. For instance, brook trout may currently be prevented from accessing habitat by fish-passage barriers such as culverts. Repairing and replacing culverts may allow brook trout access to areas where they can compete with or hybridize with native salmonids.

Effects of proposed FPHCP on Aquatic Community Composition

Fish access may increase the number of species using some stream reaches. This may have a negative effect on some species (competing and prey species) or a beneficial effect on other species (predator species, or species benefiting from other interactions). In the case of anadromous access, increases in marine-derived nutrient delivery can also change the local stream community.

Reduction in wood recruitment due to activities under FPHCP in headwater reaches could potentially reduce the pattern of nutrient delivery downstream. Large and small wood pieces can store sediment and organic matter (detritus) in headwater streams which allow for organisms to process this detritus into usable size particles and useable forms for downstream organisms. Reductions in wood could result in minor disruption of these patters. Reduced shade in some headwater reaches may result in an increase in primary production having a mixture of negative and beneficial effects to nutrient and energy flow within the stream system. Reductions in shade would be expected to be a short-lived phenomenon on most narrow streams. Increased sunlight for 1 or 2 years may increase primary production (algae and diatoms) within streams during that period of time. Recovery of shade would like occur between 2 and 5 years from harvest.

7.5.9.4 Resource Relationships

This section examines interrelated topics and the indirect effects to resource topics (associated with aquatic inputs) that may emanate from changes to riparian forests, aquatic inputs, and hydrologic processes. This section is necessarily complicated in that it discusses the effects of one subject upon other subjects. For instance, large wood stores sediment in small headwater streams. These storage sites influence flows. Redirection of flows into alluvium alters surface flow, but also can affect temperature at downstream sites.

Large Wood Responses

The effects of the FPHCP upon large-wood recruitment were discussed earlier. Large wood in streams may respond to a number of other factors (such as debris flows, high flows, and channel size) that influence transport and depletion. Reduced recruitment of large wood to streams without fish may also reduce the amount of wood delivered downstream to fish-bearing streams through episodic events. This was already discussed in the discussion regarding large-wood recruitment. Large-wood depletion primarily occurs through two processes: decomposition and transport. Decomposition is influenced by size, species, and location of wood. These factors, with respect to key-piece wood, are influenced primarily by factors addressing the riparian forest. Management for a fully stocked Core Zone, RMZ management to return original species composition, and RMZ management to improve diameter growth should contribute to recruitment of more-persistent wood. Transport is also influenced by the character of the individual pieces of wood (e.g., wood size, branching, presence of a root-wad), as well as by strength of flows. Strength of flows are determined by stream size, drainage area, and individual storm events. Peak flows during large storm events have not been demonstrated to be significantly influenced by either timber harvest or road management. While small and moderate flows can be influenced by those management factors, they do not appear to alter significant storm events – See the **Effects of Activities by Resource Topic – Hydrology** section.

In areas dominated by steep topography, a portion of the large wood in fish streams is delivered through episodic and catastrophic processes. These processes have historically occurred naturally and as a result of management activities. FPHCP objectives are to avoid the acceleration of slope failures, and to provide wood with such failures when they do occur. In this way, it is not expected that delivery or persistence of large wood in fishbearing streams would be affected by slope failures as a result of the FPHCP. We do expect that debris flows would in some cases entrain fewer pieces of large wood; and, if such debris flows were to deliver to Type F streams, the incremental difference in amount of wood may have localized effects.

Hydrology Responses

Peak flows are the primary aspect of hydrology affecting instream responses and habitat formation and degradation. Increases in peak flows are generally poorly understood and can be either increased or decreased by forest management. However, large peak flows with the ability to influence habitat features (e.g., during storm events) appear relatively uninfluenced by forest management. Large peak flows are primarily a function of storm event severity and basin size. Other factors that may influence hydrology include slope failures. As mentioned above, slope failures have historically occurred naturally and as a result of management activities. FPHCP objectives are to avoid the acceleration of slope failures, and to provide wood with such failures when they do occur. In this way, it is not expected that hydrology would be affected by slope failures as a result of the FPHCP, because slope failures are expected to occur at natural rates and continue to incorporate wood which is important to the ameliorating of negative effects and realization of many of the positive attributes of slope failures. Slope failures provide coarse sediment that is used for spawning gravels. Slope failures also produce aggradation which may facilitate exchange between stream water and water within substrate that modifies stream temperatures.

Hydrological processes can be influenced by the presence of fine sediment. Sediment-laden reaches may be more prone to avulsion and erosion. Deposition of large amounts of sediment may accelerate channel migration and may increase the rate of sedimentation. The FPHCP would not be expected to result in such large amounts of sediment so as to alter hydrologic processes and channel migration in such a manner.

The importance of large wood in forming habitat features was already discussed in large wood recruitment. Large wood can influence hydrology by forming steps and sediment wedges in high-gradient streams. It can facilitate exchange with hyporheic zone and can modify flow rates. Large wood can armor banks from erosion, or it can deflect flow toward banks facilitating avulsion and bank cutting. The FPHCP is not expected to result in large changes in recruitment and distribution of large wood. There may be some local reductions of large wood within stable Type Np streams when left without buffers. However, on a system wide basis, functional levels of large wood are expected to be recruited and distributed and any reductions are not expected to affect these hydrological processes.

Substrate Responses

Substrates within streams can be affected by more than the addition of fine and coarse sediments. Decreased delivery of large wood could decrease the number and quality of pools in forced-step-pool streams, and in turn could decrease the sediment-storage capacity of such streams. As discussed earlier, within stream work may affect channel substrates. Substrate may also be disrupted by movement and positioning of logs during large wood placement. There is also the potential for loss of natural stream-channel substrates in locations where conventional culverts are placed. Culvert placements completed under the FPHCP (and HPA) should provide a high likelihood of retaining natural substrates within, upstream, and downstream of such culverts. Hydrologic changes can alter normal bedload movement and alter scour and fill patterns. This can excavate or bury redds, exposing eggs to stream flow or trapping and crushing eggs or fry. Such hydrological changes resulting from FPHCP would be expected to be minimal.

Temperature Responses

Changes in channel shape may potentially affect stream temperatures within fish-bearing streams more than the reduction in shade on Type Np streams. Due to some decrease in large wood in headwater streams, there may be some subsequent change in routing of sediment. Changes in sediment routing and storage regime could result in some level of change in channel morphology downstream. As discussed in the **Effects of Activities by Resource Topic -- Channel Morphology** section, changes in channel morphology to this extent are more likely in the case of episodic sediment input, rather than chronic inputs. It would require considerably large sediment inputs to achieve habitat changes of this scale. It is unlikely that sediment from erosion in harvest units would provide measurable sedimentation levels outside of reaches adjacent to the harvest unit. Road-related sediment delivery would need to be considerable to effect such a change in the sediment regime and fill pools and widen the stream. Such road-related sediment inputs are most likely a result of an episodic event. When habitat alteration does occur, such as filling of pools and stream widening, changes in temperature are possible depending on stream size and other characteristics. However, the FPHCP is not expected to increase such episodic events, and in fact, should decrease the occurrence of such events with respect to roads through the RMAP process.

When naturally occurring episodic events such as debris flows do occur, and during the course of the debris flow encounter areas where wood is lacking (e.g., an unbuffered Type Np reach), the debris flows may deliver a reduced level of large wood. This altered level of large wood would still be likely to contribute to functional levels of large wood. Even though changes in habitat structure could potentially have some effects on temperature, the described scenario would only involve moderate habitat alterations that would be expected to have minimal effects on stream temperature. Mass-wasting events, however, when considered as a whole, do have the ability to substantially modify stream-channel characteristics and influence stream temperature both by causing stream channel and riparian changes that may increase stream temperature, but also by creating conditions conducive to cooling of streams.

Riparian timber harvest, outside of forested wetlands, is not expected to result in warming of groundwater. Riparian and upslope timber harvest may increase the annual water yield and may provide increased flows during summer low flows. Increase groundwater is most likely to have cooling effect on surface streams. Riparian harvest in forested wetlands may remove canopy that allows shallow subsurface water to warm, although the extent to which such harvests may increase the temperatures of water within streams in uncertain.

Nutrient Responses

See the discussion in the Effects of Activities by Resource Topic -- Water Quality (Nutrients) section, as well as the discussion in the Effects of Activities by Resource Topic -- Aquatic Community section.

7.5.10 Habitat Access

7.5.10.1 Refugia and Movement

Fresh water and estuarine habitat in the Pacific Northwest has been a continuously shifting mosaic of disturbed and undisturbed habitats. One of the legacies of fish evolution in a highly fluctuating environment is the ability to colonize and adapt to new or recovered habitat. Wild salmonid stocks historically accommodated changes in their environment through a combination of three strategies. Long-term adaptation produced the highly varied life-history forms of these species, providing the genetic diversity needed to accommodate a wide range of changing conditions. High fish abundance distributed in multiple locations (stocks) increased the likelihood that metapopulations and their gene pools would survive. Occupation of refugia (higher-quality habitat) provided the base for recolonization of poor habitat as conditions improved over time (IMST 2004).

Well-distributed and interconnected local populations of fishes across the landscape help maintain their long-term productivity and survival. Should a natural disturbance event occur, these areas where habitats remain undisturbed can act as local refuges and can aid recolonization of the disturbed area. However, if refugia habitat is inadequate in terms of size, quality, number, and/or connectivity, the affected fish species may be vulnerable to regional extirpation. Small, isolated, local populations of native fish are more likely than larger local populations to become extirpated over long time scales due to stochastic events (e.g., landslides, catastrophic fires, and floods). Further isolation of local populations in shrinking habitat is likely to lead to increasing rates of extirpation not proportional to the simple loss of habitat area (Lee et al. 1997). Connectivity between populations of amphibians can also aid those species in recolonization following stochastic events.

Connectivity is also needed between habitats used by fish within a local population. Migratory corridors provide the necessary connection between spawning, rearing, and over-wintering and foraging areas. Disruption of migratory corridors can increase stress, reduce growth, decrease survival, and prevent reproduction. Movement of individual fish is essential to the persistence and interaction of local populations.

Movement and migration in tributary streams by native fish is typically in response to developmental and seasonal habitat requirements. Some fish commonly make long-distance annual or seasonal movements among various riverine and estuarine habitats searching for foraging opportunities and refuge from warm, low-water conditions in mid-summer and ice in winter.

Fish usually move upstream to spawn, but they also move to feed, hide and find better habitat as conditions in a stream change over time. Downstream migration may provide more opportunity to access denser forage, find improved protection from avian and terrestrial predators, and alleviate intra-specific competition in rearing areas. Even though juvenile fish tend to move downstream, this is not always the case when they are moving in response to unfavorable habitat conditions such as increased stream temperature or fall migrations into overwintering areas. Even resident fish need connectivity to various areas needed to fulfill all of their life-history requirements. On temperature-sensitive streams, juvenile fish may move upstream to seek sources of cool water within that system. Juvenile salmon are known to migrate upstream from main stem areas and into small tributary streams, or "off-channel" habitats to overwinter. Adult bull trout are known to move into smaller, colder tributaries from mainstem river systems during the summer in response to increasing river temperatures. For many species, juvenile fish need to move downstream to the ocean, and adults need to return to natal streams to spawn.

Habitat fragmentation can cause metapopulation systems to shift to smaller, more-isolated units. Barriers such as water diversions, dams, impassable culverts, and dewatered reaches limit or exclude the number of individual fish that can emigrate to spawning and rearing areas. Local refugia provide a protective mechanism; where refugia for fish exist in close proximity to a depopulated area, recolonization can occur rapidly. For instance, Reiman et al. (1995) found that bull trout and redband trout were greatly reduced in some stream reaches after an intense burn on the Boise National Forest, but these species rapidly recolonized the affected reaches.

It is well known that the loss of the migratory life form of westslope cutthroat trout, and of other salmonid species, has been due to the reduction of connecting corridors for dispersal (as summarized in USFWS and NMFS 2000 [NFHCP BO]). In these cases, refugia habitats become isolated in a system due to lack of connectivity, so that refounding or support for lost local populations is diminished.

Habitats influenced by groundwater inflows can be critical thermal refugia for riverine fish when river temperatures warm in the summer and when deep pool habitat becomes limiting in the winter. Floodplains having hydraulic connectivity within channels can support flowing groundwater (hyporheic) habitats and serve as refugia for macroinvertebrate communities (Quigley and Arbelbide 1997). Some of the most productive juvenile rearing habitats in streams are located in backwaters along the edge of the channel and in side-channel areas.

7.5.10.2 Impediments to Access and Connectivity

Overall, there is likely a lack of connectivity for many populations of native fish within the action area of the FPHCP. Quigley and Arbelbide (1997) suggested that the extensive heavily managed landscapes throughout the Columbia River basin have contributed to the fragmentation and simplification of most watersheds and that most watersheds are compromised, particularly in terms of persistence of local populations of native fish in light of catastrophic events. It is apparent that useable corridors, both within and among tributary streams, mainstem rivers, and lake systems are critical for native salmonids and other fish to locate refugia habitat and ultimately maintain viable populations. Land-management activities can influence the function of refugia habitats for native fish mainly through interruption of hydrologic connections and habitat degradation. Culverts and diversion dams can block or impede fish movement thereby precluding dispersal to refugia habitats. Migrations occur at certain times of the year that can be critical for survival. Impediment or delay in fish migration can be the result of culvert hydraulics, which create water-velocity barriers, depth barriers, and/or vertical jump barriers.

Upstream migration of adult salmonids to spawning areas or redistribution of rearing fish to potential habitat in upstream areas can be impeded or blocked by a number of different mechanisms. Various fish species may have other requirements, but much information has been gathered on this topic with respect to salmonids. These mechanisms can include the following:

- Water Temperature—Elevated water temperatures (e.g., 15.6 degrees C and 20 degrees C for coho salmon and fall chinook salmon, respectively) are known to stop the migration of fish (Bjornn and Reiser 1979).
- Dissolved Oxygen—At least 5 milligrams per liter (mg/l) of dissolved oxygen is recommended to provide oxygen needs for migrating fish (Bjornn and Reiser 1979). Decreased oxygen can occur as a result of high water temperatures and oxygen consumption created by decay of organic debris, chemicals, and respiration.
- Turbidity—High levels of sediment (e.g., 4,000 mg/l) have been reported (Bjornn and Reiser 1979) as ceasing upstream migration.
- Streambed Aggradation and Subsurface Flow—Debris flow deposits in fish-bearing streams have been found to cause fish blockages (Pearce and Watson 1983; Bryant 1983). High stream bedload accumulations have been found to result in subsurface flow and isolating stream reaches either inhibiting or delaying passage (Furniss et al. 1991; Hartmen et al. 1995).
- Physical Barriers—High waterfalls or cascades that are beyond the jumping or physical capabilities of fish can prevent upstream migration. Similarly, excessive water velocities that result in conditions beyond the physical capabilities of a given fish species can also restrict or prevent upstream migration. The maximum velocity beyond which coho and chinook salmon cannot successfully move upstream is about 8 feet per second (Bjornn and Reiser 1979). Shallow water depths from conditions such as low flow can impede or prevent passage (e.g., chinook and coho salmon are generally not successful at upstream migration at water depths less than about 0.8 feet or 0.6 feet, respectively (Bjornn and Reiser 1979). Such conditions can occur during low flow periods where riffles between pools can become completely dry or lack sufficient depths for fish passage.
- Man-made Barriers—Man-made barriers include features such as dams and stream crossings (usually culverts, but sometimes bridges as well).

Road crossing across streams can restrict channel geometry and prevent or interfere with migration of adult and juvenile fish (Furniss et al. 1991). Stream crossings by forest roads are the most-common passage barrier influenced by Washington Forest Practices Rules. A Hydraulic Project Approval is needed for the construction of stream crossings, which are regulated by the WDFW under the Hydraulic Code (WAC 220-110-070). Barriers such as culverts used at stream crossings can prevent passage due to high water velocities, restricted depths, excessive elevation for successful entry, size and length of the culvert, and other factors.

7.5.10.3 Passage Barriers

Habitat fragmentation and the subsequent isolation of populations is a key factor in the status of many fish species. Some of the most productive juvenile rearing habitats in streams are located in backwaters along the edge of the channel and in side channel areas. Roads built next to streams often disrupt access to these off-channel habitats by physically isolating them from the main channel (NRC 1996).

Overall, within the action area, there is a general lack of connectivity among local populations of native fish. Quigley and Arbelbide (1997) found this is true with respect to the Interior Columbia Basin. Isolating mechanisms include, physical passage blockages at mainstem impoundments that have isolated whole sub-basins (Brown 1992; Pratt and Houston 1993; Rieman and McIntyre 1995), water diversions preventing spawners access to formerly suitable habitat, poorly designed culvert installations at forest road crossings that block upstream migrations into spawning and rearing tributaries, and thermal passage barriers at both tributary and mainstem scales.

Forest roads frequently cross streams, and such crossings typically involve culverts or bridges. Bridges generally cause less physical habitat disturbance of the stream channel than culverts and generally provide better fish passage (Furniss et al. 1991). Poorly designed and installed culverts can act as barriers to migratory and resident fish movements. Barriers at road crossings can be caused by impassable outfalls at culvert exits, excessive water velocity, insufficient water depth in culverts, disorienting turbulent flow patterns, lack of resting pools below culverts, or a combination of these conditions (Furniss et al. 1991).

Fish movements may be blocked fully for all fish species and age classes, or fish movements may be impeded fully or partially for certain species and/or age classes depending on the type and timing of the obstruction or barrier. Generally, culverts can impede passage in three different ways: water-velocity barriers, depth barriers, and/or vertical jump barriers (Bell 1991; Bates 1997; Barber and Downs 1996). Different species and sizes of fish have different swimming abilities. Healthy adult fish swim more strongly than juvenile fish and can pass upstream through a culvert with less difficulty. If the culvert is too long, a fish may become exhausted while attempting to swim all the way through. If the velocity of water in the culvert is too great, a fish will not be able to swim fast enough to overcome it (Bell 1991). The value to be used in culvert design should be based on the lowest maximum average water velocity for the weakest-swimming fish requiring passage. In many situations this should be determined by the requirement to safely pass juvenile fish (Bell 1991).

Impediments to, or delay in, fish migration often is the result of culvert hydraulics (WDFW 1999b). WDFW (1999b) recommends that the culvert design allow for passage 90 percent of the time during the migration of target species and appropriate age class. Meehan (1991) recommends not providing passage during 5 percent of the year when flows are at their greatest and Baker and Votapka (1990, as cited in Meehan 1991) imply that migration delays should not exceed 3 days. Minimum water depth is a difficulty that is limited to those structures that have no natural streambed or simulated streambed. WDFW (1999b) recommends a minimum depth of 8 inches and Oregon Department of Transportation (1998) recommend a minimum depth of 9.6 inches, based on anadromous fish studies.

Culverts that are installed with a perched outlet or culverts that cause erosion at the outlet due to inadequate sizing often are characterized by increased pipe velocities which cause scour and a perched condition. This in turn can lead to a vertical barrier. New culverts should be designed without a vertical jump by placing the culvert on the average natural stream gradient (USFWS and NMFS 2000). The Services also recommended that existing culverts should be assessed to determine if the water velocity within the pipe is more of a limiting factor than the vertical jump itself. Culverts that are designed for adequate flow, for bedload and debris passage, and installed on a natural stream gradient would be expected to eliminate the vertical-jump problem.

7.5.10.4 Effects of Proposed FPHCP on Refugia and Connectivity

FPHCP construction standards would be expected to improve passage for fish, allowing access to all available habitats with few exceptions. These standards would also provide better transport of water and large wood than currently exists in the baseline condition. New and replaced culverts must meet the WDFW standards. Design guidelines are described in detail and design criteria are provided in WDFW's Design of Road Culverts for Fish Passage (Bates et al. 2003).

Stream crossings may become plugged or may fail and result in diversion of streams. Plugged stream crossings may cause a stream to cross the road, thereby increasing road-surface erosion and sediment transport and delivery. Plugged culverts would likely inhibit fish passage. When diverted across roads, streams are shallow and mostly impassable. The FPHCP standards for stream crossings and culverts are expected to greatly reduce the incidence of plugged culverts.

Crossing-structures (e.g., culverts) and cross-drainage structures would be the subject of assessment and upgrading under the RMAP process. While some of this work may generate some small amount of sediment in the short term, the improvements are expected to greatly reduce the long-term delivery of sediment. As importantly, the RMAP process also focuses on identifying and remedying fish-passage barriers. All such barriers on industrial lands are expected to be addressed by 2016.

During instream work for new roads or for other forms of maintenance, repair, or upgrading, it is often necessary to divert a stream. Such diversions (“coffer dams”) are usually in place for no more than 1 to 2 days and generally are required only once per stream crossing for the effective life of the crossing structure. This is expected to be a minor short-term disruption to fish passage and have minor effects to the stream and its biological and physical components. De-watered segments would be short, already affected areas, and would typically only be dewatered once in a several decade period. Effects include short-term desiccation of a segment of streambed (generally less than 100 feet total) and short-term disruption to passage.

On that portion of current crossings where passage is identified as a potential issue (and that would only be some subset of all culverts), we note that recent experience in western Washington indicates that about 25 percent may require full culvert replacement and about 5 percent may require bridges or abandonment (Bates et al. 2003). This experience may have been based on lower-gradient streams than would be encountered on FPHCP lands, and therefore may be an overestimate for forestlands as many of these culverts have been maintained as well or better than lower-elevation lands under other land uses. In addition, many of these crossings have already been addressed by RMAP and other processes. Some of those crossings that were addressed by RMAPs were identified as barriers. Of those barriers, some may require full replacement and, based upon our experience with forest landowners, many of those have already been replaced. Therefore, we expect that the combination of the baseline improvements made regarding fish passage in the last 10 years together with the improvements required during the next 10 years, substantial changes in connectivity will occur within the forested environment for these fish species.

There is a low level of risk that some fish-passage barriers on industrial forestlands may not be accurately assessed and may fail to be replaced. There is a moderate level of risk that some fish-passage barriers would persist on certain nonindustrial forest ownerships, especially those that are not actively harvesting timber, unless they are identified and addressed through another process such as local recovery efforts or the FFFPP. Exemptions for nonindustrial landowners as well as exemptions for 20-acre exempt parcels may therefore limit fish distribution and overall productivity to a minor, but locally relevant, degree. Blockages that preclude access to significant amounts of habitat are expected to be addressed through one of the many ongoing efforts including the FFFPP.

In addition, landowners may not be required to replace culverts that provide for passage of 150 mm fish. While such culverts may generally provide for most fish passage, there is still risk that not all fish at all times will be able to pass, and that such culverts may not fully function in passage of all wood and flows.

Riparian timber harvest is only expected to have minor effects to thermal refugia, and even these effects are expected to be short in duration (e.g., less than 2 to 5 years). Riparian timber harvest is not expected to change flow regimes, increase sediment delivery or routing, increased turbidity, decreased dissolved oxygen, or have other effects that would rise to a level that could degrade refugia or interfere with connectivity.

Road management may have effects upon sediment delivery, although in general, we expect the proposed FPHCP to contribute to improvement in the baseline of sedimentation. Sediment effects from instream work at road crossings may have localized effects, but are not expected to persist for long periods of time (e.g., not greater than 2 years on average) and we do not anticipate that these effects would rise to the level of degrading refugia or interfering with connectivity. We also expect that ongoing sediment inputs at road crossings would occur at generally low levels if crossings are properly maintained, however, short-term effects to reach-level refugia habitats may occur from road-generated sediment in proximity to road crossings (e.g., on the order of a hundred or several hundred feet downstream).

7.5.10.5 Summary: Effects of Proposed FPHCP on Refugia and Connectivity

Considering all of the actions that would occur under the proposed FPHCP, the refugia and connectivity for covered species should continue at the landscape level. Riparian timber harvest may have minor effects to temperature and sediment regimes that would be short term. Delivery of sediment from roads may be locally high during instream work, but is expected to subside following such work and subsequent flushing flows and exposed soil revegetation. Road-management standards under the FPHCP are expected to improve baseline conditions beyond the current conditions. Although passage barriers would likely persist in major rivers and in streams crossing non-forest lands, the FPHCP is expected to have a significant beneficial effect on access and connectivity through accelerated identification and remediation of fish-passage barriers. Improved access and connectivity across FPHCP lands is expected to benefit migrations as well as allow re-occupancy of extirpated locations. In addition, improved connectivity on FPHCP lands would reduce the threat of stochastic events to local population extirpations.

7.5.11 Direct Disturbance, Injury, and Death

This section addresses research, monitoring, and validation efforts (which may include species capture and handling); fish salvage in preparation for stream dewatering, electrofishing (which can be a component of any of the above activities); as well as emergency and routine work within and adjacent to streams. Research, monitoring, and model validation are components of the conservation measures of the FPHCP and would be authorized by the proposed Permit. The salvage activities involving species capture and handling are not directly addressed by the FPHCP, but have little independent utility and are therefore considered to be interrelated with or interdependent upon the proposed FPHCP. Fish salvage activities include a series of steps to minimize the potential for take of listed species related to certain road activities, but these salvage activities are not regulated by WDNR. Although such salvage activities could require future section 7 consultation regarding the issuance of a section 10(a)(1)(A) permit, the effects of these activities are analyzed herein as interrelated actions of the proposed section 10(a)(1)(B) permit. Where these actions would rely on Federal authorization, certain standards and constraints are anticipated and are described herein. Where these actions would not require Federal authorization, such standards might not be followed. These applications of electrofishing are analyzed in this Opinion. Operational stream typing using electrofishing (e.g., a landowner wishing to survey his streams for fish) is not addressed by the proposed action and is not analyzed herein. Such operational surveys would require a separate permit under section 10(a)(1)(A) or similar authorization if there was a likelihood of affecting listed species.

7.5.11.1 Research, Monitoring, and Model Validation

Activities conducted under CMER with respect to research, monitoring, and model validation are covered activities and support the conservation measures in the FPHCP. NMFS and FWS participate with other stakeholders in the CMER process and we would participate in the development and/or review of such individual proposals. Where effects may occur to listed species and would be authorized through the incidental take permit currently being contemplated, we would review proposals including methods to be used and other information and would provide either approval or recommendations for revision. While such recommendations and approval may include both exceptions from standard protocols and/or additional constraints, at this time, we are assuming standard agency protocols would be followed.

Direct effects may occur when such work requires walking or working in streams. Walking may inadvertently disturb and/or injure individual fish or amphibians, especially less-mobile life stages. Equipment may be placed in or adjacent to the stream and may require some excavation, anchoring, or other habitat modifications in the immediate area. For some surveys, block nets may be used. Block nets would only be in place for a short period of time (typically less than 1 day). Amphibian surveys sometimes involve "rubble rousing" (e.g., removing and overturning rocks and searching through substrate by hand or with rakes). This activity has the potential to injure individuals as well as displace individuals from preferred habitats.

Effects may occur to fish species in the Steep Tributary or Low-Gradient Tributary Habitat Associations when electrofishing to validate and update the water-typing model (upper extent of fish use). Electrofishing associated with model validation is expected to affect less than 0.1 percent of streams and stream-typing model verification would be preceded by visual surveys. When fish are discovered, model-validation work would cease; and, therefore, electrofishing usually would be expected to occur on those streams only once during the life of the permit (50 years). However, to address concerns about annual and seasonal variability in fish distribution, or for other model-validation purposes, some areas may be re-surveyed. Therefore, some stream reaches may be surveyed multiple times during the permit term. When fish are not discovered, model validation or updating may occur at 5-year increments. Exposure to this activity is expected to be low because generally electrofishing would be used only where fish presence would be questionable and would often be located near the upper extent of known or actual fish use, and therefore few fish would be affected. It may also be used where fish are absent, in which case, potential effects to amphibians may increase. Electrofishing does not usually kill fish, but can injure them and disrupts their movements and behaviors at the time of shocking **–** see the discussion regarding **Potential for Injury or Mortality from Electrofishing** in this section.

During research and monitoring, electrofishing may be used and would be authorized through the proposed incidental take permit as described above. Electrofishing for these purposes would be subject to a permit condition requiring a study plan for our approval, as well as requirements for qualified staff and reporting – See the **Terms and Conditions** section of this Opinion for the text of proposed permit conditions. Electrofishing for research and monitoring would only involve a very small portion of streams, but may occasionally involve repeated surveys. Such electrofishing proposals would be reviewed and may be limited to reduce adverse effects to covered species.

7.5.11.2 Capture and Handling

Where listed species are present, Federal authorization may be necessary and standard protocols would likely be required. Where listed fish are absent, such Federal authorization may not be necessary and standard protocols may not be followed.

For research and monitoring activities conducted under CMER, we anticipate utilizing the proposed section 10(a)(1)(B) incidental take permit to convey such authority for take. To be compliant with this permit, a study plan must be approved by us prior to CMER conducting or approving these activities. During such review, we may consult with local State, Federal, and tribal biologist to ensure these activities are compatible with the conservation of the listed species. We may provide stipulations beyond those that are generally anticipated herein, particularly where local populations are at a depressed status, or may provide exceptions to the conditions that are generally anticipated herein. As this program of activities is implemented, we would help provide monitoring and oversight.

For fish salvage in areas containing listed species, we anticipate utilizing section 10(a)(1)(A) or other tools to convey ESA authority as appropriate. We may consult with local State, Federal, and tribal biologist to ensure these activities are compatible with the conservation of the listed species. Permit(s) would be conditioned as necessary. For fish salvage where no listed species under FWS jurisdiction are present there are two possible scenarios. First, where listed species under NMFS jurisdiction are present, activities would be conducted in compliance with NMFS Limit #3 under the 4(d) Special Rule (July 10, 2000, 65 FR 42441-42443). Else, where there are no listed species that may be affected, activities would be conducted according to landowner procedures as discussed with and agreed to by WDFW. In this analysis, we assume these activities in the absence of listed species will be conducted as they have in the recent past.

A variety of methods may be used to handle fish and amphibian species. Fish or amphibians may be captured by hand, by net alone, or by net in conjunction with electrofishing. Fish or amphibians may be subject to handling stress and/or injury, as well as directly or indirectly contributing to disease transmission and susceptibility, or increased post-release predation.

Capture and handling of fish and amphibians has the potential to result in their injury or death. Mortality may be immediate or delayed. Handling of fish and amphibians increases their stress levels and can cause a variety of injurious conditions, including reduced disease resistance, osmoregulatory problems, decreased growth, decreased reproductive capacity, increased vulnerability to predation, and increased mortality (Kelsch and Shields 1996). Amphibians may suffer from thermal stress during handling. Fish may receive subtle injuries such as de-scaling and loss of slime layer. Handling stress; use of seines, dip nets, and traps; impingement on block nets; and electrofishing each have a probability of resulting in some injury. Serious injury and death due to handling stress and due to use of seines, dip nets, and traps is believed to be less common, however, post-release mortality is generally not known. Fish that have been stressed are more vulnerable to predation (Mesa et al. 1994; Mesa and Schreck 1989). The actual numbers of fish and amphibians affected by capture and handling is difficult to anticipate. In most cases, the handled fish and amphibians would be released shortly after their capture, minimizing stress. Depending on the number of fish or amphibians that need to be handled during each operation, some deaths may occur during the handling and/or transfer process. For example, juvenile salmonids are often vulnerable to predation by larger fish in a trap. Small fish can be trampled in a seine and can even be overlooked. Even though injury to fish may occur from capture and handling, adverse affects from electrofishing are more likely to occur.

In situations where Federal authorization is not needed for capture and handling, we are available for consultation and technical assistance to reduce effects to fish and amphibian species and can provide operating protocols for fish and amphibians to interested parties. We encourage handlers to observe standard sterilization techniques to avoid spreading diseases and parasites between geographic locations.

7.5.11.3 Fish Salvage

Fish salvage may occur when diverting a stream for instream work and consists of capturing fish and placing them back into the stream in a secure location. The likelihood of fish being present can be lessened in many areas when work is conducted during recommended fish-timing windows. However, while the likelihood of fish being present during these timing windows may be lowest for eggs and fry of salmonids of concern (listed species and anadromous salmonids); other fish species may be more likely to be present. Where no listed species are present, individual HPAs can be written with other timing based on site-specific needs and mitigation measures that would avoid effects.

When fish or amphibians are present in the reach of stream being dewatered, they would be captured and placed back into the flowing stream. This may affect individual fish, should de-scaling or other injury occur. The risk also exists that fish may not be captured and relocated, and would die during dewatering of the stream. Amphibians would be relocated when observed. Effects from actual handling have already been addressed in the discussion on **Capture and Handling** contained in this section. Depending on the number of fish or amphibians that need to be relocated during each fish-salvage operation, some deaths may occur during the handling and transfer process. Amphibians may also be present and avoid detection within the substrate, but later be subject to effects – see the discussion on **Stream and Streambank Work** within this section (below).

The salvage and handling of fish would not always occur in conjunction with the removal of a fish-passage barrier. A site-specific assessment usually informs decisions about when a diversion of stream flow and fish salvage are necessary. These decisions are generally made by WDFW during the HPA review process. During the diversion and prior to work commencing, fish (if present) are removed from the work area. Where listed species are present, this would be done according to standard protocols.

Stream Reach Isolation

Prior to dewatering a stream section, block nets, sand bags, or other obstructions would generally be placed upstream and downstream from the culvert to prevent fish entering the stream segment that would be dewatered. The use of block nets poses a mortality risk to fish, even when monitored on a continuing basis. The stream reach would usually be isolated on the same day that fish would be captured and relocated. The stream flow would be completely diverted around the project area in the same day, when possible. On rare occasions, block nets or obstructions may remain in the stream overnight when the fish capture and diversion activities require additional time to complete. This may result in some additional mortality of fish.

Seines, Dip Nets, and Traps

Seines and dip nets may be used as the first method of capture to remove any fish which may be trapped in the isolated reach. Fish are not generally injured using these methods, although these methods may disrupt foraging temporarily. Minnow traps, used in conjunction with seining, involve the use of wire-mesh traps placed in key instream fry habitat overnight prior to dewatering. Captured fish are removed, transported in large buckets filled with stream water, and relocated into flowing waters adjacent to or upstream of the project area. The fish and water temperature should be monitored to ensure the health and condition of the fish until they are released. Given the low level of effect of these capture and relocation techniques, few fish are expected to be injured using these capture methods. Nonetheless, fish would be temporarily disrupted from their normal behavior during the capture and relocation activities.

Electrofishing for Fish Salvage

Where listed species are not likely to be affected, operators may decide to proceed without further authorization from Federal agencies. Methods used and requirements for operators are developed in discussions between WDFW and landowners. Where electrofishing is used during fish salvage, and listed species may be affected, operators may require authorization from FWS and/or NMFS.

Where listed species are present or likely to be affected, electrofishing has the potential to harm and kill fish even when used according to Agency-approved protocols. Regardless of whether a project may affect NMFS and/or FWS listed species, we currently anticipate similar requirements. Electrofishing for fish salvage (even when conducted under NMFS Limit #3 for fish salvage) must comply with the NMFS guidelines of June 2000, or as they may be revised from time-to-time. Protocols used, including requirements for pre-work notification, must also comply with any such direction from WDFW. Electrofishing shall be attempted only after less harmful methods of fish removal have been used. See the discussion on **Electrofishing Conservation Measures where Listed Species may be Affected** within this section (below).

Based on studies conducted by Nielson (1998), we estimate that up to 25 percent of the salmonids remaining in the stream following stream-reach isolation would not be collected by the use of seining, trapping, and/or dip-netting, and therefore could be exposed to effects from electrofishing. This estimate may be conservative, yet reasonable, for adult and juvenile salmonids and other large species given the wide range of water bodies and habitats where projects could occur. For other smaller species, fewer individuals may be captured using those methods and therefore proportionately larger number of individuals may be subjected to electrofishing. Fewer fish of all types would be captured by these methods in larger streams with deep pools and abundant complexity (e.g., large wood pieces and large substrates). Based on our experience, sculpins are often the most-numerous type of fish in forested streams, and capturing a large proportion of sculpins may be difficult.

Instream work at road crossings that require stream diversion would likely be conducted no more than once or twice during the life of the permit and would affect a short reach of stream for each crossing. Dewatering for instream work therefore would affect a very small portion of the total stream system. Some of the effects (stress, displacement, disruption of behaviors) of actual capture and handling of fish using electrofishing during culvert removal and/or replacement would be short term in nature, typically occurring intermittently over the period of one to two days. Fish may be subjected to stress, temporarily disrupted from their normal behavior patterns, and temporarily displaced from preferred habitats. However, electrofishing may result in permanent, adverse effects to individual fish such as injury. Where agency protocols are not followed, effects may be more frequent and/or more severe.

It should be noted that use of electrofishing as part of this activity is a minimization measure to avoid death of fish from stranding. While some proportion of fish not caught by other methods may be affected, they would be stranded and likely die if not caught through the use of electrofishing. The use of electrofishing, in conjunction with the other capture methods, thereby reduces the negative effects of stream diversion for instream work. It is expected that most, if not all, adult fish of larger species would be removed using other methods of capture and release, because they are easier to see and capture that juveniles. For such species, most fish remaining following netting and thus subjected to electrofishing and/or stranding would therefore be juveniles. In some species, adult fish can be relatively small and, therefore, not readily seen or captured, e.g., sculpin and dace. For these species, adult fish may also be subjected to electrofishing or stranding.

Stream Dewatering and Stranding

Once fish capture has ceased, dewatering would be completed. The installation of the water diversion and retention structures and the dewatering of the stream could result in the stranding of fry or juvenile fish. However, sequential dewatering may allow for fish to move downstream as the water in the channel recedes, rather than be trapped in the work area.

During stream dewatering, including when sandbags are used to focus stream flows, there is a potential that some juvenile or small salmonids may avoid being captured and relocated, and thus may die because they remain undetected in stream margins under vegetation, rocks, or gravels. In a programmatic assessment of culvert replacements in eastern Oregon and Washington, we (USFWS 2004c) estimated that up to 5 percent of juvenile bull trout may avoid capture and be stranded. The portion of the fish that would be affected in this way may be considerably higher for smaller species of fish. A gradual dewatering approach should enhance the efficacy of fish removal and thus reduce, but not eliminate this risk. Large salmonids are also wary and likely to use cover (Grant and Noakes 1987). Yet, we continue to estimate that the capture methods applied to such projects would typically remove approximately 95 percent of the individual fish of salmonid species or other larger species prior to dewatering. In addition, due to the timing of the activities, the risk to adults of some fish species should be minimized because of the reduced likelihood of migratory and/or spawning fish being present in the stream reach during the construction period. Nonetheless, resident fish may be present and a lower proportion of smaller species may be removed.

For larger species, mortality is expected to be primarily limited to juvenile fish which, because of their small size (less than 120 mm), may avoid capture, become stranded, remain undetected on the dewatered streambed, or may be killed due to electrofishing or impingement on block nets. Because of their size, adults are relatively easy to detect and capture using seines or dip nets during the slow dewatering process, thereby reducing the exposure of adult fish to electrofishing procedures. However, large salmonids are more difficult to catch, and are harder to handle, therefore more likely to get injured during capture and handling. There may also be a high post-release mortality with larger fish. For smaller fish species, adults may also elude capture and become stranded.

7.5.11.4 Potential for Injury or Mortality from Electrofishing

Electrofishing can result in mortality and/or direct injuries to fish, including spinal hemorrhages, internal hemorrhages, fractured vertebra, spinal misalignment, and separated spinal columns (Hollender and Carline 1994; Dalbey et al. 1996; Thomspon et al. 1997). Even though 60 Hertz (Hz) would seldom be used in Washington, we utilize these data regarding injury that were collected from fish captured under these frequencies because they represent the maximum expected use, and because of the availability of data regarding these collection methods. For additional and more-detailed information on potential injury as a result of electrofishing see Snyder (2003). The following discussions of injury reports are often from studies using backpack style 60 Hertz (Hz) direct current (DC) pulse electrofishing equipment.

Thompson et al. (1997) found an average of 22 percent of the rainbow trout and an average of 32 percent of the brown trout sustained spinal injuries from electrofishing. Dalbey et al. (1996) found 37 percent of rainbow trout sustained spinal injuries from electrofishing. Hollendar and Carline (1994) found 22 percent of brook trout sustained injuries from electrofishing, of which 13 percent were spinal injuries, 4 percent had both spinal and hemorrhage injuries, and 11 percent had a spinal injury but no hemorrhage. Hollendar and Carline (1994) found most spinal injuries were rating class 2 (40 percent) or 3 (40 percent) (Table 7-1), involved on average 7 vertebrae, and were usually located in the region of the spinal column between the dorsal and anal fins. Thompson et al. (1997) found more than half of the injured fish were judged to have the lowest severity of spinal injury and 2.1 percent or less sustained the most severe class of injury.

Table 7-1. Injury rating system used to identify and rate the severity of electrofishing injuries (Thompson et al. 1997).

Rating Class	Internal hemorrhage	Spinal Damage
0	None apparent	None apparent
1	Mild hemorrhage with 1 or more wounds in the muscle, separate from the spine	Compression (distortion) of vertebrae only
2	Moderate hemorrhage with 1 or more small wounds on the spine (<= width of 2 vertebrae)	Misalignment of vertebrae, including compression
3	Severe hemorrhage with 1 or more large wounds on the spine (> width of 2 vertebrae)	Fracture of 1 or more vertebrae or complete separation of 2 or more vertebrae

Thompson et al. (1997) found an average of 34 percent of the rainbow trout and average of 24 percent of brown trout sustained hemorrhage injuries from electrofishing. Hollender and Carline (1994) found 13 percent of brook trout sustained hemorrhages, 10 percent had a hemorrhage but no spinal injury, and rating class 2 hemorrhages were the most common (71 percent).

Dalbey et al. (1996), Thompson et al. (1997), and Hollender and Carline (1994) all found longer fish had a higher probability of being injured. Incidence and severity of injury were positively correlated with fish length, in that 40 percent of rainbow trout longer than 8 inches sustained injury compared to 27 percent in smaller fish (Dalbey et al. 1996). The injury rate was lowest (12 percent) for brook trout smaller than 5 inches, intermediate (26 percent) for the 5- to 7-inch- length group, and was highest (43 percent) for the 7-inch-and-longer-length group (Hollender and Carline 1994). Snyder (2003) in a comprehensive review of harmful effects from electrofishing reported that importance of size remains questionable. Thompson et al. (1997) speculated that fish in better condition may be more likely to be injured because of more powerful muscle contractions. Snyder (2003) reports that such claims are based upon supposition. He notes that fish in poor health may respond less strongly, but may also be less able to withstand the stress. Dalbey et al. (1996) found a higher and more-severe incidence of spinal injury to rainbow trout from pulsed DC (40-54 percent) than smooth DC (12 percent). Therefore, they recommend using smooth DC or pulse frequencies of 30 Hz or less to reduce the overall injury rate, especially among larger fish.

Rainbow trout with moderate to severe injuries had markedly lower growth and body condition after 335 days than fish with no or low spinal injuries (Dalbey et al. 1996). Dalbey et al. (1996) speculate that in a dynamic stream environment (rather than a pond) skeletal damage could possibly have an even greater negative effect on growth and survival.

Very few of the fish collected by Thompson et al. (1997) exhibited external signs of injury although a higher percentage of rainbow and brown trout were injured by electrofishing than would have been suspected from external examination. Dalbey et al. (1996) found that rainbow trout X-rayed soon after capture, exhibited no detectable signs of spinal injury, but later showed calcification indicative of old injuries when X-rayed again after 335 days in a pond. Hollender and Carline (1994) found hemorrhages and spinal compressions in the smallest fish were small and difficult to see and might have been overlooked. Therefore, their reported injury rate (average of 22 percent) may be a conservative estimate. In addition, most studies have focused on injuries exhibited by adults, but stress from electrofishing can be the main problem for juveniles (P. Bisson, USDA Forest Service; S. Parmenter, California Department of Fish and Game, Personal Communications as cited in Nielson 1998).

Snyder (2003) noted that evidence to date strongly indicates that salmonids seem especially susceptible to brands, spinal injuries, associated hemorrhages, and probably mortality during electrofishing than most other fishes. Data on the harmful effects of electrofishing on fishes other than the salmonids are limited and seldom comparable, but among species included in such reports, and under at least some environmental and electrical-field conditions, burbot and sculpins may be particularly sensitive to electrofishing mortality and some suckers may be sensitive to electrofishing-induced spinal injuries and associated hemorrhages. However, according to Barrett and Grossman (1998), sculpins do not appear to be readily affected by electrofishing. Mountain whitefish are at least sometimes especially susceptible to bleeding at the gills when subjected to electrofishing fields (Snyder 2003). Most investigators addressing the matter reported little or no electrofishing mortality among non-salmonids. However, differences in rates and degree of injury, especially between investigations, are often difficult to attribute to species, fish size or condition, environment (including water conductivity and temperature), field intensity, or other current or field characteristics. Fredenberg (Personal Communication as cited in Snyder 2003) found spinal injuries in 2 to 20 percent of rainbow trout captured with DC, 15-Hz PDC, or CPS, but only 0 to 2 percent of mountain whitefish, white sucker, or longnose sucker captured with the same currents. When specimens with only hemorrhages along the spine or associated musculature (all minor) were added to these figures, the percentages of injured fish increased to 6 to 42 percent for rainbow trout, 2 to 29 percent for mountain whitefish, and 4 to 18 percent for the suckers. However, results for smaller species should be considered with caution because injuries in small fish are difficult to detect. The Chondrostei, sturgeon, have electroreceptors, but whether these fish are also more susceptible to electric fields has not been reported. Snyder (2003) summarizes information regarding paddlefish (*Polyodon spathula*) indicating they may be highly susceptible to spinal injuries including ruptured notochords. Catfish (Order: *Siluriformes*) which also have electroreceptors are easy to catch with extremely simple low-voltage devices.

Summary of Potential Injury and Mortality from Electrofishing

This information indicates that, while the data is not conclusive, assuming other fish species are equally susceptive to injury and mortality as salmonids would be a conservative assumption. Although often not externally obvious or fatal, spinal injuries and associated hemorrhages sometimes have been documented in up to and over 50 percent of fish examined internally (Snyder 2003). Other harmful effects, such as bleeding at gills or vent and excessive physiological stress, are also of concern. Mortality, usually by asphyxiation, is a common result of excessive exposure to tetanizing intensities near electrodes or poor handling of captured specimens. Reported effects on reproduction are contradictory, but electrofishing over spawning grounds can harm embryos.

Snyder (2003) noted significantly fewer spinal injuries are reported when direct current, low-frequency pulsed direct current (no more than 30Hz), or specifically designed pulse trains are used. Zeigenfuss (1995) found injuries were lower for fish shocked in colder temperatures. Long-term effects from proposed electrofishing would likely include reductions in growth rate and/or body condition in individual fish during variable periods of time after electrofishing (Gatz et al. 1986; Taube 1992; Dwyer and White 1995).

We estimate that up to 50 percent of fish exposed to electrofishing could be injured or killed. With respect to stream-typing model validation, our estimate is that up to 50 percent of the fish in the immediate area or reach that is checked could be injured or killed. For research, we estimate that up to 50 percent of the fish in an area addressed in an approved study plan could be injured or killed. Requests of this nature would be scrutinized based on need, as well as sensitivity of the species in the area and their population status. For fish salvage, we estimate that 75 percent of the fish in a stream reach would escape during isolation or be removed prior to use of electrofishing. We estimate that 20 percent would be removed by the use of electrofishing and the remaining 5 percent would be stranded and killed. Therefore, we estimate that up to 50 percent of the 20 percent removed via electrofishing would be injured or killed as a result of electrofishing during fish salvage.

Electrofishing Conservation Measures Where Listed Species May Be Affected

Where electrofishing for fish-salvage operations may affect listed species and Federal authorization is necessary, all such operations must be conducted in accordance with guidelines developed by NMFS (NMFS 2000, or as revised), and all applicable State and Federal permits shall be obtained. Procedures required by WDFW, whether under an HPA or a scientific-collection permit, must be followed, and in case of conflict, such conflicting guidance must be resolved by the agencies prior to conducting work. Operators must also follow WDFW direction regarding pre-work notification. Where FWS listed species may be affected by fish salvage, operators would require authorization from FWS. Electrofishing for research, monitoring, or stream-type model validation would require a study plan and approval by the Federal Services, and we expect that such plans would generally comport with the NMFS guidelines. In either case, whether a section 10(a)(1)(A) recovery permit is issued or whether work is conducted under the proposed section 10(a)(1)(B) incidental take permit, we would utilize the opportunity to assess the effects upon listed species and further condition such activities – see below.

Generally, there would be no electrofishing in anadromous waters from October 15th to May 15th and no electrofishing in resident waters from November 1st to May 15th. Sampling shall only occur at times and locations that avoid disturbing spawning native salmonids, incubating eggs, or newly emerged fry, unless specifically approved by the Services as part of a necessary research project. Only trained and experienced professionals may perform electrofishing surveys under Federal permits. Personnel conducting electrofishing would carefully survey the area to be sampled before beginning electrofishing. This pre-electrofishing survey should ensure that they do not contact spawning adult salmonids or active redds. To be compliant with the NMFS guidelines, equipment must be in good working condition and operators shall go through the manufacturer's pre-season checks, adhere to all provisions, and record major maintenance work in a logbook. Operators must also ensure that an adequate number of trained personnel are available.

Operators shall measure conductivity in the stream to be sampled and shall set voltage accordingly. Only Direct Current (DC) or Pulsed Direct Current (PDC) shall be used, unless otherwise approved. Each session shall begin with pulse width and rate set to the minimum needed to capture fish. If needed, these settings would be gradually increased only to the point where fish are immobilized and captured.

Electrofishing shall be performed in a manner that minimizes harm to fish. Operators shall not allow fish to come in contact with the anode. The zone of potential fish injury is within 0.5 m of the anode. Care shall be taken in shallow waters, undercut banks, near structures such as wood, or where fish may be concentrated in high numbers because, in such areas, fish are more likely to come into close contact with the anode. The stream segment shall be worked systematically, moving the anode continuously. Each area shall not be electrofished for an extended period of time. Fish shall be removed from the electrical field immediately and not held in the net while continuing to net additional fish.

The condition of the sampled fish shall be carefully observed. Dark bands on the body and long recovery times are signs of injury or handling stress. When such signs are noted, the settings for the electrofishing unit would be adjusted. Specimens shall be released in an area that provides refuge. Each fish shall be completely revived before releasing.

After capture, holding time shall be minimized, with no overcrowding in the containers. Large fish shall be kept separated from smaller fish to avoid predation during containment. Water-to-water transfers; the use of shaded, dark containers; and supplemental oxygen shall all be considered in designing fish-handling operations. Also, unless otherwise approved, electrofishing activities that involve extensive shocking or handling of fish shall be conducted at times or in locations (e.g., cold, groundwater-dominated streams) that avoid temperature stress of fish.

With respect to the electrofishing and species handling activities that would be authorized under the proposed section 10(a)(1)(B) Permit, adaptive management shall be applied to electrofishing procedures, applications, as well as the amount of electrofishing conducted. We will screen proposals to avoid electrofishing within certain areas containing depressed local populations (i.e., local populations listed as high risk within the Bull Trout Risk Analysis), or where necessary, to modify procedures used within these areas to further minimize effects to bull trout.

7.5.11.5 Stream and Streambank Work

Emergency repair work at road crossings may involve the use of heavy equipment within steams. While equipment may be allowed to operate within streams, it is typically only the bucket which enters the stream. Wheeled or tracked equipment is rarely allowed within the stream. These types of activities are typically done so as to minimize adverse effects by incorporating timing windows, isolation and dewatering or the reach, and other measures. Emergency projects likely have a higher risk of adverse effects to aquatic life because they are typically done on short notice during urgent events such as floods. The intent of these projects is usually to prevent damage from events such as road wash-out or failure that would have greater adverse effects than the activities themselves. These activities would occur infrequently but may occur at any time of year, although winter storms may be associated with the need for such work. Emergency instream work may injure or kill fish (e.g., primarily eggs and alevins) and amphibians. Culvert repair, replacement, and similar work may also injure or kill fish and amphibians, whether or not fish-salvage operations are attempted. Work with heavy equipment within the ELZ may also result in injury and death for adult amphibians.

7.5.11.6 Summary of Effects on Direct Injury and Mortality

In an effort to reduce lethal effects on fish from dewatering the stream, capture and relocation of fish from project construction sites are attempted prior to the initiation of construction activities. Seines, traps, dip-nets, block nets, and electrofishing may be used. Although fish-salvage operations should reduce the overall negative effect to fish from stream-reach dewatering, in some cases, fish may experience immediate or delayed injury or death from the use of nets and/or electrofishing techniques. Minimization measures can be utilized during stream diversion and fish salvage that should reduce the level of effect.

Effects from electrofishing would likely be minimized when appropriate measures are followed, including work-timing windows, use of qualified personnel, and appropriate electrofishing unit settings dependent on site conditions. Regardless of the purpose, when electrofishing is conducted, procedures should be followed that minimize injury to fish or other aquatic organisms. Sampling should only occur at times and locations that avoid disturbing spawning native salmonids, incubating eggs, or newly emerged fry.

Blocknets are typically in place during daylight hours and for less than a day. Removing blocknets prior to nightfall would reduce the likelihood of impingement, especially for nocturnally active species. Sand bags are more likely to be used than blocknets during water diversion and should further reduce the threat of impingement. Impingement and stranding are primarily anticipated to affect fish which are less than 120 mm in length. The most-significant effects for larger fish species should be the loss of some juvenile fish from an age class. For smaller fish species, some adults may also be lost. Effects would also include temporary displacement, stress, and injury. We expect fish injuries and death could occur from stranding, block nets, and electrofishing; while mortality associated with handling stress, seines, traps, and dip nets is less likely based upon our experience with these capture techniques.

In stream work may result in injury or death for fish and amphibians within the work area. Amphibians may also be injured or killed by ground-based equipment operating within the Riparian Zone. In all cases, we expect death or serious injury would occur to but a small portion of fish or amphibians within a stream reach. We do not expect long-term population effects to occur as a result of such direct effects under the FPHCP.

7.6 EFFECTS TO GUILDS (HABITAT ASSOCIATIONS)

7.6.1 Introduction

In this section we explain the approach we are taking to address the needs of the 47 unlisted species covered by the FPHCP. We identify guilds (Habitat Associations) that are being used to relate effects to habitat features to the individual species in an efficient and understandable manner. We address situations where species may be associated with more than one Habitat Association or are affected by other relevant factors. For each Habitat Association, we summarize the baseline and cumulative effects, as well as the major effects of the action which were previously discussed in **General Effects by Resource Topic**. Each species will be affiliated with at least one Habitat Association. For a species-specific discussion regarding the effects to individuals and the population, please see the **Effects of the Action** and **Incidental Take Statement** for each species.

7.6.2 Habitat Approach

Analysis of the effects to unlisted fish and amphibian species as a result of the proposed action (issuance of an ITP) is habitat-based. That is, this Opinion analyzes the likely effects of the FPHCP on aquatic and riparian habitat. The most-significant effects of the FPHCP on covered species are through its influence on riparian characteristics and processes, aquatic inputs, aquatic connectivity, and hydrologic and geomorphic responses of stream systems to these above factors. Effects of the FPHCP on native fish and amphibian populations are more subtle, and difficult to predict.

Therefore, effects of the FPHCP on native fish and amphibian populations are generally considered in this Opinion as consequences of habitat effects. To conduct this analysis, the best scientific and commercial data available is used to characterize potential changes to riparian processes and characteristics, aquatic inputs (such as solar radiation, large woody debris, sediment, detritus, and water quantity), aquatic connectivity (such as physical barriers to migration and floodplain and off-channel habitats), and hydrologic and geomorphic responses of stream systems (such as channel condition and complexity).

An underlying assumption of this analytical approach is that the covered species will experience demographic changes (that is, changes in vital rates, population size, and distribution) commensurate with changes in these habitat-related variables. Positive changes in the habitat variables would result in positive population trends; negative changes in the variables would result in negative population trends. Thus, habitat variables described above are used as surrogates or indices of covered species population trends for purposes of this analysis. This approach is consistent with approaches used in previous Opinions involving unlisted species.

The relationship between changes in habitat quantity, quality, and connectivity and the status and trends of fish and wildlife populations has been the subject of extensive scientific research and publication, and the assumptions underlying the habitat approach in this Opinion are consistent with this extensive scientific background. For more-extensive discussion of and data supporting the relationship between changes in habitat variables and the status and trends of fish and wildlife populations, readers are referred to the work of Fiedler and Jain (1992), Gentry (1986), Gilpin and Soulé (1986), Nicholson (1954), Odum (1971,1989), and Soulé (1986,1987). For detailed discussions of the relationship between habitat variables and the status and trends of fish populations, readers are referred to the work of the Forest Ecosystem Management Assessment Team (FEMAT 1993), Gregory and Bisson (1997), Hicks et al. (1991), Murphy (1995), National Research Council (1996), Nehlsen et al. (1991), Spence et al. (1996), MBTSG (1998), and any of the numerous additional references contained in this rich body of literature.

The relationship between habitat and populations is embodied in the concept of carrying capacity. The concept of carrying capacity recognizes that a specific area of land or water can support a finite population of a particular species because food and other resources in that area are finite (Odum 1971). By extension, increasing the carrying capacity of an area (that is, increasing the quality or quantity of resources available to a population within that area) increases the number of individuals the area can sustain over time. By the same reasoning, decreasing the carrying capacity of an area (that is, decreasing the quality or quantity of resources available to a population) decreases the number of individuals the area can support over time.

Restoring habitat that has been previously destroyed or degraded can increase the size of a population the habitat can support; conversely, habitat destruction and alteration can reduce the size of a population the habitat can support. In either case, there is a corresponding, but often non-linear, relationship between changes in the quality and quantity of resources available to a species in an area and the number of individuals that area can support.

The approach used in this Opinion is intended to determine whether the proposed action is likely to contribute to restoration or maintenance of properly functioning stream and riparian processes and conditions or to degrade those processes. Ultimately, the Opinion, with respect to unlisted covered species, is intended to determine whether implementation of the proposed FPHCP is likely to decrease the size, number, dynamics, or distribution of unlisted covered species populations in the action area in ways that would appreciably reduce the likelihood of their survival and recovery in the wild.

To accomplish this, the analysis examines specific habitat characteristics that are essential to supporting populations of the covered species. These characteristics have been derived from a synthesis of published reviews on the status and trends of native fish and amphibian species in or near the action area, and must be present to ensure that watersheds and nearshore marine habitats function properly for these native populations. These habitat characteristics include water quality, water quantity, channel conditions, physical barriers to fish migration, and specific habitat variables such as stream temperature, sediment, large wood, nutrients, and refugia (USDA Forest Service et al. 1993; Murphy 1995; Gregory and Bisson 1997). These characteristics, or variables, are relevant to many species considered in this Opinion.

To facilitate an understanding of the likely effects of the proposed action to these species, an overview of the general effects of forest, road, and other management activities on native fish habitats has already been presented (see **General Effects by Resource Topics**). That overview was a synthesis of information from the literature and other sources that discussed how the specific forest practices can change or would change important habitat parameters. The following section addresses specific effects of these management actions with respect to specific habitats in the Habitat Associations so that the general effects can be better related to the individual species. For each Habitat Association, this discussion will address the major effects on those individual habitat parameters most important to the covered species.

7.6.3 Definition of Habitat Associations

Each of the covered species has been categorized into a "guild", mainly according to the habitat characteristics where the species spends most of its life history. Because this categorization is primarily reliant on the habitats used by the species, we refer to these as Habitat Associations. Montgomery and Buffington (1997) provide a useful classification of channel-reach morphology that reflects the relationship between stream morphologies and the relative magnitudes of sediment supply and transport capacity.

It should be noted that many species are placed in a "guild" (e.g., Habitat Association) for discussion purposes, but that during the assessment of effects to those species, the other Habitat Associations used by the species are also considered. These Habitat Associations are described below:

7.6.3.1 Headwater Habitat Association

Species in this Habitat Association are heavily reliant on small headwater streams. These streams include perennial and seasonal streams (Type Np and Type Ns) located beyond the range of fish. Frequently, they are too steep to be accessible to fish, have natural or artificial barriers to fish, or fail to provide suitable fish habitat. These streams may be commonly referred to as "source reaches" for sediment and rock debris from lateral-transport processes adjacent to the streams. Often, these streams will have spatially intermittent reaches of surface and subsurface water.

7.6.3.2 Steep Tributary Habitat Association

The streams that are generally inhabited by species in this guild are typically high-gradient, cold, narrow, confined, nutrient-poor waters, located above most non-forest human influences (e.g., residential, industrial, commercial, and agricultural developments). These may be high-elevation streams and are generally low-order streams. These streams are generally located just below headwater streams and are often the smaller fishbearing (Type F) streams within the stream system. These streams may be comprised of streams known as "transport reaches".

7.6.3.3 Low-Gradient Tributary Habitat Association

The streams in this Habitat Association are not as steep as the steep tributary streams and therefore are often less confined. These may be found in less-dissected watersheds (less steep topographically) or may be found in lower portions of highly dissected watersheds. Low-gradient tributary streams may contain streams that would be called "response reaches."

7.6.3.4 Mainstem Stream and River Habitat Association

These streams and rivers are comprised of lower-gradient reaches. These streams and rivers are often wide and meandering and may be associated with floodplains or channel migration zones. Many of these streams and rivers will be Shorelines of the State (Type S waters).

7.6.3.5 Lentic Habitat Association

This Habitat Association contains a variety of lakes, ponds, wetlands, low-gradient, and low-velocity waters within the action area. These waters are often associated with shallow wetlands and dense aquatic vegetation, but also include large deep lakes.

7.6.3.6 River System Habitat Association

Unless otherwise noted, the species in this guild are found in the Snake and/or Columbia Rivers. In some specific cases, a species may be associated with other large river systems (e.g., Nooksack dace). These fish are almost exclusively associated with the mainstem of these major rivers.

7.6.3.7 Near-shore Marine Habitat Association

This area is generally the shallow portion of the marine environment. These habitats may be shallow "open" water, or may be estuaries. The habitat features contained within or influencing the near-shore marine may include bluffs, beaches, marshes, riparian vegetation, sandflats, mudflats, rock and gravel habitats, non-vegetated subtidal areas, kelp beds, inter-tidal algae, and eelgrass beds. It generally does not include deeper marine waters, but species associated with this Habitat Association may also use deeper water at times.

7.6.4 Species Contained within Habitat Associations

7.6.4.1 Headwater Guild

Amphibian species are grouped as their own guild. Even though their requirements differ from each other to some degree, these species are heavily reliant on headwater streams, and as such are placed in the Headwater Guild. These amphibians include both species of tailed frog, all three species of torrent salamanders, and both species (Van Dykes and Dunn's) of lungless salamanders. At times, we discuss effects according to three groupings: tailed frogs (adults and larvae), torrent salamanders, and lungless salamanders.

This guild includes all of the covered amphibian species: Columbia torrent salamander (*Rhyacotriton kerzeri*), Cascade torrent salamander (*Rhyacotriton cascadae*), Olympic torrent salamander (*Rhyacotriton olympicus*), Dunn's salamander (*Plethodon dunni*), Van Dyke's salamander (*Plethodon vandykei*), Pacific tailed frog (*Ascaphus truei*), and the Rocky Mountain tailed frog (*Ascaphus montanus*).

7.6.4.2 Nearshore Marine Guild

There are no species in this guild. However, we retain the Habitat Association for our analysis because several species associated with other Habitat Associations are also found extensively in the near-shore marine habitats, and therefore we analyze the effects of the FPHCP to these habitats so that those effects may also be considered for those species.

7.6.4.3 Lentic Guilds

Although we differentiated between less-sensitive and more-sensitive species with respect to sediment and temperature, this had little utility in terms of numbers of species except for the Lentic Habitat Association. Yet, even for this Guild, we discuss effects to the entire Habitat Association within this effects analysis. Individual sensitivity of each species is only discussed in detail with respect to temperature and sediment within the sections on **Effects of the Action** for each species.

7.6.5 Exceptions to Guilds

While this analysis is primarily based upon Habitat Associations, a number of species will be associated with more than one Habitat Association. For instance, some lake (Lentic Habitat Association) species spawn in associated streams. Amphibians do not only use stream habitat, but are found in adjacent riparian areas, especially within the splash zone, and in associated sensitive habitats such as side-slope seeps. They may also be found within channels of seasonal streams. The torrent salamanders would be expected to occur along both Type Np and Ns streams. Dunn's and Van Dyke's salamanders are included in the headwater guild along Type Np and Ns streams; however, they would also be expected to occur in riparian areas along Type S and F streams. Juveniles and adults of both of the tailed frog species would be expected to occur primarily along Type Np streams and possibly the upper portions of Type F streams; tadpoles would occur within these streams. The species in this guild also use special habitats, such as seeps, springs, and waterfall splash zones. Some species also use upland habitats periodically, especially during rainy seasons.

These deviations from the groupings will be discussed in the **Status of the Species** section for each such species, and will again be considered when assessing baseline, effects, and cumulative effects on a species-specific basis.

7.6.6 Baseline of Habitat Associations

Many of these streams have been affected by historical logging and road building. Many of the larger streams, lower-elevation streams, lakes, and other waters have experienced effects associated with other land and water uses described in the **Comprehensive Environmental Baseline**. The section below identifies some of the baseline conditions on the covered lands and within the action area.

7.6.6.1 Headwater Streams

These reaches were often affected by landslides, debris torrents, and debris flows. In some extreme cases, such streams were scoured to bedrock leaving little if any habitat. Other streams are not associated with unstable slopes, but were likely subject to several rotations of timber harvest and resulting sedimentation. These streams may not have abundant large wood of considerable size, but often have functional wood loading to meet their requirements for sediment storage and channel morphology due to presence of smaller wood which may function in these channels.

7.6.6.2 Steep Tributaries

These reaches were often affected by landslides, debris torrents, and debris flows. In some extreme cases, such streams were scoured to bedrock leaving little if any habitat structure to support fish. However, in segments with deep alluvial cover and less steep gradients, the post-debris-torrent channel bed is often composed of large cobbles in step-pool channel morphology. Fish movements were likely affected by undersized culverts in many areas. These streams may not have abundant large wood of considerable size, but often have functional wood loading for sediment storage and channel morphology due to presence of smaller wood which may function in these channels and the presence of boulders and other channel roughness features.

7.6.6.3 Low-Gradient Tributaries

These reaches have been affected by a variety of stream-simplification effects. Riparian harvest, large-wood removal, and cedar salvage, have all affected channel complexity. These reaches have also experienced accumulations of coarse and fine sediments, associated with delivery from upstream. Low-gradient tributaries may also have low amounts of large wood. Due to locations on forest lands and away from other land and water uses, many of these streams may currently be in functional condition; but, in some cases, these streams may be still recovering from past timber harvests.

7.6.6.4 Mainstem Streams and Rivers

These are generally larger meandering streams and rivers, often with floodplains or channel migration zones. Many of these streams and rivers have been subject to water-withdrawal, diking, channelization, bank hardening, and flood-control efforts. Historical logging often included splash dams and these streams and rivers also were impacted by activities associated with transportation and removal of large wood. These streams and rivers often lost key pieces, log jams, deep pools, and complex habitat. Additionally, they were often disconnected from off-channel habitats within the floodplain, and from the floodplain itself due to changes in streambed elevation.

7.6.6.5 Lentic Habitats

These habitats are highly variable. Some of these habitats are naturally dynamic, for instance beaver ponds or oxbows and backwaters of larger streams and rivers. Some of these habitats have been created or modified by the construction of dams. In some situations, natural lakes or wetlands were impounded and managed for deeper lakes. Many of these lakes and reservoirs are subject to a variety of effects including changing water depth and loss of natural habitats, shoreline development, reduced water quality, negative effects associated with cooler temperatures as well as warmer temperatures, water withdrawal, water quality, and a variety of effects associated with development, industry, transportation, and recreation on those waters and adjacent shorelines.

7.6.6.6 River Systems

Large river systems such as the Columbia and Snake Rivers suffer from some of the same effects as Mainstem Streams and Rivers, as well as the effects mentioned for larger impoundments. Construction of a series of major dams on both these rivers has had major influence over the character of these waters. Many species are isolated from populations upstream and downstream. Dams affect habitat features both above and below dams. Sediment and wood is no longer passed downstream. Anadromous species no longer supply nutrients to portions of these systems. These habitats have also been subject to introduction of nonnative species.

7.6.6.7 Nearshore Marine

A variety of effects have occurred to nearshore marine areas. Loss of estuaries and coastal wetlands has often been locally severe. Construction of bulkheads and simplification of shoreline habitats has reduced spawning and foraging habitats for many species. These shallow marine waters also suffer from contaminant issues associated with coastal development (commercial and residential), transportation (e.g., oil spills and leakage), and industry.

7.6.7 Effects to Habitat Associations

The **General Effects** section contained earlier in this document forms a basis for the assessment of effects to guilds. Because the foundations in the science and literature for conclusions were presented with respect to fish and fish habitat throughout those discussions, the foundations (including literature citations) are not repeated for each of the guilds. However, because stream-associated amphibians may not have been as fully discussed as the fish throughout each of the relevant topics in the **General Effects** section, the headwater Habitat Association (amphibian) section that follows contains additional details to form the foundations of our conclusions, including literature citations.

7.6.7.1 Headwater Habitat Association

<u>Headwater Habitat Association - Overview</u>

The primary effects of the action, as described in the **Description of the Activities that are Effects of the Permit** section, on the headwater amphibian guild are expected from riparian timber harvest adjacent to Type Np and Ns streams. Secondary effects may result from road construction and maintenance activities. Other activities such as electrofishing related to adaptive-management research may have limited effects as well. Riparian timber harvest along Type Np and Ns streams may have adverse effects on the guild due to the removal of overstory canopy that may in turn increase solar radiation that reaches riparian ground surface areas and adjacent streams, potentially increasing water temperatures. The equipment used to remove timber (e.g., rubber-tired skidders) may cause adverse effects on the guild by causing direct mortality of an amphibian.

Timber harvest may also have adverse effects on the guild by the removal of potential recruitable wood that serves as: (1) habitat for the guild; (2) substrate for aquatic invertebrates that are food sources for the guild; and (3) sediment storage. Adverse effects on the guild may result from increased sediment being transported to streams from adjacent harvested areas and from forest roads that are hydrologically connected to nearby streams (this latter effect is expected to decrease over time under the proposed action and associated road maintenance prescriptions). Sediment may fill interstitial spaces between stream bed cobble and gravel substrate that is important to several members of the guild. Fine sediment may also settle on substrate surfaces where some members of the guild feed on algae.

Changes in Type Np and Ns stream channel morphology may sometimes occur under the proposed action. Equipment operating within the ELZ may affect streambanks and may cause localized changes within the riparian area. Localized portions of the Riparian Zone may experience soil compaction and rutting which would route water into streams more quickly and may also increase soil erosion. Localized changes that may lead to adverse effects on the guild may be experienced in rain-dominated watersheds, particularly in coastal areas of Washington, and in smaller watershed basins (USFWS and NMFS 2006). These localized changes may increase peak flow rates and debris slides in adjacent non-buffered Type Np and Ns channels during storm events. Increased peak flow rates and debris slides as a result of roads may result in stream scouring adversely affecting guild habitat. In reaches where riparian timber harvest occurs and buffers are not retained, the lack of riparian forest adjacent to those streams may reduce the resiliency of these species with respect to effects that may emanate from other processes (e.g., peak flows, sedimentation, and scouring).

Aside from forest roads that may transport sediment to streams, as mentioned above, road construction and particularly culvert and bridge installations may have adverse effects on the guild in that construction efforts may crush or bury some less-mobile members of the guild. These adverse construction effects are short term, from the standpoint of the amphibian population. The long-term beneficial effects of improved roads and stream-crossing structures on guild habitat are acknowledged.

Specific Effects of the Action on the Headwater Guild

The discussion on the effects of the action, as described in the **Description of the Activities that are Effects of the Permit** section, are discussed in terms of three groups within the headwater guild. These three groups are as follows: (1) the torrent salamander group that includes the Columbia torrent salamander, Cascade torrent salamander, and the Olympic torrent salamander; (2) the Plethodon salamander group (whose group name, meaning lungless, was selected from their common genus name) that includes the Dunn's salamander and the Van Dyke's salamander; and (3) the tailed frog group that includes the Pacific tailed-frog and the Rocky Mountain tailed frog.

Effects from Changes in Riparian and Streambank Conditions

Changes in Type Np and Ns riparian and streambank conditions have a high potential to adversely affect the torrent salamander group. As described in more detail in the **Status of the Species** section for these species, they are found primarily in cool-water, stream-margin habitat where the cobble and gravel substrate is moist or water-washed, yet out of the direct fast flow of water in the stream. Waterfall splash zones, seeps, and springs are specialized habitats used by the torrent salamander group. Changes to the overstory canopy through timber harvest may increase solar radiation, thus warming the water in shallow stream margins and reducing the quality of the habitat for the torrent salamander group. Any direct damage to streambank conditions through yarding timber within yarding corridors or from yarding equipment would also have a high potential to have an adverse effect on the stream margin habitat of this group. It is acknowledged that ELZs should minimize the direct damage to streambank conditions.

The changes in conditions from riparian timber harvest, particularly along the non-buffered portions of Type Np and Type Ns streams, have a high potential to adversely affect the Plethodon salamander group. As described in detail in the Status section for these species, they are found primarily in shaded, moist riparian areas and along stream edges. The removal of riparian timber may change the microclimate of these areas by increasing solar radiation that reaches the riparian ground surface and causing greater diurnal fluctuations in surface humidity and moisture (Nordstrom and Milner 1997; Petranka 1998; Ken Risenhoover, Personal Communication, Port Blakely Tree Farms, January 23, 2006). Any direct damage to streambank conditions through yarding timber within yarding corridors or from yarding equipment would also have a high potential to have an adverse effect on the stream margin habitat of this group. It is acknowledged that ELZs should minimize the direct damage to streambank conditions.

The tailed frog group is not as likely to experience adverse effects from changes in riparian and streambank conditions as the torrent and Plethodon salamander groups. As opposed to the torrent and Plethodon salamander groups, whose juveniles and adults use similar habitats, the tailed frog group is discussed here in terms of effects to adults/juveniles and then effects to tadpoles. Adults/juveniles use a range of habitats from instream to riparian areas and, periodically, upland sites for migration and foraging. Because adults/juveniles are quite mobile, changes in overstory riparian conditions are not expected to have significant adverse effects. However, other changes to instream conditions due to riparian timber harvest may have adverse effects, as discussed later on in this section. Tadpoles are not expected to be significantly adversely affected by changes in overstory riparian conditions as they are exclusively found instream. However, as with the adults/juveniles, other changes due to riparian timber harvest may have adverse effects, as discussed later on in this section. The same conclusions are drawn for changes in streambank conditions for the tailed frog group.

Effects from Changes in Wood Recruitment Potential

The torrent salamander group is expected to experience a moderate potential of adverse effects from reduced wood recruitment along Type Np and Ns streams, particularly non-buffered portions of these streams. While the torrent salamander group is not known to depend on riparian or instream wood as a primary habitat element, the presence of adequate wood (i.e., the amount of wood that occurs in streams adjacent to unmanaged forests) plays a role in storing sediment, as substrate for aquatic invertebrate production, and in the maintenance and dynamics of channel morphology, as described in detail in the **General Effects** section under **Aquatic Inputs** and **Wood**. These elements of wood function are important to the torrent salamander group to maintain cool, clear waters with abundant invertebrate production as a source of food. A reduction in wood recruitment would be expected to impair these functions to some degree and adversely affect the torrent salamander group.

A reduction in wood recruitment potential along Type Np and Ns streams is expected to result in a high potential to adversely affect the Plethodon salamander group. A study under the State's Adaptive Management Cooperative Monitoring, Evaluation, and Research committee that is nearing completion has found that both Van Dyke's and Dunn's salamanders utilize downed wood as habitat. Van Dyke's salamanders were found in downed wood more than 75 percent of the time they were captured and preliminary analysis indicates that they seem to differentially use large-sized pieces (i.e., greater than 50 centimeters in diameter) than other sizes of downed wood (Marc Hayes, Personal Communication, Washington Department of Fish and Wildlife, January 26, 2006). More investigation is needed to determine how the availability of large-sized, downed wood pieces relates to Van Dyke's salamander occurrence.

The tailed frog group is expected to experience a moderate potential of adverse effects in buffered portions of Type Np streams due to reduced wood recruitment potential from a no-harvest buffer width of only 50 feet that would not encompass all the potentially recruitable wood to riparian and instream areas used by tailed frogs. There is a high potential for adverse effects in the non-buffered portions of Type Np and Ns streams, as all potentially recruitable wood is subject to harvest. The reduction or complete removal of potentially recruitable wood adversely affects the tailed frog group because recruited wood serves to store sediment as described in detail in the **General Effects** section under **Aquatic Inputs and Wood.** As shown in Dupuis and Steventon (1999) and Ashton et al. (2005), increased sediment input may be the most-important factor behind tailed frog population declines. Further discussion on the effects of sediment on the tailed frog group is provided in the next section, Effects from Changes in Sediment Inputs.

Effects from Changes in Sediment Inputs

The effects of increased sediment inputs following timber harvest are expected to have a moderate potential of adversely affecting the torrent salamander group. These effects would be more likely in non-buffered portions of Type Np and Ns streams than in buffered portions of Type Np streams because buffers would likely provide more recruitable instream wood and organic material that would serve to filter and trap sediment more effectively than non-buffered streams. Increased sedimentation is suspected to reduce habitat quality for torrent salamanders by filling interstitial spaces in stream substrate that impairs movement, egg deposition, and larval development (Corn and Bury 1989; Diller and Wallace 1996; Nordstrom 1997). However, available research is inconclusive and geology, substrate, and stream gradient may override sediment levels. Regardless, sedimentation is considered to have a moderate potential of adversely affecting the torrent salamander group. Increased sediment inputs from hydrologically connected forest roads or from road construction across Type Np and Ns streams would also have the potential to adversely affect the torrent salamander group.

There is a low potential of adversely affecting the Plethodon salamander group from increased instream sedimentation following timber harvest in either buffered or non-buffered portions of Type Np and Ns streams. This is because the Plethodon salamander group is a riparian associate and not an instream associate and is thus not expected to be significantly affected by instream sedimentation.

The tailed frog group has a high potential of being adversely affected by increased sediment inputs into Type Np and Ns streams following timber harvest. These effects would be more pronounced in non-buffered portions of Type Np and Ns streams than in buffered portions of Type Np streams because buffers would likely provide more filtering and trapping of sediment than non-buffered streams. Several studies have indicated that increased sediment levels may result in negative effects on tailed frog adults, juveniles, and tadpoles. Bury and Corn (1988) found that tailed frogs were sensitive to increased levels of fine sediment that filled interstitial spaces and reduced instream refugia. Another study indicated a negative association between tailed frog presence and the increasing percentage of fine sediments and increasing amounts of substrate embeddedness (Diller and Wallace 1999). The density of tailed frogs also was lower in substrates with greater than 40 percent embeddedness (Hawkins et al. 1988). Tailed frog tadpoles are expected to be especially sensitive to increased sedimentation following clearcutting, particularly in non-buffered portions of Type Np streams and also from the Type Ns downstream effects, as they cannot adhere as well to rocks that are coated with fine sediment with their sucker-like mouth that is used to cling to instream rocks and scrape food (i.e., algae) off the rocks (Jackson et al. 2003). Increased sediment levels may also reduce the availability of algae and other foods that the tadpoles feed on (Welsh and Ollivier 1998). Dupuis and Steventon (1999) and Ashton et al. (2005) suggest that increased sediment inputs may be the most-important factor behind tailed frog population declines following timber harvest. Riparian buffers would help to ameliorate the effects of timber harvest on tailed frogs.

Effects from Changes in Shade on Stream Temperatures

As described in detail in the Status section for these species, the torrent salamander group is found in stream margins and in other specialized habitats (e.g., seeps, waterfall splash zones) with permanent, cold flowing water and they are among the most desiccation-intolerant salamander genera known. Because of the type of habitat they use and their dependence on constant moisture contact with their skin, the torrent salamander group would have a moderate potential of being adversely affected by reductions in shade and thus increases in stream temperatures following timber harvest in non-buffered portions of Type Np and

Ns streams. In contrast, the potential of adverse effects in buffered portions of Type Np streams is expected to be low as much of the potential shade to streams is expected to be provided by the 50-foot no-harvest buffers. These buffers should reduce the likelihood of significant increases in stream temperatures, thus maintaining moist microclimates in the stream margins.

The Plethodon salamander group is found in moist sites in riparian areas, streambanks, and other wet sites, as described in the Status sections for these species. Riparian buffers would be expected to maintain stable, moist microsites more so than non-buffered riparian areas. However, because the Plethodon group is a riparian associate and not an instream associate, changes in stream temperatures would have a low potential of adversely affecting the Plethodon group.

Reductions in shade that result in increased stream temperatures, along non-buffered portions of Type Np and Ns streams, would have a moderate to high potential to adversely affect the tailed frog group. As described in the Status section for these species, tadpoles (exclusively) and juveniles and adults (at times) are found in cold, fast-flowing waters of headwater streams. Increases in stream temperatures would be expected to adversely affect the habitat of the tailed frog group. This conclusion is supported by Hawkins et al. (1988) that found tailed frogs in streams less than 18 degrees C and absent in streams near or above 20 degrees C. Diller and Wallace (1999) also found a negative association between tailed frog presence and increased water temperatures. The potential for adverse effects in buffered portions of Type Np streams would be low as stream temperatures are not expected to be significantly affected with the presence of a 50-foot no-harvest buffer.

Effects from Changes in Hydrology and Channel Responses

The potential for adverse effects is expected to be low to moderate for all species in the headwater guild. Changes in hydrology and thus channel responses (in the form of peak and debris flow increases) are expected to be localized in rain-dominated or rain-on-snow zones, particularly in the smallest of basins. Changes in hydrology and channel responses from timber harvest are not expected to be widespread. The Plethodon group would likely be affected the least by peak and debris flow increases as they are a riparian associate; the tailed frog group is found in fast-flowing waters and also is not expected to be susceptible to these increases except in extreme events; finally the torrent salamander group that is found along stream margins would likely be impacted the most by increasing peak and debris flows as these changes could scour these local areas and potentially cause mortality of individuals.

Effects from Electrofishing, Culvert/Bridge Work, and Heavy Equipment Use

Adverse effects in the form of stress, wounding, or mortality from electrofishing, related to adaptive-management research and stream typing to determine the extent of fish habitat, may occur with the torrent salamander group and the tailed frog group that are associated with instream and stream margin habitats where electrofishing would be used. Culvert and bridge maintenance and installation could have adverse effects (stress or mortality) on all species of the headwater guild in that these activities potentially affect instream and riparian habitats. Instream, heavy equipment use could have adverse effects (stress or mortality) on the torrent salamander group and the tailed frog group; heavy equipment use for harvesting timber in riparian areas could have adverse effects (mortality) on the Plethodon salamander group.

7.6.7.2 Steep Tributary Habitat Association

Riparian and Bank Condition

Effects to these small Type F streams are difficult to measure or quantify. Where effects do occur they are expected to be localized in nature. Effects to fish-bearing streams are also possible where distribution of fish is underestimated (see Headwater Streams). In these cases where fish distribution is underestimated, the narrower buffers left on Type Np streams (in comparison to Type F streams) may be more likely to be subject to some windthrow. Beyond the first 300 to 500 feet upstream from the confluence with a Type F stream, ground-based equipment may be more likely to be used in proximity to the stream where buffers are not retained than if Type F buffers were retained, which may result in some soil compaction, effects to interstitial spaces within the soil, and potentially collapsed banks in some cases. However, along properly classified Type F streams, riparian and bank condition would be expected to be retained, with occasional small openings for yarding corridors.

Wood

Where distribution of fish is underestimated in small streams, wood recruitment may be reduced as a result of non-buffered segments or segments with 50-foot buffers, but wood should still be delivered from within-rotation suppression mortality as these streams have low-energy and smaller wood may function in sediment storage and channel morphology. However, to the extent that large pieces of wood are necessary, there may currently be a degraded baseline with a possible low potential for near-term recruitment. When mature timber is available along such Type Np streams, it could be reduced in some reaches as a result of riparian timber harvest along streams misclassified as streams without fish. Portions of these streams will receive buffers, including special sites, alluvial fans, and sensitive site at the confluence of Type F and Np streams, and these areas will provide about half to most of the potential recruitment, depending on geographic area, forest vegetative zone, and management option. Other reaches may be left unbuffered during harvests which would result in removal of potential large wood recruitment.

Streams in steep topography may have wood delivered with debris flows. Recruitment of wood may be reduced as a result of riparian timber harvest in that episodic debris flows (emanating from above Type Np streams) may not incorporate as much wood from Type Np riparian areas as they otherwise might have prior to harvest. Debris flows naturally deliver wood in a sporadic and uneven pattern. Wood would be expected to accumulate at tributary junctions, abrupt channel direction changes, and low-gradient reaches. At these points, the accumulations of wood may be somewhat reduced due to the riparian harvest along portions of Type Np streams. Regarding Type F stream buffers, key-piece wood would continue to be recruited to the channel from near-bank sources and is expected to be more-evenly distributed than wood from episodic sources. When debris flows deliver to Type F streams, incremental changes in amount of large wood may influence sediment storage and routing at these depositional sites as well as pool formation and other changes in channel morphology.

Hydrology

As a result of riparian timber harvest, low base flows may be somewhat improved or remain unchanged where harvest occurs upslope. Exceptions may include some small streams in the coastal fog-drip zone. Peak flows may be influenced during small peak flow events, or to a minor degree at moderate peak flows. Peak flows may occur sooner and may be somewhat larger as a result of the road network, resulting in some incremental increase in stream dynamics and redd scour.

Sediment

Sediment delivered directly through the Riparian Zone of Type F streams and 50-foot no-harvest buffers is expected to be negligible, except where the distribution of fish may be underestimated by more than 300 to 500 feet. In those cases, sediment input may be somewhat higher where equipment operation occurs within the ELZ. Sediment delivery at road crossings and stream-adjacent parallel roads may occur and may be locally heavy. In smaller streams, inputs of sediment from roads may be proportionally high compared to stream size and may overwhelm the ability of smaller streams to route sediment.

Due to the limited strength of flows in small streams, sediment may enter interstitial spaces and be stored over a period of time from one to several years. On larger tributaries, sediment residence time may be shorter due to the ability of these streams to transport sediment. Some sediment from upstream may be stored in low-gradient reaches, eddies, and backwater areas. Sediment may settle into substrate during low flows, but would be resuspended during subsequent increases in flows.

Detritus

Where the distribution of fish is underestimated by more than 300 to 500 feet, detritus inputs may be affected by harvest in non-buffered reaches. This may reduce the year-round inputs (e.g., from conifer needles and other plant parts), but would increase the quality of detritus in coming years during recovery of harvested areas. Canopy openings would provide for off-setting primary production within the stream for a short period of time (several years to a decade).

On larger steep tributaries, detritus input may decrease from upstream headwater streams following harvest along headwater streams (Type Np). This also may slightly reduce year-round inputs (conifer needles) while slightly increasing the quality of detritus in short term. Organic matter transported from above may change somewhat in response to changes following upstream harvest, including a change in macroinvertebrate composition reflecting change in leaf input and increase in primary production

Shade / Temperature

Where distribution of fish is underestimated, some streams with fish may be treated as Type Np streams. Where fish distribution is underestimated by more than 300 to 500 feet, effects from lack of shade may be locally severe for the short term (2 to 7 years) following adjacent riparian timber harvest in non-buffered reaches. Species found in this Habitat Association (e.g., coastal cutthroat trout, shorthead sculpin, Dolly Varden trout) are generally temperature sensitive and increases in water temperature may be detrimental. In some cases, stream velocities will be sufficiently swift through harvested sections, banks will be steep, and alluvium may be present so that stream warming is less likely to occur. However, where stream velocities are slower, the channel is composed of bedrock, and banks or vegetation do not provide much shade, water temperature may be adversely affected especially during the middle of the day, for a number of days during the late spring and summer months. Diurnal fluctuations are expected as nighttime temperatures will likely be as cool as or cooler than in buffered reaches, especially in bedrock channels.

In some cases, portions of steep tributaries may be affected by upslope harvest. When streams flow through harvested areas, they may have some potential to warm or cool downstream areas. Delivery of warmed waters is more likely to occur in landscapes where debris flows are not common and there is little interchange between surface waters and groundwater. However, it may be likely in situations where debris flows have scoured stream beds down to the bedrock. A major factor in ability of headwater streams to warm and their ability to cool as they travel through downstream shaded reaches appears to be the condition of the channel substrate. A bedrock channel will have less hydraulic retention time, less mixing, and less heat exchange with the substrate than a stream with a gravel bed.

Streams of significant discharge and velocity are less likely to warm while passing though a harvest unit; conversely, streams with low discharge may warm but would have less ability to affect temperature of downstream receiving waters. Streams of moderate discharge, but still contributing substantial discharge relative to downstream fish-bearing receiving waters, would be relatively uncommon. But such a stream may have some potential to alter temperature regimes within receiving waters. Such a change could occur through a small amount of warming when received by a cooler fishbearing stream, or a slightly dampened cooling effect when received by warmer fishbearing water. In addition, two headwater streams that combine to form a small fishbearing stream would have some potential to influence the temperature regime of the downstream receiving water, especially if they both flowed through a recently harvested area.

Steep-tributary fish may also be exposed to some thermal effects when fish distribution is underestimated. This may reduce or eliminate the distance between fish and unbuffered reaches normally provided by the sensitive site at the confluence of Type F and Np streams of 300 to 500 feet. The potential for Type Np streams to delivery excessively warm or cold water is more likely to be realized when the intervening sensitive site at the confluence of Type F and Np streams is not functioning as intended; perhaps due to previous harvests (e.g., over the last several decades); natural events such as windthrow, fire, or debris flows having denuded the adjacent riparian zones; or other land uses. It is possible that Type Np streams under forest practices jurisdiction could directly enter into reaches under alternate land uses just prior to joining with fish-bearing waters. In these cases, however, the level of degradation to stream temperatures caused by timber harvest will likely be overwhelmed by the impacts associated with the other land uses. It should be noted that not all harvests will occur adjacent to the sensitive site at the confluence of Type F and Np streams. In most cases, harvests would occur further up the stream network allowing for additional time and distance over which stream temperatures would equilibrate to normal levels.

Some stream velocities will be sufficiently swift through harvested sections so that stream warming is less likely to occur. However, where stream velocities are slower, water temperature within the Type Np streams may be warmed during the middle of the day, especially for a number of days during the late spring and summer months. These low-discharge streams will have a reduced ability to alter receiving waters. The substrate controls many aspects of the heat budget. Streams with alluvium are expected to heat more slowly in the open sun and cool more quickly in the shade than bedrock channels. Bedrock streams of moderate discharge in areas with low levels of groundwater interchange are a subject of concern. Yet a number of factors moderate this concern. Diurnal fluctuations are expected as nighttime temperatures may in some cases be cooler in unbuffered reaches than in buffered reaches. In other cases, minimum temperatures may remain unchanged even where maximum temperatures are increased as these two temperature parameters (daytime highs and nighttime lows) result from different heat budgets. Where long travel times are involved, water mixing may modify peaks and troughs in temperature and will provide additional opportunities for heat exchange with substrate and hyporheic zone, equilibration with air temperature, long-wave radiation, and groundwater inputs. On landscapes where mixing with groundwater is common, the overwhelming influence of groundwater may negate these concerns about downstream thermal effects. Additionally, in a number of cases, low flows in harvested reaches will be increased due to enhanced groundwater inputs following harvest. Harvest generally removes a significant source of water loss from evapo-transpiration and may increase the amount of cool groundwater entering the headwater stream.

However, where thermal recovery does not completely occur prior to the confluence with a Type F stream, thermal refugia at the tributary junction may suffer from reduced effectiveness for a period of several years or more until shading of the upstream harvested reach recovers. Some steep-tributary fish such as shorthead sculpin and Dolly Varden trout may depend on such thermal refugia during hot summer periods.

In larger steep tributaries (e.g., properly classified Type F streams), stream temperature changes from activities within the buffers of westside Type F streams are expected to be small to negligible. On the eastside, the risk of stream temperature increase is low within the Bull Trout Overlay. Some additional probability of effects (e.g., moderate risk) may occur to eastside Type F streams which are not within the Bull Trout Overlay. Substantial portions of eastern Washington are outside the Bull Trout Overlay, but would continue to receive a 30-foot Core Zone, as well as an additional 50 to 120 trees per acre retained depending on the vegetative zone and existing stand density. The degree of shading and protection from stream warming is somewhat less certain along these small eastside streams outside the Bull Trout Overlay.

Another concern is abnormal cooling of streams that may contribute to direct mortality and injury, or to habitat degradation and loss, from icing. Headwater streams flowing though harvest units may cool excessively, and may contribute to negative effects during the winter. These effects, should they occur, would be geographically limited to high elevation areas and to eastside streams, and would likely be influenced to only a moderate degree by riparian timber harvest under the proposed FPHCP.

Channel / Habitat Responses

Where extent of fish distribution is underestimated by over 300 to 500 feet, streambanks within the ELZ may be subject to heavy equipment use. Streams may become simplified and banks flattened, reducing cover for these species. In some cases, banks may be collapsed due to heavy equipment.

As mentioned earlier under effects to large wood, reduced delivery of wood could occur as a result of debris flows that pass through unbuffered Type Np streams. Minor changes in pools and sediment routing may be expected where differences in wood delivery from upstream are able to influence wood-pool relationships. In many cases, areas of accumulation will already exceed levels at which the stream will respond to additional wood. In some cases, channel morphology may be affected at and immediately below such delivery sites.

Sediment transported from upstream may alter water quality to some degree. Road-generated sediment may be proportionally high in these small steep streams and interstitial spaces within stream substrate may become filled and may remain filled until flushing flows occur. This may occur rapidly in some locations, or may take several years in low-flow backwater portions of these streams.

7.6.7.3 Low-Gradient Tributary Habitat Association

Riparian and Bank Condition

Adverse effects to riparian and bank condition are not expected, with the exception of small openings for occasional yarding corridors.

Wood

Recruitment of wood may be reduced in that episodic debris flows emanating from upstream of harvested Type Np stream reaches may not incorporate as much wood from Type Np riparian areas as they otherwise might have prior to harvest. These debris flows would deliver wood in a sporadic and uneven pattern. Such delivery to low-gradient tributaries is only likely in locations where one geomorphic province intersects another. The effects would be similar to that seen in the Steep Tributary Habitat Association, but would be less frequent.

Hydrology

Low base flows may be somewhat improved where harvest occurs upslope. Exceptions may include some small streams within the coastal fog-drip zone. Peak flows may be influenced during small peak flow events, and to a minor degree at moderate peak flows. As a result of roads, peak flows may occur sooner and may have somewhat higher discharge.

Sediment

Sediment delivered through the Riparian Zone is expected to be negligible; however, as discussed for previous Habitat Associations, sediment delivery at road crossings and stream-adjacent parallel roads may occur and may be locally heavy. Sediment residence time may be longer than in steep tributaries because low-gradient tributary streams are likely to be response reaches. Sediment from upstream may be stored in these low-gradient reaches. The upper end of low-gradient tributaries may be an initial site of deposition, with gradual movement through the system over the course of several to many years. Some sediment may settle into substrate during low flows, but would be resuspended during subsequent increases in flows. Sediment may alter channel morphology by altering bank erosion, braiding, aggradation, and avulsions. However, the proposed FPHCP would continue to reduce the amount of sediment introduced into the stream system from anthropogenic sources from the current high level in the baseline.

Detritus

Detritus input may decrease from upstream headwater streams following harvest. This may slightly reduce year-round inputs (conifer needles); but may slightly increase quality of detritus in the short term. Organic matter transported from above may change somewhat in response to changes following upstream harvest, including a change in macroinvertebrate composition reflecting change in leaf input and increase in primary production.

Shade / Temperature

Temperature effects from removal of shading along near-bank areas are expected to be negligible. Effects from upstream unshaded reaches are similar to that expected for Steep Tributary Streams. However, many low-gradient tributary streams will naturally be warmer than steep tributaries. In some cases, where landscape gradients change from steep to moderate, groundwater upwelling sites may occur and the areas downstream may be marked by cool stream temperatures. In other areas, low-gradient tributaries may be susceptible to warming due to their naturally higher surface area to volume ratio, as well as trend toward less influence of shade with increasing stream width. Effects of sedimentation discussed earlier may exacerbate this situation, causing filling of pools and degradation of banks, and having the overall effect of making the stream wide and shallow. However, these effects would only be expected to occur following major events such as mass-wasting events, road failures, accelerated streambank erosion, or upstream channel incision. Beaver ponds may both warm the water contained within them, as well as cool the downstream flow through recharge and downstream release of groundwater. Beaver ponds would also help stabilize summer low flows, thus ameliorating temperature peaks. Low-gradient tributaries on the eastside, outside of the Bull Trout Overlay, may have some reduction in shade that could influence stream temperatures, but these streams would still receive the 30-foot Core Zone, and 50 to 120 trees per acre depending on vegetative type and stand density.

Channel / Habitat Responses

Changes in pools may be expected where sediment is sufficient to fill pools. Small changes in the sediment regime (e.g., inputs related to riparian timber harvest) are unlikely to have this level of response. Changes in large-wood loading are also unlikely to have this level of response. Mass-wasting events, road failures, accelerated streambank erosion, and upstream channel incision may produce enough sediment to fill pools and change channel morphology. Bedload movement and instability may result when more sediment is imported than the stream can transport. Positive feedback can occur as when increased sediment input causes shallowing, which in turn reduces hydraulic energy and induces more deposition.

7.6.7.4 Mainstem Stream and River Habitat Association

Riparian and Bank Condition

Adverse effects to near-bank riparian and bank condition are not expected due to presence of the Core Zone and the low likelihood of yarding across mainstem streams and rivers.

Wood

As mentioned earlier, harvests along some Type Np streams may result in less wood delivered with debris flows and eventually less wood may reach Mainstem streams and rivers by flotation. To a small degree, this may decrease the number of wood pieces available for contribution to aggregates. Key-piece wood would come from near-bank areas and wood transported from upstream would be aggregated into log jams at close to natural rates. Potential recruitment of large wood from near-bank areas would remain in the recovery phase along many streams and rivers; but, in many other areas, large wood from near-bank areas would be contributing to improvement of the instream baseline by contributing key-piece-size wood.

Hydrology

No changes would be observed in low or high flows, or average annual yield as a result of riparian timber harvest. The FWS also does not expect to see measurable changes as a result of road-system management under the proposed FPHCP.

Sediment

Sediment delivered through the Riparian Zone is expected to be negligible. Sediment delivery at road crossings may occur and may be locally heavy, but quickly transported in most situations, and would only comprise a small portion of natural load of the river. Some small amount of sediment from upstream forested areas may be stored in low-gradient reaches, eddies, and backwater areas. This may be especially true when sediment delivery occurs to floodplains and off-channel habitats during flood events.

While sediment may alter channel morphology by altering bank erosion, braiding, aggradation, and avulsions; the relative contribution of sediment load in Mainstem Streams and Rivers as a result of FPHCP is expected to be very low. FPHCP would continue to reduce the amount of sediment introduced into the stream system from anthropogenic sources from the current high level in the baseline.

Detritus

Negligible (if any) changes are expected as a result of the proposed FPHCP.

Shade / Temperature

Temperature effects from shading along near-bank areas are expected to be negligible, as are most temperature effects from upstream harvested areas. In some cases, at tributary junctions, the effectiveness of thermal refugia may be decreased as a result of upstream harvest and may persist for several years until shade levels recover. Larger streams and rivers tend to be diurnally more variable in temperature fluctuations and slightly warmer on average than headwater streams. Large streams are less affected by riparian shade.

Channel / Habitat Responses

Changes in pools may be expected where sediment is sufficient to fill pools. Bedload movement and instability may result when more sediment is imported than the stream or river can transport. However, the relative contribution of sediment load in Mainstem Streams and Rivers as a result of FPHCP is expected to be very low.

7.6.7.5 Lentic Habitat Association

Riparian and Bank Condition

Changes in near-bank riparian condition and bank condition are not expected to result from the proposed FPHCP.

Wood

Essentially no change in wood delivery is expected from either near-bank or upstream sources. An exception may be where Lentic habitats occur immediately downstream of headwater streams. See the discussion regarding decreased wood delivery from unbuffered Type Np streams as discussed in **Steep Tributary Habitat Association – Wood.**

Hydrology

No change would be observed in low or high flows, or average annual yield as a result of timber harvest. Where smaller Lentic habitats occur immediately below headwater streams, small changes to moderate peak flows may occur or as a result of road-system management.

Sediment

Sediment delivered through the Riparian Zone is expected to be negligible; however, sediment delivery at road crossings may occur and may be locally heavy. Some sediment from upstream forested areas may be delivered to lakes, beaver ponds, and other low-gradient reaches. This may be especially true when sediment delivery occurs to floodplains and off-channel habitats during flood events. While these areas naturally accumulate such sediments, FPHCP could potentially accelerate such accumulation and exacerbate sediment-habitat problems in some local situations. However, road-related BMPs and completion of RMAPs should help reduce sediment delivery to streams and should benefit these habitats. The relative contribution of sediment load in large lakes as a result of FPHCP is expected to be very low. The contribution to smaller Lentic habitats located higher in the watershed (e.g., beaver ponds) could be proportionately larger. Even though individual actions under the FPHCP may locally contribute sediment for short periods of time, FWS expects implementation of the FPHCP at the landscape level would continue to reduce the amount of sediment introduced into the stream system from anthropogenic sources from the current high level in the baseline.

Detritus

Negligible (if any) changes are expected.

Shade / Temperature

Temperature effects from shading along near-bank areas, as well as from upstream unshaded areas, are expected to be negligible. Lentic habitats are generally wide and only a small portion of their surface may be shaded. The FPHCP is expected to provide near maximum levels of shade along Type F and S waters, and is expected to provide shade along nonforested wetlands. Some effects from harvest of forested wetlands may occur.

Channel / Habitat Responses

The degree to which the FPHCP could affect processes within large lakes is extremely limited. Smaller low-gradient streams, ponds, and other backwater habitats may be affected by accumulation of fine sediments in excess of natural levels, but such conditions are expected to generally improve under the proposed FPHCP.

7.6.7.6 River System Habitat Association

Riparian and Bank Condition

No adverse effects to near-bank riparian and streambank condition are expected.

Wood

No change in wood delivery expected from either near-bank or upstream. Potential recruitment of large wood from near-bank areas would remain in recovery phase along many rivers; but, in many other areas, would be contributing to improvement of the instream baseline by contributing key-piece-size wood. Due to the presence of dams, much of the large wood traveling down the rivers would not continue to lower reaches.

Hydrology

No change would be observed in low or high flows, or average annual yield. Flow would be primarily dictated by dams in many cases.

Sediment

Sediment delivered through the Riparian Zone is expected to be negligible. Sediment delivery at road crossings is not likely to result from the proposed FPHCP as road crossings of these rivers would be major Washington Department of Transportation or county projects and would generally not involve forest landowners. Any sediment delivered from forest lands would only comprise a small portion of the natural load of the river. Some sediment from upstream forested areas may be stored within reservoirs but would be unlikely to be routed downstream. The relative contribution of sediment load in these major river systems as a result of FPHCP is expected to be negligible.

Detritus

No changes are expected as a result of the FPHCP.

Shade / Temperature

Temperature effects from shading along near-bank areas, as well as from upstream unshaded areas, are expected to be negligible. These rivers as so wide that riparian vegetation will not influence the river's water temperature. Thermal refugia from small streams entering these rivers should generally be maintained by the FPHCP when FPHCP lands exist within proximity of these larger rivers; however, in some cases, short-term reductions in the effectiveness of thermal refugia at tributary junctions may occur as a result of upstream timber harvest along Type Np streams.

Channel / Habitat Responses

The degree to which the FPHCP could affect channel forming and habitat creating and reducing processes is negligible.

7.6.7.7 Near-shore Marine Habitat Association

Riparian and Bank Condition

Type S buffers are expected to adequately address banks, bluffs, beaches, and other shorelines of marine waters.

Wood

No change in wood delivery is expected from either near-bank or upstream, except where steep topographic areas are found adjacent to marine waters and debris-flow delivery of large wood may be slightly reduced either to beaches or estuaries indirectly through Type Np streams feeding estuaries. FWS expects no change to "key piece" wood delivered to beaches and expects large wood to continue acting as a stabilizing force.

Hydrology

Low base flows may be somewhat improved where harvest occurs upslope of estuarine waters. However, in some cases, low flows in small coastal streams may be reduced due to a decrease in fog drip following timber harvest. Peak flows may be influenced during small peak flows, or to a minor degree at moderate peak flows where harvest occurs upslope of estuarine waters. Some changes in peak flows may result from roads in small drainages that provide water to estuaries. No changes are expected to the degree that the distribution or concentration of brackish water would be effected. Penetration of salt wedge upstream into lower reaches of rivers would not be altered. Tidal processes and freshwater seepage would be unaffected.

Sediment

Sediment delivered through near-shore riparian areas is expected to be negligible as a result of the FPHCP. Sediment delivery at road crossings may occur and may be locally heavy where roads cross streams near estuaries. Some sediment from upstream forested areas may be delivered to estuaries; this may be especially true during flood events. While these areas may naturally accumulate such sediments, forest practices could, in some local situations, contribute sediment and exacerbate sediment-habitat problems. However, implementation of FPHCP at the landscape level would reduce such sedimentation from existing baseline levels. The relative contribution of sediment load in marine waters (outside estuaries) as a result of FPHCP is expected to be very low. FPHCP would continue to reduce the amount of sediment introduced into the stream system from anthropogenic sources from the current high level in the baseline. Delivery of coarse sediment and sediment of sand-sized particles may be important to many near-shore environments.

Detritus

Negligible (if any) changes are expected.

Shade / Temperature

Temperature effects from shading along near-bank areas (such as beaches and bluffs), as well as from upstream unshaded areas, are expected to be negligible as a result of the proposed FPHCP.

Channel / Habitat Responses

The degree to which the FPHCP could affect processes within near-shore marine areas is extremely limited. Large wood would continue to be provided from near-shore areas as described earlier. Some of the benefit from large wood being recruited into major rivers may not be realized in estuary and marine areas as large wood in major rivers and marine transportation channels may be removed to aid navigation.

7.6.8 Cumulative Effects to Habitat Associations

There are additional cumulative effects anticipated on lands covered by the FPHCP since not all commercial forestry activities anticipated by landowners are evaluated in this Opinion. Some of the activities conducted as "covered activities" under the FPHCP would not be altered as result of permit issuance and therefore are addressed as cumulative effects. In addition, covered lands are subject to uses by other people with and without the permission of landowners. Lastly, lands and waters within the action area will likely be subject to activities that will affect waters within the action area. Cumulative effects were summarized in the **Comprehensive Cumulative Effects** section

Cumulative effects may occur in the action area on lands adjacent to FPHCP lands. FPHCP lands are interspersed with lands managed for a wide variety of purposes by many different landowners. The majority of forested lands adjacent to FPHCP lands are managed principally for commercial timber and / or other forest amenities. However, Federal, tribal, and HCP forests are either already part of the environmental baseline or subject to future Section 7 consultation and are therefore not considered to be cumulative effects for purposes of this consultation. Other activities such as grazing, mining, recreation, agriculture, and residential development also occur on adjacent lands. These types of activities were described in the **Comprehensive Cumulative Effects**. Below is a brief synopsis of the major considerations regarding cumulative effects.

Changes in land use and population expansion are likely to occur in the action area. Conversion of forest lands to residential, urban, or industrial uses could potentially degrade or fragment fish and wildlife habitat. Many lands in the action area that were historically managed for timber production are now being converted into residential, commercial, and industrial developments. It is reasonable to assume that some of the forested areas that provide fish and wildlife habitat, especially riparian corridors in valleys and low-lying areas near metropolitan areas and major transportation corridors, will eventually be converted to these land uses. Urbanization can create a lasting effect on streams through increases in impervious surfaces, loss of riparian vegetation, alterations in stream-channel configuration, and changes in water quality through urban runoff and effluents.

Further, over the 50-year permit period, population expansion is expected to continue. It is likely that acts that could negatively affect native fish species, such as introduction (i.e., illegal private action) and/or establishment of non-native fish species, or poaching of native fish species, will continue to occur. Some native fish are subject to various fishing seasons. Recreational fishing occurs in streams, lakes, rivers, and marine waters. Subsistence fishing most often occurs in rivers and marine waters. Commercial fishing occurs in marine waters. See **Comprehensive Cumulative Effects** for additional information.

The potential magnitude of cumulative effects varies across the action area, depending on the land-ownership pattern. Sub-basins with a high percentage of either FPHCP, other forest HCP, or Federal ownership have lower potential for cumulative effects than areas with low percentage of HCP and Federal land. This is because the Northwest Forest Plan, PACFISH, and INFISH management strategies for Federal lands, and completed forest HCPs provide numerous measures to reduce adverse effects to fish and are generally not subject to other land and water uses. Completed forest HCPs are considered part of the environmental baseline. Areas with high percentages of Federal lands are expected to have fewer cumulative effects since most actions on Federal lands are subject to future section 7 consultations, and areas with high percentages of Federal land have correspondingly smaller percentages of other ownerships.

In general, streams and species located higher in the watershed may be relatively less affected by cumulative effects. Streams located higher in watersheds will likely be affected by recreation and other forest uses. Streams lower in watersheds will integrate the actions and effects above them, and will be subject to effects emanating from a variety of land uses, including agriculture, commerce, industry, and residential development, as well as flood-control and water withdrawals. The challenges faced by species that depend on lower reaches and lower-elevation streams may be more severe than those that are found higher in watersheds and in higher elevation areas away from such development. The FPHCP appears to have the greatest effects on those habitats and species least affected by cumulative effects.