Chapter 3

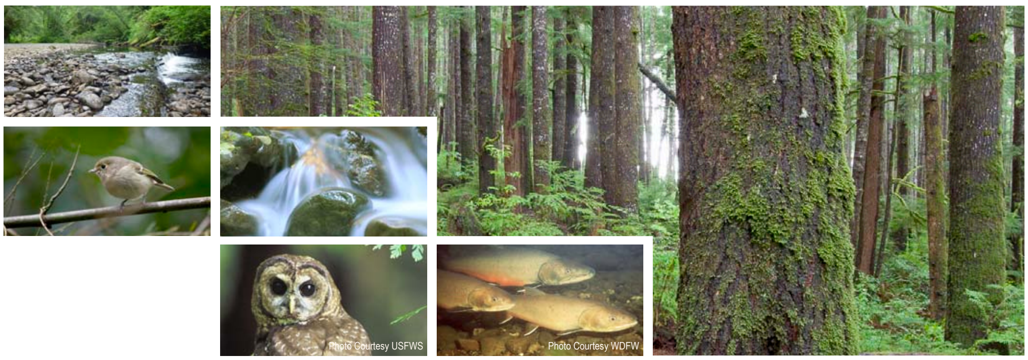
Environmental Analysis

In This Chapter

This page intentionally left blank.

Chapter 3

Environmental Analysis



This chapter contains information about the affected environment, the environmental analysis approach, the harvest schedule analyzed, and the potential environmental impacts of the alternatives being considered. “Forest Conditions and Management” covers the forest as a whole. Individual topics such as “Water Quality” and “Northern Spotted Owls” are covered in separate sections.

Affected Environment

■ Physical Attributes and Vegetation Zones

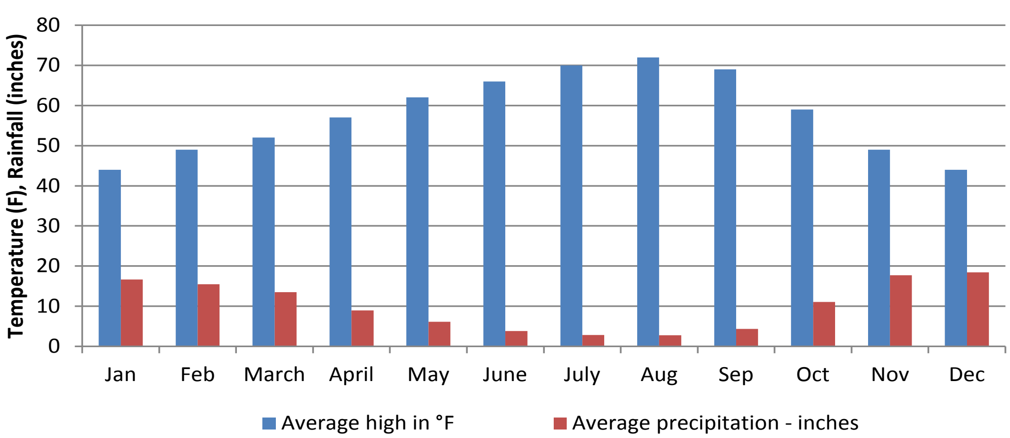
Located on the western Olympic Peninsula, the OESF is a primarily forested area that ranges in elevation from 0 to 7,952 feet. Major vegetation zones[1] on state trust lands in the OESF include western hemlock (43 percent of state trust lands), Sitka spruce (33 percent of state trust lands), and Pacific silver fir (24 percent of state trust lands) (refer to Map 3-1 on p. 3-2).

■ Climate

Seasonal rainfall of between 80 to 180 inches per year is a notable climatic feature of the OESF. The climate is maritime (strongly influenced by the Pacific Ocean) with relatively dry summers and significant precipitation during the winter. Most precipitation falls as rain (refer to Chart 3-1).

Map 3-1. Vegetation Zones in the OESF

Chart 3-1. Average Monthly Temperature and Rainfall for Forks, Washington



Fire

Fire occurrence on the Olympic Peninsula is closely tied to climate and climatic history. Some periods have had many stand-replacing fires, other periods have had none, and still others may have had high fire frequency but low fire severity.

Past fire patterns are correlated with vegetation zones. An analysis of reconstructed fire patterns on the Olympic Peninsula shows that, during the last 340 years, only 30 percent of the Pacific silver fir or mountain hemlock zones burned, while 128 percent of the western hemlock zone burned (some areas more than once) (Henderson and others 1989). The fire return interval (time between fires) for the Sitka spruce zone was 900 years; mountain hemlock, 844 years; Pacific silver fir, 629 years; western hemlock, 234 years; and subalpine fir, 208 years (Henderson and others 1989).

Wind

Wind is the most prevalent natural disturbance regime in coastal Sitka spruce forests and in higher Pacific silver fir and alpine forests, where moist conditions generally limit fire spread (Agee 1993). In the last century, hurricane-force winds have hit the coast every 20 years on average. The historical record shows 14 storms of hurricane-force winds on the coast in the past 200 years; two storms had winds in excess of 150 miles per hour (Henderson and others 1989, Mass 2008). For example, the hurricane-force winds of the Great Olympic Blowdown on January 29, 1921 (the "21 Blow") felled an estimated 20 percent of the timber along the entire coastline of the Olympic Peninsula—eight times more timber than was felled by the 1980 eruption of Mount St. Helens (Mass 2005). The Columbus Day Storm (October 12, 1962) was one of the most damaging to hit the Pacific Northwest. Hurricane-force winds along the coast blew down an estimated 15 billion board feet of timber in Washington and Oregon (Mass 2005). And the Inauguration Day windstorm of January 20, 1993 brought winds over 80 miles per hour to the Washington coast and winds over 100 miles per hour to exposed sites in the coastal mountains and the Cascades (Mass 2005).

Rivers and Streams

Major river systems that run through the OESF are shown on Map 3-2. According to DNR's GIS database, there are 10,730 miles of streams in the OESF, 2,785 miles of which are located on state trust lands (Table 3-1). Steep, erodible terrain and heavy annual precipitation promote an abundance of small streams (Type 4 and Type 5 streams).[2] Stream density (reported as miles of stream per square mile of land area) is particularly high in U-shaped glacial valleys such as the Hoh, Bogachiel, and Sol Duc drainages.

Map 3-2. Major River Systems in the OESF

Table 3-1. Stream Length (Miles) by Ownership in the OESF

Water type	Stream miles						
	DNR	Other state	Federal	Municipal	Tribal	Private[a]	Total
1	138	7	192	0	29	347	714
2	50	1	47	0	61	118	277
3	450	1	104	1	89	726	1,370
4	389	0	91	1	109	521	1,111
5	1,712	3	2,060	1	486	1,812	6,073
9[b]	46	0	895	0	121	123	1,185
TOTAL	**2,785**	**12**	**3,388**	**2**	**895**	**3,648**	**10,730**

[a]Includes industrial forestland, agricultural lands, and residential, industrial, and commercial lands.

[b]Water type unknown, refer to Section Note 2.

Wetlands

Wetlands are found in the coastal lowlands and valley bottoms of the major river systems in the OESF, including the lower Queets, Clearwater, Kalaloch, Hoh, Mosquito, Goodman, Bogachiel, Quillayute, Dickey, and Ozette rivers and their tributaries. Bogs, a special type of wetland that accumulates peat, are generally rare across Washington but are found in the OESF because of its geological and glacial history. Table 3-2 shows the estimated extent of wetlands in each watershed administrative unit in the OESF that has greater than 20 percent state trust lands (refer to "Administrative Designations" in this section for a description of watershed administrative units).

Table 3-2. Estimated Extent of Wetlands in Each OESF Watershed Administrative Unit

Watershed administrative unit	Acres	Percent of state trust lands as wetlands
Bogachiel	112	1.0%
Cedar	66	1.5%
Clallam River	217	2.1%
East Fork Dickey	318	2.8%
Goodman Mosquito	141	1.1%
Hoko	94	0.8%
Kalaloch Ridge	12	0.2%
Lower Clearwater	179	0.9%
Lower Dickey	173	2.2%
Lower Hoh River	383	5.0%
Lower Queets River	461	2.9%
Middle Hoh	596	1.5%
Quillayute River	132	1.8%
Sol Duc Lowlands	220	4.8%
Sol Duc Valley	262	1.8%
Upper Clearwater	226	0.4%
TOTAL	**3,592**	**<1%**

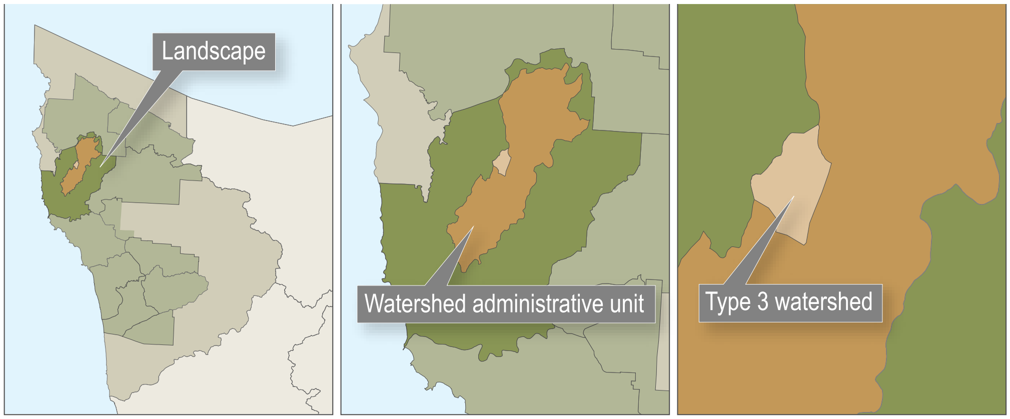
Administrative Designations

Spatial Scales Used in the OESF

DNR uses three different spatial scales to plan and manage state trust lands in the OESF. In descending order of size, these scales are landscapes, watershed administrative units, and Type 3 watersheds.[3] Each scale is defined primarily along hydrologic boundaries. The scales are illustrated in Figure 3-1.

Figure 3-1. Spatial Scales Used to Plan and Manage State Trust Lands in the OESF

For illustrative purposes only. Type 3 watershed boundaries often do not coincide with watershed administrative boundaries.



Landscape

To assist in planning and managing state trust lands in the OESF, DNR divided the OESF into 11 administrative areas called landscapes (refer to Map 3-3 on p. 3-7). Table 3-3 shows the total number of acres of state trust lands in each landscape. Totals in Table 3-3 exclude acres of non-forested areas such as administrative sites, roads, and water bodies.

Table 3-3. Landscapes in the OESF

Landscape	Acres of state trust lands	Landscape	Acres of state trust lands
Clallam	17,276	Queets	20,807
Clearwater	55,203	Reade Hill	8,479
Coppermine	19,246	Sekiu	10,014
Dickodochtedar	28,047	Sol Duc	19,146
Goodman	23,799	Willy Huel	37,428
Kalaloch	18,122		
TOTAL (All Landscapes)			**257,566**

Watershed Administrative Unit

As established by WAC 222-22-020, Washington is divided into watershed administrative units. The boundaries of these units are based on hydrology and geomorphology and were defined by DNR in cooperation with Ecology, Washington Department of Fish and Wildlife (WDFW), affected tribes, local governments, forest landowners, and the public. The boundaries are mainly located along drainage divides (ridges), with some located along rivers and other DNR management boundaries.

There are 31 watershed administrative units in the OESF. Only watershed administrative units containing at least 20 percent state trust lands by area (refer to Table 3-4 on p.

Map 3-3. Landscapes in the OESF

3-8) were selected for analysis in this FEIS. Twenty percent is the minimum ownership threshold at which DNR believes its management practices influence the environmental conditions of a watershed.[4] Of the 31 watershed administrative units, 16 exceed this threshold. Collectively, these 16 watershed administrative units represent approximately 90 percent, or 232,038 acres, of state trust lands in the OESF. The watershed administrative unit scale has been used in other DNR documents and deemed appropriate for an environmental analysis (DNR 2004, 2010). Totals in Table 3-4 exclude acres of non-forested areas such as administrative sites, roads, and water bodies. Watershed administrative units are shown on Map 3-4.

Table 3-4. Watershed Administrative Units With Greater Than 20 Percent State Trust Lands by Area

Watershed administrative unit	Acres of state trust lands	Watershed administrative unit	Acres of state trust lands
Bogachiel	11,267	Lower Dickey	7,377
Cedar	4,208	Lower Hoh River	7,120
Clallam River	10,161	Lower Queets River	14,961
East Fork Dickey	10,975	Middle Hoh	37,289
Goodman Mosquito	13,449	Quillayute River	6,187
Hoko	10,636	Sol Duc Lowlands	4,448
Kalaloch Ridge	5,753	Sol Duc Valley	13,481
Lower Clearwater	19,815	Upper Clearwater	54,911
TOTAL (All watershed administrative units)			232,038

Map 3-4. Watershed Administrative Units in the OESF

Type 3 Watershed

DNR also uses a smaller unit called a Type 3 watershed (refer to Map 3-5). There are 601 Type 3 watersheds in the OESF; of those, 427 contain greater than 20 percent state trust lands by area.[4] The riparian analysis examines potential environmental impacts at the Type 3 watershed scale.[5]

Map 3-5. Type 3 Watersheds in the OESF

Analysis Approach

Understanding This Analysis

In this FEIS, DNR analyzed the potential environmental impacts of the proposed forest land plan, which is a non-project action under SEPA. Non-project actions include the adoption of plans, policies, programs, or regulations that contain standards controlling the use of the environment, or that regulate or guide future on-the-ground actions (WAC 197-11-704(2)(b)). Non-project actions do not include design of specific activities. For example, the proposed forest land plan will include management strategies and other information that will affect how forest management activities will be planned and implemented in the OESF to meet DNR's policy objectives (refer to Chapter 2 for a detailed description of the alternatives), but will not include specific information, such as engineering drawings for a specific section of roadway, for the activities themselves.

Because the forest land plan is a non-project action, DNR did not analyze the potential environmental impacts of site-specific management activities such as individual timber sales or the construction of specific sections of roads. Those potential impacts are analyzed at the time they are proposed, at the operational stage of planning.

Instead, in this FEIS DNR analyzed long-term ecological changes across state trust lands in the OESF that may result from implementing each alternative over time. For example:

- How will each alternative affect riparian conditions across state trust lands in the OESF? Will riparian conditions improve, stay the same, or worsen over time?
- Over time and across the OESF, how will each alternative affect overall forest health, soil conditions, or the ability of state trust lands in the OESF to sequester more carbon than is released through harvest?

DNR used a 100-year analysis period because this period is long enough to identify potential long-term changes to the environment.

In this chapter, DNR analyzed potential environmental impacts of the proposed alternatives on state trust lands. Chapter 4 includes a discussion on the potential impacts of the alternatives in the context of potential impacts from past, present, and reasonably foreseeable future activities on lands in the OESF managed by other landowners.

What Topic Areas Does This Analysis Include?

In this FEIS, DNR analyzed forest conditions, soils, riparian areas, water quality, fish, wildlife habitat, northern spotted owl habitat, and climate change.

Criteria and Indicators

To analyze each topic, DNR used **criteria and indicators**. Criteria are broad concepts, such as forest health or functioning riparian habitat. Indicators are the means by which the criteria are measured. For example, the indicator stand density (crowding of forest stands) was used to measure the criterion forest health, and the indicator stream shade was used to measure the criterion functioning riparian habitat. Each criterion may have one or more indicators. This approach was based on the Montréal Process, which was established to advance the development of internationally agreed-upon criteria and indicators for the conservation and sustainable management of temperate and boreal forests (Montréal Process 1995).

DNR used its expertise, existing scientific information, and available data to select the criteria and indicators that would best describe the potential environmental impacts of the alternatives. Each topic area (such as "Northern Spotted Owls") has its own criteria and indicators.

Overlapping Indicators

Forests are complex, interrelated natural systems. Few indicators apply to only one topic in this FEIS; many overlap. DNR analyzed each overlapping indicator in the section to which it most logically applied. Stream shade, for example, was analyzed in "Riparian." Subsequent sections which used these indicators, such as "Water Quality," include a brief summary of the indicator and additional information about that indicator specific to the topic being discussed.

Additional indicators could have been used to evaluate the criteria. However, DNR used its expertise to determine which indicators were best to use with the scientific data that is currently available from Ecology, USFS, DNR, and other sources. DNR believes that the selected indicators are sufficient to understand how the criteria are affected.

■ How Did DNR Analyze the Indicators?

To analyze the indicators for the No Action and Landscape alternatives, DNR used the quantitative approach described in the following section. To analyze the indicators for the Pathways Alternative, DNR used a primarily qualitative approach, which is described at the end of this section. DNR performed all analysis using the best available scientific information and techniques.[6]

No Action and Landscape Alternatives

ANALYSIS TOOLS

To analyze each indicator for the No Action and Landscape alternatives, DNR used a forest estate model referred to in this FEIS as the "analysis model." DNR used the same analysis model for each draft of this document (DEIS, RDEIS, and FEIS). Forest estate models are powerful, computer-based tools that enable DNR to consider the entire land base at once to help find efficient and effective ways to balance multiple objectives over multiple decades.

To deepen its understanding of certain topic areas, DNR also developed other computer-based models for northern spotted owl territories and habitat and each riparian indicator.

DNR developed each of these models using data from the analysis model and other information. These computer models are described under their respective topics in this chapter.

How Does the Analysis Model Work?

The analysis model was built with information on current conditions, management objectives, management activities, an understanding of natural growth processes and how forests respond to management activities, and the unique attributes of each alternative (No Action and Landscape). By simultaneously considering all of this information, the analysis model developed an "optimal solution" for each alternative of which forest stands to harvest, when, and by what method and which stands to retain across all state trust lands in the OESF over 10 decades to meet DNR's policy objectives.

The model's optimal solution was expressed as a harvest schedule, which is a list of the model's recommendations for the type, timing, and location of harvests on state trust lands over time to meet DNR's policy objectives. The model also projected the forest conditions that may result from implementing the harvest schedule; that projection was expressed as a "state-of-the-forest file." The state-of-the-forest file included a wealth of detailed information such as tree height, diameter, and species, reported in decade intervals. The model produced a separate harvest schedule and a state-of-the-forest file for each alternative (No Action and Landscape).

DNR used both model outputs to develop this analysis. DNR used the harvest schedule to understand the intensity of harvest recommended by the model under each alternative. DNR used the state-of-the-forest file as well as other models to understand trends of change in forest ecosystems, such as an increase or decrease in the risk to forest health posed by overcrowded forest stands, that may result from implementing the harvest schedule. These long-term changes were the basis of DNR's impact ratings for most indicators.

Developing the Analysis Model

In the analysis model, DNR categorized all DNR-managed lands in the OESF as "operable," "deferred," or "partially deferred."

- Operable areas were available to the model for both thinning and variable retention harvest.
- Partially deferred areas were available to the model for thinning only.
- Deferred areas were not available to the model for thinning or variable retention harvest.

This categorization was necessary to produce a harvest schedule representative of each alternative as well as all current policies and management practices. For simplicity, DNR used only two terms in this FEIS: operable, which includes the partially deferred areas, and deferred.

Areas deferred in the analysis model included the following:

- **Old growth forests and other areas** deferred by current DNR policies.

- **Permanent deferrals,** which include natural resources conservation areas and natural area preserves. Permanent deferrals were included in acreage totals used throughout this FEIS because these areas contribute to DNR's ecological objectives.
- **Potentially unstable slopes or landforms,** which were identified using a slope stability model. DNR has guidance from both the forest practices rules and the HCP on preventing an increase in the frequency and severity of landslides.
- **Northern spotted owl habitat.** Northern spotted owl habitat will be managed in the OESF per the northern spotted owl conservation strategy, which involves restoring and maintaining threshold proportions of habitat in each of the 11 landscapes of the OESF. DNR deferred existing habitat in the model on a short- or long-term basis to represent this strategy in the model.
- Other areas as necessary to represent other HCP conservation strategies in the model.
- Forest stands that are inoperable or of such low commercial value that the cost of harvest would exceed potential revenue.

The total number of acres deferred in the analysis model is 110,832 acres, or 43 percent of DNR-managed lands in the OESF. Table 3-5 shows the number of acres in each landscape categorized as deferred and operable in the analysis model.

Table 3-5. Deferred and Operable Acres in Each Landscape in the OESF

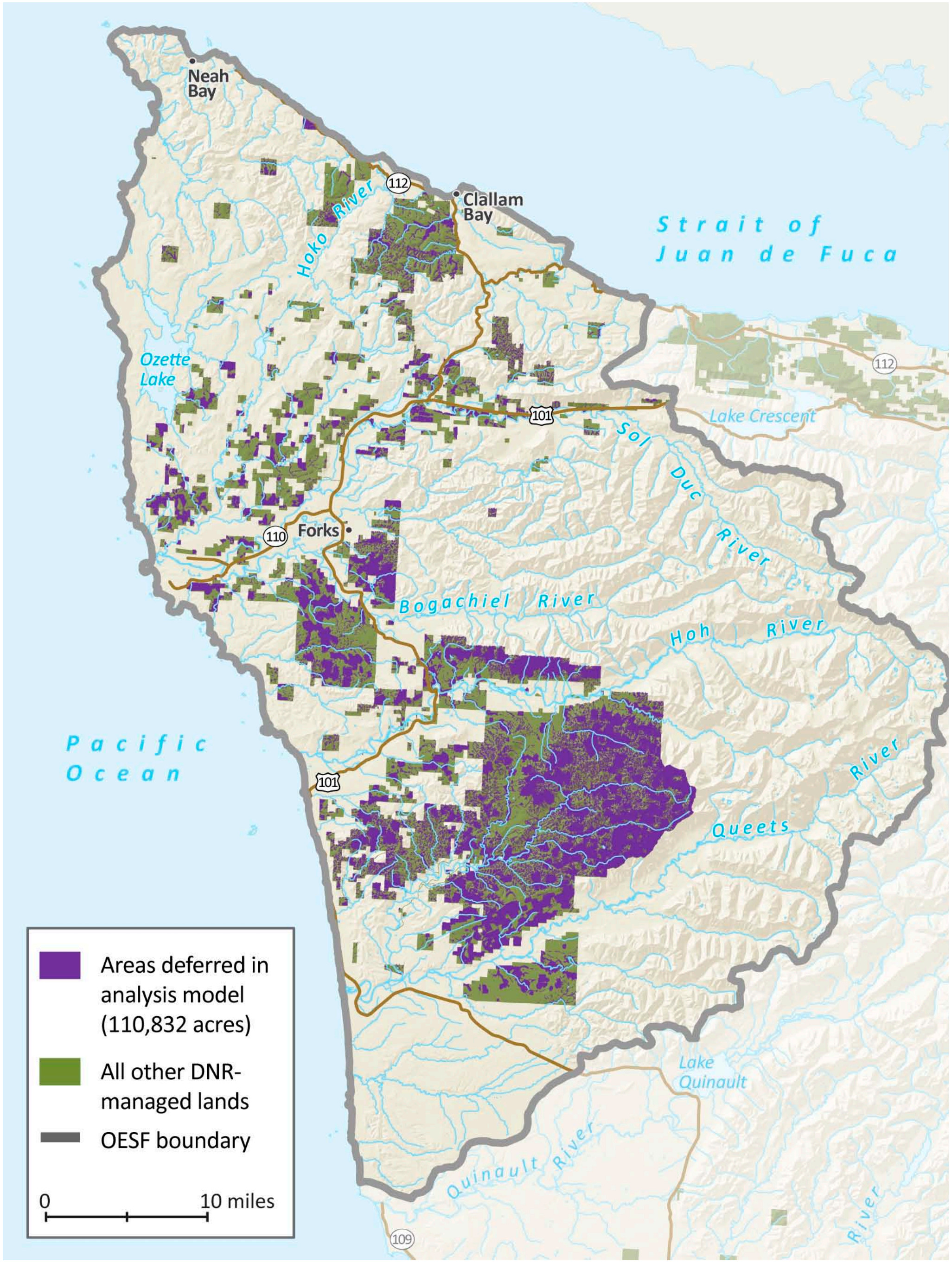
Landscape	Deferred	Operable[a]	TOTAL
Clallam	3,684 (21%)	13,592 (79%)	17,276
Clearwater	32,179 (58%)	23,024 (42%)	55,203
Coppermine	9,000 (47%)	10,246 (53%)	19,246
Dickodochtedar	8,294 (30%)	19,753 (70%)	28,047
Goodman	9,763 (41%)	14,036 (59%)	23,799
Kalaloch	7,973 (44%)	10,149 (56%)	18,122
Queets	9,245 (44%)	11,562 (56%)	20,807
Reade Hill	4,396 (52%)	4,083 (48%)	8,479
Sekiu	1,804 (18%)	8,210 (82%)	10,014
Sol Duc	5,781 (30%)	13,365 (70%)	19,146
Willy Huel	18,714 (50%)	18,714 (50%)	37,428
All landscapes	**110,832 (43%)**	**146,734 (57%)**	**257,566**

[a]Includes partially deferred areas

Totals in Table 3-5 and all subsequent tables do *not* include acres of non-forested areas such as administrative sites, roads, or water bodies. For the purposes of this analysis, DNR assumed that non-forested areas do not contribute to either revenue or ecological objectives and therefore excluded those acres from totals used throughout this analysis.

Map 3-6 shows the location of areas that were deferred in the analysis model. Note that these areas are not located in large, contiguous blocks.

Map 3-6. Areas Deferred in the Analysis Model



Analysis Model not Required to Meet Current Sustainable Harvest or Funding Levels

In developing its optimal solution (expressed as a harvest schedule) for each alternative, the analysis model was not required to meet the current sustainable harvest level or any other specific harvest level. The analysis model also was not required to meet current DNR funding levels. As a result, the harvest level that resulted from this modeling exercise was, for both the No Action and Landscape alternatives, higher than the current sustainable harvest level of 576 million board feet for the decade and higher than DNR can implement with current funding.

DNR made these decisions for the following reasons:

- DNR believed it was inappropriate to constrain the analysis model to the current sustainable harvest level, since that level currently is being recalculated. It also was inappropriate to constrain the analysis model to a future sustainable harvest level that has not been determined.
- The forest land plan will remain in effect until replaced by a subsequent planning effort. It is not possible to predict how harvest or funding levels will change over the multiple decades this plan may be implemented.

For these reasons, DNR felt that allowing the analysis model to schedule harvest without a harvest or funding level constraint was a reasonable approach to this modeling exercise.

DNR is not proposing the harvest level analyzed in this FEIS as a new sustainable harvest level for the OESF. The forest land plan is not tied to any specific level. Nor does DNR change policies, such as the sustainable harvest level, through the forest land planning process. **DNR will continue to implement the current sustainable harvest level (576 million board feet for the decade) until the new level is selected through the sustainable harvest calculation process.**

Additional information about the harvest level analyzed is presented later in this chapter. For information on the advantages and caveats of using a model for an environmental analysis, refer to Chapter 4 of this FEIS.

ANALYSIS PROCESS

To analyze indicators for the No Action and Landscape Alternatives, DNR used a two-step process.

Step 1: Assign Potential low, Medium, or High Impact Ratings

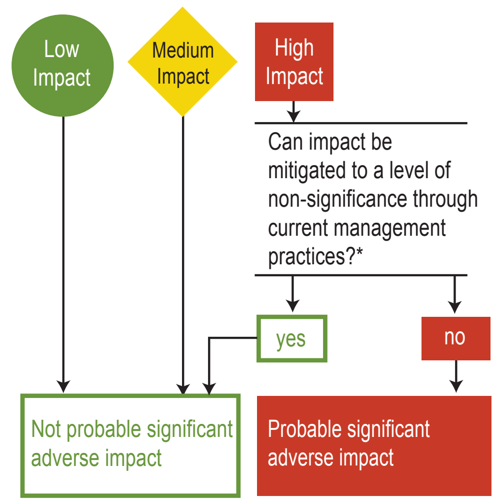
Using analysis model outputs, DNR first quantified potential environmental impacts for each indicator as low, medium, or high using parameters defined for each indicator. The exact meaning of each term (low, medium, high) was specific to each indicator. For example, some low and medium impacts are potentially beneficial (an improvement in conditions), while others are potentially adverse but not significant. For this analysis, only potential high impacts were considered potentially significant impacts.

DNR first assigned potential low, medium, or high impact ratings by analyzing management activities *exactly* as they were modeled or mapped, without considering current management practices that are expected to mitigate potential high impacts. For example, DNR first analyzed potential impacts from roads based on a straightforward assessment of the mapped size and location of the road network. In this step, DNR assumed that all roads that have not been certified as abandoned[7] can contribute sediment to streams, even though some of these roads have been mitigated already or will be mitigated in the future through current management practices to prevent the delivery of sediment from roads to stream channels (mitigation of the road network through current management practices is discussed in "Water Quality" on p. 123). Mitigation was not considered until the second step of DNR's analysis process.

Step 2: Determining if Impacts are Probable Significant Adverse

In this step, DNR considered the full range of its current management practices to identify specific programs, rules, procedures, or other measures that are expected to mitigate a potential high impact to a level of non-significance. If an impact will be mitigated, it was not considered probable significant adverse (refer to Figure 3-2). For each indicator, DNR described the specific management practice(s) that will be used to mitigate a potential high impact. DNR also determined if a potential high impact is significant based on the role the indicator plays in ecological function.

Figure 3-2. Determining Impacts for Each Indicator



*DNR may also consider the indicator's role in ecological function to determine significance

For each topic, DNR provided a detailed explanation of how each indicator was measured; the thresholds used to measure it; the specific meaning of low, medium and high in the context of that indicator; the mitigation that applies to that indicator; and the final determination of whether the impact is a probable significant adverse impact. To assist the reader, DNR used color-coded symbols in tables throughout this FEIS. A green circle indicates a potential low impact, a yellow diamond indicates a potential medium impact, and a red square indicates a potential high impact.

WHAT SPATIAL SCALES DID DNR USE TO ANALYZE THE INDICATORS?

To identify potential environmental impacts, DNR first analyzed each indicator at the spatial scale that it considered most meaningful. For example, peak flow (an indicator for functioning riparian habitat) was analyzed at the scale of the Type 3 watershed, while stand development stages (an indicator of forest structural complexity) was analyzed at the scale of each of the 11 landscapes. Scales were selected based on existing literature, available data, and professional judgment. In some cases, multiple scales were used to provide a more comprehensive understanding of potential impacts. DNR then considered potential environmental impacts for each indicator at the scale of all state trust lands in the OESF. Table 3-6 lists the scales used for each topic.

WHAT ABOUT NATURAL DISTURBANCE?

In this FEIS, DNR did not analyze the potential environmental impacts of stochastic (random), large-scale natural disturbances such as major fires or windstorms because DNR cannot predict or model the local likelihood of these disturbances. In addition, DNR cannot model future, site-specific, small-scale natural disturbance events as it is impossible to predict their location or severity. Instead, these smaller natural disturbances

Table 3-6. Scale of Analysis by Topic

Topic	Scale of analysis
Forest Conditions and Management	State trust lands in the OESF, landscape; results at watershed administrative unit and Type 3 watershed scale are presented in Appendix E
Riparian	State trust lands in the OESF, Type 3 watershed, stream reach
Soils	State trust lands in the OESF, Landscape, watershed administrative unit
Water Quality	State trust lands in the OESF, Landscape, Type 3 watershed
Fish	State trust lands in the OESF, Type 3 watershed, stream reach
Wildlife	State trust lands in the OESF
Northern Spotted Owls	State trust lands in the OESF, landscape
Climate	State trust lands in the OESF

were accounted for within the analysis model in a generalized fashion in the growth and mortality estimates for trees within forest stands over time.

Natural disturbances such as fire, windthrow, naturally occurring landslides, and other events can lead to openings in forests, loss of standing volume, alterations in the shape and depth of streams, and other changes. DNR does not imply that all changes in forest ecosystems are negative, nor does DNR imply that management activities are the only source of disturbance in the forest. Naturally occurring disturbance and change are part of a forest's natural life cycle.

A NOTE ON DECADES USED IN THIS ANALYSIS

DNR based this environmental analysis on a 100-year analysis period to more fully understand potential long-term impacts. Decade zero began in 2011. The end of the analysis period is therefore 2111.

Decades used in the HCP have an earlier starting date and therefore do not correlate exactly with the decades used in this analysis.

Pathways Alternative

DNR did not run the analysis model for the Pathways Alternative because of this alternative's similarity to the Landscape Alternative. The only difference between the Landscape and Pathways alternatives is that, under the Pathways Alternative, DNR will apply management pathways to each landscape (refer to Chapter 2 for a description of the pathways). In all other respects, these alternatives are the same. Because of these similarities, and because the total number of acres affected by pathways is anticipated to be relatively small, DNR expects that the harvest schedule the analysis model would produce for the Pathways Alternative (if the model was run) would not differ substantially from that of the Landscape Alternative.

Because of these similarities between the Landscape and Pathways Alternatives, for most indicators DNR qualitatively assessed whether potential impacts identified under the Landscape Alternative would be the same, lower, or higher under the Pathways Alternative. For example, for the indicator "forest health" in "Forest Conditions and Management," DNR qualitatively assessed how the trends in stand density identified under the Landscape Alternative would differ under the Pathways Alternative. DNR then determined if those differences were enough to shift the assessed impact from low to medium or high.

For the indicator "number of acres of modeled northern spotted owl habitat" in "Northern Spotted Owls," DNR completed a quantitative analysis similar to that conducted for the No Action and Landscape alternatives. For this analysis, DNR estimated a range in how much northern spotted habitat each landscape may have in each decade of the 100-year analysis period. These ranges were developed in a post process (outside the analysis model) and used for this indicator only. Refer to "Northern Spotted Owls" on p. 189 and Appendix A for more information.

■ Harvest Schedule Analyzed

The harvest schedule analyzed in this FEIS represents a harvest level that is higher than the current sustainable harvest level of 576 million board feet for the decade, and higher than DNR can implement with current funding. DNR is not proposing the harvest level analyzed in this FEIS as a new sustainable harvest level for the OESF. Refer to "Analysis Model not Required to Meet Current Sustainable Harvest or Funding Levels" earlier in this chapter for more information.

Following, DNR describes the harvest schedule produced by the analysis model for the No Action and Landscape alternatives. (DNR did not run the analysis model for the Pathways Alternative.) DNR provides information about the total area harvested, number of forest stand entries, acres of harvest per decade, harvest methods, and harvest volumes. The information in this section is provided to help readers compare the No Action and Landscape alternatives.

Projected Harvest Area

As explained under "Deferred and Operable Areas" earlier in this chapter, in the analysis model DNR categorized 146,734 acres (57 percent) of DNR-managed lands in the OESF as operable. However, within the operable area, the total number of acres on which the analysis model recommended harvest activities is different under each alternative due to the procedures and management strategies that are unique to each alternative. Under the Landscape Alternative, the projected harvest area, or harvest footprint, is 141,321 acres according to model results. Under the No Action Alternative, the projected harvest area is 138,948 acres.

Projected Acres Harvested per Decade

Table 3-7 shows the projected number of acres of harvest under each alternative during each decade, per the model's recommendations. With the exception of Decade 1 and 6, in each decade more acres are projected for harvest under the Landscape Alternative than under the No Action Alternative. Note that acres overlap between the decades: acres harvested in one decade may be harvested again in a subsequent decade.

Table 3-7. Projected Acres of Harvest per Decade Under Each Alternative

Decade	No Action Alternative	Landscape Alternative
1	31,466	30,568
2	22,878	26,843
3	28,473	31,468
4	35,722	38,049
5	38,077	48,293
6	45,935	44,676
7	38,665	40,382
8	39,565	46,895
9	43,000	49,220
10	25,963	26,098

Projected Number of Forest Stand Entries

Each harvest of a forest stand, whether that harvest is a variable density thinning or a variable retention harvest, is called a forest stand entry. For example, a forest stand that is not harvested at all during the 100-year analysis period has no forest stand entries. A forest stand that receives two thinning harvests and a variable retention harvest over 100 years has three forest stand entries.

The analysis model recommended more frequent forest stand entries under the Landscape Alternative than under the No Action Alternative. For example, under the Landscape Alternative, nearly 12,000 more acres are projected to receive three or more forest stand entries than under the No Action Alternative (for more information on forest stand entries, refer to "Forest Conditions and Management" on p. 3-23).

Projected Harvest Methods

Charts 3-2 and 3-3 on p. 3-20 show the projected number of acres of variable retention harvest and variable density thinning under each alternative. Considering all decades together, the analysis model recommended 15 percent more acres of variable density thinning and 8 percent more acres of variable retention harvest under the Landscape Alternative than it did under the No Action Alternative.

Chart 3-2. Projected Acres of Variable Density Thinning Under the No Action and Landscape Alternatives, by Decade

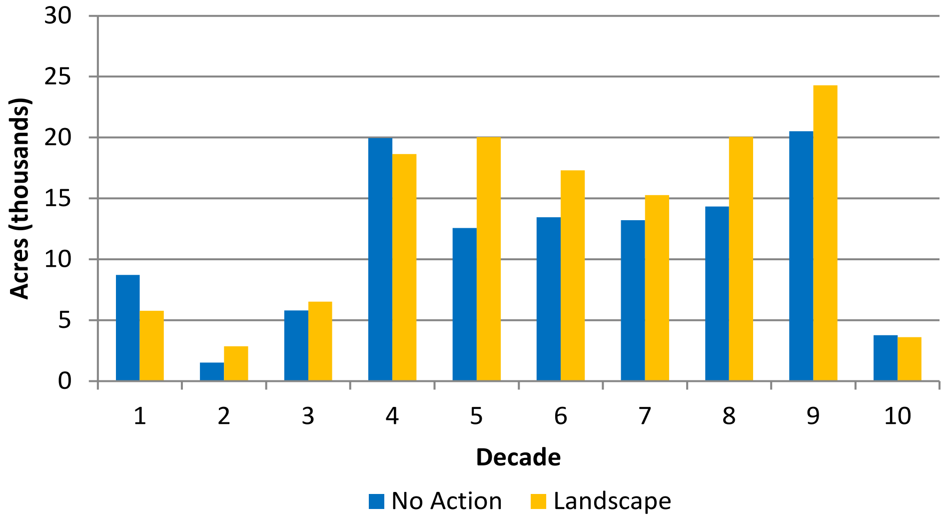
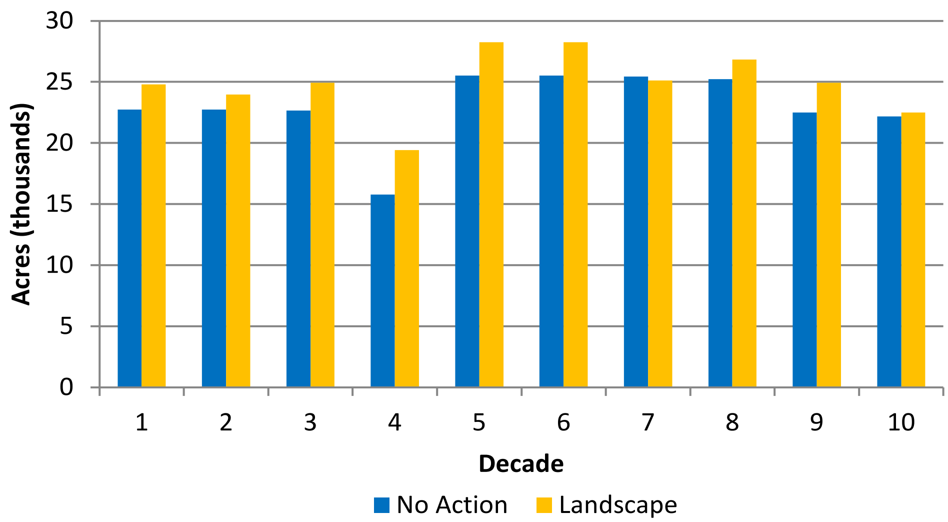


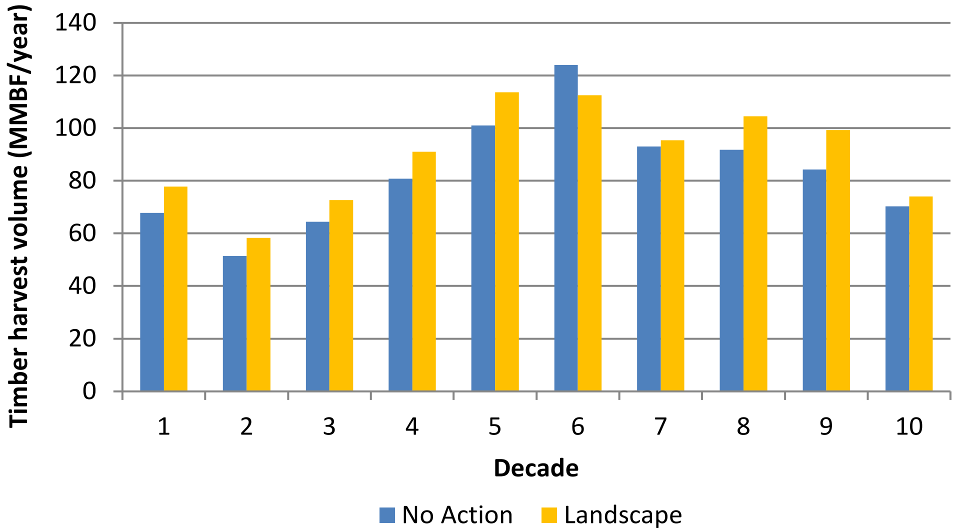
Chart 3-3. Projected Acres of Variable Retention Harvest Under the No Action and Landscape Alternatives, by Decade



Projected Harvest Volume

Chart 3-4 shows the projected harvest volume under each alternative. As explained previously, these harvest volumes are an output of the analysis model, which was not constrained to the current sustainable harvest level. As a reminder, DNR is not proposing to change the current sustainable harvest level through this planning process.

Chart 3-4. Projected Timber Harvest Volume (Millions Board Feet per Year [MMBF]) Under Each Alternative, by Decade



How is the Analysis Organized?

The remainder of Chapter 3 contains separate sections for "Forest Conditions and Management," "Riparian," "Soils," Water Quality," "Fish," "Wildlife," "Northern Spotted Owls," "and "Climate Change." The sections are generally structured as follows:

- A brief introduction to the topic;
- A description of the criteria and indicators used in the analysis, including information on how the indicators are measured;
- Current conditions for each indicator—in some sections, current conditions and results are discussed together;
- Results—in this section, DNR presents an analysis of the potential environmental impacts of the three management alternatives for each indicator;
- A summary table of potential environmental impacts by indicator; and
- Additional information pertinent to the topic.

Section Notes

1. Vegetation zones are areas with similar environmental attributes such as soils, climate, and elevation, and are defined by the dominant tree species in the absence of wildfire, windstorms, harvest practices, or other disturbances.
2. DNR uses a numerical system (one through five) to categorize streams based on physical characteristics such as stream width, steepness, and whether or not fish are present. Type 1 streams are the largest; Type 5 streams are the smallest. Type 9 streams are "unclassified" and refer to streams that are currently mapped, but lack sufficient data to determine the correct water type. Only Type 1, 2 and 3 streams are considered fish-bearing. DNR and the Federal Services have agreed that the Washington Forest Practices Board Emergency Rules (stream typing), November 1996 meet the intent of the HCP.

The current DNR GIS stream layer is believed to underestimate the number of Type 5 streams. Mapping standards and methodology vary according to ownership, which results in marked differences in mapped headwater stream density.

3. DNR also used a much smaller scale, the stream reach, to understand what is occurring at the Type 3 watershed level; refer to "Riparian" in this chapter for more information.
4. The use of a 20 percent threshold followed recommendations from federal watershed monitoring programs (Reeves and others 2004, Gallo and others 2005). Reeves and others recommended using a minimum 25 percent ownership threshold for the inclusion of a given watershed in the monitoring program. As described by Gallo and others (2005), this 25 percent threshold was selected to avoid sampling watersheds in which "the contribution of federal lands to the condition of the watershed was insignificant." A more stringent 20 percent threshold was used in this analysis.
5. Washington's current Forest Practices Board Manual refers to the Type 3 watershed as a sub-area of a watershed administrative unit, and recognizes the Type 3 watershed as a scale at which watershed analysis (WAC 222-22) can be conducted.
6. For a definition of "best available science" reference WAC 365-195-905.
7. Under the forest practices rules (WAC 222-24-52(3)), a road is considered abandoned if: (a) roads are outsloped, water barred, or otherwise left in a condition suitable to control erosion and maintain water movement within wetlands and natural drainages; (b) ditches are left in a suitable condition to reduce erosion; (c) the road is blocked so that four-wheel highway vehicles cannot pass the point of closure at the time of abandonment; (d) water crossing structures and fills on all typed waters are removed, except where DNR determines other measures would provide adequate protection to public resources; and (e) DNR has determined that the road is abandoned.

Topic:

Forest Conditions and Management

Why are Forests Important?

When managed sustainably, forests provide a wide range of essential economic, social, and environmental goods and services for the benefit of current and future generations (Montréal Process 1995). Sustainably-managed forests have a mix of forest conditions, including high-quality trees available for harvest and diverse habitats for native species such as northern spotted owls, marbled murrelets, and salmon (DNR 1997).

What are the Criteria for Forest Conditions?

The criteria for forest conditions are **forest sustainability**, **forest structural complexity**, and **forest health**. These criteria are a subset of the internationally recognized criteria for sustainable forestry used in the Montréal Process. The criteria used in the Montréal Process form a common understanding within and across countries of what is meant by sustainable forest management.

What are the Indicators for Forest Conditions?

Each criterion was analyzed using one or more indicators. The criterion forest sustainability was analyzed using the indicators **forest biomass** and **harvest methods and number of forest stand entries**. The criterion forest structural complexity was analyzed using the indicators **stand development stages**, and the criterion forest health was analyzed using the indicator **stand density**. These indicators were selected based on DNR's expertise, existing scientific information, and current data. Information about each criterion and indicator is presented in the following section.

How Were the Indicators Analyzed?

Following, DNR describes the quantitative methods used to analyze the indicators for the No Action and Landscape alternatives. DNR analyzed the indicators for the Pathways Alternative using qualitative techniques (refer to p. 3-17 through 3-18).

Criterion: Forest Sustainability

For this FEIS, forest sustainability is defined as the management of forests to provide harvesting on a continuing basis without major curtailment or cessation of harvest (RCW 79.10.310). This definition reflects DNR's responsibility as a trust lands manager, which is to manage state trust lands to provide perpetual income for current and future trust beneficiaries (DNR 2006). Forest sustainability was measured by considering the amount of wood available in the forest (forest biomass) and the type and frequency of harvest (harvest methods and number of forest stand entries) that the analysis model recommended over the 100-year analysis period.

INDICATOR: FOREST BIOMASS

Forests contain trees of all ages and often many different species. To meet its fiduciary responsibilities, DNR harvests trees when they mature. The harvested trees are replaced with seedlings as a way to constantly renew the forest.

Forest biomass is measured in total standing volume (Smith and others 2003), which is the amount of wood standing in the forest, excluding snags (standing dead trees). Total standing volume increases over time when tree growth exceeds tree mortality and removal. A drop in total standing volume over time due to harvest is not considered sustainable.

For this indicator (forest biomass), DNR used the analysis model to determine if the total standing volume is projected to increase, stay the same, or decrease as a result of harvests modeled under the No Action and Landscape alternatives. The total standing volume also has implications for carbon sequestration (storage) (refer to "Climate Change" on p. 3-213).

INDICATOR: HARVEST METHODS AND NUMBER OF FOREST STAND ENTRIES

Studies on the impacts of repeated forest stand entries in the forests of the Pacific Northwest are lacking, in part due to the relatively short histories of timber harvesting and research on the effects of timber harvesting in those forests. Therefore, DNR's threshold for potential high impacts for this indicator was based on professional judgment. The types of harvest methods used on state trust lands in the OESF are described in Text Box 3-1 on p. 3-25.

Methodology for Analyzing Harvest Methods and Number of Forest Stand Entries

Step 1: Determine the Percentage of Each Landscape with Potential High Impacts

Each harvest of a forest stand (thinning or variable retention harvest) is called a forest stand entry. Using the outputs of the analysis model and the methodology shown in Figure 3-3 on page 3-25, DNR determined the percentage of state trust lands in each landscape that is projected to receive combinations of forest stand entries that DNR considers a potential high impact for this indicator (harvest methods and number of forest stand

Text Box 3-1. Examples of Harvest Methods

Variable retention harvests are stand-replacement harvests in which "leave trees" (trees that are not harvested), snags, large logs, and other structural features are retained between one harvest and the next. These features provide the structural diversity across the landscape that is increasingly being recognized as important for biodiversity (Lindenmayer and Franklin 2002). Variable retention harvests are distinctly different from clearcuts, in which large areas are harvested (over 100 acres) and most or all of the existing forest is removed. Clearcuts leave little or no structural diversity (Franklin and others 2002).

Thinning is normally done to reduce stand density and allow the remaining trees to become larger. In uniform thinning, trees are evenly removed throughout the stand. In variable density thinning (refer to photo, above), some areas are lightly thinned ("skips") while other areas are more heavily harvested ("gaps") to create variations in stand density and canopy cover (Lindenmayer and Franklin 2002).

Figure 3-3. Method for Determining the Number of Acres in Each Landscape With Potential High Impacts

This chart was completed for each of the 11 landscapes.

In the boxes with green circles, DNR entered the number of acres of state trust lands on which the recommended combination of harvest methods over the 100-year analysis period may have potential low impacts

In the boxes with red squares, DNR entered the number of acres of state trust lands on which the recommended combination of harvest methods over the 100-year analysis period may have potential high impacts

Key
- ● Low impact
- ◇ Medium impact
- ■ High impact

		Variable retention harvest entries			
		0 entries	1 entry	2 entries	3 entries
Thinning Entries	0 entries	acres ●	acres ●	acres ◇	acres ■
	1 entry	acres ●	acres ●	acres ◇	acres ■
	2 entries	acres ●	acres ◇	acres ■	acres ■
	3 entries	acres ●	acres ■	acres ■	
	4 or more	acres ◇			
Acres and percent of total area with potential high impacts					acres (percent)

In the boxes with yellow diamonds, DNR entered the number of acres of state trust lands in this landscape on which the recommended combination of harvest over the 100-year analysis period may have potential medium impacts.

DNR was primarily concerned with potential high impacts. DNR added all of the acres in the red boxes, then divided that total by the total number of acres in the landscape. This calculation determined what percentage of the landscape may have potential high impacts.

entries). Examples of a potential high impact include three variable retention harvests, or two variable retention harvests and two thinnings of the same stand over the 100-year analysis period.

DNR's methods for defining potential impacts for harvest entries in this forest conditions and management analysis were different than those used for a similar analysis in "Soils" on p. 3-97. This forest conditions and management analysis was meant as a general assessment of harvest intensity, and therefore included consideration of harvest type (thinning or variable retention harvest). By contrast, the soils analysis was specific to soil compaction, erosion, displacement, productivity, and landslide potential. For that analysis, DNR did not believe a distinction needed to be made between harvest types since both types likely would involve moving heavy equipment over the soil.

Step 2: Assign a Potential low, Medium, or High Impact Rating to Each Landscape

DNR assigned each landscape a potential low, medium, or high impact rating based on the percentage of state trust lands in the landscape identified (in Step 1) as having potential high impacts. To assign impact ratings, DNR used the following thresholds:

- If less than 10 percent of state trust lands in the landscape have potential high impacts, the potential environmental impact for that landscape is **low**.
- If 10 to 20 percent of state trust lands in the landscape have potential high impacts, the potential environmental impact for that landscape is **medium**.
- If more than 20 percent of state trust lands in the landscape have potential high impacts, the potential environmental impact for that landscape is **high**.

As stated previously, these thresholds are based on experience and professional judgement due to the lack of studies regarding the impacts of repeated forest stand entries on Pacific Northwest forests.

Step 3: Assign a Potential low, Medium, or High Impact Rating to This Indicator

In this step, DNR determined the total number of acres of state trust lands in all landscapes with potential high impacts. DNR then used the thresholds identified in Step 2 to assign a potential low, medium, or high impact rating to this indicator. Once this step was complete, DNR determined if the identified impacts were probable significant adverse.

Criterion: Forest Structural Complexity

Forest structure is the physical structure of a forest stand such as the number of canopy layers, tree diameter and height, and the presence or absence of snags and down wood. A forest stand's structure can range from simple (one canopy, no understory) to complex (multiple canopy layers, snags, down wood, and other structural features). This criterion was measured using stand development stages.

INDICATOR: STAND DEVELOPMENT STAGES

As trees grow from planted seedlings after a harvest or regenerate on their own after natural disturbances, forest stands move in and out of stand development stages (refer to

Text Box 3-2 on p. 3-28 and 3-29). Each stand development stage is characterized by a set of measurable physical attributes. The forest classification system for state trust lands in the OESF is based on many scientific publications (Carey 2007, Van Pelt 2007, Franklin and others 2002, Carey and others 1996, Oliver and Larson 1996, DNR 2004). For this analysis, nine stand development stages were consolidated to five, as shown in Text Box 3-2.

Classifications of stand development stages are somewhat arbitrary as these stages are continuous rather than a series of discrete stages (Franklin and others 2002). It is also possible for individual stands to skip a developmental stage (Franklin and others 2002). Despite these caveats, it is still valuable to classify stands by their stand development stage as a way to understand the overall condition of the forest.

A stand's structure can result from a number of influences, including natural disturbance or harvest:

- Thinning can move a stand currently in the Competitive Exclusion stage (Photo A) into the Understory Development stage (Photo B). Forests that are not thinned or affected by natural disturbance can remain in the Competitive Exclusion stage for many decades.
- Variable retention harvests often result in a forest stand being reclassified temporarily to the Ecosystem Initiation stage; these stands then begin moving through the next stages of stand development. When a variable retention harvest is performed, snags, unique trees, down woody debris, and other structural features can be retained to help enhance structural complexity across the landscape (Franklin and others 2002).

Photo A.
Forest Stand in Competitive Exclusion Stage

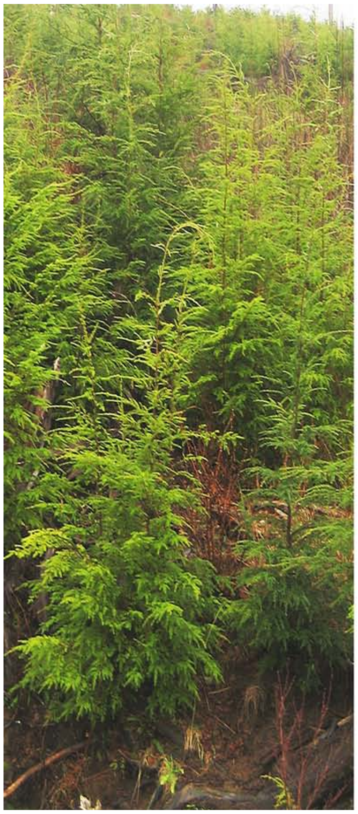
Photo B.
Thinned Forest Stand Transitioning Into Understory Development Stage

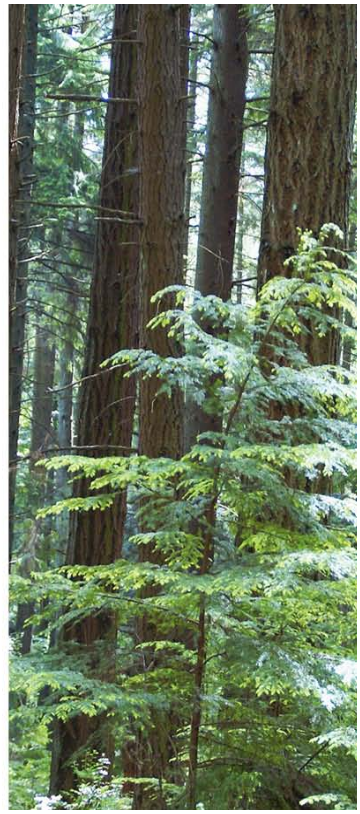
Stands in photos A and B are the same age.

For this indicator (stand development stages), DNR considered how the proportion of stand development stages across state trust lands in the OESF is projected to change over the 100-year analysis period. A shift over time (100-year analysis period) toward more complex stand development stages, particularly a reduction in the Competitive Exclusion stage and an increase in the Structurally Complex stage, was considered a potential low impact. Conversely, a shift toward less complex stand development stages, such as an increase in the Competitive Exclusion stage, was considered a potential high impact.

DNR is not implying a goal of achieving uniform conditions on state trust lands in the OESF, in which most acres are in one or two specific stand development stages. A diversity of stand development stages provides a range of ecological conditions that support both ecological values and revenue production. Instead, for this indicator DNR consid-

Text Box 3-2. Stand Development Stages





Ecosystem Initiation

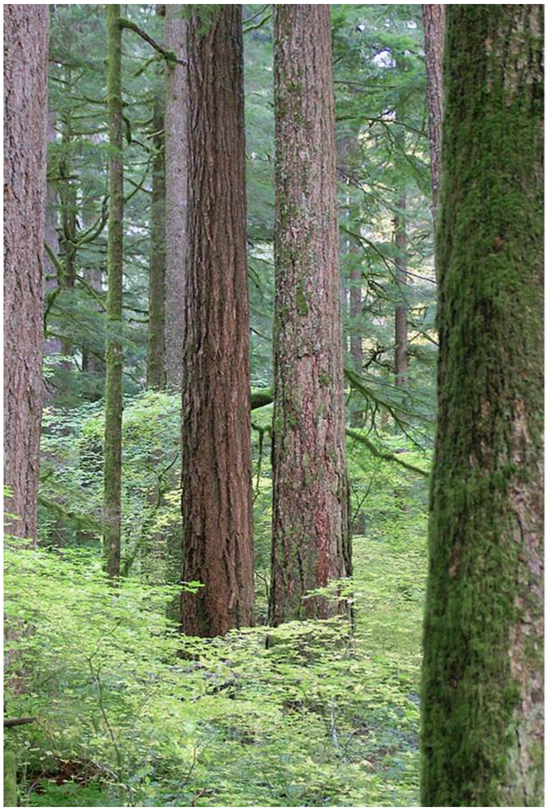
Death or removal of overstory trees by wildfire, windstorm, insects, disease, or timber harvest leads to the establishment of a new forest ecosystem (Carey and others 1996). Establishment and occupation of the site by vegetation are the main ecological process taking place (Carey 2007).

Competitive Exclusion

This stage, as used in this analysis, contains forest stands in the following subcategories: Sapling Exclusion, Pole Exclusion, and Large Tree Exclusion (forest stand development stages adopted from Carey and others 1996). The main characteristic of this stand development stage is that trees fully occupy the site. Competition for light, water, nutrients, and space is the key ecological process in this stage (Carey 2003).

Understory Development

As overstory trees die, fall down, or are harvested,canopy gaps are created. In these gaps, an understory of trees, ferns, and shrubs develops. In this stage, there is little diversification of plant communities.



Biomass Accumulation

For this FEIS analysis, DNR considers Biomass Accumulation roughly equivalent to the Maturation stand development stage defined by Franklin and others (2002). Forest stands in this stand development stage contain numerous large, overstory trees that continue to rapidly add woody biomass (grow larger in diameter). Forests in this stage fully occupy the site, and competition between trees is moderate. Franklin and others (2002) and Carey (2003) consider woody biomass production the key ecological process in this stage. Tree heights are expected to be equal to or greater than 85 feet. In this stage, forest stands lack the large snag and/or down woody debris and understory diversity that characterizes later stages.

Structurally Complex

Forest stands classified as Structurally Complex contain stands in the Niche Diversification and Fully Functional stand development stages. Forests contain live, dead, and fallen trees of various sizes, including decomposing, fallen trees or "nurse logs" on which trees and other vegetation grows. These stands have a diversity of plant communities on the forest floor. Multiple canopies of trees are present, and large and small trees have a variety of diameters and heights. The added complexity provides for the life requirements of diverse vertebrates, invertebrates, fungi, and plants.

ered how the proportion of stand development stages on state trust lands changes over time because those changes may affect the forest ecosystem. For example, an increase in structural complexity may benefit wildlife. While each stand development stage has specific structures, such as large trees, down wood, or snags, which can benefit certain wildlife guilds (a wildlife guild is a group of species that has similar habitat requirements for foraging, breeding, or shelter), the early stand development stages, such as Ecosystem Initiation, and later stages, such as Structurally Complex, can support the greatest diversity and abundance of wildlife species (Johnson and O'Neil 2001, Carey 2003). A decrease in the Competitive Exclusion stage may benefit forest health (refer to "Forest Health" in this section). Refer to Appendix M for maps of projected stand development stages under the No Action and Landscape Alternatives over the 100-year analysis period.

Criterion: Forest Health

Forest health is the perceived condition of a forest, including forest age, structure, composition, function, vigor, presence of unusual levels of insects or disease, and resilience to disturbance (adapted from definition by the Society of American Foresters).

INDICATOR: STAND DENSITY

Stand density[1] is the degree of crowding of individual trees within the portion of an area actually stocked with trees (Smith and Baily 1964). Stand density indicates the level of competition between trees, which can affect tree mortality. DNR uses a measure of stand density called Curtis' Relative Density (Curtis 1982; refer to Text Box 3-3) to compare stand density at different points in time. For simplicity, the remainder of this FEIS refers to Curtis' Relative Density as relative density.

DNR defines stands as overstocked and at increased risk to forest health if a) stands have a single canopy, and b) relative density is greater than 75, regardless of tree species. Overstocked conditions are most prevalent in the Competitive Exclusion stand development stage, but stands in the Biomass Accumulation stage can also become overstocked because trees fully occupy the site and accumulate biomass rapidly (grow taller and larger in diameter). Similar to Competitive Exclusion stands, Biomass Accumulation stands can develop with a single closed canopy that suppresses or eliminates light-dependent understory plants.

Text Box 3-3. Curtis' Relative Density

Relative density (RD) represents how the density of a given stand relates to the theoretical maximum density for a particular tree species. RD is calculated by taking the stand basal area (BA) and dividing it by the square root of its quadratic mean diameter (QMD): **$RD = BA/\sqrt{QMD}$**

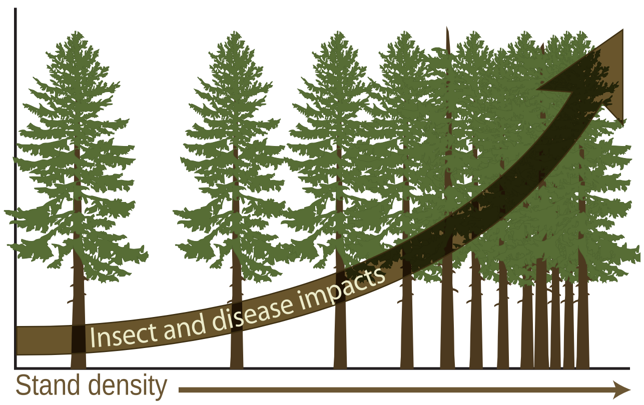
Where:

BA is the cross-sectional area of all tree stems for a given diameter range in a forest stand.

QMD is the tree of average basal area within the same stand and diameter range. QMD may be obtained by dividing the stand basal area by the number of trees per acre, then finding the diameter of this tree.

Stands in the Understory Development or Structurally Complex stages with high relative density are not considered overstocked because they have multiple canopy layers. In single canopy stands, trees of roughly the same age compete directly with each other for resources (sunlight, moisture, growing space, and nutrients). However, multiple-canopy stands have trees of different ages, sizes, and species. Although these trees compete with each other, their needs are different so competition is not as direct. High relative density in these stands is a natural part of the stand's progression and is not considered a significant risk for forest health.

Figure 3-4. Relationship Between Stand Density and Insect and Disease Impacts (Adapted from Powell 1994)



As stand density increases, competition for essential resources such as sunlight, moisture, nutrients, and growing space also increases. Although not universally true, trees with less room to grow (refer to Figure 3-4) tend to be less able to withstand attack from insects, pathogens and parasites (Safranyik and others 1998). Destructive forest insects kill substantial portions of standing volumes when epidemic levels occur in local areas. The range of acceptable stand densities varies somewhat by a species' shade tolerance, but for this analysis, DNR uses a relative density of 75 as the threshold for overstocked conditions (refer to Appendix E for additional discussion of how relative density affects certain tree species differently).

Many studies have emphasized the need to reduce forest health risks in overstocked stands by thinning to reduce competition between trees (Powell and others 2001, Kohm and Franklin 1997, Curtis and others 1998). Although forest stands can naturally self-thin over time, stands with high relative densities can remain in this condition for decades if tree competition is not reduced by thinning or natural disturbance such as wind or fire.

For this indicator (stand density), DNR considered whether the number of acres of forest in a high forest health risk category (stands in the Competitive Exclusion or Biomass Accumulation stage with a relative density over 75) is projected to increase or decrease over the 100-year analysis period according to model results.

■ Criteria and Indicators: Summary

Table 3-8 summarizes the criteria and indicators and how they were measured for the No Action and Landscape alternatives. DNR uses a qualitative process to analyze indicators for the Pathways Alternative (refer to p. 3-17 through 3-18).

Table 3-8. Criteria and Indicators for Forest Conditions and how They Were Measured for the No Action and Landscape Alternatives

Criterion/Indicator	**How the indicator was measured**	**Potential environmental impacts**
Forest sustainability/ Forest biomass	The change in standing volume on state trust lands in the OESF; a decrease in the standing volume in operable areas (places where harvest may occur) was considered unsustainable	**Low:** Forest growth (biomass) exceeds harvest removals **Medium:** Forest growth equals harvest removals **High:** Harvest removals exceed forest growth
Forest sustainability Harvest methods and number of forest stand entries	The percentage of state trust lands in the OESF with a potential for high impacts from harvest activities, calculated using the method described in Figure 3-3	**Low:** Less than 10 percent of state trust lands has potential high impacts **Medium:** 10 to 20 percent of state trust lands has potential high impacts **High:** Over 20 percent of state trust lands has potential high impacts
Forest structural complexity/ Stand Development stages	The proportion of state trust lands in the OESF in each stand development stage	**Low:** The proportion of state trust lands in each stand development stage shifts toward more complex stages **Medium:** The proportion of state trust lands in each stand development stage remains the same **High:** The proportion of state trust lands in each stand development stage shifts toward less complex stages
Forest health / Stand density	The number of acres of state trust lands in the OESF in a high forest health risk category (stands in the Competitive Exclusion and Biomass Accumulation stages with a relative density of 75 or greater)	**Low:** The number of acres of state trust lands in a high health risk category decreases **High:** The number of acres of state trust lands in a high health risk category increases

■ Current Conditions

Current conditions on state trust lands in the OESF are the result of past forest stand entries, natural forest development, and past natural disturbances (wind, fire, landslides). In the following section, DNR describes current conditions in the context of the three criteria (forest sustainability, forest structural complexity, and forest health).

Criterion: Forest Sustainability

INDICATOR: FOREST BIOMASS

As discussed previously, forest biomass will increase over time as long as tree growth exceeds tree mortality and harvest removal. DNR analyzed forest biomass using total standing volume, which was determined using DNR's forest inventory database. The current total standing volume on state trust lands in the OESF is shown in Table 3-9 for deferred and operable areas.

Table 3-9. Current Total Standing Volume by Landscape on State Trust Lands in the OESF (Billions of Board Feet[a])

Landscape	Deferred	Operable	Total board feet
Clallam	0.15	0.40	0.55
Clearwater	0.88	0.25	1.13
Coppermine	0.23	0.12	0.35
Dickodochtedar	0.32	0.35	0.68
Goodman	0.35	0.21	0.57
Kalaloch	0.24	0.13	0.37
Queets	0.33	0.13	0.46
Reade Hill	0.21	0.10	0.31
Sekiu	0.03	0.13	0.16
Sol Duc	0.23	0.36	0.59
Willy Huel	0.52	0.25	0.78
TOTAL	**3.5**	**2.44**	**5.94**

[a]A board foot is a unit of cubic measure for lumber, equal to 1 foot square by 1 inch thick.

Unpredictable natural events, such as catastrophic winds, can result in major changes to existing standing volume. An analysis of these events is beyond the scope of this FEIS.

INDICATOR: HARVEST METHODS AND NUMBER OF FOREST STAND ENTRIES

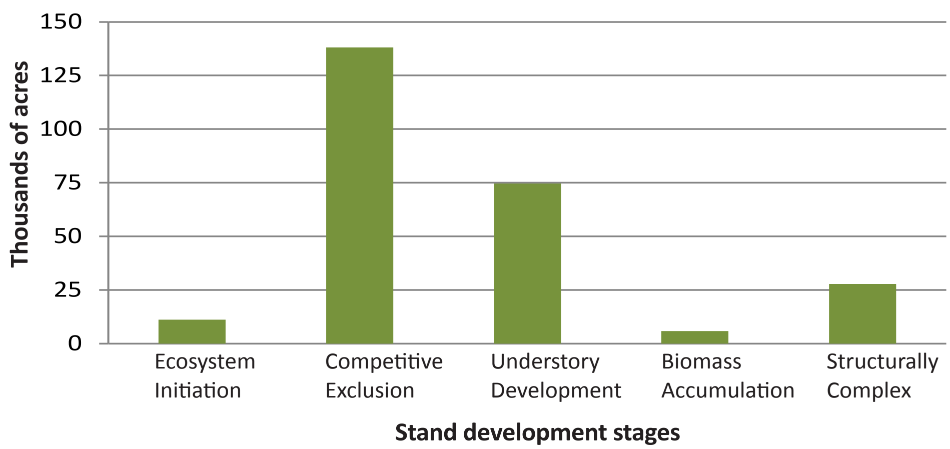
For this indicator, DNR analyzed the potential environmental impacts of forest stand entries that the analysis model recommended on state trust lands in the OESF over the next 100 years. A general discussion of forest stand entries over the past 100 years can be found in Chapter 4 of this FEIS. As mentioned previously, current conditions on state trust lands in the OESF are a result of past forest stand entries, natural forest development, and past natural disturbances. Refer to the indicators forest biomass, stand development stages, and stand density for more information on the current condition of forest stands on state trust lands in the OESF.

Criterion: Forest Structural Complexity

INDICATOR: STAND DEVELOPMENT STAGES

The current distribution of stand development stages on state trust lands in the OESF is shown in Chart 3-5. Of state trust lands in the OESF, 54 percent are in the Competitive Exclusion stage; DNR attributes this condition to harvesting in the 1970s and 1980s.[2] Of the remainder of state trust lands, 29 percent are in the Understory Development stage, 11 percent are in the Structurally Complex stage, 4 percent are in the Ecosystem Initiation stage, and 2 percent are in the Biomass Accumulation stage.

Chart 3-5. Current Stand Development Stages on State Trust Lands in the OESF



Within 70 to 100 years, DNR intends to achieve "older" forest structures across 10 to 15 percent of each HCP planning unit, including the OESF (DNR 2006). Older forest structures are represented by forest stands in the Structurally Complex stand development stage. Table 3-10 shows that state trust lands in the OESF have already met this goal. For information on stand development stages by landscape and watershed administrative unit, refer to Appendix E.

Table 3-10. Current Distribution of Stand Development Stages on State Trust Lands in the OESF

Stand development stage and current percentage	Stand development stage	Acres	Percent of state trust lands
Ecosystem Initiation (4%)	Ecosystem Initiation	11,149	4%
Competitive Exclusion (54%)	Sapling Exclusion	16,055	6%
	Pole Exclusion	71,685	28%
	Large Tree Exclusion	50,354	20%
Understory Development (29%)	Understory Re-initiation	54,920	21%
	Developed Understory	19,762	8%
Biomass Accumulation (2%)	Biomass Accumulation	5,804	2%
Structurally Complex (11%)	Niche Diversification	15,971	6%
	Fully Functional	11,866	5%
TOTAL		**257,566**	**100%**

Criterion: Forest Health

INDICATOR: STAND DENSITY

Stand density can affect tree growth and mortality. As explained previously, forest stands in the Competitive Exclusion and Biomass Accumulation stages are the most susceptible to forest health risks from increasing stand density.

Chart 3-5 (presented earlier in this section) shows the current stand development stages on state trust lands in the OESF. The majority of forest stands are in the Competitive Exclusion and Understory Development stages. This trend is similar across state trust lands in each of the 11 landscapes and most watershed administrative units (refer to Appendix E) in the OESF.

A total of 138,094 acres of state trust lands in the OESF are in the Competitive Exclusion stand development stage and 5,804 acres are in the Biomass Accumulation stages (refer to Table 3-10). Of these acres, only 20,866 acres have a relative density greater than 75 and therefore are considered to be in the high risk category for forest health. A breakdown by landscape for deferred and operable areas is provided in Table 3-11.

Table 3-11. Current Acres of State Trust Lands in the OESF in the High Risk Category for Forest Health (Competitive Exclusion or Biomass Accumulation Stands With Relative Density Greater Than 75)

Landscape	Deferred	Operable	TOTAL
Clallam (17,276)	646	2,456	3,102
Clearwater (19,246)	1,113	793	1,906
Coppermine (28,047)	108	177	285
Dickodochtedar (28,047)	333	3,014	3,347
Goodman (23,799)	615	2,273	2,888
Kalaloch (18,122)	336	727	1,063
Queets (20,807)	49	59	108
Reade Hill (8,479)	197	561	758
Sekiu (10,014)	58	511	569
Sol Duc (19,146)	682	2,699	3,381
Willy Huel (37,428)	2,864	595	3,459
TOTAL	7,001	13,865	20,866

■ Results

In the following section, DNR provides results for the No Action and Landscape Alternatives at the spatial scales of all state trust lands in the OESF, landscapes, or both. Results at the spatial scale of watershed administrative units (those with greater than 20 percent state trust lands) and Type 3 watersheds are presented in Appendix E. DNR analyzed the Pathways Alternative using primarily qualitative techniques.

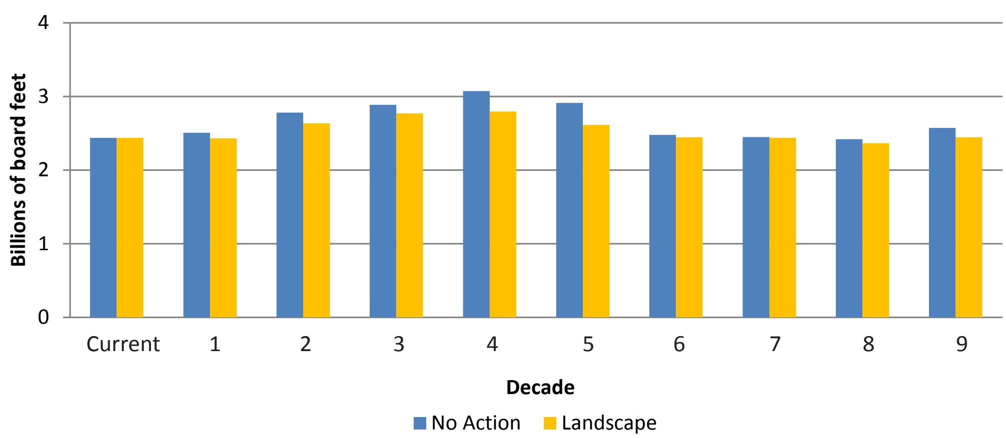
Criterion: Forest Sustainability

INDICATOR: FOREST BIOMASS

No Action and Landscape Alternatives

As shown in Chart 3-6, over the 100-year analysis period the amount of total standing volume in operable areas is projected to increase over the first four decades, and then decline slightly to current levels under both the No Action and Landscape alternatives. This chart indicates that forest growth would roughly equal harvest removals, which is a medium impact.

Chart 3-6. Projected Change in Total Standing Volume (Board Feet) on State Trust Lands in Operable Areas, No Action and Landscape Alternatives



However, DNR also considered the total standing volume on deferred areas. Chart 3-7 shows that total standing volume in deferred areas is projected to increase over the 100-year analysis period under the No Action and Landscape alternatives.

Chart 3-7. Projected Change in Total Standing Volume (Board Feet) on State Trust Lands in Deferred Areas, No Action and Landscape Alternatives

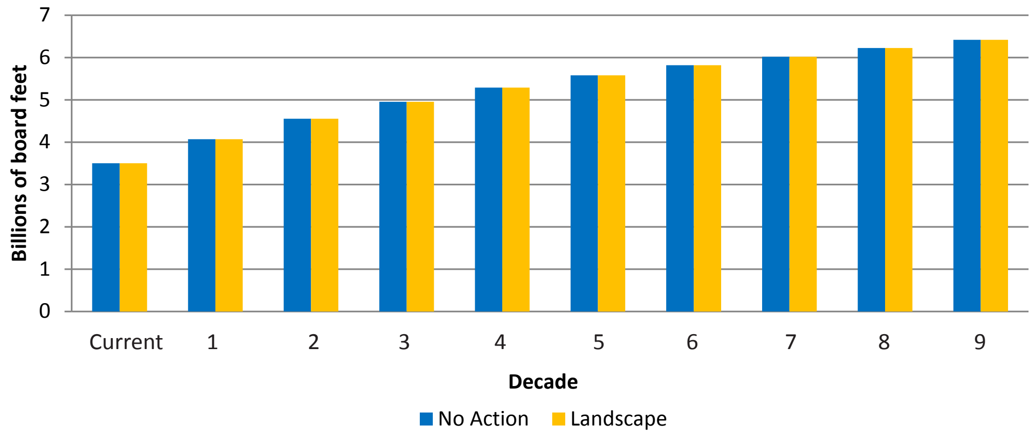
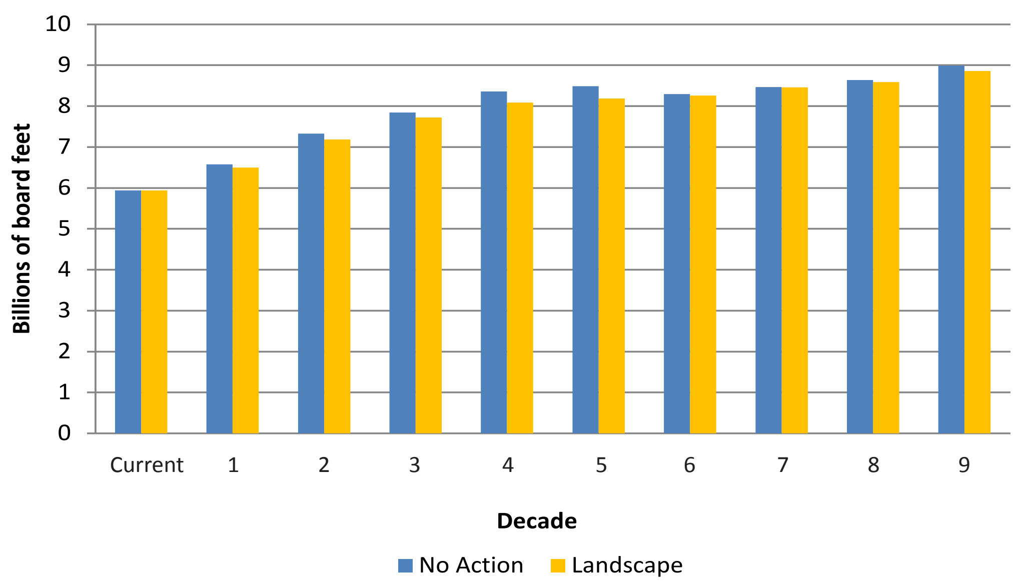


Chart 3-8 shows the total standing volume on deferred and operable acres together. Under the No Action and Landscape alternatives, the total standing volume on state trust lands (deferred and operable together) in the OESF is projected to increase over the 100-year analysis period.

Chart 3-8. Projected Change in Total Standing Volume (Board Feet) on State Trust Lands in Deferred and Operable Areas, No Action and Landscape Alternative



Because total standing volume continually increases (Chart 3-8), the potential environmental impact for this indicator is considered **low** for the No Action and Landscape alternatives. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

Pathways Alternative

DNR anticipates that under the Pathways Alternative, total standing volume in operable and deferred areas combined will increase over the 100-year analysis period similar to the trend shown in Chart 3-8 for the Landscape Alternative. The trend is expected to be similar under the Pathways and Landscape alternatives because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Following, DNR discusses expected trends in standing volume in operable and deferred areas under the Pathways Alternative.

Operable Areas

Under the Pathways Alternative, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4). Total standing volume is expected to increase in these areas as trees continue to grow (refer to "Northern Spotted Owls" on p. 3-189 for a description of northern spotted owl habitat types). In other landscapes, DNR will thin forest stands in operable areas to create or accelerate development of Young Forest Habitat (Pathway 5). These areas are expected to have a temporary decrease in standing volume followed by an increase as trees released from competition grow.

Applying Pathways 3, 4, and 5 in some operable areas may intensify harvest in other operable areas, causing a drop in standing volume in those areas. Or, the total volume of harvest in operable areas may be reduced during the restoration phase (refer to Chapter 2 for information on the northern spotted owl conservation strategy). During the maintenance and enhancement phase, Young or Old Forest Habitat in operable areas not needed to maintain thresholds will be available for harvest (thinning or variable retention).

Given that standing volume may increase in some areas and decrease in others, DNR expects forest growth to roughly equal harvest removals in operable areas, similar to the trend shown in Chart 3-6 for the Landscape Alternative.

Deferred Areas

In general, standing volume in deferred areas should continue to increase over time similar to what DNR projected under Landscape Alternative (refer to Chart 3-7). In some landscapes, DNR will thin selected forest stands in deferred areas to create or accelerate development of Young Forest Habitat (Pathway 7). Standing volume in these forest stands would decrease when individual trees are removed. However, due to decreased competition for resources, standing volume in these areas is expected to increase over time as remaining overstory, mid-story, and understory trees grow larger.

Because total standing volume in deferred and operable areas combined is expected to increase over time under the Pathways Alternative (similar to the Landscape Alternative), the potential environmental impact of the Pathways Alternative for this indicator is considered **low**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

INDICATOR: HARVEST METHODS AND NUMBER OF FOREST STAND ENTRIES

No Action and Landscape Alternatives

As explained previously, DNR first determined the percentage of state trust lands in each landscape with potential high impacts. Potential high impacts were defined as certain combinations of thinning and variable retention harvest of the same stand over the 100-year analysis period (refer to Figure 3-3).

DNR then assigned a potential low, medium, or high impact rating to each landscape based on the percentage of state trust lands in that landscape with potential high impacts. Finally, DNR assigned a potential low, medium, or high impact rating to this indicator based on the percentage of state trust lands in all landscapes with potential high impacts (refer to sidebar).

- If less than 10 percent of state trust lands have potential high impacts, the potential environmental impact is low.
- If 10 to 20 percent of state trust lands have potential high impacts, the potential environmental impact is medium.
- If more than 20 percent of state trust lands have potential high impacts, the potential environmental impact is high.

Table 3-12 shows the percentage (and number of acres) of state trust lands in each landscape projected to have potential high impacts under the No Action and Landscape alternatives.

Table 3-12. Projected Percent of State Trust Lands in Each Landscape with Potential High Impacts, by Alternative

Landscape	Percent of total area with potential high impacts	
	No Action Alternative	Landscape Alternative
Clallam (17,276)	17% (2,896) ◇	22% (3,739) ■
Clearwater (55,203)	7% (3,653) ●	9% (4,695) ●
Coppermine (19,246)	8% (1,619) ●	12% (2,227) ◇
Dickodochtedar (28,047)	13% (3,622) ◇	17% (4,826) ◇
Goodman (23,799)	10% (2,312) ◇	15% (3,646) ◇
Kalaloch (18,122)	8% (1,526) ●	12% (2,200) ◇
Queets (20,807)	17% (3,451) ◇	20% (4,232) ◇
Reade Hill (8,479)	7% (570) ●	11% (938) ◇
Sekiu (10,014)	10% (990) ◇	15% (1,514) ◇
Sol Duc (19,146)	12% (2,383) ◇	19% (3,559) ◇
Willy Huel (37,428)	1% (490) ●	<1% (30) ●
TOTAL	**9% (23,512)** ●	**12% (31,606)** ◇

● Low impact ◇ Medium impact ■ High impact

DNR's analysis shows that under the No Action Alternative, less than 20 percent of state trust lands in any given landscape have potential high impacts. Therefore, the potential environmental impact for each landscape under the No Action Alternative is considered either low or medium.

Under the Landscape Alternative, 22 percent of state trust lands in the Clallam landscape have potential high impacts. Therefore, the potential environmental impact for the Clallam landscape is considered high. The potential environmental impact for the other landscapes is considered either low or medium. (Refer to Appendix E for the number of forest stand entries and methods for each landscape by alternative, and refer to "Harvest Schedule Analyzed" on p. 3-18 for more information about proposed harvests under each alternative).

Considering all landscapes together, under the No Action Alternative, only 9 percent (23,512 acres) of state trust lands in the OESF have potential high impacts. Therefore, the potential environmental impact for the No Action Alternative for this indicator is considered **low**. Under the Landscape Alternative, only 12 percent (31,606 acres) of state trust lands in the OESF have potential high impacts. Therefore, the potential environmental impact for the Landscape Alternative for this indicator is considered **medium**. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

Possible mitigation could reduce potential high impacts on state trust lands in the Clallam landscape to a lower level. For example, DNR may eliminate combinations of thinning and variable retention harvests that are causing a high impact by lengthening the harvest rotation (time between harvests) in this landscape. As described in the introduction to this chapter, possible mitigation is something DNR may or may not implement. Although DNR may adopt possible mitigation in the future, DNR is not committed to implementing it at this time.

Pathways Alternative

Under the Pathways Alternative, harvest methods and the number of forest stand entries are, on balance, anticipated to be similar to those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Following, DNR discusses expected trends in forest stand entries in operable and deferred areas under the Pathways Alternative.

Operable Areas

- In some landscapes, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4), meaning these stands will have no harvest entries during the restoration phase.

- In other landscapes, DNR will thin forest stands in operable areas to create or accelerate development of Young Forest Habitat (Pathway 5). Under the No Action or Landscape alternatives, these areas may be scheduled for multiple harvest entries, but under the Pathways Alternative they should receive one thinning entry only during the 100-year analysis period (DNR may, in some circumstances, thin these stands again if needed).

- Considering all operable areas together, applying Pathways 3, 4, and 5 in some locations of the operable area may increase harvest entries elsewhere. Or, the total volume of harvest in the operable area may be reduced during the restoration phase. During the maintenance and enhancement phase, Young or Old Forest Habitat in operable areas not needed to maintain thresholds will be available for harvest (thinning or variable retention). None of these possibilities are expected to significantly change harvest methods and number of forest stand entries in operable areas as compared to the Landscape alternative because (as explained on p. 3-17 through 3-18) the total number of acres affected by pathways is expected to be relatively small.

  In the Clallam landscape, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathway 3). This pathway may decrease the number of forest stand entries in the operable area, or it may shift those entries to other locations in the operable area. Either way, DNR anticipates that the potential impacts in this landscape will remain high under the Pathways alternative. Similar to the Landscape Alternative, possible mitigation would be to eliminate combinations of forest stand entries that are causing a high impact (for example, lengthening harvest rotations).

Deferred Areas

In some landscapes, DNR will thin selected forest stands in deferred areas to create or accelerate development of Young Forest Habitat (Pathway 7). These areas should receive only one thinning entry over the 100-year analysis period, although DNR may, in some circumstances, thin these stands again if needed.

The differences in harvest methods and number of forest stand entries under the Pathways Alternative as compared to the Landscape Alternative, as described in this section, are not expected to be significant due to the similarities between these alternatives. On balance, in deferred and operable areas combined, the number of forest stand entries should decrease in some areas and increase in others under the Pathways Alternative. Some areas that were scheduled for variable retention harvest may be thinned and vice versa. Therefore, the potential environmental impact for the Pathways Alternative for this indicator is considered **medium**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Criterion: Forest Structural Complexity

INDICATOR: STAND DEVELOPMENT STAGES

No Action and Landscape Alternatives

Currently, over half of state trust lands in the OESF are in the Competitive Exclusion stand development stage. Using the analysis model, DNR projected the shift, over time, in the proportion of state trust lands in each stand development stage under the No Action and Landscape alternatives. DNR projected a decrease in the number of acres in the

Competitive Exclusion stage and a corresponding increase in the number of acres in the Understory Development and Structurally Complex stages (refer to Chart 3-9 and 3-10). The number of acres in the Ecosystem Initiation stage is projected to remain relatively constant. Trends are similar for each of the landscapes under both alternatives (refer to Appendix E).

Chart 3-9. Projected Stand Development Stages on State Trust Lands, No Action Alternative

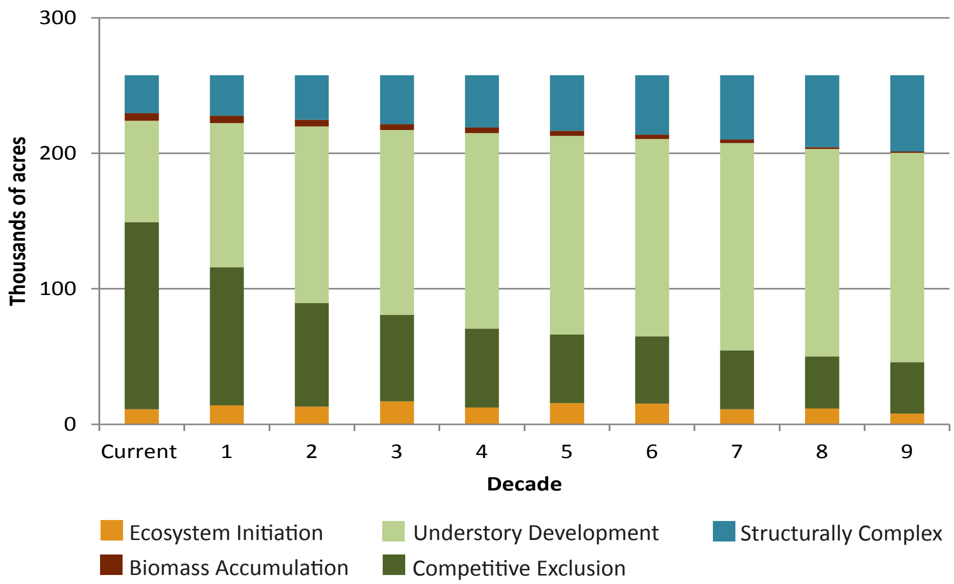
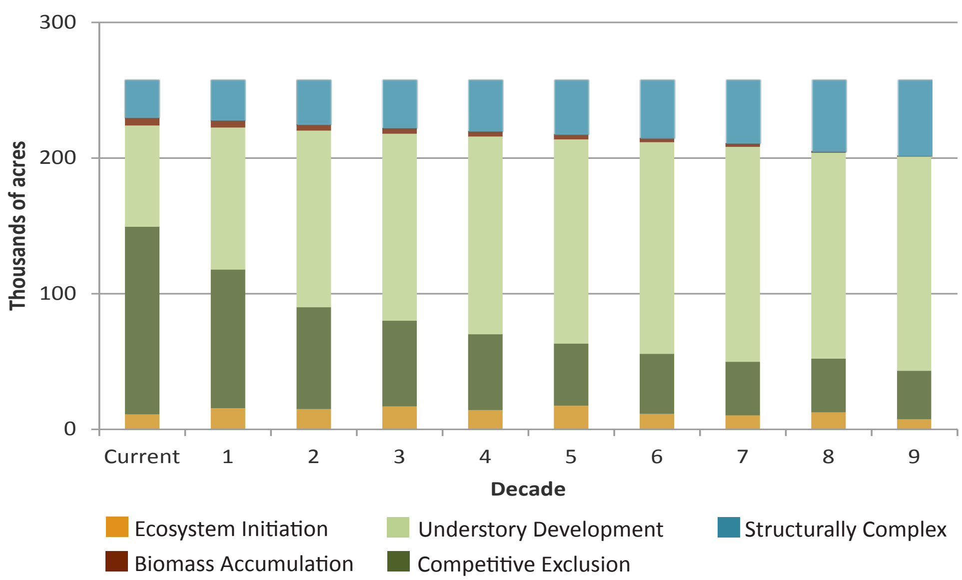


Chart 3-10. Projected Stand Development Stages on State Trust Lands, Landscape Alternative



The reduction in Competitive Exclusion may partly be due to planned harvest activities in these stands. Harvests performed to reduce competition in Competitive Exclusion stands may transition them into the Understory Development stage.

Currently, few acres of state trust lands are in the Biomass Accumulation stage. Over time under the No Action and Landscape alternatives, this stand development stage is projected to decline. Stands in the Biomass Accumulation stage may move into the Structurally Complex stage through natural processes, or they may be harvested and replanted, which moves them into the Ecosystem Initiation stage.

The potential environmental impact of either alternative for this indicator is considered **low**, since the distribution of stand development stages on state trust lands is projected to shift toward more complex stages. In particular, the number of acres in the Competitive Exclusion stage is projected to decrease and the number of acres in the Structurally Complex stage is projected to increase. DNR considers an increase in structural complexity a benefit to wildlife (refer to "Wildlife" on p. 3-165). Developing and maintaining structural complexity in managed stands is important to any forest management program that intends to maintain forest biodiversity and ecosystem processes (Lindenmayer and Franklin 2002). DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

Pathways Alternative

Under the Pathways Alternative, trends in forest stand development stages are, on balance, anticipated to be similar to those projected for the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18 for more information).

The Pathways Alternative includes thinning forest stands in operable and deferred areas in some landscapes to create or accelerate development of Young Forest Habitat (Pathways 5 and 7, respectively). Approximately one third of these stands are in the Competitive Exclusion stand development stage, while nearly two-thirds are in the Understory Development stage and approximately one percent in the Biomass Accumulation stage. Thinning stands in the Competitive Exclusion stage may shift them into Understory Development and put them on a trajectory to eventually reach the Biomass Accumulation and Structurally Complex stages.

In addition, operable areas selected for passive management (Pathways 3 and 4) may continue to develop the characteristics of structurally complex forests.

Because of the expected increase in structural complexity under Pathways 3, 4, 5, and 7, and because of the similarities between the Pathways and Landscape alternatives, DNR expects the distribution of stand development stages on state trust lands to shift toward more complex stages under the Pathway Alternative. Therefore, the potential environmental impact of the Pathways Alternative for this indicator is considered **low**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

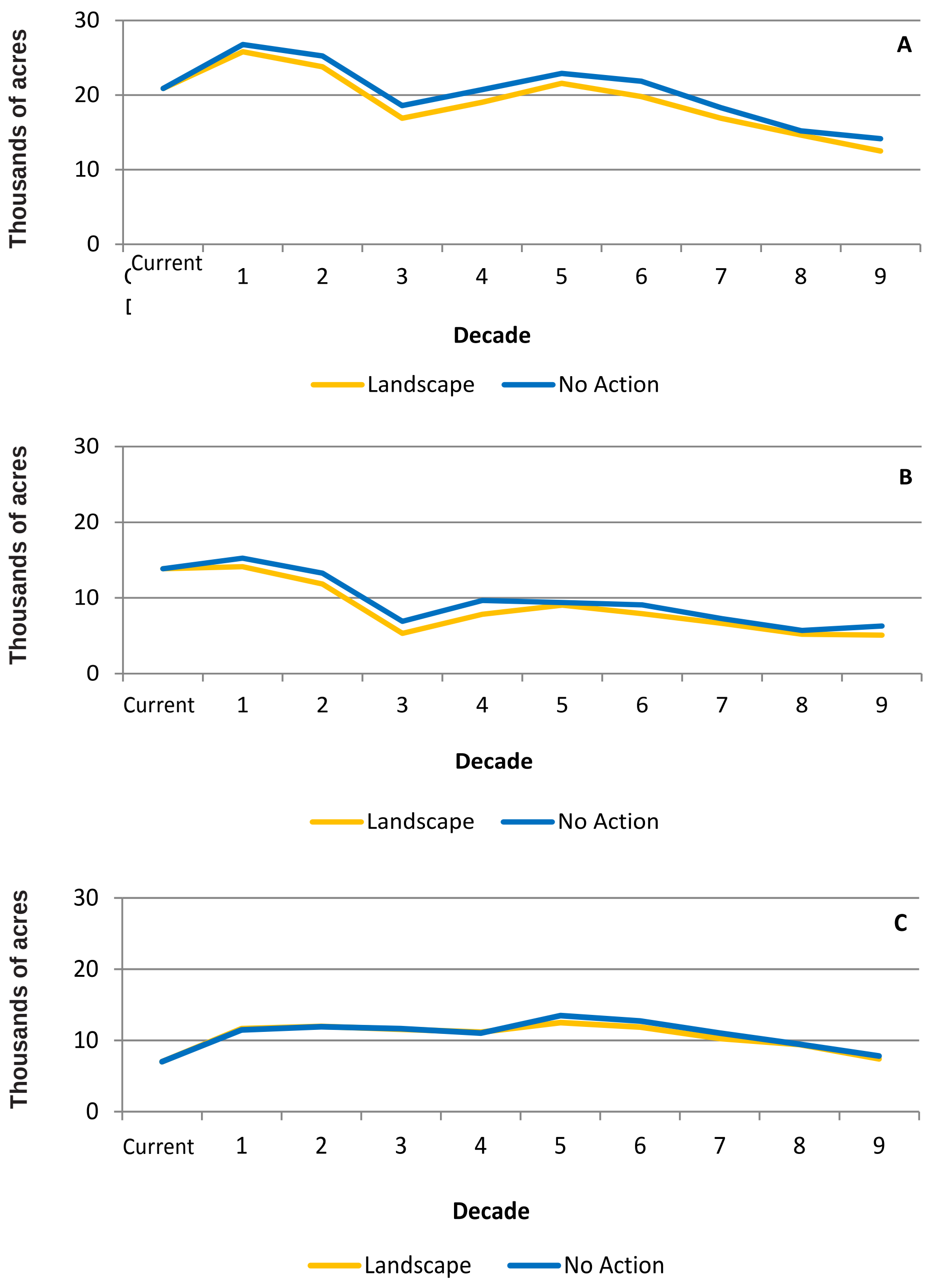
Criterion: Forest Health

INDICATOR: STAND DENSITY

No Action and Landscape Alternatives

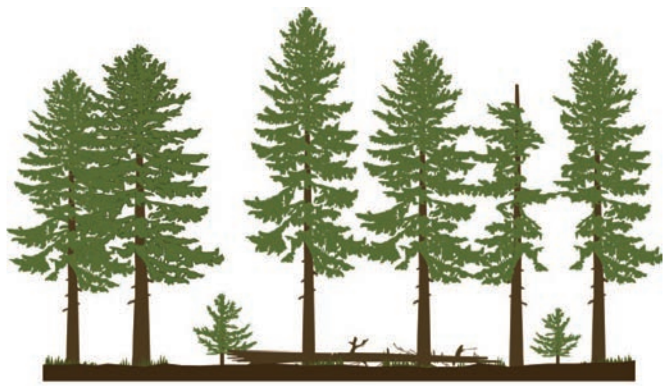
Forest stands in the Competitive Exclusion and Biomass Accumulation stand development stages with a relative density greater than 75 are considered to be in a high forest health risk category. Chart 3-11 (A through C) shows the trend for forest health at three spatial scales: all state trust lands, operable areas, and deferred areas.

Chart 3-11. Projected Acres with High Forest Health Risk for A) all State Trust Lands, B) Operable Areas on State Trust Lands, and C) Deferred Areas on State Trust Lands



When considering operable areas only (Chart 3-11 [B]), the number of acres of state trust lands in a high forest health risk category is projected to decrease over the long term under the No Action and Landscape alternatives, according to model results. This transition is largely the result of harvest and assumes stand density will be reduced by thinning. This trend is true for both alternatives and represents a beneficial environmental impact—a reduction in the potential risk to forest health posed by large areas of overstocked stands.

Figure 3-5. Natural Transition From Competitive Exclusion to More Complex Stand Development Stages



Differentiations in the crown, stem breakage, and tree mortality create small gaps in the stand, allowing the understory to develop naturally.

For deferred areas (Chart 3-11 [C]), over the first 50 years of the analysis period the number of acres of state trust lands in a high risk category is projected to increase from approximately 6,500 acres to 12,000 acres under the Landscape Alternative and to 13,000 acres under the No Action Alternative. This increase is due to natural growth of forest stands; in the absence of harvest or natural disturbance, these stands may increase in relative density to 75 and higher. Relative density is projected to decline to near-current levels by the end of the analysis period as these stands transition slowly, through natural processes, from Competitive Exclusion to more complex stages (refer to Figure 3-5). Declines could also be caused by natural disturbance events such as fire or catastrophic wind, which were not modeled as part of this analysis.

When considering all state trust lands (operable and deferred – Chart 3-11 [A]), the number of acres in a high forest health risk category is projected to decrease under the No Action and Landscape alternatives. Therefore, the potential environmental impact of either alternative for this indicator of forest health is considered **low**. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

Pathways Alternative

Under the Pathways Alternative, trends in stand density are, on balance, anticipated to be similar to those projected for the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18).

Under the Pathways Alternative, DNR will thin forest stands in operable and deferred areas to create or accelerate development of Young Forest Habitat (Pathways 5 and 7, respectively). Many of the stands DNR has identified as candidates for thinning under this alternative are at risk of forest health:

- Approximately 36 percent of these stands are in the Competitive Exclusion stage, and of these, over 80 percent have a relative density of 75 or higher.

- Approximately one percent of these stands are in the Biomass Accumulation stage, and of these, over 90 percent have a relative density of 75 or higher.

Because of the thinning anticipated under Pathways 5 and 7, and because of the similarities between the Pathways and Landscape Alternatives, DNR expects a decrease in the number of acres in a high forest health risk category under the Pathways Alternative. Therefore the potential environmental impacts of the Pathways Alternative for this indicator is considered **low**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Summary of Potential Impacts

Table 3-13 provides an overview of the potential environmental impacts on forest conditions when all of the criteria and indicators are considered. For this analysis, only potential high impacts were considered potentially significant impacts. DNR did not identify probable significant adverse environmental impacts from any alternative for any indicator for this topic.

Table 3-13. Summary of Potential Impacts on Forest Conditions, by Alternative

Criteria	Indicators	No Action Alternative	Landscape Alternative	Pathways Alternative
Forest sustainability	Forest biomass	Low ●	Low ●	Low ●
	Harvest methods and number of forest stand entries	Low ●	Medium ◇	Medium ◇
Forest structural complexity	Stand development stages	Low ●	Low ●	Low ●
Forest health	Stand density	Low ●	Low ●	Low ●

● **Low impact** ◇ **Medium impact**

Section Notes

1. Stand density can be the number of trees or the amount of basal area, wood volume, leaf cover, or a variety of other parameters (Curtis 1970, Ernst and Knapp 1985). Stocking is the proportion of any measurement of stand density to a standard expressed in the same units. In other words, stand density is what actually exists, whereas stocking is how what is there relates to an established standard of what ought to be there (Smith and others 1997).
2. DNR policy in the 1970s and 1980s mandated that the oldest timber be harvested first (Commission on Old Growth Alternatives for Washington's Forest Trust Lands, 1989).

Topic:

Riparian

▪ What are Riparian Areas, and why are They Important?

A riparian area is where aquatic and terrestrial ecosystems interact. It includes surface waters such as rivers, streams, lakes, ponds, and wetlands, and the adjacent forests and groundwater zones that connect the water to the surrounding land.

Riparian areas provide habitat for numerous species of plants and wildlife. In addition, riparian areas influence stream conditions such as water quality, quantity (Cleaverly and others 2000), temperature (Brown and Krygier 1970), and nutrient concentrations (Tabbacchi and others 1998), and are a major source of sediment and organic materials (Triska and others 1982, Gregory and others 1991).

▪ What is the Criterion for Riparian Areas?

The criterion for riparian areas is **functioning riparian habitat**. DNR's *Policy for Sustainable Forests* and the HCP define functioning riparian habitat as habitat capable of supporting viable populations of salmonid species, as well as other species that depend on healthy in-stream and riparian environments.

▪ What are the Indicators for Riparian Areas?

The indicators used to measure the criterion are **large woody debris recruitment**, **peak flow**, **stream shade**, **fine sediment delivery**, **leaf and needle litter recruitment**, and **riparian microclimate**. An additional indicator, the **composite watershed score**, combines these indicators to assess the health of the riparian system as a whole. These indicators were selected based on DNR's expertise, existing scientific information, and current data. Information about the significance of each indicator is presented in the following section. DNR incorporated an additional indicator, coarse sediment delivery, into the composite watershed score. (Refer to Appendix G for more information on this indicator.)

In-stream data such as the amount and distribution of large woody debris, the presence and amount of leaf and needle litter in the stream, stream temperature, and sedimentation (settling and accumulation of sediment on the streambed) is not available in a comprehensive or readily usable form for all streams in the OESF. Therefore, DNR used surrogates to assess current and future conditions for each indicator. For example, as a surrogate for the number and size of logs in each stream reach, DNR assessed the characteristics of the riparian forest and its potential to provide large woody debris to the stream channel. DNR used the potential of the riparian forest to provide stream shade and leaf and needle litter as surrogates for stream temperature and stream nutrients, respectively; the potential delivery of fine sediment from the road network as a surrogate for sedimentation or turbidity (water cloudiness); and hydrologic maturity within each watershed as a surrogate for peak flow (hydrologic maturity will be discussed later in this section).

Overlapping Indicators

As discussed in the introduction to this chapter, few indicators apply to only one topic in this FEIS; many overlap. For example, stream shade was used as an indicator in "Water Quality" on p. 3-123. Also in "Water Quality," DNR analyzed the potential for fine sediment delivery using the indicator traffic impact score. Large woody debris recruitment, peak flow, stream shade, leaf and needle litter recruitment, and fine and coarse sediment delivery were used as indicators in "Fish" on p. 3-147. In addition, DNR analyzed the potential for coarse sediment delivery in "Soils" on p. 3-97 using the indicators landslide potential and potential road failure.

■ How Were the Indicators Analyzed?

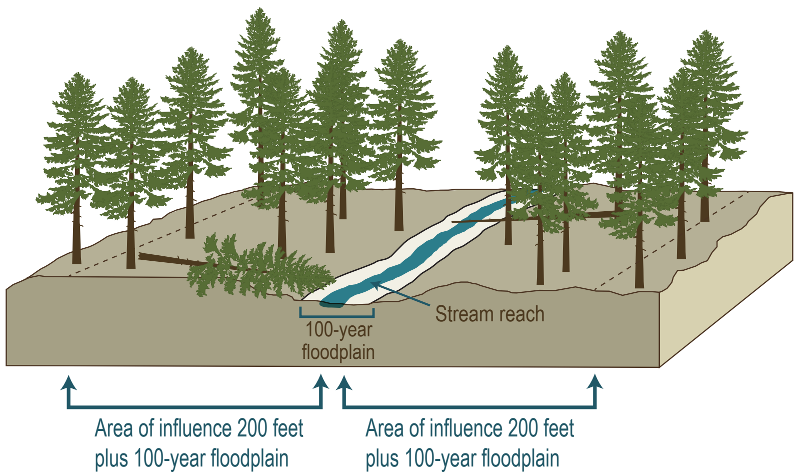
Following, DNR describes each indicator and the quantitative methods used to analyze them for the No Action and Landscape alternatives. DNR used qualitative techniques to analyze the indicators for the Pathways Alternative (refer to p. 3-17 through 3-18).

Area of Influence

DNR based its riparian analysis on an "area of influence," the area in which each indicator is expected to have an influence on the stream channel (refer to Figure 3-6). DNR used the area of influence in this analysis to better understand how DNR's management activities may affect riparian and watershed conditions over the 100-year analysis period.

The area of influence is different for each indicator and is based on DNR's review of current scientific literature. The widths of areas of influence can vary widely. For example, large woody debris recruitment generally takes place within one site-potential tree height[1] (approximately 200 feet) of the 100-year floodplain (McDade and others 1990, Forest Ecosystem Management Assessment Team [FEMAT] 1993), while the area of influence for peak flow is the entire Type 3 watershed (refer to "Spatial Scales Used in the OESF" in the introduction to this chapter).

Figure 3-6. Area of Influence for Large Woody Debris Recruitment

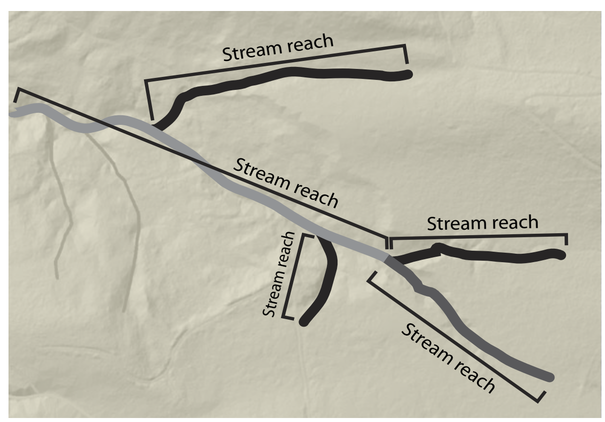


Analysis Methodology

For this analysis, DNR calculated **stream reach scores** and **watershed scores** for each indicator. Scores were developed using sophisticated computer modeling techniques which are described in detail in Appendix G. DNR built a separate model for each indicator, including the composite watershed score. These models were built using outputs of the analysis model.

STREAM REACH SCORES

Figure 3-7. Example of Stream Reaches



The basis of the analysis was a stream reach (refer to Figure 3-7). A stream reach is a section of stream with consistent channel and floodplain characteristics, such as gradient (how steep the stream is) or confinement (how much a stream channel can move within its valley). Stream reaches are typically a few hundred feet in length, and one stream may contain numerous reaches. Stream reaches are important because many riparian species interact with the environment at the reach scale, and because many ecological processes create or maintain habitat at this scale.

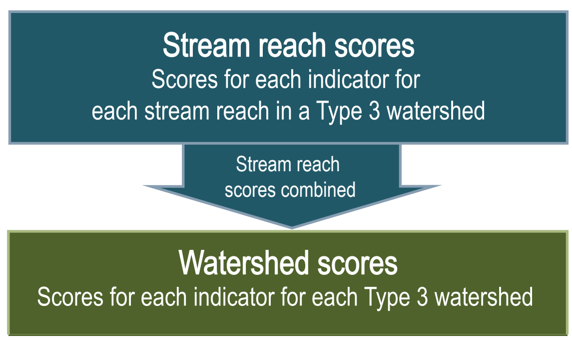
For most indicators, stream reaches were given a score based on two factors: the potential of their surrounding area of influence to provide riparian function, and their sensitivity, or expected stream channel response to that function. For example, at a given point in time, the area of influence for a given stream reach may have little or no potential to provide large woody debris to the stream channel (low potential). For that same stream reach, large woody debris may be critical to maintaining the shape of the channel, providing habitat features such as pools, trapping sediment, and protecting stream banks (high sensitivity). For most indicators, DNR used sensitivity ratings from watershed analyses that were performed (either initiated or completed and approved) in the OESF per the forest practices rules. For stream reaches for which watershed analyses were not available, DNR based sensitivity primarily on gradient and confinement.

DNR considered both potential and sensitivity when assigning stream reach scores, the scores being a measure of the overall condition of the stream reach. DNR assigned a low score to highly sensitive reaches with low potential (a high impact), indicating that conditions are degraded and riparian function is impaired. DNR assigned a high score to less sensitive reaches with high potential (a low impact), indicating that riparian function is being restored or maintained. In other words, when the function is critical, and the area of influence is not likely to provide it, the score is low; the reverse is also true. A complete description of how sensitivity and potential ratings were derived and combined can be found in Appendix G. Refer to Table 3-14 for a full definition of what low, medium, and high impacts are in the context of this analysis.

WATERSHED SCORES

To understand what is happening at a larger spatial scale, DNR combined the stream reach scores for each Type 3 watershed into a watershed score (refer to Figure 3-8). In calculating scores, DNR assigned weight to each stream reach based on its surface area (calculated by multiply the stream reach's length by its width). This process was completed for each indicator.

Figure 3-8. Stream Reach and Watershed Scores Computed for Each Indicator

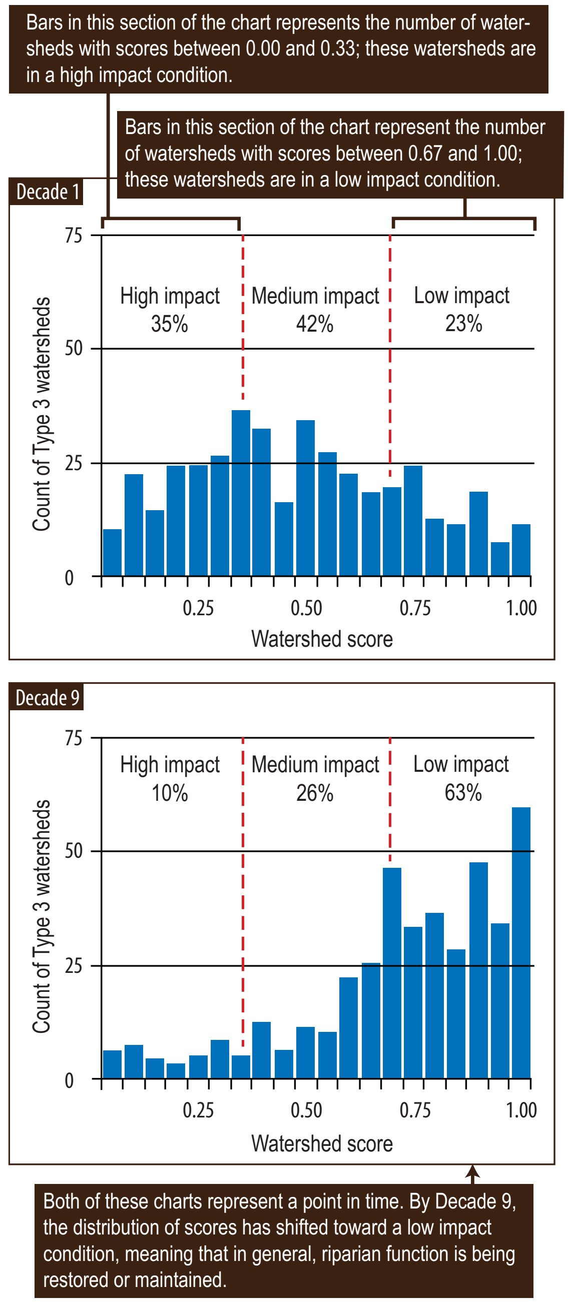


Scores were placed into three categories: high impact condition (0.00 to 0.33), medium impact condition (0.34 to 0.66), or low impact condition (0.67 to 1.00).[2] Results were graphed (refer to Figure 3-9) at four points in time: Decade 0 (current condition), Decade 1 (short-term trends), Decade 6 (mid-term trends), and Decade 9 (long-term trends). Each point in time gave DNR an indication of whether most Type 3 watersheds fell into a low, medium, or high impact category.

DNR examined the current, short-, mid-, and long-term graphs to determine how the distribution of scores shifts over time. For instance, scores may shift from a medium to a low impact condition or vice versa (refer to Figure 3-9). This analysis was repeated for each indicator for the No Action and Landscape alternatives. DNR uses this analysis to infer how the No Action and Landscape alternatives affect riparian function for each indicator.

It is important to note that **a range of watershed conditions is desirable**. A key principle of managing riparian ecosystems for habitat complexity is to focus on natural processes and variability, rather than attempting to maintain or engineer a desired set of conditions through time (Lugo and others 1999, Dale and others 2000 as cited in Bisson and Wondzell 2009). DNR is not working toward a set threshold for the number of watersheds in a low impact condition. Rather, DNR's objective is to achieve a range of conditions that provide habitat variability and complexity.

Figure 3-9. Example of a Distribution of Watershed Scores



OWNERSHIP

There are 601 Type 3 watersheds in the OESF. Only the watersheds in which DNR manages at least 20 percent of the land area were evaluated (427 out of 601 watersheds). Streams not located on state trust lands were not included in this analysis unless their area of influence extended onto state trust lands.

Description of Each Indicator

INDICATOR: LARGE WOODY DEBRIS RECRUITMENT

Large woody debris recruitment refers to logs, pieces of logs, root wads, or large chunks of wood falling into stream channels. While the definition of "large" can vary according to context (a log may provide a certain level of ecological function when it falls into a small stream; the same size log may not provide as much benefit in a large river), many biologists define large woody debris as having a minimum diameter of 4 inches and measuring 6 feet in length (Schuett-Hames and others 1999).

Large woody debris is an important habitat component for fish and other aquatic organisms (Swanson and others 1976, Harmon and others 1986, Bisson and others 1987, Maser and others 1988, Naiman and others 1992, Samuelsson and others 1994). Trees and other large pieces of wood that fall into streams help trap and retain sediment (Keller and Swanson 1979, Sedell and others 1988), change the shape and steepness of the stream (Ralph and others 1994), slow fast-moving water (DNR 1997), release nutrients slowly as they decompose (Cummins 1974), and provide fish and amphibians places to hide from predators (Bisson and others 1987, Bilby and Ward 1989).

The area of influence[3] for large woody debris recruitment is the 100-year floodplain plus one site-potential tree height (approximately 200 feet). Factors affecting large woody debris recruitment include the relative density of the forest, tree size, tree species, and the distance of trees from the floodplain (McDade and others 1990, FEMAT 1993). Refer to Text Box 3-3 in "Forest Conditions and Management" on p. 3-30 for a definition of relative density.

INDICATOR: PEAK FLOW

The term "peak flow" refers to periods of high stream flow or maximum discharge, usually associated with storm events. In the Pacific Northwest, peak flow often coincides with winter storms in which rain falls on top of an existing snowpack (Pentec Environmental, Inc. 1997). These events are commonly known as rain-on-snow events.

Peak flows can affect stream channels and in-stream habitat because of the large amount and high velocity of water moving through the stream. For example, some streambeds are composed of sand and gravel which may be lifted or scoured during peak flow events. Salmon prefer to lay their eggs in gravel streambeds, which can be damaged by scouring peak flows. Also, stream channels can shift, leaving gravel streambeds—and salmon eggs—dry. (For more information, refer to "Fish," p. 3-147.)

Peak flow is assessed by measuring the proportion of hydrologically immature forests in a watershed.

- **Hydrologically immature forests** are young (less than 25 years old) and sparse (relative density less than 25). These forests lack a dense forest canopy and therefore contribute more to peak flow—for example, more snow accumulates on the forest floor, and that snow melts rapidly, sending more water into streams (DNR 2004).

  Land use practices that reduce vegetative cover or increase soil compaction, such as timber harvesting and road building, can alter hydrologic processes and increase peak flow. For example, the deeper snow packs found in harvested areas hold more water and melt faster when rain falls on them (Grant and others 2008), which leads to higher stream flows. The effect is more pronounced in larger openings (Harr and McCorison 1979). Removing trees also decreases plant transpiration (the release of water vapor from plants), which leads to increased soil moisture and water runoff in harvested areas (Grant and others 2008).

  The effect of harvest on peak flow can be complex and sometimes counteracting. For example, although snowpacks are deeper in harvested areas, they also are subject to increased sublimation (evaporating without melting) from the wind, especially at higher elevations (Storck and others 2002 as cited in Grant and others 2008).

- **Hydrologically mature forests** have a higher relative density, meaning there is a denser canopy to intercept snowfall and often more vegetation to absorb or slow water. Much of the snow caught in the canopy melts and evaporates or sublimates and thus does not reach the stream (Grant and others 2008). Also, trees dissipate heat by long wave radiation, which can melt the snowpack under a forest canopy. Therefore, snowpacks in hydrologically mature forests are not as deep. These forests contribute less to peak flow during storm events.

- **Areas without vegetation**, such as roads, are also considered hydrologically immature. Rain may flow over the top of the road instead of being absorbed into the road surface.

The area of influence for this indicator is the Type 3 watershed. DNR considered whether harvests projected to occur in a Type 3 watershed would lower hydrologic maturity to a level that would result in a detectable increase in peak flow.

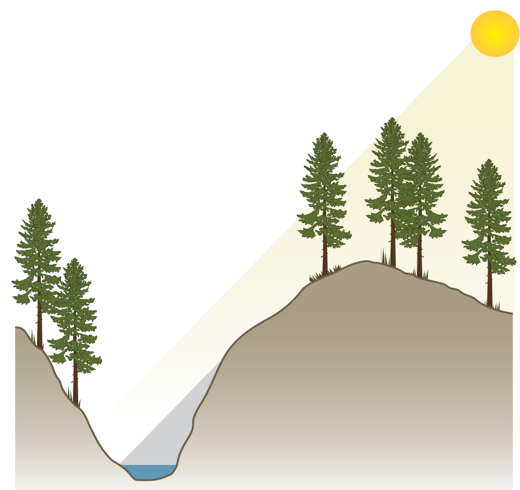
INDICATOR: STREAM SHADE

Stream shade refers to the extent to which incoming sunlight is blocked on its way to the stream channel. Stream shade is considered one of the primary factors influencing stream temperature (Brown 1969). Stream temperature influences water chemistry, which can affect the amount of oxygen present to support aquatic life. Also, all aquatic organisms have a temperature range outside of which they cannot survive.

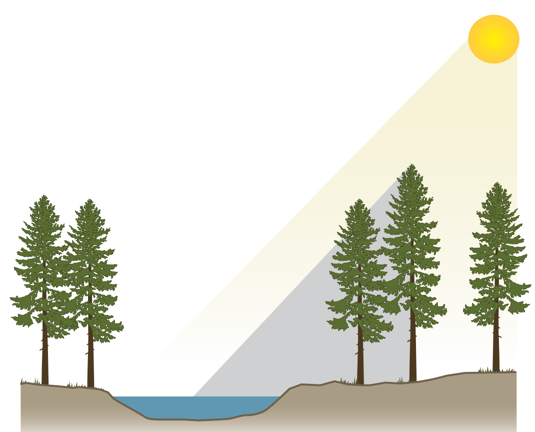
Factors that affect shading include stream size, stream orientation, local topography, tree species, tree height, stand density, and elevation (DNR 2004). For example, streams at higher elevations require less shade to maintain cool water temperatures (Sullivan and others 1990) than streams at lower elevations. In addition, at higher elevations, terrain is steeper, stream channels tend to be narrower and more confined, and the topography itself is more likely to provide shade (refer to Figure 3-10). At lower elevations, streams tend to occupy flatter terrain and are less likely to be shaded by topography. As well, wide, low-elevation streams are generally more open to the sky and naturally shade-limited.

The area of influence for shade is the area through which sunlight passes on its way to the stream. DNR used a

Figure 3-10. Stream Shade in Steep Versus Flat Terrain



At higher elevations, terrain is steeper, stream channels are more confined, and the topography itself is more likely to provide shade.



At lower elevations, streams occupy flatter terrain and are less likely to be shaded by topography. In addition, wide, low-elevation streams are more open to the sky and naturally shade-limited.

computer model to estimate the amount of shade on the stream at sample points spaced every 75 feet along each stream reach, at hourly intervals on the hottest day of the year (July 31).[4] DNR also assigned each stream reach a target shade level[5] based on the amount of shade necessary to meet Washington State Surface Water Quality Standards (WAC 173-201A) and the maximum amount of shade available, given the orientation and width of the stream channel.

To determine potential impacts, DNR compared the target shade level for each stream reach to the amount of shade that would be present after management activities have taken place. If a stream reach failed to meet its assigned shade target, DNR estimated the resulting increase in water temperature based on published studies (Sullivan and others 1990). DNR then assigned impacts based on the magnitude of that increase in temperature and professional opinion of how the temperature increase would affect the fish species associated with the reach in question.[6] Fish association was based Washington State Surface Water Quality Standards "designated uses and criteria" (WAC 173-201A), supplemented by 2010 NOAA Fisheries bull trout critical habitat designations.

INDICATOR: FINE SEDIMENT DELIVERY

The term fine sediment refers to small soil particles, such as sand, silt, or clay, generally less than about 1/16th of an inch in diameter. Fine sediment is generated from the interaction of water and exposed soil (for example, unpaved roads or soils exposed by harvest activities or natural processes such as stream bank erosion). There are several ways that fine sediment can be delivered to the riparian system, including through the erosion of stream banks (Megahan 1982 and Scrivener 1988 as cited in DNR 1996), landslides (Cederholm and Reid 1987), water flowing across the land surface (a process called overland flow) (Comerford and others 1992 as cited in DNR 1997), or improperly designed road-associated features such as ditches and culverts that drain either too near, or into, the stream channel (DNR 1997). A past study in the Clearwater landscape found that roads which were neither mitigated nor brought up to modern design standards at the time of the study were a major source of management-related stream sediment (Cederholm and Reid 1987). Information on mitigation of roads through current management practices is presented later in this section.

Increased levels of fine sediment (for example, from management-related activities) can have detrimental effects on both water quality and aquatic habitat. Sediment that settles in streams or stays suspended in the water column can reduce salmon survival (Hicks and others 1991). Fine sediment deposited in areas where salmon spawn can decrease the survival of eggs and young hatchlings by reducing the availability of oxygen, and muddy, sediment-filled water can cause stress to juvenile salmon during the summer (Cederholm and Reid 1987). Increased levels of fine sediment can also reduce populations of small aquatic insects, an important food source for salmon (Cederholm and Reid 1987). (For additional discussion of sediment and its effects on fish, refer to "Fish," p. 3-147.)

The area of influence for fine sediment delivery is all roads (on state trust lands and non-state trust lands) located within 300 feet of a stream or water body in each Type 3 watershed. DNR based this distance on the methodology of Potyondy and Geier (2011). DNR analyzed traffic on **all roads (roads on state trust lands and non-state trust lands)** in the OESF because traffic associated with harvest activities may run on roads built and maintained by DNR or on roads built and maintained by other landowners.

DNR assessed the potential delivery of fine sediment from the road network (refer to Text Box 3-4) using traffic impact scores. The role of traffic in increasing road sediment production is well-recognized (Luce and Black 2001, Reid and Dunne 1984). Traffic impact scores were based on the following factors:

- **Road surface type**: Road traffic generates sediment through surface erosion, which occurs only on unpaved roads. Paved roads were not scored as having an impact.
- **Proximity of roads to streams or other water bodies**: DNR used GIS tools to determine the proximity of roads to water bodies. Roads that were closer to the stream received a higher score (higher impact) than those farther away. Roads greater than 300 feet from a water body were not scored as having an impact.
- **Projected traffic levels**: DNR considered the number of times per day a log truck may drive over each segment of road to transport harvested timber to market. DNR included log truck traffic that may result from future harvests on all ownerships in a Type 3 watershed (state trust lands as well as federal, tribal, and private lands). Estimated traffic levels for other ownerships were based on a review of past reports of timber harvest volumes and assumptions about harvest intensity relative to DNR's projected management activities; these estimated traffic levels were held constant, meaning they did not vary from one decade to the next. Recreational and other uses were not included in the analysis because information about recreational and other

Text Box 3-4. OESF Road Network

The **road network in the OESF** ranges from temporary gravel roads used for a single timber sale and then abandoned, to roads that are paved, permanent, and used year-round. Roads are categorized according to the following:

- **Status**, such as active (in use), closed (could be temporarily closed, but not now in use), decommissioned (made impassable to vehicle traffic, expected to be reconstructed in the future), or abandoned (not expected to be reused in the future with all drainage facilities removed); and
- **Surface type**, such as asphalt, chip seal, crushed aggregate, or unpaved.

Most roads on state trust lands in the OESF are active and unpaved. This type of roads has the greatest potential to generate and deliver sediment to streams and other water bodies (causing turbidity) unless improvements are made (Potyondy and Geier 2011, Elliot and others 2009, Croke and Hairsine 2006) (refer to Appendix C for miles of road by status and surface type).

traffic levels in the OESF was not available. Traffic levels were determined based on the methods of Dubé and others (2004). (For additional information, refer to Appendix C.)

For this analysis, DNR assumed the extent of the road network in the OESF would remain unchanged under any alternative throughout the 100-year analysis period. DNR does not expect a substantial reduction of the road network because roads are essential to working forests. Although DNR has abandoned some of its roads, very little additional road abandonment is identified in current plans. Nor does DNR expect a substantial expansion of its road network, although some new roads may be needed. It is too speculative to estimate their locations or number of miles; the exact locations and lengths of roads cannot be determined until a harvest is planned and a site assessment is performed. (For more information about the accomplishment of road maintenance and abandonment plans and the methodology used to calculate traffic scores, refer to Appendix C.)

Separate Fine Sediment Analyses

In this FEIS, fine sediment delivery was analyzed in "Fish" and also in "Water Quality" as part of the traffic impact score. Each analysis of fine sediment delivery was performed at a spatial scale appropriate to the topic, and consequently the analyses had different results.

In "Riparian," DNR analyzed fine sediment delivery potential using traffic impact scores, as described in the preceding section. DNR coupled fine sediment delivery with the sensitivity of the stream channel to fine sediment delivery.

In "Water Quality," DNR analyzed fine sediment potential only; DNR did not consider sensitivity. DNR's indicators for water quality were based on Ecology's water quality standards. Those standards are primarily concerned with whether or not an impact is occurring (in this case, turbidity caused by delivery of fine sediment), regardless of the sensitivity of the stream channel to fine sediment input. For that reason, for its water quality analysis, DNR considered potential only. Fine sediment delivery potential in "Water Quality" was analyzed with four separate road-related indicators. In addition to traffic impact scores, these indicators were road density, stream crossing density, and the proximity of roads to streams and other water bodies.

INDICATOR: LEAF AND NEEDLE LITTER RECRUITMENT

Leaf and needle litter refers to fine organic materials, such as leaves and tree needles, which grow in the forest canopy and fall to the ground or into stream channels. Leaf and needle litter supply nutrients to streams; these nutrients are needed by the small aquatic insects (Richardson 1992) that are an important food source for fish and other aquatic species. Leaf and needle litter recruitment is especially important in small, headwater streams where it can provide the greatest share of total metabolic energy for the stream community (Richardson 1992).

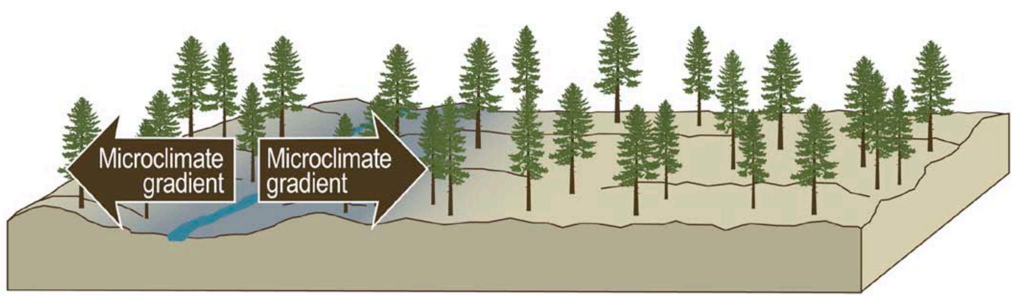
The area of influence for leaf and needle litter is the 100-year floodplain plus one site-potential tree height (approximately 200 feet) (FEMAT 1993). Factors that influence leaf and needle litter recruitment include the stand density of the adjacent forest (as measured by its basal area[7]), the species of trees, their height, and their distance from the stream. Many hardwoods provide leaf litter that has higher nutrient value and is more readily broken down than the needle litter provided by conifers (Bisson and Wondzell 2009).

INDICATOR: RIPARIAN MICROCLIMATE

Streams are known to influence climatic conditions in the surrounding forest (Meehan 1991, Naiman 1992, Maridet and others 1998 as cited in Naiman and others 2005). Air and soil temperatures near streams are cooler, and the humidity is higher next to the stream than it is in the interior forest. The effect dissipates as one moves further from the stream. This phenomenon is known as the riparian microclimate gradient (refer to Figure 3-11). A microclimate is a localized climate zone.

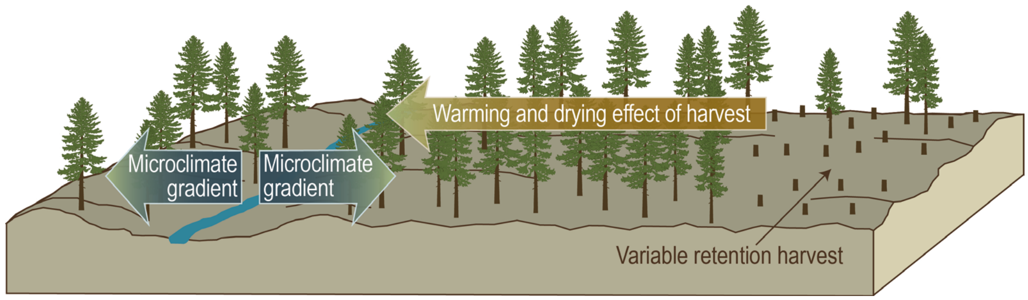
Figure 3-11. Riparian Microclimate Gradient

DNR assumed the microclimate effect is strongest in the 100-year floodplain and decreases gradually as one moves further from the stream.



Removing or altering vegetation, such as harvesting timber, in or near riparian areas can influence microclimatic conditions (Spence and others 1996). Harvested areas are exposed to increased sunlight, which heats the soil and warms and dries the air (refer to Figure 3-12). Many riparian-associated plant and animal species require cool, moist, relatively stable conditions for survival and reproduction. Vegetation removal may affect these species adversely (Brosofske and others 1997).

Figure 3-12. Effects of Harvests on Riparian Microclimate Gradient

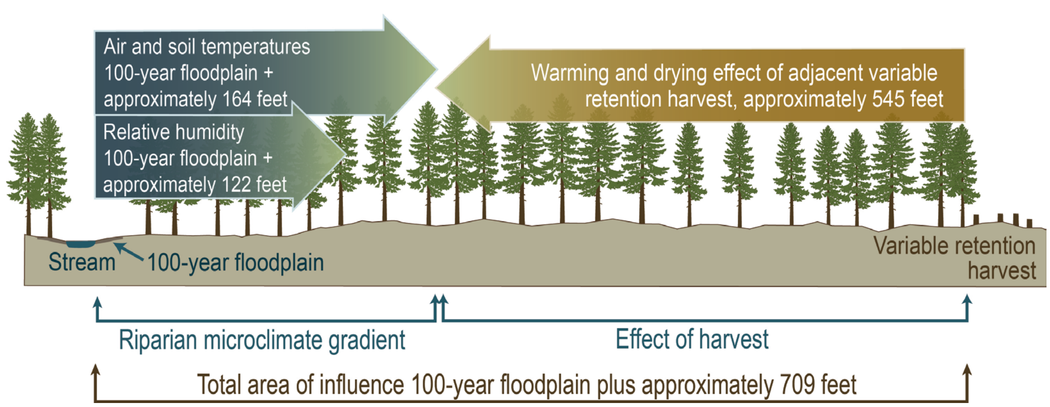


The area of influence for microclimate is derived by adding the approximate width of the riparian microclimate gradient (which includes the 100-year floodplain) and the maximum extent of warming and drying effects of adjacent variable retention harvests.

- Studies by Brosofske and others (1997) demonstrated that streams exert a cooling effect on both soil and air temperatures at distances of up to 164 feet from the stream. In addition, they noted increased relative humidity at distances up to 122 feet from the stream.
- The heating and drying effects of harvest can extend up to approximately 545 feet into the surrounding unharvested areas (Chen 1991, Chen and others 1995, FEMAT 1993).

Thus for the FEIS, DNR modeled the total microclimate area of influence as the 100-year floodplain plus an additional 709 feet (164 feet plus 545 feet) (refer to Figure 3-13). DNR analyzed this area to determine how daytime air temperature, soil temperature, and relative humidity within the riparian microclimate gradient may change as a result of nearby harvests. Only daytime conditions were evaluated, since that is when the greatest impacts of harvest are expected to occur.

Figure 3-13. Riparian Microclimate Area of Influence



INDICATOR: COMPOSITE WATERSHED SCORE

Each of the indicators corresponds to an ecosystem process that takes place in and around riparian areas. While it is meaningful to assess each indicator individually, it is the numerous interactions between them that best describe the riparian ecosystem as a whole. To approximate the complexity and interactions of these indicators, DNR used a computer model (refer to Appendix G) to create composite watershed scores for each Type 3 watershed. Composite watershed scores were calculated by combining the watershed scores for each indicator into a single score.

Indicators are not equal in their contribution to functioning riparian habitat; some are more important than others. Indicators were assigned a weighting factor. Weighting factors were based on DNR's professional judgment as informed by scientific literature (Reeves and others 2004, Gallo and others 2005). The net contributions of the indicators to the composite watershed score were as follows:

- Large woody debris recruitment – 50 percent
- Peak flow – 15 percent
- Stream shade – 12 percent
- Fine sediment delivery – 7.5 percent
- Coarse sediment delivery – 7.5 percent
- Leaf and needle litter recruitment – 5 percent
- Riparian microclimate –3 percent

Composite watershed scores were graphed, reported at decades 0, 1, 6, and 9, and examined to determine how the distribution of scores shift over time.

For more information on how composite watershed scores were calculated, refer to Figure G-23 in Appendix G. Appendix G also includes information on the incorporation of coarse sediment delivery into the composite watershed score.

▪ Criteria and Indicators: Summary

Table 3-14 summarizes the criteria and indicators and how they were measured for the No Action and Landscape alternatives. DNR analyzed the Pathways Alternative using primarily qualitative techniques (refer to p. 3-17 through 3-18).

Table 3-14. Criteria and Indicators for Riparian Areas and how They Were Measured

Criterion/ Indicator	**How the indicator was measured**	**Potential environmental impacts**
Functioning riparian habitat/ Large woody debris recruitment	Characteristics of the riparian forest, such as relative density and the size and species of trees, and distance of trees from the floodplain **Area of influence:** 100-year floodplain plus an additional 200 feet **Contribution to overall riparian impact score (importance):** 50 percent **Assessment area:** All streams that cross state trust lands within Type 3 watersheds that contain at least 20 percent state trust lands	**Low**: Most watersheds are in a low impact condition. Watershed scores generally remain stable or increase over time, indicating **maintenance or restoration of riparian function**. Less than 10 percent of watersheds are in a high impact condition, or the number of watersheds in a high impact condition steadily decreases over time. **Medium**: Most watersheds are in a medium impact condition. Watersheds scores generally remain stable or increase over time, indicating **maintenance or restoration of riparian function**. Less than 10 percent of watersheds are in a high impact condition, or the number of watersheds in a high impact condition steadily decreases over time. **High**: More than 10 percent of watersheds are in a high impact condition and the number of watersheds in a high impact condition does not steadily decrease over time, indicating **failure to restore riparian function** in these watersheds.
Functioning riparian habitat/ Peak flow	Hydrologic maturity of a Type 3 watershed **Area of influence:** Type 3 watershed **Contribution to overall riparian impact score (importance):** 15 percent **Assessment area:** All streams, regardless of ownership, within Type 3 watersheds that contain at least 20 percent state trust lands	
Functioning riparian habitat/ Stream shade	Topography, stream orientation, and characteristics of the riparian forest, including canopy closure and tree height **Area of influence**: Area through which sunlight passes on its way to the stream; shade measured at hourly intervals on the hottest day of the year (July 31) **Contribution to overall riparian impact score (importance)**: 12 percent **Assessment area**: All streams that cross state trust lands within Type 3 watersheds that contain at least 20 percent state trust lands	

Table 3-14, Continued. Criteria and Indicators for Riparian Areas and how They Were Measured

Criterion/ Indicator	**How the indicator was measured**	**Potential environmental impacts**
Functioning riparian habitat/ Fine sediment delivery	Characteristics of the road network, such as proximity of roads to streams and water bodies, surface type (paved or unpaved), and traffic levels, measured using traffic impact scores **Area of influence:** All roads (on state trust lands and non-state trust lands) that are located within 300 feet of a stream or water body in each Type 3 watershed **Contribution to overall riparian impact score (importance):** 7.5 percent **Assessment area:** All streams, regardless of ownership, within Type 3 watersheds that contain at least 20 percent state trust lands	**Low**: Most watersheds are in a low impact condition. Watershed scores generally remain stable or increase over time, indicating **maintenance or restoration of riparian function**. Less than 10 percent of watersheds are in a high impact condition, or the number of watersheds in a high impact condition steadily decreases over time. **Medium**: Most watersheds are in a medium impact condition. Watersheds scores generally remain stable or increase over time, indicating **maintenance or restoration of riparian function**. Less than 10 percent of watersheds are in a high impact condition, or the number of watersheds in a high impact condition steadily decreases over time. **High**: More than 10 percent of watersheds are in a high impact condition and the number of watersheds in a high impact condition does not steadily decrease over time, indicating **failure to restore riparian function** in these watersheds.
Functioning riparian habitat/ Leaf and needle litter recruitment	Characteristics of the riparian forest, such as relative density and the size and species of trees, and distance of trees from stream **Area of Influence:** 100-year floodplain plus an additional 200 feet **Contribution to overall riparian impact score (importance)**: 5 percent **Assessment area**: All streams that cross state trust lands within Type 3 watersheds that contain at least 20 percent state trust lands	

Table 3-14, Continued. Criteria and Indicators for Riparian Areas and how They Were Measured

<table>
<tr><th>Criterion/
Indicator</th><th>How the indicator was measured</th><th>Potential environmental impacts</th></tr>
<tr><td>Functioning riparian habitat/
Riparian microclimate</td><td>Changes to daytime air temperature, soil temperature, and relative humidity as a result of nearby harvests

Area of influence: The 100-year floodplain plus an additional 709 feet

Contribution to overall riparian score (importance): 3 percent

Assessment area: All streams that cross state trust lands within Type 3 watersheds that contain at least 20 percent state trust lands</td><td rowspan="2">Low: Most watersheds are in a low impact condition. Watershed scores generally remain stable or increase over time, indicating maintenance or restoration of riparian function. Less than 10 percent of watersheds are in a high impact condition, or the number of watersheds in a high impact condition steadily decreases over time.

Medium: Most watersheds are in a medium impact condition. Watersheds scores generally remain stable or increase over time, indicating maintenance or restoration of riparian function. Less than 10 percent of watersheds are in a high impact condition, or the number of watersheds in a high impact condition steadily decreases over time.

High: More than 10 percent of watersheds are in a high impact condition and the number of watersheds in a high impact condition does not steadily decrease over time, indicating failure to restore riparian function in these watersheds.</td></tr>
<tr><td>Functioning riparian habitat/
Composite watershed score</td><td>Combination of Type 3 watershed impact scores for all indicators</td></tr>
</table>

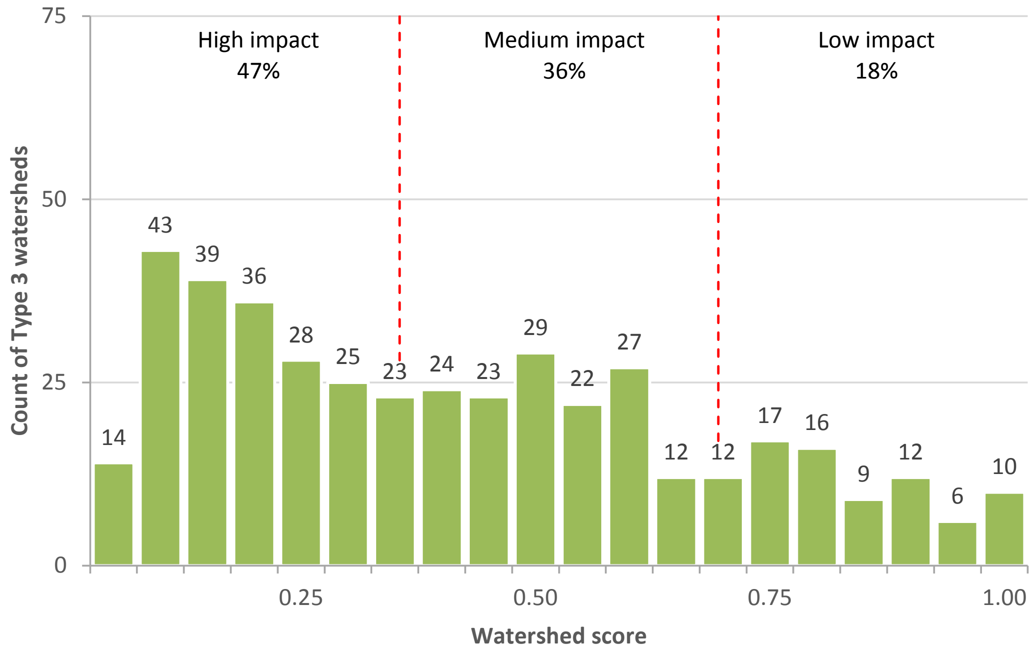
Current Conditions

As described previously, current conditions for each indicator are presented as a distribution of scores. Scores were developed using sophisticated computer modeling techniques which are described in detail in Appendix G. DNR built a separate model for each indicator, including the composite watershed score.

Indicator: Large Woody Debris Recruitment

The distribution of watershed scores for large woody debris recruitment is shown in Chart 3-12. Currently, 47 percent of Type 3 watersheds are in a high impact condition, 36 percent are in a medium impact condition, and 18 percent are in a low impact condition.

Chart 3-12. Current Distribution of Watershed Scores for Large Woody Debris Recruitment



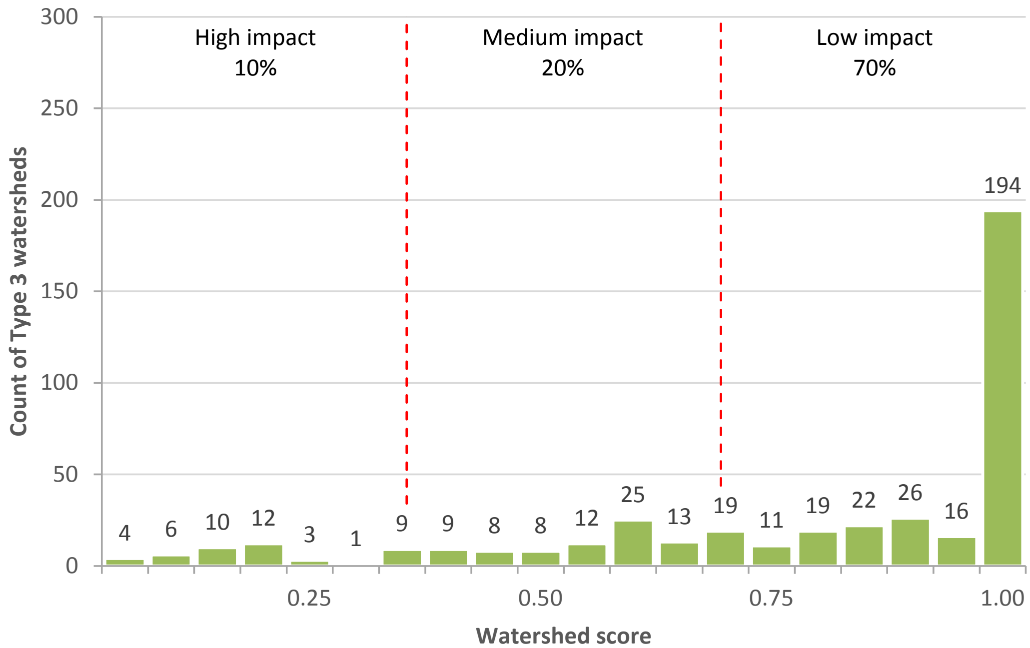
The current condition of large woody debris recruitment is primarily the result of timber harvests that occurred prior to implementation of the HCP. Between 1970 and 1990, approximately half of the forest within the area of influence for large woody debris was clearcut (today, DNR uses variable retention harvest; refer to Text Box 3-1 on p. 3-25). While regrowth has occurred, many of these areas are currently in the Competitive Exclusion stand development stage. (For a description of stand development stages, refer to Text Box 3-2, p. 3-28).

Stands in the Competitive Exclusion stage often lack the large trees, snags, multiple canopy layers, and significant large woody debris found in more structurally complex forests (Bigley and Deisenhofer 2006). The woody debris these forests provide currently consists of small diameter pieces, which decay faster, are less stable in the stream channel, and are less likely to influence in-stream habitat.

Indicator: Peak Flow

The distribution of watershed scores for peak flow is shown in Chart 3-13. Currently, 10 percent of Type 3 watersheds are in a high impact condition, 20 percent are in a medium impact condition, and 70 percent are in a low impact condition

Chart 3-13. Current Distribution of Watershed Scores for Peak Flow



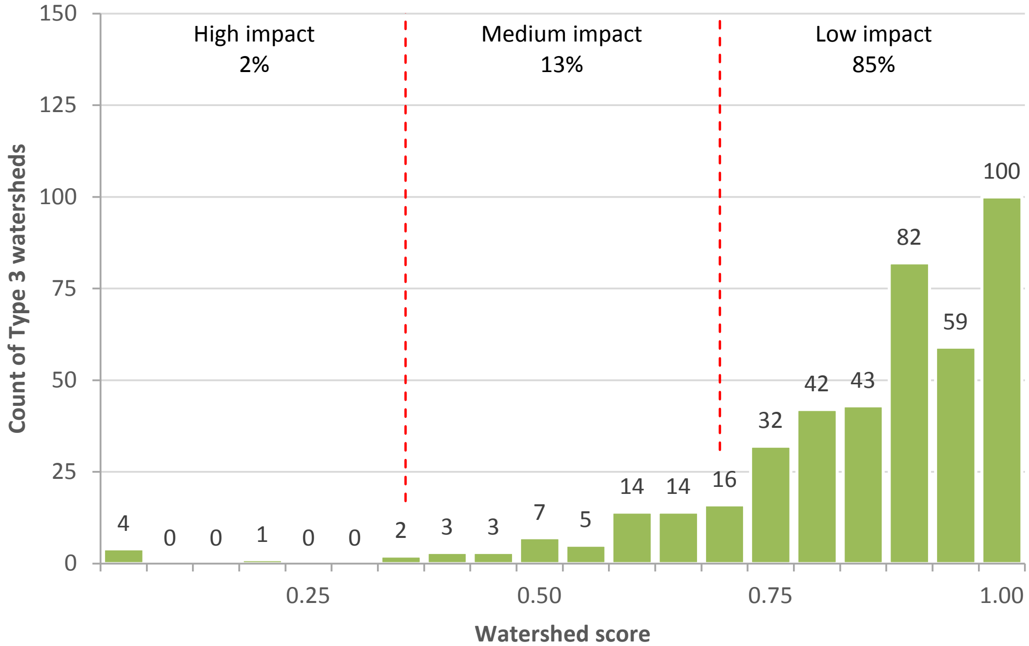
Currently, the proportion of hydrologically immature forests remains sufficiently low to prevent or minimize changes in peak flow. A large percentage of a watershed must be classified as hydrologically immature before changes to peak flow can be detected.

Studies by Grant and others (2008) have shown that peak flow response to harvest varies by hydrologic zones (areas defined by the dominant precipitation type). These studies found that changes to peak flow become detectable only when more than 40 percent of a watershed is harvested in the rain-dominated zone, and more than 20 percent of the watershed is harvested in the rain-on-snow zone. Most watersheds are currently below this threshold.

Indicator: Stream Shade

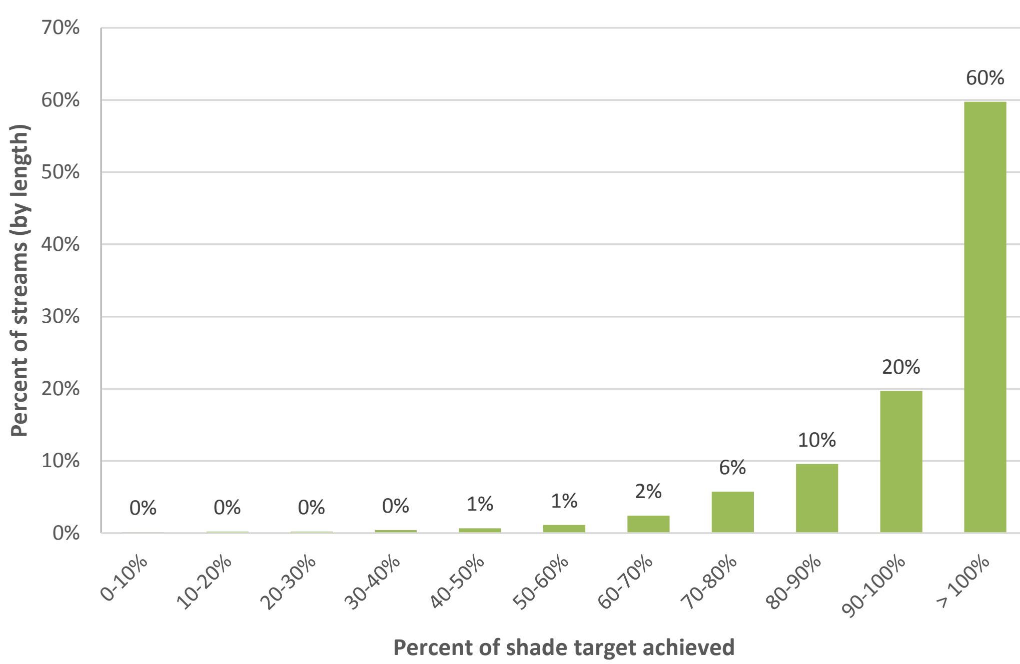
The distribution of watershed scores for shade is shown in Chart 3-14. Currently, 2 percent of Type 3 watersheds are in a high impact condition, 13 percent are in a medium impact condition, and 85 percent are in a low impact condition.

Chart 3-14. Current Distribution of Watershed Scores for Stream Shade



The current distribution of watershed scores for shade shows that most stream reaches (approximately 60 percent, by length) meet or exceed their shade targets (Chart 3-15). An additional 20 percent of streams, by length, have nearly achieved their shade target (meaning they are within 10 percent). Current shade levels are a result of many factors, including topography, stream orientation, stream width, forest conditions, and past and current harvests.

Chart 3-15. Current Progress of Streams Toward Shade Targets

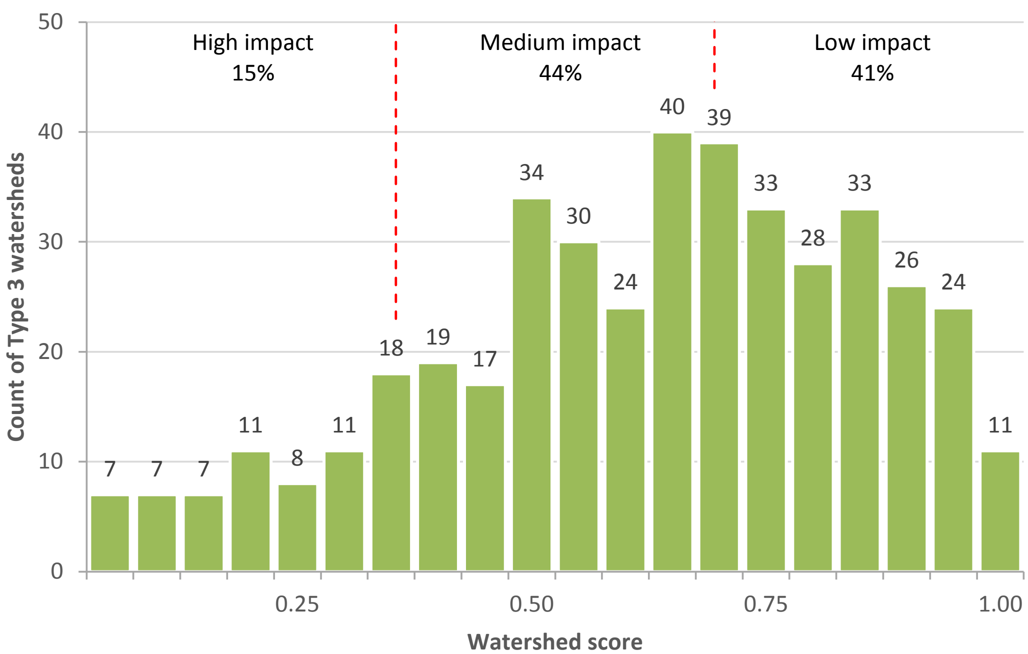


Indicator: Fine Sediment Delivery

As explained previously, for this indicator DNR considered both fine sediment delivery potential and the sensitivity, or expected channel response, to the delivery of fine sediment. Fine sediment delivery potential was determined using traffic impact scores, which were based on road surface type, the proximity of roads to streams or other water bodies, and the level of log-truck traffic that may result from future harvests in the Type 3 watershed on all ownerships (state trust lands as well as federal, tribal, and private lands).

Instead of current conditions, DNR reports results based on the first decade's worth of harvest activities under the No Action Alternative. In the first decade, 15 percent of Type 3 watersheds are in a high impact condition, 44 percent are in a medium impact condition, and 41 percent are in a high impact condition (refer to Chart 3-16).

Chart 3-16. Distribution of Watershed Scores for Fine Sediment Delivery Based on the First Decade of Harvest Activities Under the No Action Alternative



Indicator: Leaf and Needle Litter Recruitment

The distribution of watershed scores for leaf and needle litter recruitment is shown in Chart 3-17. Currently, 25 percent of Type 3 watersheds are in a high impact condition, 37 percent are in a medium impact condition, and 38 percent are in a low impact condition.

Chart 3-17. Current Distribution of Watershed Scores for Leaf and Needle Litter Recruitment

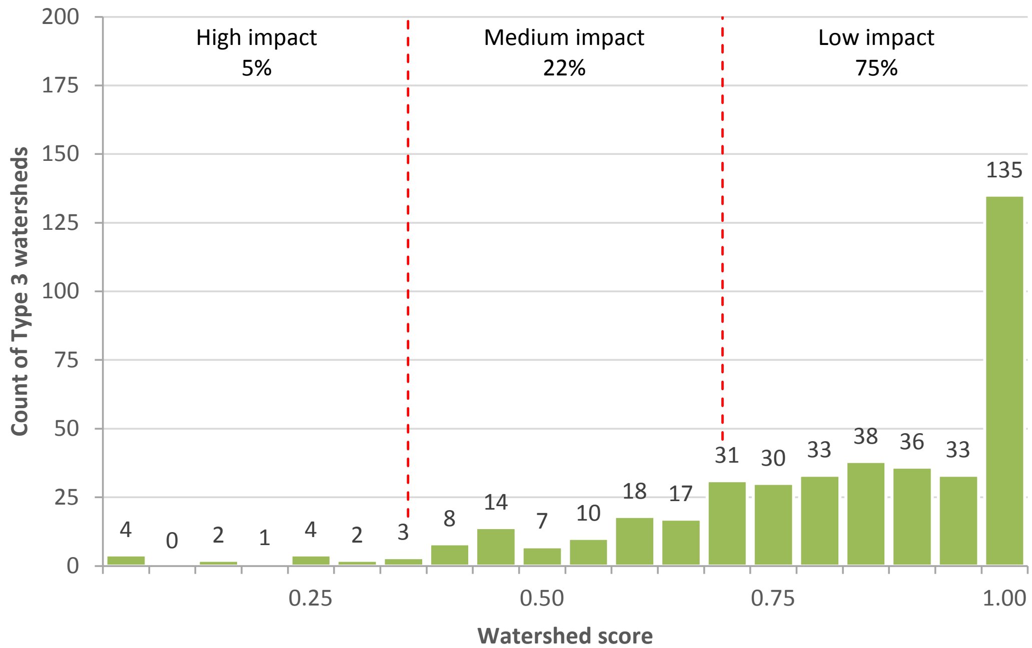
The high impact condition of many Type 3 watersheds is due to a combination of factors: the high sensitivity of headwater streams (Type 4 and Type 5 streams) to leaf and needle litter input, the abundance of these streams on state trust lands in the OESF, past harvests along Type 4 streams, and past and current harvests along Type 5 streams on stable ground.

Per DNR's current policies, procedures, and forest practice rules, interior-core buffers are applied to Type 1 through Type 4 streams,[8] and to Type 5 streams on potentially unstable slopes or landforms. Interior-core buffers are not applied to Type 5 streams on stable ground. On these streams, DNR applies only an equipment limitation zone, which is an area along the stream where heavy equipment use is limited to maintain bank stability and integrity. Refer to Chapter 2 for a discussion on the application of interior-core buffers under each management alternative.

Indicator: Riparian Microclimate

The distribution of watershed scores for riparian microclimate is shown in Chart 3-18 Currently, 5 percent of Type 3 watersheds are in a high impact condition, 22 percent are in a medium impact condition, and 75 percent are in a low impact condition.

Chart 3-18. Current Distribution of Watershed Scores for Riparian Microclimate



Variable retention harvest methods have the most influence on this indicator; harvests within 709 feet of the floodplain may affect riparian microclimate conditions. However, studies have shown these effects to be temporary.

- In the Oregon Coast Range, where plant growth is rapid, in 10 years the vegetation in a newly regenerated area can often grow as high as the base of tree crowns in riparian buffers. Side light and air movement quickly become limited, and microclimate conditions more like those of a continuous forest are reestablished (Hibbs and Bower 2001).

- Summers (1982) found that shade recovery to old-growth levels occurred within about 10 years in the Sitka spruce zone, 14 years in the Oregon Coast Range western hemlock zone, and about 20 years in the Cascade Mountain western hemlock zone. However, shade recovery was slower in higher elevation Pacific silver fir forests in the Cascade Mountains, and was only 50 percent complete after 20 years (Brown and Krygier 1970, Harris 1977, Feller 1981, and Harr and Fredriksen 1988 as cited in Moore and others 2005). Recovery took longer in some cases and was not detected in others.

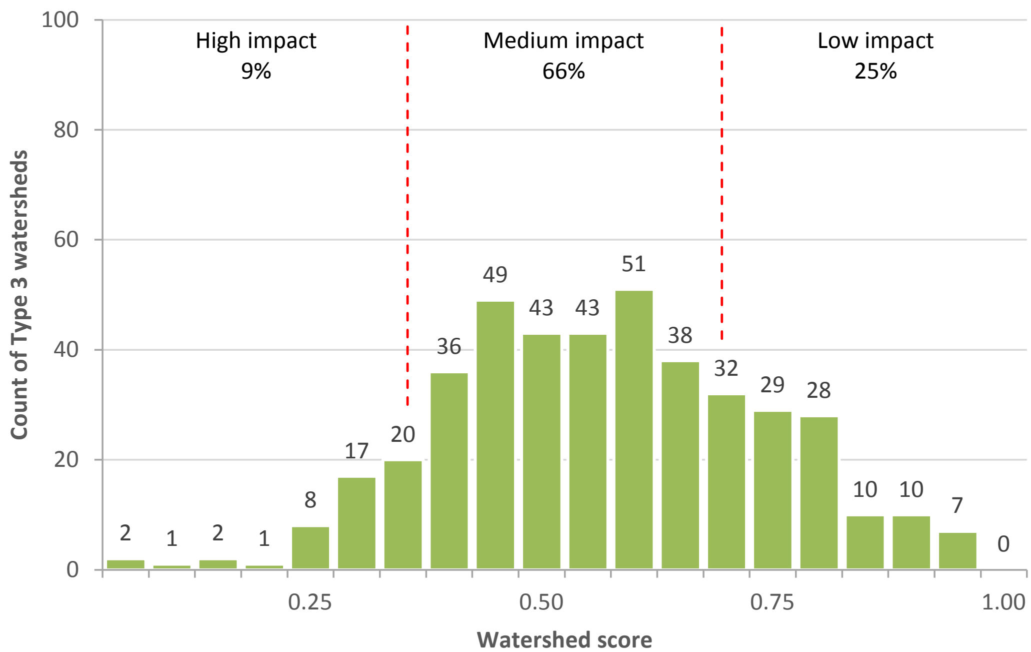
Based on a review of the available literature, DNR modeled microclimate effects as declining 50 percent in 10 years and disappearing in 20 years.

Most likely, most watersheds are currently in a low or medium impact condition for microclimate because the amount of variable retention harvest within the microclimate area of influence has declined over the last 20 years. In addition, microclimate gradients have had enough time to recover from past variable retention harvests.

Indicator: Composite Watershed Score

The distribution of composite watershed scores is shown in Chart 3-19. Currently, 9 percent of Type 3 watersheds are in a high impact condition, 66 percent are in a medium impact condition, and 25 percent are in a low impact condition.

Chart 3-19. Current Distribution of Composite Watershed Scores



Past harvest practices affected a large proportion of the OESF. As a result, many of these areas are currently in the early stages of forest development. These stages are less capable of providing the full suite of riparian functions, which is reflected by most watersheds currently being in a medium impact condition.

Results

Results for each indicator for the No Action and Landscape alternatives are presented as a distribution of scores and based on model results. Scores were developed using sophisticated computer modeling techniques which are described in detail in Appendix G. DNR built a separate model for each indicator, including the composite watershed score. Indicators for the Pathways Alternative were analyzed using primarily qualitative techniques.

Indicator: Large Woody Debris Recruitment

NO ACTION AND LANDSCAPE ALTERNATIVES

Figure 3-14 shows the distribution of watershed scores under the No Action and Landscape alternatives for large woody debris recruitment for decades 1, 6, and 9, representing short-, mid-, and long-term trends.

Figure 3-14. Distribution of Watershed Scores for Large Woody Debris Recruitment

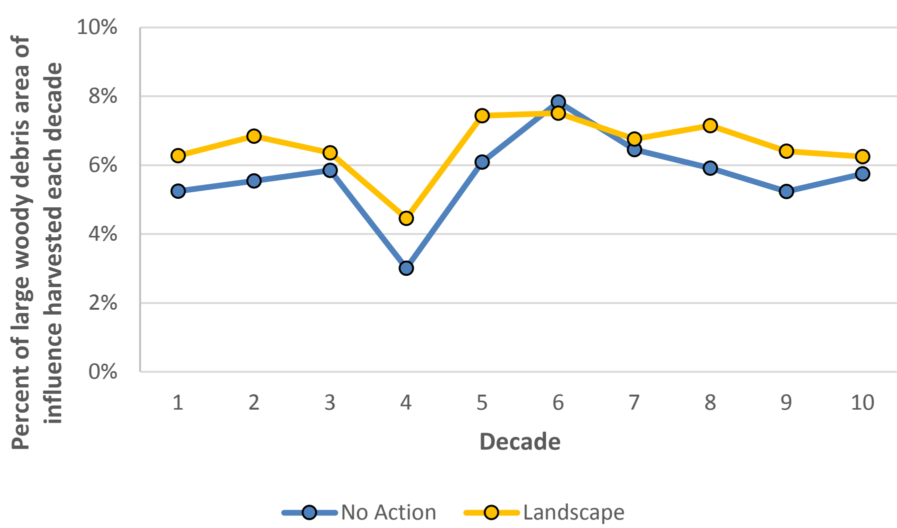
The distribution of watershed scores is nearly identical for both alternatives and steadily moves toward an improved condition (higher score, lower impact). Most watersheds remain in a medium or low impact condition for the duration of the analysis period. These results can be attributed to a combination of factors, including natural forest growth, past harvest activities, and future harvest activities.

- **Natural forest growth and past harvest activities**: Much of the area of influence for large woody debris recruitment is currently deferred from harvest. In addition, much of the area of influence is currently in the Competitive Exclusion stand development stage. In the absence of harvest or natural disturbance, forest stands can remain in the Competitive Exclusion stage for decades. An analysis of the outputs of DNR's analysis model shows that, on average, in the absence of management forest stands currently in the Competitive Exclusion stage remain in this stage for 50 years or more.

  During the Competitive Exclusion stage, stand density, or the extent to which an area is occupied by trees, typically reaches its maximum. Competition for limited resources, such as light, nutrients, and growing space, is high. Many trees in the stand may decline in growth and eventually die as competition intensifies (Franklin and others 2007). While some forest stand-level parameters such as basal area or standing volume increase at their maximum rate during the Competitive Exclusion stage because of the sheer number of trees, the growth of individual trees is generally depressed. Conditions for large woody debris therefore should improve over time through natural processes, but the change will be slow. By the end of the analysis period, DNR anticipates that many watersheds will be in a medium impact condition under both the No Action and Landscape alternatives.

- **Future harvest activities – variable retention harvest**: The analysis model projected similar levels of variable retention harvests within the large woody debris recruitment area of influence under both the No Action and Landscape alternatives. From decade to decade, the projected level of harvest varies but does not exceed 8 percent of the area of influence (Chart 3-20). Large woody debris recruitment is projected to improve gradually across the distribution of watersheds at this level of harvest.

Chart 3-20. Projected Amount of Variable Retention Harvests Within the Area of Influence for Large Woody Debris, by Alternative



- **Future harvest activities – thinning:** Thinning can reduce competition between trees for resources. Trees respond to thinning with accelerated growth, which eventually leads to higher-quality large woody debris. While there may be a short-term reduction in large woody debris recruitment immediately after harvest, long-term recruitment potential is expected to benefit from thinning (Bigley and Deisenhofer 2006).

The differences between the extent and intensity of harvests projected for the No Action and Landscape alternatives are not large enough to result in appreciable differences in large woody debris recruitment. Changes in large woody debris recruitment over time are nearly identical for the No Action and Landscape alternatives.

The potential environmental impact for large woody debris recruitment is considered **medium** for the No Action and Landscape alternatives. The distribution of impact scores moves steadily toward an improved condition, but most watersheds remain in a medium impact condition because it takes considerable time for trees to grow large enough to contribute large woody debris. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

DNR estimates that impacts to large woody debris recruitment under the Pathways Alternative will be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of large woody debris watershed scores are expected to be similar to those shown in Figure 3-14 for the Landscape Alternative.

Some of the forest stands selected for active management (thinning) or passive management under the Pathways Alternative are located within the large woody debris area of influence (within 200 feet of and including the 100-year floodplain of Type 1 through 5 streams). Following, DNR describes how active and passive management of these stands may affect potential impacts for large woody debris recruitment.

Passive Management

In some landscapes, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4), meaning these forest stands will not be harvested for as long as these pathways remain in place. These stands will continue to grow and develop forest structure that would otherwise have been harvested. Therefore, the potential impacts for large woody debris recruitment under the Pathways Alternative would be equal to or lower than those projected under the Landscape Alternative.

Active Management

In some landscapes, DNR will thin forest stands in operable (Pathway 5) or deferred (Pathway 7) areas to create or accelerate development of Young Forest Habitat. Such thinnings are expected to restore or enhance riparian habitat functions while not appreciably reducing riparian ecosystem benefits in the short term (DNR 2006, p. 4).

Many of the stands selected for thinning under Pathways 5 and 7 are currently in the Competitive Exclusion stand development stage. The woody debris these forests provide consists of small diameter pieces, which decay faster, are less stable in the stream channel, and are less likely to influence in-stream habitat. Thinning such stands is expected to accelerate tree diameter growth, thereby decreasing the time until large diameter wood is available to be delivered to the stream.

The potential environmental impact of the Pathways Alternative for large woody debris recruitment is considered **medium**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Peak Flow

NO ACTION AND LANDSCAPE ALTERNATIVES

The distribution of watershed scores for peak flow is shown in Figure 3-15 on p. 3-74. Under both the No Action and Landscape alternatives, the distribution of watershed scores remains relatively stable. Most watersheds are in a low impact condition (higher score, lower impact) for peak flow, and these alternatives track in a similar fashion.

Peak flow is influenced by the proportion of hydrologically immature forests within a watershed. Under both alternatives, the proportion of hydrologically immature forests remains sufficiently low to prevent or minimize changes in peak flow. On average, in each decade, hydrologically immature forests comprise less than approximately 25 percent of each Type 3 watershed.

The potential environmental impact of either the No Action or Landscape Alternative for peak flow is considered **low**. Most watersheds are in a low impact condition and the number of watersheds in a low impact condition is projected to increase slightly over time. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

Figure 3-15. Distribution of Watershed Scores for Peak Flow

PATHWAYS ALTERNATIVE

DNR estimates that impacts to peak flow under the Pathways Alternative will be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through

3-18). Trends in the distribution of peak flow watershed scores are expected to be similar to those shown in Figure 3-15 for the Landscape Alternative. Following, DNR describes how active and passive management anticipated under the Pathways Alternative may affect potential impacts for peak flow.

Passive Management

In some landscapes, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4), meaning these forest stands will not be harvested as long as these pathways remains in place. These stands are structurally complex enough to be classified as habitat and likely to be hydrologically mature. These stands should continue to grow and develop and help to maintain hydrologic maturity in the watershed. Therefore, potential impacts for peak flow under the Pathways Alternative should be equal to or lower than those projected under the Landscape Alternative.

Active Management

In some landscapes, DNR will thin forest stands in operable (Pathway 5) or deferred (Pathway 7) areas to create or accelerate development of Young Forest Habitat. Because DNR rarely thins stands below a relative density of 35, these thinnings should not increase the extent of hydrologically immature stands within the watershed.

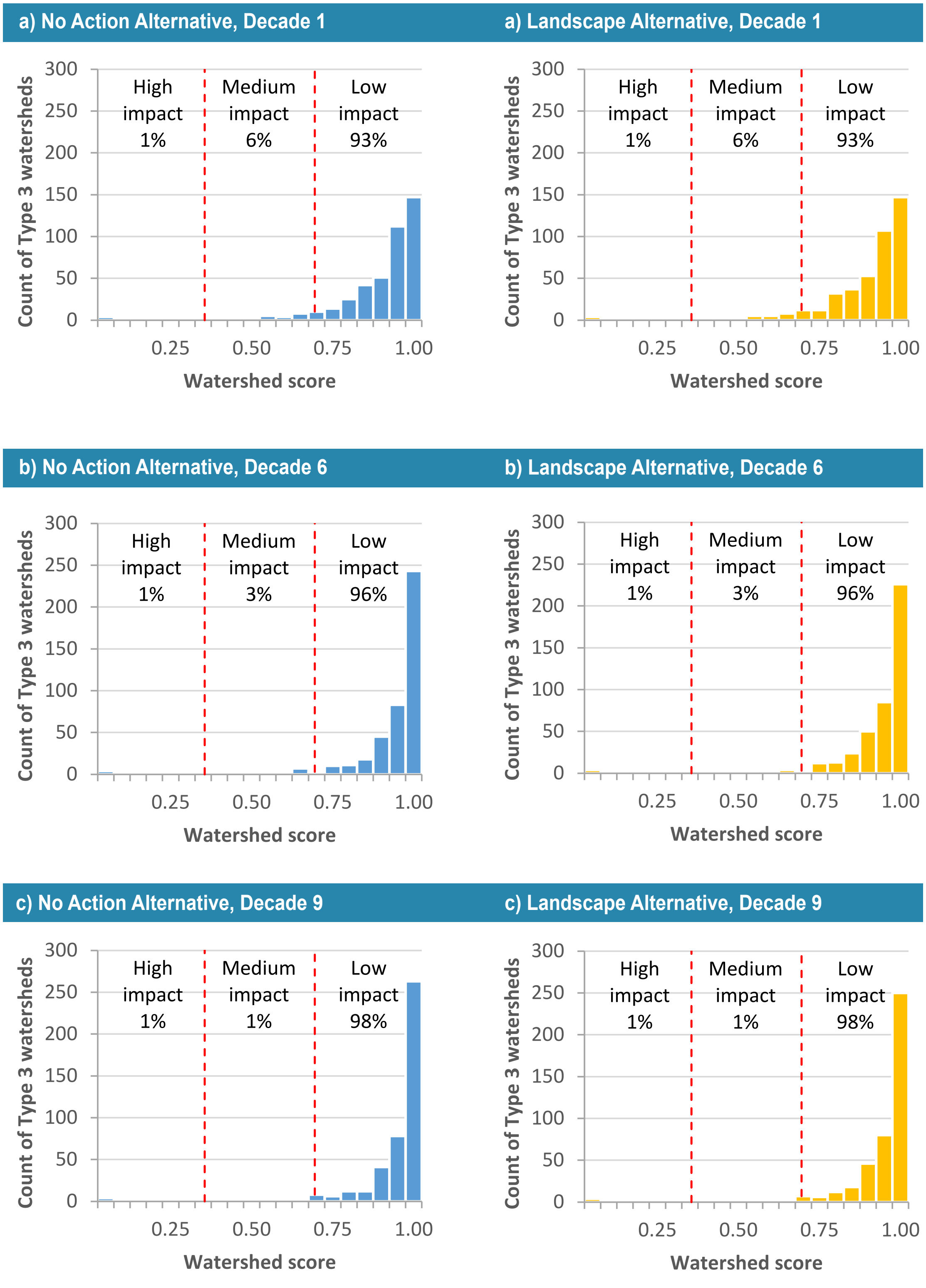
The potential environmental impact of the Pathways Alternative for peak flow is considered **low**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Stream Shade

NO ACTION AND LANDSCAPE ALTERNATIVES

The distribution of watershed scores for stream shade under the No Action and Landscape alternatives is shown in Figure 3-16. These alternatives show a nearly identical trend of low impact conditions for stream shade (higher score, lower impact). Under both of these alternatives, the distribution of scores remains relatively stable, with most watersheds in a low impact condition.

Figure 3-16. Distribution of Watershed Scores for Stream Shade



The relative stability of shade scores over the 100-year analysis period is due to a combination of factors.

- **Harvest activities – variable retention harvest**: Variable retention harvest may reduce shade levels along Type 5 streams on stable ground because DNR does not apply interior-core buffers to these streams. However, these streams tend to be found at higher elevations where temperatures are cooler, the terrain is more likely to provide shade, and the target shade level necessary to maintain cooler water temperatures is lower.

- **Harvest activities – thinning**: Chan and others (2004) found substantial reductions in shade only when harvest reduced relative density below 30. For less intensive thinnings, they found light levels to be similar to those in unthinned forests. Since DNR rarely thins below a relative density of 35, thinning is not expected to impact shade substantially.

- **Physical characteristics**: The amount of stream shade can be affected by the shape of the surrounding terrain, the orientation of the stream channel, and the width of the stream itself. These factors will not change over time, nor will they be affected by DNR management activities.

- **Natural forest growth**: Many of the streamside forests responsible for shading the stream channel[9] are currently deferred from harvest in the analysis model. In these areas, changes in stream shade will be due solely to natural growth and disturbance. In addition, many of these forests are currently in the Competitive Exclusion stand development stage, with crowded canopies and high shade levels. Changes will occur in these forests, but the shift will be slow.

The differences between the extent and intensity of harvests projected to occur under the No Action or Landscape Alternative are not large enough to result in appreciable differences in stream shade. As shown in Figure 3-16, changes in stream shade over time are nearly identical under these alternatives.

The potential environmental impact of either the No Action or Landscape Alternative for stream shade is considered **low**. Most Type 3 watersheds remain in a low impact condition. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

DNR estimates that impacts to stream shade under the Pathways Alternative will be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of stream shade watershed scores are expected to be similar to those shown in Figure 3-16 for the Landscape Alternative.

Some of the forest stands selected for active management (thinning) or passive management are located within the stream shade area of influence (sufficiently close to provide shade to the stream channel). Following, DNR describes how active and passive management of these stands may affect potential impacts for stream shade.

Passive Management

In some landscapes, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4), meaning these stands will not be harvested as long as these pathways remain in place. These stands will continue to grow and develop forest structure that would otherwise have been harvested. Therefore, the potential impacts for shade under the Pathways Alternative should be equal to or lower than those projected under the Landscape Alternative.

Active Management

In some landscapes, DNR will thin forest stands in operable (Pathway 5) or deferred (Pathway 7) areas to create or accelerate the development of Young Forest Habitat. Because DNR rarely thins forest stands below a relative density of 35, light levels in these stands should be similar to those found in unthinned forests (Chan and others 2004).

The potential environmental impact of the Pathways Alternative for stream shade is considered **low**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

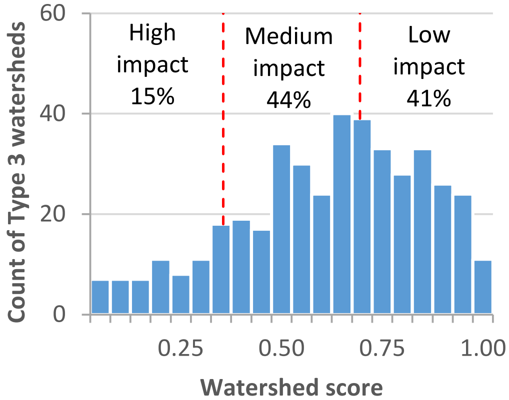
Indicator: Fine Sediment Delivery

NO ACTION AND LANDSCAPE ALTERNATIVE

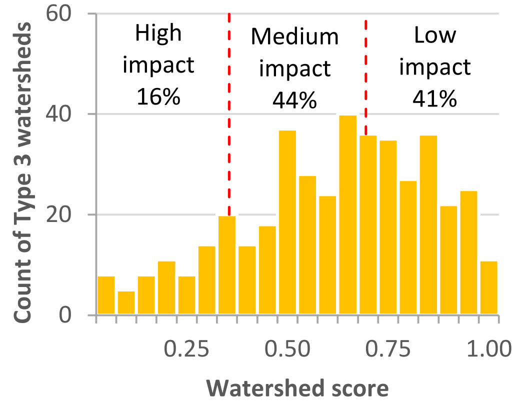
The distribution of watershed scores for fine sediment delivery for the No Action and Landscape alternatives is shown in Figure 3-17. These alternatives show a nearly identical trend for fine sediment delivery. Under both alternatives, the distribution of scores remains relatively stable.

Figure 3-17. Distribution of Watershed Scores for Fine Sediment Delivery

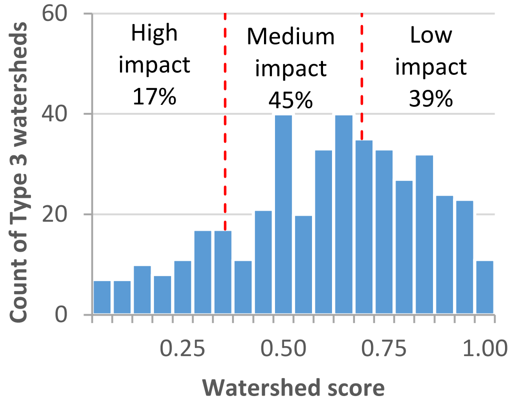
a) No Action Alternative, Decade 1



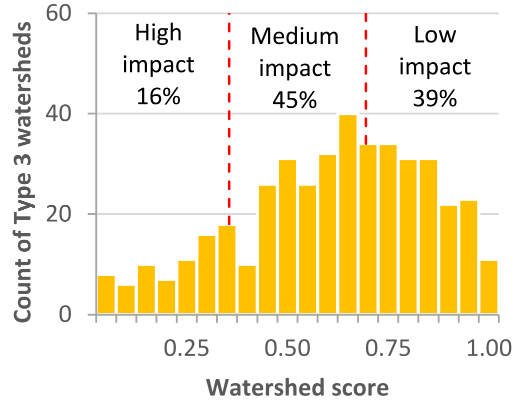
a) Landscape Alternative, Decade 1



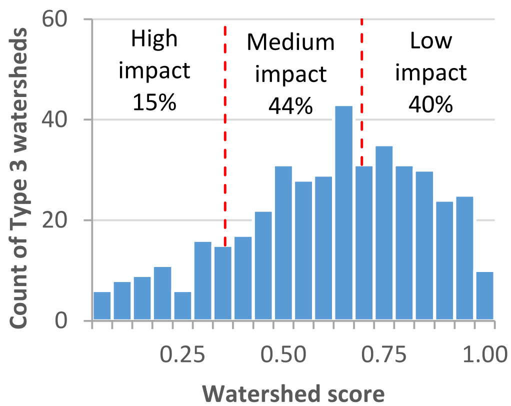
b) No Action Alternative, Decade 6



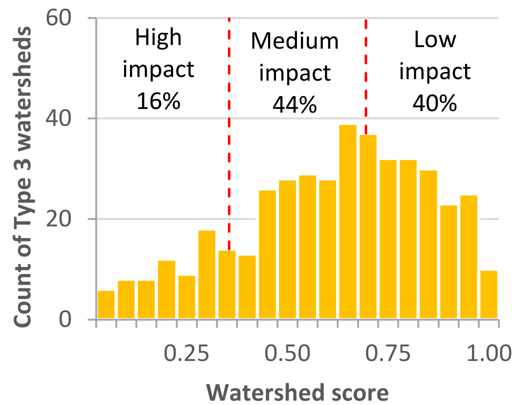
b) Landscape Alternative, Decade 6



c) No Action Alternative, Decade 9



c) Landscape Alternative, Decade 9



DNR considered both the fine sediment delivery potential and the sensitivity, or expected channel response, to the delivery of fine sediment. DNR determined the fine sediment delivery potential using traffic impact scores, which were based on road surface type, proximity of roads to streams or other water bodies, and the level of log-truck traffic that may result from future harvests in the Type 3 watershed on all ownerships (state trust lands as well as federal, tribal, and private lands).

As explained previously, the projected traffic levels for other ownerships were held constant, meaning they did not vary from one decade to the next. Because these levels did not change, and because projected traffic levels from DNR harvests vary little from one decade to the next, traffic impact scores are relatively stable. In addition, the differences between the extent and intensity of harvests projected to occur under the alternatives are not large enough to result in appreciable differences in fine sediment delivery. Changes in fine sediment delivery over time are nearly identical for the No Action and Landscape alternatives.

For this FEIS analysis, DNR used sensitivity ratings from watershed analyses that were performed (either completed and approved, or initiated) in the OESF per the forest practices rules. For stream reaches for which watershed analyses were not available, DNR based sensitivity on gradient and confinement. DNR also updated its methodology for weighing the contribution of each stream reach to the overall condition of the watershed. For the FEIS, the weight assigned to each stream reach was based on its surface area (the stream reach's length multiplied by its width). This weighting has the (intentional) effect of assigning greater importance to wide, large streams, found in the lower portions of each watershed. These streams are typically low gradient, unconfined or moderately confined, and rated highly sensitive to fine sediment delivery.

Using this methodology, 52 percent of stream reaches (by surface area) were rated highly sensitive to fine sediment delivery. In these streams, fine sediment is readily stored; increased fine sediment results in widespread filling of pools and other losses of stream bed complexity. The combination of high sensitivity to, and a moderate potential for, fine sediment delivery results in a high impact rating for approximately 15 to 17 percent of watersheds.

The potential environmental impact of either the No Action or Landscape Alternative for fine sediment delivery is considered **high**. While most watersheds are in a medium or low impact condition under either alternative, greater than 10 percent of watersheds are in a high impact condition (lower score, higher impact) at any given time. The number of watersheds in a high impact condition does not decrease over time.

However, DNR expects potential fine sediment delivery from the road network to be mitigated to a non-significant level through current practices, including accomplishing road maintenance and abandonment plans; inspecting, repairing, and maintaining roads; and suspending timber hauling during storms (refer to "Mitigation" later in this section for more information). Therefore, DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

DNR estimates that impacts from fine sediment delivery under the Pathways Alternative will be equal to or less than those projected for the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of fine sediment watershed scores are expected to be similar to those shown in Figure 3-17 for the Landscape Alternative. Following, DNR describes how the active and passive management anticipated under the Pathways alternative may affect potential impacts for fine sediment delivery.

Passive Management

In some landscapes, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4). Because these stands will not be harvested for as long as these pathways remain in place, the amount of log-truck traffic should be reduced in some areas. The drop in traffic also should decrease the potential for delivery of fine sediment.

Active Management

In some landscapes, DNR will thin forest stands in operable (Pathway 5) or deferred (Pathway 7) areas to create or accelerate development of Young Forest Habitat. Because DNR would thin some stands that are deferred under the No Action and Landscape alternatives, the amount of log-truck traffic under the Pathways Alternative may be higher in some areas, which also would increase the potential for delivery of fine sediment.

Similar to the Landscape Alternative, the potential environmental impact for the Pathways Alternative for fine sediment delivery is considered **high**. However, DNR expects potential fine sediment delivery from the road network to be mitigated to a non-significant level through current practices, including accomplishing road maintenance and abandonment plans; inspecting, repairing, and maintaining roads; and suspending timber hauling during storms (refer to "Mitigation" later in this section for more information). Therefore, DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Leaf and Needle Litter Recruitment

NO ACTION AND LANDSCAPE ALTERNATIVES

The distribution of watershed scores for leaf and needle litter recruitment under the No Action and Landscape alternatives is shown in Figure 3-18. Under both alternatives, the distribution of scores moves steadily toward a lower impact condition (higher score, lower impact). Differences between these alternatives are relatively small.

Figure 3-18. Distribution of Watershed Scores for Leaf and Needle Litter Recruitment

The differences between the extent and intensity of harvests projected to occur under the No Action and Landscape alternatives are not large enough to result in appreciable differences in leaf and needle litter recruitment. Changes in leaf and needle litter recruitment over time are nearly identical for the No Action and Landscape alternatives.

The potential environmental impact of either the No Action or Landscape Alternative for leaf and needle litter is considered **low**. The distribution of watershed scores steadily moves toward an improved condition (higher scores, lower impact). Most watersheds are in a low impact condition for the entire analysis period. DNR did not identify significant impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

DNR estimates impacts to leaf and needle litter recruitment under the Pathways Alternative will be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of leaf and needle litter watershed scores are expected to be similar to those shown in Figure 3-18 for the Landscape Alternative.

Some of the forest stands selected for active management (thinning) or passive management are located within the leaf and needle litter area of influence (within 200 feet of and including the floodplain of Type 1 through 5 streams). Following, DNR describes how active and passive management of these stands may affect potential impacts for leaf and needle litter.

Passive Management

In some landscapes, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4), meaning these stands will not be harvested for as long as these pathways remain in place. These stands should continue to grow and develop forest structure that would otherwise have been harvested. Therefore, potential impacts for leaf and needle littler under the Pathways Alternative should be equal to or lower than those projected under the Landscape Alternative.

Active Management

In some landscapes, DNR will thin stands in operable (Pathway 5) or deferred (Pathway 7) areas to create or accelerate development of Young Forest Habitat. While such thinnings are expected to reduce competition for resources and accelerate tree growth, any prompt acceleration in growth would be largely from an increase in water and nutrients supplied by the roots. The amount of foliage (the source of leaf and needle litter) is not expected to increase significantly until there has been enough time for the canopy to enlarge (Smith 1986).

The potential environmental impact of the Pathways Alternative for leaf and needle litter is considered **low**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Riparian Microclimate

NO ACTION AND LANDSCAPE ALTERNATIVES

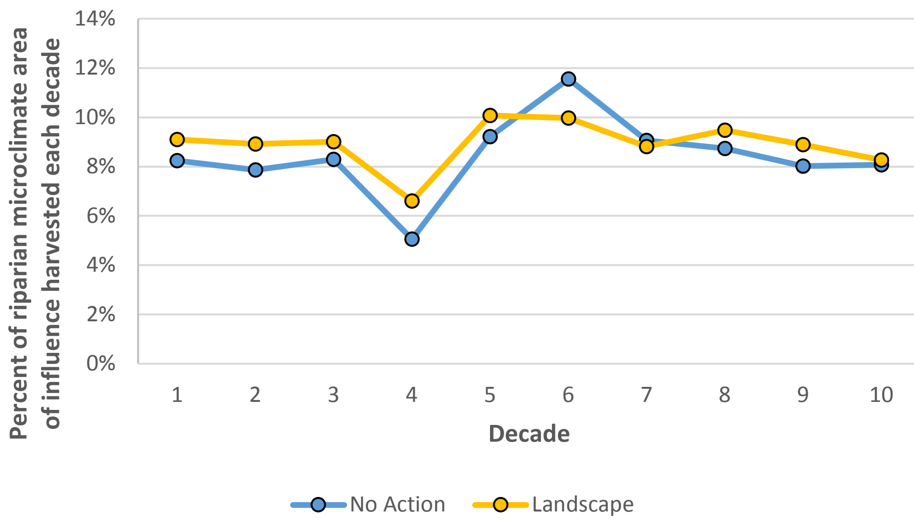
The distribution of watershed scores for the No Action and Landscape alternatives is shown in Figure 3-19. Under both alternatives, watershed scores are variable but generally decrease over time, indicating a degradation of riparian microclimate.

Figure 3-19. Distribution of Watershed Scores for Riparian Microclimate

Riparian microclimate results are due primarily to the effects of variable retention harvest.

- **Harvest activities – variable retention harvest**: For this analysis, DNR measured how the cool, moist conditions found near streams are modified by the warmer, drier conditions found in or near variable retention harvests (refer to Figure 3-12). Chart 3-21 shows a summary of projected variable retention harvests that are close enough to the stream to influence riparian microclimate. This chart includes all regeneration harvests within the area of influence (within 709 feet of (and including) the floodplain). The extent of harvests under the Landscape Alternative is higher in all decades, with the exception of Decade 6.

Chart 3-21. Variable Retention Harvests in the Riparian Microclimate Area of Influence



- **Harvest activities – thinning**: The effects of thinning on microclimate were not analyzed because DNR's review of scientific literature found that thinning has no effect on riparian microclimate. For example, Olson and Chan (2005) examined the effects of thinning along headwater streams in western Oregon and found that thinning did not affect soil temperature within the riparian forest. Changes in gradients were observed for air temperature and relative humidity, but riparian buffers as narrow as 56 feet mitigated microclimate changes associated with thinning (Olson and Chan 2005).

The potential environmental impacts for riparian microclimate are considered **medium** under the No Action Alternative. The watershed scores are variable, but generally decrease over time, indicating a worsening of riparian microclimate conditions. Most watersheds are in a medium or low impact category. The number of watersheds in a high impact condition increases under the No Action Alternative, but is not projected to exceed 10 percent in any given decade.

The potential environmental impacts for riparian microclimate are considered **high** under the Landscape Alternative. The watershed scores are variable, but generally decrease over time, indicating a worsening of riparian microclimate conditions. Most watersheds are in a medium or low impact category. However, the number of watersheds in the high impact category is projected to increase from its current level of 5 percent to more than 10 percent during decades 6 through 9.

As microclimate is only 3 percent of the composite watershed score, DNR considers these impacts to be probable and adverse but not significant. Therefore, DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

No policies, procedures, or laws currently apply to riparian microclimate. The Board is committed to continually reviewing the implementation of its policies. In the event that science provides new information about riparian microclimate, the Board will consider that information when future policy decisions are made.

PATHWAYS ALTERNATIVE

DNR anticipates that impacts to riparian microclimate under the Pathways Alternative will be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of riparian microclimate watershed scores are expected to be similar to or slightly improved over those shown in Figure 3-19 for the Landscape Alternative.

Some of the forest stands selected for active management (thinning) or passive management are located within the riparian microclimate area of influence (within 709 feet of (and including) the 100-year floodplain of Type 1 through 5 streams). Following, DNR describes the expected impacts of active and passive management on these stands for riparian microclimate.

Passive Management

In some landscapes, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4), meaning these stands will not be harvested for as long as these pathways remain in place. By temporarily not harvesting these stands, DNR helps to maintain the integrity of riparian microclimate gradients. These gradients should not be affected by the adverse warming and drying effects of adjacent variable retention harvests, which are estimated to extend approximately 500 feet into the surrounding forest. Therefore potential impacts for riparian microclimate under the Pathways Alternative should be equal to or lower than those projected under the Landscape Alternative.

Active Management

In some landscapes, DNR will thin forest stands in operable (Pathway 5) or deferred (Pathway 7) areas to create or accelerate development of Young Forest Habitat. However, such thinnings are not expected to affect riparian microclimate as described above.

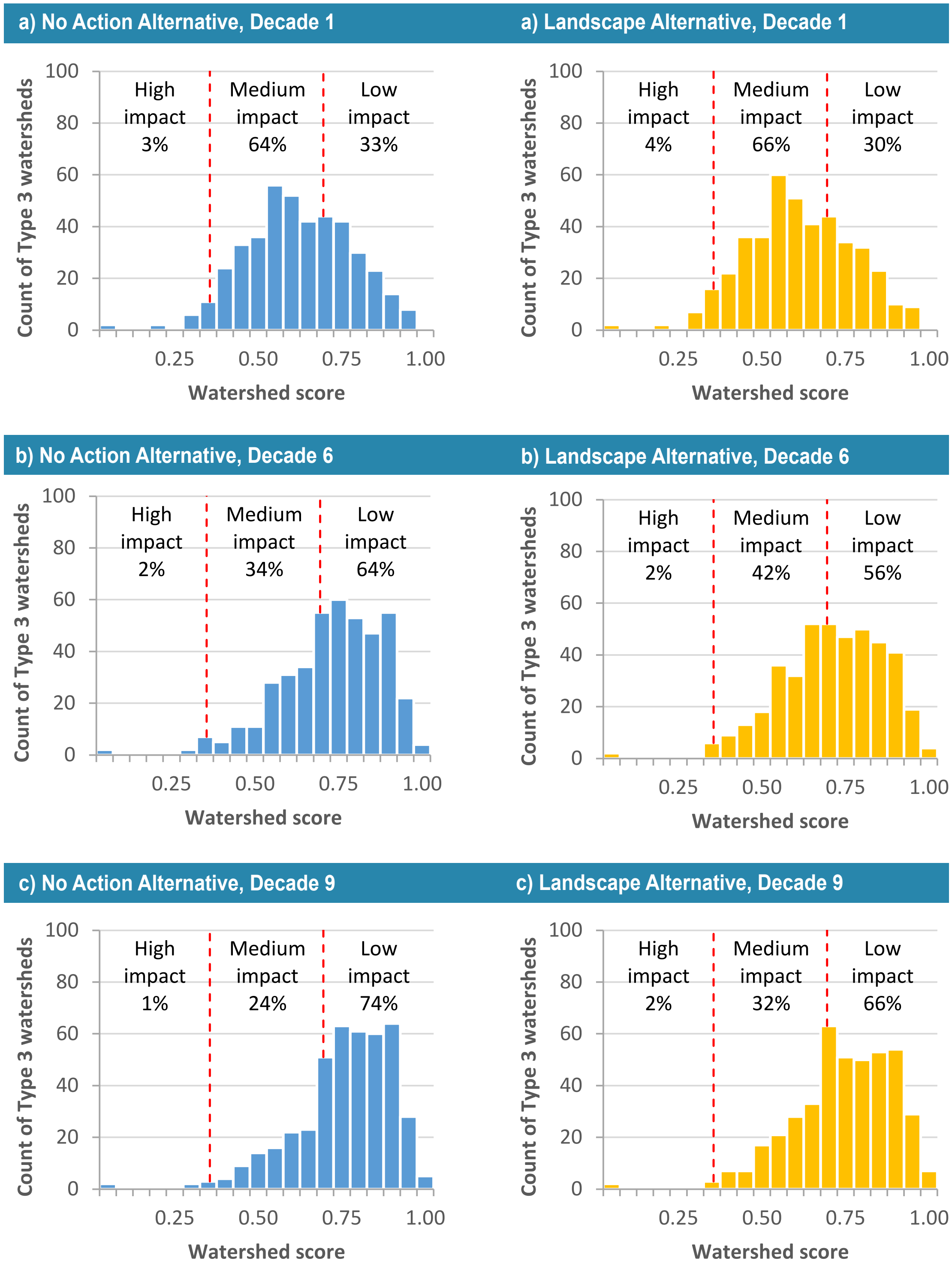
The potential environmental impact of the Pathways Alternative for riparian microclimate is considered **high**. Although DNR estimates that impacts under the Pathways Alternative will be lower than those projected for the Landscape Alternative, both the magnitude of the difference and whether it is sufficient to warrant a lower impact rating are unknown. However, as microclimate is only 3 percent of the composite watershed score, DNR considers these impacts to be probable and adverse but not significant. Therefore, DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Composite Watershed Score

NO ACTION AND LANDSCAPE ALTERNATIVES

The distribution of composite watershed scores over time (Figure 3-20) indicates a gradual improvement in riparian function. Results are similar for the No Action and Landscape alternatives.

Figure 3-20. Distribution of Watershed Scores for the Composite Watershed Score



The potential environmental impact for the No Action and Landscape alternative for the composite watershed score is considered **low.** The distribution of watershed scores moves steadily toward an improved condition. By Decade 3 for the No Action Alternative and by Decade 4 for the Landscape Alternative, the majority of watersheds are in a low impact condition. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERATIVE

DNR expects impacts to each of the indicators that comprise the composite watershed score to be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Therefore, DNR anticipates that trends in the distribution of watershed scores will be similar to or slightly improved over those shown in Figure 3-20 for the Landscape Alternative.

The potential environmental impact of the Pathways Alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Summary of Potential Impacts

Table 3-15 provides an overview of the potential environmental impacts on riparian areas when the criterion and all of the indicators are considered. For this analysis, only high impacts were considered potentially significant impacts.

Table 3-15. Summary of Potential Impacts on Riparian Areas, by Alternative

Criteria	Indicators	No Action Alternative	Landscape Alternative	Pathways Alternative
Functioning riparian habitat	Large woody debris recruitment	Medium	Medium	Medium
	Peak flow	Low	Low	Low
	Stream shade	Low	Low	Low
	Fine sediment delivery	High	High	High
	Leaf and needle litter recruitment	Low	Low	Low
	Riparian microclimate	Medium	High	High
	Composite watershed score	Low	Low	Low

● Low impact ◇ Medium impact ■ High impact

Potential high impacts were identified for fine sediment delivery under all three alternatives. However, DNR expects these impacts to be mitigated to a level of non-significance through current management practices, as described under "Mitigation" in this section. High impacts also were identified for riparian microclimate under the Landscape and Pathways alternatives. DNR considers these impacts to be probable and adverse but not significant because the contribution of riparian microclimate to riparian function is relatively minor: it is only 3 percent of the composite watershed score.

Therefore, DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for any indicator for this topic.

■ Mitigation

Mitigation Through Current Management Practices

In this section, DNR describes current management practices (established programs, rules, procedures, or other practices) that are expected to mitigate potential high impacts to a level of non-significance. This mitigation applies to fine sediment delivery.

ROAD MAINTENANCE AND ABANDONMENT PLANS

The forest practices rules contain direction for road construction and maintenance (WAC 222-24) to protect water quality and riparian habitat. Road construction and maintenance must prevent or limit actual or potential delivery of sediment and surface water to any typed water where such delivery would prevent the achievement of fish habitat or water quality goals.

The forest practices rules require large forest landowners,[10] such as DNR, to prepare road maintenance and abandonment plans for all roads that have been used or constructed since 1974.[11] These plans specify the steps that will be taken to either abandon roads or bring roads that do not meet current standards into compliance. Consistent with the forest practices rules, DNR has developed road maintenance and abandonment plans for roads on state trust lands in each of the 11 landscapes in the OESF.

Road maintenance and abandonment plans are used to prioritize road improvement, abandonment, and maintenance projects. DNR first prioritizes projects for roads that potentially cause the greatest damage to public resources:

- Roads with fish passage barriers
- Roads that deliver sediment to streams
- Roads with evidence of existing or potential instability that could affect public resources adversely
- Roads or ditch lines that intercept ground water
- Roads or ditches that deliver surface water to streams

DNR then prioritizes projects by their potential benefit to public resources; for example, projects that affect:

- Waters containing listed threatened or endangered fish species
- Waters listed as 303(d) impaired for road-related reasons
- Areas containing sensitive geology or soils with a history of landslides
- Areas with ongoing restoration projects
- Road systems that have the highest potential use for future timber harvests

Road traffic generates sediment through surface erosion, and the key to controlling sediment is controlling erosion. Erosion control measures are necessary if exposed soils can deliver sediment to streams. DNR's objective for roads is to create a stable, dispersed, non-erosive drainage pattern associated with road surface runoff to minimize potential or actual sediment delivery to streams. Depending on what is appropriate for site-specific conditions, this objective can be accomplished in a variety of ways:

- Use ditches, culverts, and other structures to collect sediment-laden water runoff from the road and direct it to areas on the forest floor where it can be captured or safely dissipated away from the stream.
- Stabilize ditch walls by seeding them with grass or lining them with rocks.
- Construct catch basins to capture water runoff and allow sediment to settle out of the water.
- Place rock on the road surface before and after a stream crossing to help stabilize the road surface and prevent sediment delivery.
- Use temporary measures, such as placing straw bales, to capture sediment while repairs are being carried out.

Work under these plans is ongoing. Table 3-39 in "Water Quality," p. 3-143 shows the number of projects completed under road maintenance and abandonment plans for roads on state trust lands in each of the 11 landscapes in the OESF.

All work completed under these plans is performed using (as appropriate) the best management practices for road construction and maintenance described in the Forest Practices Board Manual (DNR 2016) and the guidance provided in DNR's Forest Roads Guidebook (DNR 2011). Most work involves culvert replacement, maintenance, or removal. DNR continually updates and prioritizes these plans to address newly identified environmental impacts from the existing road network.

Work associated with these plans must be completed by October 31, 2021. A summary of DNR's accomplishments for roads in each of the 11 landscapes in the OESF and DNR's road maintenance priorities and standards is included in Appendix C.

Information on road maintenance and abandonment for small private forest landowners and federal agencies can be found in Chapter 4.

Effectiveness of Road Maintenance and Abandonment Plans

Correct implementation of current forest practices rules for road maintenance is expected to minimize runoff water and sediment delivery to typed waters (DNR 2016). A statewide study conducted on private forestlands in Washington found that road maintenance and abandonment appears to reduce the amount of road-related sediment that reaches streams (Martin 2009). This study found that implementing best management practices decreased the number of road miles hydrologically connected to streams, and that the majority of roads studied had a low probability of delivering sediment to streams (Martin 2009). In addition, the monitoring of the effectiveness of road maintenance and abandonment plans conducted statewide by Dubé and others (2010) from 2006 through 2008 found that as roads were brought up to modern standards, they showed decreased sediment delivery to streams.

INSPECTION, MAINTENANCE, AND REPAIR

After work identified under road maintenance and abandonment plans has been completed, DNR will continue to inspect, maintain, and repair roads and bridges as needed using the appropriate best management practices for road maintenance and repair identified in the current Forest Practices Board Manual and guidance provided in the Forest Roads Guidebook. Routine maintenance of road dips and surfaces and quick response to problems can significantly reduce road-caused slumps and slides and prevent the creation of berms that could channelize runoff (Environmental Protection Agency 2012).

SUSPENSION OF TIMBER HAULING DURING STORM EVENTS

In addition to road maintenance and abandonment plans, DNR also considers how operations can be adjusted to further prevent delivery of fine sediment to streams. For example, DNR suspends timber hauling on state trust lands in the OESF during storm events, when heavy rainfall can potentially increase surface water runoff and sediment delivery (unless the road is designed for wet-weather haul). The decision to suspend timber hauling on state trust lands is based on professional judgment. A weather event is considered a storm event when high levels of precipitation are forecast and there is a potential for drainage structures, such as culverts and ditches, to be overwhelmed, increasing the potential for sediment delivery to streams. Whether timber hauling is suspended or not, DNR compliance foresters monitor the haul roads to determine if potential problems are developing that may lead to sediment delivery to streams and take action as necessary.

■ Considered but Not Analyzed

Wetlands

Wetlands are areas that are inundated or saturated with surface or groundwater often enough, or for long enough periods during the year, to support vegetation that is typically adapted to life in saturated soil conditions.

Wetlands in forested landscapes such as the OESF include freshwater marshes, swamps, bogs (refer to photo, right), fens, seeps, wet meadows, and shallow ponds. Wetlands can be forested or dominated by smaller vegetation such as shrubs, herbs, mosses, grasses, or grass-like plants. Wetlands can be seasonal, wet for only part of the year, or permanent (wet all year). They can be either isolated from or connected to other surface water bodies, such as ponds, lakes, rivers, and streams.

Cedar bog in the OESF

Bogs are a type of wetland that accumulates peat

Wetlands provide habitat for amphibians and aquatic invertebrates and rearing habitat for coho salmon. Birds use wetlands for nesting and feeding, and wetlands provide connectivity for wildlife movement and refuge during seasonal fluctuations (DNR 2004, p. 4-132). Wetlands also augment stream flow during the summer, moderate peak flows during storm events, and provide habitat for plants and animals (Sheldon and others 2005, Adamus and others 1991).

The implementation of existing policy and laws protects existing wetlands. According to the *Policy for Sustainable Forests*, DNR will allow no net loss of acreage or function of naturally occurring wetlands. For each timber sale, DNR foresters identify wetlands in the sale area. Forested and non-forested wetlands over .25 acres and bogs over .1 acres in size are protected with wetland management zones, in which forest management activities such as timber harvest are limited. In addition, non-forested wetlands over .25 acres and non-forested bogs over .1 acres also are protected with an inner, 50-foot no-harvest zone. A series of smaller wetlands are protected if they function collectively as a larger wetland (DNR 1997, p. IV.120).

The site-specific assessment of conditions required for each timber sale under DNR's current wetland management procedure for the OESF (refer to Appendix F), is expected to avoid or minimize potential impacts to wetlands to a level of non-significance. Therefore, this FEIS did not include an analysis of wetlands.

■ Analyzed and Addressed Through Implementation

Windthrow in Interior-Core Buffers

Windthrow is the blowing over or breaking of trees by the wind. Windthrow of entire trees occurs when wind overcomes the tree's rooting strength in the soil and tips over the tree, its root ball, and some amount of root-attached soil (Coutts 1986). Wind also may break the bole, or trunk, of the tree (referred to as stem breakage), resulting in trees with broken tops.

Windthrow along forest edges is a normal occurrence, but is known to increase after timber harvesting activities expose previously interior forest stands to the direct effects of the wind (Harris 1989). Windthrow in riparian forests is a special concern in the OESF because of the alignment of the major river valleys with the prevailing winds, the fully saturated soils during the winter months, and the forest edge effects associated with variable retention harvest.

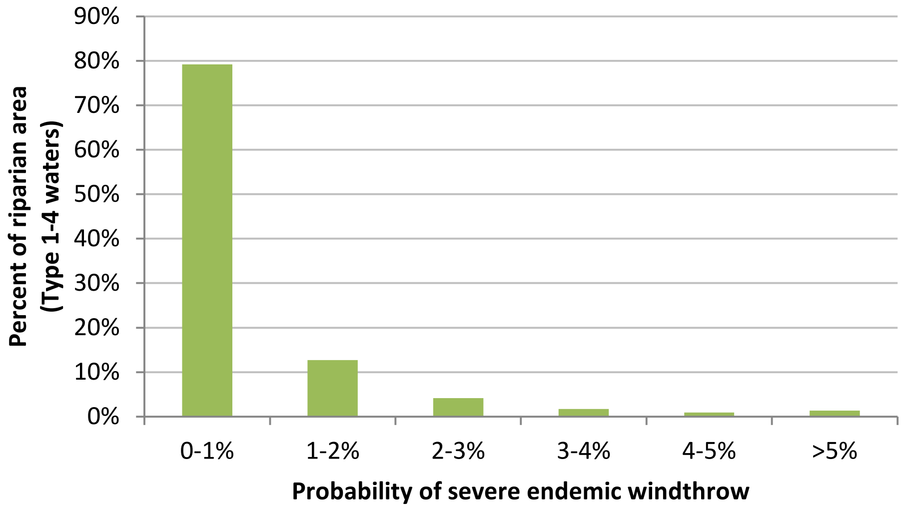
DNR uses interior-core buffers to maintain a range of ecosystem functions. Windthrow may compromise some of these functions and enhance others (Sullivan and others 1987, Grizzel and Wolff 1998). For example, windthrow in interior-core buffers may decrease stream shade or destabilize stream banks, but enhance in-stream habitat complexity by providing large woody debris to the stream channel (large woody debris is an important component of habitat for fish; refer to "Fish," p. 3-147). In certain locations, windthrow likely is the most significant mechanism by which large woody debris is recruited to the stream channel (Grizzel and Wolff 1998).

Windthrow in interior-core buffers will be addressed by implementing the OESF riparian conservation strategy (refer to Chapter 2). DNR's goal is to maintain the integrity of riparian forests and the functions they provide by protecting them from severe endemic windthrow.

Under the No Action Alternative, DNR places a 150-foot exterior buffer on the interior-core buffer of Type 1 through 3 streams, and a 50-foot exterior buffer on the interior-core buffer of Type 4 streams. Under the Landscape and Pathways alternatives, DNR uses a windthrow probability model (Mitchell and Lanquaye-Opoku 2007) especially designed and calibrated for use on the Olympic Peninsula (and other methods as needed) to identify segments of interior-core buffers for which the probability of severe endemic windthrow[12] is considered unacceptable. In the model, an unacceptable level of probability is 5 percent or greater. For all segments of interior-core buffers with a 5 percent or greater chance of severe endemic windthrow, foresters either will apply an exterior buffer or reconfigure the shape and orientation of the harvested edge, distribution of leave trees, or both to reduce severe endemic windthrow risk. If the latter, foresters will rerun the windthrow probability model on the reconfigured timber sale and, if there is still a risk of severe endemic windthrow, apply an exterior buffer where needed.

An analysis of variable retention harvests projected to occur under the Landscape Alternative reveals that, for most riparian areas, the probability of severe endemic windthrow is very low (refer to Chart 3-22 on p. 3-94). Assuming a 5 percent level of probability, only approximately 1 percent of the interior-core buffers for Type 1 through Type 4 streams on state trust lands in the OESF will require an exterior buffer. At this level of probability, a total of only 26 acres of severe endemic windthrow is expected in riparian areas in the first decade of implementing the Landscape Alternative, according to model results.

Chart 3-22. Probability of Severe Endemic Windthrow Along Type 1 Through Type 4 Streams



Because of the similarity in the harvest schedules between the Landscape and Pathways alternatives (refer to p. 3-17 through 3-18), and because DNR will follow the same procedure under both alternatives to apply exterior buffers, DNR expects the number of acres of severe endemic windthrow to be similar under the Pathways Alternative.

DNR did not identify probable significant adverse environmental impacts for any alternative (No Action, Landscape, Pathways) from windthrow. The use of a windthrow probability model (and other methods as needed) to identify severe endemic windthrow and the placement of exterior buffers or reconfiguration of the harvested edge in identified areas are expected to avoid or minimize potential windthrow impacts to riparian areas on state trust lands in the OESF.

Section Notes

1. Site potential tree height is a term used in forestry to describe the potential for how tall trees can grow at a particular location or "site." For the FEIS riparian analysis, DNR assumed that conifer trees achieve their maximum height at 200 years (Spies and Franklin 1988, 1991 as cited in DNR 1997, p. IV. 71). Using the tree height tables cited in the HCP (Wiley 1978) and the site index (height at 50 years breast height age) described in the HCP, the estimated site potential tree heights for a 200-year growing period are 204 feet (62 meters) for Type 1 and 2 streams, and 200 feet (61 meters) for Type 3 through 5 streams. For the FEIS, DNR approximated these values by assuming a 200-foot (60 meter) site potential tree height at 200 years for all stream types in the OESF.
2. As each individual parameter is evaluated, its calculated value is converted to a common scale of 0 to 1 using a mathematical construct known as a "fuzzy curve." Fuzzy curves allow the aggregation of multiple parameters, measured using disparate units, which otherwise would be difficult to compare. The shape and breakpoints for each curve determine how each value is normalized. Fuzzy curves for each parameter were adapted from multiple sources, including available literature (Gallo and others 2005), watershed analysis methods (DNR 1997), or consultation with DNR scientific staff. For additional information, refer to Appendix G. For this analysis, the parameters used to determine the composite watershed score are the seven riparian indicators.

3. Streams are dynamic. Many studies to date that make recommendations for the recruitment of large woody debris have not considered how stream channels migrate over time (Murphy and Koski 1989, Robison and Beschta 1990, McDade and others 1990, Washington Forest Practices Board [WFPB] 1994 as cited in DNR 1997). To account for lateral stream migration across the floodplain, recruitment to the floodplain was considered equivalent to the recruitment to the stream channel. Large woody debris in the floodplain provides riparian function during flood events (DNR 1997), and in time, may eventually become in-stream large woody debris as streams migrate. Therefore, the area of influence includes the floodplain itself plus an additional 150 feet. For this analysis, the width of the 100-year floodplain was defined by stream type, measured outward horizontally from the center of the stream channel along both sides of the stream: 150 feet along each side of Type 1 streams (300 feet total), 30 feet along each side of Type 2 streams (60 feet total), 15 feet along each side of Type 3 streams (30 feet total), 3.75 feet along each side of Type 4 streams (7.5 feet total), and 0 feet for Type 5 and Type 9 streams. DNR analyzed the additional 200 feet (approximately one tree height) beyond the edge of the 100-year floodplain because this area is expected to provide the largest share of large woody debris, based on FEMAT (1993) and McDade and others (1990). For a detailed description of how the area of influence for large woody debris was calculated, refer to Appendix G.
4. Based on a review of approximately 30 years of daily average temperature records for the Clearwater, Quinault, and Forks weather stations archived by the NOAA Western Regional Climate Center, July 31 is the hottest day of the year and therefore the one in which thermal loading to the stream is expected to be at a maximum.
5. The target shade level is intended solely for the purpose of conducting this environmental impact analysis, and does not connote or imply DNR policy direction.
6. Washington State Surface Water Quality Standards designated use categories are based on the most stringent temperature threshold into which the given stream drains. A stream reach may be assigned a temperature standard for a given species even if that species is not known to occur in the reach, as long as a downstream reach contains that species (Stohr, A., personal communication, Feb 16, 2016).
7. In forestry, the term basal area describes the sum of the cross-sectional area of all trees in a stand, measured at breast height. It is generally expressed as square feet per acre.
8. DNR uses a numerical system (one through five) to categorize streams based on physical characteristics such as stream width, steepness, and whether or not fish are present. Type 1 streams are the largest; Type 5 streams are the smallest. Type 9 streams are "unclassified" and refer to streams that are currently mapped, but lack sufficient data to determine the correct water type. Only Type 1, 2 and 3 streams are considered fish-bearing. DNR and the Federal Services have agreed that the Washington Forest Practices Board Emergency Rules (stream typing), November 1996 meet the intent of DNR's HCP.
9. Studies by Woodbridge and Stern (1979) and Beschta and others (1987) recognized the importance of direct solar radiation to stream heating and suggested a measure of shade called "angular canopy density" (ACD). They defined this as the portion of the sky occupied by canopy along the sun's path, usually between 10 am and 2 pm. They noted that shade is particularly important as a mechanism of preventing heat transfer during this time period. The use of angular canopy density has become a popular way of measuring stream shading. Although some riparian forests may attain an angular canopy density of 100 percent, research shows the angular canopy density of old-growth stands in western Oregon generally ranges from 80 to 90 percent (Brazier and Brown 1973; Steinblums and others 1984). Erman and others (1977), as cited in Beschta and others (1987), found that angular canopy densities averaged 75 percent along undisturbed streams in northern California. The degree of shade provided by streamside buffers varies with the species, age and density of riparian vegetation. Buffer width is also important, but by itself may not be a good predictor of stream shading (Sullivan and others 1990). Studies of the relationship between buffer width and angular canopy density show a high degree of variability, particularly for buffers less than about 75 feet in width (Brazier and Brown 1973; Steinblums and others 1984). Nonetheless, angular canopy density is positively correlated with buffer width: as buffer width increases, the level of riparian shade also increases. In the Oregon Coast Range, Brazier and Brown (1973) found that buffers approximately 70 feet wide had angular canopy densities similar to that of old-growth stands. Steinblums and others (1984) found that buffers approximately 120 feet wide in the Oregon Cascade Range were necessary to achieve angular canopy densities representative of old-growth forests.

10. In Washington, large forest landowners are those who harvest an annual average of more than 2 million board feet of timber from their own forestland in the state.

11. Older roads that have not been used since 1974 are considered “orphaned.”

12. Windthrow can be termed endemic or catastrophic. Endemic windthrow results from routine peak winds with short return intervals (less than 5 years between events). Endemic windthrow is strongly influenced by site conditions and silvicultural practices, and can therefore be predicted (Lanquaye 2003). Catastrophic windthrow results from winds with longer return periods (typically greater than 20 years between events) and is strongly influenced by wind speed, wind direction, and local topographic features. DNR is unable to predict the local likelihood of catastrophic windthrow from stand and site conditions (Zielke and others 2010). DNR cannot and does not protect against catastrophic windthrow.

    In the OESF windthrow probability model, severe endemic windthrow is defined as windthrow in which 90 percent of an area will experience 50 percent canopy loss (Mitchell and Lanquaye-Opoku 2007). This threshold was selected since it represents a level of canopy loss in excess of that which would occur under the riparian silvicultural prescriptions permitted in DNR’s 2006 *Riparian Forest Restoration Strategy*. Windthrow that results in canopy loss below this severity threshold is not considered to have a significant, adverse impact to riparian function.

Topic:

Soils

Why is Soil Important?

Soil is the foundation of a healthy forest. Soil anchors roots, supplies water to plants and trees, and provides air to plant roots and minerals for plant nutrition (Kohnke and Franzmeier 1995). Soil conditions, such as soil productivity, influence how large trees grow. Soil also recycles organic matter and provides habitat for insects and fungi.

What is the Criterion for Soils?

The criterion for soils is **soil conservation**. Since soil is the basis of plant growth, soil conservation is vital to maintaining functioning and productive forest ecosystems.

What are the Indicators for Soils?

The indicators used to analyze the criterion are **soil compaction**, **soil erosion**, **soil displacement**, **soil productivity**, **landslide potential**, and **potential road failure**. Landslide potential and potential road failure measure the potential for the delivery of coarse sediment to streams. These indicators were selected based on DNR's expertise, existing scientific information, and current data.

How Were the Indicators Analyzed?

Following, DNR describes the quantitative process it used to analyze the potential environmental impacts of the No Action and Landscape alternatives for the indicators soil compaction, erosion, displacement, and productivity. For the Pathways Alternative, DNR identified potential impacts for these indicators using qualitative techniques. All indicators except potential road failure were measured at the scale of the watershed administrative unit. Only watershed administrative units in which DNR manages at least 20 percent of the land base were included.[1]

DNR's threshold for potential high impacts was based on experience, professional judgment, and the assumption that repeated harvest entries may affect soils. Studies on the impacts of repeated harvest entries in the forests of the Pacific Northwest are lacking, in part due to the relatively short histories of timber harvesting and research on the effects of timber harvesting in those forests.

DNR's methods for defining impacts for harvest entries in this soils analysis were different than those used for a similar analysis in "Forest Conditions and Management" (on p. 3-23). In "Forest Conditions and Management," DNR considered whether a forest stand entry was thinning or variable retention harvest because in that analysis DNR was concerned with harvest intensity. For this soils analysis, DNR did not believe a distinction needed to be made between thinning and variable retention harvest since both types of harvest likely would involve moving heavy equipment over the soil.

Analysis Process

For this analysis, DNR was concerned with the potential environmental impacts of multiple forest stand entries on soils that, because of their physical properties or underlying geology, have a high likelihood of compaction, erosion, displacement, or landslides, or that are the least productive (refer to "Descriptions of the Indicators" starting on p. 3-99 for more information on these soils). DNR first mapped the extent and location of these soils using a GIS process and a tool called zonal statistics (refer to Appendix H for more information). DNR then measured each indicator using the following process:

1. For each watershed administrative unit, DNR determined the number of acres of these soils on which the analysis model recommended zero, one to two, three, or four harvest entries over the 100-year analysis period (refer to Figure 3-21) under the No Action and Landscape alternatives. For example, in the Clallam River watershed administrative unit, the analysis model recommended four or more harvest entries on 1,600 acres of soils with a high likelihood of compaction.

2. Next, DNR determined the percentage of each watershed administrative unit with potential high impacts. DNR considered potential high impacts to be four or more harvest entries recommended on the soil type being analyzed. DNR divided the number of acres with four or more harvest entries on those soil types by the total number of acres of state trust lands in the watershed administrative unit to arrive at a percentage. For example, in the Clallam River watershed administrative unit, DNR divided 1,600 acres (the acres of state trust lands with four or more harvest entries on soils with a high likelihood of compaction) by 10,161 acres (the total acres of state trust lands in the unit) to arrive at a percentage of 16 percent. In this example, 16 percent of state trust lands in this unit had potential high impacts for this indicator (soil compaction).

3. Based on the percentage identified in Step 2, DNR determined if potential impacts in each watershed administrative unit were low, medium or high (refer to Figure 21):

    a. Low impact: Less than 10 percent of state trust lands have potential high impacts

    b. Medium impact: 10 to 20 percent of state trust lands have potential high impacts

    c. High impact: More than 20 percent of state trust lands have potential high impacts

    In the Clallam River example, because only 16 percent of state trust lands had potential environmental impacts, the potential impact for the Clallam River watershed administrative unit for this indicator (soil compaction) was medium.

Figure 3-21. Method for Determining the Number of Acres with Potential High Impacts in Each Watershed Administrative Unit

In Column 1, DNR entered the name of the watershed administrative unit and the total number of acres within that unit.

In columns 2 through 5, DNR entered the number of acres in the watershed administrative unit on which the analysis model recommended zero, one or two, three, or four harvest entries on the type of soil being analyzed. For example, the Clallam River watershed administrative unit has four or more harvest entries on 1,600 acres of soils with a high likelihood of compaction; that amount was entered in column 5.

	Harvest entries			
Column 1 Clallam River	Column 2 0 entries	Column 3 1 or 2 entries	Column 4 3 entries	Column 5 4 entries
10,161 acres	1,787 acres (17.6%) (Low impact)	907 acres (9%) (Low impact)	1,962 acres (19%) (Medium impact)	1,600 acres (16%) (High impact)

DNR divided the total in Column 5 by the number of acres in Column 1 to determine what percent of this watershed administrative unit had potential high impacts. In this case, 16 percent of this landscape had potential high impacts, which meant the overall potential environmental impact for this watershed administrative unit was medium.

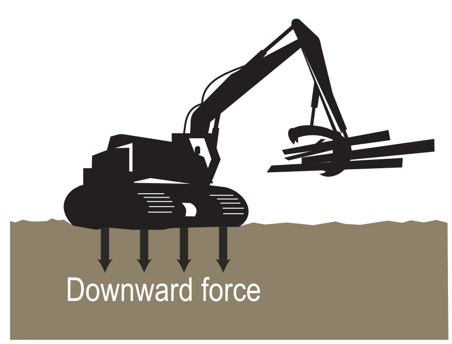
Key
- Low impact
- Medium impact
- High impact

4. DNR then determined if potential impacts were probable significant adverse by considering all state trust lands together. DNR added all of the acres in each unit that were identified as having potential high impacts, and divided that number by the total acres of state trust lands in the OESF. The percentage had to exceed 20 percent for the impact to be considered probable significant adverse.

Descriptions of Each Indicator

INDICATOR: SOIL COMPACTION

Figure 3-22. Soil Compaction; log Handler Shown



For this indicator, DNR analyzed the number of recommended forest stand entries on soils with a high likelihood of compaction. Soil compaction is the loss of void space (the space between particles of soil) within the soil caused by an external force, such as the weight of heavy machinery or the impact of trees hitting the ground (refer to Figure 3-22). Void space is essential for plant survival and productivity because water and air enter the soil through void spaces, and because tree roots absorb water, carbon dioxide, and nutrients through void spaces to sustain growth.

Soil compaction, particularly in the uppermost 2 to 4 inches of the soil, can impede root growth (Heilman 1981) and decrease the overall productivity of the soil (Cafferata 1992; Grier and others 1989). However, Ares and others (2007) have shown that high levels of soil compaction do not substantially affect tree growth in newly planted stands because compaction can help control competing vegetation and increase the availability of water, leading to lower mortality and increases in tree height and diameter.

Soils may be prone to compaction because of the shape, size, and composition of their individual particles. Also, some types of soils, such as glacially derived and organic soils, are more prone to compaction than others,[2] even those containing a variety of particle shapes and sizes (Henderson and others 1989).

INDICATOR: SOIL EROSION

For this indicator, DNR analyzed the number of recommended forest stand entries on soils with a high likelihood of erosion that are located on steep slopes (greater than 60 percent). Soil erosion is the movement of soil particles through particle detachment, transport, and deposition (Megahan 1991). Soil erosion is considered a separate process from landslides, which are discussed later in this section.

Soil erosion can reduce the capacity of a particular site to grow timber. Eroded soils can be deposited in downslope streams, lakes, and wetlands, degrading water quality and aquatic habitat. Soil erosion can be caused by natural processes such as gravity, water, wind, freeze-thaw cycles, or other forces that detach or move particles, or by human activities such as road building and timber harvesting.

Some types of soils may be prone to erosion because of their texture, structure, or porosity.[3] Other factors include the steepness of the slope, the presence or absence of vegetation, or the climate where the soil is located.

INDICATOR: SOIL DISPLACEMENT

For this indicator, DNR analyzed the number of recommended forest stand entries on soils with a high likelihood of displacement. Soil displacement is the localized movement of soil from an external force applied to the soil surface. This movement is not just downward (as in compaction), but sideways or horizontal, creating ridges and furrows in the soil (refer to Figure 3-23). Ridges and furrows can intercept shallow groundwater, concentrate surface water flow, and potentially initiate rill and gully erosion (Lal 2005).[4]

Figure 3-23. Soil Displacement; Skidder Shown

Soils may be prone to displacement because of texture, particle size, or moisture content.[5] The most common cause of soil displacement is harvesting using heavy ground-based equipment such as skidders, bulldozers, or excavators. Displacement is most pronounced on sites where trees are moved with ground based equipment or by cable without full suspension.[6] Further displacement may occur after the harvest during site preparation.[7]

INDICATOR: SOIL PRODUCTIVITY

For this indicator, DNR analyzed the number of forest stand entries the analysis model recommended on the least productive soils, those located on Site Class 5. Soil productivity is the capacity of the soil to support plant growth. In forested environments, productivity often is expressed as an index of the actual or potential tree growth for a given site. This expression, known as site index, is a species-specific measure of the average height of trees in a forest stand at a specific age (typically 50 or 100 years). Site indices are commonly grouped into site classes (1 through 5), with Site Class 1 having the most productive soils and Site Class 5 having the least productive soils.

Conservation of both the body and fertility of soil is the key to soil productivity. The body of soil can be damaged by surface erosion or displacement, landslides, compaction, and other physical impacts from activities such as road building or timber harvesting. The fertility of soil can be damaged by short harvest rotations, particularly on poor soils. Different soil types and their properties are important factors in determining the rooting depth of a tree (Crow 2005). Poor soils result in slow-growing trees and can be more prone to compaction.

Studies on the impacts of repeated harvest entries on soils in the forests of the Pacific Northwest are lacking, in part due to the relatively short histories of timber harvesting in the Pacific Northwest and research on the effects of timber harvesting in those forests. However, for this analysis DNR assumes that repeated harvest entries may reduce soil productivity.

INDICATOR: LANDSLIDE POTENTIAL

For this indicator, DNR analyzed the number of forest stand entries the analysis model recommended on soils with a high likelihood of landslides, which were defined as **soils on top of marine sediment or basalt geologic units that are located in areas that are steeply sloped (over 70 percent).**[8] In the OESF, analysis has shown that landslides often are associated with certain geologic units,[9] such as areas dominated by marine or basalt sediments (Sarikhan and others 2008, 2009). These geologic units have a much higher historic rate of landslides[10] than other units.

The areas considered in this landslide potential analysis (described in the preceding paragraph) **are separate from potentially unstable slopes or landforms**, which were identified using a slope stability model and **deferred from harvest** in the analysis model. The analysis model did not recommend **any** forest stand entries in deferred areas under either the No Action or Landscape Alternative. DNR's slope stability model rated slope instability using criteria such as steepness and landform, specifically the presence of convergent slopes.[11]

Landslides are the dislodgement or downslope movement of loose soil and rocks driven by gravity (Cruden and Varnes 1996, Nelson 2003). In contrast to erosion, which involves individual soil particles, landslides involve the movement of a large mass of soil. Landslides can be shallow-rapid or deep-seated. Deep-seated landslides have slip planes far beneath the surface and generally move very slowly, sometimes only inches to feet per year (a slip plane is the surface along which the landslide occurs). Shallow-rapid landslides have slip planes relatively close to the surface. These landslides move quickly, sometimes faster than 30 miles per hour (refer to Text Box 3-5).

Landslides are a natural process and occur throughout the OESF. Landslides can be caused by storms, prolonged rainfall, or rain-on-snow events, when rain falls on an existing snowpack. Other causes include earthquakes or streams undercutting an unstable slope. Human activities, such as tree harvesting or road building, may increase the likelihood of landslides by exposing soils to rainfall, especially if mitigation is not implemented.

Landslides can reduce the ability of a particular site to grow timber because of a loss of soil. Landslides can also degrade water quality and fish habitat by delivering coarse sediment into down-slope streams, lakes, and wetlands.

INDICATOR: POTENTIAL ROAD FAILURE

Road failure is the collapse of a roadbed. Roads may fail for many reasons, including drainage, design, construction, and maintenance (NOAA Fisheries and USFWS 2006), changes in surface erosion and runoff (MacDonald and Coe 2008), the stability of the ground on which they are built, or a combination of factors. When roads fail, they can trigger a landslide that may cause a loss of soil productivity and deliver coarse sediment to streams. Too much coarse sediment can affect salmon adversely by burying them and their nests (known as "redds") or flushing them downstream.

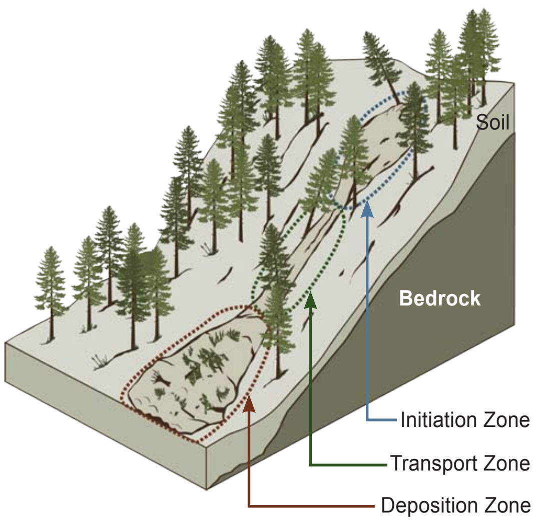
The OESF road network includes roads that were built on potentially unstable slopes or landforms as early as the 1930s, when the understanding of how slope failures occur was still evolving. In addition, these roads were built before the forest practices rules were enacted in 1974. (The forest practices rules were written to implement the Forest Practices Act and have been amended several times since 1974.) The rules include regulations for constructing and maintaining roads to prevent road-related landslides and limit the delivery of sediment and surface runoff to streams. Many roads built on potentially unstable slopes or landforms in the OESF have been mitigated to applicable standards, as will be discussed under "Results" in this section.

DNR analyzed this indicator at the landscape scale. In each of the 11 landscapes, DNR analyzed the percentage of the road network located on potentially unstable slopes or landforms. DNR then considered all landscapes together to determine if the potential environmental impact for this indicator was low, medium, or high.

In this analysis, DNR took the conservative approach of including all roads built on potentially unstable slopes or landforms, including roads that have been mitigated to applicable standards. Using GIS tools, DNR overlaid the mapped road network on potentially unstable slopes or landforms to determine what percentage of the road network may be vulnerable to failure.

Text Box 3-5. Shallow-Rapid and Deep-Seated Landslides

Shallow-Rapid Landslides

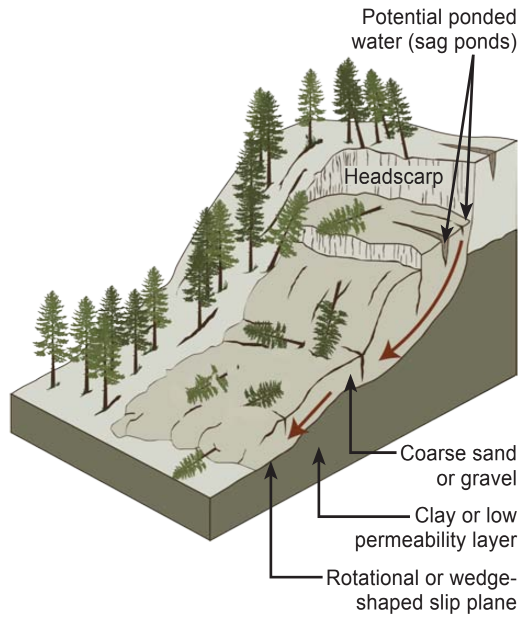


The slip plane of a **shallow-rapid landslide** is relatively close to the ground surface (a slip plane is the surface along which a landslide occurs, refer to figure, above). These landslides move relatively quickly, sometimes over 30 miles per hour (Cruden and Varnes 1996), and can travel a mile or more from their point of initiation. Shallow-rapid landslides can severely impact streams, roads, bridges, and other structures within their path of travel.

Shallow-rapid landslides generally originate in steep terrain and are typically triggered by intense rain storms or rain-on-snow events, though they can also result from stream undercutting and large magnitude earthquakes. During storms, large amounts of water enter the soil. If the water pressure forcing the soil particles apart exceeds the soil's capacity to stick together, the soil's structure fails and a shallow-rapid landslide results.

Drawings modified from Varnes 1978

Deep-Seated Landslides



A **deep-seated landslide** is the movement of a large mass of soil in which the slip plane is located far below the ground (refer to figure, above). Deep-seated landslides move slowly, only inches to feet per year, and their absolute age is often unknown (Salo and Cundy 1987).

Most often, deep-seated landslides form when water percolates through mechanically weak soils, such as sand or gravel, and becomes perched on top of stronger soils, such as clay, creating an area of weakness. These landslides are often triggered by seasonal fluctuations in precipitation, stream undercutting, or large-magnitude earthquakes.

Deep-seated landslides may appear intact and can be covered with large, mature trees. They are characterized by broken ground, extensive water seepage, ponded water, ground cracks, and deformed trees, and range in size from less than an acre to many hundreds of acres.

Criterion and Indicators: Summary

Table 3-16 summarizes the criteria and indicators and how they were measured for the No Action and Landscape alternatives. DNR used a qualitative process to analyze indicators for the Pathways Alternative (refer to p. 3-17 through 3-18).

Table 3-16. Criterion and Indictors for Soils and how They Were Measured

Criterion/Indicator	How the indicator was measured	Potential environmental impacts
Soil conservation/ Soil compaction	Number of forest stand entries (variable retention harvest or thinning) on soils that have a high likelihood of compaction; measured using the methodology in Figure 3-21	**Low**: Less than 10 percent of state trust lands have potential high impacts **Medium**: 10 to 20 percent of state trust lands have potential high impacts **High**: Over 20 percent of state trust lands have potential high impacts
Soil conservation/ Soil erosion	Number of forest stand entries (variable retention harvest or thinning) on soils that have a high likelihood of erosion and are located on steep slopes (above 60 percent); measured using the methodology in Figure 3-21	**Low**: Less than 10 percent of state trust lands have potential high impacts **Medium**: 10 to 20 percent of state trust lands have potential high impacts **High**: Over 20 percent of state trust lands have potential high impacts
Soil conservation/ Soil displacement	Number of forest stand entries (variable retention harvest or thinning) on soils that have a high likelihood of displacement; measured using the methodology in Figure 3-21	**Low**: Less than 10 percent of state trust lands have potential high impacts **Medium**: 10 to 20 percent of state trust lands have potential high impacts **High**: Over 20 percent of state trust lands have potential high impacts
Soil conservation/ Soil productivity	Number of forest stand entries (variable retention harvest or thinning) on Site Class 5 soils; measured using the methodology in Figure 3-21	**Low**: Less than 10 percent of state trust lands haves potential high impacts **Medium**: 10 to 20 percent of state trust lands have potential high impacts **High**: Over 20 percent of state trust lands have potential high impacts

Table 3-16, Continued. Criterion and Indictors for Soils and how They Were Measured

Criterion/Indicator	**How the indicator was measured**	**Potential environmental impacts**
Soil conservation/ Landslide potential	Number of forest stand entries (variable retention harvest or thinning) on soils that have a high likelihood of landslides; measured using the methodology in Figure 3-21	**Low**: Less than 10 percent of state trust lands have potential high impacts **Medium**: 10 to 20 percent state trust lands have potential high impacts **High**: Over 20 percent of state trust lands have potential high impacts
Soil conservation/ Potential road failure	Percentage of the road network built on potentially unstable slopes or landforms	**Low:** Less than 5 percent of road network in a landscape is located on potentially unstable slopes or landforms **Medium:** 5 to 10 percent of road network in a landscape is located on potentially unstable slopes or landforms **High:** Over 10 percent of road network in a landscape is located on potentially unstable slopes or landforms

Current Conditions

Following, DNR provides information on the number of acres of soils on state trust lands in each watershed administrative unit that have a high likelihood of compaction, erosion, displacement, or landslides, or that are classified in certain site classes.

Indicator: Soil Compaction

As shown in Table 3-17, all watershed administrative units have soils with a high likelihood of compaction. For example, in the Bogachiel watershed administrative unit, those soils are found on 7,757 acres, or 69 percent, of state trust lands in that watershed administrative unit. Percentages range from 27 percent (Lower Clearwater) to 97 percent (Cedar).

Table 3-17. Acres and Percent of State Trust Lands in Each Watershed Administrative Unit With Soils That Have a High Likelihood of Compaction

Watershed administrative unit (acres of state trust lands)	Acres (percent)
Bogachiel (11,267)	7,757 (69%)
Cedar (4,208)	4,066 (97%)
Clallam River (10,161)	8,549 (84%)
East Fork Dickey (10,975)	9,146 (83%)
Goodman Mosquito (13,449)	10,815 (80%)
Hoko (10,636)	9,638 (91%)
Kalaloch Ridge (5,753)	5,555 (97%)
Lower Clearwater (19,815)	5,312 (27%)
Lower Dickey (7,377)	6,414 (87%)
Lower Hoh River (7,120)	6,182 (87%)
Lower Queets River (14,961)	12,481 (83%)
Middle Hoh (37,289)	15,155 (41%)
Quillayute River (6,187)	5,138 (83%)
Sol Duc Lowlands (4,448)	3,087 (69%)
Sol Duc Valley (13,481)	9,216 (68%)
Upper Clearwater (54,911)	26,759 (49%)

Indicator: Soil Erosion

Table 3-18 shows the acres of state trust lands in each watershed administrative unit that have soils with a high likelihood of erosion. Many watershed administrative units contain less than 1 percent of these soils. Others, such as the Middle Hoh, have as much as 27 percent.

Table 3-18. Acres and Percent of State Trust Lands in Each Watershed Administrative Unit With Soils That Have a High Likelihood of Erosion

Watershed administrative unit (acres of state trust lands)	Acres (percent)
Bogachiel (11,267)	169 (2%)
Cedar (4,208)	15 (<1%)
Clallam River (10,161)	684 (7%)
East Fork Dickey (10,975)	23 (<1%)
Goodman Mosquito (13,449)	52 (<1%)
Hoko (10,636)	1,217 (11%)
Kalaloch Ridge (5,753)	258 (4%)
Lower Clearwater (19,815)	2 (<1%)

Table 3-18, Continued. Acres and Percent of State Trust Lands in Each Watershed Administrative Unit With Soils That Have a High Likelihood of Erosion

Watershed administrative unit (acres of state trust lands)	Acres (percent)
Lower Dickey (7,377)	3 (<1%)
Lower Hoh River (7,120)	11 (<1%)
Lower Queets River (14,961)	5 (<1%)
Middle Hoh (37,289)	9,921 (27%)
Quillayute River (6,187)	2 (<1%)
Sol Duc Lowlands (4,448)	46 (1%)
Sol Duc Valley (13,481)	647 (5%)
Upper Clearwater (54,911)	13,055 (24%)

Indicator: Soil Displacement

Table 3-19 shows the acres of state trust lands in each watershed administrative unit that have soils with a high likelihood of displacement. Some watershed administrative units, such as Sol Duc Lowlands, have only 2 percent, while others, such as Kalaloch Ridge, have as much as 84 percent.

Table 3-19. Acres and Percent of State Trust Lands in Each Watershed Administrative Unit With Soils That Have a High Likelihood of Displacement

Watershed administrative unit (acres of state trust lands)	Acres (percent)
Bogachiel (11,267)	2,027 (18%)
Cedar (4,208)	1,244 (30%)
Clallam River (10,161)	6,113 (60%)
East Fork Dickey (10,975)	1,365 (12%)
Goodman Mosquito (13,449)	3,281 (24%)
Hoko (10,636)	7,377 (69%)
Kalaloch Ridge (5,753)	4,851 (84%)
Lower Clearwater (19,815)	3,035 (15%)
Lower Dickey (7,377)	748 (10%)
Lower Hoh River (7,120)	1,499 (21%)
Lower Queets River (14,961)	2,217 (15%)
Middle Hoh (37,289)	15,870 (43%)
Quillayute River (6,187)	552 (9%)
Sol Duc Lowlands (4,448)	89 (2%)
Sol Duc Valley (13,481)	3,943 (29%)
Upper Clearwater (54,911)	33,769 (61%)

Indicator: Soil Productivity

Table 3-20 shows the site classes for state trust lands in each watershed administrative unit, and Table 3-21 shows the site classes for all state trust lands in the OESF. Most areas of state trust lands in the OESF were classified as Site Class 3 or Site Class 4 (site class was determined using DNR's forest inventory data). On state trust lands from which inventory data was not collected, DNR inferred that soils were either Site Class 3 or Site Class 4 based on tree growth from other areas with the same soil classification.

Table 3-20. Site Classes for State Trust Lands in Each Watershed Administrative Unit, in Acres

Watershed administrative unit (acres of state trust lands)	Site class					
	1	2	3	4	3 and 4	5
Bogachiel (11,267)	580	1,298	2,746	743	5,790	110
Cedar (4,208)	0	1,302	897	75	1,568	366
Clallam River (10,161)	240	2,477	4,063	871	2,505	5
East Fork Dickey (10,975)	710	1,625	4,018	470	4,118	33
Goodman Mosquito (13,449)	359	613	4,004	1,017	7,261	194
Hoko (10,636)	495	2,157	3,897	1,447	2,449	191
Kalaloch Ridge (5,753)	19	1,560	1,728	467	1,979	0
Lower Clearwater (19,815)	1,749	3,346	6,714	1,194	6,514	298
Lower Dickey (7,377)	0	490	2,182	744	3,370	591
Lower Hoh River (7,120)	0	579	604	87	5,447	401
Lower Queets River (14,961)	359	2,302	3,150	1,854	7,212	83
Middle Hoh (37,289)	69	547	2,603	3,554	30,277	239
Quillayute River (6,187)	224	1,405	1,955	296	2,280	27
Sol Duc Lowlands (4,448)	135	353	1,317	347	2,297	0
Sol Duc Valley (13,481)	230	1,953	5,313	1,797	4,125	63
Upper Clearwater (54,911)	748	4,316	13,430	13,473	22,931	13

Table 3-21. Site Classes for State Trust Lands, in Acres

Site class	Acres (percent[a]) of State Trust Lands
1	8,199 (3%)
2	32,059 (12%)
3	66,273 (26%)
4	32,053 (12%)
3 and 4	116,127 (45%)
5	2,856 (1%)
TOTAL	257,566

[a]Does not equal 100 percent because of rounding.

Indicator: Landslide Potential

Table 3-22 shows the acres of state trust lands in each watershed administrative unit that have soils with a high likelihood of landslides (soils located on top of marine sediment or basalt geologic units in areas that are steeply sloped [over 70 percent]). These acres do not include potentially unstable slopes or landforms, which were identified using a slope stability model and deferred from harvest in the analysis model.

Table 3-22. Acres and Percent of State Trust Lands in Each Watershed Administrative Unit With Soils That Have a High Likelihood of Landslides

Watershed administrative unit (acres of state trust lands)	Acres (percent)
Bogachiel (11,267)	68 (1%)
Cedar (4,208)	5 (<1%)
Clallam River (10,161)	259 (3%)
East Fork Dickey (10,975)	6 (<1%)
Goodman Mosquito (13,449)	21 (<1%)
Hoko (10,636)	525 (5%)
Kalaloch Ridge (5,753)	102 (2%)
Lower Clearwater (19,815)	98 (<1%)
Lower Dickey (7,377)	0
Lower Hoh River (7,120)	9 (<1%)
Lower Queets River (14,961)	2 (<1%)
Middle Hoh (37,289)	6,285 (17%)
Quillayute River (6,187)	8 (<1%)
Sol Duc Lowlands (4,448)	18 (1%)
Sol Duc Valley (13,481)	227 (5%)
Upper Clearwater (54,911)	8,499 (15%)

Ten watershed administrative units have 1 percent or less of these soils; no watershed administrative unit has more than 17 percent.

Indicator: Potential Road Failure

The road network in the OESF ranges from roads that are temporary, gravel, and used for a single timber sale and then abandoned, to roads that are paved, permanent, and used year-round. Most roads on state trust lands in the OESF are active (currently in use) and unpaved. For this analysis, DNR included all roads on state trust lands (1,800 miles of road) except roads that have been certified as abandoned.[12]

For this analysis, DNR assumed the extent of the road network in the OESF would remain essentially unchanged under all three alternatives throughout the 100-year analysis period. DNR does not expect a substantial reduction of the road network because roads are essential to working forests. Although DNR has abandoned some of its roads, very little additional road abandonment is identified in current plans. Nor does DNR expect a substantial expansion of its road network, although some new roads may be needed. It is too speculative to estimate the location or number of miles of new road needed; the exact location and length of new roads cannot be determined until a harvest is planned. (For more information about the accomplishment of road maintenance and abandonment plans, refer to the summaries in Appendix C.)

Because DNR assumed the road network would not change, DNR based its results for this indicator on the current condition of the road network. Therefore, current conditions and results are the same and are presented in the following section. Also, although there may be small differences in new road construction between all three alternatives (No Action, Landscape, Pathways), DNR assumed the road network would be essentially the same under each alternative and therefore did not present the results for this indicator by alternative.

■ Results

As explained previously, for the No Action and Landscape alternatives, and for all indicators except potential road failure, DNR first determined the percentage of state trust lands in each watershed administrative unit with potential high impacts. DNR considered a potential high impact to be four or more harvest entries (variable retention harvest or thinning) recommended by the analysis model on soils with a high likelihood of compaction, erosion, displacement, or landslides, or that are the least productive, over the 100-year analysis period.

- If less than 10 percent of state trust lands have potential high impacts, the potential environmental impact is low.
- If 10 to 20 percent of state trust lands have potential high impacts, the potential environmental impact is medium.
- If more than 20 percent of state trust lands have potential high impacts, the potential environmental impact is high.

DNR then assigned a low, medium, or high impact rating to each watershed administrative unit based on the percentage of state trust lands in that watershed administrative unit with potential high impacts (refer to sidebar, right). Finally, DNR assigned a low, medium, or high impact rating to each indicator based on the percentage of state trust lands in all watershed administrative units with potential high impacts. DNR used primarily qualitative techniques to analyze the Pathways Alternative (refer to p. 3-17 through 3-18).

Indicator: Soil Compaction

NO ACTION AND LANDSCAPE ALTERNATIVES

Soils with a high likelihood of compaction are found on a significant portion of state trust lands in the OESF (refer to Table 3-17). Yet, there are relatively few instances of four or more forest stand entries recommended on these soils over the 100-year analysis period.

Under either the No Action or Landscape Alternative, 20 percent or less of state trust lands in any given watershed administrative unit has potential high impacts (refer to Table

3-23). Therefore, potential environmental impacts for all watershed administrative units under the No Action or Landscape Alternative are low or medium.

Table 3-23. Percent and Acres of State Trust Lands in Each Watershed Administration Unit Projected to Have Potential High Impacts From Compaction, by Alternative

Watershed administrative unit (acres of state trust lands)	Percent (acres) of state trust lands with potential high impacts	
	No Action Alternative	Landscape Alternative
Bogachiel (11,267)	5% (601) ●	10% (1,074) ◇
Cedar (4,208)	15% (619) ◇	19% (804) ◇
Clallam River (10,161)	14% (1,444) ◇	16% (1,600) ◇
East Fork Dickey (10,975)	11% (1,233) ◇	19% (2,057) ◇
Goodman Mosquito (13,449)	5% (670) ●	8% (1,101) ●
Hoko (10,636)	13% (1,382) ◇	17% (1,848) ◇
Kalaloch Ridge (5,753)	8% (475) ●	13% (747) ◇
Lower Clearwater (19,815)	8% (1,578) ●	11% (2,143) ◇
Lower Dickey (7,377)	5% (395) ●	10% (756) ◇
Lower Hoh River (7,120)	4% (287) ●	4% (315) ●
Lower Queets River (14,961)	10% (1,424) ◇	14% (2,074) ◇
Middle Hoh (37,289)	1% (384) ●	<1% (42) ●
Quillayute River (6,187)	11% (702) ◇	20% (1,225) ◇
Sol Duc Lowlands (4,448)	7% (293) ●	10% (441) ◇
Sol Duc Valley (13,481)	11% (1,549) ◇	14% (1,868) ◇
Upper Clearwater (54,911)	4% (2,467) ●	6% (3,114) ●
TOTAL (232,038)	7% (15,503) ●	9% (21,209) ●

● **Low impact** ◇ **Medium impact**

Considering all watershed administrative units together, under the No Action Alternative, only 7 percent (15,503 acres) of state trust lands in the OESF have potential high impacts, and under the Landscape Alternative, only 9 percent (21,209 acres) of state trust lands in the OESF have potential high impacts. Therefore, the potential environmental impact for the No Action and Landscape alternatives for this indicator is considered **medium.** DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

Under the Pathways Alternative, harvest methods and the number of forest stand entries are, on balance, anticipated to be similar to those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Following, DNR discusses expected trends in forest stand entries in operable and deferred areas under the Pathways Alternative.

Operable Areas

- In some landscapes, DNR will select existing Young Forest Habitat in operable areas for passive management (Pathways 3 and 4), meaning these forest stands will have no harvest entries during the restoration phase (refer to Chapter 2 for information on the northern spotted owl conservation strategy).
- In other landscapes, DNR will thin selected areas of non-habitat in operable areas to create or accelerate development of habitat (Pathway 5). Under the Pathways Alternative, these areas should receive one thinning entry only during the 100-year analysis period, although DNR may thin the stand a second time if needed.
- Considering all operable areas together, applying Pathways 3, 4, and 5 in some locations of the operable area may increase harvest entries elsewhere. Or, the total volume of harvest in the operable area may be reduced during the restoration phase. During the maintenance and enhancement phase, Young or Old Forest Habitat in operable areas not needed to maintain thresholds will be available for harvest (thinning or stand replacement). None of these possibilities are expected to significantly change the number of forest stand entries in operable areas as compared to the Landscape Alternative because (as explained on p. 3-17 through 3-18) the total number of acres affected by pathways is expected to be relatively small.

Deferred Areas

In some landscapes, DNR will thin selected forest stands in deferred areas to create or accelerate development of Young Forest Habitat (Pathway 7). These areas should receive one thinning entry only over the 100-year analysis period, although DNR may thin the stand again if needed.

The differences in the number of forest stand entries under the Pathways Alternative as compared to the Landscape Alternative, as described in this section, are not expected to be significant due to the similarities between these alternatives. On balance, in deferred and operable areas combined, the number of forest stand entries should decrease in some areas and increase in others under the Pathways Alternative. Therefore, the potential environmental impact for the Pathways Alternative for this indicator is considered **medium**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Soil Erosion

Soils with a high likelihood of erosion make up varying percentages of state trust lands in each watershed administrative unit. Many watershed administrative units have less than 1 percent, others as much as 27 percent (refer to Table 3-18).

NO ACTION AND LANDSCAPE ALTERNATIVES

Under the No Action and Landscape alternatives, few instances of four or more forest stand entries occur over the 100-year analysis period on soils that are both prone to erosion and located on steep (greater than 60 percent) slopes. Under either of these alternatives, 1 percent or less of state trust lands in any given watershed administrative unit has potential high impacts. Therefore, potential environmental impacts for all watershed administrative units under either the No Action or Landscape Alternative are low (Table 3-24).

Table 3-24. Percent and Acres of State Trust Lands in Each Watershed Administration Unit Projected to Have Potential High Impacts From Erosion, by Alternative

Watershed administrative unit (acres of state trust lands)	Percent (acres) of state trust lands with potential high impacts	
	No Action Alternative	Landscape Alternative
Bogachiel (11,267)	<1% (3) ●	<1% (3) ●
Cedar (4,208)	<1% (8) ●	<1% (8) ●
Clallam River (10,161)	0 ●	0 ●
East Fork Dickey (10,975)	0 ●	0 ●
Goodman Mosquito (13,449)	<1% (10) ●	<1% (10) ●
Hoko (10,636)	0 ●	0 ●
Kalaloch Ridge (5,753)	<1% (8) ●	<1% (8) ●
Lower Clearwater (19,815)	<1% (2) ●	<1% (2) ●
Lower Dickey (7,377)	0 ●	0 ●
Lower Hoh River (7,120)	<1% (1) ●	<1% (1) ●
Lower Queets River (14,961)	0 ●	0 ●
Middle Hoh (37,289)	0 ●	0 ●
Quillayute River (6,187)	<1% (1) ●	<1% (1) ●
Sol Duc Lowlands (4,448)	0 ●	0 ●
Sol Duc Valley (13,481)	0 ●	0 ●
Upper Clearwater (54,911)	1% (545) ●	1% (549) ●
TOTAL (232,038)	<1% (578) ●	<1% (582) ●

● Low impact

Considering all watershed administrative units together, under the No Action and Landscape alternatives less than 1 percent (578 acres under the No Action Alternative, 582 acres under the Landscape Alternative) of state trust lands in the OESF have potential high impacts. Therefore, the potential environmental impact for either the No Action or Landscape Alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

As described under the indicator soil compaction, the differences in the number of forest stand entries under the Pathways Alternative as compared to the Landscape Alternative are not expected to be significant due to the similarities between these alternatives (refer to p. 3-17 through 3-18). On balance, in deferred and operable areas combined, the number of forest stand entries will decrease in some areas and increase in others under the Pathways Alternative. Therefore, the potential environmental impact for the Pathways Alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Soil Displacement

Soils with a high likelihood of displacement make up varying percentages of state trust lands in each watershed administrative unit. Some have as little as 2 percent, others as much as 84 percent (refer to Table 3-19).

NO ACTION AND LANDSCAPE ALTERNATIVES

Under both the No Action and Landscape alternatives, three watershed administrative units (Clallam River, Hoko, Kalaloch Ridge) have potential high impacts on more than 20 percent of state trust lands; the potential environmental impacts for these units is high (Table 3-25). Potential environmental impacts for all other watershed administrative units are low or medium.

Table 3-25. Percent and Acres of State Trust Lands in Each Watershed Administrative Unit Projected to Have Potential High Impacts from Displacement, by Alternative

Watershed administrative unit (acres of state trust lands)	Percent (acres) of state trust lands with potential high impacts	
	No Action Alternative	Landscape Alternative
Bogachiel (11,267)	6% (621) ●	5% (618) ●
Cedar (4,208)	19% (787) ◇	19% (787) ◇
Clallam River (10,161)	31% (3,200) ■	31% (3,198) ■
East Fork Dickey (10,975)	6% (634) ●	6% (632) ●
Goodman Mosquito (13,449)	11% (1,534) ◇	11% (1,538) ◇
Hoko (10,636)	43% (4,592) ■	43% (4,588) ■
Kalaloch Ridge (5,753)	29% (1,669) ■	29% (1,670) ■
Lower Clearwater (19,815)	5% (909) ●	6% (1,233) ●
Lower Dickey (7,377)	6% (454) ●	6% (454) ●
Lower Hoh River (7,120)	10% (686) ◇	10% (686) ◇
Lower Queets River (14,961)	4% (621) ●	4% (621) ●
Middle Hoh (37,289)	7% (2,742) ●	7% (2,742) ●

Table 3-25, Continued. Percent and Acres of State Trust Lands in Each Watershed Administration Unit Projected to Have Potential High Impacts from Displacement, by Alternative

Watershed administrative unit (acres of state trust lands)	Percent (acres) of state trust lands with potential high impacts	
	No Action Alternative	Landscape Alternative
Quillayute River (6,187)	4% (250) ●	4% (250) ●
Sol Duc Lowlands (4,448)	1% (61) ●	1% (61) ●
Sol Duc Valley (13,481)	19% (2,603) ◇	19% (2,602) ◇
Upper Clearwater (54,911)	19% (10,460) ◇	19% (10,462) ◇
TOTAL (232,038)	14% (31,823) ◇	14% (32,142) ◇

● Low impact ◇ Medium impact ■ High impact

Considering all watershed administrative units together, 14 percent (31,823 acres under the No Action Alternative and 32,142 acres under the Landscape Alternative) of state trust lands in the OESF have potential high impacts. Therefore, the potential environmental impact for either alternative for this indicator is considered **medium**. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

Possible mitigation could reduce potential high impacts within the Clallam, Hoko, and Kalaloch Ridge watershed administrative units to a lower level. As described in the introduction to this chapter, possible mitigation includes site-specific mitigation that foresters may suggest to further reduce potential impacts at the time of an individual management activity. For example, DNR may use suspended cables to move trees to landings or otherwise limit heavy machinery movement on exposed soils with a high likelihood of displacement. Site-specific mitigation is considered under SEPA as part of the SEPA review for each activity.

PATHWAYS ALTERNATIVE

As described under the indicator soil compaction, the differences in the number of forest stand entries under the Pathways Alternative as compared to the Landscape Alternative are not expected to be significant due to the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). On balance, in deferred and operable areas combined, the number of forest stand entries should decrease in some areas and increase in others under the Pathways Alternative. Therefore, the potential environmental impact for the Pathways Alternative for this indicator of soil conservation is considered **medium**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Soil Productivity

There are only 2,856 total acres of the least productive soils (Site Class 5) on state trust lands in the OESF. There are less than 591 acres of these soils on state trust lands in any given watershed administrative unit (refer to Table 3-20).

NO ACTION AND LANDSCAPE ALTERNATIVES

Under the No Action and Landscape Alternatives, potential impacts are low in all watershed administrative units (refer to Table 3-26).

Table 3-26. Percent and Acres of State Trust Lands in Each Watershed Administrative Unit Projected to Have Potential High Impacts to Soil Productivity, by Alternative

Watershed administrative unit (acres of state trust lands)	Percent (acres) of state trust lands with potential high impacts	
	No Action Alternative	Landscape Alternative
Bogachiel (11,267)	<1% (91) ●	<1% (91) ●
Cedar (4,208)	4% (182) ●	4% (186) ●
Clallam River (10,161)	<1% (3) ●	<1% (3) ●
East Fork Dickey (10,975)	<1% (22) ●	<1% (22) ●
Goodman Mosquito (13,449)	1% (150) ●	1% (152) ●
Hoko (10,636)	1% (157) ●	1% (158) ●
Kalaloch Ridge (5,753)	0 ●	0 ●
Lower Clearwater (19,815)	1% (133) ●	1% (87) ●
Lower Dickey (7,377)	6% (425) ●	6% (425) ●
Lower Hoh River (7,120)	0 ●	0 ●
Lower Queets River (14,961)	<1% (56) ●	<1% (56) ●
Middle Hoh (37,289)	<1% (81) ●	<1% (82) ●
Quillayute River (6,187)	0 ●	0 ●
Sol Duc Lowlands (4,448)	0 ●	0 ●
Sol Duc Valley (13,481)	1% (43) ●	1% (43) ●
Upper Clearwater (54,911)	<1% (8) ●	<1% (8) ●
TOTAL (232,038)	1% (1,351) ●	1% (1,313) ●

● Low impact

Table 3-27 shows the total acres of harvest that are projected to occur on all site classes on state trust lands in the OESF over the 100-year analysis period. Under the No Action Alternative, only 1,201 acres of harvest are projected to occur on Site Class 5 soils, and under the Landscape Alternative, only 1,228 acres of harvest are projected to occur on Site Class 5 soils.

Table 3-27. Total Acres of Harvest (Variable Retention Harvest or Variable Density Thinning) Projected Over 100 Years on Site Class 1 Through Site Class 5 Soils on State Trust Lands in the OESF

Site class	No Action Alternative	Landscape Alternative
1	3,820	3,853
2	17,169	17,411
3	34,748	35,206
3 and 4	42,987	43,909
4	13,814	14,005
5	1,201	1,228

Considering all watershed administrative units together, less than 1 percent (1,351 acres under the No Action Alternative, 1,313 acres under Landscape Alternative) of state trust lands in the OESF have potential high impacts. Therefore, the potential environmental impact from either alternative for this indicator is considered **low**. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

As described under the indicator soil compaction, the differences in the number of forest stand entries under the Pathways Alternative as compared to the Landscape Alternative are not expected to be significant due to the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). On balance, in deferred and operable areas combined, the number of forest stand entries should decrease in some areas and increase in others under the Pathways Alternative. Therefore, the potential environmental impact for the Pathways Alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Landslide Potential

NO ACTION AND LANDSCAPE ALTERNATIVES

For this indicator, DNR analyzed the number of forest stand entries the analysis model recommended on soils with a high likelihood of landslides, which were defined as soils on top of marine sediment or basalt geologic units that are located in areas that are steeply sloped (over 70 percent). With the exception of the Middle Hoh and the Upper Clearwater, these soils make up less than 5 percent of state trust lands in any given watershed administrative unit (refer to Table 3-22). These areas **are separate from potentially unstable slopes or landforms,** which were identified using a slope stability model and deferred from harvest in the analysis model.

Under either alternative, 3 percent or less of state trust lands in any given watershed administrative unit has potential high impacts. Thus, potential environmental impacts for all watershed administrative units under the No Action and Landscape alternatives are low (refer to Table 3-28).

Table 3-28. Percent and Acres of State Trust Lands in Each Watershed Administrative Unit Projected to Have Potential High Impacts for Landslide Potential, by Alternative

Watershed administrative unit (acres of state trust lands)	Percent (acres) of state trust lands with potential high impacts	
	No Action Alternative	Landscape Alternative
Bogachiel (11,267)	<1% (10) ●	<1% (10) ●
Cedar (4,208)	<1% (3) ●	<1% (3) ●
Clallam River (10,161)	1% (127) ●	1% (127) ●
East Fork Dickey (10,975)	<1% (4) ●	<1% (4) ●
Goodman Mosquito (13,449)	<1% (6) ●	<1% (6) ●
Hoko (10,636)	3% (272) ●	3% (273) ●
Kalaloch Ridge (5,753)	<1% (1) ●	<1% (1) ●
Lower Clearwater (19,815)	<1% (12) ●	<1% (26) ●
Lower Dickey (7,377)	0 ●	0 ●
Lower Hoh River (7,120)	<1% (2) ●	<1% (2) ●
Lower Queets River (14,961)	0 ●	0 ●
Middle Hoh (37,289)	2% (655) ●	2% (655) ●
Quillayute River (6,187)	0 ●	0 ●
Sol Duc Lowlands (4,448)	<1% (4) ●	<1% (4) ●
Sol Duc Valley (13,481)	1% (103) ●	1% (103) ●
Upper Clearwater (54,911)	3% (1422) ●	3% (1423) ●
TOTAL (232,038)	1% (2,621) ●	1% (2,637) ●

● Low impact

Considering all watershed administrative units together, less than 1 percent (2,621 acres under the No Action Alternative, 2,637 acres under Landscape Alternative) of state trust lands in the OESF have potential high impacts. Therefore, the potential environmental impact for either alternative for this indicator is considered **low**. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

As described under the indicator soil compaction, the differences in the number of forest stand entries under the Pathways Alternative as compared to the Landscape Alternative are not expected to be significant due to the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). On balance, in deferred and operable areas combined, the number of forest stand entries should decrease in some areas and increase in others under the Pathways Alternative.

Under the Pathways Alternative, DNR will conduct a limited amount of thinning in deferred areas, which include potentially unstable slopes or landforms, to create or accelerate development of Young Forest Habitat (Pathway 7). DNR anticipates only one harvest entry on these potentially unstable slopes or landforms over the 100-year analysis period, although DNR may, in some circumstances, thin these stands again if needed. Thinning on potentially unstable slopes or landforms will follow all applicable policies and laws to protect down-slope resources and public safety. Therefore, the potential environmental impact for the Pathways Alternative for this indicator is considered **low**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Potential Road Failure

NO ACTION, LANDSCAPE, AND PATHWAYS ALTERNATIVE

Table 3-29 shows the current percentage of the road network in each landscape located on potentially unstable slopes or landforms. Five landscapes have potential high impacts, meaning more than 10 percent of the road network is located on potentially unstable slopes or landforms. Road failures can deliver coarse sediment to streams.

Table 3-29. Current Percentage of Road Network Located on Potentially Unstable Slopes or Landforms, by Landscape

Landscape	Percentage of road network
Clallam	17% ■
Clearwater	23% ■
Copper Mine	13% ■
Dickodochtedar	3% ●
Goodman	3% ●
Kalaloch	8% ◇
Queets	3% ●
Reade Hill	16% ■
Sekiu	10% ◇
Sol Duc	7% ●
Willy Huel	20% ■

● Low impact ◇ Medium impact ■ High impact

Considering all landscapes together, the potential environmental impact of each alternative (No Action, Landscape, Pathways) for this indicator is considered **high**. Should it occur, the environmental impact of a road failure potentially could be adverse. However, this impact rating was based solely on the percentage of the road network located on potentially unstable slopes or landforms, and was made without considering the condition of the road network, or current management practices (established programs, rules, procedures, or other practices) that may mitigate a potential high impact to a level of non-significance. Potential road failure will be mitigated to a non-significant level through repair and maintenance of roads identified in road maintenance and abandonment plans (refer to "Mitigation" in this section). Therefore, DNR did not identify probable significant environmental impacts under any alternative (No Action, Landscape, Pathways) for this indicator.

Summary of Potential Impacts

Table 3-30 provides an overview of the potential environmental impacts on soils when the criterion and all of the indicators are considered. For this analysis, only high impacts were considered potentially significant.

Table 3-30. Summary of Potential Impacts on Soils, by Alternative

Criterion	Indicators	No Action Alternative	Landscape Alternative	Pathways Alternative
Soil conservation	Soil compaction	Medium ◆	Medium ◆	Medium ◆
	Soil erosion	Low ●	Low ●	Low ●
	Soil displacement	Medium ◆	Medium ◆	Medium ◆
	Soil productivity	Low ●	Low ●	Low ●
	Landslide potential	Low ●	Low ●	Low ●
	Potential road failure	High ■	High ■	High ■

● Low impact ◆ Medium impact ■ High impact

Potential high impacts were identified for potential road failure under all three alternatives. However, DNR expects these impacts to be mitigated to a level of non-significance through current management practices, as described under "Mitigation" in this section. Therefore, DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for any indicator for this topic.

Mitigation

Following, DNR describes current management practices (established programs, rules, procedures, or other practices) that are expected to mitigate potential high impacts to a level of non-significance. This mitigation applies to the indicator potential road failure.

Road Maintenance and Abandonment Plans

The forest practices rules require large forest landowners,[13] such as DNR, to prepare road maintenance and abandonment plans for all roads that have been used or constructed since 1974.[14] These plans specify the steps that will be taken to either abandon roads or bring roads that do not meet applicable standards into compliance. Consistent with the forest practices rules, DNR has developed road maintenance and abandonment plans for roads on state trust lands in each of the 11 landscapes in the OESF. To complete the work identified under these plans, DNR will use, as appropriate, the best management practices in DNR's Forest Practices Board Manual[15] (DNR 2016) and the guidance provided in DNR's Forest Roads Guidebook (DNR 2011).

In road maintenance and abandonment plans, priority is given to roads or road systems in areas containing sensitive geology or soils with a history of landslides, and to roads with evidence of existing or potential instability that could affect public resources adversely (WAC 222-24). Registered geologists and engineers inspect potentially unstable roads. Mitigation may range from maintaining or improving drainage structures, such as relief culverts or ditches, to building retaining walls, to redesigning or abandoning the road.

Work under these plans is ongoing. Table 3-39 in "Water Quality," p. 3-143 shows the number of projects completed under road maintenance and abandonment plans for roads on state trust lands in each of the 11 landscapes in the OESF. Refer to "Water Quality" for more information on road maintenance and abandonment plans.

EFFECTIVENESS OF ROAD MAINTENANCE AND ABANDONMENT PLANS

Implementing applicable forest practices rules for road maintenance correctly is expected to minimize runoff water and sediment delivery to typed waters (DNR 2016). A statewide study conducted on private forestlands in Washington found that road maintenance and abandonment appear to reduce the amount of road-related sediment that reaches streams (Martin 2009). This study found that implementing best management practices decreased the number of road miles hydrologically connected to streams, and that most roads studied had a low probability of delivering sediment to streams (Martin 2009). In addition, road maintenance and abandonment plan effectiveness monitoring conducted statewide by Dubé and others (2010) from 2006 through 2008 found that, as roads were brought up to modern standards, they showed decreased sediment delivery to streams.

Inspection, Maintenance, and Repair

After work identified under road maintenance and abandonment plans has been completed, DNR will continue to inspect, maintain, and repair roads and bridges as needed using the appropriate best management practices for road maintenance and repair identified in the Forest Practices Board Manual and guidance provided in the Forest Roads Guidebook. Routine maintenance of road dips and surfaces and responding quickly to problems can reduce road-caused slumps and slides significantly and prevent the creation of berms that could channelize runoff (Environmental Protection Agency 2012).

If DNR must build a new road on a potentially unstable slopes or landforms, DNR will follow all applicable forest practices standards for the design and maintenance of new roads (WAC 222-24). These standards are designed to minimize the risk of road failure.

Section Notes

1. The use of a 20 percent threshold followed recommendations from federal watershed monitoring programs (Reeves and others 2004, Gallo and others 2005). Reeves and others recommended using a minimum 25 percent ownership threshold in order for a given watershed to be included in the monitoring program. As described by Gallo and others (2005), this 25 percent threshold was selected to avoid sampling watersheds in which "the contribution of federal lands to the condition of the watershed was insignificant." A more stringent 20 percent threshold was used in this analysis.
2. Types of soils prone to compaction: basic igneous bedrock, clayey or fine-textured old alluvium, glacial drift, glacial till, non-carbonate sedimentary bedrock, silty alluvium, silty alluvium over sand and gravel, and volcanic ash over non-carbonate sedimentary bedrock.
3. Types of soils prone to erosion: basic igneous bedrock, glacial drift, glacial outwash, non-carbonate sedimentary bedrock, and volcanic ash over non-carbonated sedimentary bedrock
4. In rill or gully erosion, water runoff creates small channels in the soil. Because water tends to run through these channels, they can enlarge over time, leading to increased rates of soil erosion.
5. Types of soils prone to displacement: basic igneous bedrock, glacial drift, glacial outwash, non-carbonate sedimentary bedrock, and volcanic ash over non-carbonated sedimentary bedrock
6. After trees are cut down, they are moved to a landing (place where trees or logs are collected for transport) either with ground-based equipment or via a suspended cable. When cables are used, one or both ends of the log or tree may be suspended (full suspension).
7. The removal of competing vegetation from a site, prior to tree planting. Includes mechanical / physical removal and the use of herbicides.
8. Seventy percent has been established as the average slope for landslide initiation in the OESF. Some areas may have higher or lower average slopes for landslide initiation depending on conditions.
9. A geologic unit is a combination of similar rock types, often grouped and portrayed on a geologic map.
10. The historic landslide rate is the average number of shallow-rapid landslides per year on a given site. The historic landslide rate is averaged using landslide data from no more than 70 years. Watershed administrative units differ in the number of years of data available for calculating the historic landslide rate.
11. Convergent slopes come together from different directions.
12. Under the forest practices rules (WAC 222-24-52(3)), a road is considered abandoned if: (a) roads are out-sloped, water barred, or otherwise left in a condition suitable to control erosion and maintain water movement within wetlands and natural drainages; (b) ditches are left in a suitable condition to reduce erosion; (c) the road is blocked so that four-wheel highway vehicles cannot pass the point of closure at the time of abandonment; (d) water crossing structures and fills on all typed waters are removed, except where the department determines other measures would provide adequate protection to public resources; and (e) DNR has determined that the road is abandoned.
13. In Washington, large forest landowners are those who harvest an annual average of more than 2 million board feet of timber from their own forestland in the state.
14. Older roads that have not been used since 1974 are considered "orphaned."
15. Available at: http://www.dnr.wa.gov/about/boards-and-councils/forest-practices-board/rules-and-guidelines/forest-practices-board-manual

Water Quality

■ Why is Water Quality Important?

Water quality is important to the health of riparian areas. Riparian areas, which include streams, lakes, rivers, and wetlands, support native fish populations and other aquatic species as well as the birds and mammals that depend on these areas for all or part of their life cycles. High quality water also is essential for human life.

■ What is the Criterion for Water Quality?

The criterion for water quality is **compliance with water quality standards**. Water quality in the OESF is governed by the federal Clean Water Act and the state Water Pollution Control Act (Chapter 90.48 RCW). The Clean Water Act requires states to set water quality standards consistent with federal standards. The Water Pollution Control Act requires the state to maintain the highest possible water quality standards to ensure the purity of all waters in the state.

Consistent with these requirements, Ecology developed and published "Water Quality Standards for Surface Waters of the State of Washington" (Chapter 173-201A WAC [Ecology 2006] as revised [Ecology 2011a]). In this chapter of the code, Ecology establishes water quality standards for surface waters of the state consistent with public health and enjoyment of waters and the protection of fish, shellfish, and wildlife (Ecology 2006).

■ What are the Indicators for Water Quality?

The indicators used to assess the criterion (compliance with water quality standards) are **stream shade**, **road density**, **stream crossing density**, **proximity of roads to streams or other water bodies**, and **traffic impact scores**. DNR's indicators are based on Ecology's water quality standards.

In their water quality standards, Ecology identifies watershed resource inventory areas as the basis for environmental analysis and administration (refer to Appendix C for a description of water resource inventory areas). All of water resource inventory area 20 (Soleduck/Hoh) and portions of water resource inventory areas 19 (Lyre/Hoko) and 21 (Queets/Quinault) are located within the OESF. For each water resource inventory area, Ecology assigns water quality indicators to water bodies based on their use designation.[1] Use designations include aquatic life, recreation, water supply, and miscellaneous. Ecology indicators specific to aquatic life are stream temperature, dissolved oxygen, turbidity, total dissolved gas, and pH. The Ecology indicator specific to recreational uses is fecal coliform bacteria. Ecology indicators applicable to all uses are toxic, radioactive, and deleterious materials and aesthetic values.

DNR's indicators are meant as surrogates for Ecology's indicators:

- DNR measures the Ecology indicators **stream temperature** and **dissolved oxygen** by assessing the potential of the riparian forest to provide **shade to the stream** because shade influences both water temperature and dissolved oxygen.

- DNR measures the Ecology indicator **turbidity** by analyzing the potential of the road network to deliver **fine sediment** to streams. Roads can increase the amount of fine sediment delivered to streams to levels above what would occur naturally. DNR analyzes the potential for sediment delivery using four road-related indicators: **road density**, **stream crossing density**, **proximity of roads to streams or other water bodies**, and **traffic impact scores**.

  Turbidity is a measurement of the amount of solids suspended in water (cloudiness). Solids that cause cloudiness in water may include soil particles (fine sediment) or algae. Turbidity can affect fish and their habitat negatively (refer to fine sediment delivery discussion in "Fish," p. 3-147). Turbidity also can reduce a water body's value for recreation, drinking water, and other uses.

- This analysis does not include the Ecology indicators **total dissolved gas**; **pH**; f**ecal coliform bacteria**; **toxic, radioactive, and deleterious materials**; or **aesthetic values**. To learn why, refer to "Considered but Not Analyzed" at the end of this section. Refer to Appendix C for use designations of water bodies in the OESF.

DNR did not measure stream temperature, dissolved oxygen, or turbidity directly because comprehensive data for these indicators is not available in a readily useable form for all streams on state trust lands in the OESF:

- Limited spot water quality sampling began in the OESF in the 1950s. However, the portion of the rivers and streams sampled is small compared to the miles of rivers and streams in the entire OESF water system (10,730 miles of stream in the OESF, 2,785 miles of which are located on state trust lands; refer to Table 3-1 on p. 3-4).

- Several tribes in the OESF, a local citizen groups, USFS, and NPS have collected water quality data, with some data being collected on state trust lands; however, such data is not comprehensive for state trust lands in the OESF.

- Ecology maintains only one long-term water quality monitoring station on state trust lands in the OESF (refer to photo on p. 3-125).

Having comprehensive data for all streams in the OESF is essential to conducting an environmental analysis of DNR's alternatives. Using detailed data for some areas but not others would make it impossible to fully understand the potential impacts of the alternatives across state trust lands in the OESF.

Based on the limited data that has been collected, approximately 10 stream miles on state trust lands in the OESF are listed on the 303(d) list[2] as not meeting water quality standards for stream temperature, dissolved oxygen, turbidity, or fecal coliform bacteria (refer to Appendix C). Ten miles is approximately 0.35 percent of the total stream miles on state trust lands in the OESF.

Water Quality Monitoring Station 20B070 Hoh River
Near Hoh Oxbow Campground (Ecology 2012a)

Overlapping Indicators

Stream shade is an overlapping indicator. In addition to this section, it was used to assess functioning riparian habitat in "Riparian," p. 3-47 and "Fish," p. 3-147. Overlapping indicators are expected due to the complexity and interrelatedness of the components of the forest ecosystem. In this section (Water Quality), DNR presented the results for this indicator and discussed how they relate to water quality; refer to "Riparian," p. 3-47 for the full analysis.

Fine sediment delivery also was analyzed in "Riparian," p. 3-47 and "Fish," p. 3-147 using spatial scales appropriate to those topics. For both of those analyses, DNR coupled the potential for fine sediment delivery to streams (how likely it is to occur) with the sensitivity, or the expected stream channel response, to inputs of fine sediment to streams. DNR used sensitivity ratings from watershed analyses that were performed (either initiated or completed and approved) in the OESF per the forest practices rules. For stream reaches for which watershed analyses were not available, DNR based sensitivity primarily on gradient (how steep the stream is) and confinement (how much a stream channel can move within its valley). For example, higher gradients and stream channel confinement combine to produce enough stream energy to route most introduced fine sediment downstream (Oregon Watershed Enhancement Board [OWEB] 1999). Such streams may be less sensitive to fine sediment delivery than streams that are less steep or confined.

In this section (water quality), DNR considered potential *only*; DNR did not consider sensitivity. DNR's indicators are based on Ecology's water quality standards. Ecology's standards are primarily concerned with whether or not an impact is occurring (in this case, turbidity caused by delivery of fine sediment), regardless of the sensitivity of the stream channel to fine sediment input. For that reason, DNR considered potential only for this water quality analysis.

■ Which Roads did the Analysis Include?

DNR included the following roads in its analysis:

- For the indicators **road density**, **stream crossing density**, and the **proximity of roads to streams or other water bodies**, DNR analyzed **all roads (paved and unpaved) on state trust lands** in each of the 11 landscapes (Appendix C) *except* for roads certified as abandoned.[3] Roads certified as abandoned were not included because they have been stabilized and closed to traffic (refer to photo, right). Although there is no guarantee, DNR does not expect abandoned roads to contribute sediment to streams.

Abandoned Road

Closed to traffic, stabilized,and all drainage facilities removed

DNR does not include roads on non-state trust lands because of disparities in DNR's state trust lands transportation GIS database. This GIS database includes data for roads and streams on all ownerships in the OESF (DNR, USFS, NPS, private, tribal, and other). However, the information in this database for roads and streams on state trust lands is more complete than it is for non-state trust lands. For that reason, DNR believed that quantifying road density, stream crossing density, and proximity of roads to streams and other water bodies across all ownerships could lead to unreliable estimates. Therefore, DNR based its results for these indicators on roads and streams found on state trust lands only.

- For the indicator **traffic impact scores**, DNR analyzed traffic on **all roads (roads on state trust lands and non-state trust lands)** in the OESF because traffic associated with harvest activities may run on roads built and maintained by DNR or on roads built and maintained by other landowners.

Conservative Approach

As described in the introduction to this chapter, DNR first assigned each indicator in this FEIS a potential low, medium, or high impact. For road-related indictors, DNR based this analysis on the current extent and location of the road network. DNR assumed that all roads that have not been certified as abandoned can contribute sediment to streams, even though some of these roads have been mitigated already or will be mitigated through current management practices to prevent the delivery of sediment from roads to streams (for example, by installing culverts to direct runoff away from streams). Mitigation through current management practices was not considered until the second step of DNR's analysis process, when DNR determined if a potential high impact was probable significant adverse. DNR feels this approach is conservative.

For all indicators, DNR analyzed roads classified as decommissioned as though they have the potential to deliver fine sediment, even though these roads have been stabilized to the same forest practices standards as abandoned roads. Abandonment is permanent; decommissioned roads may be re-opened during the analysis period (DNR 2011).

In addition, 24 percent of the roads on state trust lands are classified as having the surface type "other." For this analysis, DNR took the conservative approach of assuming that roads classified as "other" are not paved, even though some may be paved. Road traffic generates sediment through surface erosion, which occurs only on unpaved roads. Refer to Appendix C for a description of road classifications and surface types.

■ How Were the Indicators Analyzed?

Following, DNR describes each criteria and indicator and the methods used to analyze them for the No Action, Landscape, and Pathways alternatives. For this analysis, DNR assumed the extent of the road network in the OESF would remain essentially unchanged under all alternatives throughout the 100-year analysis period. DNR does not expect a substantial reduction of the road network because roads are essential to working forests. Although DNR has abandoned some of its roads, very little additional road abandonment is identified in current plans. Nor does DNR expect a substantial expansion of its road network, although some new roads may be needed. It is too speculative to estimate the location or number of miles of new road needed; the exact location and length of new roads cannot be determined until a harvest is planned and a site assessment is performed. (For more information about the accomplishment of road maintenance and abandonment plans, refer to the summaries in Appendix C; for more information on the methodology used to calculate traffic scores, refer to Appendix C.)

Because the extent of the road network was held constant for this analysis, DNR based its results for all indicators except traffic impact scores on the current condition of the road network. Current conditions and results by indicator are presented under "Results" and are not, in most instances, presented by alternative.

Indicator: Stream Shade

Stream shade refers to the extent to which incoming sunlight is blocked on its way to the stream channel. Lack of shade allows sunlight to heat the water and is a common cause of elevated stream temperatures (Cafferata 1990).

Stream temperature helps determine which aquatic life forms can live in a stream. All aquatic life forms (fish, insects, zooplankton, phytoplankton, and other aquatic species) have a temperature range within which they can survive. If temperatures shift too far above or below this range, populations of aquatic life forms may decline or eventually disappear (Michaud 1991, Ecology 2012a).

Temperature influences water chemistry, such as the amount of dissolved oxygen available in water. For example, warm water holds less oxygen than cold water. Warm water may be at its maximum level of dissolved oxygen but still not contain enough oxygen for fish and other aquatic life to survive. Oxygen also is necessary for the decomposition of organic matter, such as leaves and needles that fall into the water (Michaud 1991, Ecology 2012b, Tank and others 2010).

For the No Action and Landscape alternatives, DNR used a computer model to estimate the amount of shade on the stream at sample points spaced every 75 feet along each stream reach, at hourly intervals on the hottest day of the year (July 31). DNR also assigned each stream reach a target shade level[4] based on the amount of shade necessary to meet Washington State Surface Water Quality Standards (WAC 173-201A) and the maximum amount of shade available, given the orientation and width of the stream channel.

To determine potential impacts, DNR compared the target shade level for each stream reach to the amount of shade that would be present after management activities have taken place. If a stream reach failed to meet its assigned shade target, DNR estimated the resulting increase in water temperature based on published studies (Sullivan and others 1990). DNR then assigned impacts based on the magnitude of that increase in temperature and professional opinion of how the temperature increase would affect the fish species associated with the reach in question.[5] DNR assessed all streams that cross state trust lands within Type 3 watersheds that contain at least 20 percent state trust lands.[6] For more information on the methodology used to analyze shade, refer to "Riparian," p. 3-47 and Appendix G.

DNR uses qualitative techniques to analyze this indicator for the Pathways Alternative (refer to p. 3-17 through 3-18).

Indicator: Road Density

For all three alternatives (No Action, Landscape, Pathways), DNR measured current road density in the OESF. Road density is the number of miles of road in a defined area, expressed as miles of road per square mile. Road density is calculated by dividing the miles of road in a landscape (road miles) by the area of state trust lands in that landscape (square miles). The method and thresholds used for this indicator to determine a potential low, medium, or high impact follow those described in Potyondy and Geier (2011).

Potential impacts from road density include increased delivery of fine sediment to streams due to a change in the timing, magnitude, duration, and spatial distribution of water runoff flows (Potyondy and Geier 2011). As road density increases, the potential impacts from roads also may increase (Potyondy and Geier 2011, Forman and Hersperger undated, Forman and Alexander 1998).

Indicator: Stream Crossing Density

For all three alternatives (No Action, Landscape, Pathways), DNR measured the current density of stream crossings in the OESF. Stream crossings are the points at which roads and streams intersect, commonly at bridges and culverts. Stream crossing density is the number of times a road crosses a stream per mile of stream. It was measured by dividing the number of stream crossings (how many times a road crosses a stream) by the miles of streams on state trust lands in a landscape. This calculation provided the number of stream crossings per mile of stream (Gallo and others 2005). The methods and thresholds used to determine a potential low, medium, or high impact for each landscape followed those described in Gallo and others (2005).

Stream crossings have the potential to block fish passage, alter riparian vegetation, reduce large woody debris recruitment, increase stream temperature, change channel morphology, increase stream bank erosion, reduce bank stability, and increase sediment delivery to fish-bearing waters (Potyondy and Geier 2011). Researchers have found that stream crossings, especially during road construction, are the most frequent source of sediment to streams (Taylor and others 1999, Potyondy and Geier 2011).

Indicator: Proximity of Roads to Streams or Other Water Bodies

For all three alternatives (No Action, Landscape, Pathways), DNR measures the current percentage of the road network on state trust lands that is located within 300 feet of streams or other water bodies in each of the 11 landscapes in the OESF. This distance (300 feet) was based on the methods in Potyondy and Geier (2011).

Using GIS tools, DNR calculated the number of miles of road on state trust lands in each landscape that were located within 300 feet of a stream or water body. DNR then divided that total by the total number of miles of road on state trust lands in that landscape to derive a percentage. For this analysis, DNR used percentage instead of actual miles because landscapes differ in size and using a percentage gives an index of relative impacts. The methods and thresholds used to determine a potential low, medium, or high impact for each landscape followed those described in Potyondy and Geier (2011).

Indicator: Traffic Impact Scores

For the No Action and Landscape alternatives, DNR computed traffic impact scores. The role of traffic in increasing road sediment production is well-recognized (Luce and Black 2001, Reid and Dunne 1984), particularly on roads that are unpaved and have high volumes of vehicle traffic (Elliot and others 2009). Traffic impact scores were based on road surface type, the proximity of roads to streams or other water bodies, and log truck traffic that may result from future harvests on all ownerships in a Type 3 watershed (state trust lands as well as federal, tribal, and private lands). DNR analyzed traffic on all roads (roads on state trust lands and non-state trust lands).

- On roads, traffic generates sediment through surface erosion, which occurs only on unpaved roads. Paved roads were not scored as having an impact.
- DNR assigned roads a weighted score based on how close the road is to the stream. Roads that are closer to the stream received a higher score (higher impact) than those farther away. Roads more than 300 feet from a water body were not scored as having an impact. DNR based this distance on the methodology of Potyondy and Geier (2011).
- Projected traffic levels for other ownerships were based on a review of past timber harvest volume reports and assumptions about harvest intensity relative to DNR's projected management activities; these projected traffic levels were held constant, meaning they did not vary from one decade to the next.

Thresholds for potential impacts were based on Gallo and others (2005). For more information on the methodology used to calculate traffic impact scores, refer to "Riparian," p. 3-47 and Appendix C.

DNR uses qualitative techniques to analyze this indicator for the Pathways Alternative (refer to p. 3-17 through 3-18).

■ Criterion and Indicators: Summary

Table 3-31 summarizes the criteria and indicators and how they were measured under the No Action and Landscape alternatives.

For the Pathways Alternative, DNR used qualitative techniques for stream shade and traffic impact scores; for all other indicators, DNR used the same quantitative techniques as for the No Action and Landscape alternatives.

Table 3-31. Criterion and Indicators for Water Quality and how They Were Measured

Criterion/Indicator	How the indicator was measured	Potential environmental impacts
Adherence to water quality standards/ Stream shade (surrogate for stream temperature and dissolved oxygen)	Ability of the riparian forest to provide shade to the stream Assessment area: All streams on state trust lands within Type 3 watersheds that contain at least 20 percent state trust lands	**Low**: Most watersheds are in a low impact condition. Watershed scores generally remain stable or increase over time, indicating **maintenance or restoration of riparian function**. Less than 10 percent of watersheds are in a high impact condition, or the number of watersheds in a high impact condition steadily decreases over time. **Medium**: Most watersheds are in a medium impact condition. Watersheds scores generally remain stable or increase over time, indicating **maintenance or restoration of riparian function**. Less than 10 percent of watersheds are in a high impact condition, or the number of watersheds in a high impact condition steadily decreases over time. **High**: More than 10 percent of watersheds are in a high impact condition and the number of watersheds in a high impact condition does not steadily decrease over time, indicating **failure to restore riparian function** in these watersheds.

Table 3-31, Continued. Criterion and Indicators for Roads and how They Were Measured

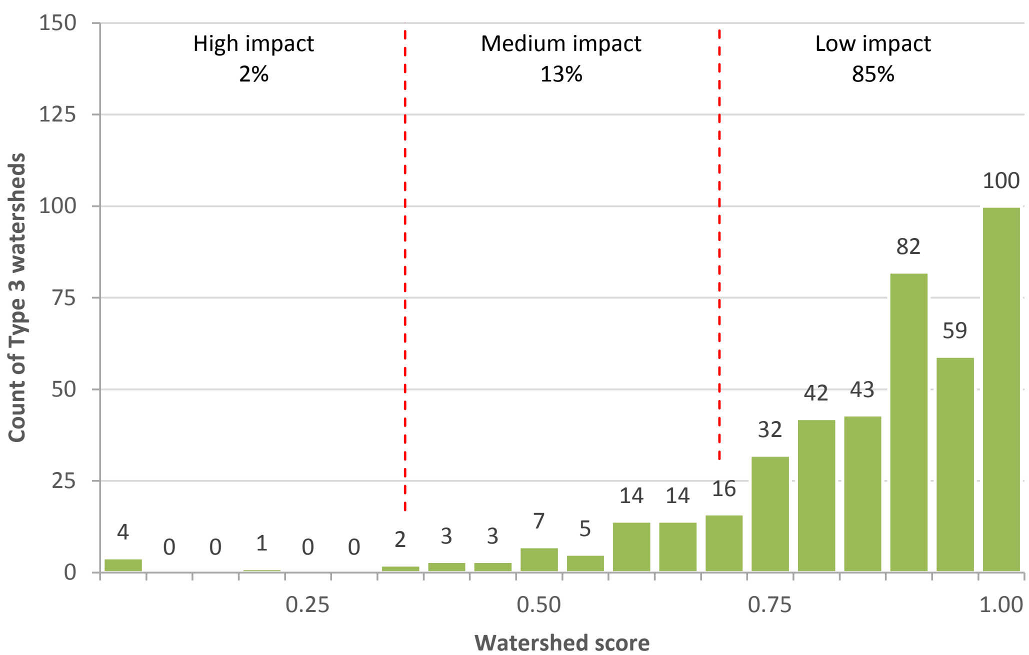
Criterion/Indicator	**How the indicator was measured**	**Potential environmental impacts**
Adherence to water quality standards/ Road density (analyzes the potential for fine sediment delivery as a surrogate for turbidity)	Road miles per square mile, measured by dividing the miles of roads on state trust lands in a landscape (road miles) by the area of state trust lands in the landscape (square miles) (Potyondy and Geier 2011) Assessment area: All roads (paved or unpaved) on state trust lands	**Low:** Less than 1.0 road mile per square mile **Medium:** 1.0 to 2.4 road miles per square mile **High:** Over 2.4 road miles per square mile
Adherence to water quality standards/ Stream crossing density (analyzes the potential for fine sediment delivery as a surrogate for turbidity)	Stream crossings per mile of stream, measured by dividing the number of stream crossings by the miles of stream on state trust lands in a landscape (Gallo and others 2005) Assessment area: All roads (paved or unpaved) on state trust lands	**Low:** Less than 1.3 stream crossings per mile of stream **Medium:** 1.3 to 2.6 stream crossings per mile of stream **High:** Over 2.6 stream crossings per mile of stream
Adherence to water quality standards/ Proximity of roads to streams or other water bodies (analyzes the potential for fine sediment delivery as a surrogate for turbidity)	Percentage of the road network on state trust lands in each landscape within 300 feet of a stream or other water body (Potyondy and Geier 2011) Assessment area: All roads (paved or unpaved) on state trust lands	**Low:** Less than 10 percent of the road network located within 300 feet of streams and water bodies **Medium:** 10 to 25 percent of the road network located within 300 feet of streams and water bodies **High:** Over 25 percent of the road network located within 300 feet of streams and water bodies.
Adherence to water quality standards/ Traffic impact score (analyzes the potential for fine sediment delivery as a surrogate for turbidity)	Traffic impact score, based on the proximity of roads to streams and water bodies, road surface type (paved or unpaved), and traffic levels Assessment area: All roads on state trust lands and non-state trust lands	**Low:** Traffic impact score less than 33 **Medium:** Traffic impact score 33 to 67 **High:** Traffic impact score 68 to 100

■ Current Conditions

Indicator: Stream Shade

Currently, 85 percent of Type 3 watersheds are in a low impact condition, 13 percent are in a medium impact condition, and 2 percent are in a high impact condition (Chart 3-14 from "Riparian" is presented here as Chart 3-23.) The current distribution of watershed scores for shade reflects that most stream reaches are at or above their shade targets.

Chart 3-23. Current Conditions for Stream Shade



Indicators: Road Density, Stream Crossing Density, and Proximity of Roads to Streams or Other Water Bodies

As stated previously, DNR based its results for these indicators on the current condition of the road network. Current conditions and results by indicator are presented under "Results" and are not, in most instances, presented by alternative.

Traffic Impact Scores

As explained previously, traffic impact scores were based on road surface type, proximity of roads to streams or other water bodies, and the level of log-truck traffic that may result from future harvests in each landscape on all ownerships (state trust lands as well as federal, tribal, and private lands). Instead of current conditions, DNR reports traffic impact scores based on the first decade's worth of harvest activities under the No Action Alternative. Scores are provided for road networks in each of the 11 landscapes (Table 3-32). All landscapes are in the low or medium impact category, meaning their traffic impact scores are below 67. DNR does not expect significant changes in the level of road use during the 100-year analysis period. Therefore, significant changes in traffic impact scores are not expected.

Table 3-32. Traffic Impact Scores for the First Decade's Worth of Harvest Activities Under the No Action Alternative, by Landscape

Landscape	Impact score
Clallam	52 ◇
Clearwater	23 ●
Copper Mine	39 ◇
Dickodochtedar	53 ◇
Goodman	39 ◇
Kalaloch	38 ◇
Queets	32 ●
Reade Hill	33 ◇
Sekiu	65 ◇
Sol Duc	29 ●
Willy Huel	30 ●

● Low impact ◇ Medium impact

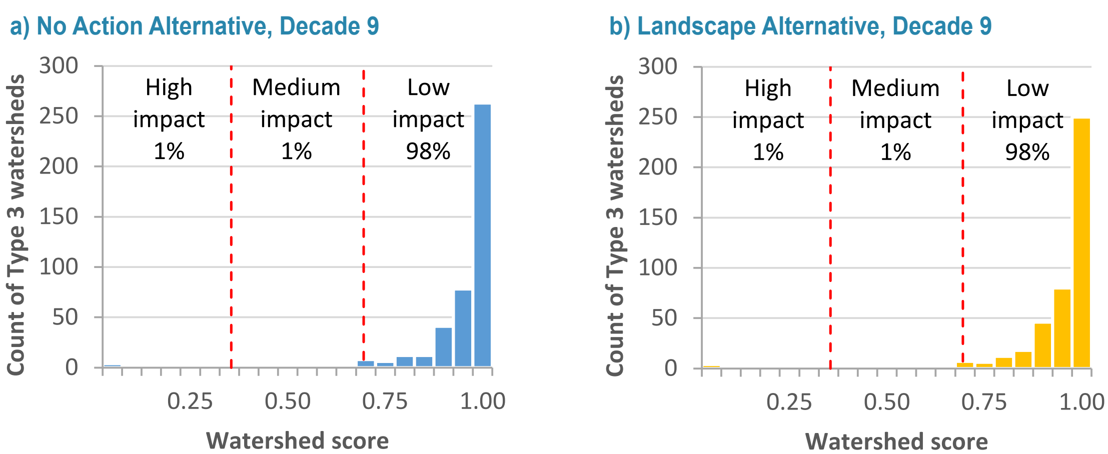
Results

Indicator: Stream Shade

NO ACTION AND LANDSCAPE ALTERNATIVES

The distribution of watershed scores for stream shade under the No Action and Landscape alternatives in Decade 9 of the analysis period is shown in Figure 3-24. These alternatives show a nearly identical trend of low impact conditions for stream shade (higher score, lower impact). Under both of these alternatives, the distribution of scores remains relatively stable, with most watersheds in a low impact condition.

Figure 3-24. Distribution of Watershed Scores for Stream Shade Under the a) No Action Alternative and b) Landscape Alternative, Decade 9



The relative stability of shade levels in Type 3 watersheds may be due to a variety of factors. For example, physical factors that affect shade, such as the shape of the surrounding terrain, the orientation of the stream channel, and the width of the stream itself, will not change over time. In addition, much of the area of influence for shade currently is deferred from harvest. In these areas, changes in stream shade will be due solely to natural growth and disturbance. Much of the area of influence is currently in the Competitive Exclusion stand development stage with crowded canopies and high shade levels. Changes will occur in these areas, but the shift will be slow.

In addition, variable retention harvest may reduce shade levels along Type 5 streams on stable ground because these streams do not receive interior-core buffers under either the No Action or Landscape Alternative. However, Type 5 streams tend to be found at higher elevations where temperatures are cooler, the terrain is more likely to provide shade, and the target shade level necessary to maintain cooler water temperatures is lower.

Because shade levels are expected to remain relatively stable over the 100-year analysis period, temperature and dissolved oxygen are expected to remain stable as well. The potential environmental impact of the No Action and Landscape alternatives for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

DNR estimates that impacts to stream shade under the Pathways Alternative will be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of stream shade watershed scores are expected to be similar to those shown in Figure 3-24 for the Landscape Alternative.

Some of the forest stands selected for active management (thinning) or passive management are located within the stream shade area of influence (sufficiently close to provide shade to the stream channel). Following, DNR describes how active and passive management of these stands may affect potential impacts for stream shade.

Passive Management

In some landscapes, DNR will select existing Young or Old Forest Habitat in operable areas for passive management (Pathways 3 and 4), meaning these stands will not be harvested as long as these pathways remain in place. These stands will continue to grow and develop forest structure that would otherwise have been harvested. Therefore, the potential impacts for shade under the Pathways Alternative would be equal to or lower than those projected under the Landscape Alternative.

Active Management

In some landscapes, DNR will thin forest stands in operable (Pathway 5) and deferred (Pathway 7) areas to create or accelerate the development of Young Forest Habitat. Because DNR rarely thins these stands below a relative density of 35, light levels in these stands should be similar to those found in unthinned forests (Chan and others 2004).

The potential environmental impact of the Pathways Alternative for stream shade is considered **low**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Road Density

NO ACTION, LANDSCAPE, AND PATHWAYS ALTERNATIVES

Table 3-33 shows the road density on state trust lands in each of the 11 landscapes in the OESF. Currently, road densities in all 11 landscapes exceed the 2.4 miles per square mile threshold for potential high impacts. Most roads in the OESF were built for timber harvesting. High road densities in the OESF are primarily due to topography; more miles of road are needed to navigate steep terrain than flat terrain. In part, high road densities are also a legacy of the 1962 Columbus Day storm, which caused extensive windthrow on the western Olympic Peninsula. A salvage logging operation after this storm required the building of an extensive road network. Impacts from road density may include increased delivery of fine sediment to streams. DNR does not expect road density to change through the 100-year analysis period.

Table 3-33. Current Road Density on State Trust Lands in the OESF, by Landscape

Landscape	Road density (road miles per square mile)
Clallam	4.3 ■
Clearwater	3.7 ■
Copper Mine	5.0 ■
Dickodochtedar	4.5 ■
Goodman	4.2 ■
Kalaloch	5.0 ■
Queets	5.0 ■
Reade Hill	3.7 ■
Sekiu	4.7 ■
Sol Duc	3.7 ■
Willy Huel	4.1 ■

■ High impact

As stated previously, it is too speculative to determine the precise number of miles of new roads necessary to complete planned harvest activities. However, using the analysis model, it is possible to compare the No Action and Landscape alternatives by determining the number of acres of harvest activities projected to occur in the first decade of the analysis period on state trust lands that are more than 800 feet from the nearest road. (DNR measured the distance from a central point in each harvest unit.) DNR predicts that harvests more than 800 feet from an existing road may require extending existing roads or building new roads. Results are shown in Table 3-34.

Table 3-34. Projected Acres of Harvest Activities on State Trust Lands More Than 800 Feet From an Existing Road in the First Decade of the Analysis Period, by Alternative

Landscape	Acres of harvest activities located more than 800 feet from an existing road	
	No Action Alternative	Landscape Alternative
Clallam	1,233	1,103
Clearwater	138	114
Coppermine	53	43
Dickodochtedar	328	351
Goodman	124	33
Kalaloch	118	76
Queets	80	71
Reade Hill	397	425
Sekiu	264	162
Sol Duc	2,033	2,610
Willy Huel	216	235
TOTAL	4,982	5,221

According to Table 3-34, during the first decade under both alternatives, the Clallam and Sol Duc landscapes have the highest projected number of acres of harvests on state trust lands that are more than 800 feet from an existing road. With the exception of the Goodman and Sekiu landscapes, the number of acres harvested over 800 feet from existing roads is similar for both the No Action and the Landscape alternatives.

DNR did not conduct this analysis for the Pathways Alternative but expects the results to be similar to the Landscape Alternative because of similarities between these alternatives and their harvest schedules (refer to p. 3-17 through 3-18). Similar to the No Action and Landscape alternatives, the exact location of roads needed under the Pathways Alternative will not be determined until implementation.

The Pathways Alternative does include thinning in areas that may not be thinned under the Landscape Alternative. For example, DNR may thin stands located on potentially unstable slopes or landforms, which are deferred from harvest in the analysis model. However, DNR does not expect a significant expansion of the road network to accommodate these thinnings. For example, in some cases the thinning may be non-commercial, in which the logs are left on the ground as down wood instead of hauled to market. Such thinnings would not require construction of new roads (refer to Chapter 2 for more information).

Because potential impacts are rated high for all landscapes, the potential environmental impact of the No Action, Landscape, and Pathways alternatives for this indicator is considered **high**. Roads can potentially deliver fine sediment to streams unless the roads have been certified as abandoned. Fine sediment delivery to streams is considered an adverse impact.

Text Box 3-6. Is the Impact Probable Significant Adverse?

DNR considers the full range of its current management practices to identify specific programs, rules, procedures, or other measures that are expected to mitigate a potential high impact to a level of non-significance. If an impact will be mitigated, it is not considered probable significant adverse.

However, this impact rating is based solely on the number of roads per square mile, and is made without considering the condition of the road network or current management practices (established programs, rules, procedures, or other practices) that are expected to mitigate a potential high impact to a level of non-significance. DNR expects potential fine sediment delivery from the road network to be mitigated to a non-significant level through current management practices (refer to Text Box 3-6), including the accomplishment of road maintenance and abandonment plans; inspecting, repairing, and maintaining roads; and suspending timber hauling during storms (refer to "Mitigation" later in this section for more information). Also, new roads will be constructed to current forest practices standards, which are designed to prevent or limit the delivery of fine sediment to streams (Martin 2009, Dubé and others 2010). Therefore, DNR did not identify probable significant environmental impacts from any alternative (No Action, Landscape, Pathways) for this indicator.

Indicator: Stream Crossing Density

NO ACTION, LANDSCAPE, AND PATHWAYS ALTERNATIVES

Table 3-35 on p. 3-138 shows the number of stream crossings per mile of stream for roads on state trust lands in each of the 11 landscapes in the OESF. Currently, stream crossing densities range from low (in seven landscapes) to medium (in four landscapes). None of the landscapes exceeds the high impact threshold of 2.6 stream crossings per mile (refer to Table 3-31 on p. 3-130). Since the road network is not expected to change significantly over the 100-year analysis period, stream crossing density is not expected to change significantly. DNR expects all landscapes to remain in the low or medium impact categories. Potential impacts from stream crossing density may include increased sediment delivery and stream bank erosion.

Table 3-35. Current Stream Crossing Density on State Trust Lands in the OESF, by Landscape

Landscape	Stream crossings per mile of stream
Clallam	1.2 ●
Clearwater	0.9 ●
Copper Mine	1.0 ●
Dickodochtedar	1.3 ◊
Goodman	0.8 ●
Kalaloch	1.4 ◊
Queets	1.5 ◊
Reade Hill	0.8 ●
Sekiu	1.0 ●
Sol Duc	1.2 ●
Willy Huel	1.3 ◊

● Low impact ◊ Medium impact

Appendix C shows the number of stream crossings by stream type for roads on state trust lands in each of the 11 landscapes in the OESF. Most (65 percent) stream crossings are on Type 5 streams, 30 percent are on Type 3 and Type 4 streams, and the remaining 5 percent are on Type 1 or Type 2 streams, or streams whose type is unknown.

Because potential impacts are rated low for seven of the landscapes, the potential environmental impact of each alternative for this indicator is considered **low**. DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for this indicator.

Indicator: Proximity of Roads to Streams or Other Water Bodies

NO ACTION, LANDSCAPE, AND PATHWAYS ALTERNATIVES

Table 3-36 on p. 3-139 shows the current percentage of the road network that is located within 300 feet of a stream or other water body in each of the 11 landscapes. All landscapes except the Queets currently exceed the 25 percent threshold (Potyondy and Geier 2011) for potential high impacts (refer to Table 3-31 on p. 3-130).

Table 3-36. Current Percentage of Road Network on State Trust Lands Within 300 Feet of Streams or Other Water Bodies

Landscape	Percentage of road network
Clallam	48% ■
Clearwater	55% ■
Copper Mine	65% ■
Dickodochtedar	44% ■
Goodman	54% ■
Kalaloch	60% ■
Queets	22% ◇
Reade Hill	64% ■
Sekiu	47% ■
Sol Duc	36% ■
Willy Huel	51% ■

◇ Medium impact ■ High impact

Overall, 50 percent of the total road network on state trust lands (all landscapes) is located within 300 feet of a stream or water body, in part because streams in the OESF are so numerous (refer to Table 3-1 on p. 3-4). Thirty-three percent of roads are located within 300 feet of a Type 5 stream (refer to Appendix C).

Because potential impacts are rated high in all landscapes except for the Queets, the potential environmental impact of each alternative (No Action, Landscape, Pathways) for this indicator is considered **high**. Roads can potentially deliver fine sediment to streams unless the roads have been certified as abandoned. Fine sediment delivery to streams is considered an adverse impact.

However, this impact rating is based solely on the percentage of roads located within 300 feet of a stream or water body, and is made without considering the condition of the road network or current management practices (established programs, rules, procedures, or other practices) that are expected to mitigate a potential high impact to a level of non-significance. DNR expects potential fine sediment delivery from the road network to be mitigated to a non-significant level through current practices, including accomplishing road maintenance and abandonment plans; inspecting, repairing, and maintaining roads; and suspending timber hauling during storms (refer to "Mitigation" later in this section for more information). Also, new roads will be constructed to current forest practices standards, which are designed to prevent or limit the delivery of fine sediment to streams (Martin 2009, Dubé and others 2010). Therefore, DNR did not identify probable significant environmental impacts from any alternative (No Action, Landscape, Pathways) for this indicator.

Indicator: Traffic Impact Scores

NO ACTION AND LANDSCAPE ALTERNATIVES

Table 3-37 shows the traffic impact scores for each landscape averaged over the 100-year analysis period for the No Action and the Landscape alternatives. As the table shows, there is little difference between the alternatives.

Table 3-37. Traffic Impact Scores by Landscape and Alternative Averaged Over 100 Years

Landscape	No Action Alternative	Landscape Alternative
Clallam	51 ◊	51 ◊
Clearwater	24 ●	24 ●
Copper Mine	39 ◊	39 ◊
Dickodochtedar	54 ◊	54 ◊
Goodman	40 ◊	40 ◊
Kalaloch	38 ◊	39 ◊
Queets	32 ●	33 ◊
Reade Hill	32 ●	32 ●
Sekiu	65 ◊	65 ◊
Sol Duc	29 ●	29 ●
Willy Huel	30 ●	30 ●
OVERALL AVERAGE	40 ◊	40 ◊

● Low impact ◊ Medium impact

Because potential impacts are rated medium in seven landscapes under the No Action Alternative and eight landscapes under the Landscape Alternative, the potential environmental impact of either alternative for this indicator is considered **medium**. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

Additional information in Appendix C includes the long-term traffic levels of roads in each landscape (by ownership). Appendix C also includes the current number of log truck trips per day from DNR harvest activities, and traffic impact scores for each landscape over the 100-year analysis period by decade.

PATHWAYS ALTERNATIVE

As stated in the introduction to this chapter (p. 3-17 through 3-18), DNR expects the harvest schedule for the Pathways Alternative to be similar to that of the Landscape Alternative because of the similarities between these alternatives. For that reason, DNR anticipates that traffic impact scores under the Pathways Alternative will be similar to those projected under the Landscape Alternative. The potential environmental impact of the Pathways Alternative for this indicator therefore is considered **medium**. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Summary of Potential Impacts

Table 3-38 provides an overview of the potential environmental impacts on water quality when the criterion and all of the indicators are considered. For this analysis, only high impacts were considered potentially significant impacts.

Table 3-38. Summary of Potential Impacts on Water Quality, by Alternative

Criteria	Indicator	No Action Alternative	Landscape Alternative	Pathways Alternative
Adherence to water quality standards	Stream shade (surrogate for stream temperature and dissolved oxygen)	Medium ◊	Medium ◊	Medium ◊
	Road density (surrogate for turbidity)	High ■	High ■	High ■
	Stream crossing density (surrogate for turbidity)	Low ●	Low ●	Low ●
	Proximity of roads to streams or other water bodies (surrogate for turbidity)	High ■	High ■	High ■
	Traffic use (surrogate for turbidity)	Medium ◊	Medium ◊	Medium ◊

● **Low impact** ◊ **Medium impact** ■ **High impact**

Potential high impacts were identified for road density and proximity of roads to streams or other water bodies. However, DNR expects these potential impacts to be mitigated to a level of non-significance through current management practices, as described under "Mitigation" in the following section. Therefore, DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for any indicator for this topic.

Mitigation

Following, DNR describes current management practices (established programs, rules, procedures, or other practices) that are expected to mitigate potential high impacts to a level of non-significance. This mitigation applies to the following indicators: road density and proximity of roads to streams or other water bodies.

Road Maintenance and Abandonment Plans

The forest practices rules contain direction for road construction and maintenance (WAC 222-24) to protect water quality and riparian habitat. Road construction and maintenance must prevent or limit actual or potential delivery of sediment and surface water to any typed water where such delivery would prevent the achievement of fish habitat or water quality goals.

The forest practices rules require large forest landowners,[7] such as DNR, to prepare road maintenance and abandonment plans for all roads that have been used or constructed since 1974.[8] These plans specify the steps that will be taken to either abandon roads or bring roads that do not meet current standards into compliance. Consistent with the forest practices rules, DNR has developed road maintenance and abandonment plans for roads on state trust lands in each of the 11 landscapes in the OESF.

Road maintenance and abandonment plans are used to prioritize road improvement, abandonment, and maintenance projects. DNR first prioritizes projects for roads that potentially cause the greatest damage to public resources:

- Roads with fish passage barriers
- Roads that deliver sediment to streams
- Roads with evidence of existing or potential instability that could affect public resources adversely
- Roads or ditch lines that intercept ground water
- Roads or ditches that deliver surface water to streams

DNR then prioritizes projects by their potential benefit to public resources; for example, projects that affect:

- Waters containing listed threatened or endangered fish species
- Waters listed as 303(d) impaired for road-related reasons
- Areas containing sensitive geology or soils with a history of landslides
- Areas with ongoing restoration projects
- Road systems that have the highest potential use for future timber harvests

Road traffic generates sediment through surface erosion, and the key to controlling sediment is controlling erosion. Erosion control measures are necessary if exposed soils can deliver sediment to streams. DNR's objective for roads is to create a stable, dispersed, non-erosive drainage pattern associated with road surface runoff to minimize potential or actual sediment delivery to streams. Depending on what is appropriate for site-specific conditions, this objective can be accomplished in a variety of ways:

- Use ditches, culverts, and other structures to collect sediment-laden water runoff from the road and direct it to areas on the forest floor where it can be captured or safely dissipated away from the stream.
- Stabilize ditch walls by seeding them with grass or lining them with rocks.
- Construct catch basins to capture water runoff and allow sediment to settle out of the water.
- Place rock on the road surface before and after a stream crossing to help stabilize the road surface and prevent sediment delivery.

- Use temporary measures, such as placing straw bales, to capture sediment while repairs are being carried out.

Work under these plans is ongoing. Table 3-39 shows the number of projects completed under these plans by the end of 2015.

Table 3-39. Percentage of Projects Identified in Road Maintenance and Abandonment Plans and Completed by Year End 2015

Landscape	Number of projects completed by end of 2012	Total number of projects identified in plan	Percent completed
Clallam	211	42	83%
Clearwater	176	153	53%
Coppermine	180	135	57%
Dickodochtedar	605	131	82%
Goodman	260	102	72%
Kalaloch	209	49	81%
Queets	229	56	80%
Reade Hill	82	0	100%
Sekiu	79	134	37%
Sol Duc	104	0	100%
Willy Huel	258	20	93
Total	2,393	822	74%

All work completed under these plans is performed using (as appropriate) the best management practices for road construction and maintenance described in the Forest Practices Board Manual (DNR 2016) and the guidance provided in DNR's Forest Roads Guidebook (DNR 2011). Most work involves culvert replacement, maintenance, or removal. DNR continually updates and prioritizes these plans to address newly identified environmental impacts of the existing road network.

Work associated with these plans must be completed by October 31, 2021. Summaries of DNR's accomplishments for roads in each of the 11 landscapes in the OESF and DNR's road maintenance priorities and standards are included in Appendix C.

EFFECTIVENESS OF ROAD MAINTENANCE AND ABANDONMENT PLANS

Implementing current forest practices rules for road maintenance correctly is expected to minimize runoff water and sediment delivery to typed waters (DNR 2016). A statewide study conducted on private forestlands in Washington found that road maintenance and abandonment appear to reduce the amount of road-related sediment that reaches streams (Martin 2009). This study found that implementing best management practices decreased the number of road miles hydrologically connected to streams, and that most roads studied had a low probability of delivering sediment to streams (Martin 2009). In addition, road maintenance and abandonment plan effectiveness monitoring conducted statewide by Dubé and others (2010) from 2006 through 2008 found that, as roads were brought up to modern standards, they showed decreased sediment delivery to streams.

Inspection, Maintenance, and Repair

After work identified under road maintenance and abandonment plans has been completed, DNR will continue to inspect, maintain, and repair roads and bridges as needed using the appropriate best management practices for road maintenance and repair identified in the current Forest Practices Board Manual and the guidance in the Forest Roads Guidebook. Routine maintenance of road dips and surfaces and responding quickly to problems can reduce road-caused slumps and slides significantly and prevent the creation of berms that could channelize runoff (Environmental Protection Agency 2012).

Suspension of Timber Hauling During Storm Events

In addition to road maintenance and abandonment plans, DNR also considers how operations can be adjusted to further prevent delivery of fine sediment to streams. For example, DNR suspends timber hauling on state trust lands in the OESF during storm events, when heavy rainfall can potentially increase surface water runoff and sediment delivery (unless the road is designed for wet-weather haul). The decision to suspend timber hauling on state trust lands is based on professional judgment. A weather event is considered a storm event when high levels of precipitation are forecast and there is a potential for drainage structures, such as culverts and ditches, to be overwhelmed, increasing the potential for sediment delivery to streams. Whether timber hauling is suspended or not, DNR compliance foresters monitor the haul roads to determine if potential problems are developing that may lead to sediment delivery to streams and take action as necessary.

■ Indicators Considered but not Analyzed

Total Dissolved gas

Total dissolved gas refers to the amount of dissolved nitrogen and oxygen in a water body. Levels of total dissolved gas above the maximum set by Ecology (2006) can cause bubbles to form in the vascular[9] systems of fish, which can kill the fish by blocking the flow of blood through their capillary vessels (Carter 2008).

High levels of total dissolved gas can occur naturally below waterfalls, in pools at the end of river rapids, and in warm shallow water where high levels of photosynthesis occur in aquatic plants. High levels of total dissolved gas caused by human activities generally occur in pools below dam spillways during spill events, and in areas where heated water is released from industrial facilities, allowing increased plant growth and increased photosynthesis to occur (Weitkamp 2008, Carter 2008).

Because no dams or industrial facilities are located on state trust lands in the OESF, only natural occurrences of high levels of total dissolved gas are expected. These levels are beyond the control of DNR. This indicator therefore was considered but not analyzed.

Fecal Coliform Bacteria

Fecal coliform bacteria are microscopic organisms that live in the intestines of warm-blooded animals and in the waste material (feces) excreted from their intestinal tracts. Fecal coliform bacteria are not necessarily agents of disease, but may indicate the presence of disease-carrying organisms that live in the same environment as the fecal coliform bacteria (Ecology 2012b).

The presence of high numbers of fecal coliform bacteria in a water sample means that the water has received fecal matter from one or more sources. For surface water, the primary sources are wastewater treatment plant discharges, failing septic systems, and animal waste (Ecology 2012b).

There are no wastewater treatment plants or septic systems on state trust lands in the OESF, nor are there grazing allotments for domestic livestock. In the OESF, fecal coliform bacteria from animal waste would come from wildlife; this occurrence is natural and beyond the control of DNR. This indicator therefore was considered but not analyzed.

Stream PH

Stream pH is a measure of how acidic or alkaline the water is. The pH of water determines the amount of chemical materials, such as nutrients or heavy metals, which can be dissolved into the water and become biologically available to aquatic organisms. The pH of water is initially determined by the geology of the watershed and the original source of the water. In unpolluted waters such as streams, fluctuations of pH are caused naturally by seasonal and daily variations in the amount of photosynthesis occurring in the water. Waters polluted by municipal or industrial effluents (liquid waste or sewage) can experience large fluctuations in pH to levels unsuitable for aquatic organisms (Michaud 1991, Ecology 2012b). Since there are no sources of these types of effluents on state trust lands in the OESF, only naturally occurring fluctuations in pH are expected. This indicator therefore was considered but not analyzed.

Toxic, Radioactive, and Delterious Materials

In managed forests, toxic or deleterious materials (materials that can cause harm or damage), such as pesticides, fertilizers, or oil or gasoline, can enter a water body during harvest activities. Radioactive materials are not expected to occur on the OESF.

DNR follows forest practices rules for forest chemicals such as fertilizer or herbicides. The rules are intended to eliminate the entry of forest chemicals to streams or other water bodies and to minimize the entry of forest chemicals to other sensitive areas, including channel migration zones, wetland management zones, and the interior core buffers of Type 1 through Type 5 streams.

In addition, DNR's riparian conservation strategy prevents the accidental release of deleterious materials to streams by limiting harvest activities in riparian buffers for Type 1 through 4 streams, as described in DNR's HCP. Because harvest activities are limited within these buffers, the potential for toxic or deleterious materials to be introduced into streams is reduced.

When management activities such as road construction or culvert replacement require in-water work, DNR follows the best management practices specified in the application for a Hydraulic Permit Approval from WDFW. These practices are designed to avoid the release of toxic or deleterious materials. Obtaining Hydraulic Permit Approval requires compliance with the Hydraulic Code (220-110 WAC). While the potential for accidental spills always exists, over the last 20 years, DNR has not experienced any release of toxic materials (gas, oil, or herbicides) into waters of the state (Rosanbalm 2012, pers. comm.) on state trust lands in the OESF. Therefore, this indicator was considered but not analyzed.

Section Notes

1. Except for the Lyre/Hoko Water Resource Inventory Area. Use designations have not been set for the Lyre/Hoko; however, protection of all waters for all use designations is required for surface waters not specifically identified for a particular use (Ecology 2006).
2. Section 303(d) of the Clean Water Act requires preparation of a list of waters in the state that do not meet water quality standards; the list is prepared every 2 years.
3. Under the forest practices rules (WAC 222-24-52(3)), a road is considered abandoned if: (a) roads are out-sloped, water barred, or otherwise left in a condition suitable to control erosion and maintain water movement within wetlands and natural drainages; (b) ditches are left in a suitable condition to reduce erosion; (c) the road is blocked so that four-wheel highway vehicles cannot pass the point of closure at the time of abandonment; (d) water crossing structures and fills on all typed waters are removed, except where the department determines other measures would provide adequate protection to public resources; and (e) DNR has determined that the road is abandoned.
4. Each stream reach is assigned a target shade level based on fish habitat (WAC 222-30-040) and the maximum amount of shade available given the orientation and width of the stream channel. The target shade level is intended solely for the purpose of conducting this environmental impact analysis, and does not connote or imply DNR policy direction. Refer to “Riparian” for more information.
5. Washington State Surface Water Quality Standards designated use categories are based on the most stringent temperature threshold into which the given stream drains. A stream reach may be assigned a temperature standard for a given species even if that species is not known to occur in the reach, as long as a downstream reach contains that species (Stohr, A., personal communication, Feb. 16, 2016).
6. This ownership threshold is used to identify areas where DNR manages enough of the watershed that its management practices could influence watershed conditions. The use of such a threshold followed recommendations from federal watershed monitoring programs (Reeves and others 2004, Gallo and others 2005).
7. In Washington, large forest landowners are those who harvest an annual average of more than 2 million board feet of timber from their own forestland in the state.
8. Older roads that have not been used since 1974 are considered “orphaned.”
9. The system of vessels and tissue that carry fluids such as blood or lymph through the body of an animal.

Topic:

Fish

Why are Fish Important?

Fish have ecological, economic, and cultural significance in Washington. Fish species such as Pacific salmon and trout are good indicators of a functioning aquatic ecosystem because they require cool, clean water; complex channel structures and substrates; and low levels of fine sediment (Bjorn and Reiser 1991). Pacific salmon transport marine nutrients from saltwater to freshwater (Cederholm and others 1999) and, because of their abundance, play an important role as both predator and prey in riparian food webs (Gende and others 2002). Salmon are important to the economy of Washington State and play an integral role in tribal culture (DNR 1997).

What is the Status of Fish in the OESF?

Sockeye Salmon
Photo courtesy WDFW

Although the waters of the western Olympic Peninsula contain several federally listed and state sensitive populations of fish, overall, this area maintains a greater proportion of robust fish populations than many other locations on the Pacific coast (Huntington and others 1996). Salmon and steelhead trout (including wild populations and those augmented by fish hatcheries) support thriving tribal and sport freshwater fisheries managed jointly by WDFW and western Washington tribes.

Nine native species of resident or anadromous[1] salmonids inhabit the rivers and stream of the OESF: sockeye salmon (*Oncorhynchus nerka*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), Chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*), cutthroat trout (*O. clarkii*), bull trout (*Salvelinus confluentus*), and mountain whitefish (*Prosopium williamsoni*). Seventeen species of non-game fish, including lampreys, minnows, suckers, and sculpins, are also found in the OESF. Following, DNR highlights species of special concern in the OESF; refer to Appendix P for a more detailed listing.

Federal Threatened and Endangered Species

The federal government lists species as threatened or endangered under the Endangered Species Act.[2]

- **Distinct population segment**: Listings for fish under the Endangered Species Act may be applied at a variety of scales, including an entire species, a sub-species, or a subset of a population known as a distinct population segment.[3] No distinct population segments in the OESF are currently listed as endangered. The southern distinct population segment of eulachon (*Thaleichthys pacificus*, also known as Columbia River smelt) is listed as threatened (76 FR 65324).[4] The Coastal-Puget Sound distinct population segment of bull trout (64 FR 58909) is currently listed as threatened and 54.5 miles of streams on state trust lands in the OESF are designated as critical habitat.

- **Evolutionarily significant unit:** For the purpose of listing under the Endangered Species Act, salmon must be part of an evolutionarily significant unit, which is a reproductively isolated population of fish that represents an important component in the evolutionary legacy of the species.

  No evolutionary significant units in the OESF are currently listed as endangered under the Endangered Species Act. The Lake Ozette evolutionarily significant unit of sockeye salmon (64 FR 14528) is listed as threatened and approximately two miles of streams on state trust lands in the OESF are identified as critical habitat (refer to Appendix P for maps showing the location of these areas).[5]

Federal Species of Concern

Species of concern is an informal category used by the federal government for species which may need concentrated conservation actions. Federal species of concern receive no legal protection. These species may, or may not, eventually be listed as threatened or endangered. In the OESF, federal species of concern include the Pacific lamprey (*Lampetra tridentata*), river lamprey (*Lampetra ayresi*), and the northern distinct population segment of green sturgeon (*Acipenser medirostris*).

State Endangered, Threatened, Sensitive, and Candidate Species

WDFW oversees the listing and recovery of species in need of protection. No fish species in the OESF currently are designated as threatened or endangered under state definitions. One species, the Olympic mudminnow (*Novumbra hubbsi*), is designated as sensitive.[6] Candidate species in the OESF include bull trout, eulachon, river lamprey, and Lake Ozette sockeye.[7]

Fish Stocks

Fisheries management of salmon is often reported by stocks (a population of fish that spawn in a particular lake or stream during a particular season). Examples include Bogachiel summer Chinook and Sekiu fall coho. Fish in a given stock do not interbreed with stocks from other locations, or with stocks spawning in the same location but in different seasons.

Individual salmon stocks are eligible for listing under the federal Endangered Species Act.[8] Information on their status is available from a variety of sources such as the Salmon and Steelhead Inventory. Maintained by WDFW and Washington tribes, the 2002 Salmon and Steelhead Inventory identified 67 salmon stocks in the OESF and provided a scientific determination of each stock as healthy, depressed, critical, extinct, or unknown.[9] In addition, the Washington State Legislature authorized the development of habitat limiting factors reports describing factors that limit salmon habitat in the state (refer to Appendix P for data from these reports on the status of individual salmon stocks in the OESF and a summary of the 2002 Salmon and Steelhead Inventory).[10]

■ What is the Criterion for Fish?

The criterion for fish is **functioning riparian habitat**. DNR's *Policy for Sustainable Forests* and the HCP define functioning riparian habitat as habitat capable of supporting viable populations of salmonid species, as well as other species that depend on healthy in-stream and riparian environments.

■ What are the Indicators for Fish?

The indicators used to assess the criterion are **large woody debris recruitment**, **peak flow**, **stream shade**, **fine sediment delivery**, **coarse sediment delivery**, and **leaf and needle litter recruitment**. These indicators were selected based on DNR's expertise, existing scientific information, and current data.

Currently, DNR does not have, in a comprehensive or readily usable form, in-stream data on fish presence and the quality of habitat such as the amount and distribution of large woody debris, the availability and composition of spawning gravel, discharge, stream temperature, and sedimentation (settling and accumulation of sediment on the stream bed) for all streams in the OESF. Therefore, DNR used surrogates to assess current and future conditions for each indicator. For example, as a surrogate for the number and size of logs in each stream reach,[11] DNR assessed the characteristics of the riparian forest and its potential to provide large woody debris to the stream channel. DNR used the potential of the riparian forest to provide stream shade as a surrogate for stream temperature, the potential delivery of fine sediment from the road network as a surrogate for sedimentation or turbidity (water cloudiness), and the hydrologic maturity of forests within each watershed as a surrogate for peak flow (hydrologic maturity will be discussed later in this section).

How Were the Indicators Analyzed?

All of the indicators used in this section of the FEIS were analyzed in other sections, either quantitatively (for the No Action and Landscape alternatives) or qualitatively (for the Pathways Alternative). In this section of the FEIS, DNR summarizes the results of these analyses and discusses the relevance of each indicator to fish. For the full analysis, refer to each indicator's respective topic area. Table 3-40 is provided for reference.

Table 3-40. Criterion and Indicators, how They Were Measured, and Where to Locate the Full Analysis

Criterion	Indicator	How the indicator was measured	Section where analyzed
Functioning riparian habitat	Large woody debris recruitment	Characteristics of the riparian forest, such as relative density and the size, species, and height of trees, and distance of trees from the floodplain	"Riparian," p. 3-47
	Peak flow	Hydrologic maturity of the Type 3 watershed	
	Stream shade	Topography, stream orientation, and characteristics of the riparian forest, including canopy closure and tree height	
	Leaf and needle litter recruitment	Characteristics of the riparian forest, such as relative density and the size, species, and height of trees, and distance of trees from stream	
	Fine sediment delivery	• Road density (road miles per square mile) • Stream crossing density (stream crossings per mile of stream) • Proximity of roads to streams or other water bodies • Traffic use	"Water Quality," p. 3-123
	Coarse sediment delivery	• Potential road failure (percentage of road network on potentially unstable slopes or landforms and therefore at risk of failure) • Landslide potential (harvests projected to occur on soils with a high likelihood of landslides)	"Soils," p. 3-97

■ Current Conditions and Results

Indicator: Large Woody Debris Recruitment


Large Woody Debris

Large woody debris recruitment refers to logs, pieces of logs, root wads, and large chunks of wood that fall into stream channels. Large woody debris causes the stream channel to move back and forth across the floodplain, which creates backwaters (areas with little or no current) along the stream edge; increases variations in stream depth (Maser and others 1988 as cited in DNR 1997); and slows the flow of water during periods of high stream flows, which decreases streambed scour and bank erosion.

Large woody debris in streams creates essential elements of fish habitat, such as pools, riffles,[12] side channels, and undercut banks (Swanston 1991, Maser and others 1988 as cited in DNR 1997), and also provides cover for fish to hide from predators and competitors (Bjornn and Reiser 1991 as cited in DNR 1997). Water and sediment can become partially dammed above a large log or group of logs, which can create an area of calm water in an otherwise steep, fast-flowing stream. Gravel of various sizes, essential to salmon spawning, can be deposited in these relatively calm areas (Bisson and others 1987 as cited in DNR 1997). Logs or groups of logs in the stream can hold fine and coarse sediments that otherwise would impact downstream salmon spawning areas (DNR 1997). Logs or groups of logs can also help increase stream productivity[13] by trapping leaf and needle litter, salmon carcasses, or other sources of nutrients that otherwise would be flushed downstream (DNR 1997). In some steeper streams, most of the suitable spawning sites are located upstream of large woody debris (Opperman and others 2006).

For the No Action and Landscape alternatives, DNR assessed the ability of the adjacent riparian forest (area of influence – refer to "Riparian," p. 3-47) to provide large woody debris to the stream. Riparian forests within Type 3 watersheds in a low impact condition are the most capable of providing large woody debris to the stream channel. Streams in riparian forests in a high impact condition may lack important fish habitat components that are provided or influenced by the presence of large woody debris. DNR used qualitative techniques to analyze this indicator for the Pathways Alternative (refer to p. 3-17 through 3-18).

CURRENT CONDITIONS

Currently, 47 percent of Type 3 watersheds are in a high impact condition, 36 percent are in a medium impact condition, and 18 percent are in a low impact condition (refer to Chart 3-12 on p. 3-63 in "Riparian").

RESULTS

DNR's analysis shows a trend of gradual improvement for the No Action and Landscape alternatives over the 100-year analysis period (refer to Figure 3-14 in "Riparian"). The number of watersheds in a high impact condition likely will decrease over time.

DNR estimated that impacts to large woody debris recruitment under the Pathways Alternative would be equal to or lower than those projected for the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of large woody debris recruitment watershed scores are expected to be similar to those shown in Figure 3-14 on p. 3-70 for the Landscape Alternative.

Both current and future conditions are influenced by timber harvests that occurred prior to the implementation of DNR's HCP. Much of the area of influence for large woody debris currently is in the Competitive Exclusion stand development stage and deferred from harvest. Woody debris recruitment occurs in these areas, but the pieces may be lower quality and smaller in diameter. Smaller-diameter woody debris decays faster, is less stable in the stream channel, and is less likely to influence in-stream habitat. In the absence of forest management, these stands will continue to grow and develop. As they do, watershed conditions will gradually improve, but the change will be slow.

The potential environmental impact of each alternative (No Action, Landscape, Pathways) for large woody debris recruitment is considered **medium**. Conditions improve, but gradually, because it takes considerable time for trees to grow large enough to contribute large woody debris. DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for this indicator.

Indicator: Peak Flow

Peak flow is a period of high stream flow or maximum discharge, usually associated with storm events. Peak flows can cause changes in the shape and function of the stream channel, which can cause long-term damage to riparian ecosystems and loss of salmon habitat. Peak flows can destabilize and transport large woody debris, fill pools with sediment, and destroy the nests (referred to as redds) where salmon lay their eggs. Peak flows can transform complex stream channels containing large woody debris, pools, riffles, and side channels into simple, more uniform channels with limited value as salmon habitat (DNR 1997).

For the No Action and Landscape alternatives, DNR assessed peak flow by measuring the proportion of hydrologically immature forests in a Type 3 watershed. Hydrologically immature forests are young (less than 25 years old) and sparse (relative density less than 25). These forests contribute more to peak flow because they lack a dense canopy and therefore have greater snow accumulations and subsequent rapid melting (DNR 2004). Excessive peak flows are more likely during storm events in watersheds with a high proportion of hydrologically immature forests; these watersheds are considered to be in a high impact condition. DNR used qualitative techniques to analyze this indicator for the Pathways Alternative (refer to p. 3-17 through 3-18).

CURRENT CONDITIONS

Currently, 2 percent of Type 3 watersheds are in a high impact condition, 13 percent are in a medium impact condition, and 85 percent are in a low impact condition (refer to Chart 3-13 in "Riparian" on p. 3-64).

RESULTS

DNR estimated that the majority of Type 3 watersheds likely would remain in a low impact condition for the duration of the 100-year analysis period under the No Action and Landscape alternatives, and that the number of watersheds in a high impact condition likely will decrease over time (refer to Figure 3-15 on p. 3-74 in "Riparian"). Under both the No Action and Landscape alternatives, the amount of hydrologically immature forest remains sufficiently low to prevent or minimize changes in peak flow. On average, in each decade, hydrologically immature forests are projected to comprise less than approximately 25 percent of each Type 3 watershed.

DNR estimated that impacts to peak flow under the Pathways Alternative would be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of peak flow watershed scores are expected to be similar to those shown in Figure 3-15 for the Landscape Alternative.

The potential environmental impact of each alternative (No Action, Landscape, Pathways) for peak flow is considered **low**. In the majority of watersheds, hydrologic maturity remains sufficient to prevent or minimize damaging peak flows and their effects on fish habitat. DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for this indicator.

Indicator: Stream Shade

Hemispherical Photo of Stream Shade

Stream shade refers to the extent to which incoming sunlight is blocked on its way to the stream channel. Stream shade is one of the primary factors influencing stream temperature (Brown 1969). Water temperature affects the rate of salmon growth and development. Salmon are cold-water fish, and their preferred temperature range is between 50 and 57 degrees Fahrenheit (Bjornn and Reiser 1991 as cited in DNR 1997). Bull trout favor even colder water; in Washington, most bull trout spawn in water between 41 and 42.8 degrees Fahrenheit (Brown 1994 as cited in DNR 1997). Adult bull trout prefer deep pools of cold water and are often found near cold perennial springs. High water temperatures also can reduce dissolved oxygen levels in the water (DNR 1997), which can stress populations of fish and the aquatic insects that support them. For example, salmon eggs require a high concentration of dissolved oxygen in order to incubate successfully.

For the No Action and Landscape alternatives, DNR assessed the ability of the area of influence to provide shade to the stream. DNR assigned each stream reach a target shade level[14] based on the amount of shade necessary to meet Washington State Surface Water Quality Standards (WAC 173-201A) and the maximum amount of shade available, given the orientation and width of the stream channel. DNR compared the target shade level for each stream reach to the amount of shade that would be present after management activities have taken place. If a stream reach failed to meet its assigned shade target, DNR estimated the resulting increase in water temperature based on published studies (Sullivan and others 1990). DNR then assigned impacts based on the magnitude of that increase in temperature and professional opinion of how the temperature increase would affect the fish species associated with the reach in question.[15] Fish association was based on Washington State Surface Water Quality Standards "designated uses and criteria" (WAC 173-201A), supplemented by 2010 NOAA Fisheries bull trout critical habitat designations. DNR used qualitative techniques to analyze this indicator for the Pathways Alternative (refer to p. 3-17 through 3-18).

CURRENT CONDITIONS

Currently, 2 percent of Type 3 watersheds are in a high impact condition, 13 percent are in a medium impact condition, and 85 percent are in a low impact condition (refer to Chart 3-14 on p. 3-65 in "Riparian"). The current distribution of watershed scores for shade reflects that most (approximately 60 percent) stream reaches are at or above their shade targets (refer to Chart 3-15 on p. 3-65 in "Riparian").

RESULTS

Under the No Action and Landscape alternatives, most watersheds are projected to remain in a low impact condition for the duration of the 100-year analysis period (refer to Figure 3-16 on p. 3-76 in "Riparian").

DNR estimated that impacts to stream shade under the Pathways Alternative would be equal to or lower than those projected for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of stream shade watersheds scores are expected to be similar to those shown in Figure 3-16 for the Landscape Alternative.

The relative stability of shade levels in Type 3 watersheds may be due to a variety of factors. For example, physical factors that affect shade, such as the shape of the surrounding terrain, the orientation of the stream channel, and the width of the stream itself, will not change over time. Also, much of area responsible for shading the stream channel is deferred from harvest and most of this area currently is in the Competitive Exclusion stand development stage. Changes will occur in these areas, but the shift will be slow.

Variable retention harvest may reduce shade levels along Type 5 streams on stable ground because DNR does not apply interior-core buffers to these streams. However, these streams tend to be found at higher elevations where temperatures are cooler, the terrain is more likely to provide shade, and the target shade level necessary to maintain cooler water temperatures is lower.

The potential environmental impact of each alternative (No Action, Landscape, Pathways) for stream shade is considered **low**. On most streams, shade remains sufficient to maintain water temperatures within acceptable limits for most species of fish, including threatened, endangered, sensitive, and candidate species. DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for this indicator.

Indicator: Fine Sediment Delivery

Aquatic Habitat

Fine sediment refers to small soil particles, such as sand, silt, or clay, generally less than approximately 1/16th of an inch (2 millimeters) in diameter. Increased levels of fine sediment in streams can have detrimental effects on both water quality and aquatic habitat. Fine sediment can fill in pools and reduce overall habitat complexity. As particles of silt, clay, and other organic materials settle to the streambed, they can suffocate newly hatched fish larvae (Cederholm and Reid 1987) and fill in spaces between rocks which could have been used by aquatic organisms as habitat (Cederholm and Reid 1987, Cederholm and Salo 1979). Fine sediment can clog or damage sensitive gill structures, decrease a fish's resistance to disease, prevent proper egg and larval development, and potentially interfere with feeding activities.

Fine sediment that settles on streambeds or stays suspended in the water column can reduce salmon survival (Hicks and others 1991). For example, fine sediment deposited in areas where salmon spawn can decrease the survival of eggs and young hatchlings by reducing the availability of oxygen. Muddy, sediment-filled water causes stress to juvenile salmon during the summer (Cederholm and Reid 1987). Increased levels of fine sediment can also reduce populations of small aquatic insects, an important food source for salmon (Cederholm and Reid 1987).

Fine sediment is derived primarily from the erosion of road surfaces over time. DNR assessed the potential delivery of fine sediment to streams from the road network using four separate indicators: **road density**, **stream crossing density**, **proximity of roads to streams or other water bodies**, and **traffic impact scores**.

For this analysis, DNR assumed the extent of the road network would remain essentially unchanged under any alternative (No Action, Landscape, Pathways) throughout the 100-year analysis period. DNR does not expect substantial expansion or reduction of the road network because roads are essential to a working forest. Although some road abandonment has occurred (refer to road maintenance and abandonment plan accomplishment summaries in Appendix C), very little additional road abandonment is identified in current plans. Also, it is too speculative to estimate the number of miles of road that will be needed in the future. The exact locations and lengths of roads cannot be determined until a harvest is planned and a site assessment is performed. Because the extent of the road network was held constant for this analysis, DNR based its results for all indicators except traffic impact scores for all three alternatives on the current condition of the road network.

The OESF road network includes roads built prior to enactment of the forest practices rules in 1974. The forest practices rules include regulations for constructing and maintaining roads to limit the delivery of sediment and surface runoff to streams. (The forest practices rules were written to implement the Forest Practices Act and have been amended several times since 1974.) Many of these older roads have been mitigated, as will be explained later in this section. DNR took the conservative approach of including all roads on state trust lands in this analysis, regardless of whether or not they have been mitigated.

- **Road density:** Road density is the number of miles of road in a defined area (in this analysis, each of the 11 landscapes), expressed as miles of road per square mile. Impacts from road density may include increased delivery of fine sediment to streams due to a change in the timing, magnitude, duration, and spatial distribution of water runoff flows (Potyondy and Geier 2011). As road density increases, the potential for impacts from roads also increases (Potyondy and Geier 2011, Forman and Hersperger undated, Forman and Alexander 1998).

  Since road density is above 2.4 road miles per square mile in each landscape (refer to Table 3-33 on p. 3-135 in "Water Quality"), the potential environmental impact of each alternative (No Action, Landscape, Pathways) for this indicator is considered **high**.

- **Stream crossing density**: DNR measured the number of times a road crosses a stream per mile of stream. Stream crossings have the potential to increase sediment delivery to fish-bearing waters (Potyondy and Geier 2011). Potential environmental impacts from stream crossing density are low in seven landscapes and medium in four (refer to Table 3-35 on p. 3-138 in "Water Quality"). The potential environmental impact of each alternative (No Action, Landscape, Pathways) for this indicator is considered **low**.

- **Proximity of roads to streams or other water bodies**: DNR measured the percentage of the road system located within 300 feet of a stream or water body (Potyondy and Geier 2011). In every landscape except Queets (refer to Table 3-36 on p. 3-139 in "Water Quality"), more than 25 percent of the road network is located within 300 feet of a stream or water body. The potential environmental impact of each alternative (No Action, Pathways, Landscape) for this indicator is considered **high**.

- **Traffic impact scores**: Traffic impact scores were based on road surface type, the proximity of roads to streams or other water bodies, and the log truck traffic that may result from future harvests on all ownerships in a Type 3 watershed (state trust lands as well as federal, tribal, and private lands). The role of traffic in increasing road sediment production is well recognized (Luce and Black 2001, Reid and Dunne 1984), particularly on roads that are unpaved and have high volumes of vehicle traffic (Elliot and others 2009).

For the No Action and Landscape alternatives, DNR averaged traffic impact scores for each landscape over the 100-year analysis period. Under both alternatives, potential environmental impacts are medium in seven landscapes and low in four (refer to Table 3-37 on p. 3-140 in "Water Quality").

DNR expects the harvest schedule for the Pathways Alternative to be similar to that of the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). For that reason, DNR anticipates that traffic impact scores under the Pathways Alternative will be similar to those projected under the Landscape Alternative.

The potential environmental impact of each alternative (No Action, Landscape, Pathways) for this indicator is considered **medium**.

Considering all four indicators together, the potential environmental impact of each alternative (No Action, Landscape, Pathways) for fine sediment delivery is considered **high**. This impact rating is influenced largely by potential high impacts for road density and proximity of roads to streams or other water bodies. Roads can potentially deliver fine sediment to streams unless they have been abandoned. Fine sediment delivery to streams is considered an adverse impact.

However , these impact ratings were made without considering the condition of the road network or current management practices (established programs, rules, procedures, or other practices) that are expected to mitigate a potential high impact to a level of non-significance. DNR expects potential fine sediment delivery from the road network to be mitigated to a level of non-significance through current practices, including accomplishing road maintenance and abandonment plans; inspecting, repairing, and maintaining roads; and suspending timber hauling during storms (refer to "Mitigation" later in this section for more information). Also, new roads will be constructed to current forest practices standards, which are designed to prevent or limit the delivery of fine sediment to streams (Martin 2009, Dubé and others 2010). Therefore, DNR did not identify probable significant environmental impacts from any of the alternatives (No Action, Landscape, Pathways) for this indicator.

Indicator: Coarse Sediment Delivery

Coarse sediment usually refers to material ranging in size from small rocks and gravel to boulders that can be delivered to streams by landslides or road failures. Excessive amounts of coarse sediment can impact salmonids and their habitat. For example, coarse sediment can bury and suffocate salmon (including eggs, juveniles, and adults) or flush them downstream. On a larger scale, coarse sediment delivered by landslides can block stream channels and prevent fish passage (Meehan and Swanston 1977). Landslides also can reshape stream channels and affect the movement, distribution, and composition of spawning gravels, thereby reducing the quantity of suitable habitat or restricting access to it (Swanston 1980, Cederholm and Salo 1979). In some cases, landslides completely scour stream channels and riparian zones, leaving streams in a highly unproductive state, at least for the near future (Independent Multidisciplinary Science Team [IMST] 1999).

Not all landslides result in the transport of material to streams. Also, the effects of landslides are not always negative. Landslides can be an important source of suitable spawning gravel, and large woody debris delivered by landslides can enhance fish habitat significantly by adding structural complexity (IMST 1999).

Coarse sediment delivery is measured by two indicators, landslide potential and potential road failure.

- **Landslide potential**: Landslides are the dislodgement or down-slope movement of soil and rock. For this indicator, for the No Action and Landscape alternatives DNR analyzed the number of forest stand entries the analysis model recommended on soils with a high likelihood of landslides, which were defined as soils on top of marine sediment or basalt geologic units that are located in areas that are steeply sloped (over 70 percent). These areas **are separate from potentially unstable slopes or landforms**, which were identified using a slope stability model and **deferred from harvest** in the analysis model.

  A potential high impact was defined as four or more harvest entries on soils with a high likelihood of landslides over more than 20 percent of a watershed administrative unit over the 100-year analysis period. Under either alternative, 3 percent or less of state trust lands in any given watershed administrative unit has potential high impacts (refer to Table 3-28 on p. 3-18 in "Soils"). Thus, the potential environmental impact of the No Action and Landscape alternatives for this indicator is considered **low.**

  Potential environmental impacts from the Pathways Alternative are expected to be similar to those identified for the Landscape Alternative because of the similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Under the Pathways Alternative, DNR will thin forest stands in deferred areas (Pathway 7), which include potentially unstable slopes or landforms, to create or accelerate development of Young Forest Habitat. However, DNR does not believe such thinning will increase impact levels because DNR anticipates only one harvest entry in these areas over the 100-year analysis period, although DNR may, in some circumstances, thin these stands again if needed. Also, DNR will follow all applicable policies and laws to protect down-slope resources and public safety. Therefore, the potential environmental impact for the Pathways Alternative is considered **low**.

- **Potential road failure**: Road failure is the collapse of the road bed. Roads may fail for many reasons, including drainage, design, construction, and maintenance (NOAA Fisheries and USFWS 2006), changes in surface erosion and runoff (MacDonald and Coe 2008), the stability of the ground on which they are built, or a combination of factors.

  Because the extent of the road network was held constant for this analysis (refer to "Fine Sediment Delivery" earlier in this section), DNR based its results for this indicator for all three alternatives on the current condition of the road network. DNR measured the percentage of the road network in each landscape that is located on potentially unstable slopes or landforms. All roads were included in the analysis, including older roads that have been mitigated to current standards. Potential impacts are considered high in five landscapes and medium in three landscapes (refer to Table 3-29 on p. 3-119 in "Soils").

The potential impact of each alternative for this indicator is considered **high**. Should it occur, the environmental impact of a road failure potentially could be adverse. However, this impact rating is based solely on the percentage of the road network located on potentially unstable slopes or landforms, and is made without considering the condition of the road network, or current management practices (established programs, rules, procedures, or other practices) that may mitigate a potential high impact to a level of non-significance. Potential road failure will be mitigated to a non-significant level through repair and maintenance of roads identified in road maintenance and abandonment plans (for more information, refer to "Mitigation" later in this section). Therefore, DNR did not identify probable significant environmental impacts under any alternative (No Action, Landscape, Pathways) for this indicator.

Considering both indicators together, the potential environmental impact of each alternative (No Action, Landscape, Pathways) for coarse sediment delivery is considered **medium**, primarily because the potential high impacts for potential road failure will be mitigated to a level of non-significance. DNR did not identify probable significant environmental impacts from any of the alternatives (No Action, Landscape, Pathways) for this indicator.

Indicator: Leaf and Needle Litter Recruitment


Leaf litter

Leaf and needle litter recruitment refers to fine organic material such as leaves and tree needles that grow in the forest canopy and fall to the ground or into streams. In small streams, leaf and needle litter from riparian forests is often the main energy source for small aquatic insects (Cummins and others 1989, Wallace and others 1997, and Suberkropp 1998 as cited in Wipfli and others 2010) which are an important food source for juvenile salmon. Small aquatic and terrestrial insects may be less abundant along streams where adjacent harvest results in an inadequate supply of leaf and needle litter. Downstream fish populations may also be less abundant in these watersheds (Wallace and others 1997, Wallace and Webster 1996, Cummins and others 1989, Wipfli and Gregovich 2002).

For this indicator, for the No Action and Landscape alternatives DNR assessed the ability of the area of influence to provide leaf and needle litter to the stream. Riparian forests within Type 3 watersheds in a high impact condition are considered less capable of providing leaf and needle litter to the stream channel than riparian forests in a low impact condition. DNR analyzed this indicator for the Pathways Alternative using qualitative techniques.

CURRENT CONDITIONS

Currently, 25 percent of Type 3 watersheds are in a high impact condition, 37 percent are in a medium impact condition, and 38 percent are in a high impact condition (refer to Chart 3-17 on p. 3-67 in "Riparian").

RESULTS

Under the No Action and Landscape alternatives, there is a steady shift toward improved conditions. Most watersheds remain in a low impact condition throughout the 100-year analysis period (refer to Figure 3-18 on p. 3-82 in "Riparian").

DNR estimated that impacts to leaf and needle litter recruitment under the Pathways Alternative would be equal to or lower than those projected for the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Trends in the distribution of leaf and needle litter watershed scores are expected to be similar to those shown in Figure 3-18 for the Landscape Alternative.

The potential environmental impact of each alternative for this indicator is considered **low.** Under the No Action and Landscape Alternatives, the distribution of watershed scores steadily moves toward an improved condition (higher scores, lower impact) and most watersheds are in a low impact condition for the entire analysis period. DNR expects a similar trend under the Pathways Alternative. DNR did not identify significant impacts from any of the alternatives (No Action, Landscape, Pathways) for this indicator.

■ Summary of Potential Impacts

Table 3-41 provides an overview of the potential environmental impacts on fish when the criterion and all of the indicators are considered. For this analysis, only high impacts were considered potentially significant.

Table 3-41. Summary of Potential Impacts on Fish, by Alternative

Criteria	Indicators	No Action Alternative	Landscape Alternative	Pathways Alternative
Functioning riparian habitat	Large woody debris recruitment	Medium ◆	Medium ◆	Medium ◆
	Peak flow	Low ●	Low ●	Low ●
	Stream shade	Low ●	Low ●	Low ●
	Fine sediment delivery	High ■	High ■	High ■
	Coarse sediment delivery	Medium ◆	Medium ◆	Medium ◆
	Leaf and needle litter recruitment	Low ●	Low ●	Low ●

● **Low impact** ◆ **Medium impact** ■ **High impact**

Potential high impacts were identified for fine sediment delivery under all three alternatives. However, DNR expects these impacts to be mitigated to a level of non-significance through current management practices, as described under "Mitigation" in this section. Therefore, DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for any indicator for this topic.

■ Mitigation

In this section, DNR describes current management practices (established programs, rules, procedures, or other practices) that are expected to mitigate potential high impacts to a level of non-significance. This mitigation applies to fine sediment delivery.

Road Maintenance and Abandonment Plans

Culvert Replacement

The forest practices rules contain direction for road construction and maintenance (WAC 222-24) to protect water quality and riparian habitat. Road construction and maintenance must prevent or limit actual or potential delivery of sediment and surface water to any typed water where such delivery would prevent the achievement of fish habitat or water quality goals.

The forest practices rules require large forest landowners,[16] such as DNR, to prepare road maintenance and abandonment plans for all roads that have been used or constructed since 1974.[17] These plans specify the steps that will be taken to either abandon roads or bring roads that do not meet current standards into compliance. Consistent with the forest practices rules, DNR has developed road maintenance and abandonment plans for roads on state trust lands in each of the 11 landscapes in the OESF.

Work under these plans is ongoing. Table 3-39 in "Water Quality," p. 3-143 shows the number of projects completed under road maintenance and abandonment plans for roads on state trust lands in each of the 11 landscapes in the OESF. Work associated with these plans must be completed by October 31, 2021. A summary of DNR's accomplishments for roads in each of the 11 landscapes in the OESF and DNR's road maintenance priorities and standards are included in Appendix C.

All work completed under these plans is performed using (as appropriate) the best management practices for road construction and maintenance described in the Forest Practices Board Manual (DNR 2016) and the guidance provided in DNR's Forest Roads Guidebook (DNR 2011). Most work involves culvert replacement, maintenance, or removal. DNR continually updates and prioritizes these plans to address newly identified environmental impacts from the existing road network.

Refer to "Water Quality," p. 3-123 for more information on road maintenance and abandonment. Information on road maintenance and abandonment for small private forest landowners and federal agencies can be found in Chapter 4.

EFFECTIVENESS OF ROAD MAINTENANCE AND ABANDONMENT PLANS

Correct implementation of current forest practices rules for road maintenance is expected to minimize runoff water and sediment delivery to typed waters (DNR 2016). A statewide study conducted on private forestlands in Washington found that road maintenance and abandonment appears to reduce the amount of road-related sediment that reaches streams (Martin 2009). This study found that implementing best management practices decreased the number of road miles hydrologically connected to streams, and that the majority of roads studied had a low probability of delivering sediment to streams (Martin 2009). In addition, the monitoring of the effectiveness of road maintenance and abandonment plans conducted statewide by Dubé and others (2010) from 2006 through 2008 found that as roads were brought up to modern standards, they showed decreased sediment delivery to streams.

Inspection, Maintenance, and Repair

After work identified under road maintenance and abandonment plans has been completed, DNR will continue to inspect, maintain, and repair roads and bridges as needed using the appropriate best management practices for road maintenance and repair identified in the current Forest Practices Board Manual and guidance provided in the Forest Roads Guidebook. Routine maintenance of road dips and surfaces and quick response to problems can significantly reduce road-caused slumps and slides and prevent the creation of berms that could channelize runoff (Environmental Protection Agency 2012).

Suspension of Timber Hauling During Storm Events

In addition to road maintenance and abandonment plans, DNR also considers how operations can be adjusted to further prevent delivery of fine sediment to streams. For example, DNR suspends timber hauling on state trust lands in the OESF during storm events, when heavy rainfall can potentially increase surface water runoff and sediment delivery (unless the road is designed for wet-weather haul). The decision to suspend timber hauling on state trust lands is based on professional judgment. A weather event is considered a storm event when high levels of precipitation are forecast and there is a potential for drainage structures, such as culverts and ditches, to be overwhelmed, increasing the potential for sediment delivery to streams. Whether timber hauling is suspended or not, DNR compliance foresters monitor the haul roads to determine if potential problems are developing that may lead to sediment delivery to streams and take action as necessary.

Section Notes

1. Resident fish spend their entire lives in freshwater. Anadromous fish spend part of their life at sea and return to freshwater to reproduce.
2. An endangered species is one that is in danger of extinction throughout all or a significant portion of its range; a threatened species is one that is likely to become endangered within the foreseeable future.
3. A distinct population segment is one that is discrete from other populations of the species and considered significant in relation to the entire species.
4. Eulachon are not common in the OESF and have been observed only occasionally or anecdotally in the Queets River (76 FR 65324). As their namesake implies, the highest incidence of eulachon spawning within Washington occurs in the Columbia River Basin.
5. These areas were identified as critical habitat, but were exempted from the designation because of DNR's HCP.
6. A state sensitive species is one that is vulnerable or declining and is likely to become threatened or endangered throughout a significant portion of its range within the state without cooperative management or removal of threats (WAC 232-12-297).
7. A state candidate species is one that the state is considering for designation as endangered, threatened, or sensitive.
8. As stated in 56 FR 58612 (Nov. 20, 1991), Policy on Applying the Definition of Species Under the Endangered Species Act to Pacific Salmon: "The Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq. The Endangered Species Act defines "species" to include any "distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." … A salmon stock will be considered a distinct population, and hence a "species" under the Endangered Species Act, if it represents an evolutionary significant unit (ESU) of the biological species. The stock must satisfy two criteria to be considered an ESU: (1) It must be substantially reproductively isolated from other nonspecific population units; and (2) it must represent an important component in the evolutionary legacy of the species. Only Pacific salmon stocks that meet these criteria will be considered by NMFS for listing under the Endangered Species Act."
9. The Salmon and Steelhead Inventory defines a healthy stock as robust. A depressed stock is one whose numbers are below expected levels but sufficient to avoid permanent damage. A critical stock is one that has declined to the point that it is in danger of significant loss of genetic diversity or is at risk of extinction. An extinct stock is one that is no longer present in its original range.
10. Engrossed Substitute House Bill 2496 and Second Engrossed Second Substitute Senate Bill 5596, now Title 77 RCW.
11. A stream reach is a section of stream with consistent channel and floodplain characteristics, such as gradient (how steep the stream is) or confinement (how much a channel can move within its valley).
12. A riffle is a short, relatively shallow and coarse-bedded length of stream over which the stream flows at higher velocity and higher turbulence.
13. Stream productivity refers to the level of biomass that is produced or generated in the stream. Biomass can be generated by organisms (such as plants, algae, and some bacteria) that fix carbon through photosynthesis. These organisms are called autotrophs, and a measure of their abundance is known as primary productivity. Biomass can also be generated by organisms that consume other organisms. These organisms are called heterotrophs, and a measure of their abundance is known as secondary productivity. Stream productivity, as a general term, refers to the sum of both primary and secondary productivity.
14. The target shade level is intended solely for the purpose of conducting this environmental impact analysis, and does not connote or imply DNR policy direction.
15. Washington State Surface Water Quality Standards designated use categories are based on the most stringent temperature threshold into which the given stream drains. A stream reach may be assigned a temperature standard for a given species even if that species is not known to occur in the reach, as long as a downstream reach contains that species (Stohr, A., personal communication, Feb 16, 2016).
16. In Washington, large forest landowners are those who harvest an annual average of more than 2 million board feet of timber from their own forestland in the state.
17. Older roads that have not been used since 1974 are considered "orphaned."

This page left intentionally blank.

Topic:

Wildlife

What is Wildlife Habitat, and why is it Important?

Wildlife habitat is defined as the combination of resources (food, water, cover) and environment (climate, soils, vegetation structure) that attracts and supports a species, population, or group of species (Johnson and O'Neil 2001). Wildlife habitat, regardless of its location—uplands, riparian areas, or wetlands—serves a variety of important functions for both terrestrial and aquatic species. For example, wildlife habitat provides areas for foraging (finding food), roosting, breeding, nesting, and refuge (hiding from predators or other dangers).

Which Wildlife Species Does This Analysis Include?

In this section of the FEIS, DNR considers how each alternative impacts the ability of state trust lands in the OESF as a whole to support wildlife. For that reason, the analysis in this section focuses on the habitat needs of a broad range of wildlife species rather than the needs of specific species, and emphasizes potential environmental impacts at the largest spatial scale (all state trust lands in the OESF) instead of smaller scales such as landscapes or watershed administrative units. Results at the landscape scale can be found in Appendix K.

The potential environmental impacts of the alternatives on northern spotted owls are analyzed in a separate section of this FEIS (p. 3-189) because northern spotted owls are listed as threatened under the Endangered Species Act. In this FEIS, DNR did not include a separate section for the potential environmental impacts of the alternatives on marbled murrelets. Although marbled murrelets also are listed as threatened under the Endangered Species Act, DNR is currently developing a marbled murrelet long-term conservation strategy in a separate planning process. Instead, DNR includes marbled murrelets in the following analysis of wildlife habitat.

What is the Criterion for Wildlife Habitat?

The criterion for assessing wildlife habitat is **conservation of biodiversity**. The Washington Biodiversity Council defines biodiversity as "the full range of life in all its forms" including the habitats in which life occurs, the ways that species and habitat interact with each other, and the ecosystem processes necessary for those interactions.

Biodiversity is an environmental end point (goal) that is difficult to measure directly. Instead, biodiversity is measured by surrogate indicators including habitat structure (such as forest structure), landscape patterns (such as patch size), species abundance, species populations, genetic processes, or ecosystem processes (Franklin 1988, Noss 1990). Given that structural features provide critical habitat components for forest-dwelling wildlife species, it follows that the presence or absence of these species may be positively correlated with the presence or absence of such structural features (McCleary and Mowat 2002). For this analysis, DNR measures biodiversity by habitat structure and landscape patterns because they represent the physical places and structures that provide habitat for wildlife species, and because they can be quantified and modeled through time.

What are the Indicators for Wildlife Habitat?

The indicators used to measure the criterion are **stand development stages supporting wildlife guilds** and **interior older forest**. These indicators were selected based on DNR's expertise, existing scientific information, and current data. The following sections provide information on each indicator.

Stand development stages are analyzed in "Forest Conditions and Management," p. 3-23. In this chapter, DNR discusses stand development stages in context with wildlife.

How Were the Indicators Analyzed?

Following, DNR describes the quantitative process it used to analyze the indicators for the No Action and Landscape alternatives. For the Pathways Alternative, DNR identified potential impacts for these indicators using qualitative techniques (refer to p. 3-17 through 3-18).

Indicator: Stand Development Stages Supporting Wildlife Guilds

As forest stands grow from planted seedlings after a harvest or regenerate on their own after natural disturbances, they move in and out of stand development stages (refer to Text Box 3-2 in "Forest Conditions and Management," p. 3-28). Stand development stages are based on stand structure, not age. Stand structure is a combination of measurable attributes such as tree height and diameter, stand density, canopy layers, understory vegetation, down wood, and snags.

Each stand development stage has specific structures, such as large trees, down wood, or snags, which can benefit certain wildlife guilds (a wildlife guild is a group of species that has similar habitat requirements for foraging, breeding, or shelter). For example, the understory found in the Understory Development and Structurally Complex stages can benefit understory-gleaning insectivores (insect-eating birds). Species with general habitat requirements can belong to several guilds, and since they use a wide variety of forest structures, can benefit from all stand development stages (refer to Table 3-42).

Table 3-42. Wildlife Guilds Benefitting From all Stand Development Stages

Benefitting wildlife guilds	Representative species
Foliage-gleaning insectivores (feed on insects)	Warbling vireo, golden-crowned kinglet, yellow-rumped warbler, western tanager
Large mammal predators	Cougar and black bear
Small mammal predators	Bobcat, long-tailed weasel, and spotted skunk

In general, the early stand development stages, such as Ecosystem Initiation, and later stages, such as Structurally Complex, can support the greatest diversity and abundance of wildlife species (Johnson and O'Neil 2001, Carey 2003). For this indicator, DNR considered whether the proportion of state trust lands in each of the 11 landscapes in the OESF in early and late stand development stages is projected to increase, stay the same, or decrease over the 100-year analysis period. This analysis was conducted using the outputs of the analysis model.

Following, DNR provides descriptions of each stand development stage and examples of representative species of wildlife that benefit from the structures found in those stages. The tables in the following section are adapted from Brown (1985) and Johnson and O'Neil (2001).

ECOSYSTEM INITIATION

The establishment of a new forest ecosystem begins with rapidly growing young trees and shrubs. Many wildlife species use this stand development stage more for foraging than for breeding. Brown (1985) identified 70 species in western Washington and Oregon that used this stage (grass/forb stage in Brown 1985) as their primary foraging habitat, compared to 26 species that used this stage as their primary breeding habitat. Table 3-43 lists the wildlife guilds that may benefit from the Ecosystem Initiation stand development stage.

Table 3-43. Wildlife Guilds That may Benefit From the Ecosystem Initiation Stand Development Stage

Benefitting guilds	Representative species
Perching/hawking birds	Red-tailed hawk, great horned owl, olive-sided flycatcher, cedar waxwing
Herbivorous (plant-eating) mammals	Columbia black-tailed deer, Roosevelt elk, snowshoe hare, mountain beaver, creeping vole
Foliage-gleaning insectivores	Golden-crowned kinglet, warbling vireo, black-throated gray warbler (these species also benefit from Understory Development and later stand development stages)

Ecosystem Initiation stands adjacent to mature forests have high contrast edges (refer to photo, right). Ecosystem Initiation stands with high contrast edges may have increased wildlife use (Hunter 1990, Patton 1992, Johnson and O'Neil 2001) because they provide foraging habitat (in the Ecosystem Initiation stand) next to cover and perching habitat (in the adjacent stand). For example, hawks and several species of owls (Johnsgard 1988, 1990) are known to use high contrast edges for hunting. High contrast edges provide escape and cover for deer, elk (Kirchhoff and others 1983, Yahner 1988), and other species that forage within these relatively open areas. Table 3-44 provides examples of wildlife guilds that may benefit from Ecosystem Initiation stands with high contrast edges.

Harvested Area with High Contrast Edges
Harvested area will develop into an Ecosystem Initiation stand.

Table 3-44. Wildlife Guilds That may Benefit From Ecosystem Initiation Stands With High Contrast Edges

Benefitting guilds	Representative species
Aerial salliers (perch in foliage and catch flying insects)	Western tanager, olive-sided flycatcher
Forage on high contrast edge	Blue grouse, Cooper's hawk, northern pygmy-owl, northern saw-whet owl, western screech-owl, ruby-crowned kinglet, Vaux's swift, big brown bat, silver-haired bat, hoary bat, California myotis, Keen's myotis, little brown myotis, American marten, short-tailed weasel, mountain lion, Columbia black-tailed deer, bobcat
High contrast edge species	Great horned owl, American robin, spotted towhee, dark-eyed junco, brown-headed cowbird, common raven, Steller's jay, vagrant shrew, mountain beaver
Edge species	Western screech owl, great horned owl, Columbia black-tailed deer, Roosevelt elk, big brown bat, silver-haired bat, hoary bat, California myotis, Keen's myotis, little brown myotis
Herbivorous mammals	Columbia black-tailed deer, Roosevelt elk, snowshoe hare, mountain beaver, creeping vole

Table 3-45 lists an example of a wildlife guild that may benefit from Ecosystem Initiation stands when other, older stands also are available in the area.

Table 3-45. Wildlife Guild That May Benefit From the Ecosystem Initiation Stand Development Stage When Other, Older Stands are Available in Area

Benefitting guild	Representative species
Herbivorous mammals	Columbia black-tailed deer, Roosevelt elk, snowshoe hare, mountain beaver, creeping vole

COMPETITIVE EXCLUSION

In this stage, trees are often close together and compete closely for light, water, nutrients, and space (refer to photo, right). No wildlife species in Western Washington are found exclusively in the Competitive Exclusion stand development stage (Carey and Johnson 1995) because of its low structural diversity and low or absent shrub cover (Johnson and O'Neil 2001). However, some species use these stands as cover for hiding, escape, breeding, and protection from weather.

Competitive Exclusion Stand Development Stage

UNDERSTORY DEVELOPMENT

Forest stands in this stage begin to have gaps in the canopy. These gaps allow some sunlight to reach the forest floor, which allows an understory of trees, ferns, and shrubs to develop. Fewer and larger trees have larger crowns that produce more seeds.

Understory Development Stand Development Stage

Wildlife species associated with arboreal seed-eating and needle/bud-eating wildlife guilds use this stage (Johnson and O'Neil 2001). Table 3-46 lists examples of wildlife guilds that may benefit from the Understory Development stand development stage. Other common species such as black bear, coyote, ruffed grouse, Townsend's solitaire, and hermit thrush also use this stage (Johnson and O'Neil 2001).

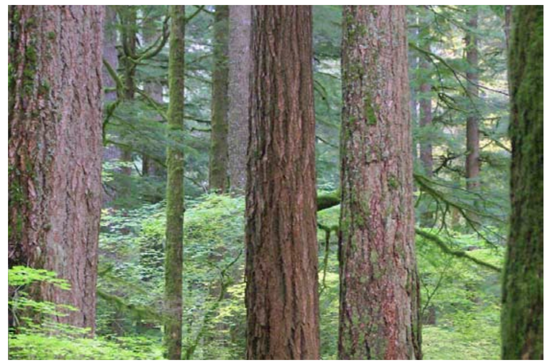
Table 3-46. Wildlife Guilds That may Benefit From the Understory Development Stand Development Stage

Benefitting guilds	Representative species
Arboreal (live in trees) seed-eaters	Pine siskin, Douglas squirrel, Townsend's chipmunk
Arboreal needle/bud-eating	Blue grouse, Douglas squirrel
Arboreal omnivores (feed on plants and animals)	Raccoon, forest deer mouse
Bark probers/gleaners	Hairy woodpecker, red breasted nuthatch, brown creeper

Table 3-46, Continued. Wildlife Guilds That may Benefit From the Understory Development Stand Development Stage

Benefitting guilds	Representative species
Understory birds	Dark-eyed junco, fox sparrow, Swainson's thrush, orange-crowned warbler, ruby-crowned kinglet, Wilson's warbler, Pacific wren
Understory-gleaning insectivores	Pacific wren, song sparrow

BIOMASS ACCUMULATION



Biomass Accumulation Stand Development Stage

For this FEIS analysis, DNR considers Biomass Accumulation roughly equivalent to the maturation stand development stage defined by Franklin and others (2002). Forest stands in the Biomass Accumulation stage contain numerous large, overstory trees that continue to rapidly add woody biomass (grow larger in diameter). Forests in this stage occupy the site fully, and competition between trees is moderate. This stage lacks the large snag and/or down woody debris and understory diversity that characterize later stages.

Johnson and O'Neil (2001) listed 11 wildlife species closely associated with this stand development stage, although many require the presence of remnant snags for breeding. Trees in the Biomass Accumulation stage are sufficiently mature to produce large cone crops and food for seed-eating wildlife such as the red crossbill, Douglas' squirrel, and Townsend's chipmunk (Adkisson 1996, Chapman and Feldhammer 1982) and are large enough to support primary and secondary cavity nesters (primary nesters excavate cavities; secondary nesters use cavities excavated by other wildlife). Larger crowns and crown growth in this stage may support needle-eating wildlife (Cade and Hoffman 1990). Wildlife species that feed or breed in large trees (generally greater than 24 inches in diameter) also may benefit from this stage. For example, marbled murrelets, a seabird that forages in the ocean and nests in the forest, may benefit from trees (generally, greater than 30 inches in diameter) that have branches large enough to produce platforms on which they can nest (Huff and others 2006). (Refer to "Structurally Complex" in the following section for more information.)

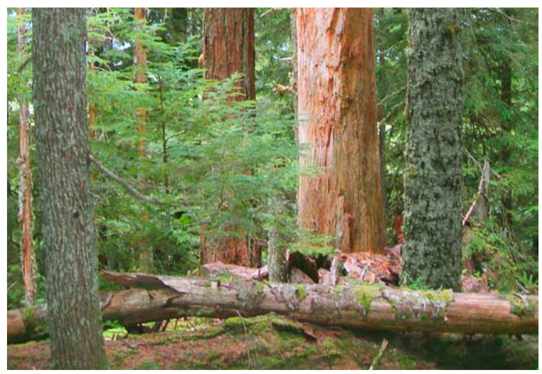
Table 3-47 lists examples of wildlife guilds that may benefit from the Biomass Accumulation stand development stage.

Table 3-47. Wildlife Guilds That may Benefit From the Biomass Accumulation Stand Development Stage

Benefitting guilds	Representative species
Feed and/or breed in large trees (generally greater than 24 inches diameter)	Chestnut-backed chickadee, brown creeper, red crossbill, pileated woodpecker, northern flying squirrel, marbled murrelet
Primary cavity nesters	Hairy woodpecker
Secondary cavity nesters	Chestnut-backed chickadee, saw-whet owl
Arboreal seed-eaters	Pine siskin, Douglas squirrel, Townsend's chipmunk
Arboreal needle/bud-eating	Blue grouse, Douglas squirrel
Arboreal omnivores	Raccoon, forest deer mouse
Bark probers/gleaners	Hairy woodpecker, red-breasted nuthatch, brown creeper
Understory birds	Dark-eyed junco, fox sparrow, Swainson's thrush, orange-crowned warbler, ruby-crowned kinglet, Wilson's warbler, Pacific wren
Understory-gleaning insectivores	Pacific wren, song sparrow

STRUCTURALLY COMPLEX

Key elements of the Structurally Complex stand development stage include large live trees, dead trees (snags), down woody debris of various sizes and conditions (DNR 2004), multiple vertical canopy layers (for example hemlock, vine maple), in-stand structural diversity (patches of larger trees and small openings), and a diverse understory of tree and shrub species of varying sizes and shapes.



Structurally Complex Stand Development Stage

Numerous studies have shown that many wildlife species depend on Structurally Complex stands for some or all of their life history requirements (Zobrist and Hinckley 2005). The structural features and complexity of these forest stands may benefit rare and endangered wildlife species such as northern spotted owls, northern goshawks, and marbled murrelets. For example, marbled murrelet populations in Washington, Oregon, and California nest on large tree limbs covered with a thick layer of moss or duff, mistletoe brooms, or other deformities that create a sufficiently wide and flat space on which to lay eggs (Hamer and Nelson 1995). Nesting sites for marbled murrelets are limited to forests with large-limbed trees (typically old-growth and mature coniferous forests) that are within commutable (flying) distance of the sea (Hamer 1995). The primary marbled murrelet nesting range for Washington encompasses suitable habitat within 40 miles of the coast (Madsen and others 1999), which includes state trust lands in the OESF.

The wildlife guilds associated with this stand development stage include large snag-dependents (species that depend on large snags for nesting, foraging, and other essential activities), large down wood-dependents, ground insectivores, and late successionalist specialists (species that depend on structurally complex forest). Many of these wildlife species depend on forest structures (such as large trees, snags, and down wood) that are found in this stand development stage to a greater extent than in other stages. Table 3-48 lists examples of wildlife guilds that benefit from the Structurally Complex stand development stage.

Table 3-48. Wildlife Guilds That may Benefit From the Structurally Complex Stand Development Stage

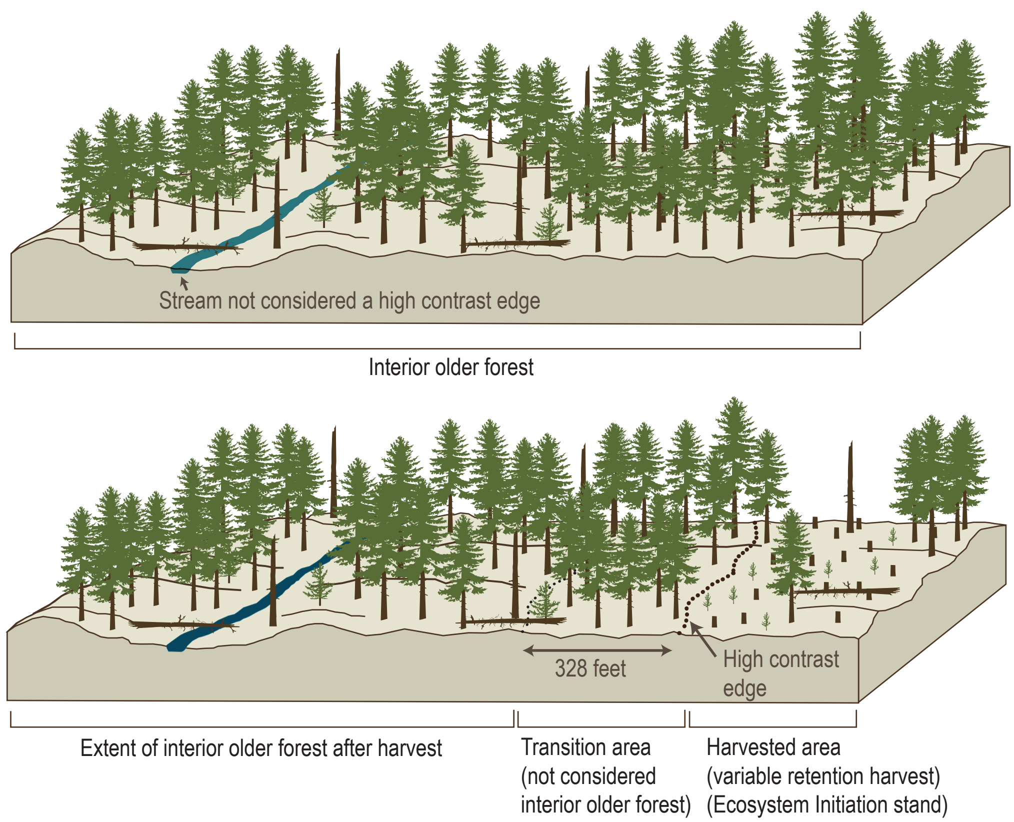
Benefitting guilds	Representative species
Arboreal insectivores (nesting)	Tree swallow, violet green swallow, Vaux's swift
Arboreal seed-eaters	Pine siskin, Douglas squirrel, Townsend's chipmunk
Arboreal needle/bud-eating	Blue grouse, Douglas squirrel
Arboreal omnivores	Raccoon, forest deer mouse
Bark probers/gleaners	Hairy woodpecker, red-breasted nuthatch, brown creeper
Understory birds	Dark-eyed junco, fox sparrow, Swainson's thrush, orange-crowned warbler, ruby-crowned kinglet, Wilson's warbler, Pacific wren
Understory-gleaning insectivores	Pacific wren, song sparrow
Large snag-dependent	Pileated woodpecker, northern saw-whet owl, western screech owl, northern spotted owl, black bear, fisher, bats
Herbivorous and fungivorous (fungus-eating) forest floor small mammals (truffles and fungi, seeds, berries, insects)	Trowbridge's shrew, shrew-mole, red backed vole
Ground insectivores	Western toad, northwestern salamander, Pacific tree frog, shrews, moles, black bear
Large down wood-dependent	Ensatina, northwestern salamander, black bear, fisher
Late successional specialists	Northern goshawk, northern spotted owl, marbled murrelet, northern flying squirrel
Feed and/or breed in large trees (generally greater than 24 inches diameter)	Chestnut-backed chickadee, brown creeper, red crossbill, pileated woodpecker, northern flying squirrel, marbled murrelet
Primary cavity nesters	Hairy woodpecker
Secondary cavity nesters	Chestnut-backed chickadee, saw-whet owl

Indicator: Interior Older Forest

Interior older forest refers to stands that are in the Biomass Accumulation or Structurally Complex stand development stage. For this analysis, stands in these stages must be located at least 328 feet (100 meters) from high contrast edges to be considered interior older forest. Examples of high contrast edges include an Ecosystem Initiation stand, paved road, large water body, or openings in the forest created by natural disturbance (for example, windthrow, fire, or landslides) or human activities (for example, rock pits). DNR does not consider the 328-foot area between the high contrast edge and the remainder of the stand to be interior older forest (refer to Figure 3-25) because this area is subject to edge effects and therefore not part of the interior. However, this 328-foot area provides support for wildlife commensurate with its stand development stage; refer to "Stand Development Stages Supporting Wildlife Guilds" for more information.

Along high contrast edges, more sunlight may reach the forest floor, trees may be more vulnerable to windthrow, and the air and soil may become warmer and drier. Some wildlife species may move away from the edge due to these conditions, while other species may find the conditions along the edge advantageous. Other species may be affected adversely because the high contrast edge can give predators easier access into the stand. For example, predation has been the most significant cause of nest failure in marbled murrelets, with corvids[1] being the primary predator (Nelson and Hamer 1995, Raphael and others 2002).

Figure 3-25. Extent of Interior Older Forest Before and After a Variable Retention Harvest

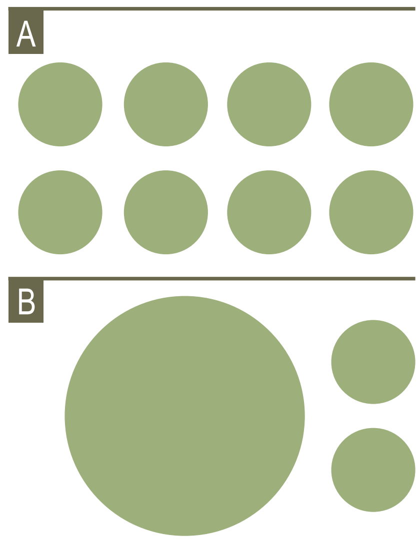


Interior older forest can support a wide range of wildlife species and may provide a refuge for species that are preyed upon by other species, such as great horned owls or crows, generally associated with edges and openings. Interior older forest also is able to provide, for long periods and without the influence of edge effects, the specific forest structures (snags, large trees, and down wood) on which many threatened and rare species depend. These threatened or rare species, such as northern spotted owls, often are vulnerable to predation or starvation because they have poor dispersal ability (ability to move from one patch to another). Some species, such as marbled murrelets, may be vulnerable because they have very specific breeding requirements.

Using the outputs of the analysis model, DNR measured this indicator with three metrics:

- **Acres of interior older forest**: DNR considered whether the total number of acres of interior older forest on state trust lands in the OESF is projected to increase, stay the same, or decrease over the 100-year analysis period.
- **Average edge-to-area ratio of interior older forest patches**: For patches of interior older forest on state trust lands in the OESF, DNR considered whether the average edge-to-area ratio is projected to increase or decrease over the 100-year analysis period (refer to Figure 3-26).
- **Average size of interior older forest patches**: DNR considered whether the average size of interior older forest patches on state trust lands in the OESF is projected to increase, stay the same, or decrease over the 100-year analysis period.

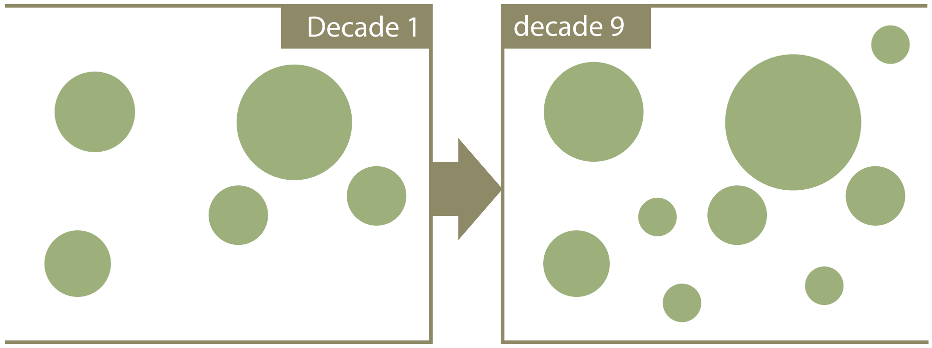
Figure 3-26. Edge-to-Area Ratio



The edge-to-area ratio is a relative metric that compares the length of the edge to the area of either a shape or collection of shapes. In the example above, both collections of shapes have approximately the same area, but the edge-to-area ratio of (A) is higher than (B)

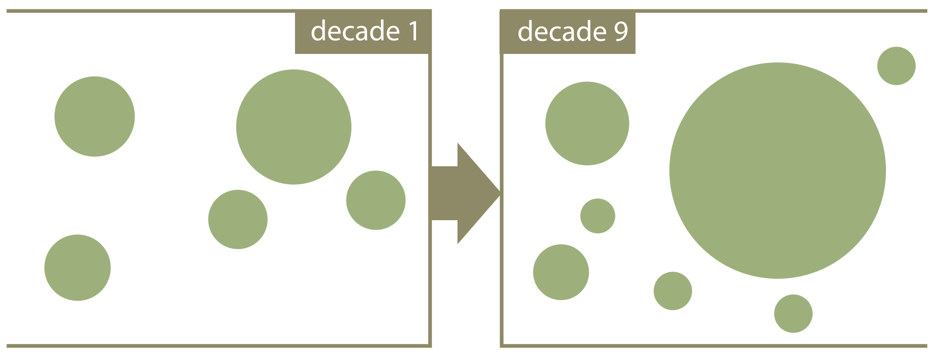
To understand how interior older forest is configured across the landscape, these three metrics must be considered together. For example, assuming the amount of interior older forest increases, an increase in the edge-to-area and a decrease in the average patch size may indicate that interior older forest is developing in many small patches (refer to Figure 3-27). However, it is also possible that interior older forest is developing in both large and small patches (refer to Figure 3-28).

Figure 3-27. Example 1, Increased Number of Acres of Interior Older Forest, Decreased Average Patch Size, and Increased Edge-to-Area Ratio



Even though existing patches remain the same size or grow slightly larger, new, smaller patches develop. These new patches decrease the average patch size and increase the edge-to-area ratio.

Figure 3-28. Example 2, Increased Number of Acres of Interior Older Forest, Decreased Average Patch Size, and Increased Edge-to-Area Ratio



While one patch has grown larger, the development of new, smaller patches increases the edge-to-area ratio and decreases the average patch size.

For each of the three metrics, DNR excluded from analysis any interior older forest patches that are less than 100 acres in size because these smaller patches are less likely to meet the needs of some species of wildlife, such as fishers, which are believed to need large, contiguous tracts of forest (Powell and Zielinski 1994). DNR felt this was a conservative approach because this analysis considered the habitat needs of all wildlife species, and because the size and isolation of patches does not affect all wildlife species equally (Carey 2007). In other words, this analysis considers only larger patches even though some wildlife species, such as deer mice, do not require larger patches.

■ Criterion and Indicators: Summary

Table 3-49 summarizes the criteria and indicators and how they were measured for the No Action and Landscape alternatives. DNR used a qualitative process to analyze indicators for the Pathways Alternative.

Table 3-49. Criterion and Indicators for Wildlife and how They Were Measured

Criterion/Indicator	How the indicator was measured	Potential environmental impacts
Conservation of biodiversity/ Stand development stages supporting wildlife guilds	The proportion of state trust lands in the OESF in each stand development stage.	**Low**: Proportion of stands in the Structurally Complex stand development stage increases, and Ecosystem Initiation and Biomass Accumulation stages are present **Medium**: Proportion of stands in the Structurally Complex stand development stage remains the same, and Ecosystem Initiation and Biomass Accumulation stages are present **High**: Proportion of stands in the Structurally Complex stand development stages decreases, and Ecosystem Initiation and Biomass Accumulation stages are absent
Conservation of biodiversity/ Interior older forest	Measured with three metrics: **Number of acres**: The total number of acres of interior older forest on state trust lands in the OESF. **Average edge-to-area ratio**: The amount of edges compared to area of all patches of interior older forest on state trust lands in the OESF. **Average patch size**: The average size of interior older forest patches on state trust lands in the OESF.	**Low**: Number of acres of interior older forest increases, edge-to-area ratio decreases, and average patch size increases **Medium**: Number of acres of interior older forest increases, edge-to-area ratio increases, and average patch size decreases **High**: Number of acres of interior older forest decreases, edge-to-area ratio increases, and average patch size decreases

■ Current Conditions and Results

Indicator: Stand Development Stages Supporting Wildlife Guilds

As mentioned previously, each stand development stage has specific forest structures that benefit different guilds of wildlife. A change in the proportion of stand development stages can affect the wildlife that depend on these structures.

CURRENT CONDITIONS

The current distribution of stand development stages is presented in Chart 3-5 in "Forest Conditions and Management," p. 3-34. Currently, 54 percent of state trust lands in the

OESF are in the Competitive Exclusion stage, 29 percent are in the Understory Development stage, 11 percent are in the Structurally Complex stage, 4 percent are in the Ecosystem Initiation stage, and 2 percent are in the Biomass Accumulation stage.

RESULTS, NO ACTION AND LANDSCAPE ALTERNATIVES

Chart 3-9 and Chart 3-10 from "Forest Conditions and Management" are presented here as Chart 3-24 and Chart 3-25 to show how the proportion of stand development stages is projected to change over the 100-year analysis period. The trends for both alternatives are very similar. Refer to Appendix E for charts showing the stand development stages for each of the 11 landscapes.

Chart 3-24. Projected Stand Development Stages on State Trust Lands in the OESF, No Action Alternative

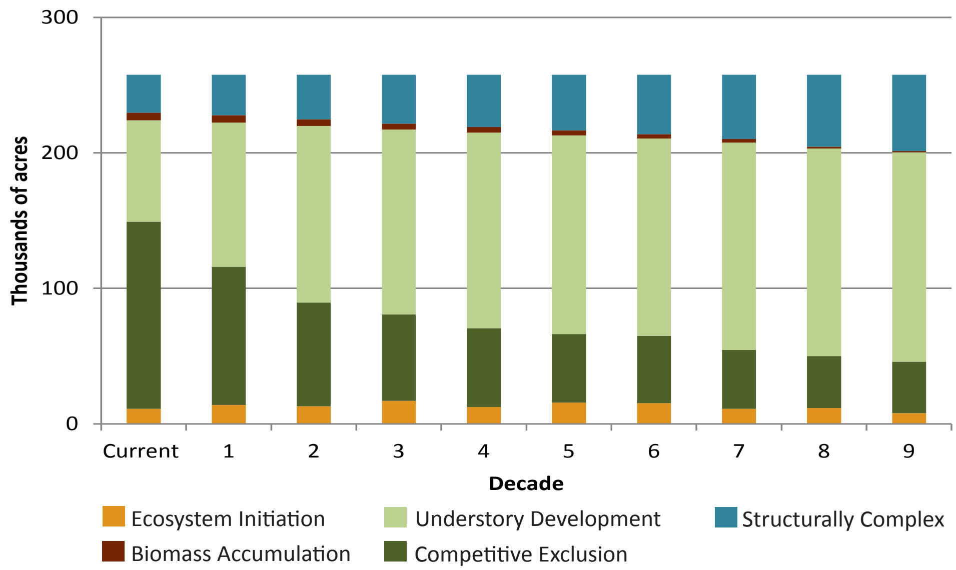
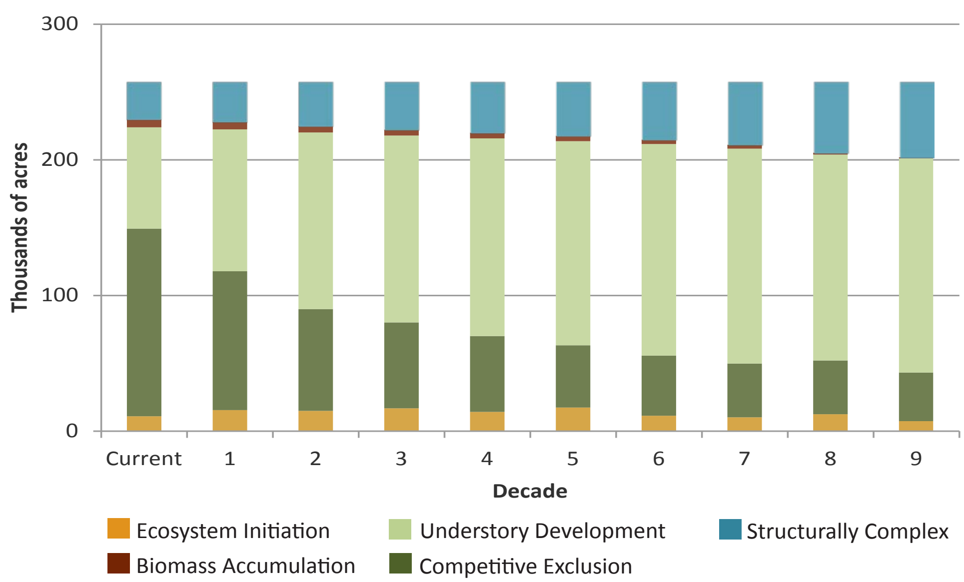


Chart 3-25. Projected Stand Development Stages on State Trust Lands in the OESF, Landscape Alternative



The Structurally Complex stand development stage is projected to increase steadily and almost double over the 100-year analysis period under both alternatives. Numerous studies have shown that many species require Structurally Complex stands for some or all of their life history requirements (Zobrist and Hinckley 2005). An increase in this stand development stage could benefit numerous species of wildlife (refer to Table 3-48 on p. 3-172). For example, this stand development stage may benefit marbled murrelets, which are associated with the forest structures found within this stage (Hamer 1995, Hamer and Nelson 1995).

The Ecosystem Initiation stand development stage is projected to remain nearly constant throughout the 100-year analysis period under both alternatives, remaining near its current level of approximately 4 percent.

Many wildlife species use the Ecosystem Initiation stand development stage, although more for foraging than for breeding. Deer and elk populations have been declining in the Northwest coastal region since the 1990s because of declining foraging habitat (Spencer 2002). The presence of the Ecosystem Initiation stand development stage on state trust lands in the OESF could provide habitat for these species.

The Biomass Accumulation stand development stage is the least represented on state trust lands in the OESF and is projected to decrease under both alternatives through the 100-year analysis period, most likely because stands in this stage are becoming more complex and moving into the Structurally Complex stage, or are being harvested and planted with new trees.

The Biomass Accumulation stage supports primary and secondary cavity nesters and species that feed or breed in large trees. Some species, such as marbled murrelets, need large trees (30 inches in diameter and larger) for nesting because large trees have a higher likelihood of developing nesting platforms (Huff and others 2006). Although the proportion of this stage is projected to decline over the 100-year analysis period, it remains present and continues to provide support for these species.

Because the proportion of state trust lands in the Structurally Complex stand development stage is projected to increase and both Biomass Accumulation and Ecosystem Initiation stages are present throughout the 100-year analysis period, the potential environmental impact of the No Action and Landscape alternatives for this indicator is considered **low**. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

RESULTS, PATHWAYS ALTERNATIVE

Changes in the distribution of stand development stages under the Pathways Alternative are not anticipated to differ significantly from that of the Landscape Alternative (refer to Chart 3-25 on p. 3-127) because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). DNR anticipates that under the Pathways Alternative, the percentage of forested state trust lands in the Structurally Complex stand development stage will increase, the percentage of lands in the Ecosystem Initiation stand development stage will remain nearly constant, and the Biomass Accumulation stand development stage will remain present over the 100-year analysis period.

The Pathways Alternative includes thinning of forest stands in operable and deferred areas in some landscapes to create or accelerate development of Young Forest Habitat (Pathways 5 and 7, respectively). Approximately one third of these stands are in the Competitive Exclusion stand development stage, while nearly two-thirds are in the Understory Development stage and approximately one percent are in the Biomass Accumulation stage. Thinning stands in the Competitive Exclusion stage may shift them into Understory Development and put them on a trajectory to eventually reach the Biomass Accumulation and Structurally Complex stages.

In addition, operable areas selected for passive management (Pathways 3 and 4) may continue to develop the characteristics of structurally complex forests.

DNR will continue to harvest timber in the remaining operable areas under the Pathways Alternative, and natural disturbances will continue to occur. Therefore, the Ecosystem Initiation stand development stage is expected to persist throughout the 100-year analysis period.

As described under current conditions, no wildlife species in western Washington are found exclusively in the Competitive Exclusion stand development stage (Carey and Johnson 1995). However, several species are associated with the Understory Development stand development stage (refer to Table 3-46 on p. 3-169) and a larger number of species are associated with the Biomass Accumulation and Structurally Complex stand development stages (refer to Tables 3-47 and 3-48 on p. 3-171 and 3-172, respectively). Therefore, reducing the amount of area in the Competitive Exclusion stand development stage and encouraging development of the Understory Development and later stages could benefit many wildlife species. Increasing the proportion of state trust lands in the Structurally Complex stage could benefit species associated with this stage, including marbled murrelets.

Because the distribution of stand development stages is expected to shift toward more complex stages (similar to the trend under the Landscape Alternative), the potential environmental impact of the Pathways Alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Interior Older Forest

Interior older forest refers to stands that are in Biomass Accumulation or Structurally Complex stand development stages and at least 328 feet away from high contrast edges. Interior older forest was assessed with three metrics. These metrics must be considered together to understand how the configuration of interior older forest across the landscape changes over time. A summary of the three metrics is provided at the end of this section.

NUMBER OF ACRES OF INTERIOR OLDER FOREST

For this metric, DNR considered the total number of acres of interior older forest that are projected to develop over the 100-year analysis period.

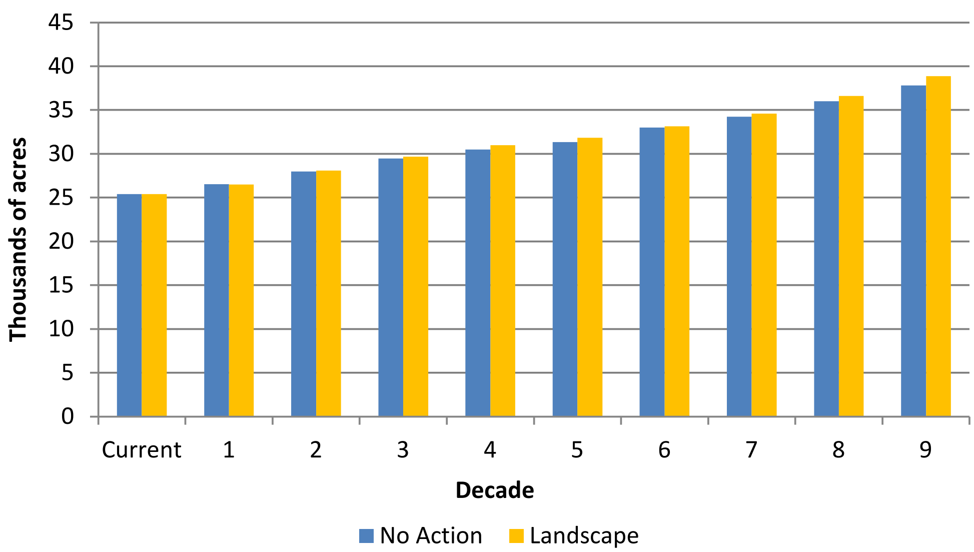
Current Conditions

The projected number of acres of interior older forest is approximately 26,000 acres, as shown in Chart 3-26.

Results, No Action and Landscape Alternatives

Chart 3-26 shows that the number of acres of interior older forest is projected to increase over the 100-year analysis period to approximately 38,000 acres under both the No Action and Landscape alternatives (trends by landscape are included in Appendix K). The increase in the number of acres of interior older forest is primarily due to an increase in the Structurally Complex stand development stage, since the number of acres in the Biomass Accumulation stage decreases over the 100-year analysis period (refer to "Stand Development Stages Supporting Wildlife Guilds" earlier in this section).

Chart 3-26. Projected Number of Acres of Interior Older Forest on State Trust Lands in the OESF



Results, Pathways Alternative

Under the Pathways Alternative, the number of acres of interior older forest is expected to increase over the 100-year analysis period similarly to the increase projected for the Landscape Alternative (refer to Chart 3-26). This trend is expected to be similar under the Pathways and Landscape alternatives because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). However, the Pathways Alternative may result in a larger amount of interior older forest as compared to the Landscape Alternative because DNR will consider patch size and proximity to existing northern spotted owl habitat on DNR-managed lands or adjacent federal lands in selecting stands for active or passive management.

AVERAGE EDGE-TO-AREA RATIO

Edge-to-area ratio compares the amount of edge to the area of interior older forest patches (refer to Figure 3-26 on p. 3-174).

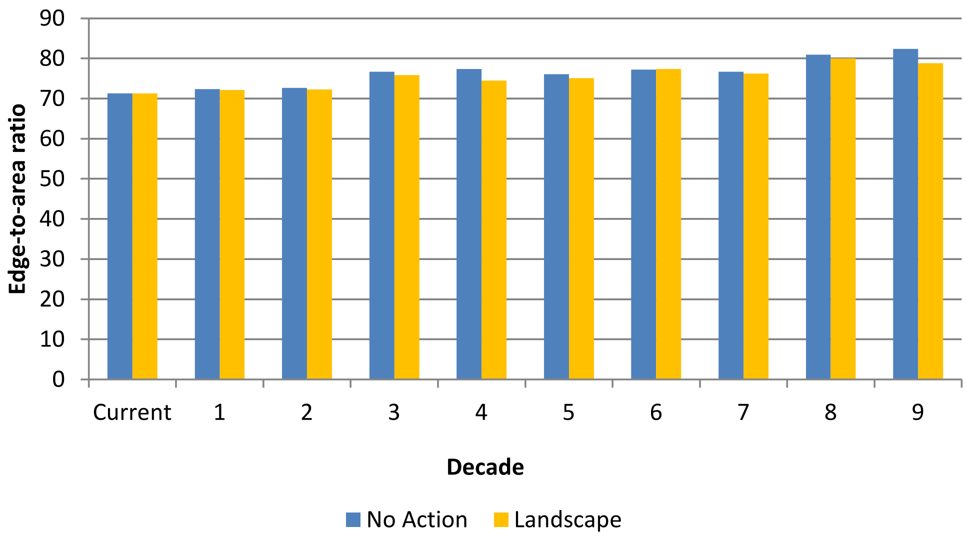
Current Conditions

The current average edge-to-area ratio of interior older forest patches is shown in Chart 3-27.

Results, No Action and Landscape Alternatives

Chart 3-27 shows a trend of increased average edge-to-area ratio over the 100-year analysis period under both alternatives. The No Action Alternative has slightly higher ratios in the middle and late decades than the Landscape Alternative.

Chart 3-27. Projected Average Edge-to-Area Ratio of Interior Older Forest on State Trust Lands in the OESF



Results, Pathways Alternative

Under the Pathways Alternative, the change in the average edge-to-area ratio over the 100-year planning period is expected to be similar to the change projected under the Landscape Alternative (refer to Chart 3-27). This trend is expected to be similar under the Pathways and Landscape alternatives because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18).

The increase in edge-to-area ratio may be slightly less under the Pathways Alternative, however, because DNR will consider patch size and proximity to existing northern spotted owl habitat on DNR-managed lands or adjacent federal lands in selecting stands for active or passive management.

AVERAGE SIZE OF PATCHES OF INTERIOR OLDER FOREST

DNR considered whether the average size of interior older forest patches on state trust lands in the OESF is projected to increase, stay the same, or decrease over the 100-year analysis period.

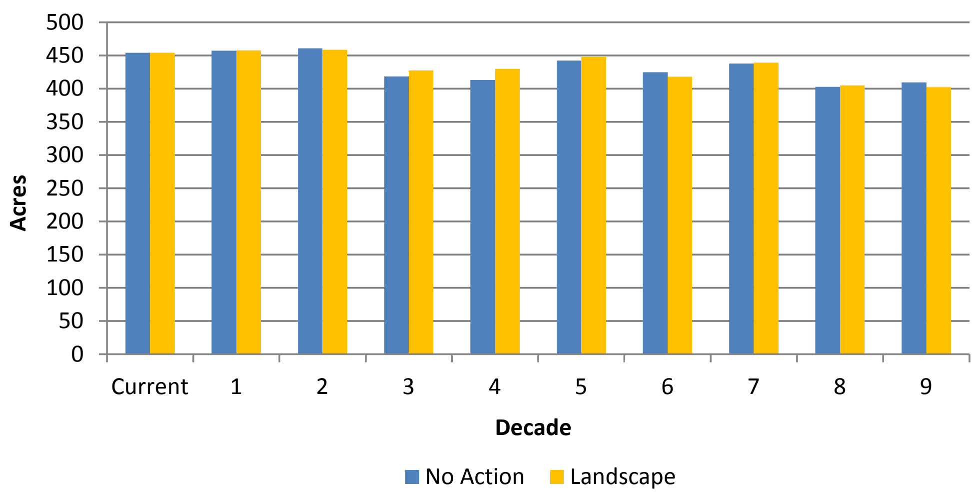
Current Conditions

The average size of patches of interior older forest is approximately 450 acres, as shown in Chart 3-28.

Results, No Action and Landscape Alternatives

Chart 3-28 shows that the average size of patches of interior older forest is projected to decrease under both alternatives, from the current average of 450 acres to 410 acres (No Action Alternative) or 400 acres (Landscape Alternative).

Chart 3-28. Projected Average Acre Size of Patches of Interior Older Forest on State Trust Lands in the OESF



For a better understanding of both this metric and the edge-to-area ratio, DNR considered how acres of interior older forest are distributed between different categories of patch sizes. Chart 3-29 on p. 3-183 shows that the total number of acres of interior older forest in the small patch category—100 to 250 acres—is projected to increase over the 100-year analysis period. The total number of acres in the large patch category—over 1,000 acres— also is projected to increase, from approximately 10,000 acres to over 17,000 acres. Only small changes are projected in all other categories. Trends are similar for both alternatives (No Action and Landscape).

Chart 3-29. Projected Number of Interior Older Forest Acres on State Trust Lands in the OESF, Separated by Patch Size

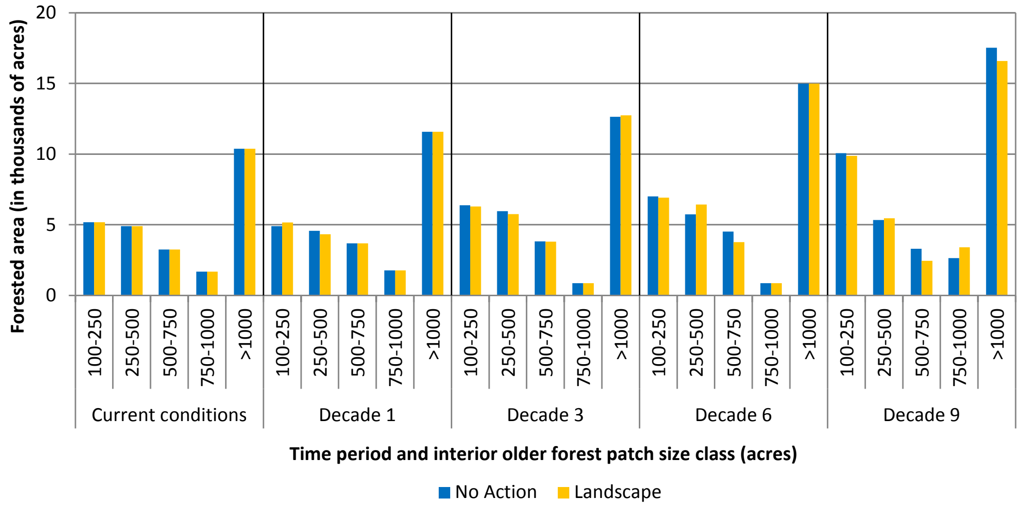
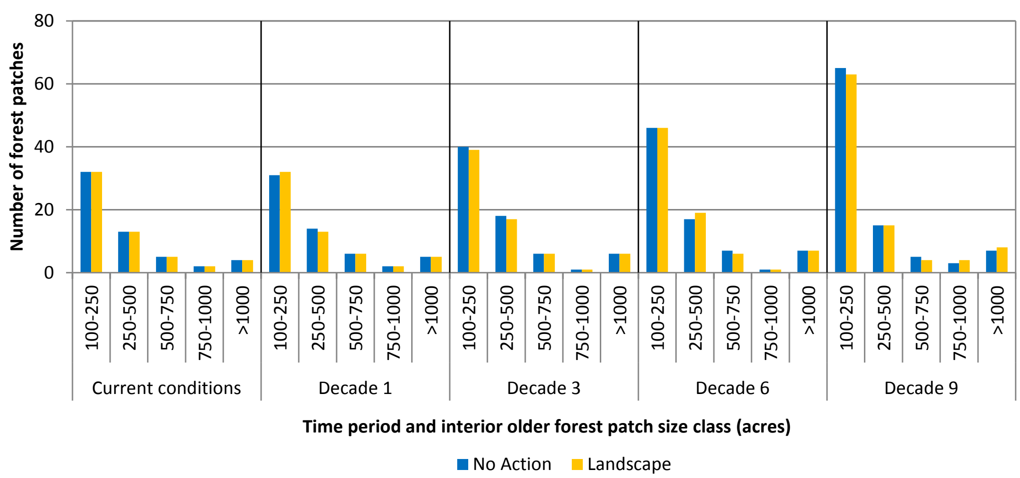


Chart 3-30 shows that the number of patches in the small patch category—100 to 250 acres—is projected to increase from approximately 31 to 62. The number of patches in the large patch category—over 1,000 acres—also is projected to increase, from approximately 4 to 8. Only small changes are projected in all other categories. Trends are similar for both the No Action and Landscape alternatives. Refer to "Interior Older Forest Summary" in the following section for a discussion of these results.

Chart 3-30. Projected Number of Interior Older Forest Patches on State Trust Lands in Different Patch Size Classes



Results, Pathways Alternative

Due to the similarities between the Pathways and Landscape alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18), trends in patch size under the Pathways Alternative are expected to be similar to those projected under the Landscape Alternative: a decrease in average patch size, an increase in the number of acres in the largest and smallest patch categories, and an increase in the number of small and large patches. However, the number of acres in larger patches may increase more under the Pathways Alternative because DNR will consider patch size and proximity to existing northern spotted owl habitat on DNR-managed lands or adjacent federal lands in selecting stands for active or passive management.

INTERIOR OLDER FOREST SUMMARY

Under all alternatives, over the 100-year analysis period on state trust lands in the OESF:

- The number of acres of interior older forest is projected to increase (Chart 3-26),
- The average edge-to-area ratio is projected to increase (Chart 3-27), and
- The average patch size is projected to decrease (Chart 3-28).

As stated previously, these results can lead to different conclusions (Figure 3-27 and Figure 3-28). To clarify these trends, DNR also considered how interior older forest is distributed between different patch size categories (Chart 3-29 and Chart 3-30). Under all three alternative (No Action, Landscape, Pathways), the analysis suggests that across state trust lands,

- Interior older forest most likely will develop in numerous small patches,
- A few larger patches of interior older forest may develop, most likely from mid-size patches growing larger, and
- Existing large patches of interior older forest are likely to expand in size.

Places where interior older forest is projected to increase include riparian areas and areas currently deferred as Old Forest Habitat for northern spotted owls. The development of structural complexity in riparian areas was predicted in the HCP. Patches in riparian areas may tend to be smaller and long and narrow in shape, which would increase the edge-to-area ratio and decrease average patch size.

Interior older forest may have more value to some species of wildlife when located in large patches. Large patches are especially important for rare or threatened species that are sensitive to disturbance, have specific breeding requirements, have poor dispersal ability, or require specific forest structures such as snags and deformed trees well away from high contrast edges (Noss 1983). For example, the nesting success of marbled murrelets may be lower near high-contrast edges due to predation (Malt and Lank 2009, Raphael and others 2002): high contrast edges may increase the chances of marbled murrelet eggs or chicks being found and killed by predators (Malt and Lank 2009, Nelson and Hamer 1995).

Landscapes dominated by small interior older forest patches may support fewer specialized species unable to use small, isolated forest patches, and more common generalist species such as small and large mammal predators (Noss 1983, Carey 2007). Small interior older forest patches may have more value to wildlife when patches are located closer together and surrounded by forest stands that do not produce high contrast edge effects (Forman and Godron 1986, Noss 1983). McShane and others (2004) summarized numerous studies on a specialist species, the marbled murrelet, and its habitat use at the landscape scale:

> Studies using audio-visual detection data to characterize murrelet nesting habitat at a landscape scale have often found murrelet use to be associated with (1) the presence of mature and old-growth forests, (2) larger core areas of old-growth, (3) low amounts of edge…(4) lower fragmentation levels, and (5) proximity to the marine environment. In some cases, murrelet use was associated with lower elevations, more complex landscape patterns, and stands that were less isolated from other similar stands (p. 6-2 to 6-3).

The potential environmental impact of all three alternatives for this indicator is considered **medium**. Most of the interior older forest patches that develop are smaller and potentially isolated, but because the overall amount of interior older forest is projected to increase and some large patches are projected to develop, the impact is considered medium. DNR did not identify probable significant adverse impacts from any alternative (No Action, Landscape, Pathways) for this indicator.

Summary of Potential Impacts

Table 3-50 provides an overview of the potential environmental impacts on wildlife when the criterion and all of the indicators are considered. For this analysis, only high impacts were considered potentially significant impacts. DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for any indicator used for this topic.

Table 3-50. Summary of Potential Environmental Impacts on Wildlife, by Alternative

Criteria	Indicators	No Action Alternative	Landscape Alternative	Pathways Alternative
Conservation of biodiversity	Stand development stages supporting wildlife guilds	Low ●	Low ●	Low ●
	Interior older forest	Medium ◊	Medium ◊	Medium ◊

● **Low impact** ◊ **Medium impact**

Considered but not Analyzed

Forest Stand-Level Impacts

DNR did not evaluate the impacts of harvest on individual forest stands because it is too fine a scale for an analysis of wildlife guilds and species. Individual timber harvests may alter a specific site and affect the wildlife guilds using that site, but the same general forest type and structure (stand development stage) and associated wildlife guilds are found in other areas on state trust lands. As explained in Chapter 2, the potential environmental impacts of individual timber sales are analyzed through SEPA when the sales are proposed.

Table 3-51 lists some of the general disturbances and benefits to wildlife that may occur at the forest stand level following either variable retention harvest or thinning (refer to Text Box 3-1 on p. 3-25 for a description of harvest methods).

Table 3-51. Potential Disturbance and Benefit to Wildlife at the Forest Stand Scale, by Harvest Method

Harvest Type/ Duration	Potential disturbance	Potential benefits
Variable retention harvest/ Short-term	May eliminate habitat for species currently using the forest stand being harvested (Hayes and others 2003, Wallendorf and others 2007). Noise from harvest activities may cause wildlife (including deer, elk, and bear) to leave the immediate area temporarily. Physical disturbance from yarding (moving trees from where they are felled to where they are collected for transport) may reduce shrub layers and affect habitat for ground-associated species. Harvest may result in possible direct mortality (unintentionally cutting down a nest tree). Potential removal of snags for worker safety can reduce habitat for cavity nesting birds.	Immediately opens stand and promotes shrub growth, providing foraging habitat for species that use the Ecosystem Initiation stand development stage. May produce habitat for species that are rare or absent in other stand development stages. Leave trees (trees that are not harvested) provide perches for olive-sided flycatchers, red-tailed hawks, and great horned owls. Wildlife reserve trees[a] can provide habitat for cavity-nesting birds such as woodpeckers. The high contrast edge (edge where forested and non-forested areas meet) created by harvest supports species such as western screech owls and accipiter hawks. Retained snags and large woody debris support cavity-nesting birds, small mammals, and amphibians.
Variable retention harvest/ Long-term	May reduce or eliminate habitat for wildlife species, such as hermit warblers and northern flying squirrels, that require mature overstory trees.	Legacy trees[b] and leave patches (patches of unharvested trees) may eventually support species, such as brown creepers, pileated woodpeckers, and many species of bats, that require large trees and snags.

[a] A tree that is suitable for wildlife and is not harvested; a type of leave tree.

[b] A tree, usually mature or old-growth, that is retained on a site after harvesting or natural disturbance to provide a biological legacy (Society of American Foresters).

Table 3-51, Continued. Potential Disturbance and Benefit to Wildlife at the Forest Stand Scale, by Harvest Method

Harvest Type/ Duration	**Potential disturbance**	**Potential benefits**
Variable density thinning/ Short-term	Noise and management activity may cause wildlife to leave the area temporarily. Physical disturbance can reduce shrubs and associated habitat for birds. Potential removal of snags for worker safety may reduce habitat for cavity-nesting birds. Could potentially result in direct mortality (unintentionally cutting down a nest tree). Thinning may suppress northern flying squirrel populations, possibly for several decades (Wilson 2010).	Opens stand to provide flying space for birds such as sharp-shinned and Cooper's hawks. Creates openings used by many types of wildlife that forage within Ecosystem Initiation stands. Dead and down wood created and retained within legacy patches (areas left from a previous harvest) provide hiding or nesting cover for amphibians, small mammals, and insects.
Variable density thinning/ Long-term	Tree removal may reduce habitat for species, such as blue grouse, that require denser stands.	Encourages development of large trees that are necessary components of structurally diverse stands, which support breeding habitat for woodpeckers, bats, and other species. Can potentially lead to development of greater structural complexity, which can lead to an increase in wildlife diversity and abundance.

Roads

Because of its isolation from major population centers, the OESF has limited road use. Most road traffic is associated with forest management activities. Approximately 94 percent of the roads on state trust lands in the OESF are unpaved and approximately 89 percent of roads have low use (refer to Appendix C). For the following reasons, roads were considered but not analyzed for wildlife impacts:

- Although vehicles on roads have the potential to kill wildlife, the infrequent loss of individual members of a species has a minimal effect on wildlife populations (Forman and Alexander 1998).
- Road density can affect some far-ranging species such as grizzly bears and wolves. However, the OESF does not contain populations of species known to be affected by road density.

Section Note

1. Corvids are a large family of birds that includes species of jays, crows, and ravens.

Topic:

Northern Spotted Owls

Photo courtesy USFWS

■ What is the Status of Northern Spotted Owls?

The northern spotted owl (*Strix occidentalis caurina*; refer to Text Box 3-7 on p. 3-190), a subspecies of spotted owl,[1] was listed as threatened under the Endangered Species Act in 1990.[2] In 2004, USFWS conducted a five-year review[3] of the status of the northern spotted owl and concluded that the subspecies should remain listed as threatened.

Northern spotted owl populations in Washington are declining between 5.9 and 7 percent per year (Anthony and others 2006; Forsman and others 2011). According to Courtney and others 2004, Gutierrez and others 2006, Olson and others 2004, major threats to owl populations in Washington are competition with barred owls (*Strix varia*) and loss of habitat from past harvest activities and natural disturbance (refer to Appendix I for more information).

Northern spotted owls on the Olympic Peninsula are considered a distinct sub-population that is geographically isolated by a lack of suitable habitat connecting them to other sub-populations (DNR 1997).[4] Holthausen and others (1995) found that the Olympic sub-population of northern spotted owls is likely to be maintained, but factors such as competition with barred owls could change the sub-population's stability. Currently, owl numbers are declining on the Olympic Peninsula by 4.3 percent per year (Lint 2005, Forsman and others 2011).

In June 2011, USFWS released the *Recovery Plan for the Northern Spotted Owl* (USFWS 2011b). The plan recommends the development of spatially explicit computer models to evaluate northern spotted owl habitat and territories. To evaluate habitat for this FEIS analysis, DNR developed stand-level models and a territory model, as will be discussed later in this section. Additional information on these models can be found in Appendix I.

In 1997, DNR developed the HCP, a long-term management plan to maintain and improve habitat for threatened and endangered as well as unlisted native species on state trust lands within the range of the northern spotted owl. Authorized under the federal Endangered Species Act, this plan includes conservation objectives (p. IV.86) and mitigation strategies for the northern spotted owl. Per the HCP, DNR's objective is to restore and maintain northern spotted owl habitat capable of supporting the species on state trust lands in each of the 11 landscapes in the OESF by developing and implementing a forest land plan that does not appreciably reduce the chances for the survival and recovery of the northern spotted owl sub-population on the Olympic Peninsula. DNR's contribution to federal recovery objectives for the northern spotted owl is to provide

Text Box 3-7. Northern Spotted Owl Biology

Northern spotted owls are medium size owls with dark brown feathers and white spots on the head and breast. Non-migratory and highly territorial, northern spotted owls generally rely on older, structurally complex forests for nesting, roosting, and foraging, though they will move through less complex forest to reach other habitat patches or new territories (a territory is an area the owl occupies and defends). The Olympic Peninsula sub-population of northern spotted owls lives in low and mid-elevation forests up to approximately 3,000 feet above sea level.

Their predominant prey species is the northern flying squirrel. Flying squirrel abundance on the Olympic Peninsula is low (Carey and others 1995) and as a result, northern spotted owl home ranges (the geographic area to which it normally confines its activity) on the Olympic Peninsula are some of the largest that have been reported (Holthausen and others 1995). Forsman and Biswell (2007) reported that the median size of annual home ranges of owl pairs on the Olympic Peninsula is 12,434 acres. For a more complete description of northern spotted owl biology, refer to Appendix I. Information may also be found in the HCP (p. III.1 through III.22).

habitat on state trust lands in the OESF that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal on state trust lands in the OESF.[5] DNR meets its obligations under the Endangered Species Act by implementing its HCP, and is not required to produce a recovery plan or follow the federal recovery plan for the northern spotted owl.

What is the Criterion for Northern Spotted Owls?

The criterion is the **amount of habitat capable of providing support for the recovery of the Olympic Peninsula sub-population of northern spotted owls on adjacent federal lands**. Most northern spotted owl recovery on the Olympic Peninsula is anticipated to occur on federal lands (Olympic National Park, Olympic National Forest) that are managed by the federal government for this purpose. This criterion is in accordance with the guidance of the *Recovery Plan for the Northern Spotted Owl* (USFWS 2011b).

What are the Indicators for Northern Spotted Owls?

The indicators used to assess the criterion are the **number of acres of modeled northern spotted owl habitat**, the **number of acres supporting northern spotted owl life history requirements**[6] **(movement, nesting, roosting, and foraging)**, and the **number of modeled potential northern spotted owl territories**. These indicators were selected based on DNR's expertise, existing scientific information, and current data. The following section includes information about the significance of each indicator.

How Were the Indicators Analyzed?

Indicator: Number of Acres of Modeled Northern Spotted Owl Habitat

The two categories of northern spotted owl habitat types used in this FEIS are Old Forest Habitat and Young Forest Habitat (refer to Text Box 3-8 and Appendix I). These habitat types are based on the habitat definitions in the HCP.[7]

Text Box 3-8. Northern Spotted Owl Habitat Types

Old Forest Habitat

Old Forest Habitat is a grouping of northern spotted owl habitat types[a] that supports owl nesting, roosting, foraging, and dispersal (movement).

Old Forest Habitat has multiple species of trees, more than one canopy layer, and enough canopy closure to protect owls from predators and buffer temperatures. The dominant trees are large (over 20 or 30 inches in diameter) and have deformities that can provide nesting sites. There is an abundance of large snags and down wood.

[a]Old Forest Habitat is an aggregation of Type A, Type B, high-quality nesting (1997 *Habitat Conservation Plan* p. IV.11), and mapped Old Forest Habitat. These habitat types are described in Appendix I.

Young Forest Habitat

Young Forest Habitat is a grouping of northern spotted owl habitat types[b] which supports dispersal (movement) and provides some opportunities for roosting and foraging.

The canopy is closed enough to protect owls from predators and the forest is not too dense for owls to fly though. Trees are at least 85 feet tall and at least 30 percent of them are conifers (such as Douglas fir). A few larger snags are present and the forest floor has some down wood.

[b]Young Forest Habitat is an aggregation of sub-mature habitat (1997 *Habitat Conservation Plan* p. IV.11) and young forest marginal habitat (Procedure 14-004-120, modified from WAC 222-16-085). These habitat types are described in Appendix I.

The amounts of Old Forest Habitat and Young Forest Habitat on state trust lands in each of the 11 landscapes in the OESF provide different levels of support for northern spotted owls. For this analysis, in each landscape, DNR considered:

- The number of acres of modeled Old Forest Habitat in each landscape, and
- The number of acres of modeled Young Forest Habitat and better (acres of Young Forest Habitat and Old Forest Habitat added together). DNR combined these two habitat types (Young Forest and Old Forest) to understand the full range of modeled northern spotted owl habitat in each landscape.

DNR refers to habitat as "modeled" to emphasize that the current conditions and results of this analysis are based on the outputs of the analysis model.

As stated in the introduction to this chapter, DNR did not run the analysis model for the Pathways Alternative. Instead, in a post process (outside the analysis model) DNR modified the harvest schedule for the Landscape Alternative to incorporate the pathways and estimated a range of how much northern spotted owl habitat each landscape may have at each decade of the 100-year analysis period under the Pathways Alternative.

As a result of applying the pathways in each landscape, DNR anticipates that the total amount of northern spotted owl habitat in each landscape eventually will meet and then exceed northern spotted owl habitat thresholds. In accordance with the northern spotted owl conservation strategy in the HCP, habitat in excess of northern spotted owl habitat thresholds in each landscape is available for harvest so long as thresholds are maintained in the landscape.

The analysis model would have been able to optimize the selection for harvest of those forest stands in operable areas that a) developed into northern spotted owl habitat as a result of applying the pathways, and b) were not needed to maintain northern spotted owl habitat thresholds. Because DNR did not run the analysis model for the Pathways Alternative, DNR was not able to determine which of these forest stands would be harvested in the context of all of DNR's management objectives. Instead, DNR reported the total amount of northern spotted owl habitat in each landscape at each decade of the 100-year analysis period as a range (using an upper and lower bound for each habitat type). At the upper bound, none of the habitat that develops as a result of applying the pathways would be harvested. The remainder of the range represents varying levels of harvest of these stands during the maintenance and enhancement phase. In developing these upper and lower bounds, DNR assumed that non-habitat would become Young Forest Habitat immediately following a thinning, and habitat that was thinned would become Old Forest Habitat four decades later through natural forest growth. Refer to Appendix A for more information on how the upper and lower bounds were calculated.

For all three alternatives, DNR first assigned each landscape a potential low, medium, or high impact rating based on whether the amount of modeled Old Forest Habitat and Young Forest Habitat and better on state trust lands is projected to increase, stay the same, or decrease by the end of the 100-year analysis period. DNR then considered all landscapes together to assign a potential low, medium, or high impact rating to this indicator.

Indicator: Number of Acres Supporting Northern Spotted Owl Life History Requirements

The four life history requirements of northern spotted owls are movement, roosting, foraging, and nesting (United States Department of Agriculture [USDA] and United States Department of Interior [USDOI] 1994). The stand conditions necessary for each of these life history requirements are as follows:

- **Movement**: Sufficient canopy cover for protection from predators and adequate flying space, including canopy lift (tree limbs off the ground) and tree densities low enough not to impede flight.
- **Roosting**: Adequate tree height, multiple tree and shrub layers for owls to move up and down in the canopy, a canopy deep enough to provide a thermal buffer (insulation) against temperature extremes, and sufficient canopy cover for protection from predators.
- **Foraging**: Adequate prey, which depends on the number of snags and amount of down wood, and a heterogeneous (varied) forest with multiple canopy layers that provide hunting perches to make catching prey easier.
- **Nesting**: Adequate number of trees from larger diameter classes, either large standing trees or snags, although on the Olympic Peninsula, large live trees are used for nesting approximately three times as often as snags (Forsman and Giese 1997).

For the No Action and Landscape alternatives, DNR developed four northern spotted owl stand-level models to assess the ability of state trust lands in the OESF to support these four life history requirements. These models, which evaluate output data from the analysis model, are specific to the Olympic Peninsula and incorporate stand-level habitat conditions such as snags and down wood.

Forest stands were given a habitat score for each life history requirement based on specific forest attributes (for example, down wood or snags). Scores ranged from 0 to 100, 100 being best. The minimum habitat score for supporting a life history requirement was assumed to be 50. For this indicator, DNR determined the number of forested acres on state trust lands in the OESF projected to have a habitat score of 50 and above for each life history requirement (refer to Appendix I for a detailed description of stand-level models).

DNR analyzed this indicator for the Pathways Alternative using qualitative techniques (refer to p. 3-17 through 3-18).

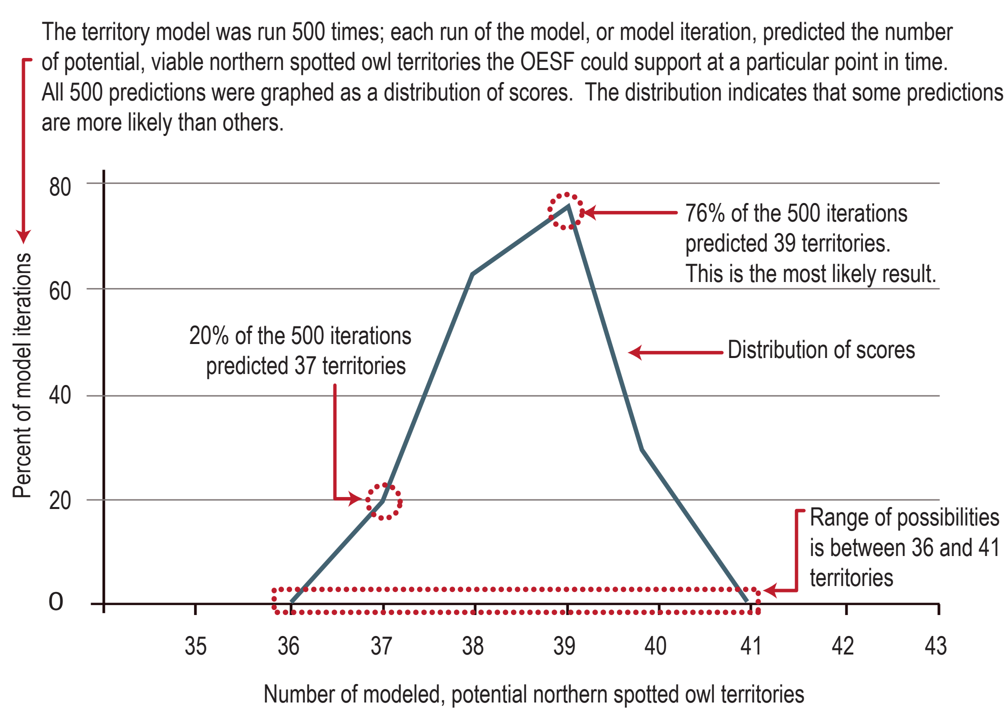
Indicator: Number of Modeled, Potential Northern Spotted Owl Territories

For this indicator, for the No Action and Landscape alternatives DNR evaluated how many modeled, potential northern spotted owl territories the OESF could support over time under each alternative (a territory is an area that an owl defends, while the home range of a northern spotted owl is the geographic area to which it normally confines its activity). DNR evaluated state trust lands in the OESF as well as lands within a 10-mile distance, mostly to the east, encompassing adjacent federal lands.

DNR developed a northern spotted owl territory model to identify areas in the OESF with the potential to support a northern spotted owl territory. The territory model evaluated habitat quality using a habitat score averaged from the results of the stand-level model for all four life history requirements. The model also considers territory size and the maximum amount of overlap a territory can have. These territories are hypothetical; they are not actual territories. While it is unlikely that northern spotted owls will behave as predicted by the model, the model provides an objective analysis of the landscape's ability to support them. The model was based on one developed by Sutherland and others (2007) for the former British Columbia Ministry of Forests and Range (now known as the Ministry of Forests, Lands and Natural Resource Operations). The model was informed by literature on northern spotted owl ecology specific to the Olympic Peninsula and by DNR's professional experience (refer to Appendix I).

To reflect uncertainty in how owls use the landscape, DNR ran the territory model 500 times per alternative.[8] Each model run, or iteration, predicted the number of potential northern spotted owl territories that the OESF could potentially support at a particular point in time, such as currently (Decade 0) or at the end of the analysis period (Decade 9). All 500 model predictions were then graphed as a distribution of scores (refer to Figure 3-29). The distribution showed that some predictions were more likely than others (refer to Appendix I for a detailed description of the territory model).

Figure 3-29. Example of a Distribution of Scores



The data used in the model for non-state trust lands in the OESF and the lands within the 10-mile buffer remained unchanged throughout the 100-year analysis period. In other words, the model did not account for the continued growth or reduction of habitat on non-state trust lands over time. Therefore, the projected increase in the number of modeled, potential territories in the OESF in this analysis is due to the increased capability of state trust lands to support northern spotted owls. It is expected, however, that there will be a substantial amount of habitat development on federal lands (USDA and USDOI 1994 and USDOI 1997) over the 100-year analysis period.

DNR analyzed this indicator for the Pathways Alternative using qualitative techniques (refer to p. 3-17 through 3-18).

■ Criterion and Indicators: Summary

Table 3-52 summarizes the criteria and indicators used in this analysis and how they were assessed for the No Action and Landscape Alternatives. For the Pathways Alternative, DNR used qualitative techniques (refer to p. 3-17 through 3-18) to assess all indicators except the number of acres of modeled northern spotted owl habitat.

Table 3-52. Criterion and Indicators for Northern Spotted Owls and how They Were Measured

Criterion/Indicator	How indicator was measured	Potential environmental impacts
Amount of habitat capable of providing support for the recovery of the Olympic Peninsula sub-population of northern spotted owls on adjacent federal lands/ Number of acres of modeled northern spotted owl habitat	The number of acres of Old Forest Habitat and Young Forest Habitat and better on state trust lands in the OESF	**Low**: The number of acres of Old Forest Habitat and Young Forest Habitat and better increases **Medium**: The number of acres of Old Forest Habitat and Young Forest Habitat and better stays the same **High**: The number of acres of Old Forest Habitat and Young Forest Habitat and better decreases
Amount of habitat capable of providing support for the recovery of the Olympic Peninsula sub-population of northern spotted owls on adjacent federal lands/ Number of acres supporting northern spotted owl life history requirements	The number of acres with a habitat score of at least 50 (on a scale of 0 to 100) for each northern spotted owl life history requirement (nesting, roosting, foraging, and movement) on state trust lands in the OESF	**Low**: The number of acres with habitat scores of 50 or above increases **Medium**: The number of acres with habitat scores of 50 or above remains the same **High**: The number of acres with habitat scores of 50 or above decreases

Table 3-52, Continued. Criterion and Indicators for Northern Spotted Owls and how They Were Measured

Criterion/Indicator	How indicator was measured	Potential environmental impacts
Amount of habitat capable of providing support for the recovery of the Olympic Peninsula sub-population of northern spotted owls on adjacent federal lands/ Number of modeled potential northern spotted owl territories	The number of modeled potential northern spotted owl territories the entire OESF could support over time, reported by decade using a territory model	**Low**: The number of territories increases **Medium**: The number of territories stays the same **High**: The number of territories decreases

Current Conditions and Results

Indicator: Number of Acres of Modeled Northern Spotted Owl Habitat

NO ACTION AND LANDSCAPE ALTERNATIVES

Table 3-53 and 3-54 show the current and projected acres of modeled northern spotted owl habitat in each landscape. By the end of the 100-year analysis period, the estimated number of acres of modeled Old Forest Habitat and Young Forest Habitat and better on state trust lands in the OESF[9] is projected to increase in each of the 11 landscapes (refer to Appendix I for the number of acres of Old Forest Habitat and Young Forest Habitat and better by decade and landscape).

Table 3-53. Current and Projected Acres (and Percent) of Modeled Old Forest Habitat on State Trust Lands in the OESF at the end of the Analysis Period Under the No Action and Landscape Alternatives, by Landscape

Landscape (acres)	Current conditions: Old Forest Habitat acres (percent)	Results: Old Forest Habitat acres (percent) No Action Alternative in Decade 9	Results: Old Forest Habitat acres (percent) Landscape Alternative in Decade 9
Clallam (17,276)	314 (2%)	3,492 (20%) ●	3,485 (20%) ●
Clearwater (55,203)	14,101 (26%)	18,587 (34%) ●	18,546 (34%) ●
Copper Mine (19,246)	3,107 (16%)	4,363 (23%) ●	3,991 (21%) ●
Dickodochtedar (28,047)	2,570 (9%)	6,274 (22%) ●	6,213 (22%) ●
Goodman (23,799)	4,822 (20%)	8,936 (37%) ●	8,667 (36%) ●
Kalaloch (18,122)	2,472 (14%)	4,845 (27%) ●	4,796 (26%) ●
Queets (20,807)	5,179 (25%)	6,557 (31%) ●	6,534 (31%) ●
Reade Hill (8,479)	1,933 (23%)	4,268 (50%) ●	4,154 (49%) ●
Sekiu (10,014)	75 (1%)	2,095 (21%) ●	2,099 (21%) ●
Sol Duc (19,146)	643 (3%)	4,715 (25%) ●	4,613 (24%) ●
Willy Huel (37,428)	7,520 (20%)	10,597 (28%) ●	13,105 (35%) ●

● **Low impact**

Table 3-54. Current and Projected Acres (and Percent) of Modeled Young Forest Habitat and Better on State Trust Lands in the OESF at the end of the Analysis Period Under the No Action and Landscape Alternatives, by Landscape [Amount of Old Forest Habitat in Brackets]

Landscape (acres)	Current conditions	Results	
	Young Forest Habitat and better acres (percent)	Young Forest Habitat and better acres (percent) No Action Alternative in Decade 9	Young Forest Habitat and better acres (percent) Landscape Alternative in Decade 9
Clallam (17,276)	5,976 (35%) [314]	7,475 (43%) [3,492] ●	7,464 (43%) [3,485] ●
Clearwater (55,203)	17,206 (31%) [14,101]	30,780 (56%) [18,587] ●	28,522 (52%) [18,546] ●
Copper Mine (19,246)	3,815 (20%) [3,107]	8,353 (43%) [4,363] ●	7,848 (41%) [3,991] ●
Dickodochtedar (28,047)	7,629 (27%) [2,570]	13,602 (48%) [6,274] ●	12,179 (43%) [6,213] ●
Goodman (23,799)	7,214 (30%) [4,822]	12,923 (54%) [8,936] ●	12,682 (53%) [8,667] ●
Kalaloch (18,122)	4,428 (24%) [2,472]	9,091 (50%) [4,845] ●	8,345 (46%) [4,796] ●
Queets (20,807)	6,758 (33%) [5,179]	10,822 (52%) [6,557] ●	10,015 (48%) [6,534] ●
Reade Hill (8,479)	3,971 (47%) [1,933]	5,701 (67%) [4,268] ●	5,410 (64%) [4,154] ●
Sekiu (10,014)	1,499 (15%) [75]	4,284 (43%) [2,095] ●	4,509 (45%) [2,099] ●
Sol Duc (19,146)	5,325 (28%) [643]	9,011 (47%) [4,715] ●	8,255 (43%) [4,613] ●
Willy Huel (37,428)	8,513 (23%) [7,520]	15,213 (41%) [10,597] ●	15,905 (42%) [13,105] ●

● **Low impact**

When considering all state trust lands together, the projected trend over time is an increase in both modeled Old Forest Habitat and Young Forest Habitat on state trust lands, as indicated by Chart 3-31 and Chart 3-32.

Chart 3-31. Projected Trend of Modeled Northern Spotted Owl Habitat on State Trust Lands in the OESF, No Action Alternative

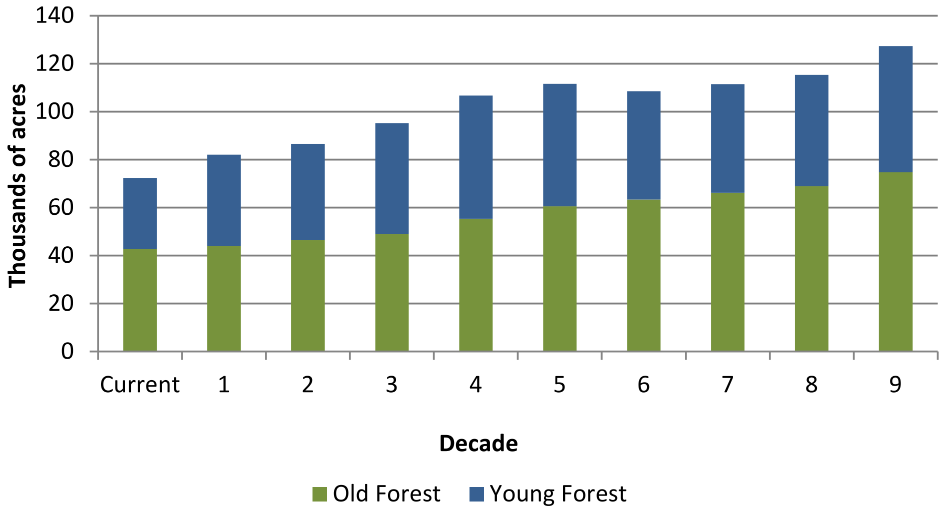
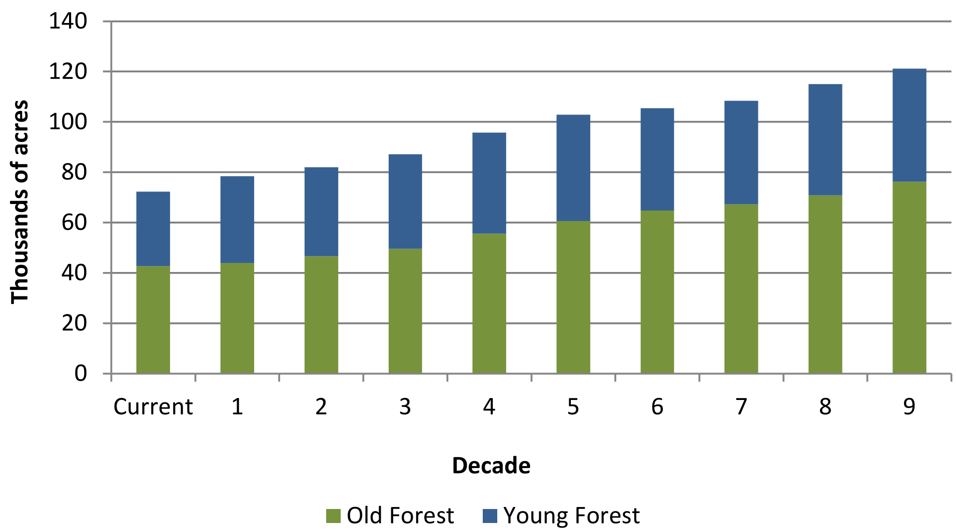


Chart 3-32. Projected Trend of Modeled Northern Spotted Owl Habitat on State Trust Lands in the OESF, Landscape Alternative



The potential environmental impact of the No Action and Landscape alternatives for this indicator is considered **low**. The number of acres of modeled Old Forest Habitat and Young Forest Habitat and better in each landscape is projected to increase by the end of the analysis period for the No Action and Landscape alternatives. Considering all landscapes together, the trend over time is an increase in modeled Old Forest Habitat and Young Forest Habitat. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

Tables 3-55 shows the range in the number of acres of modeled northern spotted owl habitat that may develop under the Pathways Alternative by the end of the 100-year analysis period. Both tables show the lower and higher bounds of the range: at the lower bound, habitat not necessary to maintain thresholds is harvested during the maintenance and enhancement phase in each landscape. The remainder of the range represents varying levels of harvest of these stands during the maintenance and enhancement phase.. DNR expects the actual amount of habitat to fall somewhere within this range.

By the end of the 100-year analysis period, the estimated number of acres of modeled Old Forest Habitat and Young Forest Habitat and better on state trust lands in the OESF for the Pathways Alternative is projected to increase in each of the 11 landscapes at either end of the range (refer to Appendix I for the number of acres of Old Forest Habitat and Young Forest Habitat and better by decade and landscape).

Table 3-55. Projected Acres (and Percent) of Modeled Northern Spotted Owl Habitat on State Trust Lands in the OESF Under the Pathways Alternative at the end of the Analysis Period, by Landscape

Landscape (acres)	Current conditions		Results	
	Old Forest Habitat acres (percent)	Young Forest Habitat and better acres (percent)	Old Forest Habitat acres (percent) Pathways Alternative in Decade 9	Young Forest Habitat acres (percent) Pathways Alternative in Decade 9
Clallam (17,276)	314 (2%)	5,976 (35%)	3,467 - 5,618 (20 - 33%) ●	6,910 - 9,149 (40 - 53%) ●
Clearwater (55,203)	14,101 (26%)	17,206 (31%)	21,352 - 21,634 (39%) ●	23,770 - 29,423 (43 - 53%) ●
Copper Mine (19,246)	3,107 (16%)	3,815 (20%)	4,521 - 4,679 (24%) ●	7,698 - 8,474 (40 - 44%) ●
Dickodochtedar (28,047)	2,570 (9%)	7,629 (27%)	6,501 - 7,519 (23 - 27%) ●	11,219 - 13,191 (40 - 47%) ●
Goodman (23,799)	4,822 (20%)	7,214 (30%)	9,570 - 11,321 (40 - 48%) ●	10,052 - 14,015 (42 - 59%) ●
Kalaloch (18,122)	2,472 (14%)	4,428 (24%)	5,350 - 7,216 (30 - 40%) ●	7,248 - 9,771 (40 - 54%) ●
Queets (20,807)	5,179 (25%)	6,758 (33%)	6,900 - 6,928 (33%) ●	8,323 - 10,264 (40 - 49%) ●
Reade Hill (8,479)	1,933 (23%)	3,971 (47%)	4,154 (49%)[a] ●	5,410 (64%)[a] ●
Sekiu (10,014)	75 (1%)	1,499 (15%)	2,099 (21%)[a] ●	4,509 (45%)[a] ●
Sol Duc (19,146)	643 (3%)	5,325 (28%)	4,819 - 6,079 (25 - 32%) ●	7,654 - 9,353 (40 - 54%) ●
Willy Huel (37,428)	7,520 (20%)	8,513 (23%)	12,452 - 18,380 (33 - 49%) ●	14,971 - 20,900 (40 - 56%) ●

● **Low impact**

[a] In landscapes for which DNR selected Pathways 1 and 2 only, results are the same as the Landscape Alternative.

When considering all state trust lands together, the projected trend of habitat development under the Pathways Alternative is an increase in both modeled Old Forest Habitat and Young Forest Habitat on state trust lands, as indicated by Chart 3-33 and Chart 3-34. The trend is the same for both the lower and upper bounds.

Chart 3-33. Projected Trend of Modeled Northern Spotted Owl Habitat on State Trust Lands in the OESF, Pathways Alternative (Lower Bound)

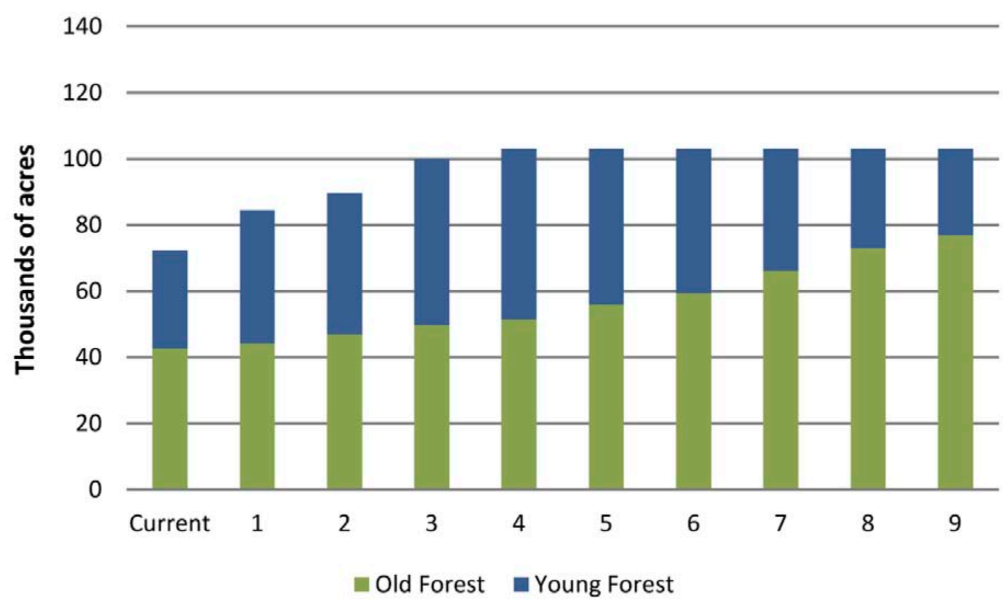
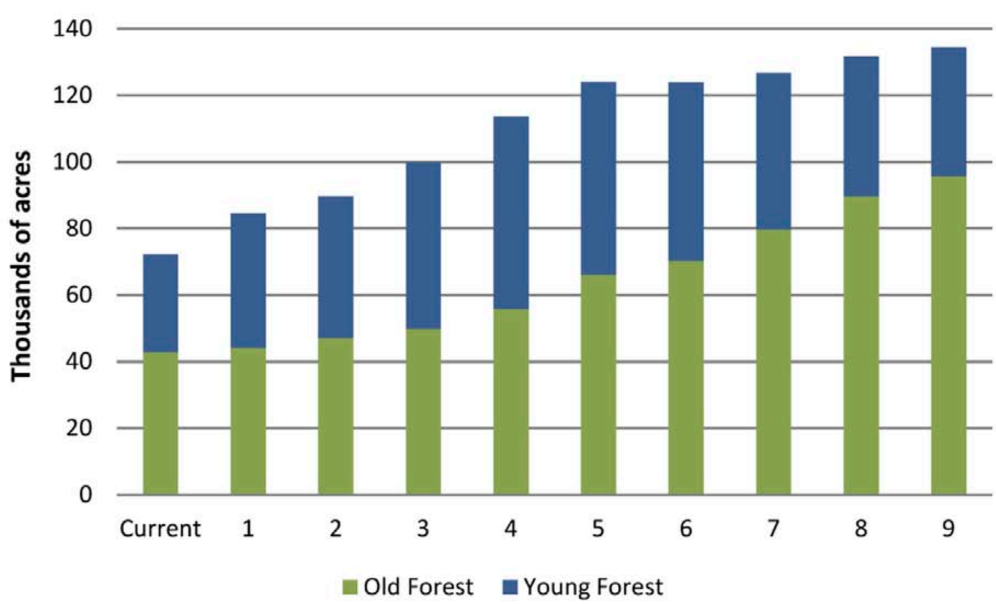


Chart 3-34. Projected Trend of Modeled Northern Spotted Owl Habitat on State Trust Lands in the OESF, Pathways Alternative (Upper Bound)



Because the number of acres of modeled Old Forest Habitat and Young Forest Habitat and better in each landscape is projected to increase by the end of the analysis period for the Pathways Alternative, the potential environmental impact of the alternatives for this indicator is considered **low.** Considering all landscapes together, the trend over time is an increase in modeled Old Forest Habitat and Young Forest Habitat. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

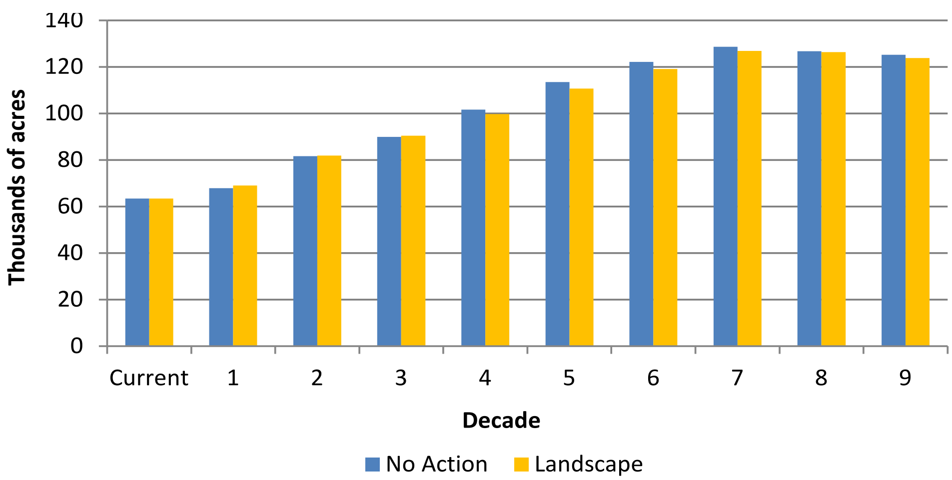
Indicator: Number of Acres Supporting Northern Spotted Owl Life History Requirements

NO ACTION AND LANDSCAPE ALTERNATIVES

Habitat scores for northern spotted owl life history requirements are a way to represent the general trend of habitat development on state trust lands in the OESF. For this analysis, habitat scores of 50 and above (on a scale of 0 to 100) indicate that habitat provides moderate to full support for owl life history requirements.

Chart 3-35 shows that the number of acres with habitat scores of 50 or above is projected to increase over the 100-year analysis period for both the No Action and Landscape alternatives. In fact, the number of acres with these scores is projected to approximately double by Decade 6. Similarly, the number of acres with habitat scores of 75 to 100 also is projected to increase (refer to Appendix I for these results).

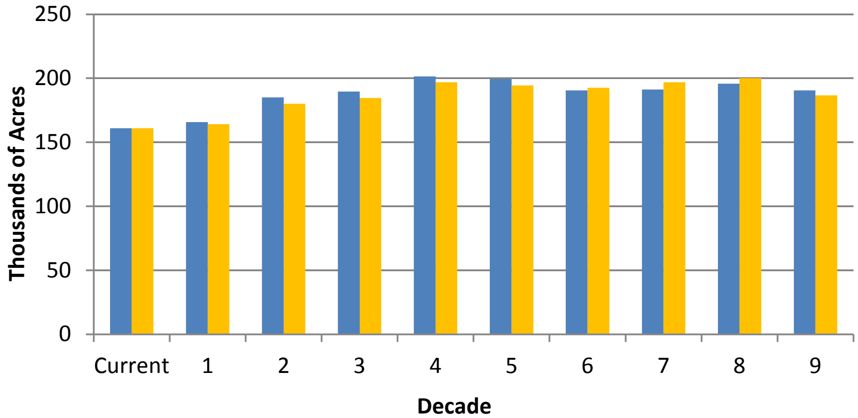
Chart 3-35. Projected Acres of State Trust Lands in the OESF with Habitat Scores of 50 or Above



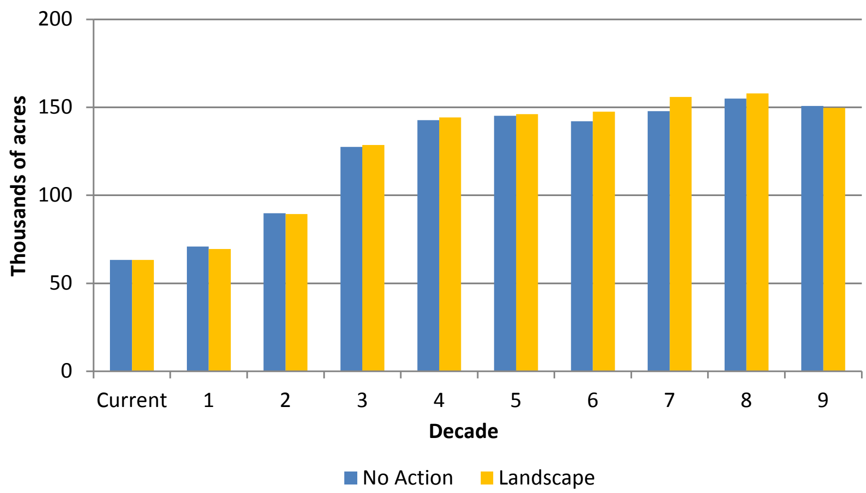
For each individual life history requirement, the differences between the alternatives are negligible. Both the No Action and Landscape alternatives show that the projected number of acres with habitat scores of 50 or above for all four life history requirements increases over 100 years (Chart 3-36 A through D on p. 3-303 and 3-304). The number of acres projected for foraging (B) increase the most, followed by roosting (C), then nesting (D), with the number of acres for movement (A) increasing the least. The slow increase in the number of acres for nesting may be due to the time it takes forests to develop elements of structural complexity such as large snags and down wood. The small increase in the number of acres for movement suggests that state trust lands in the OESF already have forest conditions that allow movement.

Chart 3-36. Number of Projected Acres With Habitat Scores of 50 or Above for A) Movement, B) Foraging, C) Roosting, and D) Nesting

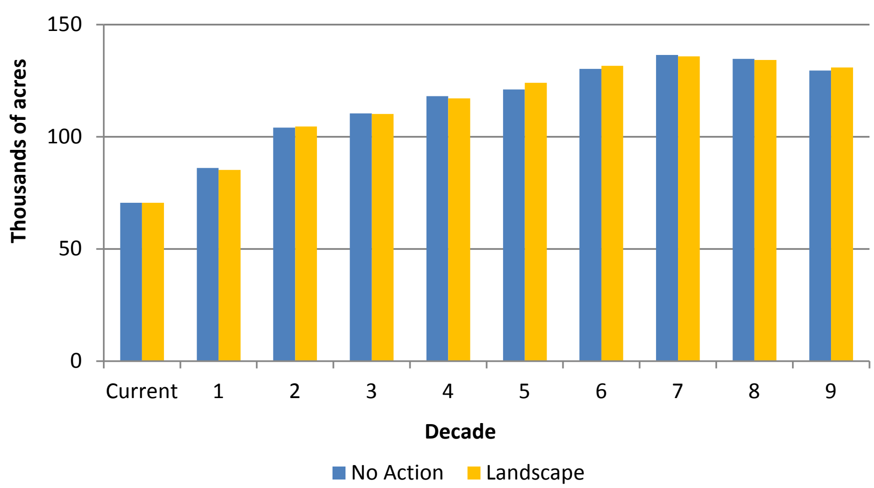
A) Movement



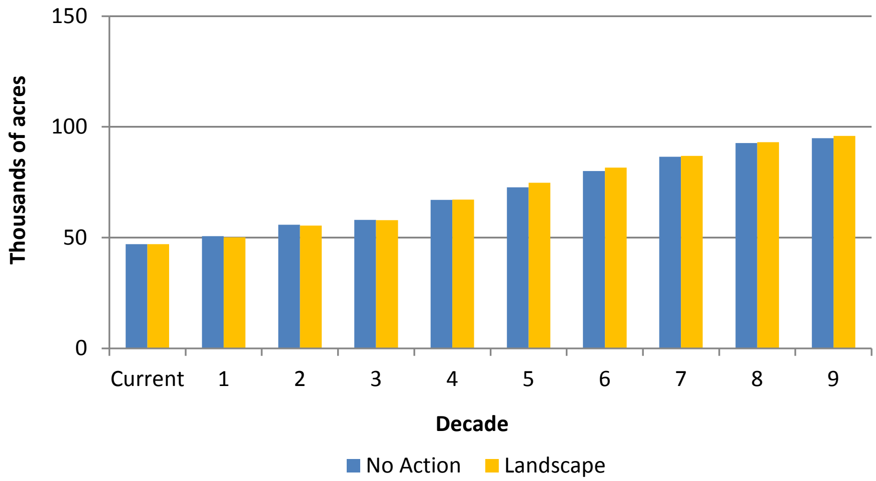
B) Foraging



C) Roosting



D) Nesting



Because the ability of state trust lands to support northern spotted owl life history requirements is expected to increase over time, the potential environmental impact of the No Action and Landscape alternatives for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

The stand-level model evaluates output data from the analysis model. Because DNR did not run the analysis model for the Pathways Alternative, it was not possible to run the stand-level model to generate habitat scores for the Pathways Alternative. However, habitat scores under the Pathways Alternative are anticipated to be similar to, or slightly higher than, the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Following, DNR discusses expected trends in how operable and deferred areas may support northern spotted owl life history requirements under the Pathways Alternative.

Operable Areas

In general, DNR expects operable areas to provide a level of support to northern spotted owl life history requirements that is similar to the Landscape Alternative. Areas that are selected for passive or active management under the Pathways Alternative, however, may provide more support over time than they would under the Landscape Alternative. For example, areas of existing habitat selected for passive management (Pathways 3 and 4) should continue developing characteristics of structurally complex forests for as long as those pathways remains in effect. For this analysis, DNR assumed that areas selected for active management (Pathway 5) will transition to Young Forest Habitat immediately after thinning and develop into Old Forest Habitat through natural forest growth four decades later. Young or Old Forest Habitat in operable areas not needed to maintain thresholds will be available for harvest (thinning or stand replacement) during the maintenance and enhancement phase. The lower bound of habitat development is shown in Chart 3-33 on p. 3-201.

Deferred Areas

DNR also expects deferred areas to provide a level of support to northern spotted owl life history requirements that is similar to the Landscape Alternative. However, areas that are selected for active management under the Pathways Alternative (Pathway 7) to create or accelerate development of habitat may provide more support over time than they would under the Landscape Alternative.

Because the ability of state trust lands to support northern spotted owl life history requirements is expected to increase over time, similar to the Landscape Alternative, the potential environmental impact of the Pathways Alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Number of Modeled, Potential Northern Spotted Owl Territories

NO ACTION AND LANDSCAPE ALTERNATIVES

The number of modeled, potential northern spotted owl territories is similar for the No Action and Landscape alternatives. By Decade 6, the most likely number of territories increases from 39 (current condition) to 46 for the No Action Alternative and 47 for the Landscape Alternative (refer to Chart 3-37). By Decade 9, the No Action Alternative has one more potential territory than the Landscape Alternative (refer to Chart 3-38 on p. 3-206).

Chart 3-37. Number of Modeled, Potential Northern Spotted Owl Territories in the OESF, Decade 6

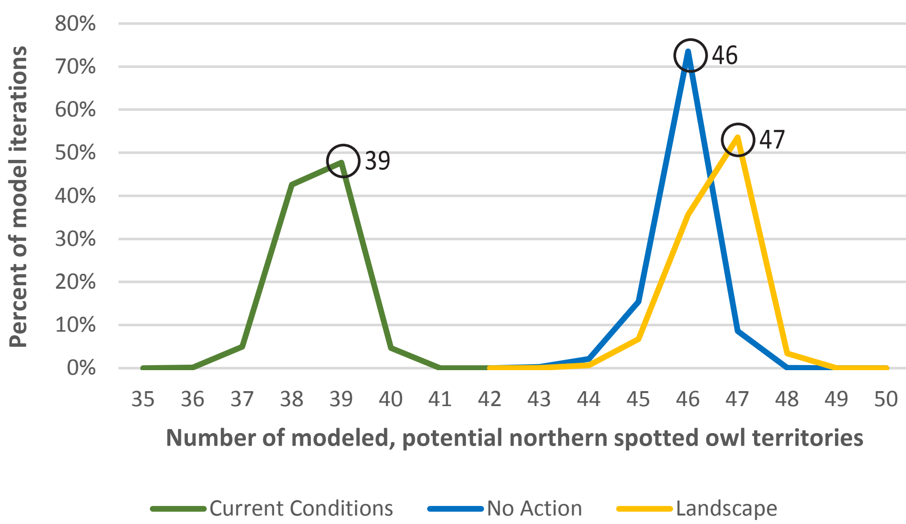
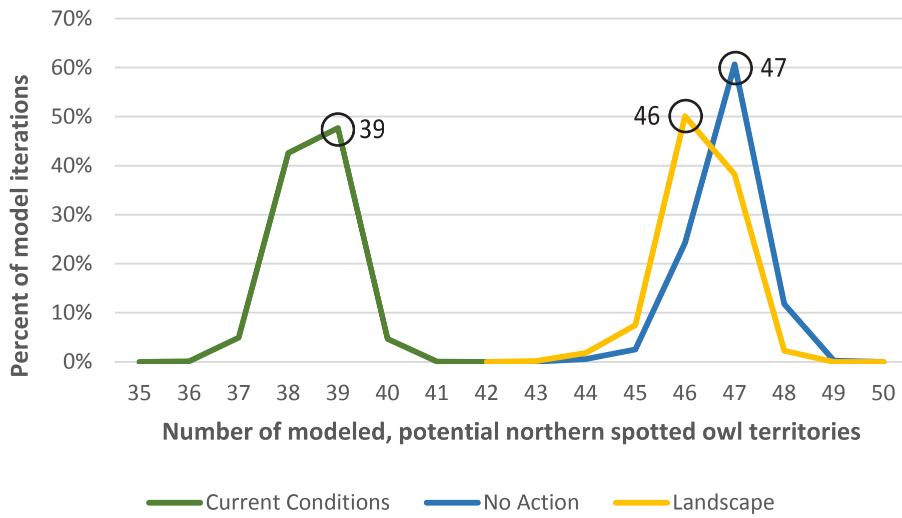


Chart 3-38. Number of Modeled, Potential Northern Spotted Owl Territories in the OESF, Decade 9



As previously stated, the habitat input data used in the model for non-state trust lands in the OESF was held constant throughout the 100-year analysis period. Therefore, the increase in the number of modeled, potential territories in the OESF in this analysis is due to the improved capability of state trust lands to support northern spotted owls.

Because the number of modeled, potential northern spotted owl territories is projected to increase, the potential environmental impact of the No Action and Landscape alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

It was not possible to run the territory model for the Pathways Alternative because the territory model requires habitat scores as input data. As stated under the previous indicator, DNR did not generate habitat scores for this alternative.

However, DNR anticipates that the number of modeled, potential northern spotted owl territories under the Pathways Alternative will be similar to, or slightly higher than, the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Under the Pathways Alternative, DNR will select stands of non-habitat in operable (Pathway 5) and deferred areas (Pathway 7) for active management. In selecting stands, DNR will consider patch size and proximity to existing northern spotted owl habitat on DNR-managed lands or adjacent federal lands. While the Pathways Alternative is not anticipated to dramatically change habitat patch sizes, patch size could increase slightly under this alternative as compared to the Landscape Alternative, which in turn could increase the number of modeled, potential northern spotted owl territories.

Because the number of modeled, potential northern spotted owl territories is expected to increase over time, similar to the Landscape Alternative, the potential environmental impact of the Pathways Alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Summary of Potential Impacts

DNR's analysis shows an increase in the amount of northern spotted owl habitat over the 100-year analysis period. Table 3-56 provides an overview of the potential environmental impacts on northern spotted owls when the criterion and all of the indicators are considered. For this analysis, only high impacts were considered potentially significant impacts. DNR did not identify probable significant adverse environmental impacts from any of the alternatives (No Action, Landscape, Pathways) for any indicator used for this topic area.

Table 3-56. Summary of Potential Impacts on Northern Spotted Owl Habitat, by Alternative

Criteria	Indicators	No Action Alternative	Landscape Alternative	Pathways Alternative
Amount of habitat capable of providing support for the recovery of the Olympic Peninsula sub-population of northern spotted owls	Number of acres of modeled northern spotted owl habitat	Low ●	Low ●	Low ●
	Number of acres supporting northern spotted owl life history requirements	Low ●	Low ●	Low ●
	Number of viable northern spotted owl territories	Low ●	Low ●	Low ●

● **Low impact**

What are the Potential Short-Term Impacts on Northern Spotted Owls?

As a way to assess the potential short-term impacts of the alternatives on northern spotted owls, DNR assessed the amount of harvest the analysis model recommended in owl circles in the first decade of the analysis period under each alternative.

As explained previously, DNR did not run the analysis model for the Pathways Alternative. To determine acres of projected harvest for the Pathways Alternative, DNR used the harvest schedule it modified in a post process (outside the analysis model) to incorporate the pathways.

Owl circles are a simplified representations of an owl's home range. Field studies determined that the median home range of northern spotted owls on the Olympic Peninsula can be represented by a circle with a 2.7-mile radius centered at a nest or detection point. Status 1 owl circles are designated when a male and a female owl are found close together, a female is on the nest, or one or both adults are found with young (WAC 222-16-010). Since 2001, no northern spotted owls have been surveyed or detected within previously occupied owl circles on state trust lands in the OESF. These circles, however, represent the last known occupied habitat and may represent the habitat most likely to be re-occupied. As part of implementing the HCP, DNR shifted from managing habitat in owl circles to managing habitat on a landscape scale per habitat thresholds.

Results of this analysis are shown in Table 3-57. The acres shown in this table are used only to assess potential environmental impacts; they are neither management targets nor planned amounts of harvest in owl circles.

Table 3-57. Acres of Projected Harvest Activities on State Trust Lands in all Status 1 Owl Circles in the OESF (2011–2021)

	No Action Alternative			Landscape Alternative			Pathways Alternative		
Harvest type	Non-habitat acres	Young Forest Habitat acres	Old Forest Habitat acres	Non-habitat acres	Young Forest Habitat acres	Old Forest Habitat acres	Non-habitat acres	Young Forest Habitat acres	Old Forest Habitat acres
Variable retention harvest	7,684	0	0	8,119	0	0	7,595	0	0
Variable density thinning	823	3,417	0	666	2,200	0	665	1,060	0
Active management (thinning), Pathways Alternative only	0	0	0	0	0	0	1,024	0	0
Total per habitat type	8,507	3,417	0	8,785	2,200	0	9,284	1,060	0
Total all activities in combined habitat types			11,924			10,985			10,344

DNR and USFWS analyzed the impacts of harvest on northern spotted owl circles as part of the 1996 *Draft EIS for the Habitat Conservation Plan* and 1998 *Final (Merged) EIS for the Habitat Conservation Plan* (completed by DNR, USFWS, and NOAA Fisheries), and the USFWS biological opinion (USFWS 1997) completed for DNR's HCP. All of these documents anticipate that management activities implemented under the HCP would result in incidental take of territorial northern spotted owls (refer to page p. 4-55 through 4-57 of the *Draft EIS for the Habitat Conservation Plan*). The USFWS incidental take permit (USFWS 1997) anticipated that in each decade, between 3,330 and 16,300 acres of habitat in owl circles on state trust lands in the OESF would be harvested. The amounts in Table 3-57 are within or below that range.

As a reminder, the analysis model was not constrained to the current sustainable harvest level. Refer to the introduction of this chapter for more information on the harvest schedule analyzed.

■ Considered but not Analyzed

Barred Owls


Barred Owl

Barred owls are native to eastern North America and have expanded their range to the west (USFWS 2012). Barred owls were first detected in the Olympic Peninsula in 1985 (Sharpe 1989) and the number of sightings has steadily increased (Forsman and others 2011). The range of the barred owl now completely overlaps with the range of the northern spotted owl (USFWS 2012).

Anthony and others (2006) found evidence suggesting that barred owls affect northern spotted owl survival on the Olympic Peninsula negatively. Weins (2012) found that competition for territory space between high densities of barred owls and spotted owls can constrain the availability of critical resources required for successful recruitment and reproduction of northern spotted owls.

Barred owls are recognized as an “extremely pressing and complex” threat requiring specific and immediate actions (USFWS 2011b). The USFWS is currently determining if the removal of barred owls would increase northern spotted owl site occupancy and improve population trends. Results from these experiments may be used to inform future decisions by the USFWS on potential long-term management strategies for barred owls (USFWS 2012). However, although studies are being conducted, the degree to which competition with barred owls will affect northern spotted owl recovery is not fully understood (Gutiérrez and others 2006). Addressing the threat from habitat loss is relatively straightforward with predictable results. However, addressing a large-scale threat of one raptor to another, closely related raptor has many uncertainties (USFWS 2011). For example, although impacts of barred owls on northern spotted owls are well documented (Duggar and others 2011, Forsman and others 2011, USFWS 2011), little is known about how forest management might influence the competition between these species. Recent studies of barred owl removal from previous northern spotted owl territories have shown that northern spotted owls reoccupy these territories when barred owls are removed (Diller and others 2016). However, this study did not include data on how forest management activities might influence the interaction between these two species. Because of this lack of understanding, evaluating the potential impacts of the management alternatives on competition between barred and northern spotted owls was not feasible.

Roads

Wasser and others (1997) found that male northern spotted owls living within a quarter-mile of a logging road had elevated levels of corticosterone (a stress hormone). Females showed no increase in these levels related to road proximity. Hayward and others (2011) found a strong association of decreased reproductive success of northern spotted owls and nearby roads with loud traffic. Weigl (2007) reported that wide, exposed roads act as a barrier to movement for northern flying squirrels, the owl's primary prey species.

Road use in the OESF is limited because of its isolation from major population centers; most road traffic is associated with forest management activities. DNR does not believe that road traffic within the OESF poses an adverse impact to northern spotted owls. Also, further research is needed to identify the impacts of roads on northern flying squirrel populations. Therefore, the potential impacts of existing roads on northern spotted owls were not analyzed for this FEIS.

Over the 100-year analysis period, DNR may build small sections of new road through Young Forest Habitat to provide access to planned timber harvests. Because road building is a site-specific action that is evaluated separately through SEPA when it is proposed, it was not analyzed for this FEIS.

Section Notes

1. The other two subspecies are *Strix occidentalis occidentalis* (California spotted owl) and *Strix occidentalis lucida* (Mexican spotted owl).
2. Under the Endangered Species Act, an endangered species is one that is in danger of extinction throughout all or a significant portion of its range; a threatened species is one that is likely to become endangered within the foreseeable future.
3. A five-year review is an Endangered Species Act-mandated process that is conducted to ensure that the listing classification of a species as either threatened or endangered is still accurate. It is a verification process with a definitive outcome: the review either does or does not indicate that a change in classification may be warranted.
4. Isolated populations are vulnerable to genetic, environmental, and demographic changes (USFWS 1992).
5. Demographic support refers to the contribution of individual territorial spotted owls or clusters of spotted owl sites to the stability and viability of the entire population (Hanson and others 1993). Maintenance of species distribution refers to supporting the continued presence of the northern spotted owl populations in as much of its historic range as possible (Thomas and others 1990; USFWS 1992). Dispersal refers to the movement of juvenile, sub-adult, and adult animals (northern spotted owls) from one sub-population to another. For juvenile northern spotted owls, dispersal is the process of leaving the natal (birth) territory to establish a new territory (Forsman and others 2002; Miller and others 1997; Thomas and others 1990).
6. Life history requirements are the environmental conditions necessary for completing life cycles.
7. Recent studies of spotted owl habitat relationships corroborate the earlier understanding of the habitat requirements of the species used in the HCP definitions (Courtney and others 2004). Indicators used in this evaluation are based on the HCP and the northern spotted owl procedure (Northern Spotted Owl Management Westside, Appendix E). These habitat definitions were built

into model outputs representing the growth and yield of forest stands under different silvicultural treatments. The future projections of habitat were simulated using DNR's analysis model (Appendix D). The habitat definitions are reported in this analysis as aggregations of Young Forest Habitat (young forest marginal, sub-mature) and Old Forest Habitat (Type A, Type B, high quality nesting, and additional forests identified through aerial photo-interpretation).

8. This technique is known as a Monte-Carlo simulation. In a Monte-Carlo simulation, one repeatedly runs a simulation and randomly varies one or more parameters.

9. The estimated acres of northern spotted habitat in Tables 3-53 through 3-55 are different from acreages reported in other DNR documents because these estimates were generated using different methodologies. For example, when the HCP was written, DNR used the best available data, which was stand age. Since stand age only describes the age of the stand, not its structure, DNR made assumptions that forest stands would become habitat when they reached a certain age. This methodology was found to overestimate the amount of habitat present. Currently, DNR uses stand structure (such as snags, tree diameter, and tree height, identified using forest inventory data) to estimate the amount of habitat present.

This page intentionally left blank.

Climate Change

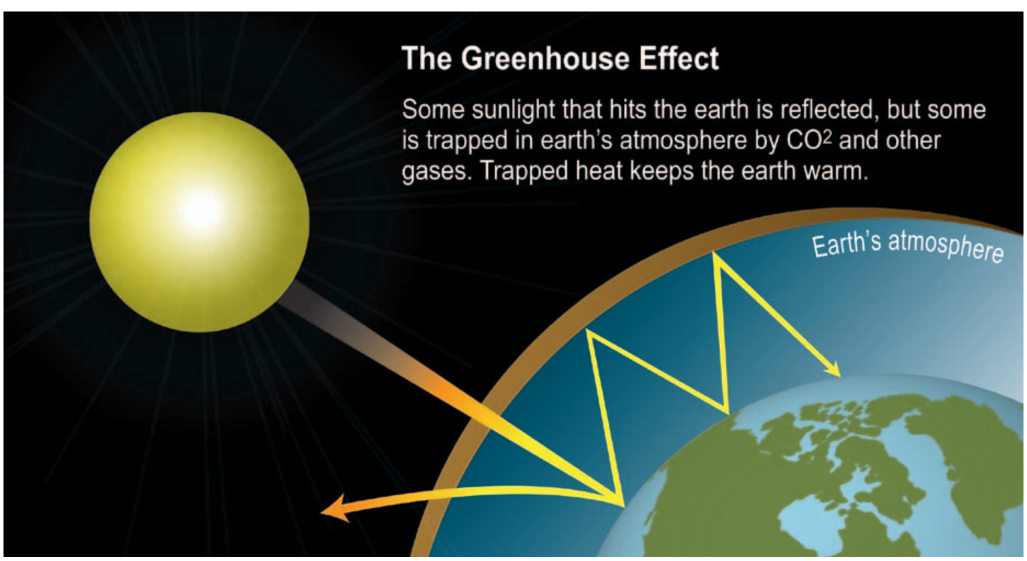
What is Climate Change?

Climate change is a change in average temperature and weather patterns that occurs on a regional or global scale over decades to centuries. Climate change is closely linked to a global rise in temperature, often referred to as global warming (Ecology 2011b).

The earth is naturally warmed by the greenhouse effect. Greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, trap heat from the sun and warm the atmosphere much like a greenhouse (refer to Figure 3-30). However, when the volume of greenhouse gases in the atmosphere increases to a certain point, because of natural or human causes, global temperatures begin to rise (Ecology 2011b).

Current science suggests a link between global warming and human activity over the last century. Two possible causes are the burning of fossil fuels and deforestation (Karl and others 2006, Intergovernmental Panel on Climate Change 2007a, Ecology 2011b). Burning fossil fuels (coal, oil, and gas) releases greenhouse gases, particularly carbon dioxide, to the atmosphere. Deforestation reduces the number of trees available to remove carbon dioxide from the atmosphere, contributing to a net rise in greenhouse gases. Deforestation often is a result of changing land use patterns.

Figure 3-30. Greenhouse Effect



Adapted from Ecology, http://www.ecy.wa.gov/climatechange/whatis.htm

When discussing climate change, it is important to distinguish between climate change, climate variability, and weather. **Climate change** is a long-term trend, measured over decades or centuries. **Climate variability** is measured on a shorter scale, such as year-to-year or decade-to-decade. **Weather** is experienced daily and seasonally (Littell and others 2009).

In the Pacific Northwest, climate variability is strongly affected by the Pacific Ocean—in particular, by two large-scale patterns caused by changes in ocean temperature: the El Niño/Southern Oscillation and the Pacific Decadal Oscillation. For a discussion of these two oscillations, refer to Appendix O.

▪ Why is Climate Change a Concern?

Photo courtesy Federal Emergency Management Agency

Climate change, which results in long-term shifts in weather and temperature, can affect human populations and natural systems in various ways, some catastrophic. Examples may include increases in the number and severity of storms, extreme high temperatures, prolonged periods of drought, severe flooding, and a rise in sea level. Climate change is not expected to affect all areas of the earth in the same way. For example, some areas may experience drought while others will experience increased rainfall (Huber and Gulledge 2011, Intergovernmental Panel on Climate Change 2007b).

In Washington, the anticipated impacts of climate change may include warmer temperatures, reduced snowpack, increased frequency of extreme weather events, and a rise in sea level (Ecology 2011, USFWS 2011b). Appendix O contains detailed discussions of these impacts.

Climate change may have impacts on the OESF; a discussion of possible impacts is provided at the end of this section. However, it is not possible to predict and measure exactly what those impacts are likely to be. Instead, this analysis considers the extent to which forest stands on state trust lands in the OESF may help sequester carbon.

▪ What is the Criterion for Climate Change?

The criterion is **carbon sequestration (storage)**. Carbon that is sequestered does not enter the atmosphere as a greenhouse gas (carbon dioxide) or contribute to global warming.

■ What are the Indicators for Climate Change?

The indicators used to assess the criterion are the **amount of carbon sequestered in forest stands** and the **difference between the amount of carbon sequestered and emitted (released)**. These indicators were selected based on DNR's expertise, existing scientific information, and current data.

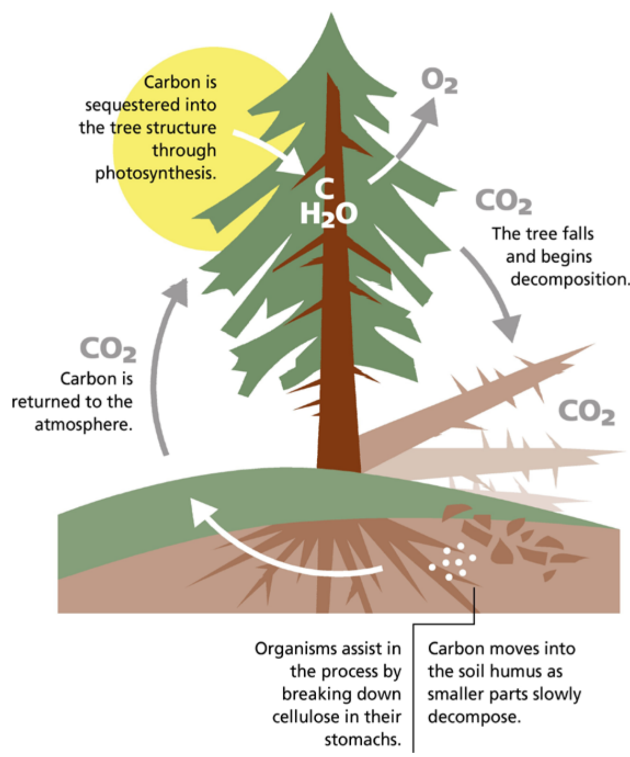
■ How Were the Indicators Analyzed?

Following, DNR describes the quantitative process it used to analyze potential environmental impacts of the No Action and Landscape alternatives. For the Pathways Alternative, DNR identified potential impacts using qualitative techniques (refer to p. 3-17 through 3-18).

Indicator: Amount of Carbon Sequestered in Forest Stands

For this indicator, DNR considered whether the total amount of carbon sequestered in forest stands on state trust lands in the OESF is projected to increase or decrease over the 100-year analysis period.

Figure 3-31. Carbon Sequestration and Movement Through the Decomposition Cycle



Carbon is sequestered in forest stands through the process of photosynthesis. Trees (and other plants) absorb carbon dioxide from the atmosphere and, at the cellular level, combine it with water to form sugar (glucose) and oxygen (Figure 3-31). The tree uses some of this sugar as energy for growth, converts the remainder to starch, and stores it as wood, bark, needles/leaves, and roots (Carter 1996). Through this process, forest stands can absorb large quantities of carbon dioxide and sequester carbon for potentially long periods of time (McPherson and Simpson 1999). Carbon is released over time through decomposition or wildfire, and the cycle begins again.

Forests sequester carbon primarily in live trees (Smith and others 2006). In general, most of the carbon sequestered in a live tree is in the trunk (up to 51 percent), while branches and stems sequester 30 percent, and the below-ground root biomass holds 18 to 24 percent. Two to five percent of sequestered carbon is in the leaves or needles (McPherson and Simpson 1999).

The amount of carbon sequestered in a forest stand depends on factors such as tree growth, mortality, species composition, age distribution, structure class, time between harvests, and forest health (Ryan and others 2010). Newly planted forests accumulate carbon rapidly for several decades; sequestration declines as trees mature and growth slows. Once a tree dies, it becomes either a standing dead tree or down woody debris on the forest floor.[1] It can take several decades or longer for large trees to decay. Smaller pieces of wood decompose faster than larger pieces and therefore return carbon to the atmosphere faster than larger ones. Old forests generally store considerable amounts of carbon in standing dead trees or down woody debris (DNR 2004).

Carbon sequestration also differs by forest type. Forests in the Pacific Northwest have a high potential for carbon storage because trees grow quickly, live for a long time, decompose slowly, and have a relatively low wildfire frequency (Ryan and others 2010).

Different components of a forest stand, such as live trees or standing dead trees, store different amounts of carbon. To make it easier to analyze and compare the amounts of carbon sequestered over time, these components are separated into pools (categories). Table 3-58 lists the pools used in this analysis.

Table 3-58. Forest Stand Carbon Pools

Forest stand carbon pool	Description
Live trees	Live trees with a diameter at breast height of at least 1 inch; includes tree trunk, coarse roots, branches, and foliage.
Standing dead trees	Standing dead tree with a diameter at breast height of at least 1 inch; includes tree trunk, coarse roots, and branches.
Understory vegetation	Live vegetation; includes shrubs, bushes, and tree trunk, roots, branches, and foliage of seedlings (trees less than 1-inch diameter at breast height).
Down dead wood	Logging residue and other down woody debris; includes woody material larger than 3 inches in diameter, stumps, and the coarse roots of stumps.
Forest floor	Organic material on forest floor; includes fine woody debris up to 3 inches in diameter, tree litter, humus, and fine roots in the organic layer of the forest floor above the mineral soil.
Soil organic carbon	Below-ground carbon without coarse roots but including fine roots and all other organic carbon not included in other pools, to a depth of 3 feet.

Source: Smith and others 2006

Of these pools, live trees and understory vegetation actively sequester carbon. Standing dead trees, down dead wood, and forest floor organic material all sequester carbon that is released over a long period of time through decomposition. All pools may release carbon in a short period through wildfires. Carbon is released from soils through decomposition and respiration by microbial organisms, but in general, soil organic carbon remains fairly constant (Tyrell and others 2009).

Indicator: Difference Between Amount of Carbon Sequestered and Emitted

For this indicator, DNR considered whether, in the OESF, the total amount of carbon sequestered in forest stands on state trust lands and in wood harvested from state trust lands is projected to be greater or less than the amount of carbon emitted from the burning or decay of wood harvested from state trust lands over the 100-year analysis period (refer to Figure 3-32). If the amount of carbon emitted is greater than the amount sequestered, carbon dioxide is being added to the atmosphere.

Figure 3-32. How This Indicator was Measured

Amount of carbon sequestered in forest stands on state trust lands in the OESF	plus	Amount of carbon sequestered in wood harvested from state trust lands in the OESF	equals	Total amount of carbon sequestered	Total amount of carbon sequestered	is greater than or less than	Total amount of carbon emitted from wood harvested from state trust lands in the OESF

CARBON SEQUESTERED IN HARVESTED WOOD

When trees are harvested, some of the carbon they contain remains on site (for example, as slash or stumps) and some is removed as cut timber. Wood that is removed from the site is made into a variety of wood-based products, such as paper or lumber for homes and furniture.

Wood-based products sequester carbon for varying lengths of time. For example, paper may sequester carbon for only a short time if it is discarded after use or burned. However, paper can last longer if it is stored in books or magazines or recycled. Items made from wood, such as houses or furniture, also can sequester carbon for a long time (Smith and others 2006). Products made from wood are eventually discarded and placed in a landfill, where they are covered and decay slowly due to a lack of oxygen in landfills (Ryan and others 2010).

To make it easier to analyze and compare the amounts of carbon sequestered over time, harvested wood is separated into carbon pools. Table 3-59 lists the carbon pools used in this analysis.

Table 3-59. Harvested Wood Carbon Pools (Sequestered Carbon)

Harvested wood carbon pool	Description
Products in use	Wood that has not been discarded or destroyed, such as houses and other buildings, furniture, wooden containers, paper products, and lumber.
Landfills	Wood that has been discarded and placed in landfills. Carbon is stored long term, because of the slow rate of decay.

Source: Smith and others 2006

CARBON EMITTED FROM HARVESTED WOOD

Carbon is emitted from harvested wood through burning or decay. If burned, the energy released may be captured to warm a home or generate electricity. To make it easier to analyze and compare the amounts of carbon emitted over time, carbon emitted from harvested wood is separated into carbon pools. Table 3-60 lists the carbon pools used in this analysis.

Table 3-60. Harvested Wood Carbon Pools (Emitted Carbon)

Harvested wood carbon pool	Description
Emitted with energy capture	Wood products are burned and the energy is captured or used. For example, wood is burned in a fireplace, and the energy (heat) is captured in the home for a period of time (Ryan and others 2010). Or, wood is burned to generate electricity, which is referred to as biomass energy. Biomass energy is used primarily by the forest products industry to run sawmills.
Emitted without energy capture	Wood products are burned intentionally or accidentally and no effort is made to capture or use the energy, such as a house fire or burning trash. Or, wood products decay naturally. Wood products that are exposed to weather and microbial fungi will eventually decompose, with rates of decomposition varying by type of wood product, size, and site conditions.

Source: Smith and others 2006

How Were Carbon Sequestration and Emission Measured?

Text Box 3-9. Tonnes of Carbon

One tonne = 1,000 kilograms
= 2,205 pounds

For this analysis, DNR followed the methodology described in *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States* (Smith and others 2006). This method estimates the amount of carbon sequestered in forest stands and the amount of carbon sequestered and emitted from harvested wood over time. Estimates of carbon sequestered in forest stands are provided for common forest types within each of the 10 regions of the United States. DNR uses the "Pacific Northwest, West" region and the Douglas fir forest type. The unit of measure used in this analysis is tonnes of carbon (also known as metric tons of carbon) (refer to Text Box 3-9 for tonne to kilogram and pound equivalent). Harvest levels were determined using the harvest schedule provided by the analysis model.

■ Criterion and Indicators: Summary

Table 3-61 summarizes the criteria and indicators and how they were measured for the No Action and Landscape alternatives. The rating "medium" was not defined or used in this analysis. DNR analyzes the Pathways Alternative using qualitative techniques (refer to p. 3-17 through 3-18).

Table 3-61. Criterion and Indicators for Climate Change and how They Were Measured

Criterion/ Indicator	**How the indicator was measured**	**Potential environmental impacts**
Carbon sequestration/ Amount of carbon sequestered in forest stands	Whether the amount of carbon sequestered in forest stands on state trust lands increases or decreases over the 100-year analysis period	**Low**: The amount of carbon sequestered in forest stand carbon pools increases over time **High**: The amount of carbon sequestered in forest stand carbon pools decreases over time
Carbon sequestration/ Difference between amount of carbon sequestered and emitted	Whether the total amount of carbon sequestered in forest stands on state trust lands and in wood harvested from state trust lands is greater than, or less than, the total amount of carbon emitted from wood harvested from state trust lands	**Low**: The amount of carbon sequestered is greater than the amount of carbon emitted at the end of the analysis period **High**: The amount of carbon sequestered is less than the amount of carbon emitted at the end of the analysis period

■ Current Conditions

Instead of current conditions, DNR reports results for the end of the first decade of the analysis period under the No Action Alternative. DNR used the methods described in Smith and others (2006).

Indicator: Amount of Carbon Sequestered in Forest Stands

Table 3-62 shows the amount (and percentage) of carbon projected to be sequestered in each of the forest stand carbon pools on state trust lands in the OESF at the end of the first decade of the analysis period under the No Action Alternative. These totals reflect both harvest and natural forest growth.

Table 3-62. Amount of Carbon Projected to be Sequestered in Forest Stands on State Trust Lands in the OESF by the end of the First Decade of the Analysis Period, in Tonnes

Forest stand carbon pool	Tonnes of carbon sequestered in each carbon pool type	Percentage of total carbon sequestered in forest stands
Live trees	14,088,938	44%
Standing dead trees	1,390,453	4%
Understory vegetation	329,374	1%
Down dead wood	3,292,155	10%
Forest floor	2,488,323	7%
Soil organic carbon	11,358,178	34%
TOTAL	32,947,422	100%

Currently, most carbon is sequestered in live trees, followed by soil. The least amount is sequestered in understory vegetation. As shown in Table 3-10 of "Forest Conditions and Management" on p. 3-34, 54 percent of the OESF is currently in the Competitive Exclusion stand development stage, and 29 percent is in the Understory Development stand development stage. These stand development stages explain why large amounts of carbon are stored in trees and very little is stored in understory vegetation. Forest stands in the Competitive Exclusion stage have little to no understory vegetation and stands in the Understory Development stage are just starting to develop an understory.

Indicator: Difference Between Amount of Carbon Sequestered and Emitted

As explained previously, when wood is harvested from state trust lands, some of that carbon will be sequestered in wood-based products (in use or in landfills) and some will be emitted, for example through burning (refer to Figure 3-33).

Figure 3-33. Harvested Carbon

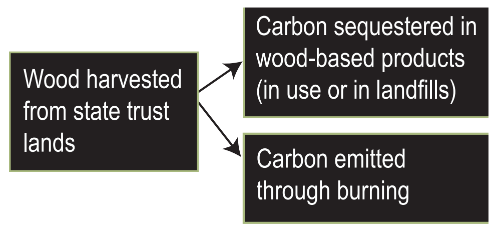


Table 3-63 shows the amount of carbon projected to be sequestered in wood harvested from state trust lands in the OESF at the end of the first decade of the analysis period. Most carbon is sequestered in lumber or other items made from wood. No carbon is sequestered in a landfill, because the method used by Smith and others (2006) assumes there is no harvest previous to the first decade, and thus no wood-based products in landfills.

Table 3-63. Amount of Carbon Projected to be Sequestered in Wood Harvested From State Trust Lands at the end of the First Decade of the Analysis Period, in Tonnes

Harvested wood carbon pool	Tonnes carbon sequestered	Percent of total carbon harvested sequestered in each carbon pool
Carbon in use	402,175	66%
Carbon in landfill	0	0%
TOTAL	402,175	66%

Table 3-64 shows the amount of carbon projected to be emitted from wood harvested from state trust lands in the OESF by the end of the first decade of the analysis period. Carbon is emitted through burning, with or without energy capture.

Table 3-64. Amount of Carbon Projected to be Emitted from Wood Harvested From State Trust Lands by the end of the First Decade of the Analysis Period, in Tonnes

Harvested wood carbon pool	Tonnes carbon emitted	Percent of total carbon harvested emitted from each carbon pool
Carbon emitted with energy capture	121,424	20%
Carbon emitted without energy capture	85,688	14%
Total	207,112	34%

COMPARING CARBON SEQUESTERED AND EMITTED

The total amount of carbon projected to be sequestered by the end of the first decade of the analysis period is as follows:

32,947,422	Tonnes of carbon sequestered in forest stands on state trust lands in the OESF (Table 3-62)
+ 402,175	Tonnes of carbon sequestered in wood harvested from state trust lands in the OESF (Table 3-63)
33,349,597	Total tonnes of carbon sequestered

The total amount of carbon emitted is 207,112 tonnes (Table 3-64).

■ Results

Indicator: Amount of Carbon Sequestered in Forest Stands

NO ACTION AND LANDSCAPE ALTERNATIVES

Chart 3-39 on p. 3-222 shows the amount of carbon projected to be sequestered in forest stands on state trust lands in the OESF in each decade of the 100-year analysis period under the No Action and Landscape alternatives. These totals reflect both harvest and natural forest growth and include the first decade of the analysis period. Table 3-65 shows the amount of carbon projected to be sequestered under the No Action and Landscape alternatives in each of the forest stand carbon pools at the end of the 100-year analysis period. There is little difference between the alternatives in the amount of carbon sequestered.

Chart 3-39. Amount of Carbon Projected to be Sequestered in Forest Stands on State Trust Lands in the OESF at the end of the 100-Year Analysis Period Under the No Action and Landscape Alternatives

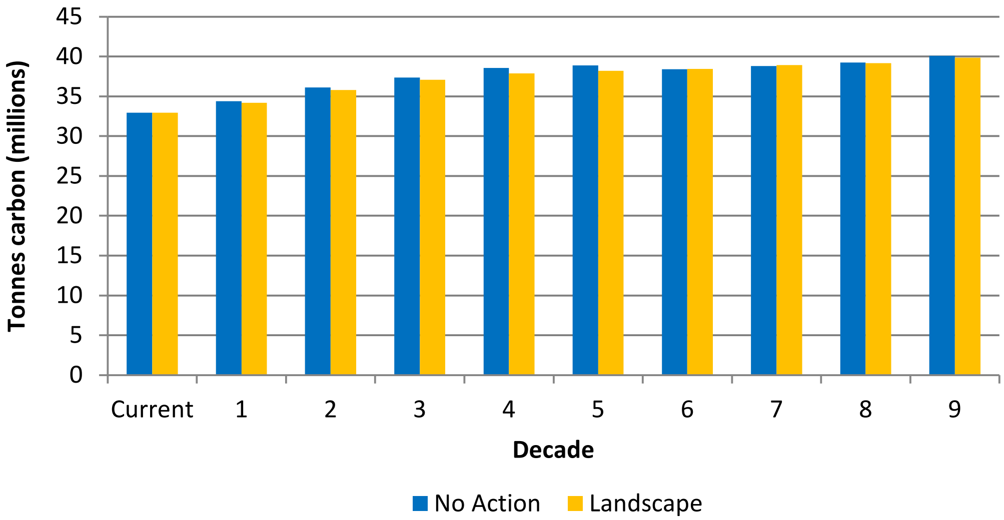


Table 3-65. Amount of Carbon Projected to be Sequestered in Forest Stand Carbon Pools on State Trust Lands in the OESF at the end of the 100-Year Analysis Period Under the No Action and Landscape Alternatives, in Tonnes

Forest stand carbon pool	No Action Alternative		Landscape Alternative	
	Tonnes of carbon sequestered in each carbon pool type	Percent of carbon sequestered in each carbon pool type	Tonnes of carbon sequestered in each carbon pool type	Percent of carbon sequestered in each carbon pool type
Live trees	20,017,403	50%	19,759,925	50%
Standing dead trees	1,935,513	5%	1,911,427	5%
Understory vegetation	303,658	<1%	305,906	<1%
Down dead wood	3,516,881	9%	3,531,457	9%
Forest floor	2,778,709	7%	2,783,471	7%
Soil organic carbon	11,527,292	29%	11,536,072	29%
Total	40,079,456	100%	39,828,258	100%

Table 3-66 compares the Landscape Alternative to the No Action Alternative. Approximately 251,199 tonnes less carbon is projected to be stored in forest stand carbon pools under the Landscape Alternative, as compared to the No Action Alternative.

Table 3-66. Comparison of the Landscape Alternative to the No Action Alternative: Amount of Carbon Sequestered

Forest stand carbon pool	Comparison of Landscape Alternative to No Action Alternative
Live trees	257,478 tonnes less
Standing dead trees	24,086 tonnes less
Understory vegetation	2,248 tonnes more
Down dead wood	14,576 tonnes more
Forest floor	4,762 tonnes more
Soil organic carbon	8,780 tonnes more
TOTAL	251,199 tonnes less

Table 3-67 shows the projected increase or decrease in tonnes of carbon sequestered in forest stand carbon pools under the No Action and Landscape alternatives. To determine these amounts, DNR subtracted the amount of carbon sequestered by the end of the first decade (Table 3-62) from the amount sequestered by the end of the 100-year analysis period (Table 3-65).

Table 3-67. Projected Increase or Decrease in Carbon Sequestered in Forest Stand Carbon Pools at the end of the 100-Year Analysis Period Under the No Action and Landscape Alternatives, in Tonnes

Arrows indicate increase or decrease

Forest stand carbon pool	No Action Alternative	Landscape Alternative
	Increase or decrease in tonnes of sequestered carbon	Increase or decrease in tonnes of sequestered carbon
Live trees	↑ 5,928,465	↑ 5,670,987
Standing dead trees	↑ 545,060	↑ 520,974
Understory vegetation	↓ 25,716	↓ 23,468
Down dead wood	↑ 224,726	↑ 239,302
Forest floor	↑ 290,386	↑ 295,148
Soil organic carbon	↑ 169,114	↑ 177,894
TOTAL	↑ 7,132,035	↑ 6,880,837

Under both the No Action and Landscape alternatives, the amount of carbon sequestered in forest stands on state trust lands in the OESF is projected to increase for all forest stand carbon pool types except understory vegetation, which decreases. Most of this increase is in live tree growth (refer to Table 3-67).

Forest stands accumulate carbon as they move through stand development stages and studies have found that the greatest rate of carbon uptake occurs during the Competitive Exclusion stage (Tyrell and others 2009). The amount of carbon in standing dead trees, down dead wood, and forest floor organic matter also increases as trees die, primarily due to competition for sunlight in dense stands, and from needles falling to the ground. Appendix O includes charts showing carbon sequestered in forest stand carbon pools for the No Action and Landscape alternatives by decade.

For this indicator, the potential environmental impact of the No Action and Landscape alternatives is considered **low**. The total amount of carbon sequestered in forest stands on state trust lands in the OESF is expected to increase under either alternative. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

PATHWAYS ALTERNATIVE

DNR expects the amount of carbon sequestered in forest stands for the Pathways Alternative to be similar to the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18). Following, DNR discusses expected trends in carbon sequestration in operable and deferred areas under the Pathways Alternative.

- Under the Pathways Alternative, DNR will thin forest stands in operable and deferred areas to create or accelerate development of Young Forest Habitat (Pathways 5 and 7). These areas are expected to have a temporary decrease in standing volume followed by an increase as trees released from competition grow. Over time, DNR expects these stands to sequester more carbon as compared to an untreated stand in a similar condition.

  DNR expects some thinnings to be non-commercial, in which the logs are left as down wood instead of hauled to markets. As these logs decay, some carbon will be absorbed into the soil but some will be emitted. Because these non-commercial thinnings would occur on a relatively small portion of the OESF, they are not expected to change the ability of the forest to increase the amount of carbon sequestered over time.

- Forest stands in operable areas that are selected for passive management (Pathways 3 and 4) are expected to continue developing elements of structural complexity, sequestering carbon in large trees, snags, and down wood. DNR expects these stands to contribute to the forest's ability to increase the amount of carbon sequestered over time.

Because the total amount of carbon sequestered in deferred and operable areas is expected to increase over time under the Pathways Alternative (similar to the Landscape Alternative), the potential environmental impact of the Pathways Alternative for this indicator is considered **low.** DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

Indicator: Difference Between Amount of Carbon Sequestered and Emitted

NO ACTION AND LANDSCAPE ALTERNATIVES

Table 3-68 shows the amount of carbon projected to be sequestered in wood harvested from state trust lands at the end of the 100-year analysis period under the No Action and

Landscape alternatives. Of that carbon, 21 percent may be in use, meaning it is sequestered in wood-based products such as houses or furniture. This amount includes the wood in use from all previous decades and the wood harvested in the last decade. The remaining 16 percent may be in landfills, where wood-based products decompose slowly.

Table 3-68. Amount of Carbon Projected to be Sequestered in Wood Harvested From State Trust Lands in the OESF at the end of the 100-Year Analysis Period Under the No Action and Landscape Alternatives, in Tonnes

	No Action Alternative		Landscape Alternative	
Harvested carbon pool	Tonnes carbon sequestered	Percent of total carbon harvested sequestered in each carbon pool	Tonnes carbon sequestered	Percent of total carbon harvested sequestered in each carbon pool
Carbon in use	1,540,350	21%	1,597,452	21%
Carbon in landfill	1,163,764	16%	1,203,390	16%
TOTAL	2,704,114	37%	2,800,842	37%

Table 3-69 shows the amount of carbon projected to be harvested from state trust lands in the OESF that is emitted, with or without energy capture, by the end of the 100-year analysis period.

Table 3-69. Amount of Carbon Projected to be Emitted From Wood Harvested From State Trust Lands in the OESF by the end of the Analysis Period Under the No Action and Landscape Alternatives,, in Tonnes

	No Action Alternative		Landscape Alternative	
Harvested carbon pool	Tonnes carbon emitted	Percent of total carbon harvested emitted in each carbon pool	Tonnes carbon emitted	Percent of total carbon harvested emitted in each carbon pool
Carbon emitted with energy capture	2,436,436	34%	2,520,233	34%
Carbon emitted without energy capture	2,073,366	29%	2,146,143	29%
TOTAL	4,509,802	63%	4,666,376	63%

Comparing Carbon Sequestered and Emitted

No Action Alternative

The total amount of carbon projected to be sequestered under the No Action Alternative by the end of the analysis period is as follows:

40,079,456	Tonnes of carbon projected to be sequestered in forest stands on state trust lands in the OESF under the No Action Alternative (Table 3-65)
+ 2,704,114	Tonnes of carbon projected to be sequestered in wood harvested from state trust lands in the OESF (Table 3-68)
42,783,570	Total tonnes of carbon sequestered

The total amount of carbon emitted is 4,509,802 tonnes (Table 3-69). That amount is far below the total amount of carbon sequestered (42,783,570 tonnes).

Landscape Alternative

The total amount of carbon projected to be sequestered under the Landscape Alternative is as follows:

39,828,258	Tonnes of carbon sequestered in forest stands on state trust lands in the OESF under the Landscape Alternative (Table 3-65)
+ 2,800,842	Tonnes of carbon sequestered in wood harvested from state trust lands in the OESF under the Landscape Alternative (Table 3-68)
42,629,100	Total tonnes of carbon sequestered

The total amount of carbon emitted is 4,666,376 tonnes (Table 3-69). That amount is far below the total amount of carbon sequestered (42,629,100 tonnes).

For this indicator, the potential environmental impact of the No Action and Landscape alternatives is considered **low**. The amount of carbon emitted is far below the amount of carbon sequestered under either alternative. DNR did not identify probable significant adverse environmental impacts from either the No Action or Landscape Alternative for this indicator.

The analysis does not calculate carbon emitted in the process of harvesting the wood or in the exhaust from logging equipment and vehicles transporting the harvested trees. A study conducted in Montana (Healey and others 2009) evaluated carbon emissions from vehicles transporting harvested trees as a percentage of the carbon emitted from the transported wood. Over the course of the study (1998 to 2004), the percentage rose from 0.5 to 1.7 percent. The increase was attributed to mill closures resulting in longer hauling routes; however, the overall percentage was low.

DNR anticipates that the OESF will store sufficient carbon to not only offset emissions from the wood harvested from state trust lands and the equipment used to harvest the wood, but also to store enough additional carbon to act as a biological carbon sink.

PATHWAYS ALTERNATIVE

DNR expects the percentage of carbon emitted compared to carbon sequestered under the Pathways Alternative to be similar to the Landscape Alternative because of similarities between these alternatives and their respective harvest schedules (refer to p. 3-17 through 3-18).Therefore, the potential environmental impact of the Pathways Alternative is considered **low.** The amount of carbon emitted is far below the amount of carbon sequestered. DNR did not identify probable significant adverse environmental impacts from the Pathways Alternative for this indicator.

■ Summary of Potential Impacts

Table 3-70 provides an overview of the potential environmental impacts of the alternatives when the criterion and all of the indicators are considered. The three management alternatives perform in a similar manner. For this analysis, only high impacts were considered potentially significant impacts. DNR did not identify probable significant adverse environmental impacts from any alternative (No Action, Landscape, Pathways) for any indicator used for this topic.

Table 3-70. Summary of Potential Impacts for Climate Change, by Alternative

Criteria	Indicators	No Action Alternative	Landscape Alternative	Pathways Alternative
Carbon sequestration	Amount of carbon sequestered in forest stands	Low ●	Low ●	Low ●
	Difference between amount of carbon sequestered and emitted	Low ●	Low ●	Low ●

● **Low impact**

■ How Might Climate Change Affect State Trust Lands in the OESF?

Climate change is an emerging science. Although studies are being conducted, there are no definitive answers on the severity and timing of climate change or the extent to which climate change will affect Pacific Northwest forests and the plant, fish, and wildlife species associated with them. For that reason, it is not possible to draw clear conclusions about the relative impacts of climate change under each of the proposed alternatives. Also, because climate change impacts likely would be similar under the three alternatives, the information is not essential for selecting an alternative. Therefore, DNR did not conduct this analysis in this FEIS. However, DNR has summarized recent studies of potential climate change impacts to help readers understand changes that may occur over time.

Potential Changes to Forest Conditions

- The **National Climate Assessment (2014)** states that the combined impacts of increasing wildfire, insect outbreaks, and tree diseases are currently causing widespread tree mortality, and that mortality is expected to increase in the future. Forest composition in the subalpine zone also is expected to change, with new tree species moving into this zone and converting subalpine forests to other forest types (Mote and others 2014).

- A study conducted by **Aubry and others (2011)** assessed potential impacts of predicted changes in climate on 15 overstory tree species in the Pacific Northwest. These tree species were selected because they are common to Western Washington and because changes in their distribution or health could change forest structure and habitat at a broad scale. The study analyzed each tree species to determine its vulnerability, based on a variety of characteristics, to the impacts of climate change. An overall climate change vulnerability score was calculated for each tree species, using a scale from zero to 100, with a higher score indicating higher climate change vulnerability. Table 3-71 lists the selected trees and their vulnerability scores.

Western Hemlock

Table 3-71. Overall Climate Change Vulnerability Scores for 15 Common Overstory Trees in Western Washington

Tree species	Overall vulnerability score
Pacific Silver Fir *(Abies amabilis)*	81
Subalpine Fir *(Abies concolor)*	71
Engelmann Spruce *(Picea engelmannii)*	66
Noble Fir *(Abies procera)*	61
Grand Fir *(Abies grandis)*	54
Mountain Hemlock *(Tsuga mertensiana)*	51
Alaska Yellow Cedar *(Callitropsis nootkatensis)*	51
Western White Pine *(Pinus monticola)*	38
Douglas Fir *(Pseudotsuga menziesii)*	31
Bigleaf Maple *(Acer macrophyllum)*	29
Black Cottonwood *(Populus trichocarpa)*	28
Sitka Spruce *(Picea sitchensis)*	26
Western Red Cedar *(Thuja plicata)*	26
Western Hemlock *(Tsuga heterophylla)*	22
Red Alder *(Alnus rubra)*	20

Source: Aubry and others 2011

State trust lands in the OESF have three major vegetation zones (refer to Map 3-1, p. 3-2): Sitka spruce (33 percent of the land base), western hemlock (43 percent of the land base), and silver fir (24 percent of the land base). Based on the assessment conducted by Aubrey and others (2011), Sitka spruce and western hemlock have a relatively low vulnerability to the impacts of climate change, while silver fir has a relatively higher vulnerability; therefore, the impacts of climate change may be greater in the silver fir zone.

- A recent study by **van Mantgem and others** (2009) suggests that regional warming (reported as 0.5 to 0.7 degrees Fahrenheit per decade from the 1970s to 2006) may be the dominant contributor to increases in tree mortality rates. In the Pacific Northwest, the tree mortality rate is one of the highest in the nation and on a trajectory to double in the next 17 years (van Mantgem and others 2009), although there may be an increase in tree growth and establishment at higher elevations (Halofsky and others 2011).
- **Halofsky and others (2011)** used three different modeling techniques to assess potential changes in vegetation on the Olympic National Forest and Olympic National Park in response to climate change. All modeling efforts in this study suggest that changes would occur, generally with shifts in the upper elevation range limits of tree species. Some models also predicted that high summer temperatures may cause drought stress in forest types that are not currently stressed during summer, particularly Sitka spruce. Also, more drought tolerant species such as western redcedar may become dominant in low elevation stands on the west side of the Olympic Peninsula. Halofsky and others (2011) identified a high level of uncertainty around what the extent of climate change will be and the level of impacts associated with it. Suggested methods for handling uncertainty include focusing on change that has already occurred, monitoring trends, using local knowledge, and planning for adaptability.
- **Littell and others (2009)** assessed the potential for climate change to alter the distribution of important Pacific Northwest tree species, with a focus on Douglas-fir because of its broad distribution and economic importance. The results of this study suggest that by the end of the 2060s climate will be different enough from the late 20th century to constrain the distribution of Douglas-fir in many parts of Washington, including some lower elevation portions of the Olympic Peninsula (Littell and others 2009).
- The findings of a study by **Running (2006)** suggested that earlier snowmelt, higher summer temperatures, longer fire seasons, and expanded areas of vulnerable high-elevation forests were contributing to larger, more intense fires in the west.

Potential Changes to Riparian Areas and Fish Survival

Recent studies have indicated that climate change is likely to impact key aspects of freshwater salmon habitat.

- Projected warming along the Pacific coast of North America is expected to result in more precipitation falling as rain rather than snow, leading to a smaller snowpack and changes in the timing of snowmelt (**Independent Science Advisory Board 2007**).
- **Mantua and others (2009)** indicate that climate change is likely to alter summer stream temperature, seasonal low flow (less water in streams during periods when flow is typically low), and the frequency and timing of peak flow events (periods of high stream flow, typically due to storms).
- Current projections (**Mantua and others 2010**) indicate pending shifts in the dominant hydrologic processes in Pacific Northwest watersheds. By the 2080s, as the pro-

jected climate of Washington warms, no basins will be classified as snowmelt-dominated, and only about 10 basins in the north Cascades will be classified as transient (dominated by both rain and snow). The largest changes are predicted to occur as transient basins shift to rainfall-dominated basins. These basins would undergo more severe summer low flow periods and more frequent and intense winter flooding.

- As noted by **Bisson (2008)**, more frequent, severe floods are likely to increase scouring of the streambed, which may increase the mortality of salmon eggs and alevin (young salmon still attached to the yolk sak). Summer base flows (the amount of water in the stream not attributed to runoff) may be lower; therefore, the network of perennial streams (streams that flow year round) may be smaller. Summer water temperatures may approach or exceed lethal levels, and warmer temperature may favor other, better adapted predators and competitors.
- **Mantua and others (2009)** concluded that initial increases in water temperature would increase thermal stress (stress from high temperatures) slightly in the short term; thermal stress would increase later in the 21st century.
- **Halofsky and others (2011)** identify a number of ways that increased precipitation and storm intensity associated with climate change may impact physical watershed processes. For example, increased precipitation and storm intensity in conjunction with higher snowlines and loss of snow cover may increase the rate and volume of water delivered to streams, increase landslides and debris flows, and increase the amount of sediment and wood delivered to streams. Increased precipitation and storm intensity may also increase winter and spring flow volume in streams, which would lead to increases floodplain inundation, channel migration, and channel erosion and scour. This study also found that higher temperatures, smaller snowpacks, and changes in the timing of runoff may lead to the drying of some wetland habitat and a decrease in the amount of riparian habitat around headwater streams (Type 4 or 5 stream).

Not all of these projected trends are necessarily harmful to aquatic organisms. For example, predicted increases in the severity or frequency of disturbance events (large floods, wildfires, and outbreaks of forest pathogens) may improve fish habitat complexity by increasing large woody debris recruitment (wood falling into streams) and reconnecting the floodplain[2] (Bisson 2008).

However, the combined effects of warming stream temperatures and altered stream flows are likely to reduce the reproductive success for many salmon populations in Washington watersheds (Mantua and others 2009). In additional studies focused on the Olympic Peninsula, Mantua and others (2011) concluded that unless they are able to quickly adapt to changing habitat conditions, many Olympic Peninsula salmon, steelhead, bull trout, and resident fish populations are likely to experience widespread declines in the quality and quantity of freshwater habitat.

Potential Changes to Wildlife Habitat and Survival

Halofsky and others (2011) predicted that wildlife species' ranges will shift northward and upward in elevation as temperatures increase. Wildlife species at higher elevations likely will experience range contractions because they are already at the upper limit of suitable habitat. New stressors due to climate change may interact negatively with other stressors such as habitat loss and fragmentation, natural disturbance, and invasive species.

Following is a summary of changes to specific types of wildlife habitat found in the OESF per Halofsky and others (2011). For a more general discussion on forest conditions, refer to "Potential Changes in Forest Conditions" at the beginning of this section.

- **Talus fields**: At higher elevations, the extent of talus fields may increase with decreased snow cover. However, decreased snowpack and earlier snowmelt likely will change micro-environments within talus fields, which could negatively affect wildlife dependent on these areas.
- **Meadows**: Wet meadows are found primarily on the west side of the Olympic Peninsula. Decreased snowpack, earlier snowmelt, and longer summer droughts may dry out these areas.
- **Montane forests**: In the OESF, montane forests are found in the western hemlock and pacific silver fir vegetation zones. Increased temperatures are likely to result in shifts in the distribution of plant species; for example, several tree species are expected to shift their ranges to higher elevations. In these forests, a longer summer drought and more frequent fires could result in a more open canopy and larger "residual" trees (trees that survive the fire). An increase in natural disturbances initially may create more snags and down wood. However, those features may eventually be lost to repeated fires. Repeated fires also could increase the proportion of stands in early stand development stages such as Ecosystem Initiation. This shift could affect northern spotted owls, marbled murrelets, and other wildlife that depend on older forests.
- **Lowland forests**: The outlook for lowland forests is similar to that of montane forests. Non-native plant species already prevalent in these forests could out-compete native plants needed by wildlife. Natural disturbance could increase the number of deciduous trees such as big leaf maple and alder. An increase in mast-producing trees (trees that grow nuts and acorns) could benefit some species of wildlife.
- **Cliffs**: Increased temperatures may affect cliff habitats.

POTENTIAL CHANGES SPECIFIC TO NORTHERN SPOTTED OWL HABITAT AND SURVIVAL

- In 2015, **Mauger and others** prepared a synthesis of peer-reviewed literature on climate change in the Puget Sound. One study cited found that, through the end of this century, the probability of maintaining current levels of high quality northern spotted owl in some coastal Washington watersheds was low. The study cited used the best available science and models at the time. A more recent DNR analysis (Halofsky and others, in preparation) using newer, updated models found an increase in potential northern spotted owl habitat in western Washington over the same timeframe under all climate change scenarios modeled. The amount of increase was gradual absent any fire suppression. When a fire suppression rate of 50 percent was added to the model, DNR found that the increase in potential habitat was still smaller, but much closer, to the "no climate change" scenario.

- Using a combination vegetation and climate model, **Carroll (2010)** projected that over time, the suitability of northern spotted habitat (the habitat's potential to support a species) would decrease at lower elevations near the coast, especially in Oregon. Initially, there would be a northward expansion of highly suitable northern spotted owl habitat, but this expansion could be followed by a contraction as climate change intensifies (Carroll 2010).

  The model used by Carroll (2010) predicted changes in the composition and age of forest stands; those changes could mitigate or compound predicted changes in owl distribution. Old-growth forests of the Pacific Northwest may stabilize the owl's distribution under climate change, as these forests may lag in adjusting to a changing climate; however, changes in natural disturbance may destabilize owl distribution by causing sudden changes in vegetation. As well, barred owls may occupy potential habitat before it becomes suitable for northern spotted owls (Carroll 2010).

- **Glenn and others (2011)** used regional and local weather data across six study areas to determine the relationships, if any, between weather or climate effects and survival of northern spotted owls. Specifically, Glenn and others (2011) examined how variation in precipitation, temperature, number and timing of storms, and long-term patterns of climate were associated with apparent annual survival of northern spotted owls. In general, study results suggest that hotter, drier summers and wetter winters and nesting seasons may have a negative impact on the subspecies' annual survival across the six study areas.

Section Notes

1. This chapter uses terminology from the Smith and others (2006) methodology. The chapter uses "standing dead tree" instead of "snag," and "down dead wood" or "down woody debris" instead of "down wood."
2. Floodplain connectivity refers to the hydrologic connectivity of the river and its surrounding floodplain, and the exchange of water, organic matter, and nutrients between the river and the floodplain. The exchange can occur through subsurface or surface flow. Disturbances can alter channel morphology (shape) and add structural elements (such as large woody debris) that divert surface and subsurface flow and increase floodplain connectivity.